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Abstract

Because much of the value of equity depends on the option characteristics of investment projects, it is not feasible to calculate equity duration directly. As a result, recent literature has focused on estimating equity duration empirically. By using 25 size and book-to-market portfolios, this paper shows that estimates of equity duration are critically dependent on the specification of the regression model used to estimate equity duration. In particular, including all three Fama-French factors in the regression can have a dramatic impact on the estimated coefficients.

Key words: Equity duration, Growth options, Asset pricing.

* I thank Eugene Fama and Kenneth French for providing the factor and portfolio return data used in this paper.

1. Introduction

Equity duration, defined as the sensitivity of stock returns to interest rate changes, is an important, but murky, element of portfolio management. The issue is important because interest rates affect the investment environment in which portfolio managers operate. For instance, the liabilities of most pension funds depend on the level of interest rates. To the extent that those liabilities are funded with equities, it is obviously important to know the duration of the equity portfolio. In addition, managers who invest in both stock and bonds will want to know how the two portfolios are likely to behave in relation to each other as interest rates change.

The concept of equity duration has proved murky for four different reasons. The first two are largely a matter of definition. The second two raise tricky theoretical and empirical issues.

First, duration, as classically defined, relates the return on an asset to changes in the discount rate. For common stock, the discount rate, k, includes both the risk-free nominal rate and the equity risk premium. Because the equity risk premium may vary over time, equity duration estimated using changes in k will differ from the equity duration estimated using changes in interest rates.[1] In practice, the equity duration that investors focus on is duration measured with respect to changes in interest rates. That is the definition of equity duration used here.

Related to the foregoing is the question of what interest rate to use. Given the other difficulties in estimating equity duration, the standard approach taken in the literature is to

[1] Because the equity risk premium is unobservable, attempting to estimate duration using k is a difficult problem in itself.

use the yield on long-term Treasury bonds. Recognizing that this approach pushes complex issues related to the term structure under the rug, it is adopted here.

Second, as Liebowitz, Sorenson, Arnott and Hanson [1989] observe, when dealing with equity duration, the distinction between real and nominal interest rates changes may be important. This distinction is irrelevant for fixed income securities. When the cash flows are fixed, duration depends only on the nominal discount rate. Whether changes in that nominal rate are due to variation in real rates or expected inflation is irrelevant. The distinction becomes relevant in the case of common stock because the cash flows investors receive may vary with interest rates. Consequently, duration will depend on both changes in the discount rate and associated induced changes in equity cash flows. Because variation in real rates and variation in expected inflation may influence equity cash flows in different ways, the distinction could be important. Fortunately, empirical work shows that this is not the case. Hevert, McLaughlin and Taggart [1998], HMT, report that splitting changes in the nominal interest rate into changes in the real rate and changes in expected inflation does not significantly affect their estimates of equity duration. For this reason, and because this paper focuses on other issues, equity duration is defined exclusively with respect to changes in the nominal interest rate.

The preceding paragraph raises a third more general problem associated with equity duration. Changes in interest rates affect equity cash flows in a variety of complex, non-linear ways. For this reason, equity durations can be markedly different from the duration of fixed income securities and may even be positive. HMT present a simple example using growth options. Following Brealey and Myers [1996], HMT divide the value of a company into the value of assets in place and the value of future growth opportunities. They then note that if growth opportunities are strictly analogous to call options on securities – that is, if they convey the right to undertake a project by investing a certain amount on or before a specified date – option price theory teaches that they will have *positive* duration because the value of an option increases as interest rates rise. Unfortunately, growth options are a good deal more complex than stock options. There is no fixed maturity date, there is generally not an underlying traded asset and, most importantly, the value of the project and the exercise price both depend upon movements in interest rates. Because the relation between interest rates, the value of the underlying project and the exercise price are virtually impossible to specify ex-ante and are almost certain to be complex and non-linear, it is not feasible to attempt to use option pricing theory to calculate the duration of growth options. Furthermore, many of the same problems arise in the case of "assets in place" because such assets also have significant option characteristics. For instance, firms have the option to expand, contract or terminate current operations.

Because of the complexities introduced by managerial discretion and the associated real options, studies of equity duration, including HMT, typically fall back on empirics. That is, they attempt to estimate the sensitivity of stock prices to changes in interest rates. Here, however, the fourth problem arises. A simple regression of stock returns on changes in interest rates may produce misleading results. To the extent that interest rate changes are correlated with variables omitted from the regression, spurious correlations result. What appears to be equity duration may simply be the result of interest rate movements serving as a proxy for movements in the market or other factors that influence stock prices. This point emerges clearly from the HMT analysis. HMT find that when the change in the ten-year Treasury Bond yield is the sole explanatory variable, both high and low book-to-market portfolios have significant negative durations. However, when the market return is added to the regression, the coefficient of the change in the Treasury bond yield becomes positive for low book-to-market portfolios. The authors interpret this as evidence that growth options have positive duration. (HMT assume that low book-to-market firms have more growth opportunities.) Putting the conclusion aside for the time being, the HMT results show clearly that the coefficient of the change in interest rates is highly sensitive to the other explanatory variables included in the regression.

This paper extends the work of HMT by examining more fully the impact of the specification of the regression model on empirical estimates of equity duration. More specifically, Fama and French [1992, 1993, 1996] present convincing evidence that equity returns are best captured by a three factor model. This raises the obvious question of how estimates of the response of stock prices to interest rates changes evolves when progressing from a univariate regression using only the change in rates as an explanatory variable, to a model where the market return is added, and finally to a model in which all three Fama-French factors are included. Furthermore, an adequate test of the HMT suggestion that equity duration depends on the fraction of a company's value attributable to growth options requires examining more than two portfolios. Here all 25 portfolios constructed by Fama and French and sorted by both market capitalization and the book-to-market ratio are used as dependent variables.[2]

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[2] I am greatly indebted to Eugene Fama and Kenneth French for kindly providing monthly return data for their 25 size and book-to-market sorted portfolios and for their three explanatory factors.

2. The data and the empirical method

The empirical analysis employed here is based on the following three regressions:

$$R_{i,t} = a + b*R_{TB,t} + u_{i,t} \quad (1)$$

$$R_{i,t} = a + b*R_{TB,t} + c*R_{M,t} + u_{i,t} \quad (2)$$

$$R_{i,t} = a + b*R_{TB,t} + c*R_{M,t} + d*SMB_t + e*HML_t + u_{i,t}\,. \quad (3)$$

In these equations, $R_{i,t}$ refers to the monthly return on each of the 25 size and book-to-market sorted portfolios constructed by Fama and French (1992).[3] $R_{TB,t}$ is the monthly return on 20-year Treasury bonds reported by Ibbotson Associates. The Treasury bond return is used, rather than the change in interest rates, to avoid potential errors due to nonsynchronous data. For instance, HMT choose the change in the average yield on ten-year constant maturity Treasury notes as their explanatory variable. The problem with this choice is that it represents an average for the month, whereas stock returns are measured from the beginning of the month until the end. For this reason, the change in interest rates and the stock returns do not align properly. During months such as September, October and November, 1987, the failure to properly align the data can introduce significant measurement error. This problem is avoided entirely by using the Ibbotson return series which is perfectly aligned with the stock return series.

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[3] The 25 portfolios are constructed by ranking all NYSE firms on market capitalization and BE/ME at the end of June of each year. On the basis on this ranking, unconditional quintile breakpoints are established for both size and book-to-market. All NYSE, Amex and Nasdaq stocks are placed into the five size and book-to-market portfolios based on these break points. Returns are then calculated for the next 12 months at which point the procedure is repeated.

Using a return series, rather than a change in interest rates, does alter the estimated coefficient. Assuming that the modified duration, MD, of the bonds used to compute returns (and measure yields) remains constant, the estimated coefficient will be multiplied by the factor, -MD, when Treasury returns are substituted for the change in interest rates. To the extent, that modified duration varies over time the two regressions coefficients will not be strictly proportional. Nonetheless, except for the change in scale the results should be similar.

The three remaining explanatory variables are the market portfolio and the Fama-French factor mimicking portfolios. To review briefly, Fama and French construct the factor returns as follows. Each June, NYSE, AMEX and Nasdaq stocks are allocated to two size groups, S and B, based on whether the market equity is below or above the NYSE median. Stocks are also allocated to three book-to-market groups based on the bottom 30 percent, middle 40 percent and top 30 breakpoints for BE/ME for NYSE stocks. SMB is the average monthly return on stocks in the three small firm portfolios (one for each BE/ME category) minus the average return on the three large firm portfolios. Similarly, HML is the average monthly return on the two highest book-to-market portfolios (for both size groups) minus the average return on the two lowest book-to-market portfolios. $R_{M,t}$ is the return on the value-weighted average of all stocks that went into the construction of the size and BE/ME portfolios, net of the one-month Treasury bill rate.

The sample period for the study is January 1966 through December 1998. The starting pointing is selected based on the work of Cornell [1999] who reports that the relation between interest rates and stock market returns changed in the mid-1960's. The pre-war data are also excluded because of the large variance of stock returns during the depression. In addition, the relationship between interest rates and stock returns could have been affected by the Federal Reserve Accord that led to pegging of interest rates on short-term government securities through the war and up until 1951. Results for sub-periods are discussed following the presentation of the primary results.

3. The results

The primary results are reported in Figures 1, 2 and 3. The figures correspond to equations (1), (2) and (3). Each figure presents the estimated coefficient, b, for the Treasury bond return as a bar and the associated t-statistic as a line. The 25 portfolios on the x-axis are arranged first by market capitalization and then by book-to-market ratio. The quintile of the smallest firms are on the far left and the largest are on the far right. Within each size quintile, the portfolios run from low book-to-market to high.

The findings portrayed Figure 1 are consistent with the results reported by HMT, James, Koreisha and Partch (1985) and Lee (1992), among others. When stock returns are regressed on Treasury bond returns, the estimates of b are positive and highly significant for all 25 portfolios.[4] The figure also reveals a tendency for both the coefficients and the t-statistics to rise when moving from small to large firms. The t-statistics increase more than the coefficients because the return standard deviation is smaller for the large firm portfolios. In addition, there is a slight indication that the coefficients and t-statistics rise when moving from low to high book-to-market portfolios. However, such a book-to-market effect does not hold for the large firm portfolios and is weak for the other four size groupings. Overall, Treasury bond returns do not explain much of the return variance for the 25 portfolios. The R^2's for the regressions range from around 0.02 to 0.12.

[4] Remember that a positive coefficient for the Treasury bond return implies a negative duration.

When the market excess return is added to the regression, Figure 2 reveals a markedly different set of results. To begin, the coefficients on the Treasury bond return are much smaller and periodically insignificantly different from zero. More importantly, there is now a pronounced cross-sectional pattern. The most striking result is that the coefficients for small firms remain highly significant, but the duration switches from negative to *positive*. As firm size increases, the coefficients rise. For medium-sized firms, the coefficients still negative, but closer to zero and often insignificant. Finally, for large firms the coefficient become significantly positive. Even for larger firms, however, the coefficients are much smaller than before inclusion of the market portfolio. They achieve statistical significance only because the market absorbs much of the return variance. The R^2's for the regressions are on the order of 0.65 to 0.70.

As HMT report, the coefficients also rise when moving from low to high book-to-market portfolios. The trend, however, is much less pronounced than that observed when moving from small to large firm portfolios. HMT miss this fact because they analyze only two portfolios sorted on book-to-market. Using this limited sample, they find that duration switches from negative to positive for high growth (low book-to-market) portfolios when the market return is added as an explanatory variable. HMT interpret the finding as evidence that growth opportunities have significantly different, and apparently positive, duration compared to the negative duration of assets in place. The more complete results reported here show that their conclusion is not based on a sufficiently large, or diverse, sample. What they are interpreting as a book-to-market effect is seen to be a size effect when all 25 portfolios are considered. Nonetheless, it is still possible that their interpretation has merit in that small firms may have more growth opportunities than large ones. However, the story must be related more strongly to size than to book-to-market ratios.

When all three factors are included, the pattern of results changes once again. As Figure 3 shows, now virtually all of the coefficients are less than 0.08 in absolute value or about 20 percent of the coefficients reported in the univariate regressions. Furthermore, the coefficients, with a few exceptions are insignificantly different from zero. In addition, the economic importance of the few significant coefficients should not be exaggerated. Because the three-factor model explains between 90 and 95 percent of the time-series variation in returns for the 25 portfolios, the coefficient of any added variable does not have to be large to be statistically significant. In this regard, it is worth noting that adding the Treasury bond return to the three-factor model has almost no impact on the R^2 of the regression or on the coefficients of the three factors which are all highly significant in every case.

In the full three factor model, there is no longer any evidence of size, or book-to-market, variation in the duration coefficients. The estimates of b are basically randomly distributed about a mean value of 0.02, indicating a slightly negative, but both economically and statistically insignificant, duration. The pattern on which HMT focus is seen to be an artifact of failing to include SMB and HML in the regression.

Results for subsamples

To check the robustness of the findings, the sample period was divided into three subsamples – January 1966 to December 1976, January 1977 to December 1987 and January 1988 to December 1998. Although the results (not reported) are not identical, the same basic pattern emerges as presented in Figures 1, 2 and 3. In the univariate regressions, the Treasury bond return coefficients are positive and significant in virtually every case. When the market variable is added, the coefficients drop, significance levels fall, and a pronounced size pattern and a less pronounced book-to-market pattern emerge. Finally, when the size and book-to-market factors are added as explanatory variables, the relationship between stock returns and Treasury returns disappears. Virtually all of the b coefficients are less than 0.10 and statistically insignificant.

The relation between the Fama-French factors and changes in interest rates

The fact that equity duration disappears when a three-factor model is used, suggests that changes in interest rates (Treasury returns) are correlated with at least one of Fama-French factors: SMB, HML and MKT. In the case of HML, the correlation turns out to be totally insignificant. When HML is regressed on the Treasury bond return, the coefficient is –0.003 and the t-statistic is 0.07. The fact that there is no relation between Treasury bond returns and HML is consistent with the fact that in the market model regression, with the Fama-French factors omitted, there is no meaningful relation between the estimated b coefficients and the book-to-market ratio. This further confirms the finding that the book-to-market effect reported by HMT is due to their omission of a size variable in the analysis.

When SMB is regressed on the Treasury bond return, the coefficient is –0.122 and the t-statistic is –2.53. The significant relation between SMB and Treasury bond returns explains why the size pattern apparent in Figure 2 disappears in Figure 3. The negative correlation between SMB and Treasury bond returns means that when interest rates *drop* (bond prices rise) small firms *underperform* (SMB is negative). This is consistent with duration being positive for small firms and falling as firm size increases as observed in Figure 2.

By far the most significant relation is between Treasury returns and MKT. This is not surprising because all of the 25 sorted portfolios have highly significant b coefficients and MKT is basically a weighted average of the 25 portfolios. More specifically, a regression of MKT on Treasury bond returns yields a b coefficient of 0.46 with a t-statistic of 6.54. This shows that the predominant impact of interest rates on the individual portfolios is through the market factor. That impact produces a significant negative duration that is the same for all securities independent of size or book-to-market. Conditional upon the return on the market, and holding size constant, there is no relation between book-to-market ratios and changes in interest rates. If SMB is excluded, then the relation between changes in interest rates and stock returns is seen to be significantly related to size. It cannot be determined, however, whether this implies that small and large firms have conditionally different durations or whether the result is an artifact of an improperly specified model that excludes SMB.

4. Implications of the results

Much of the value of equity is related to strategic options. This is true by definition for growth options – projects that management has yet to undertake, but it is also true of on-going projects that can be expanded, strategically altered, contracted or even terminated. As Hevert, McLaughlin and Taggart stress, the existence of these real options makes it virtually impossible to theoretically calculate equity duration. Consequently, increased attention has been focused on attempts to estimate equity duration empirically.

The results reported in this paper make it clear that careful attention must be paid to the context in which equity duration is evaluated. Simple univariate regressions indicate significant negative durations for common stocks independent of the market capitalizations or the book-to-market ratios of the companies in question. However, when the return on the market is added to the equation, the conditional duration that emerges is markedly different. Not only is the conditional duration correlated with market capitalization, but small firms are found to have negative conditional duration. When a full Fama-French three factor model is employed, the conditional duration changes again. The cross-sectional dependence on size disappears and the conditional duration is close to zero and statistically insignificant in virtually every case.

Overall, the results demonstrate that the impact of interest rates on stock prices is transmitted almost exclusively through the market factor. That mechanism produces a negative duration for stocks generally. Beyond that, the evidence for a conditional relation between stock returns and changes in interest rates depends critically on the conditioning variables. In the context of the Fama-French three-factor model, there is no evidence of any significant conditional duration.

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Figure 1

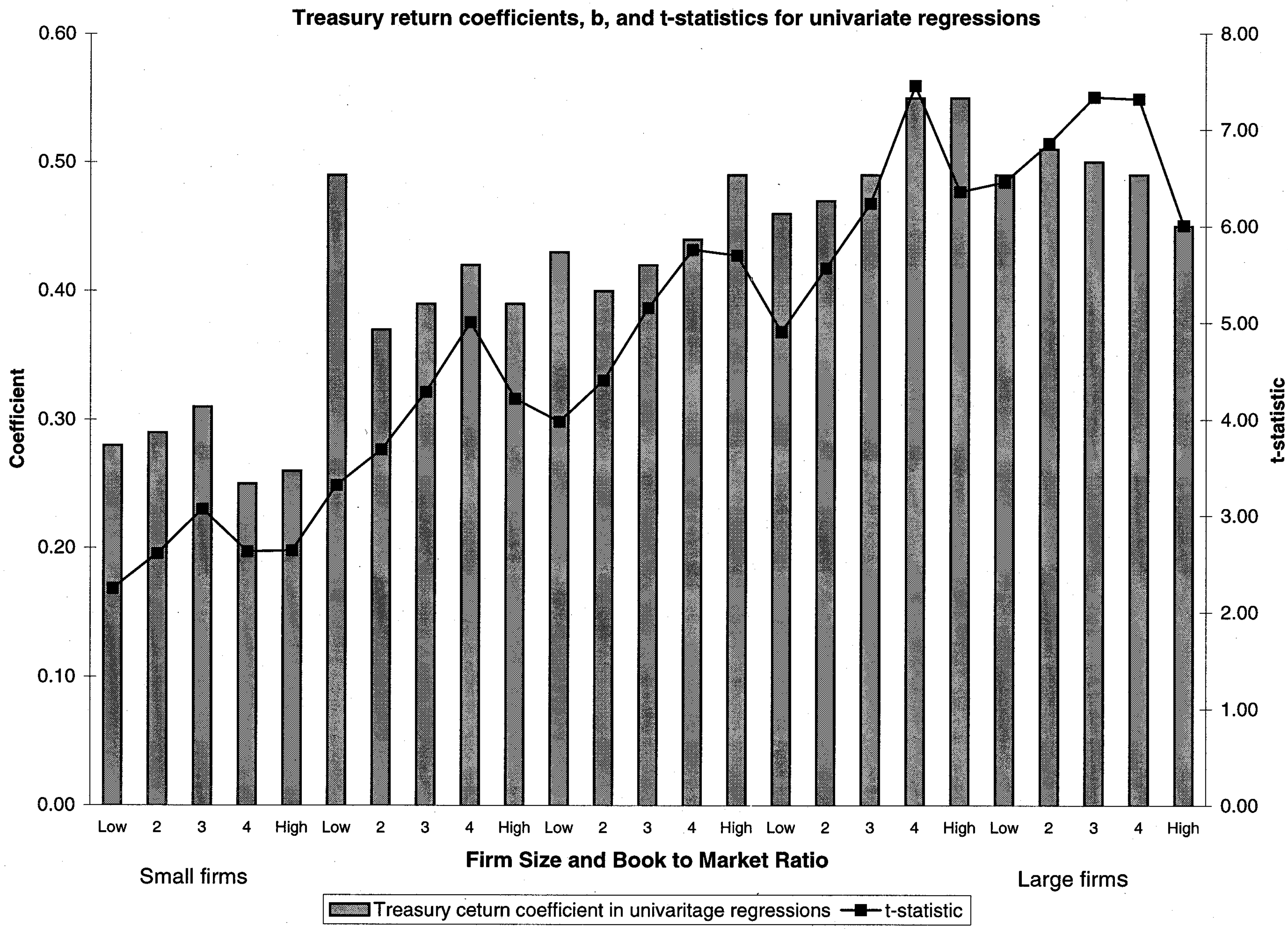

Treasury return coefficients, b, and t-statistics for univariate regressions
Coefficient
0.60
0.50
0.40
0.30
0.20
0.10
0.00
t-statistic
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Low 2 3 4 High Low 2 3 4 High Low 2 3 4 High Low 2 3 4 High Low 2 3 4 High
Firm Size and Book to Market Ratio
Small firms
Large firms
Treasury ceturn coefficient in univaritage regressions
t-statistic

Figure 2

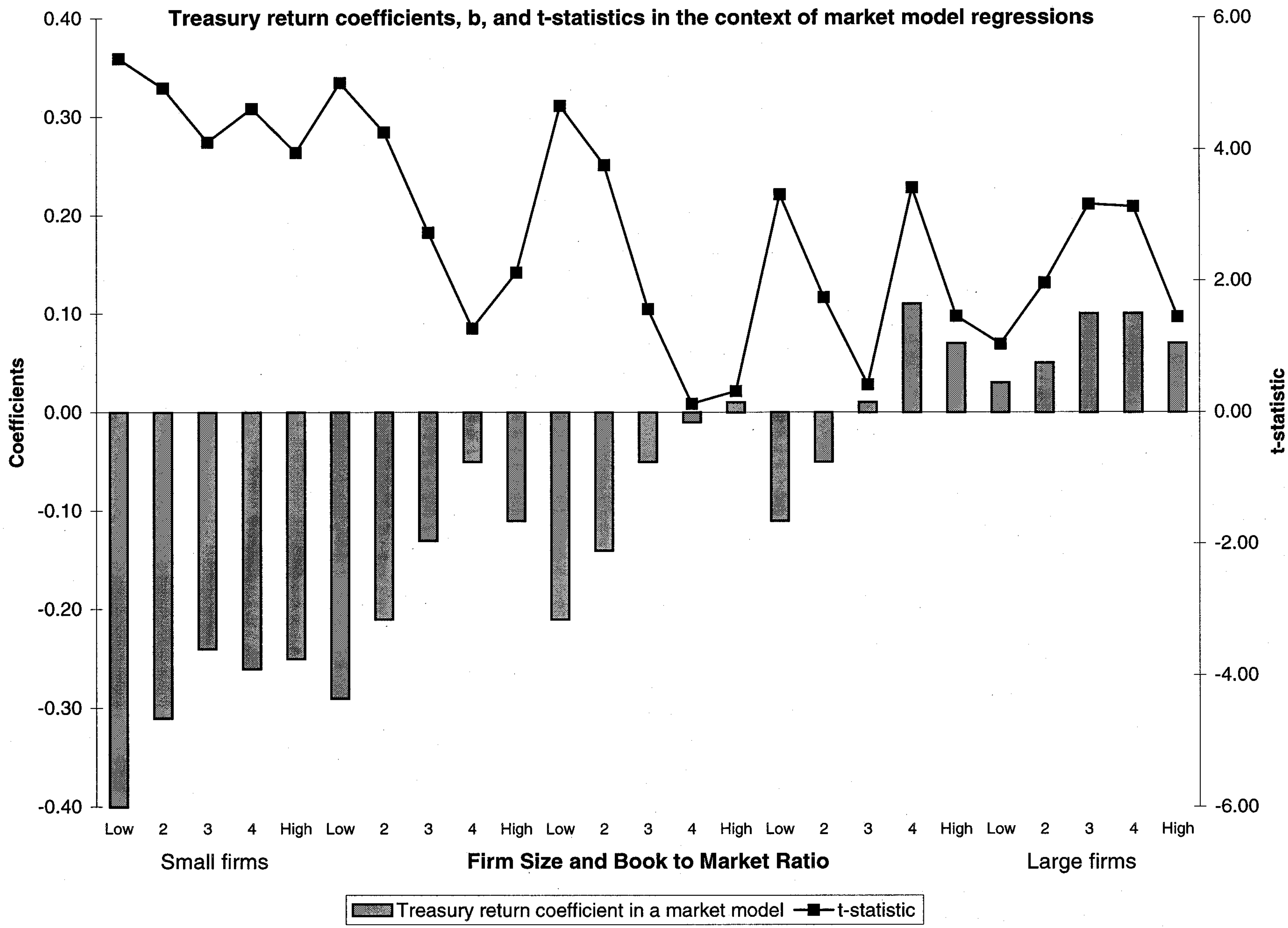
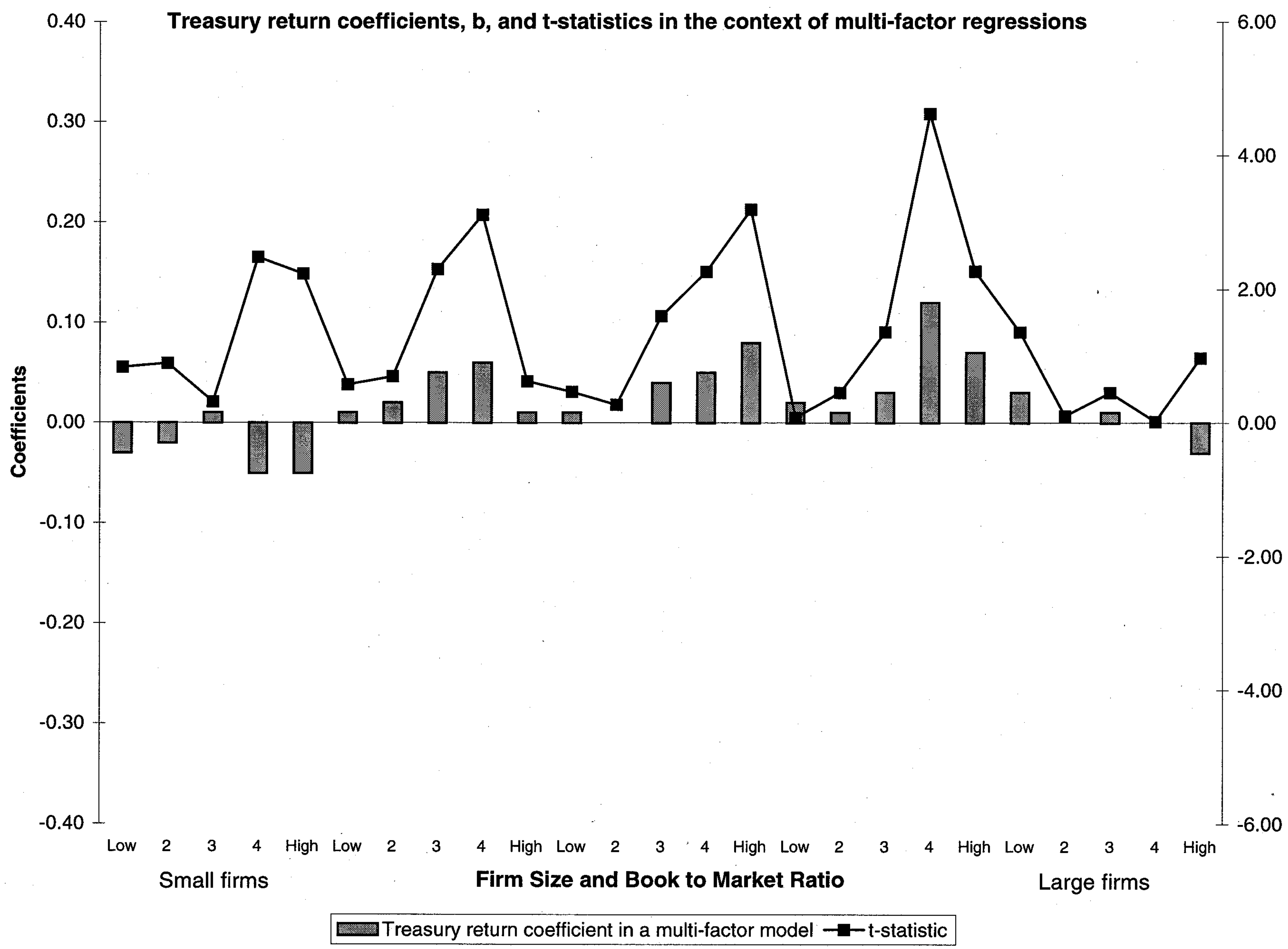

Treasury return coefficients, b, and t-statistics in the context of market model regressions
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
-0.40
Coefficients
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
t-statistic
Low 2 3 4 High Low 2 3 4 High Low 2 3 4 High Low 2 3 4 High Low 2 3 4 High
Small firms
Firm Size and Book to Market Ratio
Large firms
Treasury return coefficient in a market model
t-statistic

Figure 3



Treasury return coefficients, b, and t-statistics in the context of multi-factor regressions
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
-0.40
Coefficients
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
t-statistic
Low 2 3 4 High Low 2 3 4 High Low 2 3 4 High Low 2 3 4 High Low 2 3 4 High
Small firms
Firm Size and Book to Market Ratio
Large firms
Treasury return coefficient in a multi-factor model
t-statistic