THE CAPITAL ASSET PRICING MODEL'S RISK-FREE RATE

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ABSTRACT

The risk-free rate is an important input in one of the most widely used finance models: the Capital Asset Pricing Model. Academics and practitioners tend to use either short-term Treasury bills or long-term Treasury bonds as the risk-free security without empirical justification. This study investigates the market and inflation risks of Treasury securities with different maturities over different investment horizons. The results show that mean real returns, volatility, and market and inflation risks, of Treasury securities increase with the maturity period. Only Treasury bills do not have any market risk for 1- and 5-year periods, and they have the lowest market risk over 10 years. Although Treasury securities of all maturities have significant inflation risk, Treasury bills have the lowest inflation risk over all three horizons. Further, the inflation beta and explanatory power of inflation for real Treasury bill returns decline with the investment horizon. Over 10 years, inflation and market risks explain only 13% of variations in real Treasury bill returns, compared to 20% of intermediate government bond returns, and 23% of long government bond returns. These findings indicate that Treasury bills are better proxies for the risk-free rate than longer-term Treasury securities regardless of the investment horizon.

JEL: G11; G12

KEYWORDS: Risk-free rate, Capital Asset Pricing Model, investment horizon

INTRODUCTION

The Capital Asset Pricing Model (CAPM), developed by Sharpe (1964) and Lintner (1965), is one of the most widely used models in finance. According to this model, a firm's cost of equity (Ke) is a linear function of its market risk: $Ke = Rf + (Rm - Rf)\,\beta e$, where Rf is the risk-free rate, Rm is the expected market return, (Rm – Rf) is the market risk premium, and βe is the equity beta, denoting market risk.

The importance of identifying appropriate inputs for practical applications of this model has produced a voluminous body of empirical studies, aimed primarily at estimating the market risk premium and beta. The third component of the model — the risk-free rate — has received scant attention. The risk-free rate is an important model input since it not only determines the intercept, but also affects the slope of the linear equation. A higher risk-free rate implies a higher intercept and flatter slope compared to a lower rate. Academics and practitioners tend to use either short-term Treasury bills or long-term Treasury bonds as the risk-free security without empirical justification.

The CAPM is a single-period model, but the period is not specified. In theory, it could be applied to periods of any length, for example, 1, 5, or 10 years. Although a 10-year period does contain 1- and 5-year periods, a 1-year period also contains months and weeks. The length of the period does not matter as long as all the parameters are measured over the same period. Treasury bills, intermediate-term government bonds, and long-term government bonds match the time horizons of short-, medium-, and long-term investments, respectively. Matching the maturity period of the risk-free security with the investment horizon minimizes interest rate risk, although it does not eliminate inflation risk, and its effect on market risk is an empirical issue.

For a risk-free security, the return actually realized should be equal to the expected return. No security is truly risk-free, but Treasury securities are normally used as the closest proxy for a risk-free security because they have practically no default risk. Although the nominal returns on Treasury securities are risk-free, their real returns are not; they are exposed to inflation risk. Unanticipated inflation inversely affects real returns on securities with fixed cash flows, and it has a stronger influence on longer-term securities, whose cash flows are fixed for longer periods.

Since the relevant risk measure in the CAPM is market risk, indicating the sensitivity of an investment's returns to movements in market returns, the market beta of a risk-free security must be zero. The CAPM is a one-factor model, which assumes that market risk is the only risk that is priced by investors. However, as Fama and French (2002) noted, the goal of investment in portfolio theory is consumption, which is related to real rather than nominal returns. Therefore, the realized real return on a risk-free security should be equal to its expected real return. An appropriate proxy for the risk-free rate for each horizon should have no significant market or inflation risk. This study empirically investigates the market and inflation risks of Treasury securities with different maturities over different investment horizons.

The remainder of the paper is organized as follows. Section 2 reviews the literature. The data and methodology are described in Section 3. Section 4 presents the empirical results and Section 5 concludes the paper.

LITERATURE REVIEW

Empirical tests of the CAPM have provided mixed results. Black, Jensen, and Scholes (1972) regressed average monthly excess returns over T. Bills against betas of portfolios during 1931-65 and reported that the slope and intercept were significantly different from the values predicted by the CAPM. Fama and Macbeth (1973) found a positive linear relationship between average return and beta during 1926-68. Fama and French (1992) showed that book-to-market equity and firm size have significant explanatory power for stock returns, but beta is not significantly related to stock returns, during 1963-90. Kothari, Shanken, and Sloan (1995) drew attention to survivor bias in the Compustat data used in the Fama and French (1992) study and took issue with the interpretation of their results.

In a survey by Graham and Harvey (2001), responses from chief financial officers at a cross-section of 392 U.S. firms indicated that 73.5% of respondents always, or almost always, use the CAPM to estimate the cost of equity. Another survey of highly regarded corporations, leading financial advisors, and best-selling textbooks and trade books by Bruner et al. (1998) revealed that 85% of sample firms use the CAPM or a modified CAPM. These studies indicate the widespread use of the CAPM and the importance of identifying appropriate inputs for the model.

Empirical studies of the CAPM parameters have focused primarily on the input that is hardest to estimate: the market risk premium. Since a stock market index is a common proxy for the market portfolio, the equity premium is generally considered the market risk premium. Blanchard (1993) estimated that the equity premium over 20-year government bonds increased from 3% to 5% in the early 1930s to more than 10% in the late 1940s, but declined to 2% to 3% by the early 1990s due to a fall in expected real returns on stocks and an increase in expected real risk-free rates. Siegel (1998) reported that the equity premium was 4.0% over T. Bills, and 3.3% over long-term government bonds, over a longer period, from 1802 through 2004. Dimson, Marsh and Staunton (2002) showed that, while the geometric mean U.S. equity premium has been above average, at 5.6% over T. Bills and 4.8% over long-term government bonds, five of sixteen countries studied offered higher premiums than the U.S. over a 102-year period. Claus and Thomas (2001) estimated the equity premium over 10-year government bonds at about 3% or less in the

U.S. and five other large stock markets. These studies indicate that researchers have measured the equity premium relative to both T. Bills and long-term government bonds, with varying results.

Some studies have indicated that the return interval used in the regression has a significant impact on the beta estimate. Reilly and Wright (1988) showed that there were large differences in the betas estimated by Value Line Investment Survey and Merrill Lynch Investment Service, which calculate beta over five years, using weekly and monthly returns, respectively. Gunthorpe and Levy (1994) found that stocks with betas below one based on daily returns had betas above one based on annual returns, and vice versa. Levy, Gunthorpe, and Wachowicz (1994) indicated that the return interval used for the beta estimate should be consistent with the investor's expected holding period.

No previous study has attempted to identify the appropriate risk-free rate for the CAPM. Academics and practitioners arbitrarily use short-term or long-term government securities as proxies for the risk-free security. Bruner et al. (1998) found wide variation in the choice of risk-free rates for the CAPM. Practitioners strongly prefer long-term bonds; 70% of corporations and financial advisors use Treasury bonds with maturities of ten years or greater, while 10% or less use Treasury bills. By contrast, 43% of books recommend using Treasury bills and only 29% recommend long-term Treasury bonds. Observing that the risk-free rate should match the period of the cash flows, the authors conclude: "for most capital projects and corporate acquisitions, the yield on the US government Treasury bond of ten or more years in maturity would be appropriate." (p. 26)

The yields on risk-free securities are related to their maturity periods. As Wilson and Shailer (2004) noted, long-term bonds with no default risk normally offer higher yields than similar short-term securities due to an interest rate risk premium. Yields for different long-term maturities, however, tend to be fairly similar. Bruner et al. (1998) observed that the specific maturity of the long-term bond used is not important because yield curves are generally flat beyond 10 years. There is evidence that Treasury bonds are exposed to both market and inflation risks. Cornell (1999) found that 5- and 20-year Treasury bonds have significantly positive market betas, measured over 48-month periods. Fama and Schwert (1977) reported that government bond returns were strongly negatively related to unanticipated changes in expected inflation, and the negative relationship was stronger for longer-term bonds.

Treasury inflation-protected securities (TIPS), introduced in 1997, are indexed to inflation. However, these securities are offered only in maturities of 5 and 10 years, and they pay semiannual coupons, which are exposed to inflation risk. Moreover, TIPS are likely to have negative market betas because real stock returns have negative inflation betas. Fama and Schwert (1977) found that monthly, quarterly and semiannual stock returns were negatively related to expected and unexpected inflation as well as to changes in unexpected inflation. The results of Boudoukh and Richardson (1993) also indicated that 5-year real stock returns were negatively related to inflation. These findings suggest that TIPS, which are indexed to inflation, will have negative market betas.

DATA AND METHODOLOGY

Monthly returns during 1926-2007 are obtained from Ibbotson Associates (2008) and deflated by the inflation rate, measured by changes in the Consumer Price Index, to compute real returns on the following securities: Treasury bills – the bill with the shortest maturity not less than one month; intermediate-term government bonds – a bond with a maturity near five years; long-term government bonds – a bond with a maturity near twenty years; and large company stocks – the Standard and Poor's 500 stock composite index, which is the commonly used proxy for the market.

The data available for 82 years contain only sixteen 5-year and eight 10-year non-overlapping returns. Bootstrapping reduces estimation risk when the parameters of a distribution are not known. Bootstraps resample data using the observed distribution, instead of an assumed distribution, to approximate the distribution of an estimator. Block bootstraps preserve both serial and cross-sectional correlations within the blocks. The returns for different horizons are estimated by drawing 1,000 random blocks with replacement from the real monthly returns for 1926-2007. For the annual returns, a month is randomly sampled with replacement a thousand times, the continuously compounded real monthly returns on stocks, Treasury securities, and inflation are aggregated for each 12-month period starting with the sampled month, and the 12-month real returns are calculated by subtracting inflation from the security returns. For the annualized 5-year returns, the continuously compounded real monthly returns on stocks, Treasury securities, and inflation are summed for each 60-month period starting with the sampled month, and the annualized real returns are estimated as the differences between the mean 12-month returns on the securities and inflation. The annualized 10-year real returns are estimated in a similar manner as the annualized 5-year real returns, except that the mean 12-month real returns are calculated for 10-year periods.

The market and inflation risks of each of the three Treasury securities are investigated through the following univariate and multiple regression models, separately for 1-, 5-, and 10-year periods:

$$Rt = \alpha + \beta i \text{ Inflation} + \varepsilon t \qquad (1)$$

$$Rt = \alpha + \beta m \text{ Market Return} + \varepsilon t \qquad (2)$$

$$Rt = \alpha + \beta i \text{ Inflation} + \beta m \text{ Market Return} + \varepsilon t \qquad (3)$$

where Rt is the real return on Treasury security t, α is the regression intercept, βi is the inflation beta, βm is the market beta, relative to S&P 500 index returns, and εt is the error term.

EMPIRICAL RESULTS

The descriptive statistics in panel A of Table 1indicate that the mean annual inflation rate during the study period was 2.85% and the mean real risk-free returns increased with maturity, from 0.84% for Treasury bills (TB) to 2.26% for intermediate-term government bonds (IGB) and 2.38% for long-term government bonds (LGB). Stocks provided mean real returns of 6.32%. The means were above the medians for inflation, IGB, and LGB, but below the medians for TB and stocks, indicating positive skewness in the former and negative skewness in the latter continuously compounded returns. The standard deviations of real returns increased with maturity and risk, being lowest for TB and highest for stocks. However, the risk-return tradeoff, measured by the coefficient of variation (CV), was best for IGB, followed by stocks, LGB, and TB.

All the three Treasury securities will yield the same cost of equity for investments with a market beta of one. However, for defensive investments, the cost of equity will be lowest if TB is the risk-free security and highest if LGB is the risk-free security. By contrast, for aggressive investments, the cost of equity will be highest if TB is the risk-free security and lowest if LGB is the risk-free security. For example, based on the mean returns in panel A, for an investment with a beta of 0.5, using TB, IGB, and LGB as the risk-free securities produce CAPM-estimated real costs of equity of 3.58%, 4.29%, and 4.35%, respectively. For an investment with a beta of 1.5, using TB, IGB, and LGB as the risk-free securities yield real costs of equity of 9.06%, 8.35%, and 8.29%, respectively. These examples illustrate that whether TB or Treasury bonds are used as the risk-free security has a greater impact on the cost of equity than the maturity period of the Treasury bond used.

Table 1: Descriptive Statistics of Inflation and Real Risk-free and Stock Returns

	Inflation	Treasury Bills	Intermediate Govt. Bonds	Long Govt. Bonds	Stocks
Panel A. 1-Year Returns					
Maximum (%)	17.78	12.60	23.40	35.90	63.80
Mean (%)	2.85	0.84	2.26	2.38	6.32
Median (%)	2.73	1.06	1.81	2.00	7.98
Minimum (%)	-11.39	-17.42	-17.32	-32.45	-102.14
Standard Devn. (%)	4.23	4.03	6.45	9.25	20.72
Coeff. of Variation	1.48	4.82	2.86	3.89	3.28
Panel B. Annualized 5-Year Returns					
Maximum (%)	8.43	7.86	11.80	15.83	29.33
Mean (%)	2.43	0.53	2.00	2.15	5.48
Median (%)	2.37	0.69	1.69	1.58	5.98
Minimum (%)	- 6.13	- 6.27	- 6.14	-10.80	-20.83
Standard Devn. (%)	2.63	2.67	3.62	4.60	7.73
Coeff. of Variation	1.08	4.99	1.81	2.14	1.41
Panel C. Annualized 10-Year Returns					
Maximum (%)	8.46	4.54	8.89	10.77	17.38
Mean (%)	3.39	0.41	1.88	1.82	7.11
Median (%)	3.21	1.02	1.36	0.46	8.35
Minimum (%)	- 2.64	- 5.44	- 4.54	-6.28	-4.37
Standard Devn. (%)	2.39	2.22	3.10	4.09	5.17
Coeff. of Variation	0.71	5.42	1.65	2.24	0.73

Descriptive statistics of returns and volatility of inflation,, real risk-free returns, and real stock returns for periods of 1, 5, and 10 years.

The mean annualized 5-year inflation rate of 2.43% in panel B was lower than the annual rate. The mean annualized 5-year real returns of 0.53% for TB, 2.00% for IGB, 2.15% for LGB, and 5.48% for stocks were also below their annual means. This pattern of mean returns, and the relationships between mean and median returns, were similar to those for annual returns. However, the differences between the annualized 5-year mean and median returns were smaller than those for annual returns for all securities except LGB. The standard deviations were lower for all securities, and the pattern across securities was similar to that for annual returns. The CV was also lower for all securities except TB, and stocks had the lowest CV, followed by IGB, LGB, and TB.

The mean annualized 10-year inflation rate of 3.39% in panel C was the highest, while the mean real returns of 0.41% for TB, 1.88% for IGB, and 1.82% for LGB were the lowest, of all the three horizons. Mean real stock returns of 7.11% were the highest of the three horizons. Unlike the previous patterns, LGB had lower mean returns than IGB over 10 years. All the three Treasury securities had the widest difference between mean and median returns over the 10-year period, but this difference was wider for stocks in the 1-year period. Annualized 10-year returns had the lowest standard deviations for all securities, and the lowest CV for all securities except TB, which had the highest CV over 10 years. The pattern of CV across securities over 10 years was similar to that for 5 years.

The descriptive statistics in Table 1 indicate that TB had the lowest standard deviation of returns, but highest CV, because of its very low real returns, in all the three horizons. The best proxy for a risk-free security should have the lowest risk; its low return is irrelevant. TB returns have the lowest volatility, and their volatility declines with the investment horizon. However, the appropriate risk measure in the CAPM is not overall volatility, but market beta, which can be formulated as the product of the volatility of the security's returns relative to the volatility of market returns and the correlation of the security's returns with market returns. The market betas of Treasury securities over different horizons are evaluated through regressions.

Table 2: Regressions of Annual Real Risk-free Returns

	Treasury Bills	**Intermediate Govt. Bonds**	**Long Govt. Bonds**
Panel A. Regressions against Real Market Returns			
Intercept	0.01**	0.02**	0.02**
(T-statistic)	(6.69)	(10.19)	(6.78)
Market Beta	-0.01	0.01	0.05**
(T-statistic)	(-1.43)	(1.36)	(3.51)
Adjusted R-square	0.00	0.00	0.01
Panel B. Regressions against Inflation			
Intercept	0.03**	0.05**	0.06**
(T-statistic)	(28.31)	(25.96)	(19.40)
Inflation Beta	-0.72**	-0.96**	-1.19**
(T-statistic)	(-35.93)	(-25.40)	(-20.38)
Adjusted R-square	0.56	0.39	0.29
Panel C. Regressions against Real Market Returns and Inflation			
Intercept	0.03**	0.05**	0.05**
(T-statistic)	(27.76)	(24.75)	(17.99)
Market Beta	-0.00	0.02**	0.06**
(T-statistic)	(-0.83)	(2.70)	(4.97)
Inflation Beta	-0.72**	-0.96**	-1.20**
(T-statistic)	(-35.87)	(-25.56)	(-20.79
(F-statistic)	645.63	328.22	225.00
Adjusted R-square	0.56	0.40	0.31

Univariate and multiple regressions of annual real risk-free returns against real market returns and inflation.
**, ** indicate significance at the 1 and 5 percent levels, respectively.*

The regressions of annual real risk-free returns in Table 2 show that the market betas of TB and IGB are not significantly different from zero. LGB have a significant market beta of 0.05 but market returns explain only 1% of LGB returns. All the three Treasury securities have significantly negative inflation betas, which increase in magnitude with the maturity period. This indicates that inflation hurts longer-term securities, whose cash flows are fixed for longer periods, more than shorter-term securities. Inflation explains 56% of variations in TB returns, but only 29% of variations in LGB returns, suggesting that inflation is the primary determinant of the real returns of short-term Treasury securities, but other factors have a greater influence on the real returns of long-term Treasuries. In the multiple regressions, the only material change is that IGB have a significant stock beta of 0.02. These results show that, in the short-term, only TB do not have any market risk and, although Treasury securities of all maturities are exposed to significant inflation risk, TB have the lowest inflation risk.

The regressions of annualized 5-year real risk-free returns in Table 3 indicate that only LGB have a significant market beta (0.08) and market returns explain only 2% of LGB returns. Inflation betas are significantly negative for all the three Treasury securities and increase in magnitude with maturity. The explanatory power of inflation is lowest for LGB returns and highest for TB returns, but inflation explains only 38% of variations in 5-year TB returns compared to 56% of variations in 1-year TB returns. Multiple regressions slightly increase the market and inflation betas of IGB and LGB compared to the univariate regressions, and the market beta of IGB becomes significantly positive. These findings are similar to the short-term results. In the medium-term also, TB are the only Treasury security with no market risk, and they have the lowest inflation risk. Further, the inflation beta and explanatory power of inflation for TB returns are lower in the medium-term than in the short-term.

Table 4 shows that market betas are significantly positive for annualized 10-year real returns on Treasury securities of all maturities, but TB have the lowest market beta of 0.09 while LGB have the highest market beta of 0.26. All the three Treasury securities have significantly negative inflation betas, which increase in magnitude with maturity. Inflation explains only 12% of variations in TB returns, compared to 20% of variations in IGB and LGB returns. The inflation beta and explanatory power of inflation for TB returns are lowest in the long term. Multiple regressions reduce both the market and inflation betas of all the three securities, compared to the univariate regressions, and produce adjusted R-squares that are very similar to those for the inflation regressions. This suggests that the significantly positive market betas primarily reflect common variations in the real returns on stocks and Treasury securities due to inflation. The market beta of TB in the multiple regression is significant, but very low, at 0.04. These findings indicate that, in the long-term, TB have the lowest market and inflation risks, and these two factors explain only 13% of variations in TB returns, compared to 20% of IGB returns and 23% of LGB returns.

Table 3: Regressions of Annualized 5-Year Real Risk-free Returns

	Treasury Bills	Intermediate Govt. Bonds	Long Govt. Bonds
Panel A. Regressions against Real Market Returns			
Intercept	0.01**	0.02**	0.02**
(T-statistic)	(5.69)	(13.75)	(9.71)
Market Beta	-0.01	0.01	0.08**
(T-statistic)	(-0.90)	(0.90)	(4.17)
Adjusted R-square	0.00	0.00	0.02
Panel B. Regressions against Inflation			
Intercept	0.02**	0.04**	0.04**
(T-statistic)	(22.59)	(31.71)	(26.15)
Inflation Beta	-0.62**	-0.81**	-0.93**
(T-statistic)	(-24.61)	(-23.23)	(-19.73)
Adjusted R-square	0.38	0.35	0.28
Panel C. Regressions against Real Market Returns and Inflation			
Intercept	0.02**	0.04**	0.04**
(T-statistic)	(20.17)	(27.55)	(21.33)
Market Beta	0.00	0.03**	0.10**
(T-statistic)	(0.48)	(2.66)	(6.31)
Inflation Beta	-0.62**	-0.82**	-0.95**
(T-statistic)	(-24.58)	(-23.42)	(-20.48)
(F-statistic)	302.67	274.90	222.05
Adjusted R-square	0.38	0.35	0.31

*Univariate and multiple regressions of annualized 5-yeal real risk-free returns against real market returns and inflation. *, ** indicate significance at the 1 and 5 percent levels, respectively.*

Table 4: Regressions of Annualized 10-Year Real Risk-free Returns

	Treasury Bills	Intermediate Govt. Bonds	Long Govt. Bonds
Panel A. Regressions against Real Market Returns			
Intercept	-0.00	0.01**	-0.00
(T-statistic)	(-1.91)	(5.57)	(-0.27)
Market Beta	0.09**	0.14**	0.26**
(T-statistic)	(6.69)	(7.38)	(11.20)
Adjusted R-square	0.04	0.05	0.11
Panel B. Regressions against Inflation			
Intercept	0.02**	0.04**	0.04**
(T-statistic)	(13.16)	(25.21)	(21.96)
Inflation Beta	-0.32**	-0.58**	-0.76**
(T-statistic)	(-11.72)	(-15.77)	(-15.76)
Adjusted R-square	0.12	0.20	0.20
Panel C. Regressions against Real Market Returns and Inflation			
Intercept	0.01**	0.03**	0.03**
(T-statistic)	(6.33)	(14.54)	(9.54)
Market Beta	0.04**	0.05**	0.16**
(T-statistic)	(3.09)	(2.70)	(6.87)
Inflation Beta	-0.29**	-0.54**	-0.64**
(T-statistic)	(-9.95)	(-13.88)	(-12.70
(F-statistic)	74.01	128.81	153.44
Adjusted R-square	0.13	0.20	0.23

*Univariate and multiple regressions of annualized 10-yeal real risk-free returns against real market returns and inflation. *, ** indicate significance at the 1 and 5 percent levels, respectively.*

The descriptive statistics in Table 1 showed that the mean real returns and volatility of Treasury securities increase with the maturity period regardless of the investment horizon. The regression results in Tables 2 through 4 show that the market and inflation risks of Treasury securities are also directly related to the maturity period for all horizons. For each Treasury security, market risk increases moderately and inflation risk declines considerably over longer periods. TB are the best proxy for the risk-free rate, with little or no market risk and the lowest inflation risk over all periods.

CONCLUSION

The risk-free rate is an important input in one of the most widely used finance models: the Capital Asset Pricing Model. Academics and practitioners tend to use either short-term Treasury bills or long-term Treasury bonds as the risk-free security without empirical justification. The goal of this paper was to identify the appropriate proxy for the risk-free rate, which has the lowest market and inflation risks over different horizons. The returns on risk-free securities and stocks as well as inflation rates for different horizons were estimated by drawing 1,000 random blocks from the real monthly returns for 1926-2007. The market and inflation risks of Treasury securities with different maturities over different investment horizons were investigated through univariate and multiple regressions. The results showed that mean real returns, volatility, and market and inflation risks, of Treasury securities increase with the maturity period. Only Treasury bills do not have any market risk for 1- and 5-year periods, and they have the lowest market risk over 10 years. Although Treasury securities of all maturities have significant inflation risk, Treasury bills have the lowest inflation risk over all three horizons. Further, the inflation beta and explanatory power of inflation for real Treasury bill returns decline with the investment horizon. Over 10 years, inflation and market risks explain only 13% of variations in real Treasury bill returns, compared to 20% of intermediate government bond returns, and 23% of long government bond returns. These findings indicate that Treasury bills are better proxies for the risk-free rate than longer-term Treasury securities regardless of the investment horizon. Since this study uses U.S. data, the results apply only to the U.S. market. Researchers may conduct similar studies with data from other markets to identify appropriate risk-free rates for those markets.

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