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The Risk-Free Asset Implied by the Market: *Medium-Term Bonds instead of Short-Term Bills*

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KEY FINDINGS

- In empirical tests of the capital asset pricing model, the theoretical risk-free asset is typically assumed to be 1-month Treasury bills. This article examines the implications of a misspecified risk-free asset—that is, the possibility that the true risk-free asset is a longer-maturity Treasury bond.
- A simple theoretical derivation leads to the testable prediction that low-beta (high-beta) stocks should then exhibit positive (negative) bond betas.
- The author finds strong empirical confirmation for these predictions and can pinpoint the market-implied risk-free asset at medium-term (5-year) bonds. Concrete implications of this finding are a lower equity risk premium and a less steep security market line.

ABSTRACT: *In empirical tests of the capital asset pricing model, the theoretical risk-free asset is typically assumed to be 1-month Treasury bills. This article examines the implications of a misspecified risk-free asset—that is, the possibility that the true risk-free asset is a longer-maturity Treasury bond. A simple theoretical derivation leads to the testable prediction that low-beta (high-beta) stocks should then exhibit positive (negative) bond betas. The author finds strong empirical confirmation for these predictions. The market-implied risk-free asset can be pinpointed at medium-term (5-year) bonds. Concrete implications of this finding are a lower equity risk premium and a less steep security market line.*

TOPICS: ***Portfolio theory, portfolio construction, derivatives****

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The capital asset pricing model (CAPM) is a theoretical one-period model with an abstract market portfolio and risk-free asset. It does not specify the length of the one period or the practical definitions of the market portfolio and the risk-free asset. In empirical tests of the CAPM, the market portfolio is commonly assumed to be the (US) equity market portfolio, and the risk-free asset is proxied with short-term (1-month) Treasury bills. With the latter choice, the investment horizon is implicitly assumed to be 1 month. This assumption is typically not motivated as an explicit, intentional choice, suggesting that it has more to do with practical considerations, such as data availability and ensuring a sufficient number of independent observations. Although this choice has been questioned by authors such as Levhari and Levy (1977), Levy (1981), and

Gilster (1983), it remains the standard approach in almost all empirical asset pricing studies.

With the choice of equities as the market portfolio and 1-month Treasury bills as the risk-free asset, the existence of longer-maturity Treasury bonds is basically ignored in most of the asset pricing literature. Given a 1-month investment horizon, one could argue that bonds should be part of the risky asset market portfolio. Stambaugh (1982) found that for inferences about the CAPM it matters little whether bonds are included in the market portfolio. Another approach is to distinguish between separate equity and bond market factors, as in the five-factor model of Fama and French (1993). However, contrary to the three-factor model (without bond factors) proposed in the same article, this five-factor model never gained widespread popularity. Reporting three-factor alphas has effectively become a prerequisite for getting an asset pricing study published, and bonds have become the forgotten asset class.

Should Treasury bonds be seen as risky assets in the first place? Following Campbell and Viceira (2001), one could also argue that an N-year (zero coupon) Treasury bond is the risk-free asset for an investor with an N-year investment horizon.[1] In other words, there is not one but rather many risk-free assets, and every Treasury bill or bond effectively serves as the risk-free asset for investors with the corresponding investment horizon.

The one-period assumption of the CAPM is clearly a simplification of reality because different investors can have different investment horizons. If we accept the simplification of a single investment horizon, the question is which assumed length of the investment horizon gives the best approximation of reality (as in being representative for the average or marginal investor). Without empirical support, the choice of 1-month Treasury bills as the risk-free asset is as arbitrary as any other choice, such as 5-year, 10-year, or 30-year bonds.

[1] At longer horizons, inflation shocks become an increasingly important consideration, which makes inflation-indexed Treasury bonds the ultimate risk-free investment. In light of the limited availability and short history of such bonds, Campbell and Viceira (2001) found that (shorter-dated) nominal bonds are a good proxy. Moreover, because large institutional investors such as pension funds and insurance companies typically have nominal liabilities, this also makes nominal bonds the actual risk-free (liability-matching) alternative for them.

This article first examines the theoretical implications of a misspecified risk-free asset. In other words, what happens if the CAPM is tested assuming that 1-month Treasury bills are the risk-free asset, but the true risk-free asset is an N-year bond? A simple derivation leads to the testable prediction that stocks with low equity betas should then exhibit a positive exposure to N-year bond returns, and stocks with high equity betas should exhibit a negative exposure to N-year bond returns. More specifically, the analysis predicts an inverse linear relationship between equity betas and bond betas.

The second contribution of this article is that it provides strong empirical support for this theoretical prediction. Using a wide range of common test portfolios, the empirical relation between equity betas and bond betas indeed turns out to be inversely linear—not just slightly, but almost perfectly so. These empirical results are in line with, but also extend, the finding of Baker and Wurgler (2012) that stocks with low equity betas have higher bond betas (i.e., an increased sensitivity to changes in interest rates).

The third contribution of this article is that by testing bonds with different maturities, their fit with the theoretical model predictions can be compared. Empirically, bonds with a maturity of about 5 years emerge as the appropriate choice for the risk-free asset. This result is robust across subsamples and carries over to the main international markets (the United Kingdom, Japan, and the Eurozone), although the precise market-implied maturity of the risk-free asset can vary a bit, from about 2 to 10 years depending on the sample. A crucial realization is that the appropriate choice for the risk-free asset does not require arbitrary assumptions but can actually be inferred from observed market prices.

The finding that the market-implied risk-free asset is a multiyear bond has important asset pricing implications. Because bonds have a higher average return than bills, a direct implication is that the equity premium becomes smaller. As such, misspecification of the risk-free asset helps to rationalize, or at least provide a partial explanation for, the equity premium puzzle of Mehra and Prescott (1985). This result is consistent with Benartzi and Thaler (1995), who also concluded that longer investment horizons help to explain the equity premium puzzle, albeit using an entirely different (behavioral finance) approach. Our results are also consistent with the common choice in the asset allocation literature to

measure the equity premium relative to bonds instead of bills (see, e.g., the classic Dimson, Marsh, and Staunton 2003 study on long-term asset class returns). Another implication of bonds as the risk-free asset is that the slope of the security market line becomes less steep, which is consistent with the empirical results of the very first tests of the CAPM by, for example, Black, Jensen, and Scholes (1972), Miller and Scholes (1972), and Fama and MacBeth (1973).[2] More generally, our findings imply that virtually the entire existing asset pricing literature may suffer from incorrect inferences due to misspecification of the risk-free asset.

THEORETICAL ANALYSIS

The CAPM is a theoretical one-period model that predicts that the expected return on a security, in excess of the risk-free return, is proportional to its beta with respect to the market portfolio times the return of the market portfolio, also in excess of the risk-free return:

$$R_i - R_{risk\text{-}free} = \beta_i (R_{market} - R_{risk\text{-}free}) + \varepsilon \tag{1}$$

The market portfolio and risk-free asset in the CAPM are both abstract concepts that need to be replaced with appropriate practical proxies in empirical tests. In most studies, the (US) equity market portfolio is taken as the market portfolio, and short-term (1-month) US Treasury bills are assumed to be the risk-free asset. This gives the following empirical specification of the CAPM:

$$R_i - R_{bills} = \beta_i (R_{equity} - R_{bills}) + \varepsilon \tag{2}$$

Now suppose the risk-free asset in Equation 2 is misspecified because the true risk-free asset happens to be an N-year bond instead of a 1-month bill. The correct empirical specification is then not Equation 2 but

$$R_i - R_{bonds} = \beta_i (R_{equity} - R_{bonds}) + \varepsilon \tag{3}$$

[2] A misspecified risk-free asset cannot explain the later finding of Fama and French (1992) that market beta is completely unpriced in the cross section of stock returns—that is, a completely flat security market line, let alone the inverse relation between beta and return documented in more recent studies, such as by Blitz and van Vliet (2007). However, it does make those results slightly less anomalous.

Equation 3 can be rewritten as

$$R_i - R_{bills} = \beta_i (R_{equity} - R_{bills}) + (1 - \beta_i)\ (R_{bonds} - R_{bills}) + \varepsilon \tag{4}$$

Equation 4 implies that if the CAPM is tested with short-term bills as the risk-free rate, whereas the true risk-free asset consists of longer-maturity bonds, securities will exhibit exposures to this bond asset. More specifically, the model predicts a beta to the bond asset that is inversely linearly related to its equity beta. For instance, if the equity beta is 0.7, then the predicted bond beta is 0.3; if the equity beta is 1.3, then the predicted bond beta is −0.3. In other words, if we subtract 1 from the equity beta, the predicted bond beta is equal to the remaining equity beta with the sign flipped.

We empirically test Equation 4 by regressing test assets simultaneously on the equity market portfolio and bonds:

$$R_i - R_{bills} = \beta_{equity,i} (R_{equity} - R_{bills}) + \beta_{bond,i} (R_{bonds} - R_{bills}) + \varepsilon \tag{5}$$

We next examine whether the jointly estimated bond betas and equity betas exhibit a relation that is consistent with the predictions of Equation 4.

Test Equation 5 regresses stock portfolios on the equity market portfolio and a bond asset, where all returns are taken in excess of the standard risk-free return based on 1-month bills. This relates to the work of Fama and French (1993), which is best known for proposing a three-factor model consisting of equity market, size (SMB), and value (HML) factors but which also proposes a five-factor model that additionally includes risk-free bond (TERM) and default risk (DEF) factors. The purpose of their five-factor model is to explain the returns not only on stock portfolios but also on bond portfolios. Contrary to the three-factor model, this five-factor model never gained widespread popularity, even though the bond factors are found to provide incremental explanatory power for the cross section of stock returns. An explanation for this may be that Fama and French (1993) tested their models on size/value-sorted portfolios, although, as we show later, bond factors are particularly relevant for portfolios sorted on equity market beta.

Furthermore, Fama and French (1993) did not relate the inclusion of their bond factor to a potentially

misspecified investment horizon and risk-free asset. By testing Equation 5 we aim not to pick up any kind of bond exposures, but specifically the exposures predicted by Equation 4. Fama and French (1993) noted that "the common sensitivity of stocks and bonds to TERM and DEF implies interesting intertemporal variation in expected stock and bond returns" and argued that their multifactor models may be interpreted as empirical applications of the Merton (1973) intertemporal CAPM (ICAPM). In fact, bond factors are commonly included—and found to be significant—in the ICAPM literature, but not in the context of questioning the choice of short-term bills as the appropriate risk-free asset. More recently, Brennan and Zhang (2018) proposed a CAPM in which the investment horizon is stochastic and found that the market-implied average horizon is considerably longer than 1 month. Also in that model, however, the risk-free asset is held constant at 1-month Treasury bills.

Our approach also relates to the work of Baker and Wurgler (2012), who examined the co-movement between equity and bond returns. After observing that the correlation between equity and bond returns was highly unstable, they proceeded by testing Equation 5, arguing that "this regression allows us to isolate cross-sectional differences in 'bond beta' without confusing them with the average correlation between the aggregate stock market and bonds." They found that government bonds co-move strongly with stocks of large, mature, low-volatility, profitable, and dividend-paying firms. More recently, De Franco, Monnier, and Rulik (2017) and Coqueret, Martellini, and Milhau (2017) also found that stocks with low equity betas exhibit positive bond betas. Based on these findings, these studies concluded that low-beta stocks are bond-like stocks. These results are directionally consistent with the predicted exposures in case of a misspecified risk-free asset. However, Equation 4 predicts a fully inverse linear relation between bond betas and equity betas, which remains to be investigated.

DATA

For the empirical analysis we consider a large number of widely accepted test portfolios. To properly test the relation predicted by Equation 4, we ensure that these test portfolios exhibit a large dispersion in equity betas. Most of the data are sourced from the online data library of professor Kenneth French.[3] Specifically, we gather value-weighted returns for the 10 industry portfolios, 10 portfolios sorted on size, 10 portfolios sorted on book to market, 10 portfolios sorted on operating profitability, 10 portfolios sorted on investment (1-year change in total assets), 10 portfolios sorted on earnings to price, 10 portfolios sorted on cash flow to price, 10 portfolios sorted on dividend yield and the portfolio of zero-dividend stocks, 10 portfolios sorted on accruals (change in operating working capital), 10 portfolios sorted on net share issues, 10 portfolios sorted on residual variance (past 60 days), and 10 portfolios sorted on market beta (past 60 months).[4] This yields a total of 121 well-diversified portfolios as test assets. The sample period spans more than half a century, from July 1963 to December 2018.

The standard US equity market return and risk-free return (short-term US Treasury bills) are also obtained from Kenneth French's data library. For the bond asset, we consider US Treasury bonds with a wide range of maturities because our aim is to infer the appropriate choice for the risk-free asset from the data. Specifically, we consider 2-year, 5-year, 7-year, 10-year, and 30-year Treasuries, for which we obtain returns from Datastream (using mnemonics BMUS02Y, BMUS05Y, BMUS07Y, BMUS10Y, BMUS30Y). We convert all portfolio returns to excess returns by subtracting the standard risk-free return, as in Equation 5.

MAIN RESULTS

For each of the 121 test portfolios, we obtain jointly estimated equity and bond betas by running the regression in Equation 5 over the full sample. In Exhibit 1, the estimated equity and bond betas are plotted against each other; Panels A, B, C, D, and E show the results using, respectively, 2-year, 5-year, 7-year, 10-year, and 30-year US Treasuries as the bond asset. For ease of interpretation, we subtract 1 from the estimated equity market betas.

[3] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

[4] Portfolios sorted on past return (1-month reversal, 12–1-month momentum, 60–12-month reversal) are not included in the analysis because such portfolios exhibit strong time-varying properties. However, we note that the conclusions remain unchanged if we ignore such concerns and include portfolios sorted on past return anyway.

EXHIBIT 1

Full-Sample Results (July 1963–December 2018)

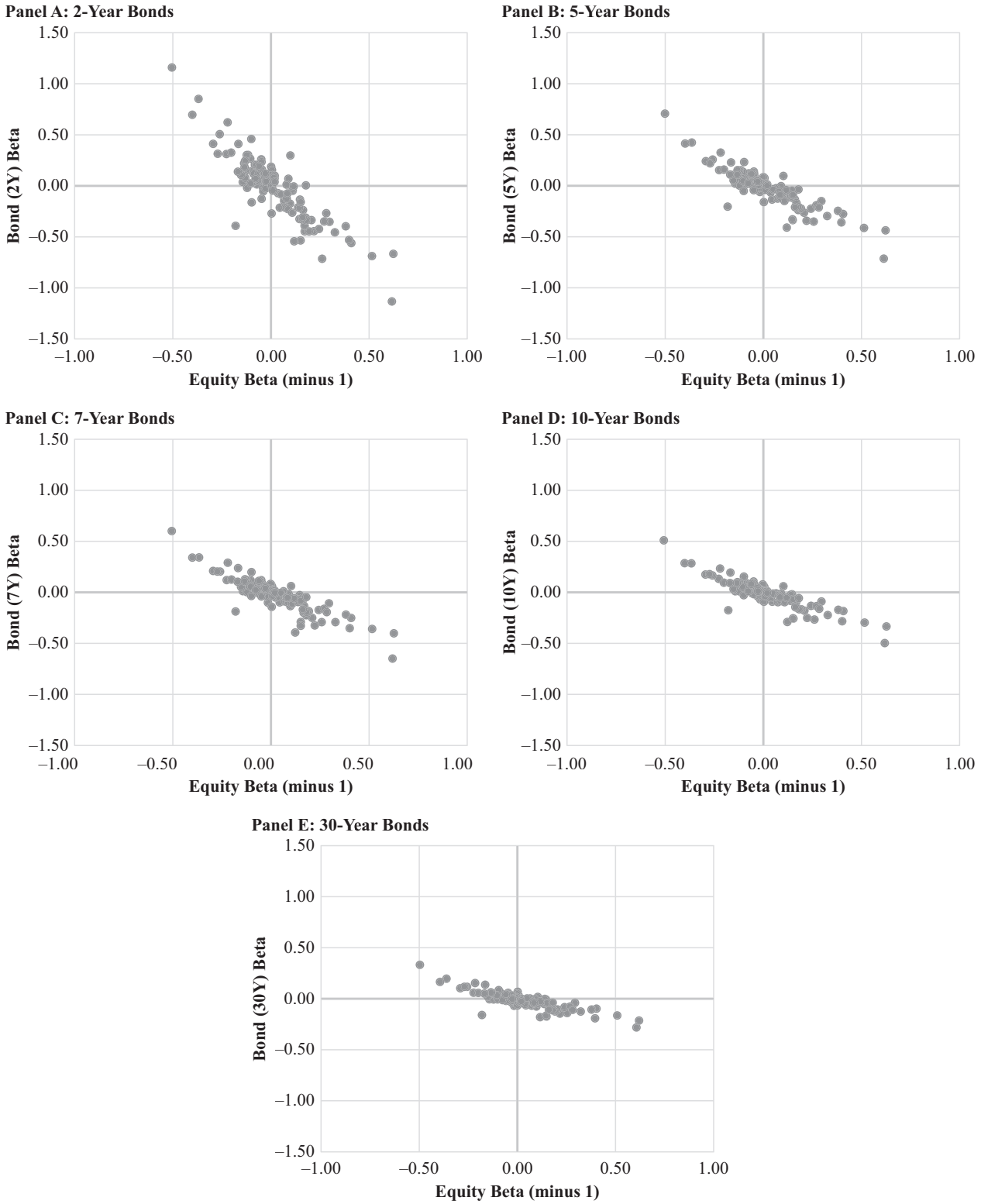
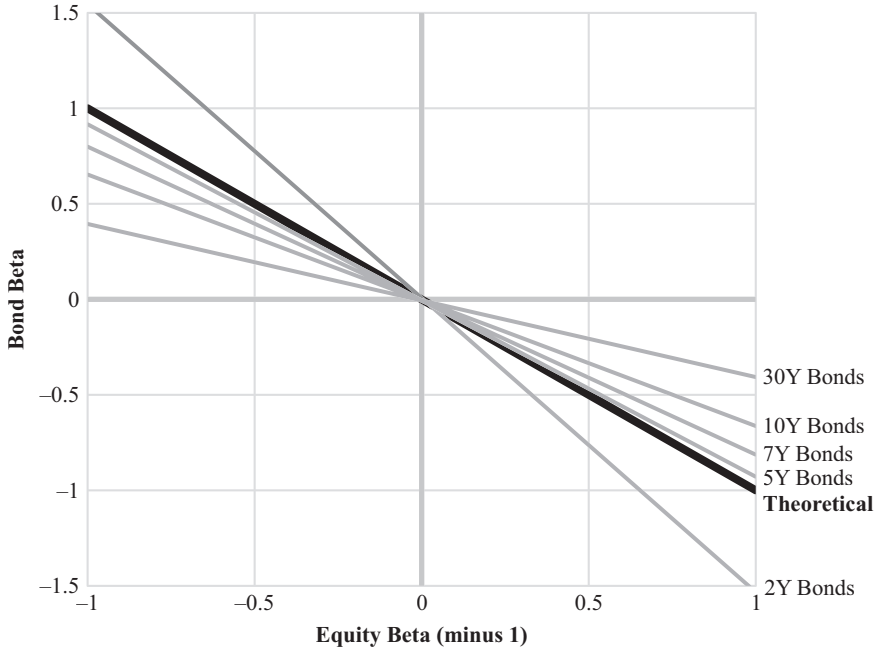


EXHIBIT 2
Estimated Regression Lines



Consistent with the predictions of Equation 4, we observe an inverse linear relation between the estimated equity and bond betas; that is, the higher the equity beta, the lower the bond beta, and vice versa. In fact, the portfolios line up almost perfectly from top left, through the origin, to the bottom right in the graphs.[5] Thus, portfolios with equity betas below 1 have positive bond betas, portfolios with equity betas above 1 have negative bond betas, and portfolios with a beta of 1 have a zero bond beta.

For each of the five graphs in Exhibit 1, we estimate an ordinary least squares (OLS) regression line. Exhibit 2 shows the five estimated regression lines in one graph, and Exhibit 3 reports the statistics for these regressions. The fit of the regressions is very strong, with adjusted R^2 levels ranging from 73% to 80%. The estimated intercepts are all statistically indistinguishable from zero, which is consistent with the predicted relation in Equation 4. The slope coefficients are all negative, and highly statistically significantly so, with *t*-statistics of about −20. They range from −0.40 for the 30-year bond asset to −1.54 for the 2-year bond asset. The coefficient that comes closest to the −1 level predicted by Equation 4 is the −0.92 estimated slope for 5-year bonds. This is also visible in Exhibit 2, where the regression line for 5-year bonds coincides almost exactly

EXHIBIT 3
Full-Sample Regressions of Estimated Bond Betas on Equity Betas (minus 1)

	Dependent Variable: Bonds with Maturity				
	2 Years	**5 Years**	**7 Years**	**10 Years**	**30 Years**
Intercept	0.01	–0.01	–0.01	0.00	–0.01
t-Statistic	0.48	–0.77	–1.01	–0.87	–1.49
Slope	–1.54	–0.92	–0.81	–0.66	–0.40
t-Statistic	–20.09	–21.49	–20.85	–21.09	–17.72
R^2	77.2%	79.5%	78.5%	78.9%	72.5%

[5] There is one notable outlier in the third quadrant: a portfolio for which we observe an equity beta below 1 but also a negative bond beta. On further inspection, this turns out to be the energy industry portfolio. This is a rather special case because this particular industry is known to be strongly dependent on the oil price. In unreported results we find that if, next to the equity and bond market factors, we include an oil factor (the GSCI Energy index), the negative bond beta virtually disappears, and we get a very high (0.3) loading on the oil factor instead. Because none of the other 120 test assets exhibit such high loadings on the oil factor (all the other estimated exposures to this factor are between −0.1 and 0.1), we do not explore this issue further.

with the predicted theoretical relation. We also observe the highest R^2 for the 5-year bond asset. Thus, the data are not only highly supportive of the theoretically predicted implications of a misspecified risk-free asset but also enable us to pinpoint the most appropriate choice for the risk-free asset as a bond with a maturity of about 5 years. Crucially, this result is inferred from the data and does not rely on arbitrary assumptions.

We note that the results for the other bond assets are consistent with this conclusion. For instance, the slope of −0.66 for the 10-year bond asset implies that a 66% position in this asset can also be interpreted as the market-implied risk-free asset. A 66% position in a 10-year bond has roughly the same duration as a 100% position in a 5-year bond. The same reasoning applies to the 2-year bond asset, where the slope of −1.54 implies that a 154% position in this asset can be interpreted as the risk-free asset, which again goes in the direction of a 5-year bond.

SUBSAMPLE ROBUSTNESS

To examine the robustness of the results, we split the sample in three subperiods of about the same length: July 1963 to December 1981, January 1982 to December 2000, and January 2001 to December 2018. The first subperiod is characterized by rising interest rates and hence low bond returns, whereas the other two subperiods are characterized by high bond returns owing to falling interest rates. Exhibit 4 plots the estimated bond betas against the estimated equity betas over the three subperiods, similar to the full-sample analysis shown in Exhibit 1. The figures show that the inverse linear relation between bond betas and equity betas is highly persistent over time.

For each chart in Exhibit 4, we again estimate the OLS regression line. Exhibit 5 shows the estimated slope coefficients, and Exhibit 6 shows the R^2 levels of the regressions. The explanatory power is consistently high, with R^2 levels ranging from over 75% in the middle subperiod to over 47% in the most recent subperiod. The slope coefficients are all negative and (not reported) highly significant at the most conservative levels for statistical significance. A slope coefficient of −1, which according to Equation 4 implies the appropriate risk-free asset, is found for 2-year bonds in the first subsample, 7-year bonds in the middle subsample, and between 2- and 5-year bonds in the last subsample.

In the full sample, we found 5-year bonds to be the market-implied choice for the risk-free asset, but the subsample results indicate that there may be some estimation error around this estimate. A less assertive claim is that the market-implied risk-free asset may be anything in between 2-year bonds and 7-year bonds. An alternative interpretation is that the market-implied risk-free asset is not constant over time—that is, that the investment horizon of the representative investor is time varying. In either case, the appropriate risk-free asset that emerges from the data is clearly not a 1-month bill but a multiyear bond. Intuitively, this also seems to be a much more reasonable investment horizon for the representative agent than the commonly assumed 1-month horizon, given that many big investors have much longer horizons (e.g., liability-driven investors, such as pension funds and insurance companies, and sovereign wealth funds investing for future generations).

INTERNATIONAL ROBUSTNESS

In this section, we examine whether the results for the US market carry over to the main markets outside the United States: the United Kingdom, Japan, and the Eurozone. Because of data availability limitations, our international analyses are based on a much smaller set of test portfolios over a shorter sample period. For each of the three markets we construct value-weighted, monthly rebalanced decile portfolios by sorting stocks on their volatility over the preceding 3 years. The universe consists of all stocks in either the S&P Broad Market Index or FTSE Index at each point in time, which gives an average of 482 stocks for the United Kingdom, 1,284 for Japan, and 861 for the Eurozone. The sample period is from January 1986 to December 2018 for the United Kingdom and Japan and, because of the introduction of the euro, from January 1999 to December 2018 for the Eurozone. We compute the standard risk-free return for each market based on 1-month deposit rates and obtain 2-, 5-, 7-, 10-, and 30-year bond returns for each market from Datastream. For Japan, we drop the 30-year bond asset because of limited data history. All returns are in local currency (i.e., GBP, JPY, and EUR) and taken in excess of the standard (1-month) local risk-free return.

For the United Kingdom, Japan, and the Eurozone, we find similar inverse relations between equity and bond betas as in the United States. In other words, in these markets as well, stocks with equity betas below

EXHIBIT 4
Subsample Results

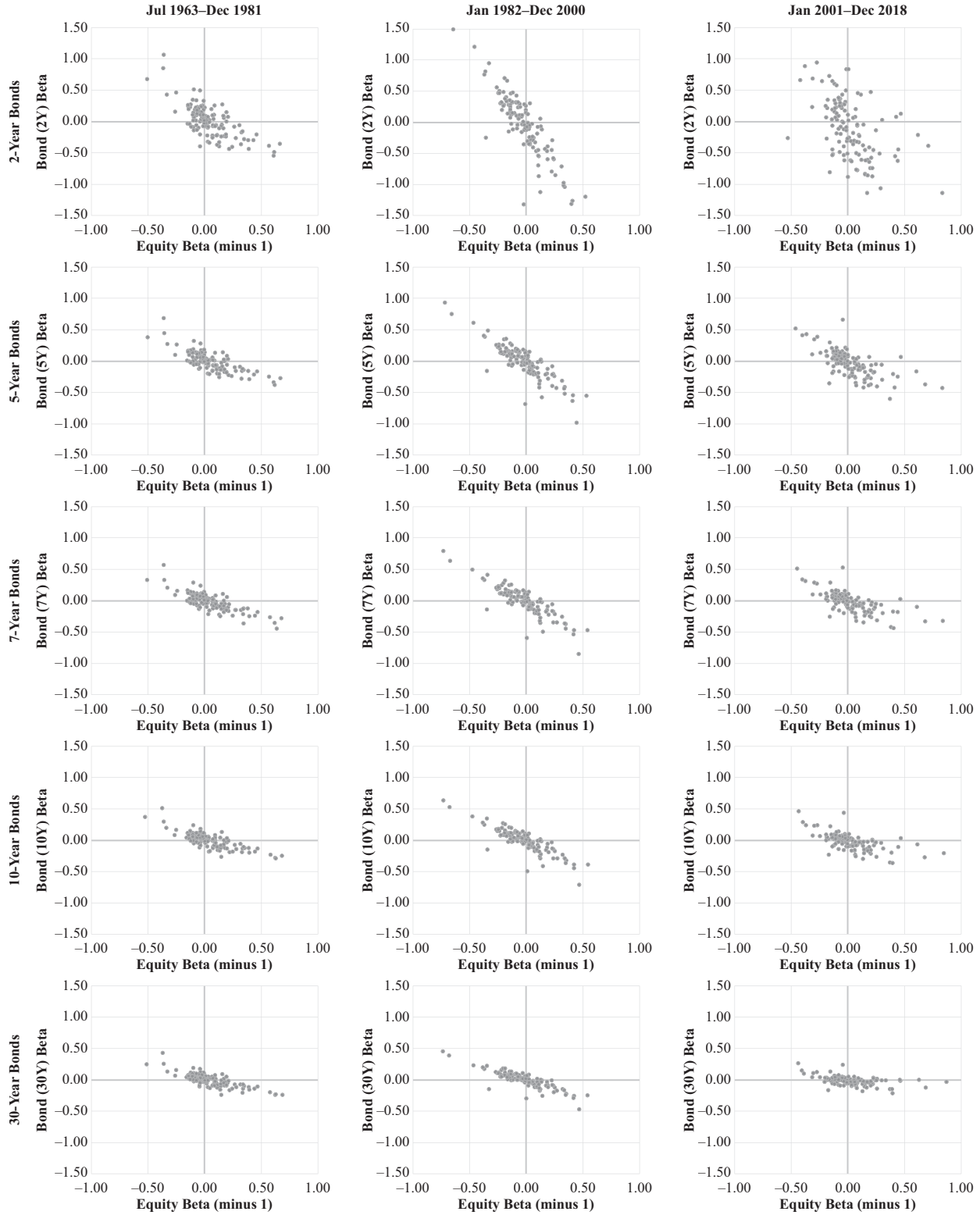


EXHIBIT 5
Estimated Regression Slopes

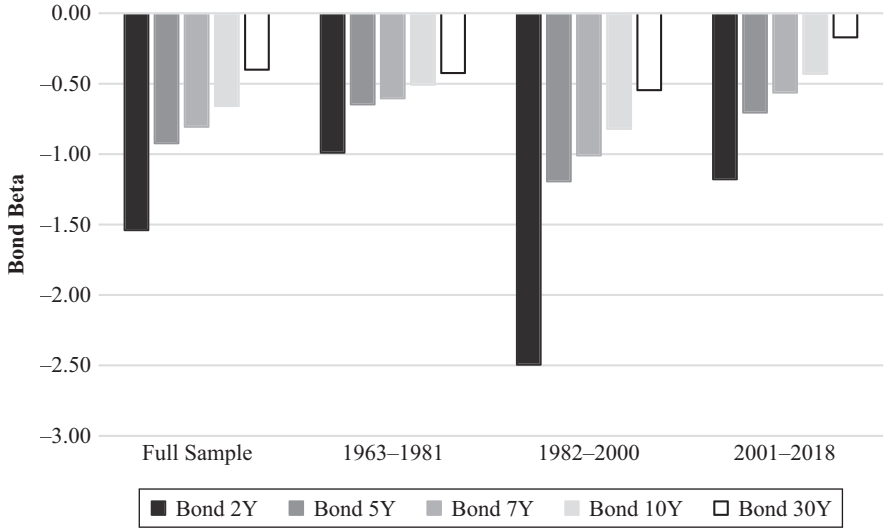
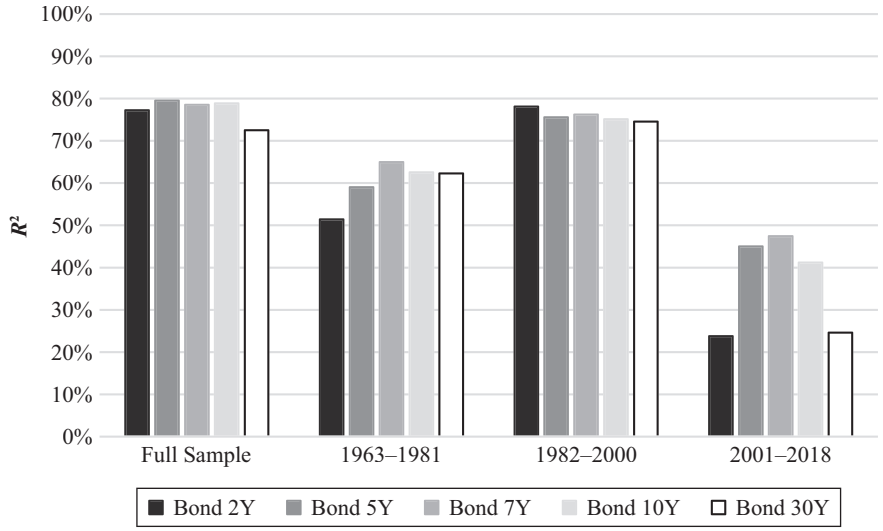


EXHIBIT 6
Regression R^2 Levels



1 have positive bond betas, whereas stocks with betas above 1 have negative bond betas. This provides three additional confirmations for Equation 4 (i.e., the predicted relation in case of a misspecified risk-free asset).

Regressing the estimated bond betas on the estimated equity betas gives the slope coefficients depicted in Exhibit 7, with corresponding R^2 levels shown in Exhibit 8. The *t*-statistics of the estimated slopes are not reported but are, again, all highly significant (about −7 on average). The regression intercepts are all statistically indistinguishable from zero, which is also consistent with Equation 4. Maximum R^2 levels for each market are over 80%. For the United Kingdom and the Eurozone, slopes of −1 can be observed for 10-year bonds, implying that these are the most appropriate choice for the risk-free asset. For Japan, the implied risk-free asset seems to have a shorter maturity but is harder to pinpoint given the less monotonic pattern of the slopes for

EXHIBIT 7

International Results, Estimated Regression Slopes

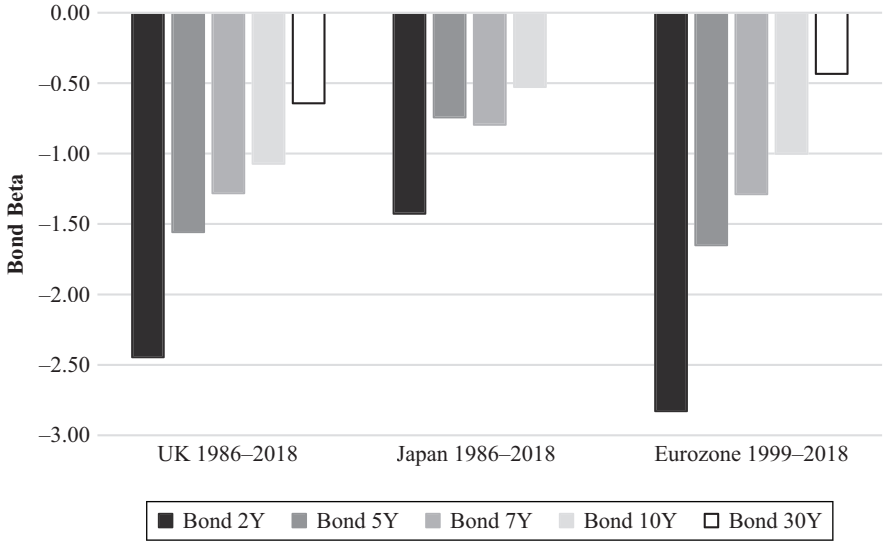
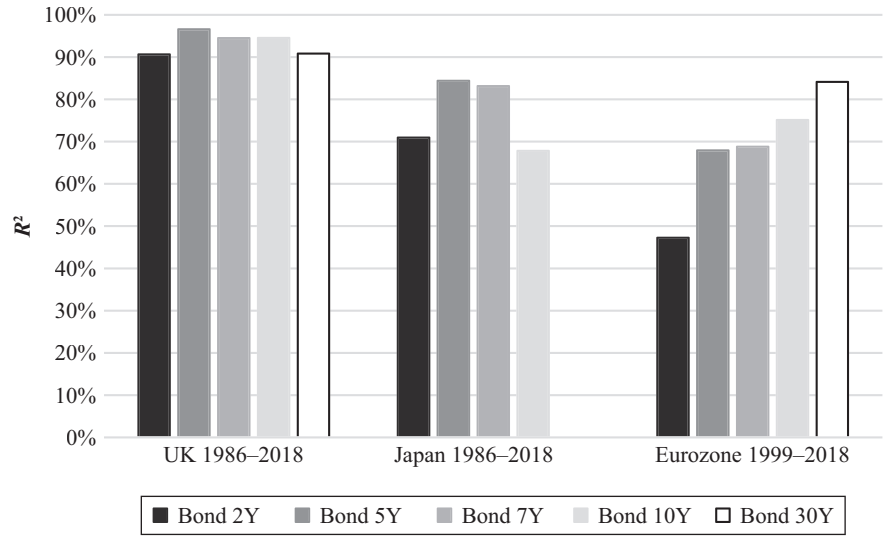


EXHIBIT 8

International Results, Regression R^2 Levels



different maturities. Together, the international results provide strong corroborating evidence for our main US results.

THE RETURN MEASUREMENT INTERVAL

The CAPM is a single-period model, and the empirical asset pricing literature commonly assumes the length of this single period to be 1 month—not only by using 1-month Treasury bills as the risk-free asset but also by using a monthly data frequency. Because our empirical tests consistently imply that the appropriate choice for the risk-free asset is a multiyear bond, the question is whether the data frequency should also be aligned with this implied investment horizon. In other words, should asset pricing tests be conducted on returns

measured over multiyear periods? Handa, Kothari, and Wasley (1989) and Kothari, Shanken, and Sloan (1995) conducted asset pricing tests using returns measured over annual horizons. More recently, Kamara et al. (2016) estimated betas using return measurement intervals ranging from 1 month to 5 years.

In our base-case tests for the United States over the full sample, 5-year bonds emerged as the market-implied risk-free asset, which would imply switching from monthly returns to returns measured over 5-year intervals. Although this might be a trivial step in theory, it is anything but straightforward in practice. For one, despite spanning more than half a century, the 1963–2018 sample period provides us with a mere 11 independent 5-year observations. The number of observations could be increased by using overlapping 5-year periods, but this does not change the fact that there are still only 11 truly independent 5-year observations, which is simply too low for meaningful statistical inferences. Another challenge is that returns measured over 5-year intervals have different properties than commonly studied monthly returns. For instance, what is the expected return on an asset with a market beta of 2 over a 5-year period with a −60% market return? What are expected asset returns if the market gains 200% over a 5-year period? Such extreme returns are well within the range of feasible outcomes or have occurred already at some point in the past. Yet another complicating matter is that many standard test assets are not constant over 5-year periods but are rebalanced annually (e.g., size or book-to-market sorted portfolios) or even monthly (e.g., momentum portfolios). A portfolio based on 12-month momentum completely changes at least five times during a 5-year interval.

Until these challenges have been resolved, it seems preferable to retain the monthly data frequency in asset pricing tests and only replace 1-month Treasury bills with 5-year Treasury bonds as the risk-free asset. We acknowledge that theoretically it would be better to also align the return measurement interval with the market-implied investment horizon, but practically this is likely to introduce more problems than it solves.

CONCLUSIONS

The risk-free asset in the CAPM is an abstract construct. In the empirical asset pricing literature, the risk-free asset is typically assumed to be 1-month Treasury bills. This article examines the possibility that the risk-free asset is misspecified with this choice—that is, that the true risk-free asset may actually be a Treasury bond with a much longer maturity. A simple theoretical derivation leads to the testable prediction that stocks with low equity betas should then exhibit a positive exposure to bond returns, and stocks with high equity betas should exhibit a negative exposure to bond returns. More specifically, the model predicts an inverse linear relationship between equity betas and bond betas.

Testing this prediction on a comprehensive sample of widely used factor and industry portfolios, we find strong empirical evidence in support of this theoretical prediction. The empirical relation between equity betas and bond betas turns out to be inversely linear indeed—almost perfectly so. By using bonds with different maturities, we are able to ascertain that bonds with a maturity of about 5 years are the most appropriate choice for the risk-free asset. This implies that the risk-free asset is misspecified in almost all empirical asset pricing studies, which simply use 1-month Treasury bills. A key insight is that the appropriate choice for the risk-free asset does not require arbitrary assumptions but can be inferred from market prices. The results are robust across subsamples and carry over to the main international equity markets (United Kingdom, Japan, Eurozone), although the implied maturity of the risk-free asset varies between 2 and 10 years depending on the sample.

The finding that the market-implied risk-free asset is a multiyear bond has important implications for asset pricing tests. For one, it implies that the results of almost the entire empirical asset pricing literature are biased to a greater or lesser extent because of misspecification of the risk-free asset. Given that the historical average return on bonds has been higher than that on bills, direct implications are that the equity premium becomes smaller and that the slope of the security market line becomes less steep. This helps to rationalize, at least partially, some of the biggest puzzles in finance.

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ADDITIONAL READING

Interest Rate Exposure of Volatility Portfolios

CARMINE DE FRANCO, BRUNO MONNIER, AND KSENYA RULIK

The Journal of Index Investing
https://jii.pm-research.com/content/8/2/53

ABSTRACT: *The authors assess the exposure of stock portfolios sorted by total volatility to interest rate risk and determine whether this nonequity risk can explain differences in risk and risk-adjusted*

returns between low- and high-volatility portfolios over a 25-year period for US equities. They find that the addition of an interest rate risk factor to the four-factor model reveals a small but positive duration for low-volatility portfolios. However, this new factor fails to improve the explanatory power of the model for both low- and high-volatility portfolios and has no significant impact on the portfolios' risk-adjusted return. The authors find that interest rate factor loadings are fairly robust across different specifications of the multifactor model for low-volatility portfolios but are unstable for high-volatility portfolios. For all volatility portfolios under study, the significance of the results is highly dependent on the choice of time period.

Equity Portfolios with Improved Liability-Hedging Benefits

Guillaume Coqueret, Lionel Martellini, and Vincent Milhau

The Journal of Portfolio Management
https://jpm.pm-research.com/content/43/2/37

ABSTRACT: *This article analyzes whether it is* desirable and feasible *for an investor endowed with liabilities to hold an equity portfolio with better liability-hedging properties than a broad cap-weighted index. From a theoretical standpoint, the authors show that liability-driven investors will generally benefit from reducing the tracking error of their performance portfolios with respect to liabilities, unless this comes at an exceedingly large loss of performance. The authors then empirically document the heterogeneity of interest-rate-hedging properties across the constituents of the S&P 500 universe, and they show that substantial welfare gains can be achieved by selecting low-volatility and high-dividend-yield stocks. These benefits are further enhanced if a minimum-variance weighting scheme is applied to the selected stocks.*

The Volatility Effect

David C. Blitz and Pim van Vliet

The Journal of Portfolio Management
https://jpm.pm-research.com/content/34/1/102

ABSTRACT: *There is empirical evidence that stocks with low historical volatility have high risk-adjusted returns, with annual alpha spreads of global low-versus high-volatility decile portfolios of 12 percentage points over 1986-2006. This volatility effect appears independently in US, European, and Japanese markets. It is similar in size to classic effects such as value, size, and momentum, and cannot be explained by implicit loadings on these well-known effects. These results indicate that equity investors overpay for risky stocks. Possible explanations include leverage restrictions, inefficient two-step investment processes, and behavioral biases of private investors. To exploit the volatility effect in practice, investors might include low-risk stocks as a separate asset class in the strategic asset allocation phase of the investment process.*