Does interest rate exposure explain the low-volatility anomaly?

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Abstract

We show that part of the outperformance of low-volatility stocks can be explained by a premium for interest rate exposure. Low-volatility stock portfolios have negative exposure to interest rates, whereas the more volatile stocks have positive exposure. Incorporating an interest rate premium explains part of the anomaly. Depending on assumptions about the interest rate premium, interest rate exposure explains between 20% and 80% of the unexplained excess return. We also find that the interest rate risk premium in equity markets exhibits time variation similar to bond markets.

Keywords: Cross-section of stock returns; Low-volatility anomaly; Interest rates; Factor model

1. Introduction

Ang et al. (2006) show that U.S. stocks with high lagged idiosyncratic volatility earn very low future average returns, and these assets are mispriced by the Fama-French three factor model. Although the debate on the low-volatility effect is relatively new, it is closely related to the criticism on the CAPM model that is around for much longer, for example Black et al. (1972) and Fama and French (1992). The unexplained returns of portfolios sorted on idiosyncratic volatility are large. Depending on the calculation

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method, estimates go up to 1.5% a month. Low-volatility equity strategies exploit this phenomenon to deliver better risk-adjusted returns than standard benchmark indices.

Over the years several explanations have been offered for the unexplained excess returns of stocks with low volatility. As will be discussed in the literature section, most of these are related to behavioral biases. Many rational explanations have been tested and rejected, especially by Ang et al. (2006), as they control for size, book-to-market, leverage, liquidity, coskewness and a number of other variables. Baker and Wurgler (2012) not only show that so called bond-like stocks comove with government bonds, but also that variables that are known predictors of bond returns predict return differences between stock portfolios sorted on volatility. Our paper builds on this work and specifically focusses on explaining the low-volatility anomaly and the level and predictability of the interest rate premium in both the bond and stock market. A relation between the low-volatility anomaly and government bonds makes sense if volatility is thought of as an indicator of the distance between equity and bonds in the capital structure.

In this study our main finding is that a significant part of the outperformance of low-volatility stocks can be explained by differences in interest rate exposure. We find that low-volatility portfolios have more exposure to interest rates. One can think of several explanations why this is the case. Portfolios based on low volatility are more exposed to defensive sectors, such as utilities and consumer staples. Following Baker and Wurgler (2012), these companies are in general, large, profitable, and have relatively low growth opportunities and frequently pay dividends. These characteristics make cash flows more predictable and result in lower valuation uncertainty, increasing the similarities with bonds. This is consistent with the finding of Ang et al. (2006) that these companies have indeed lower dispersion in analysts' forecasts. Dividend paying stocks are more likely to be used as replacement for bonds by investors looking for income.

Our results imply a strong implicit exposure to interest rate risk of low-volatility portfolios. We show that the interest rate sensitivity of the portfolio with the lowest volatility decile is equivalent to the interest rate sensitivity of a portfolio consisting for 34% of a bond portfolio and 66% of the equity market portfolio. In contrast, the sensitivity of the highest decile portfolio corresponds to a more than 100% short position of this bond portfolio.

Because of the differences in exposure, the risk premium that we estimate explains part of the excess return of a long-short volatility portfolio. We find that this exposure explains about 20% of the return if we assume that the stock market prices interest rate risk similarly as the bond market. If we relax this assumption and estimate the premium separately in the stock market, the interest rate exposure explains up to 80%. In both cases, differences in interest rate exposure combined with the estimated risk premium, results in a significantly reduced mispricing of low-volatility stocks. We find these results to be robust for taking into account time variation of the interest rate exposure.

For our study we use ten portfolios over the period from July 1963 to December 2014, defined by sorts on residual variance of individual US stocks using the Fama-French three-factor model. We define our bond factor as the return of an equally-weighted portfolio consisting of US government bonds with various maturities. In order to estimate the interest rate exposure we run standard time series regressions of portfolio returns on equity market and interest rate factors. Fama MacBeth regressions are employed to estimate the premium for the interest rate exposure in the equity market. Combined, this analysis enables us to evaluate the impact on the unexpected excess return of the long short portfolio. We use various estimations of the premium in order to test for the robustness of our findings.

When we estimate the interest rate premium from the cross-section of the ten equity portfolios, we find a surprisingly high compensation for interest rate risk of 0.91% per month. In the bond market we find an average monthly excess return of just 0.17% over the same period. We show that this difference is reduced when taking time variation into account and/or excluding the most volatile portfolio. However, these results suggest that interest rate risk is priced differently in bond and equity markets. Hence, the extent to which we explain the volatility anomaly depends on whether we assume integrated or segmented bond and equity markets. Furthermore, variables that are known to predict the excess returns of bonds to a certain extent, such as the CP factor introduced by Cochrane and Piazzesi (2005) and the yield spread, have explanatory power in the equity market as well. Our results imply a strategy that combines a long-short low-volatility portfolio with a short bond position.

Differences in interest rate exposure are a rational explanation of a phenomenon that is often explained by behavioural effects. In order to build intuition for this relationship, in the final part of the paper we take a look at interest rate risk from the perspective of the capital structure. Based on Choi et al. (2015), we explore the implications of Mertons model on the relationship between leverage, equity volatility and duration. It shows that the relation between equity volatility, duration and leverage is not necessarily monotic, but depends on company specific characteristics such as the duration and volatility of the firms assets. The suggested relation is in line with our empirical results.

In the next section we give a brief overview of relevant literature. Section 3 provides the construction method of low-volatility portfolios. In section 4 we empirically test for the impact of the interest rate exposure. After constructing a bond factor, we estimate both the exposure and risk premium. This enables us to look at the impact of interest rates on the outperformance of low-volatility portfolios. In section 5 we compare the forecasting of the interest rate premium in the bond and equity market and show that there are clear similarities. Section 6 evaluates the empirical results from a theoretical standpoint, based on Merton's model in relation to the capital structure of a firm. Summary, conclusions and suggestions for further research are given in section 7.

2. Literature

According to the standard CAPM only systematic risk is priced. About a decade ago Ang et al. (2006) showed that U.S. stocks with high lagged idiosyncratic volatility earn very low future average returns, and that these assets are mispriced by the Fama-French model. In Ang et al. (2009) the same effect is also found in markets outside the United States. However, there are theories that suggest a positive relationship between idiosyncratic volatility and expected returns, for example Malkiel and Xu (2002) argue that investors that are not able to fully diversify the risks could demand a premium. Some studies confirm this positive relationship (Lintner (1965), Lehmann (1990)), others find no significant relation (Tinic and West (1986) and Malkiel and Xu (2002))[1].

Instead of idiosyncratic volatility, related work focusses on total volatility. On stock level most volatility is idiosyncratic. Blitz and Van Vliet (2007) provide empirical evidence that stocks with low total volatility have high risk-adjusted returns. An overview of previous studies is provided by Van Vliet et al. (2011). They show that both idiosyncratic an total volatility yield similar results. Looking at Jensen's alpha, the (unexplained) monthly relative outperformance between the most and least volatile portfolio is usually somewhere between 0.5 and 1.5% a month.

The discussion on the relationship between total volatility and returns is closely related

[1] Ang et al. (2006) explain the surprising negative relation between idiosyncratic volatility and returns by pointing out that these previous studies miss the negative relationship mainly because these do not calculate the idiosyncratic volatility on firm level.

to the debate around the CAPM model, as high beta stocks are usually stocks with high volatility. Already in the seventies Haugen and Heins (1972) wrote a working paper in which they found deficiencies in earlier studies about the relationship between risk and realized returns. In addition, Black et al. (1972) showed that the relationship between risk and returns is much flatter than predicted by the CAPM. Later, Fama and French (1992) also found that the relationship was flat, prompting many to conclude that beta was dead. Haugen and Baker (1991) investigated minimum variance portfolios in the U.S. equity market, pointing out a 30% reduction in portfolio volatility, compared to both a common U.S. index and randomly selected portfolios, with no reduction in average returns.

Over the years several explanations for the outperformance of low-volatility stocks have been proposed, both behavioural and rational in nature. A common behavioural explanation is the lottery effect introduced by Barberis and Huang (2007). They argue that if investors perceive stocks as lottery tickets this may cause high-risk stocks to become overpriced, which can even make the risk-return relation turn negative, whereas the previous explanations can only explain a flat relation. This is sometimes referred to as the winners curse.

Another example of a behavioural explanation is given by Hsu et al. (2013). They argue that the anomaly is a combination of the fact that sell side analysts inflate earnings forecasts more aggressively for more volatile stocks and investors overreact to analysts' forecasts which leads to an overvaluation of high volatility stocks.

There are also rational explanations proposed. For example, Black (1993) argues that investors face leverage restrictions which tend to flatten the relationship between risk and return. An example of leverage restrictions are short selling limits. Frazzini and Pedersen (2014) introduce a model that includes leverage and margin constraints and show that this model is able to generate a relatively high return of low-beta stocks. They also show that a Betting Against Beta factor (BAB) produces significantly positive returns. Moreover, they show that this phenomenon is found in a number of other asset classes as well.

Sirri and Tufano (1998) introduce the gaming effect. This effect implies that mutual fund managers have an incentive to buy high-risk stocks and ignore low-risk stocks, also flattening the risk-return relationship. Subsequently, Blitz and Van Vliet (2007) argue that investors with a relative return perspective flatten the risk-return relationship. Even though low-volatility stocks might be attractive in terms of alpha and Sharpe ratio, they can still be unattractive for investors with relative return objectives.

The exposure of low-volatility portfolios to other factors is also frequently mentioned. For example Baker et al. (2014) find that these portfolios benefit from the small cap and value premium. Ang et al. (2006) however show that the phenomenon cannot be fully explained by conventional asset pricing models. Novy-Marx (2014) finds that high volatility and high beta stocks tilt strongly to small, unprofitable, and growth firms. According to this study these tilts explain the poor performance of the most aggressive stocks. Bali and Cakici (2008) find that the idiosyncratic volatility effect is correlated with size and Martellini (2008) shows that there is a strong relation between volatility and returns if only the surviving stocks are taken into account. Ang et al. (2006) add much to the understanding of the differences in results by demonstrating the impact of many control variables such as liquidity, trade volume and size.

Ang et al. (2009) show that there is strong covariation in the low returns to high-idiosyncratic-volatility stocks across countries, suggesting that broad, not easily diversifiable factors lie behind this phenomenon. They control for various factors that are a possible explanation of their findings such as market frictions and information dissemination and argue that none of these explanations can entirely account for the volatility anomaly.

They also show that leverage does not explain the low idiosyncratic volatility effect.

In their results they control for the option interpretation as by Johnson (2004), which involves a leverage effect interacting with idiosyncratic volatility. With leverage defined as the book value of debt over the sum of the book value of debt and the market value of equity, they find that controlling for leverage slightly strengthens the idiosyncratic volatility effect.

Chow et al. (2014) show that factor attribution analysis of the US and global developed low-volatility portfolios reveal that returns in excess of cap-weighted index returns are substantially driven by the value, BAB and duration premiums. While they construct low-volatility portfolios with the constraint of non-negative weights, the factors used to explain the excess return are long-short portfolios. This implies that the investability is limited. Also, the low-beta anomaly is likely closely related to the BAB factor, as beta is an important driver of volatility. It is therefore an intuitive outcome that the latter can explain excess returns based on the first. Finally, note that most of these explanations implicitly assume that investors use realized volatility as proxy for expected volatility. Fu (2009) finds a positive relationship between volatility and returns by using a GARCH model to estimate expected volatility.

In this study we ask ourselves whether interest rates can explain the cross sectional volatility effect. Fama and French (1993) take several bond factors into account to explain the cross section of stocks and explore the level of integration between the stock and bond market. In their study, the first bond market factor is defined as the excess returns of a long term government bond over the risk free rate. Their second bond market factor is the excess return of a market portfolio of long term corporate bonds over the same long term government bond. They show that in addition to the market, size and value factor, these two bond factors do not add much to the time-series regressions. However, this study do not look at volatility sorts. The same variables are used by Clarke et al. (2010) in the context of the cross section and volatility. They show that there is a negative correlation between their volatile-minus-stable (VMS) factor and bond returns. Baker and Wurgler (2012) show that government bonds comove more strongly with so called bond-like stocks. Furthermore, they show that variables that are known predictors of the excess bond returns predict return differences between portfolios sorted on total volatility. They argue that the relationship is driven by a combination of effects including correlation between real cash flows, risk based return premia and period flights to quality by investors. Our main contribution is to study the pricing of interest rate risk in both equity and bond markets.

3. Constructing volatility portfolios

There are many ways to construct low volatility portfolios. In the existing literature, both total and idiosyncratic volatility is used often, with comparable results (Ang et al. (2006) and Van Vliet (2011)).

Obviously, volatility is related to the beta with respect to the equity market. Hence the volatility and Betting Against Beta factor are ways of exploiting the similar effects and therefore the overlap should be large. Also minimum variance portfolios have received considerable attention. As Chow et al. (2014) write, any reasonable methodology that shifts allocations from high-beta stocks to low-beta stocks could be calibrated to have volatility comparable to that of the minimum-variance portfolio. One difference is of course that the minimum variance portfolio involves diversification between stocks whereas the construction of the low-volatility and low-beta portfolios is usually ignoring interaction between stocks. However, by looking solely at the idiosyncratic volatility, diversification no longer plays an important role.

As presented by Van Vliet et al. (2011), there are many different ways to measure the low-volatility effect. In this paper, we use the portfolios published on the website of Kenneth French. These portfolios are formed monthly, based on the variance of the residuals from the Fama French three factor model (RVar) using NYSE breakpoints.

RVar is estimated using 60 days of lagged returns[2]. The portfolios for month t (formed at the end of month $t-1$), include NYSE, AMEX/NYSE MKT, and NASDAQ stocks. In Table 3.1 we show several characteristics of these ten portfolios. The portfolio with the most volatile stocks (portfolio 10) has a monthly excess return of only 0.15%, which is 0.81% less than the portfolio with the least volatile stocks (portfolio 1). Although our main focus in this research is on the relative returns of the volatility portfolios, it is interesting to see what the differences in variance are. Evaluating the Sharpe ratio, the most volatile portfolio (portfolio 10) has a negative Sharpe ratio of -0.10 compared to 0.52 for the portfolio with the lowest volatility (portfolio 1). Looking at the Jensen's alpha based on the CAPM or Fama French three factor model, we see a similar pattern. In fact, when we control for the market beta the alpha of the 1-10 long-short portfolio increases from 0.81% to 1.25%. Finally, we note that the pattern of all these characteristics is in general smooth between the first and ninth decile and more extreme for portfolio 10. One could argue that portfolio 10 is an outlier. We will test the robustness of our results by excluding this portfolio.

4. Interest rate sensitivity

In this section we define a bond factor, discuss the exposure to this factor for the various deciles and estimate the return premium for bearing interest rate risk. We find that low-volatility stocks benefit from having negative exposure to interest rates.

4.1. Bond factor

Using the ten portfolios sorted on idiosyncratic volatility, we study the extent to which differences in level of interest rate exposure explain the low-volatility effect. Many

[2] In this study we look at lagged (realised) volatility as measure of volatility. As pointed out by Ang et al. (2009), idiosyncratic volatility is persistent and therefore related to future volatility. Fu (2009) shows that using estimated future idiosyncratic volatility calculated by employing an exponential GARCH model yields different results.

Table 3.1: This table shows several main characteristics of ten portfolios sorted on residual volatility over the sample period 1968-2014. It shows the average monthly excess return, the standard deviation, Sharpe ratio and the average marketshare of the portfolio. The last three columns show the average unexplained excess return (Jensen's Alpha) together with the market beta based on the CAPM model and the unexplained excess return based on the Fama French 3 factor model.*, **, and *** denote statistical significance at the 10, 5, and 1% levels.

Portfolio	Mean	Std	Sharpe Ratio	Market	CAPM α	CAPM β	FF3 α
1	0.96	3.63	0.52	0.27	0.20*	0.69	0.13**
2	1.01	4.21	0.49	0.17	0.17*	0.86	0.15***
3	0.95	4.59	0.41	0.13	0.08	0.94	0.02
4	1.01	4.96	0.41	0.10	0.09	1.02	−0.02
5	1.03	5.19	0.41	0.08	0.09	1.07	0.02
6	1.17	5.70	0.46	0.07	0.17**	1.18	0.13*
7	0.96	6.16	0.30	0.05	−0.09	1.28	−0.11
8	1.14	6.78	0.37	0.05	0.05	1.37	0.03
9	0.90	7.60	0.22	0.04	−0.26**	1.52	−0.26**
10	0.15	8.72	−0.10	0.04	−1.04***	1.59	−1.02***
1-10	0.81	7.35	0.38	NA	1.25***	−0.90	1.15***

different interest rate variables can be constructed that describe interest rate developments or yield curve changes. Several previous studies show that a level factor explains most of the variance of excess bond returns (Litterman and Scheinkman (1991) and Driessen et al. (2003)). A common way to define the level factor is to combine government bonds with different maturities. We follow this approach and combine the returns of U.S. government bonds of various maturities into an equal-weighted portfolio. We use the return of this portfolio as a variable that represents shifts in the yield curve, where $r_{n,t}$ is the monthly total return of U.S. governments bonds with 1, 2, 5, 7 and 10 years maturity respectively and $r_{f,t}$ is the rate on a one-month U.S. Treasury Bill. The bond returns are obtained from CRSP. Over the whole sample from 1968 until 2014 the average excess return of the bond factor is 0.17% with a standard error of 0.06%.

$$INTR_t = \frac{1}{N}\sum_n r_{n,t} - r_{f,t-1} \tag{1}$$

We use bond returns instead of bond yields, because returns enable us to estimate the premiums later in this study. In the remainder of this study we will refer to this variable as the bond factor. Positive exposure to this factor corresponds to negative exposure to interest rates.

Earlier literature, for example Cochrane and Piazzesi (2005), provides evidence that excess returns of interest rates are predictable to a certain extent. As our bond factor is a weighted average of excess returns, it can also be partly predicted. For the sake of simplicity, we ignore this predictability for now[3]. Also note that our factor is dominated by the developments of the long end of the curve. As both the change in the yield and duration are important drivers of bond returns, the bonds with a longer maturity (and therefore duration) have a larger weight in our factor. In order to test for robustness, we have looked into alternative measures of the yield curve, for example the sensitivity to the longer end of the yield curve. We separated the sensitivity to short and long maturities by regressing the equity returns simultaneously on a short and a long maturity bond factor. As this does not lead to different conclusions we do not show these results for the sake of brevity.

4.2. Interest rate exposure

In order to study the interest rate sensitivity of the different volatility portfolios, we start with a simple linear regression of excess portfolio returns on the bond factor as defined above.

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{I,i} \cdot INTR_t + \varepsilon_{i,t} \tag{2}$$

Table 4.1 shows the main results, We find that nine out ten portfolios have positive

[3] Later on, in section 5, we will show that the explanatory power of the Cochrane-Piazzesi variable (CP) is limited.

exposure to the bond factor. The results show a clear downward trend with increasing volatility. If we compare these exposures with the characteristics in Table 3.1 there is a similar jump from the ninth portfolio to the tenth (most volatile) portfolio. If the historic outperformance of low-volatility portfolios is due to the factor exposure that these portfolios have, the fact that these patterns are similar makes sense, assuming a positive premium for this risk. In order to compare the exposures with bond duration, the numbers should be multiplied with the duration of the factor portfolio, which is, on average, around three years.

Table 4.1: This table shows the factor exposures in equation (2) and equation (3), based on the period 1963 - 2014. The last column shows the correlation of the portfolios and bond factor. Each second row shows the standard error between brackets.

	Bond factor (eq. (2))			Market and bond factor (eq. (3))		
Portfolio	α_i	$\beta_{I,i}$	Correlation	α_i	$\beta_{M,i}$	$\beta_{I,i}$
1	0.44	0.62	0.23	0.15	0.68	0.33
	(0.15)	(0.11)		(0.07)	(0.02)	(0.05)
2	0.50	0.52	0.17	0.15	0.85	0.15
	(0.18)	(0.13)		(0.06)	(0.01)	(0.05)
3	0.45	0.54	0.16	0.06	0.94	0.13
	(0.19)	(0.14)		(0.07)	(0.01)	(0.05)
4	0.52	0.45	0.12	0.09	1.02	0.01
	(0.21)	(0.15)		(0.07)	(0.02)	(0.05)
5	0.55	0.41	0.11	0.1	1.07	-0.06
	(0.22)	(0.16)		(0.07)	(0.02)	(0.05)
6	0.714	0.23	0.06	0.22	1.19	-0.29
	(0.20)	(0.18)		(0.08)	(0.02)	(0.06)
7	0.49	0.33	0.07	-0.05	1.29	-0.23
	(0.26)	(0.19)		(0.08)	(0.02)	(0.06)
8	0.67	0.31	0.06	0.1	1.38	-0.29
	(0.29)	(0.21)		(0.11)	(0.02)	(0.08)
9	0.46	0.15	0.03	-0.18	1.54	-0.51
	(0.32)	(0.24)		(0.13)	(0.03)	(0.09)
10	-0.23	-0.17	-0.03	-0.91	1.63	-0.87
	(0.37)	(0.27)		(0.20)	(0.04)	(0.15)
1-10	0.67	0.79	0.15	1.07	-0.94	1.2
	(0.31)	(0.22)		(0.25)	(0.05)	(0.18)

As Table 3.1 shows, the different portfolios have a different exposure to the equity market portfolio (CAPM β). In order to correct the interest exposure in equation (2) for these differences, we run the regression including this factor.

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{M,i} \cdot MKT_t + \beta_{I,i} \cdot INTR_t + \varepsilon_{i,t} \quad (3)$$

The results in Table 4.1 show that adding the market factor lowers the estimated exposure to the bond factor. However, the negative relation with volatility still holds and the difference between the most and least volatile portfolio is slightly larger. The patterns for both the equity market and bond factor are similar to those presented by Baker and Wurgler (2012).

Of course, there are many more asset pricing models that can be evaluated next to CAPM. However, since we are interested in the overall interest rate sensitivity, in contrast to finding an additional risk factor, evaluating those complex multi-factor models is beyond the scope of this study[4].

Until now we assumed the exposure to be contant throughout time, but this does not have to be the case in reality. For instance, Baele et al. (2010) show that the stock-bond return correlation displays very substantial time variation. In order to see whether the exposure to interest rates is a function of time, we run the same regressions but now with a five year rolling time window. In Figure 4.1 we show both the average interest rate exposure and the difference in exposure between portfolio 1 and 10. We find that after 2000 the interest rate exposure of all portfolios is much lower than before and it also turns negative. Baele et al. (2010) find a similar pattern. Second, we observe an increase in dispersion between the ten portfolios sorted on volatility over time. Especially in the seventies all portfolios had about the same (positive) exposure. Starting in the mid eighties there is a growing difference between the portfolios. The difference between the exposure of the least and most volatile portfolio is shown in Figure 4.1. A possible explanation for these results is a changing economic environment. Although not the main focus of this article, we find some

[4]limiting the degrees of freedom is needed as we have only ten portfolios.

evidence for such changes across the business cycle in appendix A.

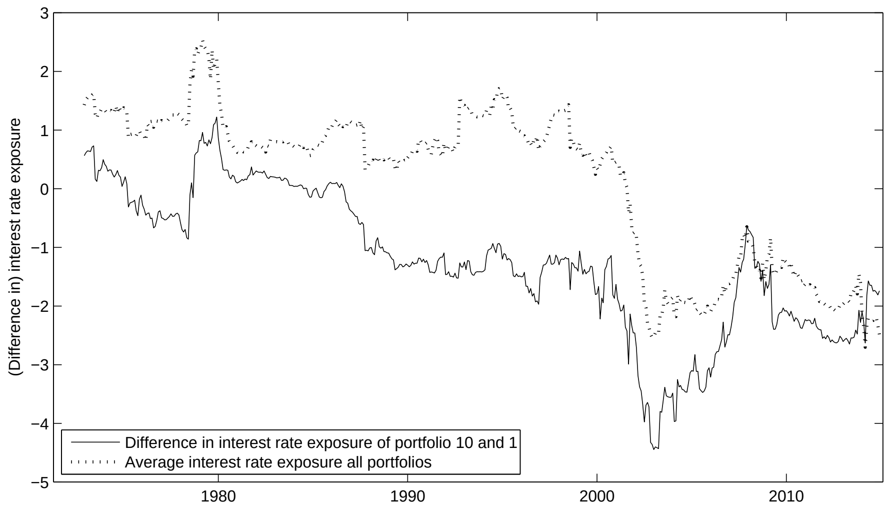


Figure 4.1: This figure shows the difference in interest rate exposure between the portfolio with the highest (portfolio 10) and lowest volatility (portfolio 1). The exposure is calculated based on a rolling window of five years.

Sometimes it is argued that equities are real assets. In order to see the impact of expected inflation, we show both the average nominal and real exposure in Figure 4.2. In order to make a fair comparison we use the 10 year Treasury to measure nominal interest rate exposure (instead of the bond portfolio earlier) and the 10 year TIPS for the real exposure.

In the run up to the GFC we find that the average real is very similar to the average nominal sensitivity. Since then, the average real interest rate sensitivity is around zero, while the nominal interest rate sensitivity remains negative. These findings point in the direction that inflation expectations matter and its impact is time-varying.

4.3. Interest rate premium

In order to assess whether the higher interest rate exposure contributes to the excess return of low-volatility stocks, we estimate the premium of this factor. Our starting

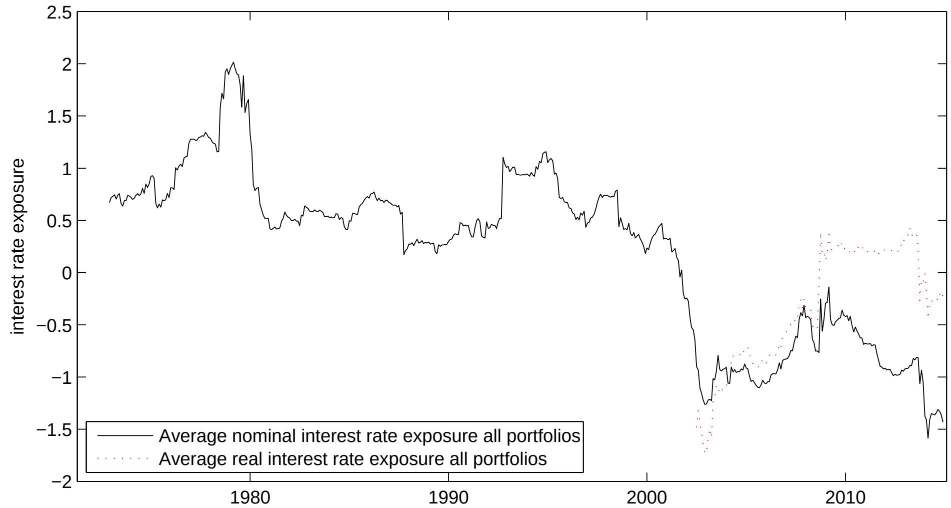


Figure 4.2: This figure shows both the nominal and the real interest rate exposure. The exposure is calculated based on a rolling window of five years. The real exposure series starts in 2002 only, as our TIPS series starts in January 1997.

point for this assessment is the two-stage Fama-MacBeth estimation, a frequently used method. After estimating the market beta $\beta_{M,i}$ and interest factor exposure $\beta_{I,i}$, the cross sectional regression used to estimate the factor premium, denoted by $\lambda_{I,t}$.

$$R_{i,t} - R_{f,t} - \hat{\beta}_{M,i} \cdot \hat{\lambda}_{M,t} = \gamma + \hat{\beta}_{I,i} \cdot \hat{\lambda_{I,t}} + u_i \tag{4}$$

While running these regressions, we assume the estimated exposures to both the market $\hat{\beta}_{M,i}$ and the bond factor $\hat{\beta}_{I,i}$ to be constant over time. Furthermore, we set the market premium, $\hat{\lambda}_{M,t}$, equal to the excess return of the market that month. This cross sectional regression results in monthly estimations for the interest rate premium $\lambda_{I,t}$, of which the average is 0.91%, with a Fama-MacBeth standard error of 0.25%[5].

Using this equity-implied estimate of the interest rate premium, we estimate the impact

[5] At this point we assume investors are rewarded for exposure to the equity market factor. We can also run the same analysis based on a univariate regression with the interest rate factor as single variable

$$R_{i,t} - R_{f,t} = \gamma + \hat{\beta}_{I,i} \cdot \hat{\lambda_{I,t}} + u_i \tag{5}$$

In this case we find an interest rate premium of 0.86%, very similar to the estimate when including the market factor.

of this exposure on the unexpected excess returns based on the CAPM model (CAPM α) presented in Table 3.1. The unexplained excess return for each portfolio i is given by equation (6).

$$\alpha_{i,t} = R_{i,t} - R_{f,t} - \hat{\beta}_{M,i} \cdot \hat{\lambda}_{M,t} - \hat{\beta}_{I,i} \cdot \hat{\lambda}_{I,t} \tag{6}$$

We show the results in the second column of Table 4.2 and graphically in Figure 4.3. The estimated unexplained excess return is the average of the time series $\alpha_{i,t}$[6]. We find that the unexplained excess return (outperformance) of low-volatility portfolios decreases with 1.06% from 1.25% to 0.19% when we take the interest rate exposure into account. This corresponds to a reduction of 80%. Our findings, based on the equity-implied estimate of the bond factor premium, show that interest rate exposure explains a large part of the outperformance.

Instead of using the equity market to estimate the interest rate risk premium, we can also turn to the bond market. If bond and equity markets are integrated, interest rate risk should carry the same price in both markets. In the bond market the most direct estimate of the interest rate risk premium is the average return of the bond factor, i.e. the historical excess return of our bond factor. Over the whole sample, the estimation based on the average monthly excess return is 0.17% with a standard error of 0.06%. We find that this estimate is significantly different from the estimate above following the Fama Mcbeth methodology (t-stat 3.4). When we use this estimate as premium in equation (6), we find the unexplained excess returns as presented in the last column of Table 4.2. We find that even though the effect is much less pronounced, this way of estimating the impact of interest rate exposure on the portfolios also leads to a significant reduction of the unexplained excess return from 1.25% to 0.99%, a

[6] As both betas are assumed to be constant, this average equals the estimate based on a full sample regression. The advantage of this method is that we have a better estimate of the standard error, similar to the Fama MacBeth approach.

reduction of 20%.

By using a beta estimate based on the full sample, we assume constant exposure. In order to evaluate the impact of this assumption, we estimate the premium based on time varying estimates of the exposures to both the market and bond factor. Applying a rolling window of five years reduces the estimated premium from 0.91% to 0.59% (S.E. 0.20%)[7]. The reduction in the unexplained excess return is shown in Table 4.2 and equals 0.75%, a relative reduction of 60%.

As mentioned in section 3, one could consider portfolio 10 to be an outlier. It is therefore interesting to see the impact of this portfolio on the results. If we remove portfolio 10 from the analysis, we find a reduced risk premium of 0.42% in the case of a constant beta and a risk premium of 0.18% if we use a five year rolling beta. For both constant and rolling beta this is less than half the estimated premium including the most volatile portfolio. However, since the unexplained return difference between portfolio 1 and 9 is also much smaller, interest rate exposure still explains a large part of the anomaly. In the case of constant beta 70% of the unexplained return between 1 and 9 is explained and 36% in the case of a time varying exposure. So even when we exclude the most volatile portfolio, the interest rate premium provides an explanation for a significant part of the unexplained returns.

It raises the question why the compensation for the same risk would be higher in the equity market than in the bond market. A possible explanation is that these two markets are not fully integrated, though it is of course also possible that some missing factors drive the difference between the equity and bond market estimates. Based on the variation in excess returns on bonds, we expect the premium for the bond factor in equity markets to be time varying as well. When we look at the time series of the premium resulting from the monthly regressions, the compensation that an equity

[7]Note that as the betas are timevarying, the estimate of the unexplained alphas can no longer be calculated by evaluating a full sample regression. It is calculated as the average of the timeseries estimates from equation (6)

investor receives for bearing the interest rate risk looks to be time varying, but without trend. We analyze this in more detail in section 5.

Table 4.2: This table shows the unexplained excess return of the 10 portfolios based on various estimates of the interest rate premium. The first method is the standard CAPM model ignoring the interest rate premium. The second method is the CAPM model extended with the bond factor (equation (3)) assuming constant exposures. Third, we use the same model but now we use rolling exposures. Last, we use the mean bond factor return as estimate of the premium in the equity market. Standard errors are given between brackets.

Portfolio	α CAPM	α Fama MacBeth constant	α Fama MacBeth rolling	α Excess return INTR
1	0.20	−0.07	0.01	0.15
	(0.07)	(0.06)	(0.05)	(0.08)
2	0.17	0.04	0.07	0.14
	(0.06)	(0.05)	(0.07)	(0.07)
3	0.08	−0.04	−0.01	0.04
	(0.07)	(0.06)	(0.08)	(0.07)
4	0.09	0.09	0.09	0.10
	(0.07)	(0.08)	(0.11)	(0.08)
5	0.09	0.13	0.12	0.10
	(0.07)	(0.08)	(0.12)	(0.08)
6	0.17	0.44	0.37	0.25
	(0.08)	(0.09)	(0.16)	(0.08)
7	−0.09	0.13	0.07	−0.02
	(0.08)	(0.08)	(0.18)	(0.09)
8	0.05	0.34	0.26	0.14
	(0.11)	(0.09)	(0.22)	(0.12)
9	−0.26	0.20	0.07	−0.14
	(0.13)	(0.07)	(0.26)	(0.14)
10	−1.04	−0.26	−0.48	−0.84
	(0.20)	(0.05)	(0.34)	(0.21)
1-10	1.25	0.19	0.50	0.99
	(0.26)	(0.05)	(0.32)	(0.25)

As all our estimates of the premium are positive, our results suggest that interest rate exposure contributes to higher returns of low-volatility stocks. As we find evidence that the unexpected excess return of low-volatility portfolios is partly due to interest rate exposure, it is insightful to see what mix of the bond factor portfolio and the market equity portfolio has the same interest rate sensitivity as the portfolios sorted on volatility. Due to the strong implicit exposure to bond returns it turns out that

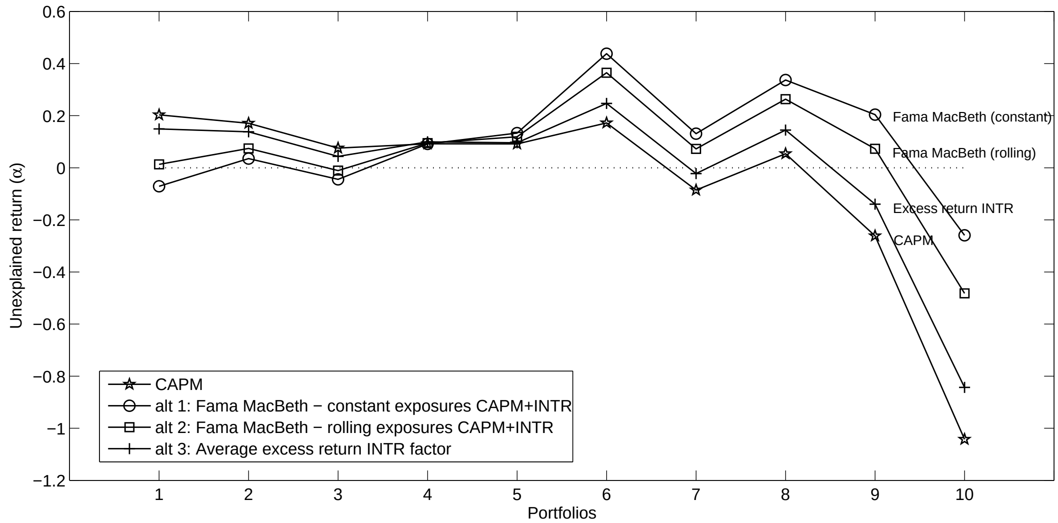


Figure 4.3: The figure shows the pattern of unexplained returns across the different portfolios as presented in Table 4.2. All models including an interest rate premium show a significant reduction in unexplained return compared to the CAPM model. The reduction depends on the chosen methodology and varies between 20% and 80%.

for the portfolio with the lowest volatility (portfolio 1) this corresponds to a large weighting of the bond portfolio of 34% (and thus 66% of the market equity portfolio). In the case of the most volatile portfolio, the negative exposure corresponds to a short position in the bond portfolio of 106%.

A higher reward for interest rate exposure in the equity market compared to the bond market suggests that investors are better off taking interest rate risk in the equity universe compared to an investment in government bonds. It implies a strategy that combines a long-short low-volatility portfolio with a short bond position[8].

[8]Although it is not the focus of this study we can think of a number of possible explanations for a possible difference in risk premium in the bond and equity market. The most obvious reason is that most investors prefer to know how much exposure they have to a specific risk factor, and the interest rate sensitivity of equity is not only time dependent, but also difficult to estimate. This results in all kind of practical difficulties. Investors looking to hedge their liabilities appreciate the effectiveness of bonds for this purpose. This increased (price insensitive) demand could result in a lower risk premium (hedging pressure). Related to this, most regulatory frameworks do not take the interest sensitivity of equity investments into account. Another possible explanation is that due to the increasing popularity of investment strategies that are aiming to benefit from the low-volatility anomaly, these inflows have been a tailwind for returns.

5. Time-varying interest rate risk premiums in bond and equity markets

In section 4 we show that the estimated premium for bearing interest rate risk is likely to be much higher in the equity market compared to the bond market. In this section we further explore the pricing of this risk in these two markets. In order to do that we look whether variables that forecast excess returns in the bond market also explain the bond factor risk premium in the equity market. We find that these variables have predictive power for the bond factor premium in both markets.

There is ample evidence that the excess return of bonds can be forecasted to a fair amount. For example, Fama and Bliss (1987) show that forward rates contain information about future excess returns, Campbell and Shiller (1991) show that a high yield spread between long and short term interest rate predict a decline in the long term interest rate and therefore a higher interest rate risk premium and Cochrane and Piazzesi (2005) are able to predict the time variation of the premium to an even larger extent with their CP factor[9]. Baker and Wurgler (2012) show that these variables are also able to predict differences in returns of equity portfolios sorted on volatility. In this section we show that these variables are also able to predict the interest rate premium in equity markets, to the same extent as they predict the premium (excess returns) in the bond market.

We start by replicating the standard bond market regressions. In line with the analysis done by Cochrane and Piazzesi (2005), we run the regression on an extended horizon, with the average excess return for the next 12 months:

[9] We have updated the CP factor from Cochrane and Piazzesi (2005) to December 2014. In the sample with an additional 10 years, the predictability of excess returns of bonds with a maturity from 1 to 5 years has decreased from 44% as reported in their article, to 27%. This corresponds to findings by Duffee et al. (2012) and Bauer and Hamilton (2017)

$$\frac{1}{12}\sum_{n=t+1}^{t+12} INTR_n = \alpha + \gamma_{CP}\cdot CP_t + \gamma_{YS}\cdot YS_t + \epsilon_{t+12} \tag{7}$$

As shown in Table 5.1 we find that the CP factor forecasts our bond factor for the next 12 months with with a coefficient of 0.100 (t-stat 11.9) over the whole sample from 1968 to 2014. The yield spread (denoted by YS) has a coefficient of -0.091 (t-stat 6.3).

We can do the same analysis for the risk premium in the equity market. On the right hand side of Table 5.1 we show the results of the same regression, but now on the monthly premium estimated in the equity market:

$$\frac{1}{12}\sum_{n=t+1}^{t+12} \lambda_{I,n} = \alpha + \gamma_{CP}\cdot CP_t + \gamma_{YS}\cdot YS_t + u_{t+12} \tag{8}$$

While the coefficient of the yield spread is different in the equity market with a value of -0.127 (t-stat 2.1), the CP factor has a similar coefficient in both the equity and bond market (estimate equal to 0.121, t-stat 3.1). In each market both variables have a t-stat larger than 2 when evaluated separately. We find that the intercept in the equity market is similar as the estimated premium in section 4. In line with the difference in estimated premiums in both markets the intercept found for the bond market is much lower.

The table also shows the results when both variables are evaluated at the same time. In this case we find that the yield spread loses its significance in the bond market, but not in the equity market. The CP factor gains significance in both markets. While the yield spread does not give consistent results, the CP factor points to a similar time variation of the premium in both markets[10],[11].

Table 5.1: In this table we show the results of the regressions ((7) and (8)). Each first row shows the coefficients γ_{CP}, γ_{YS} the intercept and the R-squares. Each second and third row shows the estimates of the same regression with each factor seperate. Below each coefficient, we show the t-stat between brackets.

	Bond market (eq. 7)			Equity market (eq. 8)		
	CP&YS	CP	YS	CP&YS	CP	YS
CP factor	0.102	0.100		0.262	0.121	
t-stat	[9.7]	[11.9]		[5.7]	[3.1]	
Yieldspread	−0.005		0.091	−0.373		−0.127
t-stat	[0.3]		[6.3]	[5.0]		[2.1]
Intercept	0.064	0.061	0.080	1.000	0.784	1.040
t-stat	[3.2]	[3.4]	[3.6]	[11.0]	[9.6]	[11.2]
R^2	20.4%	20.4%	6.7%	6.1%	1.8%	0.8%

In Figure 5.1 we show the forecast of the interest rate premium for the next 12 months in both the stock and bond market. We use the bivariate regressions in order to estimate this premium. It clearly shows both the difference in level and the presence of comovement.

6. Interest rate risk from the perspective of the capital structure

Until now we focused on empirical methods. In this section we try to understand the relationship between interest rate risk and equity volatility from a theoretical standpoint in order to evaluate our empirical findings. We find that looking at this subject from the perspective of the capital structure enables us to better understand the relationship. In addition, this model illustrates that the relationship between volatility and leverage is not trivial, as a number of firm characteristics such as asset volatility play a major role. Hence volatility and leverage are not necessarily strongly related.

[10]The much higher volatility of the equity market compared to the bond market results in lower R^2 values. In the equity market the yield spread is able to explain only 0.7%, while the CP factor explains 1.8% of the interest rate risk premium in the equity market; both roughly a factor ten less than the R^2 for the interest rate premium in the bond market (6.7% and 20.4%, respectively).

[11]We also did a pooled regression. These results did not lead to a different conclusion.

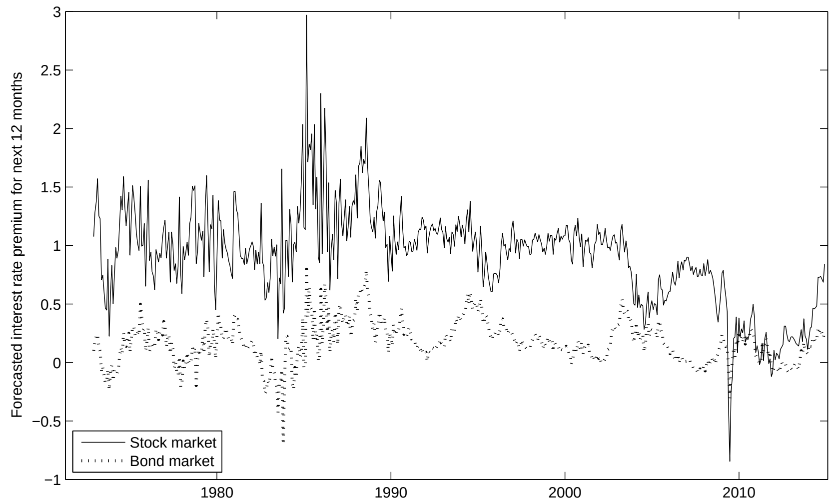


Figure 5.1: This figure shows the forecast of the interest rate premium for the next 12 months in both the stock and bond market over the period from 1963 to 2014. Forecasts are based on the bivariate regression with both the yield spread and CP factor as presented in Table 5.1.

All financial instruments have their own priority in the capital structure of a firm. Merton (1974) shows that the payoff for holding a stock in a firm is similar to that of holding a call option in that the holder of a stock gains when the value of the firm goes up and receives nothing if the firm goes bankrupt, in which case all the money that is left goes to the debt holders. The priority of different instruments in the capital structure determines to what extent they are exposed to risk factors. Volatility can be an indicator of the place these instruments have in the capital structure of the specific company, as one could argue that low volatility points towards a place closer to bonds in the capital structure. As bond returns benefit from an interest rate risk premium, it is intuitive to assume that these low-volatility stocks also profit from exposure to this risk.

Choi et al. (2015) show that the Merton model implies that lower priority securities in the capital structure have lower durations. They show that lower priority securities are effectively short higher priority fixed rate debt, in other words, they are short the bond market. In this simplified model, duration is decreasing with the priority of the instruments, because of the increasingly larger short debt position of more subordinated instruments. The most senior bonds have the highest duration and equities the lowest duration.

In this section we express this intuition in formulas, building on Choi et al. (2015). As the sum of the value of debt and equity equals the value of the firm, the duration of the assets has to be equal to the weighted sum of the duration of debt and equity:

$$Dur(V) = \frac{E}{V} Dur(E) + \frac{D}{V} Dur(D) \tag{9}$$

From this relationship it follows that the duration of the debt contributes negatively to equity duration. In a simplified case, with only one type of bonds (no distinction between junior and senior bonds), equity, a constant risk free interest rate r and maturity of the option τ, the equations for the value of debt D and the value of Equity E can be written as

$$D = Ke^{-r\tau} - P(V, K, \tau, r, \sigma_V) \tag{10}$$

$$E = V - D \tag{11}$$

Where $P(\cdot)$ is the value of an European put. In this simplified situation, the asset duration is always zero, as the constant risk free interest rate leads by definition to a zero correlation between shocks in interest rate and firm value.

As in reality the interest rate is not a constant we prefer a more sophisticated model for our calculations. Choi et al. (2015) show that when we replace the constant interest rate by an interest rate that follows a mean reverting process (Vasicek model), the duration of the debt and equity can be written as

$$Dur(D) = \frac{\partial D}{\partial V}\frac{V}{D}Dur(V) - \frac{\partial D}{\partial r}\frac{1}{D} \tag{12}$$

$$Dur(E) = \frac{\partial E}{\partial V}\frac{V}{E}Dur(V) - \frac{\partial E}{\partial r}\frac{1}{E} \tag{13}$$

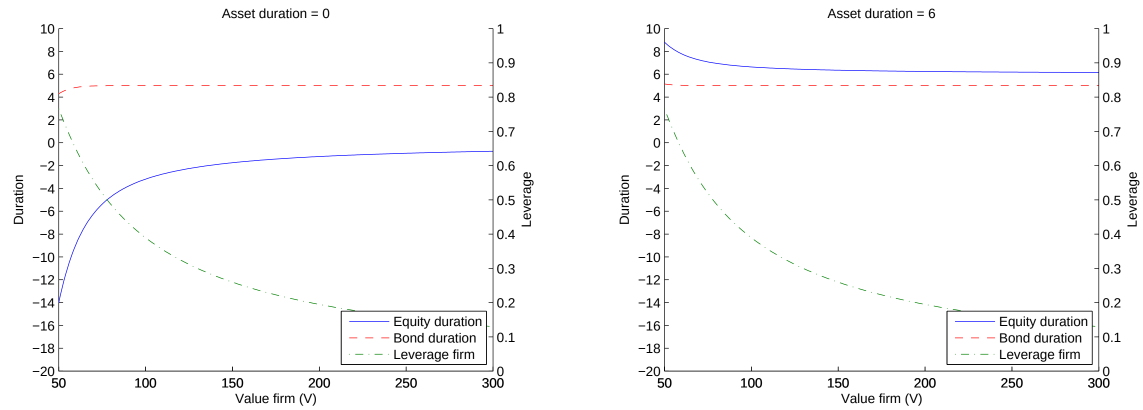
With the asset duration defined as

$$Dur(V) = -\frac{\rho\sigma_V}{\nu} \tag{14}$$

Where ν denotes the standard deviation of interest rate shocks in the Vasicek model. We refer to the first term on the right hand side in equation (12) and (13) as the cash flow duration, and the second as discount duration. As can be seen from equation (13), the duration of the firm's equity is a function of many variables including the equity value. Since in this Merton model asset volatility is an important determinant of the value of equity, this is also a driver of the duration of equity.

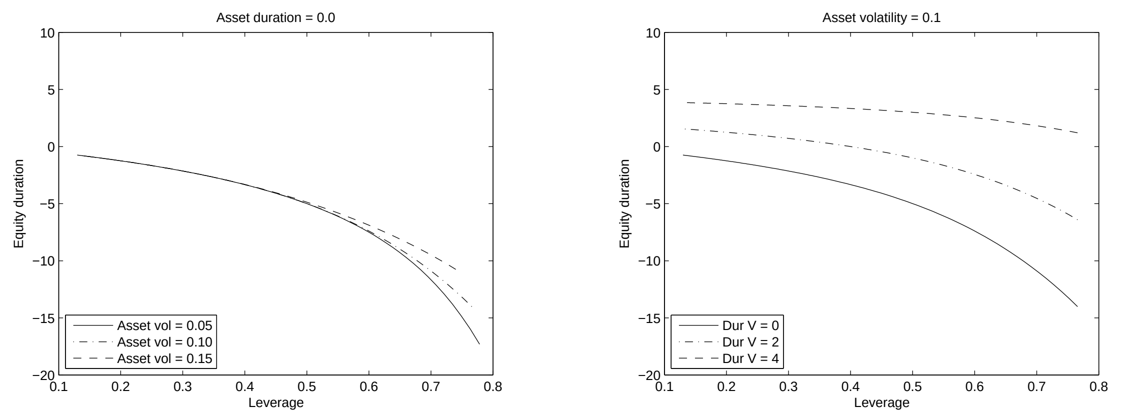
Following Choi et al. (2015), Figure 6.1 shows the duration of debt, equity and the firm leverage as function of the firm value for a fixed asset duration of zero (6.1a) and six (6.1b) years. As long as the asset duration is below that of the senior (risk free) debt, the duration of bonds is higher than the duration of equity. In this case the discount duration is dominant.

In order to visualize the impact of leverage on the duration, we plot the duration as function of the leverage in Figure 6.2. For a given value of asset duration and volatility, the interest rate sensitivity of equity is increasingly negative with the degree of leverage. These two figures show that a sort on leverage is only a sort on volatility if all else is equal. Different asset volatility and asset duration across portfolios clearly impact this relationship. As pointed out by Choi et al. (2015), the asset duration does not have to be constant over various portfolio sorts. They empirically find that asset



(a) (b)

Figure 6.1: Plots of the relationship between duration of debt and equity and the firm value assuming a fixed asset duration of zero (a) and six (b). Other parameter values are $r = 5\%$, $\sigma_V = 20\%$, $\tau = 5$, $K = 25$, $q = 0.2$, $\nu = 2\%$ and $m = 7\%$.



(a) (b)

Figure 6.2: Plots of the relationship between duration of equity and leverage for multiple values of asset volatilty (a) and asset duration (b).

duration increases and asset volatility decreases with leverage.

As mentioned, in the Merton model the duration of equity is dependent on the volatility of the assets σ_V. This model can therefore provide useful insights on the relation between interest rate sensitivity and equity volatility, when we know the relationship between asset and equity volatility. As described by Bharath and Shumway (2008), the theoretical relationship is given by equation (15)[12].

[12]When the call option on the firm's assets is deep in the money, $N(d1)$ is approximately 1 and therefore the relationship between asset volatility and equity volatility becomes linear. Correia et al.

$$\sigma_V = \frac{E}{E + D} N(d1)\sigma_E \tag{15}$$

Using these equations, we see that in an environment with asset duration smaller than the duration of debt, the duration of equity is negatively related to the volatility of equity as shown in Figure 6.3. The lower the volatility of equity, the higher the duration.

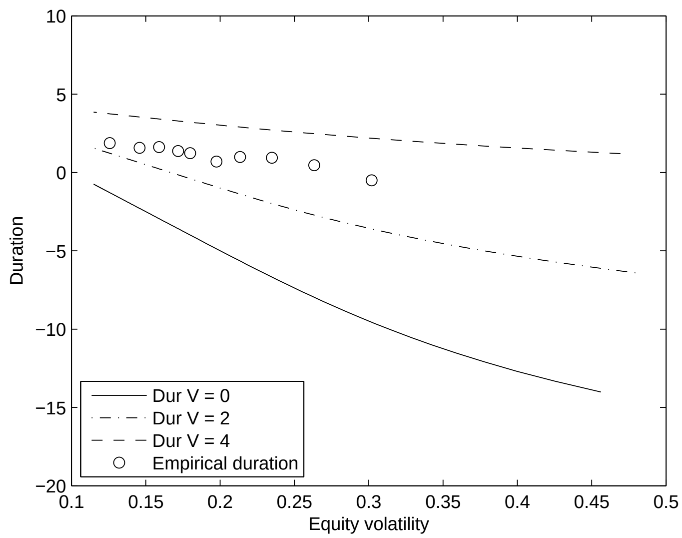


Figure 6.3: The figure shows the empirical duration for each portfolio (Table 4.1) plotted against the annualized volatility as presented in Table 3.1 (annualised), together with the theoretical relationship for several values for the asset duration.

In Figure 6.3 we plot the both the empirical duration and the volatility of our low-volatility deciles as presented earlier[13], in the same chart as the relationship between equity volatility and duration for various values of the asset duration. In sum, we find that the interest rate sensitivity of equity is negatively related to its volatility, and that the magnitudes we find empirically for the interest-rate sensitivity are well in the range predicted by the Merton model.

(2015) finds a correlation between 0.6 and 0.8 between equity volatility and asset volatility.

[13] In order to improve comparability we use the same units as Choi et al. (2015). We used a constant duration of our bond factor of 3 years. Furthermore, we annualised the volatility estimates.

7. Conclusions

The low-volatility effect has gained much attention over the last few years. This is unsurprising, as its economic significance is large. We find that portfolios consisting of stocks with low idiosyncratic volatility are exposed to more interest rate risk than portfolios with stock that have higher volatility. We show that a premium for interest rate risk explains 20% of this performance, if we assume that bond and equity markets are integrated, and up to 80% if we relax this assumption and calculate the premium for interest rate risk directly from the equity market. Interest rate risk is a rational explanation different from other already existing explanations.

Our results imply a strong implicit exposure to bonds of low-volatility portfolios, increasing the returns. Portfolios that contain stocks with high volatility are implicitly short bonds, resulting in a drag on performance given the positive risk premium. We find a large premium for interest rate exposure in the equity market, a factor up to five times higher compared to the compensation for the same risk in the bond market. The difference in premium suggests that investors are better off taking interest rate risk in the equity universe compared to an investment in government bonds. We show that variables that are known predictors of excess returns of bonds have similar power for the equity-implied interest rate risk premium and that premiums in both markets show similar time variation. Smart investors take this exposure into account when considering to make an investment in strategies based on this phenomenon. Our results imply a strategy that combines a long-short low-volatility portfolio with a short bond position.

We show that Merton's model is useful in understanding the relation between equity volatility and interest rate risk. Second, this model enables us to understand why the relationship between leverage and volatility is not trivial. For future research it would be interesting to see how controlling the empirical analysis for leverage and asset duration impacts the fit between our empirical results and the Merton model.

A. The impact of the business cycle on the interest rate exposure

In section 4.2 we discussed that the interest rate exposure is time varying. In order to take this into account for the estimation of the risk premium we look at five year rolling betas of each of the ten portfolios. Although it is not the focus of this study to identify the drivers of this dynamic, in this section we explore the possibility that the time variation can be understood from the perspective of the business cycle.

In order to model the business cycle, we use an approach where both the level and the activity are considered to be determinants of the state of the economy and each month is classified as one of four states (Driessen and Kuiper (2015)). The four economic states are referred to as overheat, slowdown, contraction and recovery. Overheat is the environment in which the level of activity is high and rising. When the level of activity is high but falling, we refer to it as slowdown. Contraction is characterized by low and falling activity. Low and rising activity is referred to as recovery. The activity is measured by the CFNAI index that is published every month by the Chicago Fed. The phases represent distinct economic environments. Driessen and Kuiper (2015) show that time is distributed roughly equally over all four phases, varying from 19 percent for the recovery phase to 30 percent for the overheat phase. They find that on average slowdown and overheat have the highest inflation, and recovery the lowest. This is due to the decrease in inflation in when the economy is in contraction and recovery.

In order to evaluate the impact of the business cycle we repeat most of the analysis for each phase separately. The main results are presented in Table A.1. First, we find that the unexplained excess return of the long-short portfolio is negative in all four phases. We also find that the anomaly is smaller when the economy is overheating, but this is only at a low level of significance.

When we take a look at the interest rate exposure without correcting for market exposure (equation (2)), the interest rate sensitivity of the market as a whole is significantly lower in slowdown than in recovery. If we take a look at the long-short portfolio, we find that in addition to this, there much less return difference between the portfolios at both end of the volatility spectrum. As inflation is high and rising in the slowdown phase and low and falling in the recovery phase, we identify inflation as a possible driver of this dynamic. We believe this is an interesting subject for further research.

We also look at the interest rate exposure after correcting for the market exposure (equation (3)). In this case the long short portfolio shows comparable numbers in all four phases. When we estimate the premium for the interest rate exposure based on a FamaMacBeth regression (equation (4)) we observe only small differences in the estimated premiums.

Table A.1: This table shows the estimates of the anomaly, the interest rate exposure and the interest rate premium for various phases of the business cycle. For the classification of the business cycle we used the methodology of Driessen and Kuiper (2015). The standard error is shown between brackets.

Model	Variable	Portfolio	Overheat	Contraction	Recovery	Slowdown	Total
CAPM	Anomaly	1-10	0.52	1.79	1.25	1.47	1.24
			(0.44)	(0.54)	(0.52)	(0.58)	(0.22)
Eq. 2	β_I	Market	0.49	0.44	0.01	1.30	0.43
			(0.32)	(0.26)	(0.29)	(0.28)	(0.14)
		1-10	1.01	0.76	1.01	-0.03	0.79
			(0.45)	(0.40)	(0.46)	(0.59)	(0.16)
Eq. 3	β_I	1-10	1.39	1.19	1.02	1.30	1.20
			(0.38)	(0.32)	(0.33)	(0.56)	(0.18)
Eq. 4	λ_I	Market	0.81	0.57	0.57	0.78	0.91
			(0.48)	(0.12)	(0.19)	(0.18)	(0.25)

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