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Conditional interest rate risk and the cross-section of excess stock returns

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ABSTRACT

Differences in excess stock returns can be rationalized by their sensitivities to conditional interest rate risk. Value stocks are particularly sensitive to upside movements in interest rate growth, while growth stocks react strongly to downside movements in interest rate growth. Consistent with the basic asset pricing theory, the upside interest rate risk commands a negative premium which is higher than the premium associated with the downside interest rate risk. Upside beta pertains its explanatory power after controlling for exposure to regular unconditional interest rate and various sources of financial and conditional macroeconomic risk.

1. Introduction

It is widely believed that monetary policy is an important determinant of asset prices (e.g. Bernanke & Kutter, 2005). Inspired by this notion, several equilibrium models allow for a risk factor in stock returns related to the stance of monetary policy (see Balvers & Huang, 2009; Chan, Foresi, & Lang, 1996; Lioui & Poncet, 2004, among others). For example, Lioui and Maio (2014) propose an extension of the standard consumption-based asset pricing model (CCAPM) to a monetary economy in which the representative agent features intertemporal recursive preferences as in Epstein and Zin (1989, 1991) and Weil (1989). This setting gives rise to a stochastic discount factor (SDF) driven by three factors: consumption growth, market return, and the growth in the (unconditional) nominal interest rate, which represents the opportunity cost of money. The basic insight of this model is that a traditional risk-averse investor requires a negative premium associated with interest rate growth because "periods of high interest rates are usually periods of tight monetary conditions in which inflation expectations are high and liquidities are in limited supply" (Lioui & Maio, 2014).

However, ample empirical evidence suggests that the effect of monetary policy on stock returns is asymmetric with asymmetries linked to different responses of stock returns to monetary policy at different stages of the business cycle (Basistha & Kurov, 2008); the aggregate status of the stock market (Chen, 2007; Jansen & Tsai, 2010; Perez-Quiros & Timmermann, 2001); firm characteristics such as firm size and the degree of firm financial constraintedness (Ehrmann & Fratzscher, 2004; Thorbecke, 1997); or the monetary policy stance itself (Jensen and Johnson, 1995; Jensen, Mercer, & Johnson, 1996). For instance, Basistha and Kurov (2008) find that stock returns react more strongly to unexpected changes in the federal funds target rate in recessions and in tight credit market conditions. Alternatively, Chen (2007) and Jansen and Tsai (2010) show that the impact of a monetary policy on stock returns is significantly greater in a bear market than it is in a bull market. Such asymmetric reactions are supportive of the view that investors have a higher aversion to unfavorable states of nature, and therefore react faster to news in bad economic times (Lobo, 2000, 2002).

Unfortunately, equilibrium specifications which allow pinning down the implied structural parameters of interest, as those in Balvers and Huang (2009) and Lioui and Maio (2014), cannot account for such asymmetries. Moreover, despite prevalent time–series evidence,[1] not much is known to date about how conditional interest rate risk is priced in the cross-section of excess returns.

Against this backdrop, this paper provides an empirical investigation of the cross-sectional implications of the conditional, i.e. upside and downside, interest rate risk in an attempt to quantify the impact of the interest rate changes on risk premia in equity markets in periods of high and low interest rate growth. While models with asymmetries

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[1] For example, Jensen and Johnson (1995) show that expected stock returns are significantly higher in expansive monetary policy periods than in restrictive periods. These results are consistent with Jensen et al. (1996) who argue that predictable variation in stock returns depends dramatically on monetary environments. In this vein, Thorbecke (1997) finds that expansionary monetary policy substantially increases ex-post stock returns.

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often postulate, either explicitly or implicitly, a non-linear relation between interest rates and stock prices (e.g. Chen, 2007; Lobo, 2000), the advantage of our analysis is that it evaluates a simple linear relation as those often employed by econometricians. The parsimonious empirical beta pricing relation we study in this paper, is flexible in allowing for variations both in the quantity and the price of risk. Our distinction between conditional upside and downside states accounts for asymmetric correlations as in Ang and Chen (2002) and provides a convenient means to capture the asymmetric effects of the monetary environment on asset prices, with asymmetry linked to inflation expectations and liquidities' supply (see Lioui & Maio, 2014).

Our empirical approach is similar to several known studies which take into account the asymmetric treatment of risk by specifying asymmetric betas. Bawa and Lindenberg (1977) and Ang, Chen, and Xing (2006), for example, introduce (conditional) upside and downside market betas which measure sensitivities of stock return to the market over periods of high and low market return. More recently, Lettau, Maggiori, and Weber (2014), Dobrynskaya (2014), and Atanasov and Nitschka (2014) employ akin risk measures to study conditional market risk in the cross-section of foreign exchange rate returns and returns on assets in other classes such as equities, commodities, sovereign bonds, and index options. Analogously, Delisle, Doran, and Peterson (2011) allow for different return sensitivities to upside and downside implied systematic volatility.

In this paper, we closely follow the empirical beta approximation of Lioui and Maio (2014) but distinguish between responses of stock returns to the interest rate risk in “upside” and “downside” states, i.e. periods with the log interest rate growth rate being above or below its sample average.[2] We proxy interest rates by the federal funds rate, because ever since the seminal paper by Bernanke and Blinder (1992), the federal funds rate has been the most widely used measure of monetary policy. In addition, we consider the one-month risk-free rate and the three-month Treasury bill rate following Lioui and Maio (2014).

Our findings are easily summarized. First, we show that the value and growth stock market anomaly, i.e. significant differences in average returns on high versus low book-to-market ratio stock portfolios, can be largely rationalized by stock returns' sensitivities to conditional interest rate risk.[3] Value stocks reveal strong sensitivity to upside movements in interest rate growth, while growth stocks tend to rather react to downside movements in interest rate growth. Thus, high excess returns on value stocks can be attributed to their failure to payoff when the growth rate of the opportunity cost of money increases. These periods are usually associated with tight monetary conditions, high inflation expectations, and restricted liquidity supply (see e.g. Taylor, 1993; Strongin, 1995). In contrast, we find no systematic relation between conditional downside interest rate betas and average stock performance. These observations are consistent with the notion of asymmetric relation between monetary policy and stock returns (e.g. Jensen et al., 1996), and extend earlier evidence according to which value stocks enjoy higher average returns because they have higher (unconditional) interest rate betas than growth stocks (Lioui & Maio, 2014).

We also show that the upside interest rate risk carries a negative premium in the cross-section of stock returns which is pervasive and statistically significant. Hence, assets whose returns covary positively with interest rate increases, i.e. in periods of tight monetary conditions and high expected inflation, require a lower premium, ceteris paribus. This result is consistent with the basic insight of the asset pricing theory (see e.g. Lioui & Maio, 2014 and references therein). Moreover, this upside interest rate risk premium is significantly higher (in absolute terms) than the downside interest rate risk premium. The latter yields instable estimates which are sometimes positive, sometimes negative, and often insignificant. This result reinforces the evidence in Basistha and Kurov (2008) who find that the response of stock returns to monetary shocks is more than twice as large in tight credit market conditions as in good economic times.

To guard against the possibility that the conditional upside beta is different from unconditional interest rate beta, we follow the approach of Ang et al. (2006) and Lettau et al. (2014) and evaluate the importance of the relative interest rate betas defined by subtracting the unconditional beta from its (conditional) upside or downside counterpart. First, the patterns in relative betas turn out qualitatively similar to the patterns in absolute upside and downside betas. Secondly, the upside beta reveals an incremental explanatory power after controlling for the (unconditional) overall interest rate beta. In a host of robustness checks, we show that the conditional upside beta pertains its explanatory power for differences in returns across assets. Our results withstand a host of sensitivity tests and are robust to the choice of test assets, model specification, alternative measures of interest rate risk, and various definitions of upside and downside states based on exogenous threshold parameter values and its endogenous determination from underlying macroeconomic fundamentals.

At the same time, our analysis cannot provide a perfect explanation of patterns in the data we observe. In fact, the empirical success of our beta pricing relation reflected in high cross-sectional measures of fit comes at a cost of significant estimates of the intercept term in the second stage Fama and MacBeth (1973) regressions similar to Jagannathan and Wang (1996) and Lettau and Ludvigson (2001), among others. Following the recommendation of Lewellen, Nagel, and Shanken (2010) we estimate both an unrestricted model version and a restricted specification with a zero-beta rate constrained to the risk-free rate. While our estimates give strong support for a tight link between asset returns and their upside interest rate risk exposure, they also indicate that other factors could play a role in explaining cross-sectional return differentials. However, (conditional) downside market, industrial production or consumption growth risks cannot account for the explanatory power of the upside interest rate beta. Overall, it remains an open question whether the upside interest rate risk comes from investor preferences or from market micro-structure constraints.

In sum, this article complements the growing literature which emphasizes that monetary policy developments are associated with patterns in stock returns. Specifically, our analysis is related to several empirical studies which highlight the asymmetric impact of monetary policy on equity markets, in particular in the time–series dimension (Chen, 2007; Basistha & Kurov, 2008, among others). Our results give strong support for the idea that the cross-section of expected stock returns reflects a premium for stocks' sensitivities to conditional upside interest rate risk which is higher than the premium for conditional downside interest rate risk. This result, which is the major point of our paper, contributes to the central idea of the asset pricing theory that differences in systematic risk should justify differences in risk premia across assets.

The remainder of the paper is organized as follows. Section 2 presents theoretical arguments that suggest that interest rate risk should be priced in the cross-section and lays out our empirical framework with upside and downside risks. Section 3 describes the data. Section 4 discusses the empirical findings and Section 5 concludes.

2. Theoretical background and empirical framework

2.1. Model with interest rate risk

To study the role of interest rate changes for the cross-section of stock returns, we follow Lioui and Maio (2014) and employ a money-in-utility function framework in which the representative consumer

[2] This definition is similar to Cover (1992) who documents asymmetric effects of positive and negative monetary policy shocks. See Sections 2.2 and 4.3 below for a formal definition and sensitivity of results to changes in specification.

[3] To facilitate comparison with previous literature, we repeat the analysis based on stock portfolios sorted on the long-term return reversal, and find analogous results.

derives utility from consumption and real balances. The household's intertemporal budget constraint can then be written as

$$W_{t+1} = R^m_{t+1}\left(W_t - C_t - \frac{R_{f,t+1}-1}{R_{f,t+1}}H_t\right), \tag{1}$$

where W_t denotes the total real wealth at the end of period t, R^m_{t+1} is the return on wealth approximated by the optimal market portfolio, C_t stands for real consumption, H_t for real money holdings, and $\frac{R_{f,t+1}-1}{R_{f,t+1}}$ denotes the present value of the opportunity cost of money between t and $t+1$, which is known at the beginning of the period.[4]

The intertemporal utility function of a representative agent with recursive preferences (Epstein & Zin, 1989, 1991; Weil, 1989) who chooses optimally between nondurable consumption goods and money balances obeys

$$U_t = \left\{(1-\delta)\left(C_t^{1-\varepsilon}H_t^{\varepsilon}\right)^{(1-\gamma)/\theta} + \delta\left(E_t\left[U_{t+1}^{1-\gamma}\right]\right)^{1/\theta}\right\}^{\theta/(1-\gamma)}, \tag{2}$$

where $\theta = (1-\gamma)/[1-(1/\phi)]$ and the intraperiod utility has a Cobb–Douglas form $u(C,H) = C^{1-\varepsilon}H^{\varepsilon}$. In Eq. (2), the parameter $\delta \in (0,1)$ is the investor's subjective discount factor, $\gamma > 0$ is the coefficient of relative risk aversion, $\phi \geq 0$ is the elasticity of intertemporal substitution, and $\varepsilon \in (0,1)$ is the weight of real balances in utility.

Exploiting the fact that the equilibrium intratemporal marginal rate of substitution between consumption and money follows $(\varepsilon/(1-\varepsilon))(C_t/H_t) = \frac{R_{f,t+1}-1}{R_{f,t+1}}$, the utility maximization implies a stochastic discount factor (SDF) which is a function of the nominal interest rate[5]:

$$M_{t+1} = \delta^{\theta}\left(R^m_{t+1}\right)^{\theta-1}\left(\frac{C_{t+1}}{C_t}\right)^{1-\gamma-\theta}\left(\frac{\frac{R_{f,t+2}-1}{R_{f,t+2}}}{\frac{R_{f,t+1}-1}{R_{f,t+1}}}\right)^{\varepsilon(\gamma-1)}. \tag{3}$$

This representation has an appealing property that it does not require measuring real balances, which is notoriously a difficult task, while interest rates can be measured fairly precisely. The SDF in Eq. (3) results in an unconditional Euler equation which can be approximated as a linear three-factor model[6]:

$$E\left[R_t^{j,e}\right] \approx b_1\left(r_t^m, R_t^{j,e}\right) + b_2 cov\left(\Delta c_t, R_t^{j,e}\right) + b_3 cov\left(\Delta i_t, R_t^{j,e}\right), \tag{4}$$

where $E[R_t^{j,e}]$ is the expected excess return on a risky asset j, Δi_t is log interest rate growth, and lower case letters denote logs.[7]

In the above representation, the expected excess return on asset j is determined by its covariance with the log return on the market portfolio, log nondurable consumption growth, and the log growth rate in the opportunity cost of money. This linear factor model can be restated as a beta pricing model:

$$E\left[R^{j,e}\right] = \lambda_0 + \lambda_m\beta_m^j + \lambda_c\beta_c^j + \lambda_i\beta_i^j, \tag{5}$$

where $\beta_m^j = \frac{cov(R^{j,e},r^m)}{var(r^m)}$, $\beta_c^j = \frac{cov(R^{j,e},\Delta c)}{var(\Delta c)}$, and $\beta_i^j = \frac{cov(R^{j,e},\Delta i)}{var(\Delta i)}$ are the sensitivities of asset j to the market, consumption, and interest rate risks, and λs are the associated prices of risk.

The main prediction from the factor model setting of Eq. (5) is that stocks with different loadings on the aggregate interest rate risk have different average returns. Moreover, the sign of the interest rate risk premium is restricted by the economic theory. If the investor is more risk averse than an investor with log utility, i.e. $\gamma > 1$, then λ_i should be negative. Thus an asset which does not payoff when the interest rate growth is high earns on average a higher return. Intuitively, periods of high interest rates are typically periods of tight monetary conditions. These periods are associated with low real balance holdings, high inflation expectations, and limited liquidity supply (see e.g. Taylor, 1993; Strongin, 1995). Hence, assets with negative interest rate betas command a higher average premium because they do not hedge against these bad economic times.

2.2. Upside and downside interest rate betas

Previous studies find that the effect of monetary policy on asset prices is asymmetric. For example, Jensen and Johnson (1995) show that expected stock returns are significantly higher in expansive monetary policy periods than in restrictive periods. This evidence is consistent with Jensen et al. (1996) who argue that predictable variation in stock returns depends dramatically on monetary environments.

Drawing on these insights, in this paper we focus on the impact of conditional interest rate risk on cross-sectional variation in stock returns. Specifically, our main goal is to address the question if there are differences in reaction of excess returns to upside and downside interest rate risk components. This approach aims to capture the idea that assets that have a more negative beta with interest rate risk conditional on high realizations of interest rate growth are particularly risky. The economic intuition underlying the upside interest rate risk is simple: Agents require a premium for securities which fail to payoff in bad economic times when interest rates growth is in the upper tail of its distribution. High interest rate growth rates signal bad economic times which are typically associated with low real balance holdings, high inflation expectations, and restricted liquidity (see e.g. Lioui & Maio, 2014).

To assess the relative importance of conditional interest rate risk, we propose that expected returns follow

$$E\left[R^{j,e}\right] = \lambda_0 + \lambda_m\beta_m^j + \lambda_c\beta_c^j + \lambda_{i^+}\beta_{i^+}^j + \lambda_{i^-}\beta_{i^-}^j, \tag{6}$$

where β_m^j and β_c^j are the market and consumption betas as above and $\beta_{i^+}^j$ and $\beta_{i^-}^j$ denote the upside and downside interest rate betas of asset j. We compute the upside interest rate beta as asset's sensitivity to upside interest rate changes

$$\beta_{i^+}^j = \frac{cov\left(R^{e,j}, \Delta i | \Delta i > \kappa\right)}{var(\Delta i | \Delta i > \kappa)}, \tag{7}$$

and the downside interest rate beta as asset's sensitivity to downside interest rate changes

$$\beta_{i^-}^j = \frac{cov\left(R^{e,j}, \Delta i | \Delta i \leq \kappa\right)}{var(\Delta i | \Delta i \leq \kappa)}. \tag{8}$$

The conditional interest rate betas are defined by an exogenous threshold, κ, and λ_{i^+} and λ_{i^-} denote the respective upside and downside

[4] The Internet Appendix to Lioui and Maio (2014) shows that the budget constraint in Eq. (1) can be rewritten in a more intuitive way as

$$W_{t+1} = \sum_{j=1}^{N} a_{j,t}R_{j,t+1} + \left(W_t - C_t - H_t - \sum_{j=1}^{N} a_{j,t}\right)R_{r,t+1} + \frac{H_t}{1+\pi_{t+1}},$$

where a_j is the real amount invested in the risky asset j with return R_j, $R_{r,t+1} = R_{f,t+1}/(1+\pi_{t+1})$ is the real gross interest rate, and π_{t+1} denotes the inflation rate between t and $t+1$.

[5] A separate appendix sketches the derivation of the Euler equation for risky asset returns.

[6] The linear factor model in Eq. (4) is derived by using a linear approximation of the SDF in Eq. (3) around its unconditional mean:

$$\frac{M_{t+1}}{E[M_{t+1}]} \simeq 1 + m_{t+1} - E[m_{t+1}],$$

where the constant in the SDF is normalized to one, because it cannot be identified.

[7] Furthermore, one can show that the vector of factor loadings in Eq. (4) is governed by the structural preference parameters with $b_1 = \frac{\gamma\phi-1}{\phi-1}$, $b_2 = \frac{1-\gamma}{\phi-1}$, and $b_3 = \varepsilon(1-\gamma)$.

Table 1
Descriptive statistics.
Panel A reports average excess returns and standard deviations in percent for 25 Fama–French portfolios sorted on size (S) and book-to-market-equity (BM). S1 (BM1) denotes the lowest size (book-to-market) quintile, S5 (BM5) denotes the highest size (book-to-market) quintile. Column "Diff." gives the differences in average excess returns between stocks with highest versus lowest book-to-market ratios for each size category. Panel B summarizes descriptive statistics for the pricing factors. Δc denotes the log consumption growth; r_m is the log return on the CRSP value-weighted index; Δi^+ is the conditional upside interest rate risk factor; Δi^- is the conditional downside interest rate risk factor. Periods in which the log federal funds rate growth is above (below) its sample mean are defined as upside (downside) states. Reported are means, medians, maxima, minima, and standard deviations in percent. AR(1) is the first order autocorrelation coefficient. N obs. denotes the number of observations. Data are quarterly and the sample period is 1963Q3 to 2014Q4.

	Panel A: 25 size and book-to-market sorted portfolios										
	Average excess returns						Standard deviations				
	BM1	BM2	BM3	BM4	BM5	Diff.	BM1	BM2	BM3	BM4	BM5
S1	0.76	2.43	2.49	3.01	3.38	2.62	16.15	13.54	11.96	11.41	12.73
S2	1.44	2.16	2.80	2.80	3.00	1.56	14.16	11.84	10.76	10.45	11.63
S3	1.52	2.33	2.35	2.64	3.18	1.66	12.83	10.75	9.77	9.88	10.51
S4	1.82	1.73	2.15	2.51	2.55	0.73	11.53	10.02	9.50	9.43	10.65
S5	1.41	1.58	1.47	1.68	1.87	0.46	9.04	8.21	7.74	7.92	9.01

	Panel B: pricing factors						
	Mean	Med	Min	Max	Std.	AR(1)	N obs.
Δc	0.49	0.48	−1.13	2.01	0.45	0.53	206
r_m	1.26	2.60	−31.18	20.95	8.69	0.06	206
Δi^+	1.16	0.91	−0.03	13.05	1.62	0.42	117
Δi^-	−1.62	−1.01	−8.16	−0.04	1.85	0.44	89

prices of interest rate risk. Our empirical framework is flexible in allowing for variations both in the quantity and the price of risk while maintaining a parsimonious parameterization with a single threshold parameter κ. In the benchmark specification, we examine the case of a threshold parameter equal to the average growth rate in interest rates, $\kappa = \overline{\Delta i}$. We consider three empirical measures of interest rates. First, we proxy interest rates by the federal funds rate, because ever since Bernanke and Blinder (1992), the federal funds rate has been the most widely used measure of monetary policy. In addition, we use the one-month risk-free rate and the three-month Treasury bill rate following Lioui and Maio (2014). In the robustness analysis, we explore alternative exogenous threshold parameter values and determine κ endogenously as a function of underlying macroeconomic fundamentals.

This decomposition of interest rate risk is appealing because it allows us to directly assess the importance of conditional interest rate risks in equity stock returns and at the same time enables us to link this assessment to standard risk factors. Our specification has the convenience of nesting the basic asset pricing models and separately estimating the risk premia associated with upside and downside interest rate risk movements.

3. Data

This section describes the source and construction of each series used in the empirical work. The data span the period from July 1963 to December 2014 and are sampled at a quarterly frequency, 206 data points in total. Panel A of Table 1 shows average excess returns and standard deviations for 25 value-weighted Fama–French portfolios formed on size (S) or market equity (ME) and the ratio of book equity to market equity (BM).[8] S1 (S5) denotes the lowest (highest) market equity or smallest (biggest) portfolio. BM1 (BM5) denotes the lowest (highest) book-to-market-equity or growth (value) portfolio. Excess returns are obtained by subtracting the compounded one-month Treasury bill rate. The portfolios are organized in a squared matrix with low BM stocks at the left, high BM stocks at the right, low ME stocks at the top, and high ME stocks at the bottom. Column "Diff." gives differences in extreme value (BM5) and extreme growth (BM1) portfolios in each size category.

Reading across the rows of the left half of Panel A, average returns increase in book-to-market-equity for a given size quintile. With average portfolio returns varying from 0.76% to 3.38%, the average value premium lies in the interval between 0.46% and 2.62% in quarterly terms. Reading down the columns of the left half of Panel A, average returns tend to decrease in size for a given book-to-market-equity quintile. In particular, stocks in the lowest market equity bin have higher returns than stocks in the highest market equity bin. The only exception are stocks in the lowest book-to-market category, where the small-stock portfolio has lower average return than the big-stock portfolio. This sample confirms the well-known value and size phenomena and the reverse size effect in returns on low book-to-market-equity stocks. Furthermore, our data support a size effect in value premium, i.e. declining value premium along the size dimension (Fama & French, 2012).

The descriptive statistics for consumption growth, equity market, upside and downside interest rate risk factors are summarized in Panel B of Table 1. Following Hansen and Singleton (1983), aggregate consumption growth is measured by the log growth rate in seasonally adjusted real per capita consumption expenditure on nondurables and services. These data are sourced from NIPA Table 7.1 of the Bureau of Economic Analysis. The market return is conventionally proxied by the value-weighted index available from the Center for Research in Security Prices (CRSP). To compute the log interest rate ratio we use the effective federal funds rate retrieved from the FRED database of St. Louis Federal Reserve. In addition, we employ two further measures of the opportunity cost of money based on the three-month Treasury bill rate and the one-month risk-free rate. The risk-free rate is from the online data library of Kenneth French. Quarterly series are obtained by compounding monthly data.

Panel B of Table 1 gives means, medians, minima, maxima, standard deviations and first order autocorrelations of the risk factors. The log excess return on the CRSP value-weighted index varies between −31.18% and 20.95% with a standard deviation of about 8.69%. The log consumption growth is substantially less volatile with the lowest (highest) realization of −1.13% (2.01%) and a standard deviation of 2.01%. We measure the interest rate risk factor by the log growth rate in the federal funds rate. Periods in which the log interest rate growth is above (below) its sample mean are defined as upside (downside) states. There are in total 117 quarters which are specified as upside states,

[8] The data on these portfolios is freely available on the website of Kenneth R. French. We employ these portfolios as main test assets in our empirical analysis but show that the results remain upheld in the cross-section of industry portfolios and portfolios built on other characteristics.

and 89 quarters which qualify as downside states. Our proxy of the upside interest rate risk factor has a mean of 1.16% and a standard deviation of 1.62%. The respective figures for the downside interest rate risk factor are −1.62% and 1.85%. Both interest rate risk factors have an autoregressive coefficient of the first order of about 0.4.

4. Empirical results

This section presents our main findings. We first discuss the cross-section of estimated betas defined in Section 2. Subsequently, we turn to cross-sectional asset pricing tests and summarize several robustness tests. A separate appendix contains background material on the sensitivity analysis.

4.1. Risk exposure estimates

Table 2 displays estimated risk characteristics of 25 value-weighted portfolios sorted on size and book-to-market-equity listed in Table 1. The sample period runs from 1963Q3 to 2014Q4. The top left panel gives the factor loadings associated with the market return; the top right panel summarizes the factor loadings associated with consumption growth; and the bottom panel shows the factor loadings associated with the interest rate risk factor, with upside interest rate betas on the left and downside interest rate betas on the right. The representation style in Table 2 is analogous to Table 1, i.e. within each panel the portfolios are organized in a squared matrix with growth stocks at the left, value stocks at the right, small stocks at the top, and large stocks at the bottom. Column "Diff." denotes differences in betas between extreme value (BM5) and extreme growth (BM1) quintiles within each size category for each risk characteristic. The HAC *t*-statistics of Newey and West (1987) are reported in parentheses below each estimate.

Three interesting observations emerge from Table 2. First, the standard market and consumption betas are estimated with a low standard error, however, they have virtually no power to explain the cross-section of average returns on stocks sorted by size and book-to-market equity ratios. In the case of the log market return, we can see that growth stocks generally have higher betas than value stocks in contrast to patterns in average returns. The lowest BM stocks have higher sensitivities to consumption risk than highest BM stocks for the first and third size quintiles whereas the opposite holds true for the second, fourth, and fifth market equity quintiles. Yet, in general, the patterns in consumption betas are not clearly pronounced. These results corroborate the established findings in the literature, e.g. Fama and French (1992) and Mankiw and Shapiro (1986).

Second, we find that factor loadings are negative on each portfolio for both upside and downside interest rate risk factors. In other words, when the opportunity cost of money rises, i.e. future nominal interest rates increase, current stock returns decline, whereas when the opportunity cost of money declines, i.e. future nominal interest rate drop, current stocks returns tend to go up. This result reinforces recent findings in Lioui and Maio (2014) who show that US stocks have negative unconditional interest rate betas.

Third and most interestingly, value and growth portfolios differ with respect to their reagibility to upside versus downside interest rate risks. Value stocks are particularly sensitive to upside movements in interest rate growth, while growth stocks react strongly to downside changes in interest rate growth. Hence, higher average returns on value stocks compensate for their higher exposure to conditional upside interest rate risk. By contrast, growth stocks earn a lower risk premium because they are less sensitive to interest rate changes during monetary policy tightening. While the differences in upside betas between the highest and lowest BM portfolios are often not statistically significant, these risk exposures generally tend to increase (in absolute terms) from BM1 to BM5 stocks.

In summary, evidence presented in Table 2 suggests that conditional interest risk might be an important determinant of average excess returns. Specifically, because value stocks have higher in absolute values exposure to upside movements in interest rates than growth stocks, we expect a negative risk premium for the upside interest rate risk factor. In the following, we test this hypothesis empirically.

4.2. Baseline risk premium estimates

This section reports our benchmark cross-sectional estimates. The asset pricing tests are assigned to evaluate the ability of our empirical beta representation with upside and downside interest rate risks in Eq. (6) to capture the variation in US equity returns over the period 1963Q3 to 2014Q4. We report the results from cross-sectional Fama and MacBeth (1973) ordinary least squares regressions of average excess returns on 25 size- and book-to-market sorted portfolios detailed in Table 1 on their estimated betas summarized in Table 2. We estimate two model specifications. The first row in Table 3 reports the results from an unconstrained specification which allows for a free zero-beta rate in the second stage Fama-MacBeth regression. In the second row of Table 3, we constrain the zero-beta rate to the risk-free rate, i.e. we do not allow for a common mispricing in the cross-section of returns. This second specification addresses the concern of Lewellen and Nagel (2006) who argue that treating the slope on the zero-beta rate as a free parameter in the second stage Fama-MacBeth regression might falsely give rise to high cross-sectional R^2 statistics. For each estimate, the table reports Newey and West (1987) adjusted *t*-statistics in parentheses and bootstrap *t*-statistics computed from 1000 simulated realizations in square brackets.[9] For each specification, we report the adjusted cross-sectional $\overline{R}^2$ and the mean absolute pricing errors (*MAPE*). Finally, Column "Diff." shows results of a *t*-test for differences in estimated upside and downside interest rate risk prices.

As signified by the cross-section of consumption betas in Table 2, consumption risk lacks power to explain financial data. The estimate of consumption risk premium is positive but statistically insignificant. Moreover, in line with the patterns in market betas in Table 2, we find no economically meaningful relation between market risk and average stock returns. The market risk premium is estimated to be negative of the order of −2.99% per quarter. Interestingly, consistent with the basic asset pricing theory, our estimates suggest that there is a negative premium for assets' sensitivities to upside interest rate risk. This implies that assets that payoff well in bad times when the opportunity cost of money increases earn a lower risk premium because they provide a hedge against periods of tight monetary conditions. The estimate of the upside interest rate risk premium is of the order of −1.80% per quarter with a *t*-statistic of −8.68. In stark contrast to this result, we find no significant premium for downside interest rate risk here. Hence, assets' sensitivities to downside movements in interest rate growth are not priced in the cross-section of stock returns. A *t*-test in Column "Diff." indicates that the difference in the estimates of λ_{i^+} and λ_{i^-} is significantly different from zero. Overall, the four-beta specification in Eq. (6) explains close to 80% of the variation in the data. However, this success comes at a cost of a large estimated value of the average zero-beta rate. In general, this finding is not uncommon in the literature. For example, Lewellen et al. (2010) report estimates for the zero-beta rate in several benchmark asset pricing models in the interval between

[9] The procedure of Fama and MacBeth (1973) does not correct the standard errors in the second stage regressions for the fact that the regressors are estimated in the first stage. Since the unconditional market and consumption betas and conditional upside and downside interest rate betas have to be estimated separately, the correction method of Shanken (1992) is not applicable here. We therefore follow related studies (e.g. Ang et al., 2006; Atanasov & Nitschka, 2014; Lettau et al., 2014) and report *t*-statistics based on heteroskedasticity robust standard errors (Newey & West, 1987). To minimize concerns about their reliability we also compute standard errors from a bootstrap exercise, details of which are summarized in a separate Appendix.

Table 2
Risk characteristics of Fama–French portfolios.
The table shows the estimated betas with Newey and West (1987) t-statistics in parentheses for 25 portfolios detailed in Table 1. Column "Diff." gives the differences in the estimates between stocks with highest versus lowest book-to-market ratios within each size category.

	BM1	BM2	BM3	BM4	BM5	Diff.	BM1	BM2	BM3	BM4	BM5	Diff.
	Market Betas β_m						Consumption Betas β_c					
S1	1.67	1.36	1.17	1.09	1.19	−0.47	7.23	6.46	5.39	5.25	6.04	−1.19
	(20.57)	(21.01)	(18.71)	(17.70)	(16.53)	(−4.66)	(2.85)	(3.13)	(2.89)	(3.05)	(2.91)	(−0.78)
S2	1.53	1.24	1.12	1.05	1.12	−0.41	5.15	4.23	4.37	4.60	5.45	0.31
	(18.20)	(21.33)	(18.00)	(19.46)	(15.60)	(−3.92)	(2.29)	(2.31)	(2.78)	(2.70)	(3.12)	(0.22)
S3	1.41	1.16	1.02	1.00	0.99	−0.42	4.67	4.09	3.58	3.97	3.70	−0.97
	(20.27)	(24.98)	(16.28)	(16.50)	(14.12)	(−4.48)	(2.19)	(2.30)	(2.38)	(2.21)	(2.54)	(−0.72)
S4	1.27	1.10	1.02	0.98	1.06	−0.21	4.15	3.91	3.93	4.13	5.07	0.91
	(22.64)	(21.20)	(17.52)	(16.79)	(12.95)	(−1.77)	(2.03)	(2.27)	(1.93)	(2.31)	(2.35)	(0.64)
S5	1.01	0.90	0.81	0.82	0.87	−0.14	3.67	2.55	3.66	3.36	3.89	0.22
	(27.13)	(28.79)	(18.14)	(13.75)	(14.23)	(−1.66)	(2.29)	(1.71)	(2.39)	(1.88)	(2.64)	(0.18)
	Upside interest rate betas β_{i^+}						Downside interest rate betas β_{i^-}					
S1	−0.29	−0.88	−1.05	−1.09	−1.32	−1.03	−2.19	−1.58	−1.55	−1.30	−1.16	1.03
	(−0.31)	(−1.30)	(−1.54)	(−2.16)	(−2.41)	(−2.19)	(−2.34)	(−2.04)	(−2.33)	(−2.10)	(−1.43)	(2.60)
S2	−0.52	−0.89	−1.09	−0.84	−0.86	−0.34	−1.88	−1.77	−1.22	−1.17	−1.17	0.71
	(−0.59)	(−1.34)	(−2.08)	(−1.51)	(−1.94)	(−0.66)	(−2.34)	(−2.54)	(−2.15)	(−2.07)	(−1.79)	(1.92)
S3	−0.61	−1.07	−1.00	−1.02	−0.91	−0.30	−2.00	−1.39	−1.24	−0.79	−1.01	1.00
	(−0.86)	(−1.61)	(−1.81)	(−2.06)	(−2.47)	(−0.80)	(−2.86)	(−2.30)	(−2.40)	(−1.31)	(−1.81)	(2.51)
S4	−0.59	−0.74	−0.90	−1.19	−1.03	−0.44	−1.71	−1.32	−1.01	−0.86	−0.67	1.04
	(−0.84)	(−1.00)	(−2.06)	(−2.47)	(−2.46)	(−0.99)	(−2.82)	(−2.32)	(−1.68)	(−1.48)	(−1.09)	(3.21)
S5	−0.48	−0.40	−0.35	−0.77	−0.77	−0.29	−1.16	−0.76	−0.32	−0.46	−0.35	0.81
	(−0.89)	(−0.69)	(−0.52)	(−2.23)	(−1.70)	(−1.00)	(−2.22)	(−1.64)	(−0.66)	(−0.74)	(−0.84)	(2.93)

7.8% and 14.3% per annum (see also, Jagannathan & Wang, 1996; Lettau & Ludvigson, 2001).

The second row in Table 3 estimates a restricted version of the model which does not allow for common mispricing. We find that this change in specification does not alter our main conclusion. There is a significant negative premium attached to upside interest rate risk which supports the view that assets with strong performance in bad economic times of unfavorable monetary conditions have lower average returns. Because value stocks have a stronger tendency to payoff poorly when monetary conditions tighten compared to growth stocks, the former are considered more risky than the latter, and therefore associated with on average higher excess returns. In addition, our estimates indicate that investors demand a positive compensation of about 0.5% for downside interest rate risk when we exclude a constant from a regression. The associated Newey and West (1987) t-statistic is 2.06, while the t-statistic from a bootstrap experiment based on 1000 repeated samples of test asset returns is 0.79. The estimate of λ_{i^-} is thus economically and statistically less important than the estimate of λ_{i^+}. This result is supported by a t-test summarized in the last column of the table.

Table 3
Baseline risk premium estimates.
The table shows risk premia in % per quarter from cross-sectional Fama and MacBeth (1973) regressions of average excess returns on 25 portfolios detailed in Table 1 on their betas reported in Table 2. The tested model is a four-factor model with market (λ_m), consumption (λ_c), upside (λ_{i^+}) and downside interest rate risks (λ_{i^-}). The first row gives the unrestricted risk premium estimates. The second row restricts the zero-beta rate to the risk-free rate. For each estimate we report Newey and West (1987) t-statistics in parentheses and bootstrap t-statistics computed from 1000 simulated realizations in square brackets. $\overline{R^2}$ is the cross-sectional adjusted R^2. Mean absolute pricing errors (*MAPE*) are in %. Column "Diff." shows results of a t-test for differences in estimated upside and downside interest rate risk prices.

λ_0	λ_m	λ_c	λ_{i^+}	λ_{i^-}	$\overline{R^2}$	*MAPE*	Diff.
2.24	−2.99	0.14	−1.80	−0.47	79.45	0.24	−1.34
(4.23)	(−2.80)	(1.10)	(−8.68)	(−1.49)			(−3.04)
[2.02]	[−1.71]	[0.80]	[−5.24]	[−0.92]			[−2.63]
	0.41	−0.05	−2.33	0.50	72.07	0.28	−2.82
	(0.60)	(−0.39)	(−8.44)	(2.06)			(−8.33)
	[0.26]	[−0.23]	[−5.68]	[0.79]			[−4.52]

Since the focus of this paper is to evaluate the cross-sectional implications of conditional interest rate risk, we follow Lioui and Maio (2014) and consider two additional measures of the opportunity cost of money: the three-month Treasury bill rate and the one-month risk-free rate. It turns out that our conclusions do not change qualitatively for these two alternative risk measures. We find further support for the significance of the upside interest rate risk in the cross-section of stock returns. By contrast, the downside interest rate risk cannot explain patterns in realized returns. The estimate of λ_{i^-} switches its sign and is typically not statistically different from zero. Furthermore, the upside interest rate risk premium is greater than the downside interest rate risk premium (in absolute values). These results are not reported in the paper for purposes of brevity. Please see a separate Appendix for this and several additional robustness checks and extensions.

Overall, our results suggest that risk premia for upside and downside interest rate risk components differ considerably. While the former carries a negative premium which is pervasive and statistically significant, the latter is estimated very imprecisely. As we show in Section 4.4, the upside interest rate risk premium is not simply a compensation for the regular unconditional interest rate beta. Upside interest rate risk is a priced factor and seems to drive most of the explanatory power of the model for the cross-section of excess returns.

4.3. Alternative definitions of upside and downside risk

To guard against the possibility that our results are due to the specific definition of upside (downside) interest rate risk as periods in which the interest rate growth is above (below) its mean, this subsection reestimates the model in Eq. (6) using other plausible cut-offs. For example, we define upside (downside) states as periods with 30% highest (lowest) realizations of interest rate growth in Panel A of Table 4; 20% highest (lowest) realizations of interest rate growth in Panel B of Table 4; and 10% highest (lowest) realizations of interest rate growth in Panel C of Table 4.

We have also defined upside and downside betas relative to the zero interest rate growth rate as:

$$\beta_{i^+}^{j} = \frac{cov\left(R^{e,j}, \Delta i | \Delta i > 0\right)}{var(\Delta i | \Delta i > 0)}, \tag{9}$$

Table 4
Alternative definitions of upside and downside risks.
The table shows risk premia in % per quarter from cross-sectional Fama and MacBeth (1973) regressions of average excess returns on 25 portfolios detailed in Table 1 on their market, consumption, upside and downside interest rate betas. Panel A defines periods with 30% highest (lowest) interest rate growth observations as upside (downside) states; Panel B defines periods with 20% highest (lowest) interest rate growth observations as upside (downside) states; Panel C defines periods with 10% highest (lowest) interest rate growth observations as upside (downside) states. The first row in each panel gives the unrestricted risk premium estimates. The second row in each panel restricts the zero-beta rate to the risk-free rate. For each estimate we report Newey and West (1987) t-statistics in parentheses and bootstrap t-statistics computed from 1000 simulated realizations in square brackets. $\overline{R^2}$ is the cross-sectional adjusted R^2. Mean absolute pricing errors (*MAPE*) are in %. Column "Diff." shows results of a t-test for differences in estimated upside and downside interest rate risk prices.

λ_0	λ_m	λ_c	λ_{i^+}	λ_{i^-}	$\overline{R^2}$	*MAPE*	Diff.
Panel A: 30% highest and lowest observations							
2.64	−2.63	0.11	−1.31	−0.62	80.78	0.24	−0.68
(7.68)	(−3.89)	(1.13)	(−8.62)	(−2.41)			(−2.40)
[3.03]	[−1.76]	[0.64]	[−5.37]	[−1.62]			[−1.78]
	2.09	−0.19	−1.86	0.32	49.30	0.36	−2.18
	(1.63)	(−0.87)	(−4.04)	(0.71)			(−4.76)
	[1.08]	[−0.69]	[−4.74]	[0.50]			[−3.35]
Panel B: 20% highest and lowest observations							
2.94	−2.88	0.20	−1.18	−0.61	85.33	0.22	−0.57
(10.94)	(−4.19)	(2.07)	(−10.51)	(−3.36)			(−2.78)
[3.47]	[−1.82]	[1.28]	[−5.36]	[−2.25]			[−2.08]
	2.86	−0.23	−1.52	0.34	55.51	0.35	−1.86
	(2.72)	(−1.18)	(−3.68)	(1.06)			(−5.89)
	[1.77]	[−0.88]	[−4.32]	[0.83]			[−4.53]
Panel C: 10% highest and lowest observations							
2.10	0.63	−0.08	−1.14	0.17	70.37	0.28	−1.31
(4.26)	(1.03)	(−0.59)	(−6.37)	(0.81)			(−6.48)
[2.22]	[0.36]	[−0.38]	[−4.95]	[0.67]			[−5.27]
	2.08	−0.04	−1.62	−0.12	63.86	0.38	−1.49
	(1.81)	(−0.17)	(−4.97)	(−0.58)			(−4.02)
	[1.12]	[−0.12]	[−5.15]	[−0.35]			[−4.34]

and

$$\beta_{i^-}^j = \frac{cov\left(R^{e,j}, \Delta i | \Delta i \le 0\right)}{var(\Delta i | \Delta i \le 0)}. \tag{10}$$

In addition, we experimented with conditioning the upside states on interest rate growth being above zero by a certain constant such as its one or two standard deviations similar to Ang et al. (2006) and Lettau et al. (2014); or periods with interest rate growth being above its sample mean by one or two standard deviations; considered symmetric and asymmetric definitions of upside and downside states[10]; and applied these various definitions of upside and downside states to our three measures of interest rate risk based on the federal funds rate, the three-month Treasury bill rate, and the one-month risk-free rate. We find that using either one of these alternative definitions yields almost identical results. Therefore, we conclude that our finding of a negative upside interest rate risk premium in the data is not affected by a particular cutoff point or specific definition for the benchmark upside and downside states.

4.4. The incremental power of upside interest rate risk

In this section, we address the question whether upside interest rate beta has incremental pricing power for the cross-section of stock returns on top of the unconditional interest rate beta. To pin down this issue empirically, we follow the approach of Ang et al. (2006). Because the regular, downside, and upside betas are by construction not independent of each other, we introduce two additional risk measures to differentiate the effect of upside interest rate risk from the unconditional interest rate risk. We compute a relative upside interest rate beta (measured by $\beta_{i^+}^j - \beta_i^j$) and a relative downside interest rate beta (measured by $\beta_{i^-}^j - \beta_i^j$), where β_i^j denotes the unconditional interest rate beta of portfolio j. The patterns in the relative interest rate betas (unreported) are qualitative strongly related to the patterns in absolute upside and downside betas summarized in Table 2.

To evaluate the importance of the relative interest rate risk (or the incremental power of the upside relative to the overall unconditional interest rate beta), Table 5 estimates a modified version of the specification in Eq. (6)

$$E\left[R^{j,e}\right] = \lambda_0 + \lambda_m \beta_m^j + \lambda_c \beta_c^j + \lambda_{i^+-i} \beta_{i^+-i}^j + \lambda_{i^--i} \beta_{i^--i}^j, \tag{11}$$

where $\beta_{i^+-i}^j \equiv \beta_{i^+}^j - \beta_i^j$ is referred to as a relative upside interest rate beta, $\beta_{i^--i}^j \equiv \beta_{i^-}^j - \beta_i^j$ is a relative downside interest rate beta, and β_m^j, β_c^j and β_i^j are the standard unconditional market, consumption, and interest rate betas as defined as above.

The estimates in Table 5 show that the relative upside interest rate beta, which captures the incremental exposure to the upside on top of the unconditional interest rate risk, is significantly related to the cross-section of stock returns, whereas the relative downside interest rate beta has no explanatory power for differences in returns across assets. The associated Newey and West (1987) t-statistic is −2.42, and the t-value based on the bootstrap standard errors is −3.01. Compared to

Table 5
The incremental power of conditional interest rate risk.
The table tests if conditional interest rate risk has incremental explanatory power on top of the unconditional interest rate risk. It shows risk premia in % per quarter from cross-sectional Fama and MacBeth (1973) regressions. The tested model is a four-factor model with market (λ_m), consumption (λ_c), relative upside (λ_{i^+-i}) and relative downside interest rate risks (λ_{i^--i}). Relative upside (downside) betas are defined as differences between conditional upside (downside) interest rate betas and unconditional interest rate betas. The interest rate risk is measured by the log growth rate in the federal funds rate (Panel A); the three-month Treasury-bill rate (Panel B), and the one-month risk-free rate (Panel C). Periods in which the log interest rate growth is above (below) its sample mean are defined as upside (downside) states. The first row gives the unrestricted risk premium estimates. The second row restricts the zero-beta rate to the risk-free rate. For each estimate we report Newey and West (1987) t-statistics in parentheses and bootstrap t-statistics computed from 1000 simulated realizations in square brackets. $\overline{R^2}$ is the cross-sectional adjusted R^2. Mean absolute pricing errors (*MAPE*) are in %. Column "Diff." shows results of a t-test for differences in estimated relative upside and relative downside interest rate risk prices.

λ_0	λ_m	λ_c	λ_{i^+-i}	λ_{i^--i}	$\overline{R^2}$	*MAPE*	Diff.
Panel A: federal funds rate							
1.20	0.56	0.02	−2.02	0.44	52.41	0.36	−2.45
(1.02)	(0.34)	(0.08)	(−2.42)	(0.60)			(−3.66)
[0.94]	[0.29]	[0.07]	[−3.01]	[0.59]			[−3.32]
	2.14	−0.08	−2.06	1.07	52.30	0.36	−3.13
	(3.08)	(−0.44)	(−2.32)	(1.89)			(−4.93)
	[1.49]	[−0.29]	[−2.87]	[1.46]			[−4.26]
Panel B: 3-month Treasury bill rate							
2.04	−1.27	0.02	−1.71	−0.87	80.56	0.23	−0.84
(3.35)	(−1.45)	(0.17)	(−7.50)	(−2.60)			(−1.72)
[1.67]	[−0.72]	[0.08]	[−3.93]	[−1.50]			[−1.44]
	1.44	−0.11	−2.28	0.06	72.13	0.29	−2.34
	(2.52)	(−0.93)	(−10.85)	(0.18)			(−6.97)
	[0.97]	[−0.43]	[−4.41]	[0.08]			[−3.35]
Panel C: risk-free rate							
2.16	−0.18	0.05	−0.20	−0.05	48.35	0.37	−0.15
(1.97)	(−0.12)	(0.27)	(−3.03)	(−1.19)			(−2.98)
[1.86]	[−0.10]	[0.23]	[−3.13]	[−0.81]			[−2.32]
	2.31	−0.04	−0.26	0.03	40.54	0.42	−0.23
	(2.19)	(−0.18)	(−2.97)	(0.59)			(−4.42)
	[1.55]	[−0.15]	[−3.21]	[0.50]			[−4.06]

[10] For example, if upside states are defined as periods in which the interest rate growth is one standard deviation above a certain threshold value, the risks are "symmetric" if downside states are defined as periods in which the interest rate growth is one standard deviation below that threshold value. Alternatively, the risks are "asymmetric" if downside states are defined as respectively other periods.

our baseline results, the specification in Eq. (11) fits the data somewhat worse with an adjusted R^2 of about 52% and the average absolute pricing error of 0.36%. The respective figures in our benchmark specification in Table 3 are 79% and 0.24%, respectively. However, it is important to note that the representation in Eq. (11) produces economically smaller and statistically insignificant estimates for the constant term. Similar to the estimates in Table 3, we find no significant relation between downside interest rate risk and average returns here. The difference between the relative upside and downside risk prices is −2.45 percentage points and strongly significant. Our results are very similar when we estimate a restricted specification of the representation in Eq. (11) which does not include a constant term. Furthermore, our findings turn out robust to alternative measures of interest rate growth based on the three-month Treasury bill rate and the one-month risk-free rate as indicated by Panels B and C in Table 5.

Moreover, we experimented with another specification in the spirit of Lettau et al. (2014) which also evaluates the impact of incremental upside on top of the unconditional interest rate risk but additionally controls for the unconditional interest rate beta:

$$E\left[R^{j,e}\right] = \lambda_0 + \lambda_m\beta_m^j + \lambda_c\beta_c^j + \lambda_i\beta_i^j + \lambda_{i^+}\left(\beta_{i^+}^j - \beta_i^j\right). \tag{12}$$

Motivated by Ang and Chen (2002), we considered asymmetric interest rate risk measures defined as differences between upside and downside betas, i.e. $\beta_{iasy}^j \equiv \beta_{i^+}^j - \beta_{i^-}^j$, with the corresponding beta pricing representation following

$$E\left[R^{j,e}\right] = \lambda_0 + \lambda_m\beta_m^j + \lambda_c\beta_c^j + \lambda_{iasy}\beta_{iasy}^j. \tag{13}$$

The specification in Eq. (13) allows us to assess the incremental impact of the upside on top of the downside interest rate risk. Our results indicate that the upside interest rate risk carries a significant incremental premium both on top of the unconditional and conditional downside interest rate risks. To conserve space, we defer a detailed discussion of these estimates to a separate Appendix.

In sum, our results in this subsection support the view that upside interest rate beta commands a negative risk premium in the cross-section of stocks returns which has an economic and statistical incremental power beyond the unconditional and downside interest rate betas.

4.5. Taylor rule fundamentals

The analysis in this section is motivated by several recent studies which emphasize the use of Taylor rules to capture the effect of monetary policy decisions on asset prices (e.g. Menkhoff, Sarno, Schmeling, & Schrimpf, 2015; Piazzesi, 2005). Against this backdrop, we define upside and downside states based on fundamental estimates from monetary policy rules by Taylor (1993). We employ the following simple calibration, which is commonly assumed as representative in the related literature:

$$TRF_t = \pi_t + 0.5\hat{y}_t + 0.5(\pi_t - 2) + 2, \tag{14}$$

where TRF_t is the Taylor rule fundamental or the fundamental value of the federal funds rate, π_t is the rate of inflation, and $\hat{y}_t$ is the output gap computed as the percent deviation of real GDP from its trend.

We follow Taylor (1993) and estimate a proxy of the trend real GDP with a Hodrick–Prescott filter with 1600 as a smoothing parameter. We then use the estimated fundamentals to define the upside (downside) states as periods in which the federal funds rate growth is above (below) its average predicted value. The data on the GDP is collected by the Bureau of Economic Analysis and retrieved from the FRED online database of the Federal Reserve Bank of St. Louis. The results from this exercise are summarized in Panel A of Table 6.

Table 6
Taylor rule fundamentals.
Periods in which the federal funds rate growth is above (below) its average fundamental value predicted by the Taylor policy rule are defined as upside (downside) states. We use the trend real GDP estimated with a Hodrick–Prescott filter with 1600 as a smoothing parameter and the current CPI inflation rate (Panel A); the trend real GDP estimated with a Hodrick–Prescott filter with 1600 as a smoothing parameter and the CPI inflation rate over the past quarter (Panel B); the estimate of the CBO's real potential GDP and the current inflation rate of the output deflator (Panel C); and the estimate of the CBO's real potential GDP and the inflation rate of the output deflator over the past quarter (Panel D). For further details see notes to Table 3.

λ_0	λ_m	λ_c	λ_{i^+}	λ_{i^-}	$\overline{R^2}$	*MAPE*	Diff.
Panel A: HP trend + current CPI							
1.35	−3.02	0.21	−1.75	−0.64	83.12	0.23	−1.10
(4.06)	(−3.37)	(2.05)	(−9.78)	(−2.32)			(−2.80)
[1.29]	[−1.78]	[1.26]	[−4.56]	[−1.48]			[−2.52]
	−1.03	0.08	−2.25	−0.20	79.62	0.25	−2.05
	(−1.31)	(0.62)	(−11.66)	(−0.75)			(−6.25)
	[−0.69]	[0.37]	[−5.28]	[−0.39]			[−3.98]
Panel B: HP trend + lagged CPI							
1.17	−2.89	0.26	−1.73	−0.64	81.87	0.23	−1.09
(3.36)	(−3.18)	(2.36)	(−9.35)	(−2.14)			(−2.73)
[1.13]	[−1.74]	[1.47]	[−4.38]	[−1.37]			[−2.35]
	−1.21	0.14	−2.17	−0.27	79.44	0.25	−1.91
	(−1.43)	(1.05)	(−11.69)	(−0.94)			(−5.68)
	[−0.81]	[0.66]	[−4.58]	[−0.53]			[−3.75]
Panel C: CBO potential + current GDP deflator							
2.78	−1.97	−0.01	−1.20	−0.67	82.43	0.22	−0.53
(6.61)	(−2.43)	(−0.07)	(−5.75)	(−1.74)			(−0.96)
[3.00]	[−1.41]	[−0.06]	[−4.88]	[−1.49]			[−1.17]
	2.61	−0.27	−1.85	0.88	65.68	0.33	−2.74
	(2.81)	(−1.50)	(−6.45)	(2.09)			(−4.94)
	[1.64]	[−1.13]	[−4.78]	[1.12]			[−3.47]
Panel D: CBO potential + lagged GDP deflator							
1.74	−2.95	0.09	−1.75	−0.71	81.20	0.23	−1.04
(4.00)	(−3.20)	(0.89)	(−9.34)	(−2.33)			(−2.54)
[1.74]	[−1.84]	[0.55]	[−5.03]	[−1.44]			[−2.11]
	−0.31	−0.05	−2.27	0.02	76.32	0.28	−2.25
	(−0.40)	(−0.41)	(−10.02)	(0.08)			(−6.75)
	[−0.21]	[−0.24]	[−5.83]	[0.04]			[−3.97]

An unrestricted model version with market, consumption growth, and conditional interest rate betas attaches a negative premium of about −1.75% per quarter to upside interest rate risk which is economically plausible and statistically significant. This premium is estimated to be −2.25% per quarter with a *t*-statistic of −11.66 in the restricted specification which does not allow for common mispricing. In contrast, the premium associated with the downside interest rate risk is estimated less reliably. Differences between λ_{i^+} and λ_{i^-} clearly indicate that there is a significantly higher (in absolute values) premium for the upside interest rate risk as opposed to downside interest rate risk.

We examined the sensitivity of our findings in a series of robustness checks. Specifically, we worked with alternative proxies for macroeconomic aggregates, i.e. potential trend GDP estimates based on a Hodrick–Prescott filter and the potential estimates provided by the Congressional Budget Office of the U.S. Congress available in the FRED database. We used GDP and potential trend in real and nominal terms as discussed in Taylor (1993). Motivated by Menkhoff et al. (2015), we experimented with the percent deviation of GDP from a 5-year moving average to proxy for the output gap available in real-time. We looked at rates of inflation in the GDP deflator and the CPI. Similar to Taylor (1993), we considered current inflation and inflation over the past quarter and past four quarters. In addition, we allowed for various definitions of upside and downside states including upside states as periods when (i) the federal funds rate growth is greater than its average fundamental value predicted by the Taylor policy rule; (ii) the federal funds rate growth exceeds its average fundamental value by a fixed constant such as one standard deviation; (iii) the growth rate in the federal funds rate fundamental is above its mean or above zero; (iv) the growth rate in the federal funds rate fundamental exceeds its mean by a fixed constant such as one standard deviation; and (v) we considered symmetric and asymmetric[11] definitions of upside and downside states. Our estimates indicate that changes in specifications of upside and downside states do not have a qualitative impact on our conclusions.

The remaining panels in Table 6 summarize some of these results. In general, our estimates support the view that upside interest rate risk is an important driver of excess stock returns. Consistent with the basic asset pricing theory, the upside interest rate beta carries a negative premium which is pervasive and statistically significant.

4.6. Summary of further sensitivity tests

To examine the sensitivity of our findings with respect to the choice of test assets, Panel A of Table 7 repeats the second-stage Fama and MacBeth (1973) regressions with 25 size and long-term reversal sorted portfolios as these portfolios were used by Lioui and Maio (2014) to evaluate the pricing ability of unconditional interest rate risk. Panel B of Table 7 re-runs the cross-sectional exercise with both 25 size and book-to-market and 25 size and long-term reversal formed portfolios. Finally, in Panel C of the table, we follow the recommendation of Lewellen et al. (2010) and additionally include 30 industry portfolios[12] in our test assets because industry portfolios reduce the commonality effects in characteristics sorted portfolios due to their factor structure. For each set of test assets we estimated an unconditional model with market, consumption growth and upside and downside interest rate risk factors, and its restricted version with zero-beta rate equal to the risk-free rate.

Similar to several most commonly used asset pricing models (see e.g. Lewellen et al., 2010), the pricing ability of our four-beta representation is empirically challenged by industry-sorted portfolios as revealed by the estimates in Table 7. However, we generally find strong evidence supporting our main conclusions. The estimates reinforce that the upside interest rate beta commands a negative premium which is higher (in absolute values) than the respective downside premium. We experimented with both value- and equal-weighted returns, in nominal and real terms, and applied alternative measures of interest rate and consumption growth risk, but found similar results.

In addition, we followed Jagannathan and Wang (1996) to test for model misspecification by using firm characteristics as additional explanatory variables. We have also verified that our results are not attributed to the specific time period we study. We splitted the sample period of portfolio returns mechanically in the middle and considered longer samples. For example, the data on the federal funds rate is available since 1955 and the series on the consumption expenditure can be retrieved from 1947 onwards. We substituted the standard proxy of aggregate consumption risk as a sum of nondurables and services with alternative consumption measures from the NIPA tables based on durables, nondurables (without services), and overall personal consumption expenditures. We have also used the S&P500 index to proxy for the market return. Results from these exercises are very similar to our benchmark findings and are hence omitted for brevity. The premium on the upside interest rate risk is estimated with a right sign and high precision in all cases. A separate Appendix provides a summary of a number of sensitivity tests and contains additional details on the estimation methodology.

Overall, our results support the view that there is an upside interest rate risk premium in the data which is higher than the downside interest rate risk premium. Differences in excess stock returns can be largely rationalized by their sensitivities to upside interest rate risk. Augmenting traditional unconditional and conditional asset pricing models and conventionally employed multifactor models with the conditional interest rate risk improves the cross-sectional fit and reduces the pricing error of each specification we examine. This result is robust to a host of robustness checks including alternative definitions of upside and downside states, the choice of test assets, pricing factors, and sample periods, among others.

Table 7
Alternative test assets.
The table shows risk premia in % per quarter from cross-sectional Fama and MacBeth (1973) regressions. The tested model is a four-factor model with market (λ_m), consumption (λ_c), upside (λ_{i^+}) and downside interest rate risks (λ_{i^-}). Panel A uses 25 portfolios formed on size and long-term return reversal as test assets; Panel B additionally adds 25 size and book-to-market sorted portfolios; and Panel C also includes 30 US industry portfolios. The first row gives the unrestricted risk premium estimates. The second row restricts the zero-beta rate to the risk-free rate. For each estimate we report Newey and West (1987) t-statistics in parentheses and bootstrap t-statistics computed from 1000 simulated realizations in square brackets. $\overline{R^2}$ is the cross-sectional adjusted R^2. Mean absolute pricing errors (*MAPE*) are in %. Column "Diff." shows results of a t-test for differences in estimated upside and downside interest rate risk prices.

λ_0	λ_m	λ_c	λ_{i^+}	λ_{i^-}	$\overline{R^2}$	*MAPE*	Diff.
Panel A: 25 SLTR portfolios							
0.92	0.21	0.02	−1.69	0.73	58.38	0.23	−2.42
(3.17)	(0.24)	(0.27)	(−8.19)	(1.31)			(−4.15)
[1.26]	[0.15]	[0.12]	[−3.83]	[1.43]			[−4.75]
	1.70	−0.07	−1.82	1.10	55.49	0.25	−2.93
	(2.87)	(−0.84)	(−8.55)	(2.19)			(−5.06)
	[1.38]	[−0.36]	[−4.20]	[2.15]			[−5.70]
Panel B: 25 SBM + 25 SLTR portfolios							
1.53	−1.52	0.05	−1.87	−0.02	71.76	0.24	−1.85
(4.94)	(−2.17)	(0.55)	(−10.85)	(−0.08)			(−5.68)
[1.85]	[−1.08]	[0.36]	[−5.79]	[−0.05]			[−4.28]
	0.85	−0.09	−2.19	0.62	65.77	0.28	−2.82
	(2.17)	(−0.98)	(−9.72)	(3.16)			(−9.02)
	[0.64]	[−0.49]	[−5.94]	[1.25]			[−5.67]
Panel C: 25 SBM + 25 SLTR + 30 industry portfolios							
2.02	−1.29	−0.04	−0.91	−0.23	25.10	0.41	−0.67
(5.54)	(−1.71)	(−0.49)	(−3.02)	(−0.99)			(−1.69)
[4.89]	[−1.58]	[−0.44]	[−4.06]	[−0.87]			[−2.52]
	1.25	−0.18	−1.23	0.14	−3.11	0.47	−1.37
	(2.16)	(−1.73)	(−3.00)	(0.43)			(−2.24)
	[1.65]	[−1.74]	[−4.81]	[0.46]			[−4.48]

5. Conclusions

Ample evidence suggests that the effect of monetary policy on stock returns is asymmetric. This paper addresses this question empirically by examining the relation between the cross-section of US stock returns and conditional interest rate risk over the period 1963–2014.

Theory posits that interest rate risk should be associated with a negative premium because periods when the opportunity cost of money increases are usually associated with tight monetary conditions, high inflation expectations, and limited liquidity supply. Using several measures of interest rates and a variety of empirical beta specifications, this article presents evidence that excess stock returns reflect a premium for conditional upside interest rate risk which is higher than the premium for conditional downside interest rate risk. The former is pervasive and statistically significant, while the latter is weak in the data and often indistinguishable from zero.

These findings are consistent with the hypothesis that monetary policy has an asymmetric impact on the cross-section of equity stock returns. Our results complement several papers which document related asymmetries in the time–series dimension (e.g. Chen, 2007; Jensen & Johnson, 1995).

Appendix A

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.rfe.2016.02.003.

[11] See for comparison Section 4.3.

[12] The set of industry portfolios is based on portfolio four-digit SIC code and is freely available in the online library of Kenneth R. French.

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