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Research article

Government bond market risk-return trade-off

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Abstract: We analyze the risk-return trade-off for international (France, Germany, Netherlands, Spain, UK, and US) government bond markets and the US stock market. We measure risk by the higher order moments (volatility, skewness, and excess kurtosis) as they are defined in Savva and Theodossiou (2018). There is no risk-return trade-off when considering a linear relationship between returns and risk. We consider good and bad volatility separately as defined by threshold regressions and find non-linear risk-return trade-off, that is negative for large lagged returns.

Keywords: risk-return trade-off; government bond markets; good volatility; bad volatility

JEL Codes: G12, G15

1. Introduction

In the paper we analyze the risk-return trade-off at international government bond markets and compare our findings with the results from the US stock market. This empirical analysis is the first contribution of our paper.

Although bonds are considered a reliable (and safer compared to stocks) investment tool this does not mean they do not come with their own risks. Some possible factors that affect the performance of bonds include interest rate risk, reinvestment risk, call risk, default risk, inflation risk among others. Therefore, it is essential for investors to know how the risk entailed in bonds affect their returns.

In our risk-return trade-off analysis, we use some distinctive risk measures. The risk measures that we use are the conditional higher moments (volatility, skewness, and excess kurtosis) from Savva and Theodossiou (2018). These are much better measures of the conditional higher moments than the simple realized measures because they consider the time varying behavior of each moment while also accounting for their interactions. Using improved and more precise risk measures is the second contribution of our paper. The third contribution of our paper is that we consider the nonlinear risk-return trade-off as it manifests itself when using the good and bad volatility instead of only the volatility itself. The good (bad) volatility is the volatility itself when the lagged returns are positive (negative). We expect that the good volatility has a positive relationship with the returns and that the bad volatility a negative relationship. The fourth contribution of our paper is to use an endogenously estimated threshold value for the lagged return be the determinant of good and bad volatility. In the threshold regression, we thereby allow the risk-return trade-off to be regime dependent. Our empirical findings show that there is no linear risk-return trade-off, and that the non-linear risk-return trade-off is strongest for the threshold regression approach. For small returns, the risk-return trade-off is mainly positive while it is mainly negative for large returns.

The remaining part of the paper is structured as follows. First, we discuss the related literature in Section 2 and we describe the data in Section 3. Then the linear risk-return trade-off is investigated in Section 4, followed by the good and bad volatility trade-off in Section 5, and the threshold risk-return tradeoff in Section 6. Section 7 concludes.

2. Previous research

According to the ICAPM in Merton (1973) there is a positive relationship between the expected excess returns and the conditional volatility. Subsequently, the literature has investigated this empirically, see e.g. the much-cited study of the stock market by Glosten et al. (1993). Related to our study of the government bond markets, Bai et al. (2021) show that for corporate bonds, the risk-return trade-off is significantly positive.

Recently, the literature has documented that the risk-return trade-off is not always linear. Aslanidis et al. (2021) show that the linear risk-return trade-off is not significant for the US and European stock markets. However, when using quantile regressions, there is significant risk-return trade-off at the tails of the distribution, with a positive relationship between volatility and returns at the upper tail and a negative relationship at the lower tail. Atilgan et al. (2020) show that for stock markets there is a negative risk-return trade-off when the risk is measured by the left tail risk such as value-at-risk. Specifically, the recent literature has documented that there are differences in the trade-off for negative and positive asset returns. Feunou et al. (2018) and Kilic and Shaliastovic (2018) distinguish between upside and downside variance risk premia which are associated with positive and negative returns, respectively. The former considers the variance risk premia for stock markets, while the latter considers both stock and bond markets. Feunou et al. (2013) consider downside stock market volatility for returns below a threshold. Zhang et al. (2021) consider the good and bad stock market variance, where the good (bad) variance is the variance itself when the stock return is positive (negative) and zero otherwise. They find that good and bad variance has predictive power for future stock returns.

The advantages of our paper are that we build on the findings in the previous research for other asset types and let the risk-return trade-off be non-linear and that we allow it to be different when the government bond returns are negative and positive, that is using exogenously defined good and bad volatility. The innovations of this paper are that in the threshold model used here to describe the risk-return trade-off for government bonds where the good and bad volatility are determined endogenously.

3. Data

Our data set is based on monthly observations and the sample period begins in March 1991 and ends in January 2022. We consider seven different government bond markets, namely France, Germany, Netherlands, Spain, UK, and US. The government bonds of these countries are all rated above A (S&P), which indicates that there are only small differences in the default risk across countries.

In Section 2.1 we describe the government bond return data and in Section 2.2 we describe the higher moments risk measures.

3.1. Government bond returns

We use the Datastream 10-year benchmark government bond total return indexes. We calculate the monthly log-returns. For comparison we also consider the US stock market returns, based on the SP500 index.[1]

Table 1. Descriptive statistics for returns.

	Mean	Std. Dev.	Skewness	Kurtosis
France	0.536	1.629	−0.062	2.872
Germany	0.496	1.535	−0.069	2.759
Netherlands	0.525	1.560	0.017	3.444
Spain	0.678	2.129	0.171	5.831
UK	0.552	1.832	-0.106	3.473
US bond	0.452	2.033	0.104	4.290
US stock	0.662	4.213	-0.773	4.769

Note: The table shows summary statistics for the monthly returns in % for the international bond markets and US bond and stock market. The sample period is 1991M03–2022M01.

Table 1 shows the descriptive statistics for the government bond returns measured in monthly percentage returns. The average government bond returns are positive (e.g., 0.552% per month for the UK) with large standard deviations (e.g., 1.832% per month for the UK). The government bond returns have low skewness (e.g., −0.106 for the UK) and are thereby about symmetric, while the government

[1] The government bond data are from Datastream and the SP500 data is price index from Yahoo Finance. The price and total return indexes are strongly correlated and therefore using the price index will have only minor effects on the results.

bond return distributions have fat tails (leptokurtic, e.g., 3.473 for the UK) with two exceptions (France and Germany).

3.2. Higher moments risk measures

We use the conditional higher moments of the government bond returns as the risk measures. We consider the volatility, skewness, and excess kurtosis and these are calculated using the methods in Savva and Theodossiou (2018), where the conditional moments are estimated for the entire sample period at one go. Higher conditional moments are coming from the skewed generalized error distribution (SGED) and under the appropriate calculations we can extract the time varying behavior of each moment. For further details, we refer to the appendix and to the work of Savva and Theodossiou (2018) and Delis et al. (2021).

Table 2. Descriptive statistics for conditional higher moments.

Conditional volatility	Mean	Std. Dev.	Skewness	Kurtosis
France	2.701	0.886	1.176	4.790
Germany	2.464	0.683	1.116	4.411
Netherlands	2.404	0.505	4.295	31.226
Spain	4.761	2.728	3.081	15.718
UK	3.304	1.202	1.489	5.369
US bond	4.033	1.510	1.931	9.874
US stock	20.269	24.312	3.823	21.667
Conditional skewness	Mean	Std. Dev.	Skewness	Kurtosis
France	−0.140	0.149	−1.065	3.933
Germany	−0.158	0.270	−0.338	2.483
Netherlands	−0.109	0.220	−0.166	2.992
Spain	0.005	0.082	−0.059	6.018
UK	−0.060	0.055	−0.189	2.966
US bond	0.022	0.109	−0.436	3.576
US stock	−0.464	0.057	0.070	4.759
Conditional kurtosis	Mean	Std. Dev.	Skewness	Kurtosis
France	1.659	0.065	2.321	8.939
Germany	1.703	0.070	0.299	1.495
Netherlands	1.693	0.143	−3.875	22.855
Spain	1.222	0.127	−2.648	11.803
UK	1.628	0.023	5.037	33.326
US bond	1.561	0.217	−0.975	3.027
US stock	1.672	0.198	−2.589	9.509

Note: The table shows summary statistics for the monthly conditional volatility (in %), conditional skewness, and conditional kurtosis for the international government bond markets and US bond and stock market. The sample period is 1991M03–2022M01.

Table 2 shows the descriptive statistics for the conditional higher moments. The average conditional volatility varies across government bond markets (between 2.404% for the Netherlands and 4.761% for

Spain). The same applies to the average conditional skewness (in absolute terms) which is on average slightly negative for most markets (e.g., −0.060 for the UK) except Spain and the US. The average conditional excess kurtosis is about the same for all the government bond markets and it is positive (e.g., 1.628 for the UK), consistent with the government bond return distribution having fat tails. Figure 1 shows the time series of the conditional volatility, conditional skewness, and conditional excess kurtosis for the UK government bond market. The conditional skewness is highly time varying, while the conditional volatility is much smother, and the conditional excess kurtosis is in-between.

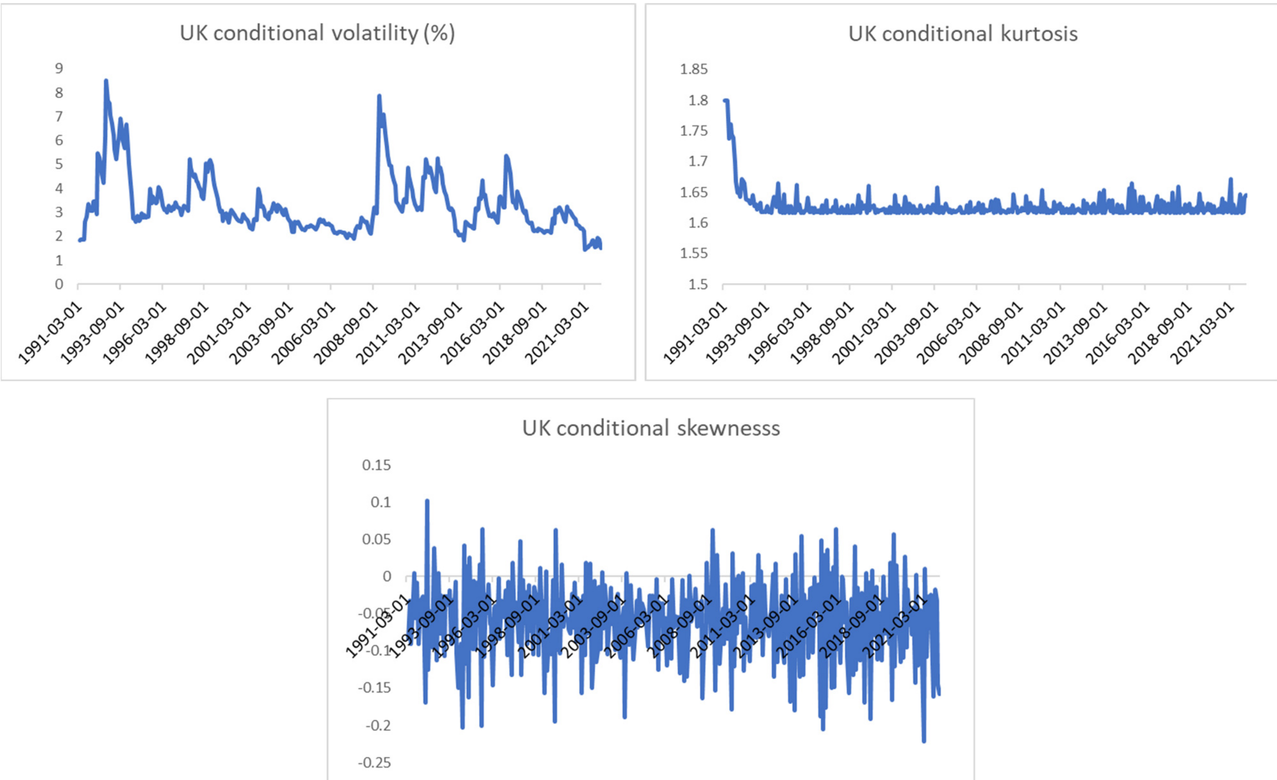

Figure 1. UK conditional higher moments.

Note: The figure shows the monthly conditional volatility, conditional skewness, and conditional kurtosis for the UK government bond market. The sample period is 1991M03–2022M01.

4. Linear risk-return trade-off

For the linear risk-return trade-off the government bond return is explained by its higher moments, namely the conditional volatility, skewness, and excess kurtosis. The government bond return on market i at month t is denoted $R_{i,t}$ and the higher moments are denoted $Vol_{i,t}$ (conditional volatility), $Skew_{i,t}$ (conditional skewness), and $Kurt_{i,t}$ (conditional excess kurtosis). The linear contemporaneous risk-return trade-off regression is given as

$$R_{i,t} = c_{i,0} + c_{i,Vol}Vol_{i,t} + c_{i,Skew}Skew_{i,t} + c_{i,Kurt}Kurt_{i,t} + \varepsilon_{i,t} \tag{1}$$

where $\varepsilon_{i,t}$ is the error term.[2]

We expect that the coefficient to the conditional volatility ($c_{i,Vol}$) is positive, which implies that the government bond returns tend to be higher, when their risk as measured by the volatility is higher. Similarly, we expect that the kurtosis coefficient ($c_{i,Kurt}$) is positive, in that the higher the conditional excess kurtosis is, the fatter tails the distribution has, and the riskier the government bond return is. We expect that risk is higher for government bonds with positive than with negative conditional skewness, because for positive skewness there is more mass at the left tail of the distribution, that is more mass for negative returns. Therefore, we expect the skewness parameter ($c_{i,Skew}$) to be negative, so that the lower the skewness is (more negative), the higher the return tends to be.

We estimate the linear risk-return trade-off for each government bond market separately and show the results in Table 3.

Table 3. Risk-return trade-off with Volatility, Skewness, and Kurtosis.

	France	Germany	Netherlands	Spain	UK	US bond	US stock
Constant	11.045	0.712	0.959	−0.393	−7.962	0.436	5.964**
	(6.096)	(2.662)	(0.987)	(2.158)	(5.104)	(1.153)	(2.833)
Volatility	0.028	−0.099	−0.234	0.037	0.005	−0.142*	0.006
	(0.108)	(0.125)	(0.171)	(0.049)	(0.085)	(0.079)	(0.019)
Skewness	−2.944*	−0.162	−0.252	3.948*	3.447*	−1.645*	10.180**
	(1.499)	(0.388)	(0.381)	(2.425)	(1.873)	(0.837)	(4.070)
Kurtosis	−6.631	0.001	0.060	0.719	5.347*	0.398	−0.411
	(3.813)	(1.564)	(0.471)	(1.662)	(3.139)	(0.564)	(1.028)
Adj. R2	0.002	−0.006	−0.001	0.009	0.003	0.022	0.011

Note: The table shows the OLS regression results of the linear risk-return trade-off regression, $R_{i,t} = c_{i,0} + c_{i,Vol}Vol_{it} + c_{i,Skew}Skew_{it} + c_{i,Kurt}Kurt_{it} + \varepsilon_{it}$, for the international bond markets and US bond and stock market. The sample period is 1991M03 – 2022M01. Newey-West standard errors with automatic lag selection are provided in parenthesis and 1%/5%/10% significance indicated with */**/***.

For all government bond markets, none of the higher moment coefficients are significant at the 5% level of significance. Also, the explanatory power of the linear regressions is very low for all government bond markets (e.g., the adjusted R-squared value for the UK government bond market is 0.003). Overall, the linear regressions do not provide evidence of any risk-return trade-off for the government bond returns and risk.

For the US stock market, there is significant trade-off in that the conditional skewness coefficient is significantly positive, which is opposite our expectations. Still, the explanatory power is low with an adjusted R-squared of 0.011, so the importance of the skewness is limited.

[2] The regressions are estimated using OLS with Newey and West (1987) standard errors with automatic lag selection. We opt for this methodology following the existing studies in the literature. In addition, as indicated by Ghysels et al. (2005), other approaches such as several variations of the GARCH-in-mean models are characterized by inflexibility of the parameterization.

5. Good and bad volatility trade-off

We now consider the risk-return trade-off where we include good and bad volatility instead of the volatility itself. The good volatility is the volatility itself when the lagged return is positive and zero otherwise: $Vol_{i,t}^{Good} = I\{R_{i,t-1} \geq 0\}Vol_{i,t}$, where $I\{\ \ \}$ is the indicator function. Similarly, the bad volatility is the volatility itself when the lagged return is negative and zero otherwise, and it is defined as: $Vol_{i,t}^{Bad} = I\{R_{i,t-1} \leq 0\}Vol_{i,t}$. The modified contemporaneous risk-return trade-off regression with good and bad volatility is given as

$$R_{i,t} = c_{i,0} + c_{i,Good}Vol_{i,t}^{Good} + c_{i,Bad}Vol_{i,t}^{Bad} + c_{i,Skew}Skew_{i,t} + c_{i,Kurt}Kurt_{i,t} + \varepsilon_{i,t} \tag{2}$$

where $\varepsilon_{i,t}$ is the error term. We expect the skewness and kurtosis parameters to have the same signs as for the linear risk-return trade-off if there is a trade-off between returns and skewness and kurtosis risk, i.e., negative skewness parameter and positive kurtosis parameter.

Kilic and Shaliastovic (2018) find a positive (negative) relationship between stock returns and good (bad) variance premia, and Zhang et al. (2021) find a positive relationship between stock returns and good (bad) volatility. Therefore, we expect that the coefficient of the good volatility risk measure ($c_{i,Good}$) is positive, while the coefficient to the bad volatility risk measure ($c_{i,Bad}$) is negative. When the government bond return is positive, the relevant volatility risk measure is the good volatility. Here the trade-off between risk and return would imply that the higher the good volatility is, the higher the return is. This is consistent with the positive good volatility coefficient. When the government bond return is negative, the relevant volatility risk measure is the bad volatility. Then the larger the volatility is, the larger is the absolute return (more negative) when the bad volatility coefficient is negative which is consistent with a negative coefficient.

We estimate the new risk-return trade-off regression for each government bond market separately and the results are shown in Table 4.

In general, the explanatory power of the new trade-off regressions is weak for all government bond markets, e.g., for the UK government bond market the adjusted R-squared is 0.004. For most government bond markets (except the UK and the US), the conditional skewness and conditional excess kurtosis risk measures continue to be insignificant as in the linear risk-return trade-off regressions. For the UK government bond market, the kurtosis parameter is significantly positive according to our expectations, while for the US government bond market, the skewness parameter is significantly negative as expected.

For most of the government bond markets, the coefficients to the good and bad volatility are insignificant. Only for Spain is the coefficient to the good volatility significantly positive as expected. So, the empirical results for the good and bad volatility show only weak signs of trade-off.

Table 4. Risk-return trade-off with good Volatility, Bad Volatility, Skewness, and Kurtosis.

	France	Germany	Netherlands	Spain	UK	US bond	US stock
Constant	10.813	0.720	0.733	0.546	−10.171	0.312	5.923
	(7.179)	(2.678)	(0.996)	(2.322)	(5.169)	(1.198)	(2.772)
Good	0.040	−0.049	−0.203	0.085*	0.002	−0.095*	0.006
volatility	(0.107)	(0.125)	(0.177)	(0.049)	(0.081)	(0.093)	(0.014)
Bad	0.027	−0.155	−0.214	−0.046	0.005	−0.163*	0.005
volatility	(0.158)	(0.134)	(0.169)	(0.081)	(0.131)	(0.088)	(0.010)
Skewness	−2.810	0.183	−0.213	−0.197	3.683	−1.828*	10.113**
	(2.185)	(0.490)	(0.666)	(4.058)	(2.681)	(0.989)	(4.018)
Kurtosis	−6.495	0.008	0.156	−0.060	6.719**	0.437	−0.408
	(4.535)	(1.576)	(0.485)	(1.784)	(3.192)	(0.607)	(1.119)
Adj. R2	0.000	−0.006	−0.004	0.017	0.001	0.025	0.008

Note: The table shows the OLS regression results of the good and bad volatility risk-return trade-off regression, $R_{i,t} = c_{i,0} + c_{i,Good}Vol_{it}^{Good} + c_{i,Bad}Vol_{it}^{Bad} + c_{i,Skew}Skew_{it} + c_{i,Kurt}Kurt_{it} + \varepsilon_{it}$, for the international bond markets and US bond and stock market. The sample period is 1991M03-2022M01. Newey-West standard errors with automatic lag selection are provided in parenthesis and 1%/5%/10% significance indicated with */**/***.

6. Threshold risk-return trade-off

In the good and bad volatility trade-off regression, it is the sign of the lagged return that determines whether the current volatility is good or bad. This implies that the threshold value for the lagged return for distinguishing between good and bad volatility is zero. Now we use a threshold regression to estimate the risk-return trade-off. Here we let an endogenously estimated threshold value for the lagged return be the determinant of good and bad volatility. In the threshold regression, we allow the coefficient of the volatility to be regime dependent, while the coefficients to the skewness and kurtosis are constant. In the simplest form, the threshold risk-return trade-off regression is given by:

$$R_{i,t} = c_{i,j,0} + c_{i,j,Vol}Vol_{it} + c_{i,Skew}Skew_{it} + c_{i,Kurt}Kurt_{it} + \varepsilon_{it} \tag{3}$$

where $c_{i,j,Vol} = \begin{cases} c_{i,Low,Vol} \text{ if } R_{i,t-1} < \gamma_i \\ c_{i,High,Vol} \text{ if } R_{i,t-1} \geq \gamma_i \end{cases}$. Thereby, the coefficient to the volatility is either $c_{i,Low,Vol}$ when the lagged return is low, i.e. below the threshold value γ_i, or the coefficient to the volatility is $c_{i,High,Vol}$ when the lagged return is high, i.e. above the threshold value γ_i. The intercept $c_{i,j,0}$ also takes on different values in the low and high lagged return regimes and is defines similarly. The threshold regression also allows that empirically there is only one regime, i.e. that the volatility coefficient is identical across the two regimes.

In the actual estimation we use a slightly more general threshold regression model, where we allow for up to three regimes instead of only two as stated in Equation (3). Further, we use not only the one-month lagged return as threshold variable, we also include further lags as possible threshold variables, namely $R_{i,t-k}$ where $k = \{1,2,3,4\}$.[3]

The results from estimating the threshold risk-return trade-off are shown in Table 5. For all government bond markets (except the Netherlands), there are two regimes for the risk-return trade-off regression. For all these government bond markets, the low-return regime has a positive threshold value, e.g. for the UK the threshold value is 1.520. This implies that the natural threshold value for the lagged return in distinguishing between the regimes for the trade-off is far higher than zero used in the good and bad volatility trade-off regression. For the Netherlands there are three regimes, where the first threshold is negative at -0.819 and the second threshold is positive at 0.614.

In the low-return regime, the volatility parameter is significant for some markets, and it is generally positive. In the high-return regime, the volatility parameter is negative, while it is only significant for the UK and the US.

Further, the lag order of the best threshold variable varies across government bond markets. It is only for the US, that the chosen lag order is 1, for the other markets it is higher at 2 for the UK, and 3 for the other markets.

The added flexibility of the threshold regression is also evident in that its explanatory power is much larger than for the first two trade-off regressions, e.g. for the UK, the adjusted R-squared is 0.036 in the threshold regression, compared to 0.001 in good and bad volatility trade-off regression and 0.003 in the linear trade-off regression.

For the US stock market, the threshold regression shows that there is only one regime, bringing us back to the linear risk-return trade-off regression. So, the risk-return trade-off for government bond markets is very different from that of the stock market.

[3] In the estimation we allow for up to three regimes but find only one or two except for the Netherlands. The number of breakpoints is found by minimizing the residual sum of squares (SSR). The threshold values are found by sequential minimization of the SSR. The best threshold variable (i.e. which lag order of the returns) is decided by minimizing the SSR.

Table 5. Threshold risk-return trade-off.

	France	Germany	Netherlands	Spain	UK	US bond	US stock
Threshold lag	−3	−3	−3	−3	−2	−1	
Low threshold	0.991	0.481	−0.819	1.605	1.520	−0.795	
constant	12.495**	0.943	−1.984	−0.690**	−15.007***	−0.526	5.881*
	(6.339)	(2.691)	(1.472)	(2.090)	(4.587)	(1.089)	(2.993)
volatility	0.040	−0.266*	0.660*	0.095	0.252*	0.007	0.006
	(0.139)	(0.146)	(0.349)	(0.046)	(0.134)	(0.085)	(0.019)
obs	205	162	73	159	257	85	369
Medium threshold			0.614				
constant			3.762**				
			(1.542)				
volatility			−1.645***				
			(0.378)				
obs			100				
High threshold	0.991	0.481	0.614	1.605	1.520	−0.795	
constant	13.471**	0.920	0.141	1.162	−12.842***	0.971	
	(6.306)	(2.722)	(1.133)	(2.227)	(4.570)	(1.190)	
volatility	−0.132	−0.044	−0.004	−0.160	−0.334**	−0.198*	
	(0.122)	(0.160)	(0.223)	(0.122)	(0.138)	(0.112)	
obs	162	205	194	108	111	285	
Skewness	−3.618**	−0.221	−0.379	3.446	3.772**	−1.875**	10.056**
	(1.578)	(0.391)	(0.340)	(2.310)	(1.869)	(0.876)	(4.298)
Kurtosis	−7.708*	−0.075	0.308	0.578	9.211***	0.291	−0.397
	(3.953)	(1.573)	(0.537)	(1.614)	(2.773)	(0.538)	(1.042)
Adj. R2	0.024	0.019	0.053	0.038	0.036	0.039	0.010

Note: The table shows the OLS regression results of the threshold regression, $R_{i,t} = c_{i,j,0} + c_{i,j,Vol}Vol_{it} + c_{i,Skew}Skew_{it} + c_{i,Kurt}Kurt_{it} + \varepsilon_{it}$, for the international bond markets and US bond and stock market. The sample period is 1991M03-2022M01. Newey-West standard errors with automatic lag selection are provided in parenthesis and 1%/5%/10% significance indicated with */**/***.

7. Conclusions

We analyze the risk-return trade-off for international government bond markets. We measure the risk by the higher order moments (volatility, skewness, and excess kurtosis) as they are defined in Savva and Theodossiou (2018). We find that there is not a linear relationship between risk and return, when we use the higher moments volatility, skewness, and excess kurtosis as risk measures. However, when we consider good and bad volatility as defined endogenously from threshold regressions there is non-linear risk-return trade-off. It is primarily for large returns that there is a risk-return trade-off, and the trade-off is negative instead of positive as expected.

The results bear important implications for investors. For instance, investors should adjust their expectations towards the risk and its negative effects in large returns when investing in bond markets.

Finally, this study opens paths for further research; for instance, by including more markets around the world to examine the risk-return tradeoff or by examining more markets under a multivariate specification to account for linkages among the markets.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflict of interest

The authors declare no conflict of interest.

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