

The Role of Term Spread and Pattern Changes in Predicting Stock Returns and Volatility of the United Kingdom: Evidence from a Nonparametric Causality-in-Quantiles Test Using Over 250 Years of Data[#]

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Abstract

Given the existence of nonlinear relationship between equity premium and term spread, as well as pattern changes and the interaction of pattern changes with the term-spread and changes in the shape of the yield curve, we use a nonparametric k -th order causality-in-quantiles test to predict the movement in excess returns and volatility based on changes in the shape of the yield curve. With the test applied to over 250 years of monthly data for the UK covering the period 1753:08 to 2017:02, we find that pattern changes and the interaction of pattern changes with the term-spread, besides the term spread itself, tends to also play an important role in predicting volatility at the upper end of its conditional distribution. In addition, the effect on excess returns from term spread, pattern changes and the interaction is found to have improved markedly over time, barring at the conditional median of the equity premium. Finally, comparisons are made with historical data of the US and South Africa, and implications of our results are discussed.

Keywords

Stock returns; Volatility; Yield curve changes; Conditional term spreads; Nonparametric causality-in-quantiles test

1. INTRODUCTION

The relations among stock market returns, economic growth, and the slope of the term structure of interest rates are the subject of much research (e.g., see Chen, Roll and Ross 1986; Campbell 1987; Harvey 1989 for the early work in this area). Wheelock and Wohar (2009) offer a comprehensive literature survey on the usefulness of the term spread for predicting changes in

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economic activity. There is also an area of literature that investigates whether the yield spread is a leading indicator of stock returns. There are many studies (e.g., see Boudoukh et al 1993; Ostdiek 1998; McCown 1999, 2001; Resnick and Shoesmith 2002; Nyberg 2013; Fernandez-Perez *et al.*, 2014) which report that the ex-ante equity risk premium is negative in periods preceded by an inverted yield curve.

In earlier work, Fama and French (1989) report that excess returns on US stocks and corporate bonds are positively related to the slope of the yield curve of US Treasury securities. They argue that the yield curve has predictive power because it is a proxy for discount rate shocks and both, stocks and long-term bonds, are long-term investments, and are highly susceptible to changes in investors' intertemporal discount rates. The large differences in the conditional risk premiums signaled by an upward-sloping or inverted yield curves may be due in part to differences in the volatility of the stock returns. Research related to this finds that in many cases, the volatility of the returns are much higher when the yield curves are upward-sloping, compared to when they are inverted.

The findings of recent work by Volkman *et al.*, (2014), using US data, concurs with previous research that find a positive significant relation between conditional term spread and future equity returns and risk premia. However, explanatory power and robustness of the term spread is enhanced by including a vector of qualitative variables that proxy changes in the shape of the yield curve. Volkman *et al.*, (2014) find the greatest economic gain occurs with a shift down in the yield curve accompanied by a steep conditional term spread. Volkman *et al.*, (2014) also find any decrease in the long-term rate, pivot clockwise and rotation long down patterns result in significant positive subsequent 6-month equity returns, especially in extreme economies.¹ In the process, Volkman *et al.*, (2014) connect to the burgeoning literature that studies whether components of yield curve incorporate any important information about future evolution in macroeconomic aggregates (see Ang *et al.*, 2006; Diebold *et al.*, 2006; Ferreira *et al.*, 2008; Moench, 2012, among others).

Overall, the above literature highlights the importance of modelling changes in the shape of the yield curve when looking into the relation between equity returns and interest rate models. Uncovering the empirics of conditional influence of the changes in shape of the yield curve on economic growth and equity returns is important both from an academic as well as practitioner point of view.

¹ These equity returns are complemented by a positive influence of the term spread. Similar results were obtained at the sectoral level by Volkman et al., (2012).

Against the backdrop of the above research, the objective of our paper is to assess the predictive ability of changes in the shape of the yield curve (patterns) for excess stock returns and its volatility for the UK, the US and South Africa. We achieve this goal by using a nonparametric causality-in-quantiles test that has been recently developed by Balcilar *et al.* (2017), applied to over 250 years of monthly data for the UK covering the period 1753:08 to 2017:02. We also draw comparisons with historical data for a developed country, i.e., the US over the period 1871:02 to 2017:02 (to compare our results with that of Volkman *et al.*, 2014), and an emerging market economy, namely South Africa, over the period 1936:01 to 2017:02. Note that, the decision to use such long-spans of data is due to two reasons: (a) The longest possible data samples available, allows us to bypass sample-size bias, and helps us in analyzing the historical evolution of the equity markets in these economies across its various market-phases; (b) In addition, we need large number of observations, since nonparametric quantiles-based methods ideally requires enough data at each point of the conditional distributions to obtain statistically robust and valid inferences. To the best of our knowledge, this is the first attempt to use historical data for developed and emerging market economies in predicting the conditional distributions of equity premium and its volatility based on changes in the shape of the yield curve.

The use of the nonparametric causality-in-quantiles test studies higher order causality over the entire conditional distribution and is inherently based on a nonlinear dependence structure between the variables of interest. Balcilar *et al.*, (2017) essentially combines the causality-in-quantile test of Jeong *et al.* (2012) and the higher-moment k^{th} -order nonparametric causality of Nishiyama *et al.* (2011). The main novelties of this econometric framework and, thus, the empirical results of our paper are as follows: First, our estimation is robust to misspecification errors, as it detects the underlying dependence structure between the examined dependent variable (i.e., excess stock returns) vis-à-vis the predictors (i.e., term-spread, its patterns, and interaction between the term spread and the patterns (interaction)). In our empirical exercise, we show that this is particularly important given that excess returns is in fact related nonlinearly with its predictors, which in turn, validates the large literature that financial markets data tend to display nonlinear dynamics with respect to its predictors (Bekiros *et al.*, 2016). Second, this methodology allows us to test not only for causality-in-mean (i.e. the first moment), but also for causality in the tails of the joint distribution of the variables. Our analysis reveals that this aspect is especially relevant in the light of the fact that the unconditional distribution of the dependent variable - i.e. excess stock returns - tends to exhibit fat tails; specifically, a heavy left tail. Thus,

the nonparametric causality-in-quantiles test allows us to capture bear, normal and bull market phases corresponding to the lower quantiles, the median, and the upper quantiles of the distribution, respectively. Third, we are also able to investigate causality-in-variance and, thus, study higher-order dependency. This again is highly pertinent since, during some periods, causality in the conditional-mean may not exist, while at the same time higher-order interdependencies may turn out to be significant. Given these advantages of the chosen approach, our paper can be considered to be an extension of the work of Volkman *et al.* (2014), which used a linear model, possibly subject to misspecification due to nonlinearity, and restricted to only studying returns and not volatility, and that too only at the conditional mean, rather than the entire conditional distribution of both returns and volatility.

Note that, nonlinear causality tests (for example, Hiemstra and Jones (1994), and Diks and Panchenko (2005, 2006), Bai et al., (2010, 2011)) and GARCH models could have been used to analyze the impact of term-spread, its patterns and interaction on excess stock returns and/or volatility, but these approaches would rely on conditional-mean based estimation, and hence fail to capture the entire conditional distribution of excess stock returns and volatility – something we can do with our approach. In the process, our test is a more general procedure of detecting causality in both returns and volatility simultaneously at each point of their respective conditional distributions. Hence, we are able to capture existence or non-existence of causality at various phases of the stock markets, as pointed out above. Being a more general test, our method is more likely to pick up causality when conditional mean-based tests might fail to do so. In addition, since we do not need to decide on the number of regimes as in a Markov-switching model, and can test for causality at each point of the conditional distribution characterizing specific regimes, our test also does not suffer from any misspecification in terms of specifying and testing for the optimal the number of regimes.

The rest of the paper is organized as follows: Section 2 discusses the theory of pattern changes, with Section 3 presenting the data. Section 4 describes the higher-moment nonparametric quantile causality test, while Section 5 discusses the main results along with robustness tests. Finally, Section 6 concludes.

2. THEORY OF PATTERN CHANGES

Previous researchers have found and demonstrated a strong relation between interest rates and economic activity and, similarly, ex ante equity returns. Most researchers have focused on a

country's monetary policy and subsequent adjustment to the short rate by their governing bodies implicitly assuming a static long rate while other researchers assumed a constant relation between the short and long rates such as previous yield curve and term spread studies. However, simple observation of the interaction between short and long rates reveals a non-constant and irregular relation between short and long rates. Previous research assumed short and long rates move in the same direction and by similar incremental changes, however, we assert that short and long rates will react differently and by different degrees of incremental changes to the same economic event. Long rates do not always behave predictably given corresponding changes in short term rates. We note that the relation between monetary policy, business conditions, and future equity returns is complicated and assert that changes in the yield curve contains information about key economic factors affecting the economy not present in static term spread or short rates.

Employing the Expectation Theory of Interest Rates, we illustrate the varying relation between interest rates, why long rates and short rates may react differently to the same economic news and why different spread patterns may have dissimilar effects on future equity returns. The Expectation Theory assumes that long rates are a product of the short rate and the long forward rate and that long rates contain two elements: information about financial market expectation of monetary policy over the duration of the investment and compensation for inflation risk premia. Therefore, long rates may change by different degrees based on the current state of the general economy and investors' varying views of future Fed policies, economic activity, and inflation expectations.

The Expectation Theory states that the market sets long-term yields equal to a weighted average of the short term rate and expected future spot rates. Future spot rates are a function of investor's expectation of future inflation, economic activity and government policies.

$$1 + LR_{t,n} = \prod_{j=0}^{nxm} E_t \left(1 + R_{t+m \times j, m} \mid I_t \right) \quad (1)$$

Separating the current known short term rate we get:

$$1 + LR_{t,n} = \left(1 + SR_{t,m} \right) \prod_{j=1}^{nxm} E_t \left(1 + R_{t+m \times j, m} \mid I(t) \right) \quad (2)$$

where $LR_{t,n}$ is the current long rate with a holding horizon of n , $R_{t+mxj,m}$ is future spot rates with holding periods of m , $SR_{t,m}$ is the current short rate with a short holding horizon of m , and E_t is the usual expectations operator based on information set I_t .

Extending Equation 1 one period (opm) into the future, we get the expected spot rate of $t+1$:

$$1 + E_t(LR_{t+m,n-m}) = \prod_{j=1}^{n/m} E_t(1 + R_{t+mxj,m} | I_{t+1}) \quad (3)$$

Substituting Equation 3 into Equation 2 we get the current relation between the current long spot rate, $LR_{t,n}$, the current spot short rate, $SR_{t,m}$, and the expected future long spot rate, $E_t(LR_{t+m,n-m} | I_t)$:

$$1 + LR_{t,n} = (1 + SR_{t,m}) (1 + E_t(LR_{t+m,n-m})) \quad (4)$$

As Equation 4 illustrates, the long spot rate is a function of both the short rate and expectation of future rates. Therefore, the long rate could increase (decrease) as the short rate increases (decreases) or change because of perceived changes to future economic environments and/or inflationary expectations.

To illustrate the relation between changes in the yield curve and ex ante equity returns, we employ the Residual Income Model introduced by Claus and Thomas (2001) and developed by Schroeder and Esterer (2013). Specifically, we import the relation between long term and short-term rates modelled in Equation 4 into the following equity valuation model:

$$\hat{P}_n = B_n + \sum_{n+1}^m \frac{E_0[e_t] - [SR_{t,m} \times E_0(B_{t-1})]}{(1 + SR_{t,m})^t} + \frac{(E_0[e_m] \times (1 + g_T)^2 - SR_{t,m} \times E_0(B_{m+1})) \times (1 + g^*)}{(LR_n - g^*)(1 + LR_n)^m} \quad (5)$$

where, B_n is the current book value per share and the expected residual income in period t is the difference between the expected earnings in period t , $E_0[e_t]$, and the dollar cost of equity, measured as the implied equity required rate of return $SR_{t,m}$ times the estimated book value of equity, $E_0(B_{t-1})$, at the beginning of the period. In our analysis, we assume an initial earnings growth phase, followed by a transitional earnings growth rate (g_T). Beyond the short-term holding period (m), earnings are assumed to grow at a stable terminal growth rate (g^*) which is the expected long-term inflation rate. The long run discount rate (LR_n) is determined using Equation 4. Equation 5 illustrates the relation between ex ante equity price and yield curve and pattern changes in the yield curve.

We model the irregular interactions between interest rates and their effect on ex ante equity returns by assuming the relation between rates and their effects on equity returns is not static and by adopting a dynamic yield curve in our analysis. To model a dynamic yield curve, we identify four broad pattern changes in the yield curve based on shifts in the long rate relative to changes in the short rate: no change, rotation, shift and pivot patterns. As implied, a no change pattern in the yield curve results when both the short and long rate demonstrate no relative shift from previous values.

A rotation pattern occurs when one end of the yield curve changes while the opposite end remains fixed, e.g., a rotation pattern results from a tightening (easing) in Fed policy, thereby increasing (decreasing) the short rate, but with no concurrent change in the long rate. Given the equality of Equation 4, if the long rate remains constant and the short rate increases (decreases), then the expected long spot rate must decrease (increase). Based on the Residual Income Model of Equation (5), a lower expected spot rate results in a lower (higher) discount rate implying increased (decreased) subsequent six month equity returns. A rotation pattern may also occur if the short rate remains fixed and long rates change. This pattern results when the Fed and investors have incongruous views of future economic activity and inflation. A decrease (increase) in the current long spot rate with the short spot rate fixed, implies a decrease (increase) in the future spot rate and corresponding discount rate. Note that research using only Fed policy as a proxy for economic activity and as an explanatory variable does not identify this significant economic shift in investor expectations. A Rotation Pattern will have an indeterminate effect on ex ante equity returns dependent on the degree of rotation. An increase in the Long rate while the short rate remains constant, rotation long up, will have a negative effect on equity returns implying investors have higher inflationary concerns than the monetary authorities and an increase in risk aversion. While a decrease in the long rate, rotation long down, indicates investors have lower future inflationary concerns and risk aversion indicating an increase in ex ante equity returns.

A shift pattern in the yield curve occurs when all rates change in the same direction with similar relative incremental conversion. An increase (decrease) in the short rate is accompanied by an increase (decrease) in the long rate implying that investors' expectations of future economic activity and anticipated inflation is congruous with monetary authorities' expectations. A shift up pattern will result in lower equity returns due an increase in all discount rates contained in Equation 5. Similarly, a shift down pattern will result in higher ex ante equity returns.

A pivot pattern occurs when short and long rates inversely change around a fixed medium rate. For example, a Fed's tight monetary policy will lead to an increase in the short rate while the long rate drops. Investors may expect forward rates to drop due to decreased economic activity or an increase in the Fed's resolve to fight inflation. In contrast, a decrease in the short rate accompanied by an increase in the long rate implies investors' expectation of increased future economic activity or increased future inflation expectations. A pivot pattern will have conflicting effects on equity returns due to opposing changes in each rate of the yield curve. As noted in Equation 5, a decrease in the short rate will diminish equity returns while the lower long rate will enrich equity returns.

3. DATA

Excess stock market returns are computed as the excess returns of a market index over the risk-free asset return, which is common in the relevant literature. Specifically we calculate the continuously compounded log return of the FTSE All Share index minus the short-term bank rate, with data on the stock prices derived from the Global Financial Database. The short-term interest rate is obtained from the Three Centuries of Data (Version 2.3) maintained by the Bank of England at: <http://www.bankofengland.co.uk/research/Pages/datasets/default.aspx>. This data is available till April, 2016. The data is then updated till end of our sample period from International Financial Statistics of the International Monetary Fund. We compute the volatility of excess stock market returns using the squared values of the equity premium. The term-spread is the difference between the long-term yield on consols less the short-term interest rate, with the long-term rate again derived from the Three Centuries of Data and International Financial Statistics. For US and South Africa stock prices measured by the S&P500 and the Johannesburg All Share Index are obtained from the Global Financial Database. For South Africa, short- and long-term interest rates are also derived from the same source, with 10 year government bond yields serving as the measure of the long-term rate and the 3-month Treasury bill rate being the short-term rate. For the US the data on the long-term interest rate (10 year government bond yield) is obtained from the data segment of Professor Robert J. Shiller's website: <http://www.econ.yale.edu/~shiller/data.htm>, and the short-term rate comes from the website of Professor Amit Goyal: <http://www.hec.unil.ch/agoyal/>. The short-term interest rate is measured in terms of the three-month Treasury bill rate from 1920 onwards, and prior is based on an estimation, as in Welch and Goyal (2008), using the Commercial paper rates for New York City, which are obtained from the National Bureau of Economic Research (NBER) Macrohistory database. Professor Goyal's data ends in 2016:12, and hence, data for the next two months are obtained from the FRED database of the Federal Reserve Bank of St. Louis. The

data sample covers the monthly periods of 1753:08 to 2017:02, 1871:02-2017:02 and 1936:01-2017:02 for UK, US and South Africa (SA), with the start and end dates being purely driven by the availability of data of the three variables involved.

As noted earlier in this research, changes in the yield curve pattern can result from either increases or decreases in the short term and/or long term rates and contain economic and expectations information not present in studies employing static yield spreads or fixed long rate assumptions. We identify a change in either the long-term or the short-term rate if the rate is more than one fifth of one standard deviation difference from the previous rate. Because interest rates have had a significant long-term variance over our 264-year sample period, we use a rolling ten-year period to determine the standard deviation. Note that using a ten-year rolling period to estimate the standard deviation implies a time varying proxy for the estimate. Periods of high interest rates are accompanied by high standard deviation estimates and, correspondingly, similar relations will occur in periods of low interest rates. By using a time varying estimate of deviation, the model correctly adjusts the relative standard deviation during high interest rate environments in comparison to the relative standard deviation during low interest rate environments. The use of a time varying measure of dispersion assists in pattern recognition in all interest rate environments. All pattern changes are present throughout the data sample regardless of the level interest rates.

Using changes in the short and long rates, we classify the yield pattern into nine categories: no change, pivot clockwise, pivot counterclockwise, rotate long rate down, rotate long rate up, rotate short rate down, rotate short rate up, shift up and shift down. The specific pattern changes are categorized as follows:

- No change (Nochg): both short and long term rates stay the same
- Pivot clockwise (Pivclo): short term rates increase and long term rates decrease
- Pivot counterclockwise (Pivcnt): short term rates decrease and long term rates increase
- Rotate long down (Roldo): Short term stay the same, long term rates decrease
- Rotate long up (Rolup): Short term stay the same, long term rates increase
- Rotate short down (Rosdo): Short term rates decrease, long term stay the same
- Rotate short up (Rosup): Short term rates increase, long term stay the same
- Shift up (Shiftup): Both short and long term rates increase
- Shift down (Shiftdo): both short and long term rates decrease

While no change, shift up, and shift down all imply no change in the term spread, the different patterns have different implications relative to economic conditions. Similarly, pivot clockwise, rotate short up, and rotate long down all decrease positive spreads but signal different

expectations of future economic activity in a narrower term spread environment. Lastly, pivot counterclockwise, rotate short down, and rotate long up all increase the term spread but have different information sets relative to future economic activity.

As can be seen from the summary statistics, reported in Table A1 in the Appendix of the paper, the equity premium of UK is skewed to the right, with excess kurtosis, resulting in a non-normal distribution. Excess returns for US and South Africa are skewed to the left, and with excess kurtosis, normality is again rejected. As can also be observed from Table A1, the squared equity premium, i.e., volatility, of all the three countries are skewed to the right and with excess kurtosis have non-normal distributions. These results provide a preliminary motivation to use the causality-in-quantiles test (to be discussed in the next section), given the heavy-tails.

4. METHODOLOGY: NONPARAMETRIC QUANTILE CAUSALITY TEST

In this section, we briefly present the methodology for the detection of nonlinear causality via a hybrid approach developed by Balcilar *et al.* (2017), which in turn is based on the frameworks of Nishiyama *et al.* (2011) and Jeong *et al.* (2012).

Let y_t denote excess stock returns and x_t denote the predictor variable, in our case the term-spread, its patterns and the interaction between the term-spread with the various patterns (as described in the data segment above) considered one at a time. Formally, suppose $Y_{t-1} \equiv (y_{t-1}, \dots, y_{t-p})$, $X_{t-1} \equiv (x_{t-1}, \dots, x_{t-p})$, $Z_t = (X_t, Y_t)$ and $F_{y_t|Z_{t-1}}(y_t, Z_{t-1})$ and $F_{y_t|Y_{t-1}}(y_t, Y_{t-1})$ denote the conditional distribution functions of y_t given Z_{t-1} and Y_{t-1} , respectively. If we denote $Q_\theta(Z_{t-1}) \equiv Q_\theta(y_t | Z_{t-1})$ and $Q_\theta(Y_{t-1}) \equiv Q_\theta(y_t | Y_{t-1})$, we have $F_{y_t|Z_{t-1}}\{Q_\theta(Z_{t-1}) | Z_{t-1}\} = \theta$ with probability one. Consequently, the (non)causality in the q -th quantile hypotheses to be tested are:

$$H_0: P\{F_{y_t|Z_{t-1}}\{Q_q(Y_{t-1}) | Z_{t-1}\} = q\} = 1, \quad (5)$$

$$H_1: P\{F_{y_t|Z_{t-1}}\{Q_q(Y_{t-1}) | Z_{t-1}\} = q\} < 1. \quad (6)$$

Jeong *et al.* (2012) employ the distance measure $J = \{\varepsilon_t E(\varepsilon_t | Z_{t-1}) f_z(Z_{t-1})\}$, where ε_t is the regression error term and $f_z(Z_{t-1})$ is the marginal density function of Z_{t-1} . The regression error ε_t emerges based on the null hypothesis in (1), which can only be true if and only if $E[\mathbf{1}\{y_t \leq Q_\theta(Y_{t-1}) | Z_{t-1}\}] = \theta$ or, equivalently, $\mathbf{1}\{y_t \leq Q_\theta(Y_{t-1})\} = \theta + \varepsilon_t$, where $\mathbf{1}\{\times\}$ is an

indicator function. Jeong *et al.* (2012) show that the feasible kernel-based sample analogue of J has the following form:

$$\hat{J}_T = \frac{1}{T(T-1)h^{2p}} \sum_{t=p+1}^T \sum_{s=p+1, s \neq t}^T K\left(\frac{Z_{t-1} - Z_{s-1}}{h}\right) \hat{\epsilon}_t \hat{\epsilon}_s. \quad (7)$$

where $K(\cdot)$ is the kernel function with bandwidth h , T is the sample size, p is the lag order, and $\hat{\epsilon}_t$ is the estimate of the unknown regression error, which is estimated as follows:

$$\hat{\epsilon}_t = 1\{y_t \leq Q_\theta(Y_{t-1})\} - \theta. \quad (8)$$

$\hat{Q}_\theta(Y_{t-1})$ is an estimate of the θ^{th} conditional quantile of y_t given Y_{t-1} , and we estimate $\hat{Q}_\theta(Y_{t-1})$ using the nonparametric kernel method as

$$\hat{Q}_\theta(Y_{t-1}) = \hat{F}_{y_t|Y_{t-1}}^{-1}(\theta | Y_{t-1}), \quad (9)$$

where $\hat{F}_{y_t|Y_{t-1}}(y_t | Y_{t-1})$ is the *Nadarya-Watson* kernel estimator given by

$$\hat{F}_{y_t|Y_{t-1}}(y_t | Y_{t-1}) = \frac{\hat{a}_{s=p+1, s^1 t}^T L((Y_{t-1} - Y_{s-1})/h) 1(y_s \leq y_t)}{\hat{a}_{s=p+1, s^1 t}^T L((Y_{t-1} - Y_{s-1})/h)}, \quad (10)$$

with $L(\cdot)$ denoting the kernel function and h the bandwidth.

As an extension to Jeong *et al.* (2012)'s framework, Balcilar *et al.*, (2017) additionally develop a test for the *second* moment. In particular, we can now extend the framework testing for the causality running from the term-spread, its patterns and interactive effects to the volatility of excess returns. Adopting the approach in Nishiyama *et al.* (2011), higher order quantile causality can be specified as:

$$H_0: P\{F_{y_t^k|Z_{t-1}}\{Q_\theta(Y_{t-1})|Z_{t-1}\} = \theta\} = 1 \quad \text{for } k = 1, 2, \dots, K \quad (11)$$

$$H_1: P\{F_{y_t^k|Z_{t-1}}\{Q_\theta(Y_{t-1})|Z_{t-1}\} = \theta\} < 1 \quad \text{for } k = 1, 2, \dots, K \quad (12)$$

Integrating the entire framework, we define that x_t *Granger causes* y_t in quantile θ up to the k^{th} moment using Eq. (11) to construct the test statistic of Eq. (10) for each k . The causality-invariance test can be calculated by replacing y_t in Eqs. (7) and (8) with y_t^2 - measuring the volatility of excess stock returns. However, it can be shown that it is not easy to combine the different statistics for each $k = 1, 2, \dots, K$ into one statistic for the joint null in Eq. (11), because the statistics are mutually correlated (Nishiyama *et al.*, 2011). To efficiently address this issue, Balcilar *et al.* (2017), include a sequential-testing method as described in Nishiyama *et al.* (2011). First, as in Balcilar *et al.* (2017), we test for the nonparametric Granger causality in the *first*

moment (*i.e.* $k = 1$). Nevertheless, failure to reject the null for $k = 1$ does not automatically lead to no-causality in the *second* moment. Thus, we can still construct the tests for $k = 2$, as discussed in detail in Balcilar *et al.* (2017). The empirical implementation of causality testing via quantiles entails specifying three important choices: the bandwidth h , the lag order p , and the kernel type for $K(\cdot)$ and $L(\cdot)$. In this study, a lag order (of one) is used on the basis of the Schwarz information criterion (SIC). Note that, with respect to choosing lags, the SIC is considered parsimonious compared with other lag-length selection criteria, since it helps to overcome the issue of the over-parameterization that typically arises with nonparametric frameworks.² The bandwidth value is chosen by employing least squares cross-validation techniques.³ Finally, for $K(\cdot)$ and $L(\cdot)$, Gaussian-type kernels are employed.

5. EMPIRICAL RESULTS

Though our objective is to analyse the causality-in-quantiles running from the term-spread, its patterns, and the interaction, to equity premium and its volatility, for the sake of completeness and comparability, we also conduct the standard linear Granger causality test based on VARs. The results are reported in Table 1. The null hypotheses that various predictors does not Granger-cause excess stock returns are rejected at the 5% significance level, in four (term-spread, Pivent, Roldo, and Rolup) out of the nineteen cases considered.

To further motivate the use of the nonparametric quantile-in-causality approach, we investigate whether the relationship between asset returns and the predictors is nonlinear or not. To assess the existence of nonlinearity, we apply the Brock *et al.* (1996) (hereforth, BDS) test on the residuals of the excess returns equation in the VAR model involving the various predictors considered one at a time. The $\hat{\alpha}$ -statistics of the BDS test are reported in Table 2 and, the null hypothesis of no serial dependence across various dimensions is overwhelmingly rejected in all cases. These results provide strong evidence of nonlinearity in the relationship between stock returns and the various predictors considered individually. Consequently, the evidence of predictability for the excess stock returns emanating from the four predictors in the linear Granger causality tests cannot be relied upon.

² Hurvich and Tsai (1989) examine the Akaike information criterion (AIC) and show that it is biased towards selecting an over-parameterized model, whereas the SIC is asymptotically consistent.

³ For each quantile, we determine the bandwidth h using the leave-one-out least-squares cross validation method of Racine and Li (2004) and Li and Racine (2004).

Table 1. Linear Granger Causality Test

Variable	F-stat	p-value
TermSpread	16.6353	0.0000*
Nochg	0.28523	0.5933
Pivclo	0.51162	0.4745
Pivent	5.15929	0.0232*
Rosdo	2.55022	0.1104
Rosup	1.78606	0.1815
Roldo	12.0636	0.0005*
Rolup	10.7482	0.0011*
Shiftup	0.27799	0.5981
Shiftdo	3.44376	0.0636
TS.Nochg	0.00108	0.9737
TS.Pivclo	0.17271	0.6778
TS.Pivent	0.07028	0.7910
TS.Rosdo	1.44389	0.2296
TS.Rosup	2.95087	0.0860
TS.Roldo	0.55243	0.4574
TS.Rolup	0.13272	0.7157
TS.Shiftup	0.14307	0.7053
TS.Shiftdo	0.09766	0.7547

Note: * indicates rejection of null hypothesis of no Granger causality at 5 percent level of significance.

Table 2. BDS Test of Nonlinearity

Variable	Dimension				
	2	3	4	5	6
Term Spread	17.1055***	22.4139***	26.3372***	30.1824***	33.9381***
Nochg	16.7646***	22.1965***	26.2175***	30.1320***	33.9555***
Pivclo	16.8071***	22.2237***	26.2390***	30.1663***	34.0180***
Pivent	16.9165***	22.3955***	26.5060***	30.4490***	34.3188***
Rosdo	16.6956***	22.1035***	26.1336***	30.0392***	33.8530***
Rosup	16.9032***	22.3437***	26.3718***	30.2965***	34.1120***
Roldo	16.8455***	22.3952***	26.4702***	30.4252***	34.2734***
Rolup	16.8068***	22.0782***	26.1054***	30.0418***	33.9282***
Shiftup	16.8060***	22.2140***	26.2240***	30.1420***	33.9810***
Shiftdo	16.8952***	22.3141***	26.3583***	30.2822***	34.1098***
TS.Nochg	13.2825***	16.4354***	19.1268***	21.1705***	23.1151***
TS.Pivclo	13.2751***	16.4146***	19.0971***	21.1348***	23.0711***
TS.Pivent	13.2916***	16.4517***	19.1373***	21.1820***	23.1270***
TS.Rosdo	13.2364***	16.3314***	18.9860***	21.0120***	22.9466***
TS.Rosup	13.0979***	16.2984***	19.0235***	21.1047***	23.0399***
TS.Roldo	13.2108***	16.3447***	19.0501***	21.0893***	23.0119***
TS.Rolup	13.2689***	16.4181***	19.1038***	21.1457***	23.0904***
TS.Shiftup	13.2551***	16.4050***	19.0892***	21.1245***	23.0591***
TS.Shiftdo	13.2712***	16.4198***	19.1105***	21.1512***	23.0976***

Note: Entries correspond to the $\hat{\alpha}$ -statistic of the BDS test; *** indicates rejection of null hypothesis of *iid* of the residuals obtained from the excess returns equation of the VAR model involving the equity premium and the predictor at 1 percent level of significance.

Given this, we now turn our attention to the nonparametric causality-in-quantiles test, i.e. a framework that, by design, is robust to the above mentioned econometric problem of nonlinearity. Table 3 highlights the outcome for the excess return series (Panel A) and the volatility series (Panel B). We find evidence for a nonlinear reaction of the excess return series to the term spread at the 0.7 and 0.75 quantile. In line with the linear Granger causality test, we also find the rotation long down important at a comparable quantile level indicating a stronger influence of a long rate increase on the upper conditional distribution.

Nonlinear causality strengthens when focusing on the volatility series. We observe a significant impact of the term spread across almost all quantiles. Since the test statistics are normalized, the effect of the moderate-upper quantiles on the conditional distribution of volatility is stronger than the one for the lower quantiles. We also observe significant influences for the pattern changes and interaction terms concentrated above the median (with the highest quantile being an exception). The strongest evidence for nonlinearity is reported for rotation long up. We only find weak evidence for reactions below the median. Applying the linear granger causality test would, in turn, lead to misleading results, because the impact of the pattern changes mainly affect the upper conditional distribution of stock market volatility.

5.1. Robustness and Comparative Analyses

In this segment, we conduct additional tests to analyze the robustness of our results, and also compare our findings with that of the US and SA. First, we observe that, our findings are only slightly affected when we increase the threshold for constructing the pattern changes to, say, 0.2 of the standard deviation's difference from the previous rate (see Table 4). However, with respect to the excess return series, rotation long down becomes insignificant implying that we do not observe any influence from pattern changes at all.

Given the long-span of data for the UK, it should not be surprising that there could be structural breaks in the relationship between excess returns and the term-spread. In this regard, we conducted the Bai and Perron (2003) tests of 1 to M globally determined multiple breaks and detected a regime change at 1825:02 for both the conditional mean of excess returns and in its relationship with the term spread, based on the powerful UD_{max} and WD_{max} tests (allowing for a maximum of five breaks, with 15 percent trimming, and error distributions to differ across the breaks). Note that the break date corresponds to the Panic of 1825. As pointed out by Bordo

Table 3a: Quantile Causality Results for UK Excess Returns

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	0.81	0.88	0.84	0.87	0.82	0.99	1.06	1.25	1.54	1.54	1.60	1.93	2.18*	2.14*	1.94	1.75	0.98
Nochg	0.42	0.53	0.48	0.32	0.25	0.08	0.04	0.01	0.04	0.09	0.12	0.23	0.34	0.53	0.50	0.61	0.35
Pivclo	0.34	0.42	0.30	0.22	0.13	0.06	0.03	0.01	0.01	0.07	0.16	0.27	0.42	0.55	0.49	0.67	0.41
Pivent	0.49	0.57	0.63	0.64	0.30	0.22	0.07	0.04	0.03	0.10	0.18	0.22	0.30	0.37	0.39	0.50	0.29
Rosdo	0.39	0.46	0.40	0.33	0.33	0.18	0.12	0.04	0.02	0.07	0.13	0.31	0.38	0.46	0.46	0.62	0.35
Rosup	0.42	0.45	0.39	0.30	0.20	0.17	0.19	0.20	0.12	0.15	0.23	0.32	0.43	0.45	0.42	0.51	0.28
Roldo	0.43	0.55	0.58	0.46	0.53	0.49	0.63	0.91	1.31	1.75	1.84	2.00*	2.22*	1.56	1.21	1.41	0.55
Rolup	0.74	1.08	0.94	0.80	0.69	0.73	0.72	0.69	0.46	0.39	0.38	0.40	0.45	0.51	0.47	0.58	0.32
Shiftp	0.45	0.60	0.57	0.40	0.40	0.32	0.37	0.36	0.50	0.46	0.46	0.35	0.35	0.43	0.42	0.57	0.35
Shiftdo	0.38	0.44	0.35	0.27	0.17	0.18	0.17	0.24	0.27	0.42	0.59	0.58	0.72	0.59	0.67	0.66	0.44
TS.Nochg	0.61	0.76	0.66	0.48	0.33	0.20	0.18	0.15	0.18	0.23	0.27	0.46	0.57	0.90	0.82	0.73	0.38
TS.Pivclo	0.37	0.43	0.31	0.22	0.13	0.07	0.04	0.03	0.04	0.10	0.19	0.32	0.46	0.59	0.52	0.69	0.39
TS.Pivent	0.49	0.54	0.54	0.43	0.25	0.14	0.06	0.03	0.03	0.07	0.09	0.17	0.28	0.40	0.43	0.54	0.33
TS.Rosdo	0.37	0.42	0.32	0.24	0.18	0.14	0.12	0.10	0.10	0.15	0.24	0.39	0.55	0.62	0.61	0.79	0.44
TS.Rosup	0.55	0.60	0.53	0.38	0.24	0.13	0.09	0.10	0.05	0.05	0.08	0.16	0.24	0.33	0.38	0.52	0.32
TS.Roldo	0.43	0.51	0.38	0.31	0.19	0.18	0.23	0.33	0.47	0.78	0.88	1.17	1.32	1.28	1.15	1.34	0.65
TS.Rolup	0.91	0.99	0.74	0.65	0.41	0.30	0.22	0.15	0.07	0.10	0.13	0.26	0.44	0.58	0.57	0.78	0.45
TS.Shiftp	0.48	0.53	0.50	0.39	0.31	0.22	0.15	0.14	0.12	0.12	0.15	0.26	0.38	0.47	0.51	0.70	0.41
TS.Shiftdo	0.41	0.49	0.38	0.35	0.23	0.15	0.13	0.15	0.26	0.36	0.38	0.47	0.57	0.57	0.58	0.65	0.45

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger cause excess stock returns; * indicates rejection at the 5% significance level.

Table 3b: Quantile Causality Results for UK Volatility

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	2.12*	2.78*	3.22*	3.50*	3.74*	4.19*	4.38*	4.77*	4.87*	5.80*	5.75*	5.84*	5.74*	5.68*	5.15*	3.92*	2.89*
Nochg	0.53	0.30	0.94	1.44	0.92	0.79	0.55	0.59	1.24	2.78*	2.78*	2.48*	3.61*	4.24*	3.66*	1.52	1.73
Pivclo	0.49	0.34	1.29	2.13*	1.36	1.30	0.80	0.76	1.39	2.55*	2.56*	2.46*	3.12*	4.70*	4.04*	1.47	1.01
Pivent	0.80	0.29	0.90	1.69	1.13	0.86	0.58	0.57	1.02	2.43*	2.63*	2.61*	3.13*	4.65*	4.13*	1.74	1.31
Rosdo	0.42	0.56	1.24	1.98*	1.35	1.31	0.80	0.78	1.16	2.27*	2.28*	1.99*	2.59*	3.96*	3.35*	1.21	0.98
Rosup	0.73	0.40	1.14	1.85	1.20	1.07	0.83	0.83	1.32	2.32*	2.55*	2.50*	2.89*	4.09*	3.40*	1.08	1.01
Roldo	0.36	0.20	1.51	2.00*	1.55	1.52	1.00	0.97	1.79	2.72*	2.75*	2.28*	2.93*	4.70*	3.41*	1.15	1.00
Rolup	0.35	0.38	1.35	2.22*	1.59	1.56	0.96	1.14	1.74	2.78*	2.91*	2.84*	3.28*	5.07*	4.50*	1.69	1.34
Shiftp	0.33	0.27	1.27	2.34*	1.62	1.33	1.05	0.99	1.39	2.33*	2.41*	2.62*	3.19*	4.58*	4.04*	1.60	1.29
Shiftdo	0.34	0.20	0.91	1.58	0.91	0.80	0.54	0.51	1.01	2.13*	2.10*	1.88	2.24*	3.68*	3.45*	1.26	1.04
TS.Nochg	0.67	0.38	0.87	1.40	0.91	0.78	0.67	0.77	1.41	3.03*	3.30*	2.90*	4.24*	4.60*	4.00*	1.79	2.05*
TS.Pivclo	0.50	0.34	1.29	2.12*	1.36	1.29	0.80	0.77	1.43	2.56*	2.58*	2.49*	3.15*	4.73*	4.06*	1.48	0.99
TS.Pivent	0.76	0.27	0.87	1.68	1.13	0.84	0.58	0.58	1.01	2.44*	2.62*	2.62*	3.14*	4.67*	4.14*	1.75	1.32
TS.Rosdo	0.41	0.52	1.19	1.94	1.31	1.30	0.78	0.68	1.00	2.17*	2.17*	1.83	2.48*	3.82*	3.19*	1.10	0.91
TS.Rosup	0.73	0.41	1.13	1.80	1.17	1.03	0.82	0.78	1.28	2.21*	2.49*	2.47*	2.82*	3.96*	3.28*	0.99	0.95
TS.Roldo	0.37	0.25	1.52	2.12*	1.63	1.59	1.02	0.98	1.82	2.81*	2.92*	2.36*	3.05*	4.85*	3.41*	1.15	1.01
TS.Rolup	0.30	0.26	1.36	2.33*	1.64	1.62	1.05	1.16	1.85	2.99*	3.12*	3.06*	3.50*	5.31*	4.72*	1.81	1.42
TS.Shiftp	0.34	0.30	1.34	2.39*	1.66	1.36	1.09	1.03	1.43	2.31*	2.41*	2.73*	3.28*	4.64*	4.08*	1.63	1.29
TS.Shiftdo	0.33	0.21	0.88	1.56	0.85	0.73	0.51	0.48	0.99	2.10*	2.04*	1.80	2.05*	3.55*	3.41*	1.26	1.03

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger cause excess stock returns volatility; * indicates rejection at the 5% significance level.

Table 4a: Quantile Causality Results for UK Excess Returns (0.2 sd)

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	0.81	0.88	0.84	0.87	0.82	0.99	1.06	1.25	1.54	1.54	1.60	1.93	2.18*	2.14*	1.94	1.75	0.98
Nochg	0.41	0.50	0.43	0.33	0.21	0.08	0.09	0.05	0.19	0.36	0.36	0.41	0.44	0.63	0.56	0.67	0.34
Pivclo	0.36	0.43	0.33	0.23	0.14	0.06	0.04	0.01	0.01	0.07	0.14	0.26	0.37	0.49	0.47	0.63	0.40
Pivent	0.44	0.57	0.58	0.51	0.31	0.19	0.10	0.03	0.01	0.05	0.09	0.17	0.26	0.35	0.38	0.49	0.28
Rosdo	0.36	0.43	0.33	0.26	0.16	0.07	0.03	0.01	0.10	0.25	0.23	0.25	0.33	0.41	0.42	0.53	0.32
Rosup	0.38	0.45	0.36	0.29	0.19	0.13	0.15	0.08	0.12	0.18	0.24	0.34	0.41	0.44	0.41	0.52	0.29
Roldo	0.38	0.44	0.42	0.35	0.43	0.37	0.29	0.50	0.53	0.69	0.83	0.84	1.03	0.88	0.87	0.94	0.50
Rolup	0.71	0.90	0.70	0.54	0.43	0.31	0.43	0.48	0.21	0.19	0.17	0.21	0.29	0.39	0.40	0.54	0.32
Shiftup	0.49	0.67	0.70	0.47	0.34	0.26	0.13	0.15	0.18	0.15	0.17	0.19	0.27	0.38	0.42	0.60	0.33
Shiftdo	0.38	0.45	0.31	0.24	0.14	0.08	0.07	0.08	0.17	0.33	0.34	0.51	0.70	0.63	0.60	0.64	0.35
TS.Nochg	0.75	0.93	0.77	0.60	0.37	0.39	0.33	0.30	0.35	0.52	0.60	0.88	1.00	1.28	1.24	1.09	0.58
TS.Pivclo	0.39	0.44	0.33	0.24	0.14	0.06	0.03	0.01	0.02	0.08	0.15	0.29	0.41	0.52	0.49	0.64	0.39
TS.Pivent	0.40	0.48	0.47	0.35	0.21	0.12	0.05	0.02	0.02	0.05	0.09	0.16	0.26	0.36	0.39	0.52	0.29
TS.Rosdo	0.39	0.44	0.35	0.28	0.17	0.10	0.07	0.05	0.05	0.06	0.10	0.20	0.31	0.42	0.43	0.54	0.34
TS.Rosup	0.45	0.49	0.43	0.31	0.21	0.12	0.09	0.05	0.05	0.08	0.12	0.21	0.30	0.39	0.43	0.61	0.37
TS.Roldo	0.45	0.53	0.37	0.35	0.23	0.21	0.23	0.35	0.40	0.59	0.68	0.77	0.84	0.77	0.75	0.97	0.52
TS.Rolup	0.76	0.82	0.60	0.51	0.32	0.19	0.12	0.07	0.04	0.08	0.13	0.29	0.51	0.63	0.60	0.79	0.48
TS.Shiftup	0.44	0.52	0.52	0.39	0.30	0.18	0.09	0.09	0.06	0.08	0.11	0.22	0.32	0.47	0.49	0.66	0.36
TS.Shiftdo	0.41	0.50	0.38	0.32	0.18	0.09	0.06	0.04	0.09	0.18	0.18	0.33	0.49	0.56	0.55	0.64	0.38

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger cause excess stock returns; * indicates rejection at the 5% significance level.

Table 4b: Quantile Causality Results for UK Volatility (0.2 sd)

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	2.12*	2.78*	3.22*	3.50*	3.74*	4.19*	4.38*	4.77*	4.87*	5.80*	5.75*	5.84*	5.74*	5.68*	5.15*	3.92*	2.89*
Nochg	0.54	0.51	1.18	1.67	1.15	1.23	1.08	1.26	1.60	2.90*	2.56*	2.43*	3.36*	4.01*	3.24*	1.20	1.22
Pivclo	0.58	0.30	1.21	2.10*	1.37	1.25	0.77	0.72	1.40	2.51*	2.66*	2.57*	3.22*	4.81*	4.11*	1.48	1.13
Pivent	0.64	0.27	0.96	1.71	1.12	0.90	0.60	0.60	1.11	2.36*	2.46*	2.38*	3.13*	4.53*	3.98*	1.50	1.23
Rosdo	0.46	0.43	0.97	1.74	1.18	1.11	0.70	0.73	1.07	2.08*	2.10*	2.05*	2.63*	4.08*	3.55*	1.29	1.03
Rosup	0.62	0.45	1.11	2.03*	1.41	1.30	1.11	1.14	1.62	2.62*	2.63*	2.56*	2.77*	4.01*	3.46*	1.17	0.92
Roldo	0.37	0.28	1.19	1.65	1.18	1.15	0.73	0.75	1.59	2.54*	2.66*	2.16*	2.46*	4.20*	3.31*	1.24	1.10
Rolup	0.34	0.27	1.48	2.38*	1.53	1.34	0.86	0.76	1.59	2.53*	2.65*	2.57*	3.09*	4.82*	4.57*	1.84	1.62
Shiftp	0.33	0.21	1.12	1.98*	1.37	1.15	0.83	0.79	1.37	2.51*	2.71*	2.82*	3.81*	5.04*	4.15*	1.55	1.23
Shiftdo	0.39	0.25	1.14	2.06*	1.23	1.08	0.75	0.75	1.36	2.61*	2.65*	2.41*	2.74*	4.32*	3.88*	1.41	1.10
TS.Nochg	0.87	0.59	1.41	1.91	1.22	1.21	1.29	1.42	1.70	3.77*	3.84*	3.56*	5.30*	5.31*	3.99*	1.65	1.93
TS.Pivclo	0.57	0.31	1.21	2.10*	1.38	1.26	0.78	0.73	1.40	2.50*	2.66*	2.57*	3.23*	4.81*	4.11*	1.49	1.13
TS.Pivent	0.63	0.26	0.94	1.70	1.11	0.87	0.58	0.58	1.09	2.36*	2.45*	2.38*	3.13*	4.53*	3.98*	1.51	1.23
TS.Rosdo	0.49	0.44	0.90	1.66	1.11	1.10	0.68	0.58	0.86	1.95	1.95	1.86	2.49*	3.90*	3.40*	1.19	0.96
TS.Rosup	0.63	0.46	1.08	2.01*	1.42	1.30	1.05	1.06	1.53	2.38*	2.45*	2.47*	2.58*	3.79*	3.32*	1.09	0.82
TS.Roldo	0.35	0.32	1.25	1.65	1.22	1.19	0.75	0.79	1.64	2.57*	2.71*	2.15*	2.37*	4.17*	3.21*	1.22	1.08
TS.Rolup	0.33	0.22	1.47	2.47*	1.59	1.40	0.92	0.83	1.69	2.63*	2.74*	2.67*	3.18*	4.92*	4.67*	1.89	1.66
TS.Shiftp	0.32	0.21	1.16	2.00*	1.40	1.17	0.89	0.84	1.43	2.57*	2.77*	2.86*	3.84*	5.07*	4.17*	1.56	1.23
TS.Shiftdo	0.39	0.26	1.16	2.08*	1.24	1.10	0.77	0.78	1.38	2.62*	2.68*	2.42*	2.72*	4.31*	3.88*	1.42	1.09

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger excess stock returns volatility; * indicates rejection at the 5% significance level.

(1998), it was a stock market crash that started in the Bank of England, arising partially due to speculative investments in Latin America, which included the imaginary country of Poyais. The crisis was felt most strongly in England, where it resulted in the closing of six London-based banks and sixty country banks, with some spillover effects also observed in Europe, Latin America, and the United States. It is understood that an infusion of gold reserves from the Banque de France saved the Bank of England from complete collapse during this period. We repeat the causality-in-quantiles analysis of the full-sample for the two sub-samples of: 1753:08-1825:01; 1825:02-2017:02.⁴ The results are conducted in Tables 5 and 6.⁵

In line with the full sample, we find relatively poor support of nonlinear effects of the predictors in the first sub-sample for excess returns (Table 5a). The asymmetric effects of pattern changes on volatility mainly reduces to the 0.6 and 0.65 quantile (Table 5b). The interactive effect of the rotation long down pattern change is found to be completely insignificant. In the second sub-sample, influences on the volatility series increases to the 0.7 and 0.8 quantile (Table 6b). The no change, rotation long down and rotation long up pattern expand their range of significance close to the median (0.55). In contrast to previous research that assumed the long rate is static with a focus on the short rate, these results indicate that the long rate has a greater impact on returns within the median volatility range.

Compared to the first subsample, relatively strong nonlinear effects are observed in terms of the excess return series (Table 6a). Although there is only weak evidence for a significant impact around the median (0.35-0.55 quantile), almost all pattern changes and interaction terms become significant at the remaining quantiles. On balance, the effects are stronger above than below the median with the rotation long up and the related interaction term being the most important pattern change.^{6,7}

⁴ Shifts in volatility of interest rates may be due to the Panic of 1825 and subsequent monetary policies of the United Kingdom. The Panic of 1825 is considered the first modern economic crisis not attributable to an external event. Prior to 1825, the British government suspended the Gold standard and engaged in a period of expansionary monetary policy to support the Napoleonic wars. The easy access to money led to speculative investments in Latin America, including the imaginary country Poyais. To address inflationary pressure and restrict speculative investing, the British government re-established the Gold standard thereby constricting the money supply leading to the Panic of 1825.

⁵ We also repeated the linear Granger causality test for the two sub-samples, and obtained similar (weak) results to those reported for the full sample in Table 1. In fact, the term spread was found to be insignificant in the first sub-sample. Complete details of these results are available upon request from the authors.

⁶ Based on the suggestion of an anonymous referee, we also conducted the analysis starting in 1980, to correspond with the period of “Great Moderation.” We observed that just like the second-subsample results reported in Table

Table 5a: Quantile Causality Results for UK Excess Returns, Sub-sample 1 (1753:08-1825:01)

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	1.39	1.46	1.60	1.91	1.93	1.75	1.70	1.58	1.66	1.86	2.03*	1.95	1.75	1.90	1.42	1.49	1.33
Nochg	1.03	0.59	0.52	0.50	0.74	0.73	1.09	1.39	1.61	1.05	1.17	1.63	1.83	1.47	0.84	0.98	0.97
Pivclo	0.75	0.43	0.41	0.50	0.58	0.34	0.55	0.59	0.70	0.46	0.72	0.84	0.53	0.68	0.57	0.61	0.92
Pivent	0.89	0.52	0.48	0.61	0.64	0.40	0.63	0.62	0.68	0.42	0.58	0.70	0.39	0.55	0.48	0.53	0.93
Rosdo	0.76	0.41	0.43	0.45	0.45	0.32	0.52	0.54	0.58	0.35	0.52	0.64	0.45	0.67	0.59	0.68	1.10
Rosup	0.81	0.64	0.51	0.70	0.72	0.42	0.80	0.75	0.75	0.52	0.59	0.73	0.43	0.63	0.51	0.57	0.87
Roldo	0.66	0.49	0.45	0.54	0.52	0.61	0.71	0.79	1.13	0.79	1.28	1.78	1.95	2.49*	1.67	1.70	1.42
Rolup	0.65	0.39	0.46	0.45	0.57	0.49	0.68	0.77	0.89	0.65	0.91	0.94	0.49	0.79	0.55	0.64	0.79
Shiftup	0.65	0.37	0.38	0.51	0.56	0.33	0.58	0.64	0.71	0.46	0.54	0.61	0.36	0.55	0.46	0.49	0.87
Shiftdo	0.73	0.39	0.34	0.43	0.51	0.32	0.50	0.52	0.68	0.41	0.60	0.70	0.44	0.69	0.68	0.70	1.08
TS.Nochg	1.48	0.85	0.70	0.65	1.00	0.94	1.32	1.71	1.87	1.34	1.41	1.67	1.57	1.06	0.60	0.60	0.79
TS.Pivclo	0.76	0.43	0.42	0.48	0.54	0.31	0.53	0.56	0.67	0.42	0.69	0.81	0.51	0.67	0.57	0.62	0.92
TS.Pivent	0.88	0.52	0.49	0.62	0.64	0.39	0.63	0.62	0.68	0.42	0.57	0.68	0.37	0.54	0.47	0.52	0.93
TS.Rosdo	0.76	0.42	0.45	0.47	0.46	0.34	0.53	0.56	0.60	0.37	0.54	0.65	0.45	0.68	0.61	0.70	1.12
TS.Rosup	0.81	0.62	0.50	0.69	0.71	0.41	0.76	0.72	0.73	0.50	0.58	0.71	0.41	0.62	0.51	0.57	0.87
TS.Roldo	0.75	0.50	0.48	0.63	0.48	0.50	0.56	0.59	0.68	0.47	1.04	1.30	1.64	2.23*	1.81	1.74	1.63
TS.Rolup	0.73	0.58	0.63	0.61	0.75	0.62	0.79	0.78	0.84	0.63	0.87	0.94	0.52	0.76	0.48	0.54	0.76
TS.Shiftup	0.60	0.34	0.35	0.49	0.55	0.33	0.58	0.64	0.71	0.46	0.54	0.61	0.37	0.56	0.46	0.50	0.87
TS.Shiftdo	0.72	0.39	0.33	0.41	0.48	0.30	0.47	0.49	0.63	0.39	0.57	0.69	0.45	0.70	0.69	0.71	1.10

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger cause excess stock returns; * indicates rejection at the 5% significance level.

Table 5b: Quantile Causality Results for UK Volatility, Sub-sample 1 (1753:08-1825:01)

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	2.07*	2.72*	2.48*	3.04*	2.99*	3.54*	3.89*	3.83*	3.38*	3.62*	3.51*	3.34*	3.28*	3.12*	3.06*	2.23*	1.83
Nochg	0.45	0.17	0.20	0.21	0.20	0.28	0.82	0.97	1.46	1.83	2.63*	2.89*	1.68	1.08	0.48	1.18	1.11
Pivclo	0.07	0.11	0.16	0.30	0.22	0.28	0.64	0.72	1.27	1.71	2.52*	2.88*	1.87	1.16	0.57	1.51	1.25
Pivent	0.07	0.12	0.19	0.29	0.20	0.34	0.71	0.78	1.35	1.75	2.60*	2.82*	1.66	0.98	0.50	1.34	1.07
Rosdo	0.11	0.14	0.23	0.23	0.18	0.26	0.59	0.61	1.15	1.51	2.23*	2.45*	1.60	1.09	0.45	1.27	1.10
Rosup	0.08	0.12	0.19	0.26	0.19	0.25	0.63	0.80	1.39	1.93	2.67*	2.84*	1.64	0.95	0.43	1.24	1.05
Roldo	0.14	0.12	0.18	0.20	0.24	0.36	0.59	1.02	1.03	1.22	1.98*	2.28*	1.30	0.88	0.47	1.14	0.81
Rolup	0.08	0.12	0.17	0.28	0.26	0.63	1.04	1.22	1.52	2.00	3.18*	3.66*	2.30*	1.53	0.53	1.50	1.20
Shiftup	0.08	0.11	0.17	0.26	0.18	0.29	0.66	0.72	1.40	1.84	2.67*	2.89*	1.82	1.28	0.63	1.62	1.27
Shiftdo	0.09	0.12	0.21	0.42	0.25	0.36	0.84	0.80	1.38	1.87	2.90*	3.27*	1.97*	1.19	0.53	1.35	1.15
TS.Nochg	0.43	0.29	0.33	0.33	0.45	0.61	1.38	1.62	2.24*	2.61*	3.53*	3.65*	2.27*	1.52	0.75	1.26	1.41
TS.Pivclo	0.07	0.11	0.16	0.31	0.23	0.30	0.66	0.68	1.23	1.67	2.48*	2.85*	1.84	1.14	0.56	1.50	1.24
TS.Pivent	0.07	0.12	0.19	0.30	0.21	0.34	0.72	0.78	1.36	1.75	2.61*	2.82*	1.66	0.98	0.50	1.35	1.07
TS.Rosdo	0.10	0.14	0.22	0.24	0.19	0.27	0.59	0.62	1.15	1.49	2.20*	2.41*	1.60	1.10	0.46	1.27	1.11
TS.Rosup	0.08	0.12	0.18	0.27	0.20	0.25	0.63	0.80	1.40	1.93	2.68*	2.85*	1.64	0.94	0.44	1.24	1.05
TS.Roldo	0.19	0.24	0.31	0.33	0.26	0.28	0.31	0.28	0.49	0.66	1.09	1.34	0.89	0.65	0.37	1.18	0.73
TS.Rolup	0.17	0.23	0.28	0.39	0.37	0.67	1.10	1.27	1.56	2.06	3.21*	3.63*	2.32*	1.57	0.61	1.42	1.20
TS.Shiftup	0.08	0.11	0.17	0.26	0.18	0.29	0.66	0.72	1.40	1.84	2.67*	2.88*	1.82	1.28	0.63	1.62	1.27
TS.Shiftdo	0.10	0.12	0.21	0.41	0.25	0.36	0.84	0.81	1.39	1.88	2.92*	3.28*	1.99*	1.21	0.54	1.36	1.16

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger cause excess stock returns volatility; * indicates rejection at the 5% significance level.

Table 6a: Quantile Causality Results for UK Excess Returns, Sub-sample 2 (1825:02-2017:02)

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	4.48*	6.56*	6.26*	6.93*	5.32*	4.80*	3.95*	3.82*	5.55*	5.04*	5.31*	6.54*	7.01*	6.68*	6.49*	6.14*	4.65*
Nochg	3.17*	4.00*	3.63*	2.69*	2.47*	1.30	0.61	0.63	1.60	2.26*	2.94*	4.20*	5.71*	7.44*	7.11*	5.87*	4.52*
Pivclo	3.11*	4.32*	3.28*	2.81*	2.25*	1.33	0.81	0.35	0.46	1.39	2.05*	3.31*	5.02*	5.39*	5.48*	5.74*	4.17*
Pivent	3.38*	4.83*	4.11*	3.95*	2.82*	1.80	0.89	0.33	0.38	1.12	1.70	2.65*	4.15*	4.58*	4.60*	4.98*	4.23*
Rosdo	2.63*	3.53*	2.69*	2.46*	1.93	1.27	0.82	0.47	0.54	1.14	1.87	3.03*	4.14*	4.59*	4.83*	4.96*	4.09*
Rosup	3.06*	4.10*	3.49*	3.34*	3.03*	1.84	1.01	0.63	0.54	1.07	1.48	2.24*	3.43*	4.00*	4.14*	4.59*	3.68*
Roldo	3.32*	4.26*	3.07*	2.62*	1.90	1.37*	1.31	1.62	3.02*	5.73*	6.44*	6.85*	8.67*	7.76*	7.64*	6.15*	5.08*
Rolup	5.00*	6.99*	5.71*	5.77*	5.17*	3.83*	2.90*	1.43	0.97	1.32	1.87	2.69*	4.06*	4.56*	4.74*	5.12*	3.88*
Shiftup	2.78*	4.13*	3.21*	2.91*	2.49*	2.14*	1.41	1.03	1.16	1.39	1.90	2.73*	4.12*	4.40*	4.73*	5.21*	4.55*
Shiftdo	3.35*	3.97*	2.94*	2.52*	1.99*	1.00	0.62	0.42	0.70	1.92	2.21*	3.47*	4.60*	4.85*	4.40*	4.92*	4.01*
TS.Nochg	3.71*	4.83*	4.29*	3.39*	3.07*	1.84	0.90	0.58	1.16	1.92	2.73*	3.96*	5.65*	6.64*	6.36*	5.78*	4.51*
TS.Pivclo	3.10*	4.38*	3.19*	2.74*	2.05*	1.21	0.73	0.31	0.52	1.55	2.26*	3.58*	5.26*	5.60*	5.62*	5.90*	4.30*
TS.Pivent	3.44*	4.85*	4.08*	3.74*	2.78*	1.73	0.83	0.32	0.37	1.13	1.73	2.81*	4.35*	4.75*	4.70*	5.04*	4.25*
TS.Rosdo	2.72*	3.57*	2.44*	2.31*	1.66	1.04	0.80	0.49	0.64	1.28	2.01*	3.09*	4.19*	4.63*	5.04*	5.15*	4.21*
TS.Rosup	3.17*	4.31*	3.79*	3.64*	3.17*	1.87	1.10	0.65	0.52	1.03	1.40	2.11*	3.30*	4.00*	4.16*	4.62*	3.73*
TS.Roldo	3.55*	4.49*	3.16*	2.70*	1.73	0.86	0.76	0.91	1.91	4.15*	5.10*	6.07*	7.87*	7.48*	7.55*	6.26*	5.04*
TS.Rolup	4.89*	6.41*	4.99*	5.02*	4.16*	2.90*	1.97*	0.88	0.68	1.32	1.97*	2.90*	4.28*	4.98*	5.16*	5.56*	4.17*
TS.Shiftup	2.62*	3.89*	3.09*	2.91*	2.36*	1.85	1.20	0.74	0.70	1.17	1.87	2.86*	4.32*	4.71*	5.19*	5.65*	4.92*
TS.Shiftdo	3.35*	4.05*	3.07*	2.76*	2.19*	1.01	0.55	0.37	0.79	1.94	2.24*	3.48*	4.71*	5.15*	4.81*	5.34*	4.43*

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger cause excess stock returns; * indicates rejection at the 5% significance level.

Table 6b: Quantile Causality Results for UK Volatility, Sub-sample 2 (1825:02-2017:02)

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	1.53	1.83	1.76	1.99*	2.03*	2.97*	3.38*	4.04*	4.03*	4.45*	4.51*	4.74*	3.98*	4.05*	3.70*	2.85*	1.94
Nochg	0.55	0.46	0.53	0.45	0.62	0.70	0.64	1.18	1.23	2.44*	3.30*	4.06*	4.39*	4.54*	3.78*	2.45*	1.45
Pivclo	0.50	0.57	0.43	0.43	0.36	0.48	0.52	0.59	0.64	1.51	1.81	2.05*	3.16*	3.41*	3.05*	1.60	0.79
Pivent	0.41	0.48	0.42	0.37	0.33	0.36	0.35	0.48	0.59	1.67	1.86	1.93	2.94*	3.18*	3.14*	1.75	0.89
Rosdo	1.08	1.39	1.80	1.78	1.41	1.46	1.51	0.82	1.01	1.51	1.68	1.95	2.63*	2.78*	2.54*	1.37	0.85
Rosup	0.85	0.69	0.61	0.85	0.81	0.86	0.77	0.67	0.62	1.40	1.62	1.78	2.51*	2.65*	2.45*	1.29	0.68
Roldo	0.32	0.37	0.39	0.42	0.39	0.50	0.42	0.98	1.49	2.55*	2.71*	2.78*	4.00*	3.89*	3.09*	1.74	1.01
Rolup	0.36	0.43	0.34	0.38	0.40	0.56	0.66	1.02	1.08	2.12*	2.24*	2.81*	4.19*	4.64*	3.63*	2.65*	1.43
Shiftup	0.59	0.79	0.64	0.89	1.03	1.13	1.37	1.26	1.36	1.87	1.93	1.96*	2.94*	3.18*	2.90*	1.65	1.01
Shiftdo	0.44	0.44	0.29	0.27	0.29	0.31	0.28	0.45	0.58	1.23	1.40	1.63	2.43*	2.85*	2.72*	1.45	0.72
TS.Nochg	0.42	0.33	0.26	0.26	0.32	0.44	0.55	1.17	1.38	2.71*	3.44*	4.07*	4.59*	4.85*	4.12*	2.78*	1.66
TS.Pivclo	0.50	0.59	0.43	0.44	0.37	0.49	0.53	0.59	0.65	1.52	1.82	2.06*	3.18*	3.42*	3.05*	1.62	0.78
TS.Pivent	0.42	0.49	0.43	0.39	0.33	0.37	0.37	0.49	0.60	1.66	1.86	1.96*	2.97*	3.18*	3.17*	1.78	0.90
TS.Rosdo	0.93	1.16	1.37	1.43	1.13	1.09	1.14	0.66	0.69	1.26	1.46	1.67	2.39*	2.46*	2.27*	1.21	0.77
TS.Rosup	0.79	0.68	0.60	0.79	0.77	0.83	0.78	0.63	0.57	1.30	1.34	1.56	2.27*	2.39*	2.28*	1.14	0.61
TS.Roldo	0.26	0.35	0.16	0.16	0.17	0.22	0.22	0.85	1.24	2.37*	2.56*	2.73*	4.01*	3.91*	3.14*	1.80	1.06
TS.Rolup	0.35	0.33	0.18	0.21	0.19	0.29	0.34	0.82	1.00	2.06*	2.22*	2.71*	3.99*	4.60*	3.68*	2.54*	1.32
TS.Shiftup	0.60	0.82	0.70	0.89	0.93	0.99	1.17	1.05	1.05	1.70	1.85	1.89	2.97*	3.20*	2.92*	1.64	0.99
TS.Shiftdo	0.46	0.46	0.32	0.28	0.33	0.36	0.27	0.43	0.53	1.20	1.33	1.51	2.22*	2.74*	2.64*	1.35	0.65

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger cause excess stock returns volatility; * indicates rejection at the 5% significance level.

As a final robustness check, we compare our findings with the US and South African (SA) data. Tables 7 and 8 present the results.

With respect to the term spread, both countries experience significant nonlinear causality across almost all quantiles. Similar to the UK stock market, the impact of the pattern changes and interaction terms turns out to be largely insignificant for US excess returns (Table 7a) – a result in contradiction with that of Volkman *et al.*, (2014), which may be do to the different linear model used by these authors. We actually, only find weak evidence for nonlinear causality around the median. Pivot clockwise, pivot counter clockwise, rotation up, and shift up remain insignificant. We, however, do not observe significant influences of pattern changes in terms of the volatility series (Table 7b), though the term spread does play an important role. In case of South Africa, a strong influence of pattern changes on the excess return series is reported for the median and up to the 0.85 quantile (Table 8a). In addition, a significant reaction to the role up pattern change and its interactive effect is detected for a bearish market scenario. Finally, with respect to the volatility series in Table 8b, the term-spread, no change and its interactive effect become significant mainly barring the lower and upper quantiles.

In general, our results tend to suggest the importance of the term spread in predicting both returns and volatility of both developed and emerging markets. However for the UK, pattern changes and the interaction of pattern changes with the term-spread tends to also play an important role in predicting especially volatility at the upper end of its conditional distribution. In addition, the effect on excess returns from pattern changes and the interaction is found to have improved markedly more recently, as suggested by a sub-sample analysis, which in turn, is also found to hold true in the emerging market of South Africa. Interestingly, for the US excess returns and its volatility is primarily driven by the term spread on its own, rather than pattern changes, and the interaction terms.

6a, predictability of the equity premium was concentrated around the median from the various predictors. However, unlike the case of volatility of the second sub-sample in Table 6b, we failed to detect any evidence of predictability from the various predictors, with the only exception being the term-spread, which predicted the entire conditional distribution of excess returns volatility, barring the extreme quantiles. Complete details of these results are available upon request from the authors.

⁷ Based on the suggestion of an anonymous referee, we also conducted a rolling (time-varying) approach-based analysis. Using a rolling window of 1753:08 to 1813:07, we found that the predictors, in general tended to forecast both equity premium and its volatility at each point in time over 1813:07 to 2017:02, across the two ends of the conditional distributions considered. Complete details of these results are available upon request from the authors.

Table 7a: Quantile Causality Results for US Excess Returns

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	1.90	2.49*	3.07*	3.30*	3.02*	3.37*	3.89*	3.90*	4.22*	4.05*	3.70*	3.85*	4.00*	3.85*	3.87*	3.00*	2.16*
Nochg	0.78	1.50	1.63	1.38	1.50	1.87	1.87	1.88	2.11*	1.65	1.51	1.54	1.57	1.28	1.55	1.60	1.55
Pivclo	0.62	1.01	1.37	0.84	0.80	0.97	1.47	1.46	1.74	1.25	1.29	1.25	1.33	1.22	1.53	1.16	0.96
Pivent	0.78	1.13	1.48	1.11	1.09	1.25	1.65	1.75	1.81	1.35	1.24	1.23	1.31	1.21	1.53	1.13	0.95
Rosdo	0.66	1.02	1.46	1.29	1.28	1.41	1.63	1.58	2.05*	1.50	1.41	1.33	1.23	0.99	1.29	0.99	0.96
Rosup	0.76	1.13	1.52	0.98	1.15	1.45	1.80	1.86	1.99*	1.83	1.87	1.69	1.64	1.47	1.60	1.21	0.95
Roldo	0.98	0.94	1.16	0.76	0.77	1.04	1.57	1.64	2.05*	1.52	1.48	1.35	1.27	1.31	1.28	0.92	0.82
Rolup	0.64	1.03	1.36	1.15	1.17	1.30	1.70	1.66	1.78	1.13	1.23	1.32	1.61	1.65	1.75	1.04	0.95
Shiftup	0.77	1.31	1.45	1.13	1.07	1.27	1.73	1.43	1.67	1.24	1.20	1.34	1.31	1.37	1.48	1.01	0.99
Shiftdo	0.73	1.40	1.67	1.34	1.23	1.42	2.00*	1.74	2.20*	1.79	1.80	1.89	1.85	1.65	1.70	1.23	1.22
TS.Nochg	0.59	1.30	1.63	1.49	1.69	2.01*	1.93	2.06*	2.31*	1.64	1.62	1.54	1.91	1.47	1.80	1.91	1.81
TS.Pivclo	0.62	1.01	1.37	0.84	0.79	0.96	1.47	1.47	1.74	1.25	1.29	1.24	1.33	1.22	1.53	1.16	0.96
TS.Pivent	0.80	1.14	1.50	1.13	1.11	1.27	1.67	1.76	1.81	1.35	1.23	1.24	1.32	1.22	1.55	1.14	0.95
TS.Rosdo	0.68	0.99	1.54	1.16	1.10	1.18	1.49	1.51	1.97	1.49	1.36	1.23	1.09	0.91	1.33	1.07	0.96
TS.Rosup	0.80	1.16	1.61	1.00	1.23	1.49	1.91	1.95	2.10	1.90	1.85	1.69	1.59	1.33	1.56	1.19	0.94
TS.Roldo	0.93	0.89	1.13	0.73	0.75	1.03	1.56	1.61	1.97	1.44	1.40	1.36	1.25	1.25	1.33	0.93	0.86
TS.Rolup	0.67	1.05	1.33	1.10	1.13	1.25	1.64	1.60	1.76	1.19	1.27	1.41	1.67	1.71	1.83	1.07	0.93
TS.Shiftup	0.81	1.30	1.47	1.15	1.06	1.21	1.68	1.38	1.58	1.12	1.13	1.20	1.24	1.23	1.39	1.00	0.94
TS.Shiftdo	0.72	1.38	1.63	1.26	1.19	1.38	1.96*	1.76	2.19*	1.77	1.75	1.82	1.83	1.63	1.70	1.25	1.25

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger cause excess stock returns; * indicates rejection at the 5% significance level.

Table 7b: Quantile Causality Results for US Volatility

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	2.13*	2.45*	2.48*	2.51*	3.31*	3.49*	3.47*	3.65*	4.48*	4.29*	4.33*	3.99*	3.66*	2.81*	2.81*	2.85*	2.25*
Nochg	0.29	0.42	0.41	0.63	0.76	0.72	1.09	1.07	1.09	1.32	1.36	1.07	1.26	0.82	0.86	0.59	0.43
Pivclo	0.24	0.09	0.17	0.19	0.19	0.25	0.46	0.43	0.73	1.17	1.32	1.05	1.38	0.95	0.65	0.22	0.15
Pivent	0.35	0.12	0.15	0.16	0.14	0.30	0.71	0.64	0.90	1.39	1.52	1.19	1.47	1.03	0.76	0.26	0.19
Rosdo	0.27	0.19	0.22	0.23	0.21	0.27	0.51	0.53	0.80	1.34	1.25	1.06	1.32	0.90	0.64	0.38	0.18
Rosup	0.29	0.13	0.12	0.14	0.14	0.24	0.70	0.63	0.91	1.21	1.60	1.22	1.43	0.99	0.56	0.23	0.16
Roldo	0.22	0.13	0.22	0.22	0.32	0.36	0.45	0.44	0.81	1.03	1.25	1.01	1.41	1.17	0.76	0.31	0.20
Rolup	0.27	0.14	0.18	0.13	0.11	0.23	0.48	0.40	0.83	1.27	1.54	1.05	1.46	1.05	0.70	0.26	0.19
Shiftup	0.41	0.18	0.19	0.20	0.17	0.29	0.69	0.69	1.07	1.33	1.51	1.17	1.41	1.05	0.69	0.28	0.16
Shiftdo	0.28	0.10	0.13	0.12	0.11	0.22	0.42	0.52	0.82	1.24	1.42	1.02	1.43	0.97	0.68	0.29	0.17
TS.Nochg	0.40	0.48	0.41	0.56	0.69	0.66	0.99	0.86	0.72	1.09	1.08	0.90	1.11	0.75	0.89	0.63	0.55
TS.Pivclo	0.24	0.09	0.16	0.18	0.17	0.24	0.46	0.43	0.74	1.17	1.33	1.06	1.38	0.96	0.65	0.22	0.15
TS.Pivent	0.35	0.12	0.16	0.17	0.14	0.31	0.70	0.64	0.91	1.40	1.53	1.21	1.48	1.04	0.77	0.26	0.20
TS.Rosdo	0.27	0.19	0.23	0.23	0.21	0.29	0.56	0.55	0.88	1.43	1.36	1.12	1.39	0.97	0.71	0.42	0.25
TS.Rosup	0.33	0.17	0.15	0.20	0.21	0.30	0.76	0.67	0.94	1.24	1.46	1.20	1.42	0.98	0.59	0.26	0.20
TS.Roldo	0.24	0.15	0.25	0.23	0.28	0.34	0.41	0.48	0.85	1.02	1.23	1.04	1.43	1.20	0.81	0.35	0.21
TS.Rolup	0.29	0.16	0.20	0.16	0.13	0.26	0.50	0.42	0.80	1.17	1.44	1.04	1.51	1.09	0.70	0.25	0.18
TS.Shiftup	0.43	0.19	0.18	0.23	0.19	0.33	0.76	0.75	1.12	1.42	1.61	1.28	1.51	1.10	0.71	0.29	0.16
TS.Shiftdo	0.30	0.12	0.16	0.14	0.14	0.23	0.41	0.54	0.84	1.25	1.43	1.04	1.46	1.01	0.71	0.31	0.18

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger cause excess stock returns volatility; * indicates rejection at the 5% significance level.

Table 8a: Quantile Causality Results for SA Excess Returns

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	2.89*	4.65*	5.74*	5.44*	4.92*	4.52*	4.37*	5.13*	5.96*	5.75*	5.35*	4.98*	4.74*	4.72*	3.92*	3.33*	2.94*
Nochg	1.29	1.15	1.70	1.55	1.81	1.65	1.76	2.61*	3.36*	3.75*	3.20*	2.92*	2.93*	2.84*	2.33*	2.08*	1.66
Pivclo	1.07	1.04	1.45	1.25	1.57	1.52	1.55	2.24*	3.25*	3.44*	3.21*	2.76*	2.52*	2.07*	1.64	1.37	1.64
Pivent	1.09	1.01	1.40	1.16	1.38	1.35	1.46	2.20*	3.25*	3.50*	3.31*	2.90*	2.74*	2.30*	1.94	1.64	1.86
Rosdo	1.12	1.03	1.53	1.34	1.63	1.76	1.62	2.54*	3.70*	4.11*	3.95*	3.65*	3.34*	2.64*	2.24*	1.90	1.80
Rosup	1.05	0.89	1.44	1.29	1.60	1.50	1.70	1.97*	3.16*	3.30*	2.94*	2.45*	2.48*	1.95	1.73	1.26	1.53
Roldo	1.05	0.90	1.22	1.12	1.31	1.37	1.62	2.28*	3.28*	3.62*	3.64*	3.30*	3.06*	2.58*	2.01*	1.86	1.77
Rolup	1.30	1.94	2.85*	2.87*	2.97*	2.35*	2.03*	3.01*	3.35*	3.60*	3.23*	2.91*	2.51*	2.40*	2.05*	1.78	1.87
Shiftp	1.04	1.07	1.48	1.39	1.53	1.44	1.58	2.30*	3.41*	3.85*	3.38*	2.59*	2.39*	1.96*	1.52	1.28	1.50
Shiftdo	1.04	1.09	1.60	1.27	1.39	1.37	1.40	2.06*	3.19*	3.36*	3.12*	2.66*	2.52*	2.10*	1.80	1.48	1.78
TS.Nochg	1.72	1.54	1.84	1.64	1.94	1.91	2.12*	3.18*	3.79*	3.52*	2.88*	2.49*	2.41*	2.42*	2.00*	1.51	1.43
TS.Pivclo	1.07	1.04	1.45	1.25	1.57	1.52	1.56	2.24*	3.26*	3.44*	3.21*	2.76*	2.52*	2.07*	1.64	1.36	1.64
TS.Pivent	1.09	1.01	1.40	1.16	1.37	1.35	1.45	2.18*	3.24*	3.48*	3.31*	2.90*	2.73*	2.29*	1.93	1.61	1.85
TS.Rosdo	1.12	1.03	1.53	1.34	1.63	1.76	1.62	2.54*	3.70*	4.11*	3.95*	3.65*	3.34*	2.64*	2.24*	1.90	1.80
TS.Rosup	1.05	0.89	1.44	1.29	1.60	1.50	1.70	1.97*	3.16*	3.30*	2.94*	2.45*	2.48*	1.95	1.73	1.26	1.53
TS.Roldo	1.05	0.90	1.22	1.12	1.31	1.37	1.62	2.28*	3.28*	3.62*	3.64*	3.30*	3.06*	2.58*	2.01*	1.86	1.77
TS.Rolup	1.30	1.94	2.85*	2.87*	2.97*	2.35*	2.03*	3.01*	3.35*	3.60*	3.23*	2.91*	2.51*	2.40*	2.05*	1.78	1.87
TS.Shiftp	1.04	1.07	1.48	1.39	1.53	1.44	1.58	2.30*	3.41*	3.85*	3.38*	2.59*	2.39*	1.96*	1.52	1.28	1.50
TS.Shiftdo	1.04	1.09	1.60	1.27	1.39	1.37	1.40	2.06*	3.19*	3.36*	3.12*	2.66*	2.52*	2.10*	1.80	1.48	1.78

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger cause excess stock returns; * indicates rejection at the 5% significance level.

Table 8b: Quantile Causality Results for SA Volatility

	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
TS	1.70	1.99*	2.71*	2.84*	4.20*	4.67*	6.06*	5.11*	4.71*	4.41*	5.22*	5.46*	4.97*	3.86*	3.59*	2.93*	2.48*
Nochg	1.33	2.46*	1.73	2.06*	2.43*	2.28*	2.40*	2.23*	2.19*	1.67	1.79	2.14*	2.00*	1.09	1.05	0.58	0.35
Pivclo	0.20	0.33	0.51	0.43	0.65	0.57	0.75	0.69	0.32	0.30	0.28	0.28	0.25	0.23	0.26	0.28	0.29
Pivent	0.21	0.35	0.55	0.45	0.64	0.60	0.80	0.73	0.33	0.33	0.31	0.38	0.34	0.34	0.43	0.46	0.42
Rosdo	0.39	0.58	0.86	0.66	0.82	0.91	1.06	1.13	0.61	0.48	0.46	0.47	0.45	0.41	0.26	0.37	0.27
Rosup	0.26	0.35	0.36	0.41	0.55	0.49	0.59	0.61	0.37	0.44	0.41	0.37	0.32	0.24	0.25	0.27	0.31
Roldo	0.29	0.49	0.61	0.38	0.65	0.57	0.63	0.56	0.28	0.31	0.29	0.25	0.25	0.27	0.52	0.35	0.36
Rolup	0.19	0.34	0.59	0.45	0.82	1.12	1.46	1.05	0.58	0.54	0.52	0.76	0.64	0.43	0.31	0.38	0.28
Shiftp	0.30	0.50	0.48	0.40	0.56	0.50	0.63	0.53	0.26	0.29	0.28	0.26	0.27	0.27	0.27	0.30	0.39
Shiftdo	0.26	0.28	0.51	0.41	0.62	0.58	0.75	0.71	0.26	0.27	0.26	0.37	0.45	0.31	0.34	0.50	0.30
TS.Nochg	1.02	1.82	1.48	2.29*	2.66*	2.40*	2.41*	2.19*	2.53*	2.15*	2.40*	2.26*	2.04*	1.31	1.15	0.77	0.57
TS.Pivclo	0.20	0.33	0.51	0.43	0.65	0.57	0.75	0.69	0.31	0.30	0.28	0.28	0.25	0.24	0.27	0.28	0.29
TS.Pivent	0.21	0.35	0.55	0.44	0.65	0.60	0.80	0.73	0.32	0.32	0.29	0.36	0.33	0.32	0.41	0.45	0.42
TS.Rosdo	0.39	0.58	0.86	0.66	0.82	0.91	1.06	1.13	0.61	0.48	0.46	0.47	0.45	0.41	0.26	0.37	0.27
TS.Rosup	0.26	0.35	0.36	0.41	0.55	0.49	0.59	0.61	0.37	0.44	0.41	0.37	0.32	0.24	0.25	0.27	0.31
TS.Roldo	0.29	0.49	0.61	0.38	0.65	0.57	0.63	0.56	0.28	0.31	0.29	0.25	0.25	0.27	0.52	0.35	0.36
TS.Rolup	0.19	0.34	0.59	0.45	0.82	1.12	1.46	1.05	0.58	0.54	0.52	0.76	0.64	0.43	0.31	0.38	0.28
TS.Shiftp	0.30	0.50	0.48	0.40	0.56	0.50	0.63	0.53	0.26	0.29	0.28	0.26	0.27	0.27	0.27	0.30	0.39
TS.Shiftdo	0.26	0.28	0.51	0.41	0.62	0.58	0.75	0.71	0.26	0.27	0.26	0.37	0.45	0.31	0.34	0.50	0.30

Note: Quantile causality results for the null hypothesis that term spread, pattern changes, and interaction terms do not Granger cause excess stock returns volatility; * indicates rejection at the 5% significance level.

6. CONCLUSION

This paper assesses, for the first time, the predictive ability of the term-spread, its pattern changes, and the interaction of pattern changes with the term-spread for excess stock returns in the UK, as well as its volatility, over the monthly period 1753:08-2017:02, using a nonparametric causality-in-quantiles test developed by Balcilar *et al.* (2017). In addition, we also compare the results with historical data for a developed country, i.e., the US over 1871:02 to 2017:02, and an emerging economy namely, South Africa, over 1936:01-2017:02.

Starting off with a linear framework as generally done in the literature, we observe that, while term spread on its own plays an important role in predicting the excess returns of the UK, pattern changes and the interaction of pattern changes with the term-spread are not of major importance. However, formal tests of nonlinearity confirm that the linear model is misspecified and results obtained from it cannot be relied upon. Using the nonparametric causality-in-quantiles test, which is robust to such misspecification, we obtain similar results at that of the linear model for excess returns, but are able to show the importance of term spread, pattern changes, and the interaction of pattern changes with the term-spread in predicting the volatility of the equity premium, especially at the upper end of its conditional distribution, i.e., when volatility is relatively high. But, we also observe that over time, term spread, pattern changes, and the interaction of pattern changes with the term-spread have also become important in predicting the excess returns of the UK, barring when the market is performing at its normal mode, i.e., when we consider the median of the conditional distribution, which could be an indication of herding by investors when the market is not in its bearish and bullish phases. Clearly then for the UK, besides the term spread, pattern changes and the interaction of pattern changes with the term-spread, is found to have important predictive content for excess returns and, especially, (high) volatility. Finally, while the importance of the term spread in general is also found for the excess returns and volatility of the US and South Africa, the role of pattern changes and the interaction of pattern changes with the term-spread is only restricted to the excess returns of the latter.

As is well-known, predictability of stock returns and volatility (when interpreted as uncertainty) becomes key inputs to investment decisions and portfolio choices for practitioners in finance. Further, volatility is the most important variable in the pricing of derivative securities, and financial risk management according to the Basle Accord. Moreover, financial market volatility can have wide repercussions on the economy as a whole, via its effect on real economic activity and public confidence. At the same time, academics in finance are interested in predictability of

stock market movements, since they have important implications for tests of market efficiency, which in turn, helps to produce more realistic asset pricing models. Given that, predicting stock markets is important for practitioners, academics and policymakers alike, our findings are of paramount importance to all these groups of economic agents. The fact that term spread, as well as pattern changes and the interaction of pattern changes with the term-spread, can predict both first and second moments of the equity premium, not only suggests the violation of the efficient market hypothesis, but should also be of assistance in asset allocation and policy-making that aims to curb financial market volatility. However, it must be emphasized that to obtain accurate predictability of equity return and volatility, economic agents would need to rely on nonlinear rather than linear econometric approaches. As part of future research, it would be interesting to extend our study to examine if these results hold in an out-of-sample exercise given that in-sample predictability does not guarantee the same in a forecasting set-up (Rapach and Zhou, 2013).

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Appendix:

Table A1. Summary Statistics:

Statistic	Variable					
	Excess Returns_UK	Excess Returns_US	Excess Returns_SA	Volatility_UK	Volatility_US	Volatility_SA
Mean	-0.0019	0.0016	0.0010	0.0013	0.0017	0.0024
Median	-0.0015	0.0038	0.0043	0.0002	0.0005	0.0006
Maximum	0.5325	0.4073	0.1619	0.2836	0.1659	0.0958
Minimum	-0.3177	-0.3112	-0.3096	0.0000	0.0000	0.0000
Std. Dev.	0.0354	0.0407	0.0486	0.0070	0.0060	0.0056
Skewness	1.0527	-0.4211	-0.9211	27.5585	16.3830	7.5446
Kurtosis	32.2115	14.4096	6.7438	981.3459	371.2495	94.8871
Jarque-Bera	113043.2000	9560.3130	706.5248	127000000.0000	9983431.0000	351895.1000
<i>p</i> -value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	3163	1753	974	3163	1753	974

Note: Std. Dev. symbolizes the Standard Deviation; *p*-value corresponds to the null of normality based on the Jarque-Bera test.