Short-term and long-term interest rate spread’s dynamics to risk and the yield curve

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Received: 25 February 2022 / Accepted: 7 September 2022 / Published online: 30 September 2022
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Abstract
The yield curve is perceived to be an indicator of the future state of the economy. For example, an inverted yield curve is considered to be a signal of a forthcoming economic slowdown. Does risk explain the slope of the yield curve as well? In this paper, we explore the dynamics of short-term and long-term interest rate spread to changes in risk and government debt using time-series data. Government-issued bonds are perceived to be risk-free assets. Financial intermediaries consider government-issued securities as a secondary reserve, and they are also used during open market operations. We explore the dynamics while controlling for a potential long-run common trend between the interest rate spread and government debt. We employ the bounds test for cointegration in an auto-regressive distributed lag model and evaluate impulse responses to develop insights into the dynamics. The ARDL bounds test finds evidence of cointegration between the measures interest rate spreads and government debt. A shock to government-issued bonds indicates that the short-term spread decreases, whereas the long-term spread rises by a small margin. We conjecture an upward sloping yield curve resulting from a shock to government debt. A shock to the financial market risk index indicates that the short-term spread decreases for a brief period before returning to its pre-shock level, whereas the long-term spread more or less remains unchanged. We conjecture a downward sloping yield curve resulting from a shock to risk. This conjecture on the impact of risk on short-term and long-term interest rate spreads make the prediction about the inverted yield curve based on the expectation hypothesis and the segmented market theory somewhat weak.

Keywords Spread · Bank reserve · Cointegration · Bounds test · ARDL

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JEL Classification E43 · G11 · G17

Introduction

The yield curve’s slope is perceived as an indicator of the state of the future economy. The yield curve, by definition, is a tool used in explaining the term structure of interest rates. According to Wheelock et al. (2009), the yield curve’s ability to predict the state of the economy depends on the Federal Reserve’s (henceforth the Fed) monetary policy regime. As per the segmented market theory, the inverted yield curve arises due to contractionary monetary policy, but the expectation hypothesis posits that higher short-term interest rates cause an economic slowdown by reducing aggregate investment (Brandl 2020). Given its theoretical underpinnings, is it justified to view the inverted yield curve as a crystal ball for predicting the state of the future economy? Arguably, it is very much probable that financial market risk, in addition to the Fed’s monetary policy intervention, may impact market interest rates and thus affect the yield curve.

Commercial banks face interest rate risks that may impact their profitability. To mitigate default and interest rate risk, depository institutions purchase government-issued securities of different maturities. In particular, short-term securities are considered default free and are also known as 'secondary reserve'. An increase in financial market risk may also motivate banks to buy short-term government-issued securities in a bid to increase their holding of risk-free assets [see Brandl (2020), Mishkin (2014)]. It is common knowledge that interest rates move together. Open market operations by the Fed alter the federal funds rate, and subsequently other short, medium, and long-term interest rates change as well. Open market operations by the Fed, in general, involve the purchase or sale of government-issued securities or bonds held by commercial banks. We may, therefore, observe a common long-run trend between interest rate spread and government debt in the USA. We argue that it is imperative to incorporate the presence of this long-run common trend while investigating the impact of financial market risk on interest rate spread.

Financial experts often interpret the inverted yield curve as an indication of an ensuing economic slowdown. This research envisages evaluating the validity of using the yield curve as a tool for predicting the future. Although interest rates tend to move together, we also observe a spread among different interest rates (see Fig. 1). We posit that the spread between the interest rates, short-term and long-term, may depict a common trend with government debt in the USA. Any changes in the financial market risk may also change the dynamics of the interest rate’s spread over time. In this research, we aim to analyze the dynamics of interest rate spread to variations in financial market risk while controlling for the long-run common trend between interest rate spread and government debt. The study of these dynamics may provide some interesting and practical insights for practitioners in the financial sector. A rise in risk may increase the spread between two interest rates of different maturity (Mishkin 2014). As government debt rises, more securities are issued of different maturities. The purchase or sale of these securities impacts a commercial bank’s liquidity which, in turn, affects the interest rates in the market. As
government debt rises over time, these opposing variations may provide alternative scenarios for policymakers and financial market practitioners to develop remedial or correctional strategies when faced with economic stress.

In this paper, we define two different measures of interest rate spread, where one represents the spread between short-term financial market instruments and the other represents the spread between long-term financial market instruments. The short-term spread is defined as the 3-month Treasury constant maturity minus the effective federal funds rate. The long-term spread is defined as the 10-year Treasury constant maturity minus the effective federal funds rate. We examine how these two measures of spread vary to changes in the financial market risk. While examining this, we consider the presence of a long-run relationship between the interest rate spread and government debt. We use quarterly time-series data from 1982 to 2020. We begin our analysis by investigating the stationarity property of the data. Statistical test results indicate that the interest rate spread measures are stationary at the level, but the debt-to-GDP ratio is not. The bounds test in an auto-regressive distributed lag model proposed by Pesaran et al. (2001) finds evidence of cointegration between the interest rate spread measures and debt-to-GDP ratio. Using impulse response analysis, certain insights and inferences were drawn. Examining the dynamics between the debt-to-GDP ratio and the short-term and long-term spreads, it is posited that the yield curve may have an upward slope. However, when the dynamics between the spread measures and market risk were examined the yield curve is posited to have a negative slope, thereby weakening the conventional expectations theory and segmented market hypothesis.

![Fig. 1 Long-term and short-term interest rate spread](image-url)
The rest of the paper is organized as follows: “literature review” discusses the relevant literature and the following section discusses the data and methodology. The next section discusses the results and analysis and the final section gives the “Conclusion”.

Literature review

In this section, we will discuss the relevant literature on interest rate spread and its determinants. Usage of the interest rate spread, or the difference between interest rates, as a forecasting metric—be it for the state of the economy or future inflation—is a relatively well-established practice. Theoretical models such as the pure expectations theory and the segmented market theory are used to explain the inverted slope of the yield curve. An inverted yield curve is considered to be a signal of a forthcoming economic slowdown or recession. Pure expectations theory tells us that high short-term interest rates increase the cost of borrowing, leading to a potential decline in aggregate spending, which in turn leads to an economic slowdown. The segmented market theory, on the other hand, argues that the Federal Reserve is conducting contractionary monetary policy to curb inflation. The monetary contraction is expected to lead to an economic slowdown (Brandl 2020; Mishkin 2014).

Wheelock et al. (2009) provide an extensive review of the literature in this context. A variety of econometric approaches are used to investigate the interest rate term structure spread’s ability to predict future economic states. They argue that the spread’s ability to predict the economy is ambiguous. In an early contribution, Simon (1990) showed that the spread between the 3-month Treasury bill and the federal funds rate had significant predictive power for the future change in the federal funds rate when the Fed followed a well-defined policy and did not have to mitigate shocks to the federal funds rate. Examining nine indicators of real activity and the inflation rate, Bernanke (1990) found that the difference between the Treasury bill rate and the commercial paper rate was a good predictor but that its reliability was sensitive to changes in monetary policy operating procedures. Dotsey (1998) used the yield curve spread between short- and long-term interest rates as a predictor for future economic growth and found it to be a useful measure, however, one whose power was waning.

Empirically, the slope of the yield curve is perceived to predict inflation and real economic activity. Estrella (2005) constructs a rational expectation model to explain the underlying causes of this relationship. The rational expectation model suggests that the relationships are not structural but influenced by the monetary policy regime. However, the yield curve should have predictive power for output and inflation in most circumstances. Harvey (1988) argues that expected real term structure contains information that can predict consumption growth, and the empirical evidence is strongest for the 1970s and 1980s. Harvey (1988) developed an inter-temporal consumption model to support his argument.

Closer to the spirit of the current paper, Sarno and Thornton (2003) examined the dynamic relationship between the federal funds rate and the 3-month Treasury bill rate and found a stable long-run relationship between the two across various monetary policy regimes. Monetary policy regime seems to be a common theme
in explaining the predictive power of the yield curve (Estrella 2005; Eo and Kang 2020; Evans 1987). It is common knowledge that the interest rates are cointegrated, and we hypothesize that the spread between interest rates is cointegrated as well. Estrella (2005) concludes that the extent to which the yield curve is a good predictor depends on the form of the monetary policy reaction function, which in turn may depend on explicit policy objectives. He argues that the yield curve has predictive capacity when the monetary authority follows inflation targeting, as defined by Svensson (1997). He further argues that the yield curve also has significant predictive power when monetary policy follows the Taylor (1993) rule.

Eo and Kang (2020) shed further light on the predictive power of yield curves by showing that they were affected by the extant monetary policy framework, a conclusion reinforced by Evgenidis et al. (2020) who further concluded that the yield curve became a less useful predictor in the presence of well-functioning stock markets, a hallmark of developed economies. Tillmann (2020) demonstrated that the term structure of interest rates responded in a nonlinear fashion to monetary policy shocks especially in the presence of uncertainty. Tillmann (2020) argues that uncertainty is a key aspect in explaining the behavior of the term structure of interest rates along with monetary policy. Wheelock et al. (2009) opined that the use of nonlinear econometric tools such as the Markov switching model to explain the term structure of the interest rate is owed to underlying risk or uncertainty.

We hypothesize that financial market risk is an important factor in explaining the term structure of interest rates. An increase in financial market risk may result in increased uncertainty, which may result in a flight to safety. Thereby, financial institutions may purchase government-issued bonds. We thus hypothesize that the interest rate spread may depict a common trend with government debt. We seek to explore the linkage between interest rate spread and risk while controlling for the long-run common trend to fill up a gap hitherto unexplored.

**Data and methodology**

In this section, we will discuss the data and methodology used in this paper. Our research investigates the dynamics among interest rate spread—both short-term and long-term, government debt, and financial market risk. We use the difference between 3-month Treasury constant maturity and the federal funds rate as a measure of short-term interest rate spread (henceforth short-term interest rate spread, denoted by STS). We use the difference between 10-year Treasury constant maturity and the federal funds rate as a measure of long-term interest rate spread (henceforth long-term interest rate spread, denoted by LTS). We use the debt-to-GDP ratio as the measure of government debt in the USA (denoted by DB). We use the Chicago Fed National Financial Conditions Risk Sub-index as a measure of risk in this paper (denoted by RS). We use quarterly data from 1982: Q1 to 2020: Q1\(^1\), which is the

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\(^1\) We have monthly and daily frequency available for the interest rate spread measures. But the debt-to-GDP ratio is available in quarterly frequency. As such, we use the quarterly frequency for all the variables.
longest time series available. Our research uses the sample period from 1982: Q1 to 2020: Q1. The measure for long-term spread is available from 1982: Q1. Although the other variables in this research have longer available frequencies, we started from 1982: Q1 due to the long-term spread measure being documented from that time period. Our sample ends in 2020: Q1 due to the COVID-19 pandemic. We exclude the COVID-19 pandemic period in our data set, because it created extraordinary economic circumstances. Since the early 1980s, we observe that the short-term and long-term interest rates in the USA portray, in general, a falling trend over time. We also observe that government debt is rising since the early 1980s. The data was collected from the electronic database at the Federal Reserve Bank of St. Louis website.

Figure 1 presents the short-term and long-term interest rate spread measures used in this paper. It is interesting to note that the long-term interest rate spread measure is mostly positive, whereas the short-term interest rate spread is negative. The short-term interest rate spread is close to its zero-lower bound since the Financial Crisis period. Both the measures of interest rate spread show similar patterns in their dynamics. It seems that the variations in the long-term measure of the interest rate spread is more profound than the variations in the short-term measure of the interest rate spread. Figure 2a shows the risk index and 2b shows the debt-to-GDP ratio in the USA.

Time-series theory defines the presence of a long-run equilibrium relationship between two variables as cointegration. When two variables are cointegrated, they portray a common trend. As argued earlier, the measures of the interest rate spread, and debt-to-GDP ratio may depict the presence of a common long-run trend. This long-run common trend or cointegration may stem from the following: first, the commercial banks prefer to hold government-issued securities as these assets are relatively risk free, and secondly, the Fed’s open market operation involves the purchase and sale of government-issued securities. In general, cointegration definition requires the variables to have the same order of integration. If two variables have different orders of integration, i.e., one has a unit root and the other does not, we can use the bounds test in an auto-regressive distributed lag (ARDL) model as proposed by Pesaran et al. (2001). The presence of cointegration or a long-run equilibrium relationship does not imply a causal relationship. The error-correction model, derived from the cointegration between the variables, can help us analyze the dynamics in the short run. The variation in the short-run dynamics resulting from a shock to one variable in the error-correction model may allow us to develop important insights.

We begin our analysis by investigating the stationarity of the variables by examining the presence of a unit root. We will use a set of tests for this purpose. Our tests include the Dickey and Fuller (1979) and Phillips and Perron (1988) tests. These two tests do not take account of potential structural breaks in the data at unknown dates. Lee and Strazicich (2003) argue that in the presence of structural break the unit root tests may give erroneous conclusions. The variables used in this research are presented in Figs. 1 and 2 depict the presence of structural break in the data. To address structural break in the data, we use the Zivot and Andrews (2002) and Lee and Strazicich (2003) tests to examine the presence of a unit root in the series with
Fig. 2 Risk index and debt-to-GDP ratio
one or more structural breaks in the data. We will not discuss these approaches in detail for the purpose of brevity. We can proceed to cointegration testing once the order of integration for the variables is determined.

The Engle and Granger (1987) procedure for cointegration require the variables under consideration in the model to have the same order of integration. Specifically, this procedure requires the variables to be integrated of order one, i.e., \( I(1) \). If the variables under consideration have different orders of integration, we cannot use this approach. In such a scenario, we can use the Pesaran et al. (2001) approach to detect the presence of cointegration or a long-run equilibrium relationship among variables irrespective of their order of integration. The subsequent discussion on the autoregressive distributed lag model (henceforth ARDL model) is based on Jordan and Philips (2018). The ARDL model specification is useful due to its generalization, flexibility and robustness to a variety of data-generating processes. This specification can account for multiple lags of independent variables, either in their levels or in first differences, as well as multiple lags of the dependent variable. Jordan and Philips (2018) use the ARDL setup to implement the ARDL-bounds testing procedure developed by Pesaran et al. (2001) and also to simulate the effect of some \( X \) on \( y \) using dynamic simulations. The simulations help in developing inferences of some \( X \) on \( y \): (1) in both the short run and long run, (2) allowing \( X \) to appear in both levels, lagged level, and first differences, and (3) finally allow for control of other variables.

We estimate the following ARDL model to conduct the ARDL-bounds test to detect cointegration. We use the specification to simulate the impact of the independent variables on the interest rate spread measures. The following equation depicts the error-correction model for short-term interest rate spread:

\[
STS_t = \alpha_t + \theta_1 STS_{t-1} + \theta_2 LD_{t-1} + \beta_1 \Delta LD_{t-1} + \beta_2 \Delta Risk_{t-1} + \tau_1 Trend + \epsilon_t, \tag{1}
\]

where \( \epsilon_t \sim N(0, \sigma^2) \). Short-term interest rate spread is denoted by \( STS_t \), changes in federal government debt-to-GDP ratio is denoted by \( \Delta LD_t \), and changes in risk is denoted by \( \Delta Risk_t \). We include the change in the federal government debt-to-GDP ratio as a control variable because an increase in the supply of federal government debt is usually financed by Treasury-issued bonds, which may impact the short-term and long-term interest rates and thereby spread. Similarly, changes in the financial market risk and state of the economy may also impact the interest rates and thereby the spread. To control for these factors, we include these variables in our specification. We add the trend variable in our econometric specification as well. We will obtain the residuals, \( (\hat{\epsilon}_t) \), from Eq. 1 for further diagnostic tests and subsequent re-specification of our model. Specifically, we will investigate the presence of residual correlation. Auto-correlation is especially pernicious when using the ARDL-bounds test for cointegration, as the test relies on the assumption of serially uncorrelated errors (Pesaran et al. 2001). In our post-estimation diagnostics using the residuals, we will use the Lagrange multiplier (LM) test to detect serial correlation developed by Breusch (1978) and Godfrey (1978). The null hypothesis for the LM test is no auto-correlation. If we detect the presence of any auto-correlation using this test, we will add the lagged first difference of the dependent variable to our model to
mitigate this problem. We specify the following equation for the long-term interest rate spread denoted by \( \text{LTS}_t \). We use the same post-estimation diagnostic for Eq. 2 as well.

\[
\text{LTS}_t = \alpha_t + \theta_1 \text{LTS}_{t-1} + \theta_2 \text{LD}_{t-1} + \beta_1 \Delta \text{LD}_{t-1} + \beta_2 \Delta \text{Risk}_{t-1} + \tau_1 \text{Trend} + \epsilon_t. \quad (2)
\]

The ARDL model is used for the bounds test for cointegration as proposed by Pesaran et al. (2001).\(^2\) We can use the model specified by Eq. 1 to elaborate the bounds test. In this equation, the variables that appear in levels are the only ones that can possibly be in a cointegrating relationship with the dependent variable. The ARDL-bounds test for cointegration works by using a Wald or F test on the following restriction from Eq. 1:

\[
H_0 : \theta_1 = \theta_2 = 0.
\]

In other words, the coefficients on variables appearing in first lags are jointly equal to zero. The null hypothesis implies no cointegration. Thus, rejecting the null hypothesis indicates that there is a cointegrating relationship between the variables. In addition to the F test, a one-sided \( t \) test may be used to test the null hypothesis that the coefficient on the lagged dependent variable in levels is equal to zero.

\[
H_0 : \theta_1 = 0.
\]

The alternative hypothesis for the \( t \) test is \( H_1: \theta_1 < 0 \) or the dependent variable is cointegrating with the regressors. This is known as the bounds \( t \) test. The critical values for these tests are non-standard and are from Pesaran et al. (2001). We conclude the presence of cointegration when the \( F \)-statistic exceeds the critical value at the upper \( I(1) \) bound of the test. We conclude otherwise, when the \( F \)-statistic lies between or below the \( I(1) \) and \( I(0) \) critical values. When the auxiliary \( t \) test statistics on the lagged dependent variable falls below the \( I(1) \) critical value, we conclude that this lends further support for cointegration. If this falls between or above \( I(0) \) and \( I(1) \), we conclude otherwise. We can conduct these tests for a number of different cases, with or without unrestricted intercept and trend. We will apply this testing for both Eqs. 1 and 2. The model can be specified in an error correction form in the following way. We use the short-term spread as the dependent variable. We are not presenting the equation for the long-term spread for brevity.

\[
\Delta \text{STS}_t = \alpha_t + \theta_1 \text{STS}_{t-1} + \theta_2 \text{LD}_{t-1} + \sum_{m=1}^{M} \alpha_m \Delta \text{STS}_{t-m} + \sum_{n=1}^{N} \beta_n \Delta \text{LD}_{t-n} + \sum_{p=1}^{P} \rho_{t-p} \Delta \text{Risk}_{t-p} + \tau_1 \text{Trend} + \epsilon_t. \quad (3)
\]

Once we have established the appropriate model—accounting for the appropriate lags of the independent variables, first-difference variables, and so on—to develop conclusions on cointegration using the bounds test, we can proceed to inference on

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\(^2\) This test does not support higher-order cointegration.
the dependent variable using stochastic simulations. The following discussion is based on Jordan and Philips (2018). In these simulations, we are not interested in any individual simulation in any individual time period. Rather, we develop insight into the central impact on the dependent variable from a shock to one of the independent variables by doing some meaningful analysis across the simulations within any time period. The shock is distributed appropriately, as defined by the model specified. We use the appropriate ARDL model specification for OLS estimation to simulate the quantities of interest. Specifically, the coefficients are simulated as draws from a multivariate normal distribution with mean of the coefficient and variance from the variance-covariance matrix of the estimated model. Uncertainty is introduced into these simulations by simulating $\hat{\sigma}^2$ scaled by random draws from the Chi-squared distribution. We then use this estimate of $\hat{\sigma}^2$ to add back in the fundamental random error to the predicted value of each simulation. These predictions come from set levels of the independent variables: the independent variable in levels is held at their means and other variables in differences are held at 0. We introduce a shock to one of the independent variables at time $+1$ and retain the summary quantities of interest along with their upper and lower percentiles for statistical significance (at 75, 90 and 95 percentiles of the predictions from the simulations, something akin to a confidence interval). We present the output of the simulation as plots.

Results and analysis

In this section, we will discuss the results and analyze them. We begin our analysis with the tests for unit root, followed by ARDL model specification post-estimation tests, ARDL bounds test for cointegration, and finally present and discuss the simulation plots.

Unit root test and structural break

The plots of the data in Figs. 1 and 2 indicate the presence of multiple structural breaks in the data series for all the variables. As such, we employ unit root tests that allow for structural break in the data. We present the results from the Zivot and Andrews (2002) test for unit roots in the data in Table 1. We inspect three separate cases: break in intercept, break in trend and breaks in intercept and trend. The results indicate that the short-term spread, measured by the difference between 3-month Treasury bill rate and the federal funds rate, does not have a unit root for all three cases. The financial market risk index also do not have a unit root for all three cases as well. The short-term interest rate spread and the risk index are stationary at level. The long-term measure of the spread, measured by the difference between 10-year Treasury bill rate and the federal funds rate, has a unit root only when there is a break in the trend. But for break in intercept and breaks in the intercept and trend, indications are otherwise. For the debt-to-GDP ratio series, we can find that the data

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3 There are a number of other tests such as the Dickey & Fuller (1981) and Perron (1997) tests. These tests are susceptible to rejection of the null of a unit root in the presence of structural breaks in the data leading to erroneous conclusions.
has a unit root when we consider break in the trend and breaks in the intercept and trend. But for break in intercept, the data does not indicate a unit root. This inconsistency may stem from the presence of multiple structural breaks in the data series.

The Zivot and Andrews (2002) test allows for one structural break in the data. In reality, the data generation process may have more than one structural break at unknown dates. To address this aspect, we employ the Lee and Strazicich (2003) test. In this approach, we consider two separate cases—trend break model with two breaks and the crash model with two breaks. Table 2 presents the results from this test. The results indicate that the short-term interest rate spread and long-term interest rate spreads do not have a unit root in both cases in the presence of two structural breaks. We conclude that these two variables are stationary at level or integrated of order ‘0’ (I(0)). For the debt-to-GDP ratio and the risk index, the test results indicate that the data series have a unit root for both cases. We can conclude that these two

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**Table 1**  Unit root test (single break)

| Variables                        | Break in intercept | Break in trend | Breaks in intercept and trend |
|---------------------------------|--------------------|---------------|-------------------------------|
|                                 | Test statistics    | Test statistics | Test statistics               |
| Government debt-to-GDP ratio    | – 5.34**           | – 3.02        | – 4.24                        |
| 3-month Treasury bill rate minus federal funds rate | – 6.82**           | – 6.08**       | – 6.66**                      |
| 10-year Treasury bill rate minus federal funds rate | – 4.58            | – 4.48**       | – 4.76                        |
| Financial market risk index     | – 6.04**           | – 5.46**       | – 6.37**                      |

1.5% critical value for break in intercept: – 4.80, 2. 5% critical value for break in trend: – 4.42, 3.5% critical value for breaks in intercept and trend: – 5.08, 4

*Indicates significance at 5%

**Indicates significance at 1%

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**Table 2**  Unit root test (with two structural breaks)

| Variables                        | Trend break model with two breaks | Crash break model with two breaks |
|---------------------------------|----------------------------------|----------------------------------|
|                                 | Test statistics                  | Test statistics                  |
| Government debt-to-GDP ratio    | – 3.91                           | – 2.59                           |
| 3-month Treasury bill rate minus federal funds rate | – 8.30**                          | – 3.84**                          |
| 10-year Treasury bill rate minus federal funds rate | – 6.06**                           | – 4.03**                          |
| Financial market risk index     | – 3.94                           | – 3.09                           |

1. 5% critical value for the trend break model: – 5.47, 2. 5% critical value for the crash break model: – 3.58, 3

*Indicates significance at 5%

**Indicates significance at 1%
series are non-stationary at level. The Lee and Strazicich (2003) test finds more consistent results for all the four series.

The unit root or stationarity tests presented in this section clearly indicate that the variables do not have the same order of integration. The interest rate spread measures are stationary at level. Whereas the other variables are non-stationary at level. This implies that we cannot use the conventional tests for cointegration.

**Cointegration test**

In this research, we explore the dynamics of interest rate spread to changes in the measure of risk while controlling for a common long-run trend between the spread and government debt. Government debt is likely to have a common long-run trend with the measures of interest rate spread. Ignoring this long-run common trend in the econometric specification may lead to inaccurate predictions. The unit root tests for stationarity indicate that the variables do not have the same order of integration. In such a scenario, we employ the bounds test for cointegration in an ARDL setup proposed by Pesaran et al. (2001). We estimate two separate cases using Eqs. 1 and 2 discussed earlier. First, we explore the presence of cointegration between short-term interest rate spread and government debt-to-GDP ratio, and second, we explore the presence of cointegration between long-term interest rate spread and government debt-to-GDP ratio. The following equation shows an ARDL(1, 1, 1, 1) model for Eq. 1.

\[
S\hat{T}S = -1.01 - 0.80 STS_{t-1} - 0.003 LD_{t-1} - 0.05 \Delta STS_{t-1} - 0.05 \Delta RS_{t-1} - 0.010 \text{Trend.}
\]

\[
N = 150, \text{ Adjusted } R - \text{ squared } = 0.40
\]

We selected the above specification for the ARDL model using the Breusch (1978) and Godfrey (1978) LM testing procedures. The null-hypothesis, \(H_0\), is no autocorrelation up to AR1. The \(p\) value is 0.98, which indicates we cannot reject the null and the above is the preferred specification for the ARDL estimation. We conduct the bounds test described in the methodology section for this model. Table 3

**Table 3** Cointegration test for short-term interest rate spread: \(F\) test and \(t\) test

|                      | \(F\) test | \(t\) test |
|----------------------|------------|------------|
|                      | \(I(0)\)   | \(I(1)\)   | \(I(0)\) | \(I(1)\) |
| 10% critical value   | 6.59       | 6.26       | −3.13  | −3.40  |
| 5% critical value    | 6.56       | 7.30       | −3.41  | −3.69  |
| 1% critical value    | 8.74       | 9.63       | −3.96  | −4.26  |

\(F\) statistics 27.82 \(t\) statistics −7.46
presents the $F$ test and $t$ test results for cointegration between the short-term interest rate spread and debt-to-GDP ratio with unrestricted intercept and unrestricted trend. Both the $F$ test and $t$ test results confirm that these two variables are cointegrated with each other. The $F$ test statistics, 27.82, exceeds the critical values for the upper $I(1)$ bound for all significance levels. The $t$ test statistics, $-7.46$, falls below the $I(1)$ critical values. These test results imply that the short-term interest rate spread and the debt-to-GDP ratio have a common long-run trend. This is plausible because the financial intermediaries purchase short-term government-issued securities because they are relatively risk-free. In addition, these securities are frequently traded in open market operations. The short-term securities are considered as secondary reserve as well. It is common knowledge that the Fed’s open market operations target the federal funds rate. The spread between the 3-month Treasury bill and the federal funds rate is thus very likely to be cointegrated with the debt-to-GDP ratio.

We estimated an ARDL(1, 1, 2, 1) for Eq. 2. We selected the above specification for the ARDL model using the Breusch (1978) and Godfrey (1978) LM testing procedures. The null hypothesis, $H_0$, is no autocorrelation up to AR 1. The $p$ value is 0.14, which indicates we cannot reject the null and the above is the preferred specification for the ARDL estimation. We conduct the bounds test described in the methodology section for this model. Tables 4 presents the $F$ test and $t$ test results of cointegration between the long-term interest rate spread and debt-to-GDP ratio with unrestricted intercept and unrestricted trend. Both the $F$ test and $t$ test results confirm that these two variables are cointegrated with each other. The $F$ test statistics, 7.68, exceeds the critical values for the upper $I(1)$ bound at 10% and 5% critical values. The $t$ test statistics, $-3.85$, falls below the $I(1)$ critical values at 10% and 5% critical values. This test results implies that the long-term interest rate spread and the debt-to-GDP have a common long-run trend. Thus, we can find formal statistical evidence of cointegration for both the measures of interest rate spread. This is plausible because the financial intermediaries purchase long-term government-issued securities because they are relatively risk free. In addition, these long-term securities are also used in open market operations. The Fed target’s the federal funds rate for monetary policy. It is also plausible that the government-issued securities are used in intra-bank transactions which will impact the federal funds rate. We thus argue that it is very likely that the interest rate spread between the 10-year Treasury bond and the federal funds rate is cointegrated with the debt-to-GDP ratio.

|                | $I(0)$ | $I(1)$ | $I(0)$ | $I(1)$ |
|----------------|--------|--------|--------|--------|
| 10% critical value | 6.59   | 6.26   | $-3.13$| $-3.40$ |
| 5% critical value  | 6.56   | 7.30   | $-3.41$| $-3.69$ |
| 1% critical value  | 8.74   | 9.63   | $-3.96$| $-4.26$ |
| $F$ statistics     | 7.68   |        | $t$ statistics $-3.85$ |
The presence of a long-run common trend between the measures of interest rate affirms our argument that they have a common long-term trend with the debt-to-GDP ratio. To explore the dynamics, we estimate the impulse responses described in the methodology section. The following section discusses the impulse responses to explore the short-run dynamics.

Figures 3 and 4 show the impulse responses for the short-term interest rate spread and the long-term interest rate spread measures to a 1 standard deviation shock in debt-to-GDP ratio. Figures 5 and 6 present the impulse responses for the short-term interest rate spread and long-term interest rate spread to a 1 standard deviation shock to the financial market risk index. The short-term interest rate spread, measured by

$$L̂TS = -0.26 - 0.30 \text{LTS}_{t-1} - 0.011 \text{LD}_{t-1} - 0.20 \Delta \text{STS}_{t-1}$$

$$- 0.06 \Delta \text{STS}_{t-2} - 0.16 \Delta \text{RS}_{t-1} + - 0.001 \text{Trend.}$$

$$N = 150, \text{Adjusted } R^2 = 0.40$$

**Impulse response**

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Figures 3 and 4 show the impulse responses for the short-term interest rate spread and the long-term interest rate spread measures to a 1 standard deviation shock in debt-to-GDP ratio. Figures 5 and 6 present the impulse responses for the short-term interest rate spread and long-term interest rate spread to a 1 standard deviation shock to the financial market risk index. The short-term interest rate spread, measured by
3-month Treasury bill rates minus the federal funds rate, in the USA has been mostly negative. This implies that the federal funds rate has been higher than the 3-month Treasury bond rate for most of the periods. The long-term interest rate spread, measured by 10-year Treasury minus the federal funds rate, is positive for most periods. This implies that the federal funds rate was lower than the 10-year Treasury bond rate.

Figure 3 presents the impulse response for short-term interest rate spread to a 1 standard deviation shock to the debt-to-GDP ratio. The impulse response shows that the spread between the two rates decreases implying the 3-month Treasury bill rate going up. In the bond market, an increase in government debt may increase the supply of such bonds, and given bond demand, this will lower the bond price. We know that the bond price and interest rate are inversely related. As such, a decrease in bond prices will increase the interest rate. The decline in the spread could be the result of a decline in the federal funds rate as well. An increase in the federal government debt is financed by issuing bonds. Commercial banks and financial intermediaries perceive such bonds as risk free and liquid relative to other bonds. These short-term bonds are also known as secondary reserve that is used a lot in open market operations. As a result, we argue that intra-bank borrowing and lending may decline, which in turn lowers the federal funds rate.
Figure 4 presents the impulse response for long-term interest rate spread to a 1 standard deviation shock to the debt-to-GDP ratio. A 1 standard deviation shock to the debt-to-GDP ratio leads to an increase in the spread, albeit rather slowly. In the bond market, an increase in government debt may increase the supply of such bonds, and given bond demand, this will lower the bond price. Bond price and interest rate are inversely related. As such, a decrease in bond prices will increase the interest rate. The decline in the spread could be the result of a decline in the federal funds rate as well. An increase in the federal government debt is financed by issuing bonds. Commercial banks purchase them as safe assets and as secondary reserve. As a result, intra-bank borrowing and lending may decline, which in turn lowers the federal funds rate. In comparison to the short-term interest rate spread, the long-term interest rate spread grows very slowly. Perhaps the market for short-term assets is more volatile than the long-term spread. We use these two impulse response comparisons to conjecture on the shape of the yield curve with respect to a shock to the debt-to-GDP ratio. The short-term interest spread rises fast, and we observe similar nature of dynamics in the long-term interest rate spread. We predict the yield curve to have an upward slope.

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Figure 5 presents the impulse response for short-term interest rate spread to a 1 standard deviation shock to the financial market risk index. A 1 standard deviation shock to the financial market risk reduces the spread between the 3-month Treasury bill and the federal funds rate for a short period and then the spread returns to its pre-shock level. An increase in financial market risk may lead to financial intermediaries becoming more cautious, which may reduce their commercial lending operations. We observed such a credit crunch following the financial meltdown during the 2007–2008 financial crisis. The financial intermediaries may have excess liquidity that lowers intra-bank borrowings, which subsequently lowers the federal funds rate. At the same time, we may observe a capital flight to safety. Banks and financial intermediaries may purchase more government-issued securities. In the bond market, an increase in demand for government-issued bonds, given their supply, will increase the bond’s price. Bond price and interest rate are inversely related. As such, an increase in the bond price will decrease the interest rate. As financial intermediaries push to increase their holdings of risk-free assets such as government-issued bonds, the demand for liquidity increases. This may lead to an increase in the federal funds rate caused by an increased intra-bank borrowing. The rise in federal funds rate brings the spread to its pre-shock level.

Figure 6 presents the impulse response for long-term interest rate spread to a 1 standard deviation shock to the financial market risk index. A 1 standard deviation shock to the financial market risk brings about a small decline in the spread between the 10-year Treasury bill and the federal funds rate for a short period and remains
unchanged. The small decline may be caused by a small decline in the 10-year Treasury rate or an increase in the federal funds rate. We argue that the increased risk in the financial market may prompt the Fed to take precautionary measures by raising the target for the federal funds rate to depress the liquidity in the banking sector. In the process, the federal funds rate may increase until the risk diminishes.

In comparison to the short-term interest rate spread, the long-term interest rate spread shows very little variation. Perhaps the market for short-term assets depicts more volatility than the long-term spread. We use these two impulse response comparisons to conjecture on the shape of the yield curve with respect to a shock to the financial market risk index. The short-term interest spread rises fast for a brief period of time before it returns to its pre-shock level. However, the long-term interest rate spread decreases by a relatively slow margin. We predict the yield curve to have a downward slope arising from a shock to financial market risk. This conclusion, that an inverted yield curve may arise due to increased financial market risk, makes the pure expectations theory and segmented market hypothesis weaker.

Conclusion

In this paper, we explored the linkage between measures of interest rate spread and financial market risk and how it may affect the shape of the yield curve. The shape of the yield curve is perceived to be the crystal ball into the future state of the economy. In this research, we contradict this view as financial market risk may impact market interest rates. In addition, we argue that the interest rate spread and government debt may depict a common long-run trend. We envisage exploring the dynamics between interest rate spread and financial market risk while controlling for a common long-run trend between the interest rate spread and government debt. We used quarterly time-series data, spanning from 1982:Q1 to 2020:Q1, on debt-to-GDP ratio, a financial market risk index, and two measures of interest rate spread.

We use time-series econometric approach in our research. We begin our analysis with the unit root tests. The unit root tests with structural break indicate that the interest rate spread measures, both short-term and long-term, are stationary. On the contrary, the debt-to-GDP ratio and the risk index are non-stationary. We employ the ARDL bounds test to detect cointegration proposed by Pesaran et al. (2001) between the measure of interest rate spread and debt-to-GDP ratio. The bounds test findings indicate that the two measures of interest rate spread are cointegrated with the debt-to-GDP ratio as hypothesized. Using impulse response analysis certain insights and inferences were drawn about the short run dynamics. Examining the dynamics between the debt-to-GDP ratio and the short-term and long-term spreads it is posited that the yield curve may have an upward slope. However, when the dynamics between the spread measures and market risk were examined the yield curve is posited to have a negative slope as hypothesized. This finding provides empirical evidence weakening the conventional belief that the inverted yield curve is predicting
an upcoming economic slowdown. Thereby weakening the conventional expectations theory and segmented market hypothesis.

Financial market risk’s impact on the interest rate spread and our subsequent conjecture on the shape of the yield curve is an empirical exercise. We believe these findings merit a structural interpretation for future research.

Author contributions HAA conceptualized the study and is also responsible for data collection, methodology, estimation and analysis, and writing. MWRK is responsible for writing and editing.

Funding This study was not funded by any internal or external research grants.

Declarations

Conflict of interest No conflict of interest exists. Author Haydory Akbar Ahmed declares that he has no conflict of interest. Author M Wasiqur Rahman Khan declares that he has no conflict of interest.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

Consent for publication We, Haydory Akbar Ahmed, Ph.D., and M Wasiqur Rahman Khan, Ph.D., provide our full consent for publication. We did not use any graphs or materials from another journal or source.

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