THE EXPECTATIONS THEORY OF TERM STRUCTURE: EVIDENCE AND IMPLICATION FOR FOUR DEVELOPED COUNTRIES

JOHURA BEGUM
Master of Social Science, Shahjalal University of Science and Technology, 2014

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LETHBRIDGE, ALBERTA, CANADA

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JOHURA BEGUM

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Duane W. Rockerbie Thesis Supervisor	Professor	Ph.D.
Ricard Mueller Thesis Examination committee member	Professor	Ph.D.
Md Kamar Ali Thesis Examination committee member	Associate Professor	Ph.D.
Pascal Ghazalian Thesis Examination Chair	Associate Professor	Ph.D.

DEDICATION

To my daughter, husband and my parents who provide love and enormous support throughout my life.

ABSTRACT

The Yield curve is very prominent in the economics and finance literature to analyze the behavior of households and investors towards bonds markets. In this paper we explore and test the Expectations Hypothesis (EH) of the term structure for a number of international bond markets. We use data at the short and long end maturities for the Treasury bill rate and the Government of Canada bond rate. The sample includes monthly yields for maturities ranging from 1, 3, 5-month treasury bills and 1, 5, 10 and more years for Government of Canada bonds, USA bonds, UK bonds and France bonds. We use the Engle-Granger cointegration test and OLS to estimate the spread between short and long term interest rates, including tests for serial correlation in residuals, and to test the validity of the EH. The EH is rejected in all cases.

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All praises be to the Almighty Allah for giving me the opportunity, strength, wisdom, and courage to complete this research and master program.

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CHAPTER 1: INTRODUCTION

Bonds have multitude maturities and bond holders receive interest that is partly based on the term to maturity. There is a general relationship between the yield of bonds and their maturities that is called the term structure of interest rates. However, interest rates on long term bonds are also very important in economic analyses in terms of business and investment decisions. Households spending behaviors and the interest rate relationship are also explained by the term structure of interest rates. An increasing number of economists and researchers are devoting attention to studying the term structure to demonstrate how future economic activity is influenced by it.

1.1 Theories of the Term Structure

To explain the term structure empirically, the yield curve must first be developed using several theories of the term structure. These include the Expectations Hypothesis (EH), the Market Segmentation theory (MS) and the Liquidity Premium theory (LP). These three theories compete to explain the characteristics of bonds and the term structure of interest rates for short term and long term securities.

According to the EH, the yield curve incorporates information about expectations of future interest rates that are beneficial to foretell future inflation, yielding valuable information for monetary policy that follows an inflation targeting rule. The upward sloped “normal” yield curve indicates that financial markets are expecting higher future interest rate. In the EH, long term interest rates are a weighted average of short term

interest rates since arbitrage activities are assumed to eliminate any excess profit from trading between maturities.

The LP theory suggests that investors demand higher yields from longer term bonds because there is a greater risk of holding longer duration bonds due to bond price fluctuations. The usual yield curve is then upward sloping. An inverted yield curve appears if higher yields emerge from short term bonds instead of long term bonds. Sometimes this inverted graph is called as negative yield curve and it is thought to be a predictor of a coming economic recession. The following graphs demonstrate the recent yield curve pattern for Canada and US.

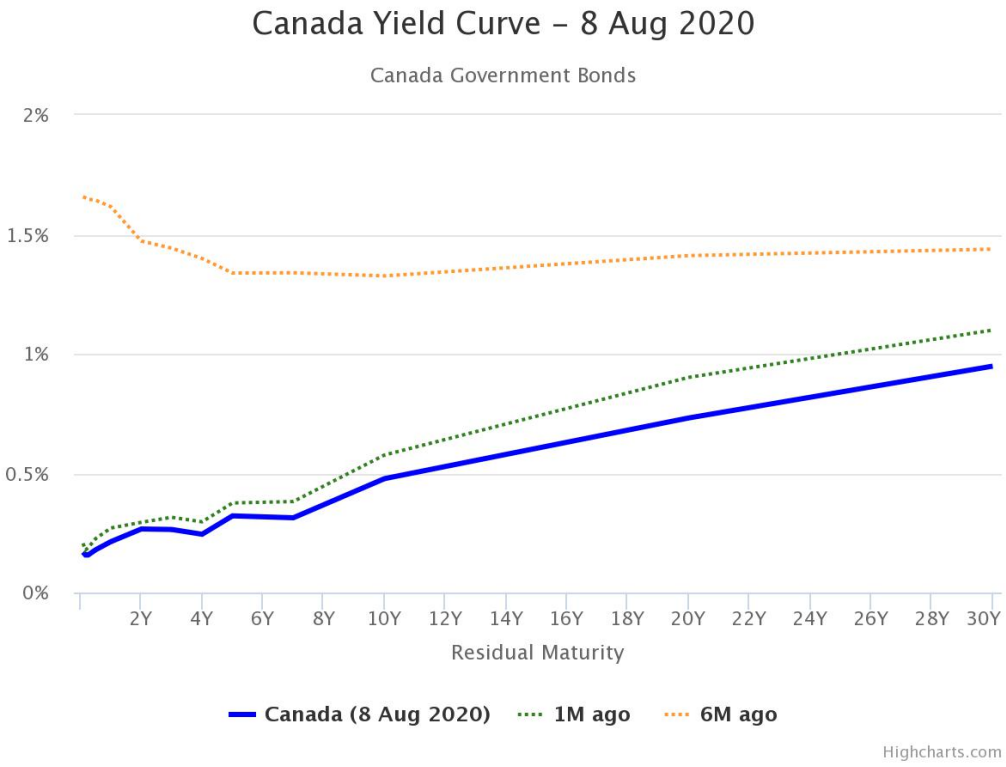

Figure 1. 1 Canada Yield Curve, Source: www.worldgovernmentbonds.com

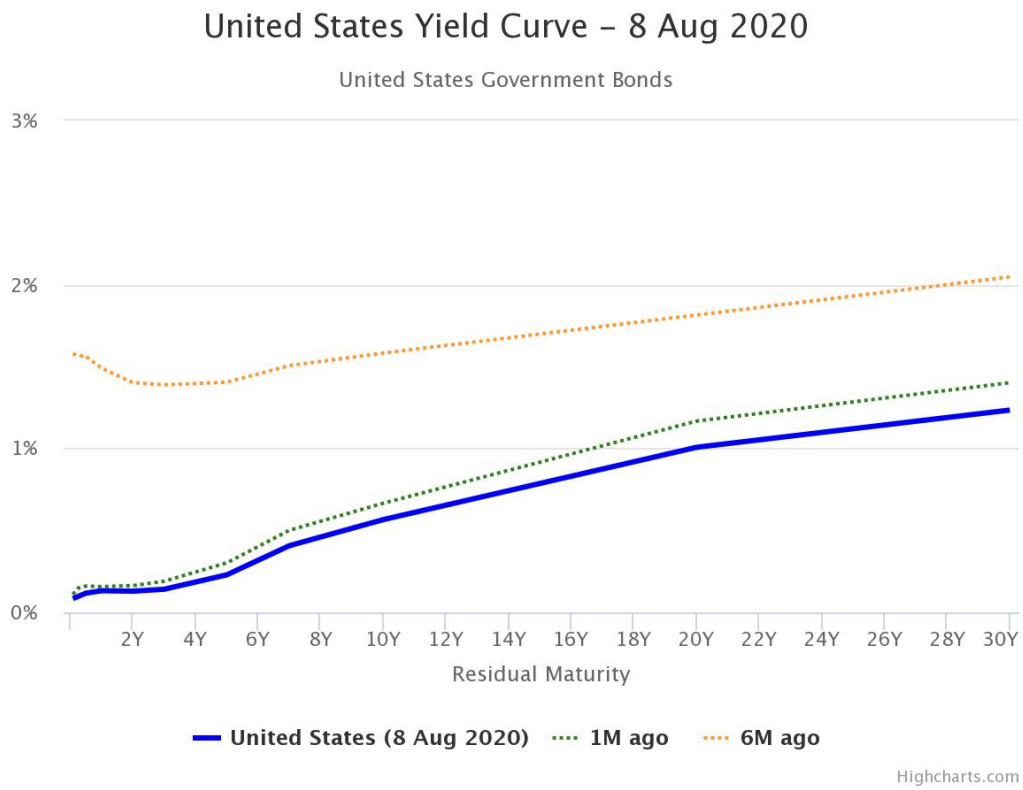

Figure 1. 2. U.S. Yield Curve, Source: www.worldgovernmentbonds.com

The MS theory asserts that short-term and long-term interest rates are determined separately by different market forces (Mustafa &Matiur, 1995) and are not substitutable (not cointegrated). This suggests that the yield curve is simply a curious diagram and not useful for predicting future movements in yields. Any econometric analysis of the yield curve is miss-specified.

Generally, the LP theory is incorporated with the EH theory of the term structure. The interest rate of long-term bonds is equal to the average of a succession of short-term interest rates, expected to be continued over the life of the long-term bonds, plus a term premium based on liquidity risk. Investors usually prefer less risky short term securities,

so here the term premium compensates investors who move to long term bonds. Another approach related to the LP theory is the Preferred Habitat theory that implies that investors only choose a bond of a single maturity given that other maturities can be chosen with the same term premium. Here the term premium is positive for both cases and typically rises with maturity.

The literature exploring and estimating the linkage between short-term and long-term interest rates has witnessed a great expansion over the past few years, but most of these papers used data from the USA and the UK. Only a few of them performed cointegration tests by collecting data from different developed and developing countries. We noted the three theories to explain the term structure, but the EH theory is the most widely accepted and dominant theory to elucidate the connection between short and long term interest rate. There exist a large number of studies by researchers on the EH theory of the term structure; these studies employed diverse econometric methods, test various inferences of the EH theory and utilized data from different interest rate maturities. Moreover, a number of tests are proposed and demonstrated in the literature to assess the EH model.

Technically, the yield spread is defined as the difference between interest rates in various maturities, which move over time. In particular, it explains how long-term interest rate rates adjust to short term interest rates. Based on the three theories of the term structure, we will analyze how the spread between the yields of different maturities move over time. In particular, what speed the long term rates adjust to short term rates, if at all, and their volatilities are vital points of this study. The economic analysis of interest rates is also important because central bank changes to the policy interest rate (overnight rate)

have delayed effects to stimulate the economy and control inflation. Figures 1.3 to 1.6 are plotting how the spread between yields of different maturities move over time. In each Figure, a long-term bond yield is compared to a one-year bond yield. In each case, the bond yields appear to be moving together but they are not cointegrated in every maturity as EH suggests. Where the EH is rejected that indicates that spread between short and long term interest rate two are not cointegrated. In many of the cases, the time-series properties of yield spreads are different, even though they seem to move together. One series is I(1) and the other is I(0) for instance. This suggests that random shocks that hit the two series result in different behaviors. Shocks dissipate quickly for an I(0) series but have long-run effects on an I(1) series. So, they do not share a long-run equilibrium relationship.

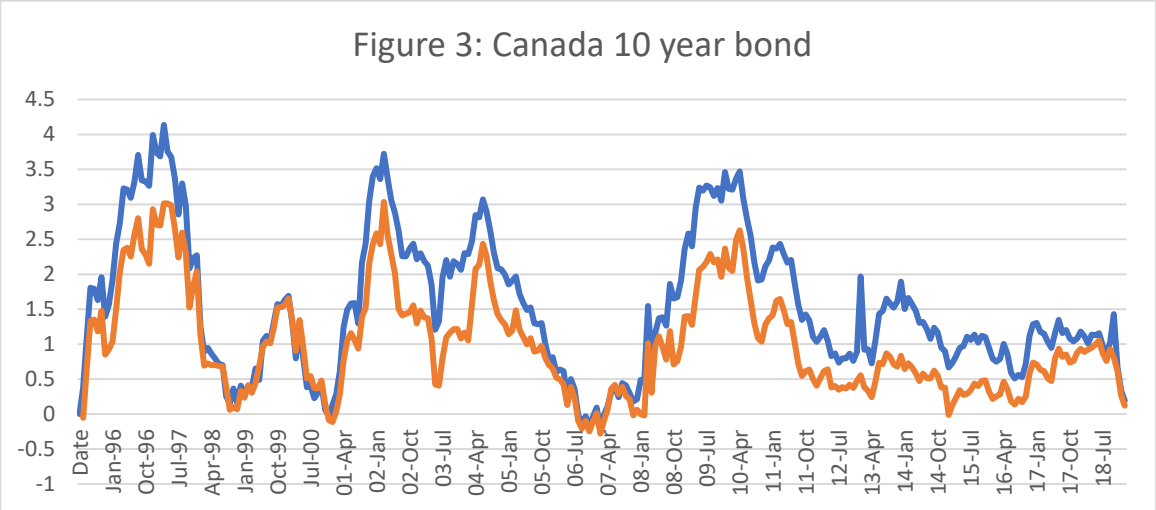

Figure 1. 3. Canada 10-Year Bond Spread, Source: www.investing.com

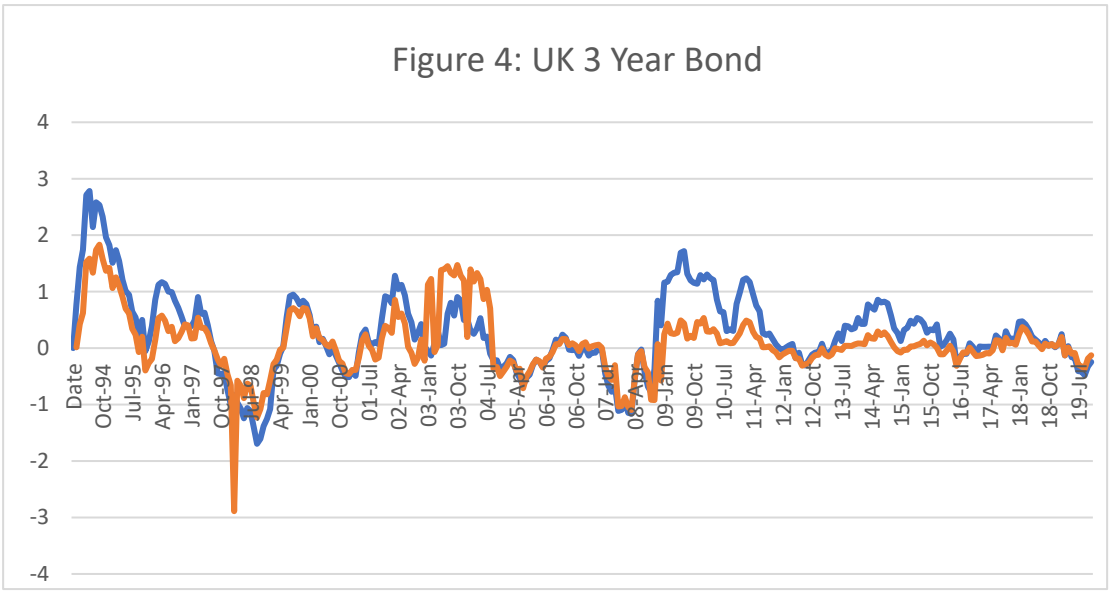

Figure 1. 4. U.K. 3-Year Bond Spread, Source: www.investing.com

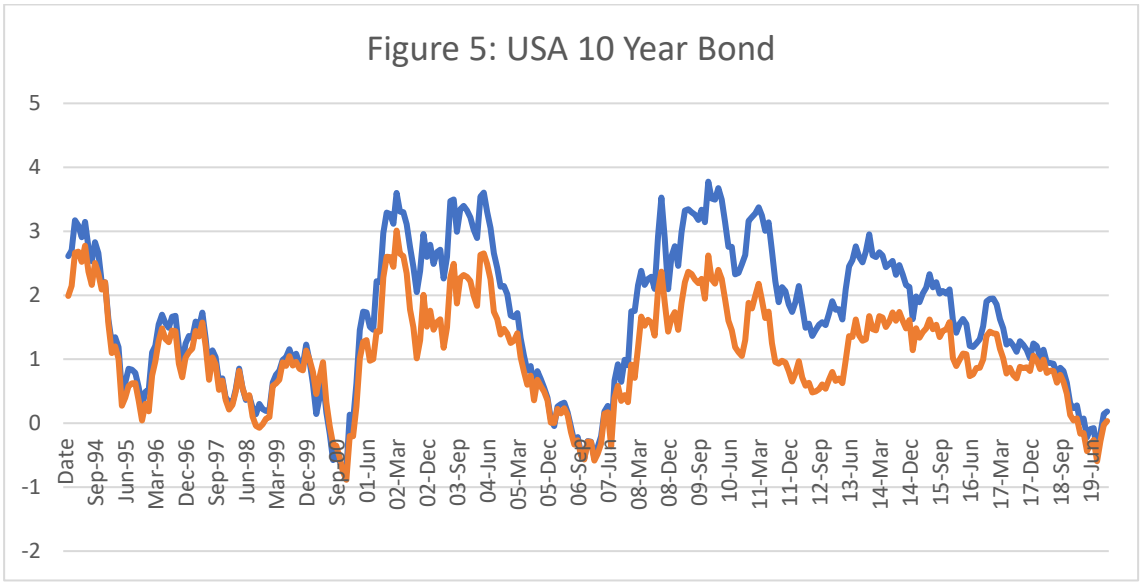

Figure 1. 5. U.S. 10-Year Bond Spread, Source: www.investing.com

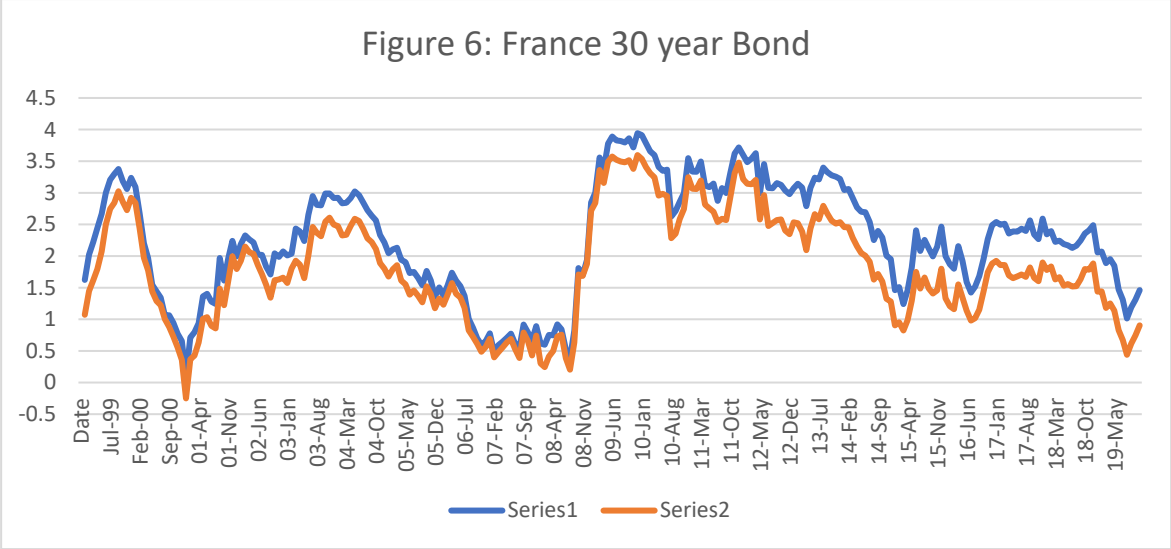

Figure 1. 6. France 30-Year Bond Yield, Source: www.investing.com

Generally, the EH posits that long term interest rates are a weighted average of current and future short term interest rates over the life of the long term security, plus a time invariant term premium (from the LP).According to the EH, the short-term and long-term yields follow a common stochastic trend and they are share a long run equilibrium, (Mustafa &Matiur 1995) that is, they are cointegrated. This is known as the Expectations Hypothesis Trend Stochastic model or EHTS. The EHTS is also applicable to the finance literature in the context of the pricing of fixed income securities and the assessment of interest rate derivatives Guerello and Tronzano (2016).

1.2 Empirical Evidence for Theories of the Term Structure

Several research papers extending back to the 1980's, and more recent investigations, provide support for the EHTS using empirical data for a variety of developed and emerging market economies (Arize et al, 2002; Robert and Giles, 1995; Keith C. et al,

2000; Engsted, 1994; Mankiw and Miron 1986; Rudebusch, 1995; Cuthbertson 1996a; Torricelli C., 1997).. Gerlach and Smets (1997) found evidence in favor of the EH or EHTS in 35 out of 51 cross sectional regression cases. They tested the EH simply using OLS method to infer their results. Arize et.al (2002) found a stable relationship between short term and long term interest rates, providing empirical support in favor of the EHTS using quarterly data and cointegration techniques.

The EH or EHTS was decisively rejected by other researchers (Campbell and Shiller (1991), Macdonald and Speight (1991) and alternately they provided statistical evidence for other theories. Thornton et al (2007) reinvestigated the term structure of US repo rates[1] ranging in maturity from overnight to three months in using statistical tests. Interestingly, the EH is rejected by their statistical tests, but their economic analyses are compatible with the EH model of the term structure. Very few studies have found evidence for the MS theory (Mustafa and Matiur, 1995), and even for the LP theory (Mankiw and Summers, 1984).Before 2000, the responsiveness of long-term bond yields to changes in short-term yields were similarly strong in the low and high frequencies, but this relationship has weakened substantially for recent years in the US, Canada, Germany and the UK (Hanson et al, 2018).

Additionally, policy makers need accurate forecasting instruments to obtain a useful understanding of the economy. Estrella and Mishkin (1997) consider the yield curve to be an authentic and straightforward measure of real economic activity and inflation and

[1] A repo is an overnight loan in the private money market that uses government securities as collateral.

explore the connection of term structure to monetary policy tools in a few European countries and for the US by using a VAR methodology. Although the results vary from country to country, the 3 month government rate is important for Germany, but this argument is rejected by Torricelli (1997), and a narrow money aggregate is vital for the US. Other interesting results about the term structure include that it contains independent information regarding future economic growth and inflation, and also a can be a good indicator of monetary policy for the European Central Bank.

The yield spread has become a "stylized fact" among macroeconomists to better explain the state of the economy. However, the yield spread is a pragmatic tool in forecasting economic activity in many major world economies, those of the US, Canada, and Europe, more importantly during financial crises. Movements in interest rates can be influenced by monetary policy and the monetary transmission mechanism and are needed to be guided so as to obtain economic stability. (Evgenidis, A. et al, 2018).

Longstaff (2000) tested the expectation hypothesis at the short end (short-term bonds) of the term structure using repo rates which could be a better estimate of the short-term riskless term structure than Treasury bill rates. In particular, this study employed a test conducted under the assumption that interest rates follow a VAR-GARCH method. Further, the EH model was tested in unconditional and conditional levels to get deeper implications of the term structure[2] The results from the unconditional and conditional

[2] Conditional being including the GARCH process for the error term.

tests are reconcilable with the pure form of the EH and it is also concluded that very short-term rates are better explained by the EH except for the one week repo rate.

Arize et al. (2002) estimates the long run relationship between long term and short term interest rates for 19 countries and also examines the possibilities of statistical stability using Lc, MeanF, and SupF statistics[3]. They found a very stable relationship between short term and long-term interest rates in most cases and also found considerable support for the EH model, except for the UK. They then analyzed the relationship between short term and long-term interest rates in a diverse spectrum. It is worth mentioning that they develop the dynamic structure of the model and test for cointegration using multivariate cointegration techniques.

Torricelli and Boero (1997) tested the EH model using two approaches and employed a monthly database of zero coupon bond yields over the period 1985(2) - 1994(12) for the German government bond market. The results provide evidence in favor of the EHTS model, except for the 3-month bond rate, and are strong in comparison to previous studies of the German government bond market.

Cuthbertson and Bredin (2000) examined the Irish spot rate [4]based on the quoted discount rate with a term to maturity of less than six months from January 1984 to October 1997 and the rates are converted to continuously compounded rates. Importantly they used a VAR methodology and also applied cointegration techniques. Their results

[3] Each of these tests is a parameter constancy test for an I(1) process.
[4] Current market value of a bond at the moment of the quote.

supported the EH and are largely compatible to recent findings for the UK, but not for the US. Though in general they accepted the EH model, they also postulated their results in different spectrums. Using the Johansen procedure for multivariate cointegration on the 1, 3 and 6 month interest rates, they argued that the cointegrating vector between any pair of interest rate is {1, -1}, giving weak evidence in support of the EH. From the perspectives of the perfect foresight and theoretical spreads, they found consistency with the EH.

Campbell and Shiller (1991) collected post-war US term structure data consisting of continuously compounded yields on riskless pure discount bonds ranging from maturities of one month to ten years. Their results are puzzling in some cases and also interesting for other cases. The yield spread is considered as a predictor of changes in future interest rates. Through arbitrage, a high yield spread directs the longer rate to fall and the short rate to rise. By regressing long and short rate data, they concluded that the EH model is rejected at the short end of the term structure and surprisingly not rejected at the long end (long term bond rates) of the term structure. Hence the slope of the term structure almost always provides an erroneous trend for the shorter change in the long term yield and produces a forecast in the right direction for longer term changes in shorter term yields. This fact is now coined the Campbell Shiller Paradox by Thornton (March 2006) and he provides an argument to resolute the paradox econometrically.

1.3 The Term Structure and Monetary Policy

Most economists agree on the notion that the short end of the yield curve largely reflects the monetary policy decision because the central bank sets the level of short term

interest rates through its choice of the overnight rate, but there is not much agreement on the determinants of long term interest rates. From other empirical tests it can be suggested that EHTS is more appropriate for the longer term yields instead of shorter yields. Employing data from emerging market economies could reveal interesting results for the Expectations Hypothesis, yield curve and monetary policy because these financial markets are well known by traders for their fast growth and volatility. Very few studies consider those markets (Ghazali and Soo- Wah, 2002; Benjamin, 2009; M. J. Holmes et al. 2011; Shareef and Shijin, (2017). Interestingly, for all of those countries the EH model cannot be rejected.

The term structure of interest rates is also vital to analyze the influence of alternative macroeconomics policies and there is a general belief that the monetary transmission mechanism depends on the behaviors of the term structure. Shareef and Shijin (2017) focused on the relationship between monetary policy and the yield curve and concluded that monetary policy and real economic activity are influenced by the behavior of the yield curve. Mankiw and Summers (1984) claim that, at least at the short end of the term structure, the Expectations Hypothesis is not very worthwhile in explaining the spread between short and long term interest rates. Additionally, they also decisively reject the alternative hypothesis that postulates that long rates are overly sensitive to the short rates. They demonstrated that spending decisions, asset valuations, impact of policies on future short term rates, predicting long term rates, and all these effects of policies on the shape of the yield curve may rely mostly on the liquidity premium, rather than on expectations theory.

We are also to trying to shed light on the relationship between the monetary transmission mechanism and interest rates at various maturities. Generally, the monetary policy action transmits to the economy through its effect on market interest rates. An expansionary monetary policy is congenial to economic activity and contractionary monetary policy effects conversely in the economy. The typical theoretical relationship between a monetary policy action and long term rates is positive and straightforward, but the empirical studies show a weak and less reliable connection. Numerous empirical studies are done by researchers to demonstrate and test this connection statistically and economically. In general studies are highlighted by Wood H., 1964;Rudebusch, 2002; Kung, 2015; Taylor B. and Williams C., 2011; and country specific researches are documented by, Rudebusch, 1995; Vance and Gordon, 1995; Cook and Hann, 1988; Kelilume, 2014; Buchholz et al, 2012; Smith and Taylor, 2007.

Vance and Gordon (1995) re-examined the relationship between monetary policy and market interest rates in regard to the standard theoretical view to challenge the effectiveness of monetary policy. The standard view recommends that the monetary transmission mechanism depends on the expectation theory of the term structure of interest rates. As the long term rates are the average of current short term rates and expected future short term rates, monetary policy should affect the long rates to the extent that it could leverage both current and future short term rates. On the contrary, the current and the expected future short term rates are increased due to the rise in the desired level of overnight borrowings, which pushes up the interest rate in all maturities. However, the results from Vance and Gordon (1995) revealed that the standard view and

the actual behavior of the relation between U.S. Federal Reserve policy action and the market interest rate are not consistent.

The systemic interlink between short and long term rates can regulate both the attribute of monetary transmission and the ability of the government to direct the real economy which is mostly inclined to longer term interest rates. On the contrary, the central authorities can only put more influential power on short term interest rates (Macdonald and Speight (1991).

An important recommendation derived from G. Bekaert et.al (1997) that researchers should use Monte Carlo experiments, rather than a VAR model with bias adjusted parameters, to evaluate the significance of the test statistics. The VAR model cannot resolve the biases which are raised from the rather small samples that are typically used.

The EH of the term structure also recommends that the monetary policy regulates long term rates by directly manipulating short term rates and by prompting a change in the market expectation of future short term rates. So, to investigate the reaction of long term rates to monetary policy actions, measures of both current short term rates and expected future short term rates are needed. Unfortunately, while it is simple to observe current short term rates, measures of expected future short term rates are not readily accessible.

Tabak (2009) has shown that the EH holds for the Brazilian interest rate under the maturities from 1 to 12 months. He made an inference that causality tests might not be the appropriate way to test the EH model because of the presence of nonstationary variables in the regression. Hence, a vector error correction model (VECM) and cointegration

techniques would be suitable to analyze the connection between short and long term interest rates.

Though from economic and statistical benchmarks, the EH model is crucial to assess the movements of long term yields in Canadian economy, however we found very few studies. Lange (1999) investigated the EH model in terms of the longer end of the term structure for Canadian interest rates and used three empirical techniques to test the hypothesis and found considerable support for the expectation hypothesis. The remainder of the thesis is organised as follows. Chapter 2 outlines the EHTS whilst Chapter 3 introduces data and Econometric methodology. The EHTS is tested and the results are interpreted in Chapter 4. Finally, Chapter 5 concludes the study.

CHAPTER 2: DEFINITION OF THEORY, DATA, VARIABLES AND ECONOMETRIC METHODOLOGY

2.1 The Expectation Theory of The Term Structure

In the world of perfect certainty and absolute foresight the traditional view of the term structure model the EH model posits that long term interest rates are a weighted average of current and future short term interest rates over the life of the long term security, plus a time invariant term premium. In particular, the EH is stated as return on n period bond R_t^n is merely determined by the expected return of current and future rates r_t^m, where n is the number of periods to maturity of a long-term bond and m is the set of short period rates whose maturities sum to m.

$$R_t^n = \frac{1}{K} \sum_{i=1}^{k-1} E_{t+i}\, r_{t+i}^m + \varepsilon \tag{2.1}$$

In (2.1), ε is the liquidity risk premium that may vary with n and m, but for simplicity we assume that does not change over time. The spread is proportional to the slope of the term structure (followed by Campbell and Shiller, 1991) between m and n. The spread can be obtained by subtracting very short-term rates from both sides of equation 1 and rearranging.

$$R_t^n - R_t^m = \frac{1}{K} \sum_{i=1}^{k-1} E_{t+i}\, r_{t+i}^m - R_t^m + \varepsilon \tag{2.2}$$

$$\frac{1}{K} \sum_{i=1}^{k-1} E_{t+i}\, r_{t+i}^m - R_t^m = R_t^n - R_t^m - \varepsilon \tag{2.3}$$

This is the spread between a long-term bond rate and a short-term bond rate which indicates the adjustment of long term rates with short rates in the EH of the term

structure. The difficulty is dealing with the first term in (2.3). In a world of uncertainty an individual at time t can only observe the current market short rate (of given short-term maturity) and the current market long rate on a bond which has maturity date n. However, he or she has to form an expectation about future rates. Investors are rational in the sense that they do not have information for future expected interest rates and thus cannot form their expectation of what their expectations will be in the future regarding rates. However, according to the law of iterative expectations market participants can acquire information from past and present interest rates in their information set $I_t = \{R_{t-1,}\ R_{t,\ldots\ldots}\}$ and they can form their expectation of their future expectations according to this dataset.[5] Accordingly, the rational expectation is given by

$$\frac{1}{K}\sum_{i=1}^{k-1} E_{t+i}\, r_{t+i}^{m} = \frac{1}{K}\sum_{i=1}^{k-1} E_t\, r_{t+i}^{m} \tag{2.4}$$

In (2.4), the right-side term is just the average of a set of short-term bond rates that mature in the same period as a long-term bond. Of course, there are different combinations of short-term bond rates that yield the same maturity as m. Parameterizing (2.4) results in the regression equation given by (2.5).

$$\left(\frac{1}{K}\sum_{i=1}^{k-1} E_t\, r_t^m - R_t^m\right) = \alpha + \beta\,(R_t^n - R_t^m) + u_t \tag{2.5}$$

In (2.5), the intercept is zero if the EH holds, β is the proportional to the slope of the yield curve and u is a random error term with $u_t \sim N(0, \sigma_u^2)$. The left-hand side of (2.5)

[5] Essentially the law of iterative expectations states that $E_t[E_{t+1} r_{t+2}] = E_t r_{t+2}$ of a future bond yield with a given maturity.

can be called the Average spread and right hand is depicted as the Actual spread. The EH is tested using (2.5) and testing the null hypothesis that β= 1, if the EH holds.

2.2 Data for Testing

To our best knowledge, very few works have been done on Canada, USA, UK and France bond rates of the term structure and the interest rate spread in recent decades. Appropriately, the econometric analysis will utilize data from a sample of those countries bond yields to investigate alternative explanations of the term structure. Furthermore, we will employ monthly data of short and long term bonds starting from 1995 to 2019.The most obvious representation of the term structure of interest rates is with spot rates on long-term government bonds of over one year maturity zero coupon bonds and Treasury bills yields are used for the short end of the term structure. Real return bonds are interesting, as those are adjusted for changes in the inflation rate.

The data used in our study are monthly data derived from http//www.investing.com. We have selected 1, 3,5,7,10,20,30 years bond for Canada; 2, 7,10 years bond for US and 2,3,4,5,10,20 and 30 year bond for UK and lastly 2,3,5,10,20, and 30 years bond for France. The data period runs from 1995:05 to 2019:01 for Canada, 1999:01 to 2019:11 for France, 1994:02 to 2019:11 for UK, 2008:07 to 2019:11 for US. The descriptive statistics for the bond yields used for each country are provided in the tables below.

Table 2.1 Descriptive Statistics for Canada Bond Yields

Variables	μ_{ac}	μ_{av}	σ^2_{ac}	σ^2_{av}	N

B1	0.356614	0.200667	0.116573	0.045188	285
B2	0.555337	0.356614	0.265769	0.116573	285
B3	0.734505	0.455975	0.404268	0.173278	285
B4	0.914568	0.54556	0.554431	0.217771	285
B5	1.050491	0.635591	0.646565	0.26228	285
B7	1.275572	0.824537	0.818212	0.47358	285
B10	1.544761	1.006011	0.987395	0.573425	285
B20	1.925519	1.539902	1.180697	0.984567	285
B30	1.98096	1.769919	1.288984	1.146442	285

Notes: B1-B30 are government bonds of maturities 1 to 30 years, ac and av refer to government bonds, actual spread, and average spread, respectively.

Table 2.2 Descriptive Statistics for US Bond Yields

Variables	μ_{ac}	μ_{av}	σ^2_{ac}	σ^2_{av}	N
B2	0.437949	0.196387	0.083705	0.0662959	137
B7	1.558086	0.776332	0.680202	0.200204	128
B10	1.626727	1.085309	1.225352	1.005104	311

Notes: B, ac and av refer to government Bonds, actual spread, and average spread, respectively.

Table 2.3 Descriptive Statistics for UK Bond Yields

Variables	μ_{ac}	μ_{av}	σ^2_{ac}	σ^2_{av}	N
B2	0.210044	-0.01614	0.725714	0.126509	310
B3	0.260476	0.096953	0.497538	0.295967	310

B4	4.132424	0.210044	333.9683	0.725714	310
B5	0.49525	0.235831	0.843336	0.502399	310
B10	0.841353	0.49525	1.578611	0.843336	310
B20	1.088598	0.841353	2.367553	1.578611	310
B30	5.112292	0.964976	402.4574	1.932404	310

Notes: B, ac and av refer to government Bonds, actual spread, and average spread respectively

Table 2.4 Descriptive Statistics for France Bond Yields

Variables	μ_{ac}	μ_{av}	σ^2_{ac}	σ^2_{av}	N
B2	0.307801	0.146355	0.145417	0.063201	251
B3	0.479928	0.227078	0.224554	0.094963	251
B5	0.877382	0.393865	0.384971	0.179623	251
B10	1.579498	0.877382	0.667019	0.667019	251
B20	2.068227	1.579498	0.807335	0.667019	251
B30	2.241191	1.823863	0.810033	0.727817	251

Notes: B, ac and av refer to government Bonds, actual spread, and average spread respectively.

CHAPTER 3: PORTFOLIO CONSTRUCTIONS

3.1 Arbitrage Portfolios

The EH of the term structure is tested by estimating (2.5) in the previous chapter. This requires the construction of a number of portfolios of short-term bonds whose maturity ends in the same period as a long-term bond. For instance, a 30-year long-term bond rate can be replicated in a portfolio including a 10-year bond held for 10 years (purchased today), followed by a 20-year bond held for 20 years (purchased 10 years from today). Since the yield on the 20-year bond purchased 10 years from today is not known, the law of iterative expectations dictates that the investor uses the current 20-year bond rate in his or her arbitrage decision.

The number of arbitrage portfolios is limited by the availability of bonds with different maturities. For Canada, the sample period contained bond rates that allowed the construction of the bond spreads detailed below.

3.1.1 Portfolio Construction for Canada, U.K., U.S., and France

To estimate (2.5) and test the EH, it necessary to construct the spread in bond yields using the EH. Each of the equations below describes how each bond spread at each different maturity was constructed for Canadian bond yields. The point is that the sum of the bond maturities in the portfolio must match the maturity of the long term bond. In every case, the spread in the long term yield is determined using the shortest maturity treasury bill (y represents the number of years and s the number of months of maturity).

$$R^{30y} - R^{1s} = \frac{R^{20y}+R^{10y}}{2} - R^{1s} \qquad (3.1)$$

$$R^{20y} - R^{1s} = \frac{R^{10y} + R^{10y}}{2} - R^{1s} \quad (3.2)$$

$$R^{10y} - R^{1s} = \frac{R^{7y} + R^{3y}}{2} - R^{1s} \quad (3.3)$$

$$R^{7y} - R^{1s} = \frac{R^{4y} + R^{3y}}{2} - R^{1s} \quad (3.4)$$

$$R^{5y} - R^{1s} = \frac{R^{3y} + R^{2y}}{2} - R^{1s} \quad (3.5)$$

$$R^{3y} - R^{1s} = \frac{R^{2y} + R^{1y}}{2} - R^{1s} \quad (3.6)$$

$$R^{1y} - R^{1s} = \frac{R^{6s} + R^{6s}}{2} - R^{1s} \quad (3.7)$$

The portfolio structures are as follows for U.S., U.K., and France.

U.S.

$$R^{10y} - R^{3s} = \frac{R^{5y} + R^{5y}}{2} - R^{3s} \quad (3.8)$$

$$R^{7y} - R^{1s} = \frac{R^{5y} + R^{2y}}{2} - R^{3s} \quad (3.9)$$

$$R^{2y} - R^{3s} = \frac{R^{1y} + R^{1y}}{2} - R^{3s} \quad (3.10)$$

U.K.

$$R^{30y} - R^{3s} = \frac{R^{20y} + R^{10y}}{2} - R^{3s} \quad (3.11)$$

$$R^{20y} - R^{3s} = \frac{R^{10y} + R^{10y}}{2} - R^{3s} \quad (3.12)$$

$$R^{10y} - R^{3s} = \frac{R^{7y} + R^{3y}}{2} - R^{3s} \quad (3.13)$$

$$R^{5y} - R^{3s} = \frac{R^{3y} + R^{2y}}{2} - R^{3s} \quad (3.14)$$

$$R^{4y} - R^{3s} = \frac{R^{2y} + R^{2y}}{2} - R^{3s} \quad (3.15)$$

$$R^{3y} - R^{3s} = \frac{R^{2y} + R^{1y}}{2} - R^{3s} \quad (3.16)$$

$$R^{2y} - R^{3s} = \frac{R^{1y} + R^{1y}}{2} - R^{3s} \quad (3.17)$$

France

$$R^{30y} - R^{1s} = \frac{R^{20y} + R^{10y}}{2} - R^{1s} \quad (3.18)$$

$$R^{20y} - R^{1s} = \frac{R^{10y} + R^{10y}}{2} - R^{1s} \quad (3.19)$$

$$R^{10y} - R^{1s} = \frac{R^{7y} + R^{3y}}{2} - R^{1s} \quad (3.20)$$

$$R^{5y} - R^{1s} = \frac{R^{3y} + R^{2y}}{2} - R^{1s} \quad (3.21)$$

$$R^{3y} - R^{1s} = \frac{R^{2y} + R^{1y}}{2} - R^{1s} \quad (3.22)$$

$$R^{2y} - R^{1s} = \frac{R^{1y} + R^{1y}}{2} - R^{1s} \quad (3.23)$$

The left side of the equation is denoted as the Actual spread and the right side represents the Average spread. Furthermore, the actual long-term bond is a dependent variable and average spread independent variable. The long-term bond market is much "thinner" than the short-term bond market, meaning it has less activity. It might be reasonable to assume that the short-term market moves first, then the long-term bond rate reacts, since the short-term rates are thought to be determined by expectations of investors. A lag order of 2 is used in our regression since the spread typically adjusts quickly in financial market - no later than 2 months.

Several statistical approaches are suggested by different authors to estimate the term structure. The estimation of the term structure will be based on a non-linear regression approach that is recommended by Campbell and Shiller (1987).The vector autoregressive model (VAR) can be used for infinitely long periods due to its convergence assumptions, while conversely for finite long periods, a modified VAR approach can be applied. Moreover, a VAR method can ignore the time-series structure of the error term in the system regression. Thornton (2006) recommends that a VAR is a better method to test the EH model, regardless of whether the interest rate is either stationary or nonstationary. The VAR is a dynamic model and it treats all variables as endogenous variables in a simultaneous system of equations. All variables in the VAR model are functions of each other unless exogeneity restrictions are imposed and tested. Moreover, computing impulse response functions and historical variance decompositions provide a reliable platform to better analyze the dynamic behavior of the VAR model of the term structure. Our purpose here is to determine if short-term and long-term rates share a long-run equilibrium relationship. This can be tested with cointegration techniques developed by Engle-Granger. Tabak (2009) argues that when interest rates of different maturities share a common long run trend, they are cointegrated, which is a natural consequence of EH.

Specifically, whether the expectation hypothesis is applicable to investors decision making for choosing bonds, first it is important to test if the spread equation is cointegrated, that the spreads have a long run relationship and are not drifting apart. This is quite standard in working with time series data. In this context a cointegration test (Engle-Granger) is performed to determine the stationarity of the spread. The Engle-

Granger test is a two-step regression procedure to test whether the cointegrating residuals are unit root. If the residuals have a unit root, it indicates that the variables do not have a constant variance and they are drifting apart over time.

A prerequisite in applying the cointegration procedure is to test the unit root properties of the time series. If the time series has unit root and dependent and independent variables are both I(1), then the first difference is required for our time series data to avoid spurious regression problem. In the event where both time series reject the null hypothesis of a unit root in the first stage of the Engle- Granger procedure, they are both stationary in levels and do not need to be first-differenced. Moreover, if the dependent and independent variable both are I(0), then the errors will be I(0) and the two variables are cointegrated. An OLS regression is run where it is applicable to interpret the value of β, coefficient of average spread. Particularly, a t test is performed to reach in a statistical conclusion of our regression results.

$t\ value = \frac{coefficient-1}{se}$, where the degrees of freedom are determined by n-k-1

Se = standard error of the slope coefficient, n= sample size, k= number of independent variables in the cointegrating regression

Additionally, the Durbin Watson test is a measure of serial correlation in residuals from a statistical regression analysis. The hypothesis for the Durbin Watson test:

H_0: error term is not correlated

H_1: error term is positively or negatively correlated

The D-W test statistics inferences for positive serial correlation are following based on lower and upper values with a significance level:

$D < D_{La,}$ we reject the null

$D > D_{Ua,}$ we do not reject the null

$D_{La} < D < D_{Ua,}$ the test is inconclusive

For negative serial correlation

$(4-D) < D_{La,}$ we reject the null

$(4-D) > D_{Ua,}$ we do not reject the null

$D_{La} < (4- D) < D_{Ua,}$ the test is inconclusive

3.2 Additional Items

3.2.1: Unit Root Tests

Unit root test is the test of non-stationarity and unit root in econometrics time series data. The null hypothesis indicates the presence of stationarity of variables and the alternative hypothesis is either stationary, trend stationary or spurious root based on the test. A very beginning and pioneering work of unit root for time series was conducted by Dicky and Fuller (Dicky and Fuller,1979, Fuller, 1976). In the context of our model, the presence of a unit root in the actual and average spread indicates that both variables are I(1) and if a unit root also exist in the residuals of a regression model, this represents a

non-constant variance. That is indicates that the variables are not cointegrated as the EH suggests. This test is covered in the next section.

The Dickey-Fuller unit root test is performed by estimating the regression model below. The test can be computed with or without an intercept in (3.24) depending upon whether a drift term is thought necessary. We included an intercept so as not to force the drift term to zero.

$$y_t = \alpha + \beta_1 y_{t-1} + \beta_2 (y_{t-1} - y_{t-2}) + e_t \tag{3.24}$$

The second term on the right-hand side of (3.24) is included in order to allow the testing of the restriction $\beta_1 = 1$. This can be tested using a t-test or an F-test, however the estimated value of β_1 will be biased towards zero, creating the possibility of a spurious rejection of the restriction. Dickey and Fuller (1979) computed critical values for the t and F tests using a bootstrap method.

3.2.2: Cointegration Test

The Engle-Granger method tests whether the two non-stationary time series variables are integrated together or drifting apart over time. If it does not hold, or in other words, if the two times series share a unit root, this is not supportive of a relationship of long and short term interest rates over the time period. The relationship of the actual and average spread over time being should not be drifting apart. If the two time series share a unit root, we can say that the data is difference stationary and the data should be first differenced. The first difference of time series is the series of changes from one period to next. In regard to our model, for instance actual spread is denoted as π_t and this is the

value of time series actual spread at time period t, then the first differencing of the actual spread at period t is equal to $\pi_t - \pi_{t-1}$.

Testing for the cointegration of only two time series is straightforward. The requirement is that each time series be difference stationary of the same order, otherwise the two series cannot be cointegrated. In this case, a regression model can still be estimated using least squares, however a long run equilibrium may not exist. If the two time series are both I(0), then they are both stationary in levels and differencing is not required. In this case, a cointegration test is not necessary and the regression model can be estimated using least squares. The first step is to estimate the cointegrating regression model $y_t = \alpha + \beta x_t + e_t$ where $e_t \sim N(0, \sigma_e^2)$. In our case, the dependent variable is the average spread and the independent variable is the actual spread at each bond maturity, as in equation (2.5). Next, the residuals are tested for a unit-root using the Dickey-Fuller test, or another method. If the null hypothesis of a unit root in the residuals is not rejected at a level of confidence, the two time series are not cointegrated, even though they are stationary of the same order. In the case of our test of the EH, an additional step is to test the null hypothesis that $\beta = 1$. If not rejected, the test suggests that the constructed portfolio spread is identical to the actual spread of two bond yields and the EH holds.

CHAPTER 4: EMPIRICAL RESULTS AND INTERPRETATION

In order test the empirical credibility of the EH theory of term structure for Canada, USA, UK and France Government bonds, equation (2.5) was estimated based on arbitrage portfolio. The time series data ranging from 1995 to 2019 and employing cointegration technique developed by Engle-Granger. The sample has a total of 6,855 observations. The following four tables present the summary of the results from the unit root tests of the actual and average spreads, as well as the cointegration test results.

4.1 Unit Root Test and Cointegration Test Results for Canada

Table 4.1 Summary Results for Canadian Government Bonds

Var.	P_{ac}	P_{av}	$\hat{\beta}$	$P_{\hat{\beta}}$	$\hat{\alpha}$	$P_{\hat{\alpha}}$	R^2	P_{re}	DW	N
B1	0.00078	0.00031	0.58831	< 0.0001	−0.00913	0.1275	0.89288	< 0.0001	0.773	282
B2	0.00362	0.00078	0.58466	< 0.0001	0.03193	0.0233	0.77932	0.02019	0.351	282
B3	0.01634	0.00188	0.61270	< 0.0001	0.00594	0.6558	0.87585	0.00101	0.445	282
B4	0.04023	0.00662	0.59238	< 0.0001	0.00379	0.7919	0.89341	0.01093	0.312	282
B5	0.07781	0.01455	0.60093	< 0.0001	0.00432	0.7947	0.89021	0.00654	0.303	282
B7	0.12380	0.02725	0.72813	< 0.0001	−0.10424	< 0.0001	0.91598	0.00207	0.298	282
B10	0.19480	0.05287	0.72648	< 0.0001	−0.11623	< 0.0001	0.90881	0.01075	0.294	282
B20	0.27800	0.20770	0.89900	< 0.0001	−0.19113	< 0.0001	0.96919	0.02267	0.214	282
B30	0.05949	0.03708	0.91970	< 0.0001	−0.05198	0.0614	0.95103	< 0.0001	1.381	282

Notes: P_{ac} and P_{av} are p-values from the unit-root tests for the actual spread and average spreads, respectively. The null hypothesis is a unit-root in each case. The estimated slope coefficient and intercept from the cointegrating regression in (2.5) is given by $\hat{\beta}$ and $\hat{\alpha}$ respectively, and their p-

values testing the null hypothesis that each is equal to zero are $P_{\hat{\beta}}$ and $P_{\hat{\alpha}}$ respectively. R^2 is the coefficient of determination from the cointegrating regression and DW is the Durbin-Watson statistic. The p-value for the unit-root test on the residuals from the cointegrating regression is given by P_{re}.

Table 4.2 First Differenced Results for Canada

Var.	$\hat{\beta}$	$P_{\hat{\beta}}$	$\hat{\alpha}$	$P_{\hat{\alpha}}$	R^2
B10	0.986279	< 0.0001	−0.00124155	0.8810	0.762558
B20	0.921216	< 0.0001	−0.00037842	0.9319	0.914183

Notes: The estimated slope coefficient and intercept from the cointegrating regression in (2.5) is given by $\hat{\beta}$ and $\hat{\alpha}$ respectively, and their p-values testing the null hypothesis that each is equal to zero are $P_{\hat{\beta}}$ and $P_{\hat{\alpha}}$ respectively. R^2 is the coefficient of determination from the cointegrating regression.

4.1.1 Analysis for One-Year Canadian Bonds

The p-value for the unit-root test for the actual spread is 0.00078, suggesting that the null hypothesis of a unit root is rejected at any reasonable level of confidence. Moreover, the p-value for the average spread is 0.00031, less than the critical value of 0.05 at 95% confidence, which also rejects a unit root. Both the actual spread and the average spread for Canadian one-year treasury bills are trend-stationary (I(0)) and a cointegration test is not necessary, however we proceeded with the cointegration test in order to obtain confirmation of our suspicion. The cointegration test tests for a unit root in the residuals of the cointegrating regression in (2.5) to determine if their variance is constant. For the residuals, a unit root is rejected as well as the p value is very small, much less than 0.05 at 95% confidence. The results suggest that a cointegrating relation exists between the actual and average spread for the one-year Canada treasury bill rate and our result is

statistically significant. The last step to find evidence in favor of the EH is to test the null hypothesis $H_o: \beta = 1$ as suggested in equation (2.5). The OLS regression of (2.5) suggests that its slope coefficient is significantly different from 1 with a t value of -33.987 > critical t value of 1.968 at 95% confidence. This result suggests evidence against the EH. In this maturity, the critical values for the Durbin-Watson test are $D_L = 1.7969$ and $D_U = 1.8112$ at the 5% significance level. Since DW = 0.773 < D_L, we reject the null hypothesis that error term is not serially uncorrelated. This suggests that the least squares regression model in (2.5) is mis-specified, possibly due to omitted variables. Although the results suggest that a long-run association exists between the average and actual spread at the one-year maturity, the EH is not confirmed.

4.1.2 Analysis for Longer Maturity Canadian Bonds

The results of the unit-root tests and cointegration tests for Canadian bonds of maturities from 2 to 30 years are summarized in Table 4.1. The null hypothesis of a unit root for the average and actual spreads is rejected in the case of the 2, 3 and 4-year maturities. Again, a cointegrating regression test is not necessary when both series are I(0), however we performed the test at each maturity to provide confirmation anyway. In each case, the p-value for the unit-root test of the residuals from the least squares regression of (2.5) rejected a unit root, suggesting that the residuals have constant variance and the two series are cointegrated. The hypothesis $H_o: \beta = 1$ from the cointegrating regression was rejected in each case at a very high level of confidence (t_2 =

-22.458, t_3 = -28.244, t_4 = -33.513). As is the case with the one-year bond, the results suggest evidence against the EH for the 2, 3 and 4-year bond maturities.

The p-values for the actual spread of the 5, 7 and 30-year Canadian bonds are 0.07781, 0.1238 and 0.05949, which are greater than critical value 0.05 at 95% confidence suggest that the null hypothesis of a unit root in their time series is not rejected. On the other hand, the p-value for the average spread for those bonds rejected the null hypothesis of a unit root at any reasonable level of confidence. In this case, the dependent variable in (2.5) is I(0) and the independent variable is I(1). Though in each case, the p-value for the unit-root test of the residuals from the least squares regression of (2.5) rejected a unit root, suggesting that the residuals have constant variance, but as the two series do not share the same time series process, we must conclude that no cointegrating relationship exists between short and long term interest rates for these maturities.

4.1.3 Analysis for Ten and Twenty-Year Canadian Bonds

Table 4.2 summarizes the results for the 10 and 20-year Canadian bonds. The null hypothesis of a unit root for the average and actual spreads could not be rejected in the case of the 10 and 20-year maturities as their p-values all fall above the 0.05 significance level. As the two series are both I(1), a cointegrating regression of the first difference of these spreads is necessary to insure the two series are stationary. In each case, the p-value for the unit-root test of the residuals from the least squares regression of (2.5) rejected a unit root, suggesting that the residuals have constant variance, and the two series are cointegrated. Unfortunately, the results in Table 4.2 also suggest that the slope coefficient

of the actual spread from the cointegrating regression is significantly below 1 in each case (t_{10} = -20.740, t_{20} = -8.829, less than critical t value of 1.96847 at 95% confidence). As is the case with all of the other Canadian bond maturities, the results indicate a rejection of the EH.

4.2 Unit Root Test and Cointegration Test Results for U.S.

Data limitations for U.S. bond yields did not allow for the same number of equivalent bond portfolios ((3.8) to (3.10)) as was the case for Canada. It is a somewhat surprising fact that the U.S. Treasury does feature as wide an array of bond maturities as does the Department of Finance in Canada. The results of the unit root test and cointegration tests are summarized in Tables 4.3 and 4.4.

Table 4.3 Summary Results for US Government Bonds

Var.	P_{ac}	P_{av}	$\hat{\beta}$	$P_{\hat{\beta}}$	$\hat{\alpha}$	$P_{\hat{\alpha}}$	R^2	P_{re}	DW	N
B2	0.1941	0.0034	0.47265	<0.0001	−0.01061	0.5007	0.64821	0.003	0.384	134
B7	0.5152	0.3207	0.51210	<0.0001	−0.02157	0.4443	0.89100	0.605	0.191	125
B10	0.1885	0.0246	0.68200	<0.0001	−0.02413	0.3509	0.89725	0.019	0.177	308

Notes: P_{ac} and P_{av} are p-values from the unit-root tests for the actual spread and average spreads, respectively. The null hypothesis is a unit-root in each case. The estimated slope coefficient and intercept from the cointegrating regression in (2.5) is given by $\hat{\beta}$ and $\hat{\alpha}$ respectively, and their p-values testing the null hypothesis that each is equal to zero are $P_{\hat{\beta}}$ and $P_{\hat{\alpha}}$ respectively. R^2 is the coefficient of determination from the cointegrating regression and DW is the Durbin-Watson statistic. The p-value for the unit-root test on the residuals from the cointegrating regression is given by P_{re}.

Table 4. 4 First Difference Results for U.S.

Var.	$\hat{\beta}$	$P_{\hat{\beta}}$	$\hat{\alpha}$	$P_{\hat{\alpha}}$	R^2
B7	0.700047	<0.0001	0.00331665	0.4614	0.902345

Notes: The estimated slope coefficient and intercept from the cointegrating regression in (2.5) is given by $\hat{\beta}$ and $\hat{\alpha}$ respectively, and their p-values testing the null hypothesis that each is equal to zero are $P_{\hat{\beta}}$ and $P_{\hat{\alpha}}$ respectively. R^2 is the coefficient of determination from the cointegrating regression.

4.2.1 Analysis for U.S. Bond Maturities

The results of the unit-root tests and cointegration tests for U.S. bonds of maturities from 2, 7 and 10 years are summarized in Table 4.3. Whilst the null hypothesis of a unit root could not be rejected for the actual spread in the cases of 2 and 10-year bonds, the null hypothesis of a unit root for average spread is rejected in both cases. Since the two time series are difference stationary of different orders, a cointegrating regression cannot exist, although the null hypothesis of a unit root in the residuals of the cointegrating regression is rejected at 95% confidence, this is misleading. In addition, the slope coefficients of the cointegrating regression are both significantly below 1, suggesting that EH is not supported for those bonds.

The p value for the actual spread of the 7-year USA bond is 0.5152, suggesting that a unit root is not rejected. Moreover, the p value for the average spread is 0.3207, also failing to reject the null hypothesis of a unit root. We conclude that both time series are difference stationery and should be first differenced before estimating the cointegrating regression in (2.5). These results are summarized in Table 4.4. For the residuals of the cointegrating regression, we are also unable to reject the unit root because the p value is 0.605, which is significantly larger than the 0.05 significance level. We conclude there is no cointegrating

relation that exists between the actual and average spread for the 7-year US bond. The OLS regression of the average spread indicates that slope coefficient of the actual spread is significantly different from unity because the t value is -14.56203 > critical t value 1.9794 at 95% confidence, which rejects the expectation hypothesis of the term structure. In this maturity, we found the critical Durbin-Watson test values D_L is 1.6919 and D_U is 1.7241 at the 5% significance level. Particularly, D = 1.826420 > D_U, we do not reject the null that error term is serially uncorrelated. This suggests that the least squares regression model in (2.5) is not mis-specified, but not a long-run relationship.

4.3 Unit Root Test and Cointegration Test Results for U.K.

The U.K. bond market features a broader range of maturities than the U.S., allowing for a larger number of equivalent portfolios to analyze ((3.11) to (3.17)). The results are broadly consistent with the results for Canadian bonds, that is, long-run relationships at most maturities but a lack of support for the EH. The results are summarized in Tables 4.5 and 4.6 below.

Table 4.5 Summary Results for UK Government Bonds

Var.	P_{ac}	P_{av}	$\hat{\beta}$	$P_{\hat{\beta}}$	$\hat{\alpha}$	$P_{\hat{\alpha}}$	R^2	P_{re}	DW	N
B2	0.00259	0.00153	0.22849	< 0.0001	−0.06413	0.0003	0.29950	0.00532	0.482	307
B3	0.00239	0.00301	0.60314	< 0.0001	−0.06015	0.0037	0.61154	0.00057	0.689	307
B4	< 0.0001	0.00259	0.01548	< 0.0001	0.14607	0.0020	0.11028	0.00208	0.496	307

B5	0.01505	0.00654	0.63478	< 0.0001	−0.07854	0.0028	0.67639	0.01061	0.487	307
B10	0.1535	0.01505	0.68733	< 0.0001	−0.08304	0.0001	0.88433	0.02902	0.117	307
B20	0.2354	0.1535	0.79902	< 0.0001	−0.02846	0.1160	0.95751	0.1058	0.120	370
B30	0.00160	0.1979	−0.00474	0.2299	0.989203	< 0.0001	0.00468	0.392	0.034	307

Notes: P_{ac} and P_{av} are p-values from the unit-root tests for the actual spread and average spreads, respectively. The null hypothesis is a unit-root in each case. The estimated slope coefficient and intercept from the cointegrating regression in (2.5) is given by $\hat{\beta}$ and $\hat{\alpha}$ respectively, and their p-values testing the null hypothesis that each is equal to zero are $P_{\hat{\beta}}$ and $P_{\hat{\alpha}}$ respectively. R^2 is the coefficient of determination from the cointegrating regression and DW is the Durbin-Watson statistic. The p-value for the unit-root test on the residuals from the cointegrating regression is given by P_{re}.

Table 4.6 First Difference Results for U.K.

Var.	$\hat{\beta}$	$P_{\hat{\beta}}$	$\hat{\alpha}$	$P_{\hat{\alpha}}$	R^2
B20	0.955337	<0.0001	−0.00100299	0.8274	0.900978

Notes: The estimated slope coefficient and intercept from the cointegrating regression in (2.5) is given by $\hat{\beta}$ and $\hat{\alpha}$ respectively, and their p-values testing the null hypothesis that each is equal to zero are $P_{\hat{\beta}}$ and $P_{\hat{\alpha}}$ respectively. R^2 is the coefficient of determination from the cointegrating regression.

4.3.1 Analysis for Two, Three, Four and Five-Year U.K. Bonds

The results of the unit-root tests and cointegration tests for UK bonds of maturities from 2 to 30 years are summarized in Table 4.5. The null hypothesis of a unit root for the actual and average spread are rejected for the 2, 3, 4 and 5-year bonds which indicate that both series I(0). It is not necessary to do a cointegration test when both series are I(0), however we performed the test regardless as an exercise. For the residuals of the

cointegrating regression in (2.5), the unit root is rejected because the p value is much smaller than the 5% significance level in all 4 cases. This evidence suggests that a long-run association exists between short and long-term bonds. As is the case with the Canadian and U.S. bonds, the hypothesis $H_o: \beta = 1$ from the cointegrating regression is rejected as the t values ($t_{2=}$ -38.747, $t_{3=}$ -14.489 , $t_{4=}$ -392.954 , $t_{5=}$ -14.598) are very much larger at any reasonable level of confidence. So, these conditions suggest evidence not in favor of the Expectation Hypothesis of the term structure, although we do find a long-run association.

4.3.2 Analysis for Ten, Twenty and Thirty-Year U.K. Bonds

For the 10-year U.K. bond, the p value of the unit root test for the actual spread is 0.1535, suggesting that we fail to reject the unit root null hypothesis, however the p value for the average spread is 0.01505, which rejects the unit null hypothesis root. The same divergent results was found for the 30-year U.K. bond: the p value for the actual spread is 0.00164, suggesting that null hypothesis of a unit root is rejected, however the p value for the average spread is 0.1979, significantly large than the .05 significance level and rejecting a unit root. Here the time series properties of the two series for both cases are different, one is I(1) and the other is I(0). This suggests that random shocks that hit the two series result in different behaviors. Shocks dissipate promptly for an I(0) process but have long run effects on an I(1) series. So, the relation between the actual spread and average spread cannot be cointegrated. We performed a cointegration test for each bond maturity as an exercise. The residuals in the 10-year bond reject a unit root because the p

value is much smaller than the .05 significance level, but a unit root in the residuals for the 30-year bond could not be rejected. This is a curious result for the 10-year bond but misleading since the two series are not stationary of the same order. The regression of (2.5) revealed t values that rejected the hypothesis $H_o: \beta = 1$ ($t_{10=}$ -22.074 , $t_{30=}$ -255.069) at any reasonable significance level, more than strong enough to say that EH is rejected for the 10 and 30-year UK bonds.

The null hypothesis of a unit root could not be rejected for the actual and average spreads for the 20-year U.K. bond. Since the two series are I(1), the data should be first differenced before estimating the cointegrating regression in (2.5). The results are summarized in Table 4.6. For the residuals of (2.5), a unit root is not rejected because the p value is 0.1058 significantly larger than the .05 significance level. So, it can be determined that a cointegrating relation does not exist between the actual and average spread for the 20-year UK bond. In addition, the OLS regression of (2.5) indicates that slope coefficient of the actual spread is significantly different from 1 where the t value is -2.47087 > critical t value 1.968 at 95% confidence. Unfortunately, this is not the only criterion to confirm the expectation hypothesis of term structure is rejected. In this maturity we found the Durbin-Watson critical values of D_L = 1.8073 and D_U = 1.8202 at the 5% significance level. Since, D = 0.106081< D_L, we reject the null that error term is serially uncorrelated. This suggests that the cointegrating regression model in (2.5) is mis-specified for this maturity.

4.4 Unit Root Test and Cointegration Test Results for France

The equivalent portfolio constructions for French bonds are given in (3.18) to (3.23). The results for France provide more clear evidence, but agree with, the results for Canada, the U.S. and the U.K. Shorter term bonds appear to display long-run associations between average and actual bond spreads, while the longer maturities do not. No evidence could be found in favor of the EH. The results are summarized in Tables 4.7 and 4.8.

Table 4.7 Summary Results for France Government Bonds

Var.	P_{ac}	P_{av}	$\hat{\beta}$	$P_{\hat{\beta}}$	$\hat{\alpha}$	$P_{\hat{\alpha}}$	R^2	P_{re}	DW	N
B2	0.00100	0.00048	0.58877	< 0.0001	−0.03487	0.0002	0.79759	0.01902	0.452	248
B3	0.00566	0.00058	0.60081	< 0.0001	−0.06127	< 0.0001	0.85357	0.00617	0.335	248
B5	0.04137	0.00274	0.62018	< 0.0001	−0.15027	< 0.0001	0.82433	0.01441	0.271	248
B10	0.1089	0.04137	0.70663	< 0.0001	−0.23874	< 0.0001	0.86516	0.0803	0.208	248
B20	0.1643	0.1089	0.88991	< 0.0001	−0.26104	< 0.0001	0.95854	0.1496	0.154	248
B30	0.1713	0.1358	0.92692	< 0.0001	−0.25355	< 0.0001	0.95624	0.3168	0.109	248

Notes: P_{ac} and P_{av} are p-values from the unit-root tests for the actual spread and average spreads, respectively. The null hypothesis is a unit-root in each case. The estimated slope coefficient and intercept from the cointegrating regression in (2.5) is given by $\hat{\beta}$ and $\hat{\alpha}$ respectively, and their p-values testing the null hypothesis that each is equal to zero are $P_{\hat{\beta}}$ and $P_{\hat{\alpha}}$ respectively. R^2 is the coefficient of determination from the cointegrating regression and DW is the Durbin-Watson statistic. The p-value for the unit-root test on the residuals from the cointegrating regression is given by P_{re}.

Table 4.8 First Differenced Results for France

Var.	$\hat{\beta}$	$P_{\hat{\beta}}$	$\hat{\alpha}$	$P_{\hat{\alpha}}$	R^2

B20	0.978621	<0.0001	−0.000686841	0.8682	0.924416
B30	0.978498	<0.0001	−6.19126e-06	0.9987	0.936629

Notes: The estimated slope coefficient and intercept from the cointegrating regression in (2.5) is given by $\hat{\beta}$ and $\hat{\alpha}$ respectively, and their p-values testing the null hypothesis that each is equal to zero are $P_{\hat{\beta}}$ and $P_{\hat{\alpha}}$ respectively. R^2 is the coefficient of determination from the cointegrating regression.

4.4.1 Analysis for Two, Three and Five-Year France Bonds

The results of the unit-root tests and cointegration tests for shorter-term France bonds are summarized in Table 4.7. The null hypothesis of a unit root for the average and actual spread is rejected in the case of the 2, 3, and 5-year maturities, implying that the pairs of spreads in each maturity are I(0) and a cointegration test is not necessary. However, we performed the test anyway as an exercise. In all three cases of maturities, the null hypothesis of a unit root in the residuals of (2.5) is rejected, suggesting that a long-run association exists. Also, the t values for the slope coefficient from the OLS regression of (2.5) (t_2=-21.87865, t_3= -25.31325, t_5= -20.93463) are much greater than critical t value of 1.9697 at 95% confidence. These suggest evidence rejecting the expectation hypothesis of the term structure for the 2, 3 and 5-year France government bonds.

4.4.2 Analysis of Long-Term France Bonds

The results for the 10, 20 and 30-year France bonds are summarized in Tables 4.7 and 4.8. The p value for the unit root test for the actual spread of the 10-year France bond is 0.1089, suggesting that we fail to reject the null hypothesis of a unit root. Moreover, the p value for the average spread is 0.04137, less than the.05 significance level, rejecting the

null hypothesis of a unit root. The results suggest that there is no cointegrating relation between the actual and average spread for 10-year France bonds since the two time series are stationary of different orders. As per our practice, we estimated the cointegrating regression anyway as an exercise. The p-value for the unit-root test of the residuals from the least squares regression of (2.5) could not reject a unit root, suggesting that the residuals do not have constant variance and confirming that the two series are not cointegrated. In addition, the test of the hypothesis $H_o: \beta = 1$ produced a t value of -16.59447, rejecting the null hypothesis at any reasonable level of confidence. The EH is rejected for the 10-year France bond. The Durbin-Watson test statistic of 0.208 strongly suggests that residuals of (2.5) are positively serially correlated and the regression model is mis-specified.

The null hypothesis of a unit root for the average and actual spreads could not be rejected in the case of the 20 and 30-year maturities. This indicates that the data should be first-differenced before estimating the cointegrating regression in (2.5). These results are summarized in Table 4.8. From the residuals, we are unable to reject a unit root for both maturities, suggesting that there is no cointegrating relation between the actual and average spread for 20 and 30-year France bonds and our result is statistically significant. The OLS regression of (2.5) found that the slope coefficient of the actual spread is very close to 1 in both cases, but not close enough to find evidence in favor of the EH (t_{20}= -3.229 and t_{30}= -2.706) at 95% confidence.

4.5. Further Interpretation

Overall, we do not find supportive evidence for the EH for any of the maturities for any of the four countries since we are unable to accept the hypothesis that $\beta = 1$ at any reasonable level of confidence. More specifically, for the Canadian bond markets 1,2,3,4,5,7,10,20 and 30-year bond have shown no supportive evidence to the EH and for the U.S 2,7,10 year bond follows the same track. The results for France and UK also agree with, the results for Canada, the U.S. In earlier research works on US bond market researchers have found very little evidence in favor of EHTS whilst France data on bond markets are not consistent with the EHTS. The deviation from the expectation theory might be caused by difference in risk premium which could make an arbitrage between dependent and independent variable in our model. Also, the transactions costs make it difficult for investors to trade between short and long-term bonds. Short and long-terms bonds have different properties that might not be reflected in their relative yields, such as risk and liquidity.

Moreover, investors do not perceive short and long-term bonds as substitutes, as EHTs suggest, that could lead to support the market segmentation theory where short and long-term interest rate are determined separately by different market forces. One can plot yields of different maturities on a graph, but there is not really a yield curve that links them.

Broadly speaking, these results are consistent with previous empirical evidence on the failure of the expectation hypothesis and to the role of the term premia . Based on the finding, those countries central bank has a poor ability to influence the long rate through

monetary policy adjustments of short rates. Since, under the expectation hypothesis investors are risk neutral and their expectations are rational. In contrary, where the expectation hypothesis is rejected, these behaviours of investors might not hold for the bonds selected.

CHAPTER 5: CONCLUDING REMARKS

The EH theory thus plays a vital rule in economics and finance literature and not surprisingly has been tested with wide varieties data and method from developed to emerging market economies. Many of the empirical research papers cited in Chapters 1 and 2 have struggled to find evidence in favor of the EH across varieties of datasets, countries and with sophisticated testing procedures. This paper has provided new empirical evidence concerning the relationship between short term and long-term interest rates, as predicted by the EH of the yield curve, for four developed countries with monthly time series data over the period 1995-2019. Generally, the empirical evidence rejects the expectations theory of the term structure of interest rates for Canada, USA, UK, and France, and our results are statistically significant. In addition, the empirical results could not find support for a long-run association between long-term bond spreads and short-term bond spreads. However, shorter term bonds appear to display a long-run relationship between average and actual bond spreads based on cointegration tests, providing confirmation of a yield curve relationship, while the longer maturities do not.

Though in many cases we found that a long run relationship exists between spreads, there is a lack of extensive evidence in support of the EH at any maturity. The Engle-Granger cointegration test and OLS were used to estimate the equilibrium relationship between the spreads of short and long-term interest rates, including tests for serial correlation in their residuals, and to test the empirical validity of the EH. The rejection of the EHTS implies that arbitrage activities are unable to eliminate any excess profit from trading between maturities. This could happen for a number of reasons. First, the

Campbell and Shiller (1991) method assumes that any risk premium embedded in a bond yield is constant over time. The changing behavior of this component over time introduces bias into the testing of the EH. Second, the EH assumes that bonds of different maturities are strong substitutes in the eyes of investors. Instead, it could be the case that investors do not view short and long-term bonds as substitutes, rather they are independent financial products with unique features. Thus, we may have found support for the market segmentation theory where short and long rates are not substitutable. Third, transactions costs are assumed to be negligible or zero in the EH. Although these costs have certainly fallen with the development of internet trading, they are not zero and could drive a wedge between bond yields of different maturities if the volume of transactions is much thinner at longer maturities.

The results found in this study are consistent with some of the existing literature where the EH is rejected, principally Macdonald and Speight (1991) and Thorton et al (2007). They differ in the data and methodology used here, as we used longer time series data and documented a precise and concrete statistical estimation procedure to infer our results. We have highlighted the fact that as the EH is far from our expected result, it is reasonably assumed that the short-term yield spread fails to correctly predict the movement of longer-term interest rates as the EH argues. The rejection of the EHTS implies that the yield spread between long and short-term rate may not be an optimal predictor of future changes in short rates over the life of the long-term bond. Due to missing observations, the availability of bond maturities is not the same for all countries. The findings could be directed in a different way if data were collected from other

emerging market economies. Since the study encountered a limitation of observations for a specific country, it is suggested that future research can be conducted adding more observations and even more countries from emerging to developed countries. In addition to that, several other researchers use different econometric methodologies, so in the future, the same sample of data could be tested using different methods such as a Vector Error Correction model (VECM) that uses a Johansen test procedure. Furthermore, future studies can be conducted on how other market efficiency models, such as the MS theory behaves statistically where the EH fails.

Appendix 1: Gretl Results for Canada

Canada 1 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spead

Augmented Dickey-Fuller test for Average_spead
including 2 lags of (1-L)Average_spead
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.186471
  test statistic: tau_c(1) = -4.38539
  asymptotic p-value 0.0003098
  1st-order autocorrelation coeff. for e: -0.008
  lagged differences: F(2, 278) = 4.529 [0.0116]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.148355
  test statistic: tau_c(1) = -4.15764
  asymptotic p-value 0.000775
  1st-order autocorrelation coeff. for e: -0.007
  lagged differences: F(2, 278) = 0.996 [0.3707]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1995:05-2019:01 (T = 285)
Dependent variable: Average_spead

                 coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const          -0.00913396   0.00597533   -1.529    0.1275
  Actual_spread   0.588313     0.0121132    48.57     2.68e-139 ***

Mean dependent var   0.200667   S.D. dependent var   0.212574
Sum squared resid    1.374728   S.E. of regression   0.069697
R-squared            0.892878   Adjusted R-squared   0.892500
Log-likelihood       355.7308   Akaike criterion    -707.4615
Schwarz criterion   -700.1565   Hannan-Quinn        -704.5331
rho                  0.612356   Durbin-Watson        0.773426

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 282
```

```
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.338287
  test statistic: tau_c(2) = -5.95198
  asymptotic p-value 1.413e-006
  1st-order autocorrelation coeff. for e: -0.007
  lagged differences: F(2, 279) = 1.580 [0.2077]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Canada 2 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.148355
  test statistic: tau_c(1) = -4.15764
  asymptotic p-value 0.000775
  1st-order autocorrelation coeff. for e: -0.007
  lagged differences: F(2, 278) = 0.996 [0.3707]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.108642
  test statistic: tau_c(1) = -3.73884
  asymptotic p-value 0.003618
  1st-order autocorrelation coeff. for e: -0.009
  lagged differences: F(2, 278) = 0.322 [0.7248]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1995:05-2019:01 (T = 285)
Dependent variable: Average_spread
                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------

  const            0.0319308    0.0140024     2.280    0.0233    **
  Actual_spread    0.584660     0.0184942    31.61     7.45e-095 ***
```

```
Mean dependent var   0.356614   S.D. dependent var   0.341427
Sum squared resid    7.305990   S.E. of regression   0.160674
R-squared            0.779319   Adjusted R-squared   0.778540
Log-likelihood       117.6933   Akaike criterion    −231.3865
Schwarz criterion   −224.0815   Hannan-Quinn        −228.4581
rho                  0.824070   Durbin-Watson        0.351209

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 282
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.12969
  test statistic: tau_c(2) = -3.66736
  asymptotic p-value 0.02019
  1st-order autocorrelation coeff. for e: -0.023
  lagged differences: F(2, 279) = 4.584 [0.0110]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Canada 3 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.124792
  test statistic: tau_c(1) = -3.9236
  asymptotic p-value 0.001875
  1st-order autocorrelation coeff. for e: -0.007
  lagged differences: F(2, 278) = 0.226 [0.7982]

Step 2: testing for a unit root in ActualSpread

Augmented Dickey-Fuller test for ActualSpread
including 2 lags of (1-L)ActualSpread
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0778063
  test statistic: tau_c(1) = -3.26923
  asymptotic p-value 0.01634
  1st-order autocorrelation coeff. for e: -0.001
```

```
  lagged differences: F(2, 278) = 0.434 [0.6486]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1995:05-2019:01 (T = 285)
Dependent variable: Average_spread

                coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const          0.00593981    0.0133113     0.4462   0.6558
  ActualSpread   0.612706      0.0137124    44.68     3.14e-130 ***

Mean dependent var   0.455975   S.D. dependent var   0.416267
Sum squared resid    6.109460   S.E. of regression   0.146929
R-squared            0.875852   Adjusted R-squared   0.875413
Log-likelihood       143.1803   Akaike criterion    -282.3605
Schwarz criterion   -275.0555   Hannan-Quinn        -279.4321
rho                  0.773832   Durbin-Watson        0.444572

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 282
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.185595
  test statistic: tau_c(2) = -4.53893
  asymptotic p-value 0.001012
  1st-order autocorrelation coeff. for e: -0.010
  lagged differences: F(2, 279) = 2.550 [0.0799]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Canada 4 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0999553
  test statistic: tau_c(1) = -3.55897
  asymptotic p-value 0.006622
  1st-order autocorrelation coeff. for e: -0.002
  lagged differences: F(2, 278) = 0.347 [0.7074]
```

```
Step 2: testing for a unit root in Actual_spready

Augmented Dickey-Fuller test for Actual_spready
including 2 lags of (1-L)Actual_spready
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0623935
  test statistic: tau_c(1) = -2.94621
  asymptotic p-value 0.04023
  1st-order autocorrelation coeff. for e: -0.002
  lagged differences: F(2, 278) = 0.401 [0.6702]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1995:05-2019:01 (T = 285)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const            0.00378650    0.0143345     0.2642   0.7919
  Actual_spready   0.592381      0.0121631    48.70     1.33e-139 ***

Mean dependent var   0.545560   S.D. dependent var   0.466659
Sum squared resid    6.592357   S.E. of regression   0.152626
R-squared            0.893409   Adjusted R-squared   0.893032
Log-likelihood       132.3399   Akaike criterion    −260.6798
Schwarz criterion   −253.3749   Hannan-Quinn        −257.7515
rho                  0.841325   Durbin-Watson        0.311627

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 282
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.130795
  test statistic: tau_c(2) = -3.86867
  asymptotic p-value 0.01093
  1st-order autocorrelation coeff. for e: -0.002
  lagged differences: F(2, 279) = 2.689 [0.0697]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Canada 5 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spreadx
```

```
Augmented Dickey-Fuller test for Average_spreadx
including 2 lags of (1-L)Average_spreadx
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.086399
  test statistic: tau_c(1) = -3.30816
  asymptotic p-value 0.01455
  1st-order autocorrelation coeff. for e: -0.003
  lagged differences: F(2, 278) = 0.177 [0.8377]

Step 2: testing for a unit root in Actual_spready

Augmented Dickey-Fuller test for Actual_spready
including 2 lags of (1-L)Actual_spready
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0519753
  test statistic: tau_c(1) = -2.67821
  asymptotic p-value 0.07781
  1st-order autocorrelation coeff. for e: -0.007
  lagged differences: F(2, 278) = 0.287 [0.7509]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1995:05-2019:01 (T = 285)
Dependent variable: Average_spreadx

                   coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const            0.00432009    0.0165847     0.2605   0.7947
  Actual_spready   0.600929      0.0125446    47.90     8.68e-138 ***

Mean dependent var   0.635591   S.D. dependent var   0.512133
Sum squared resid    8.177728   S.E. of regression   0.169990
R-squared            0.890213   Adjusted R-squared   0.889825
Log-likelihood       101.6307   Akaike criterion    -199.2614
Schwarz criterion   -191.9564   Hannan-Quinn        -196.3330
rho                  0.846473   Durbin-Watson        0.303349

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 282
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.135437
  test statistic: tau_c(2) = -4.02637
  asymptotic p-value 0.006542
  1st-order autocorrelation coeff. for e: -0.006
```

```
  lagged differences: F(2, 279) = 0.616 [0.5409]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Canada 7 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in AverageSpread

Augmented Dickey-Fuller test for AverageSpread
including 2 lags of (1-L)AverageSpread
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0688209
  test statistic: tau_c(1) = -3.09098
  asymptotic p-value 0.02725
  1st-order autocorrelation coeff. for e: -0.002
  lagged differences: F(2, 278) = 0.443 [0.6427]

Step 2: testing for a unit root in ActualSpread

Augmented Dickey-Fuller test for ActualSpread
including 2 lags of (1-L)ActualSpread
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0433785
  test statistic: tau_c(1) = -2.46646
  asymptotic p-value 0.1238
  1st-order autocorrelation coeff. for e: -0.000
  lagged differences: F(2, 278) = 0.857 [0.4255]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1995:05-2019:01 (T = 285)
Dependent variable: AverageSpread

                coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const          −0.104243    0.0204862    −5.088    6.59e-07  ***
  ActualSpread    0.728128    0.0131085    55.55     3.10e-154 ***

Mean dependent var   0.824537   S.D. dependent var   0.688172
Sum squared resid    11.29987   S.E. of regression   0.199822
R-squared            0.915984   Adjusted R-squared   0.915687
Log-likelihood       55.54952   Akaike criterion    −107.0990
Schwarz criterion   −99.79407   Hannan-Quinn        −104.1707
rho                  0.849245   Durbin-Watson        0.297651

Step 4: testing for a unit root in uhat
```

```
Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 282
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.146834
  test statistic: tau_c(2) = -4.3528
  asymptotic p-value 0.002066
  1st-order autocorrelation coeff. for e: -0.004
  lagged differences: F(2, 279) = 0.001 [0.9993]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Canada 10 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0564842
  test statistic: tau_c(1) = -2.8391
  asymptotic p-value 0.05287
  1st-order autocorrelation coeff. for e: -0.002
  lagged differences: F(2, 278) = 0.753 [0.4719]

Step 2: testing for a unit root in ActualSpreadx

Augmented Dickey-Fuller test for ActualSpreadx
including 2 lags of (1-L)ActualSpreadx
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0383071
  test statistic: tau_c(1) = -2.23244
  asymptotic p-value 0.1948
  1st-order autocorrelation coeff. for e: -0.007
  lagged differences: F(2, 278) = 0.259 [0.7722]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1995:05-2019:01 (T = 285)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
```

```
  ------------------------------------------------------------
  const            -0.116239    0.0251139    -4.628    5.62e-06  ***
  ActualSpreadx     0.726487    0.0136800    53.11     3.41e-149 ***

Mean dependent var   1.006011   S.D. dependent var   0.757248
Sum squared resid    14.85137   S.E. of regression   0.229081
R-squared            0.908805   Adjusted R-squared   0.908483
Log-likelihood       16.60412   Akaike criterion    -29.20823
Schwarz criterion   -21.90325   Hannan-Quinn        -26.27985
rho                  0.851910   Durbin-Watson        0.293737

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 282
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.127942
  test statistic: tau_c(2) = -3.87401
  asymptotic p-value 0.01075
  1st-order autocorrelation coeff. for e: -0.003
  lagged differences: F(2, 279) = 1.906 [0.1507]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Model 2: OLS, using observations 1995:06-2019:01 (T = 284)
Dependent variable: d_Average_spread

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	0.00110623	0.00733730	0.1508	0.8803	
d_ActualSpreadx	0.773166	0.0256916	30.09	<0.0001	***

Mean dependent var	0.000616	S.D. dependent var	0.253307
Sum squared resid	4.311590	S.E. of regression	0.123650
R-squared	0.762558	Adjusted R-squared	0.761716
F(1, 282)	905.6584	P-value(F)	4.88e-90
Log-likelihood	191.6702	Akaike criterion	−379.3405
Schwarz criterion	−372.0425	Hannan-Quinn	−376.4146
rho	−0.203287	Durbin-Watson	2.401171

Canada 20 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spreadx

Augmented Dickey-Fuller test for Average_spreadx
including 2 lags of (1-L)Average_spreadx
sample size 282
```

```
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0345266
  test statistic: tau_c(1) = -2.19655
  asymptotic p-value 0.2077
  1st-order autocorrelation coeff. for e: -0.008
  lagged differences: F(2, 278) = 0.851 [0.4279]

Step 2: testing for a unit root in Actual_spready

Augmented Dickey-Fuller test for Actual_spready
including 2 lags of (1-L)Actual_spready
sample size 282
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.027708
  test statistic: tau_c(1) = -2.0208
  asymptotic p-value 0.278
  1st-order autocorrelation coeff. for e: -0.015
  lagged differences: F(2, 278) = 2.214 [0.1112]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1995:05-2019:01 (T = 285)
Dependent variable: Average_spreadx

                   coefficient   std. error   t-ratio    p-value
  ------------------------------------------------------------------
  const             −0.191136    0.0210562    −9.077    1.95e-017 ***
  Actual_spready     0.898998    0.00952761   94.36     6.70e-216 ***

Mean dependent var   1.539902   S.D. dependent var   0.992254
Sum squared resid    8.614128   S.E. of regression   0.174467
R-squared            0.969193   Adjusted R-squared   0.969084
Log-likelihood       94.22220   Akaike criterion    −184.4444
Schwarz criterion   −177.1394   Hannan-Quinn        −181.5160
rho                  0.892678   Durbin-Watson        0.214243

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 282
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.102113
  test statistic: tau_c(2) = -3.62764
  asymptotic p-value 0.02267
  1st-order autocorrelation coeff. for e: 0.002
  lagged differences: F(2, 279) = 1.219 [0.2971]

There is evidence for a cointegrating relationship if:
```

```
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Model 1: OLS, using observations 1995:06-2019:01 (T = 284)
Dependent variable: d_Average_spread

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	0.000323862	0.00458890	0.07058	0.9438	
d_Actual_spready	0.992366	0.0181058	54.81	<0.0001	***

Mean dependent var	−0.000602	S.D. dependent var	0.263517
Sum squared resid	1.686470	S.E. of regression	0.077333
R-squared	0.914183	Adjusted R-squared	0.913878
F(1, 282)	3004.053	P-value(F)	2.1e-152
Log-likelihood	324.9613	Akaike criterion	−645.9226
Schwarz criterion	−638.6246	Hannan-Quinn	−642.9967
rho	−0.126197	Durbin-Watson	2.250450

Canada 30 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average

Augmented Dickey-Fuller test for Average
including 2 lags of (1-L)Average
sample size 295
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.060644
  test statistic: tau_c(1) = -2.9773
  asymptotic p-value 0.03708
  1st-order autocorrelation coeff. for e: -0.021
  lagged differences: F(2, 291) = 2.713 [0.0680]

Step 2: testing for a unit root in Actual

Augmented Dickey-Fuller test for Actual
including 2 lags of (1-L)Actual
sample size 295
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0451964
  test statistic: tau_c(1) = -2.79123
  asymptotic p-value 0.05949
  1st-order autocorrelation coeff. for e: -0.025
  lagged differences: F(2, 291) = 1.614 [0.2008]

Step 3: cointegrating regression
```

```
Cointegrating regression -
OLS, using observations 1995:05-2020:02 (T = 298)
Dependent variable: Average

             coefficient   std. error   t-ratio    p-value
  ---------------------------------------------------------
  const      -0.0519786    0.0276861    -1.877    0.0614    *
  Actual      0.919705     0.0121308    75.82     6.19e-196 ***

Mean dependent var   1.769919   S.D. dependent var   1.070721
Sum squared resid    16.67540   S.E. of regression   0.237352
R-squared            0.951026   Adjusted R-squared   0.950860
Log-likelihood       6.746985   Akaike criterion    -9.493970
Schwarz criterion   -2.099783   Hannan-Quinn        -6.534145
rho                  0.308132   Durbin-Watson        1.381184

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 295
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.452853
  test statistic: tau_c(2) = -6.35153
  asymptotic p-value 1.581e-007
  1st-order autocorrelation coeff. for e: -0.002
  lagged differences: F(2, 292) = 15.006 [0.0000]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Appendix 2: GRETL Results for U.S.

USA 2 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 134
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.165962
  test statistic: tau_c(1) = -3.7539
  asymptotic p-value 0.003432
  1st-order autocorrelation coeff. for e: -0.114
  lagged differences: F(2, 130) = 1.174 [0.3124]
```

```
Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 134
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0874762
  test statistic: tau_c(1) = -2.23447
  asymptotic p-value 0.1941
  1st-order autocorrelation coeff. for e: -0.028
  lagged differences: F(2, 130) = 1.610 [0.2039]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 2008:07-2019:11 (T = 137)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const           −0.0106088    0.0157121    −0.6752   0.5007
  Actual_spread    0.472648     0.0299676    15.77     2.01e-032 ***

Mean dependent var   0.196387   S.D. dependent var   0.169846
Sum squared resid    1.380158   S.E. of regression   0.101111
R-squared            0.648212   Adjusted R-squared   0.645607
Log-likelihood       120.5536   Akaike criterion    −237.1071
Schwarz criterion   −231.2672   Hannan-Quinn        −234.7339
rho                  0.795117   Durbin-Watson        0.383831

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 134
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.217796
  test statistic: tau_c(2) = -4.22226
  asymptotic p-value 0.003323
  1st-order autocorrelation coeff. for e: -0.064
  lagged differences: F(2, 131) = 0.681 [0.5077]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

USA 7 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread
```

```
Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 125
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0645223
  test statistic: tau_c(1) = -1.92548
  asymptotic p-value 0.3207
  1st-order autocorrelation coeff. for e: -0.010
  lagged differences: F(2, 121) = 1.042 [0.3560]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 125
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0379919
  test statistic: tau_c(1) = -1.53658
  asymptotic p-value 0.5152
  1st-order autocorrelation coeff. for e: -0.004
  lagged differences: F(2, 121) = 0.147 [0.8637]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 2009:04-2019:11 (T = 128)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const           −0.0215678    0.0281059    −0.7674   0.4443
  Actual_spread    0.512103     0.0159566    32.09     1.71e-062 ***

Mean dependent var   0.776332   S.D. dependent var   0.447442
Sum squared resid    2.771359   S.E. of regression   0.148307
R-squared            0.891003   Adjusted R-squared   0.890138
Log-likelihood       63.66819   Akaike criterion    −123.3364
Schwarz criterion   −117.6323   Hannan-Quinn        −121.0188
rho                  0.904362   Durbin-Watson        0.190811

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 125
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0720298
  test statistic: tau_c(2) = -1.85076
  asymptotic p-value 0.605
```

```
  1st-order autocorrelation coeff. for e: 0.007
  lagged differences: F(2, 122) = 2.648 [0.0749]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Model 1: OLS, using observations 2009:05-2019:11 (T = 127)
Dependent variable: d_Average_spread

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	0.00331665	0.00448903	0.7388	0.4614	
d_Actual_spread	0.700047	0.0205983	33.99	<0.0001	***

Mean dependent var	−0.010177	S.D. dependent var	0.160610
Sum squared resid	0.317400	S.E. of regression	0.050391
R-squared	0.902345	Adjusted R-squared	0.901564
F(1, 125)	1155.022	P-value(F)	5.37e-65
Log-likelihood	200.2727	Akaike criterion	−396.5455
Schwarz criterion	−390.8571	Hannan-Quinn	−394.2343
rho	−0.046664	Durbin-Watson	2.067329

USA 10 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 308
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.062753
  test statistic: tau_c(1) = -3.12823
  asymptotic p-value 0.02456
  1st-order autocorrelation coeff. for e: 0.004
  lagged differences: F(2, 304) = 0.446 [0.6407]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 308
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0336184
```

```
  test statistic: tau_c(1) = -2.25048
  asymptotic p-value 0.1885
  1st-order autocorrelation coeff. for e: 0.012
  lagged differences: F(2, 304) = 1.401 [0.2480]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1994:01-2019:11 (T = 311)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
  ------------------------------------------------------------
  const           −0.0241245    0.0258202    −0.9343   0.3509
  Actual_spread    0.682003     0.0131291    51.95     9.97e-155 ***

Mean dependent var   1.085309   S.D. dependent var   0.797002
Sum squared resid    20.23259   S.E. of regression   0.255886
R-squared            0.897253   Adjusted R-squared   0.896920
Log-likelihood      −16.38642   Akaike criterion     36.77283
Schwarz criterion    44.25242   Hannan-Quinn         39.76252
rho                  0.910057   Durbin-Watson        0.177437

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 308
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0898976
  test statistic: tau_c(2) = -3.68375
  asymptotic p-value 0.01924
  1st-order autocorrelation coeff. for e: -0.005
  lagged differences: F(2, 305) = 0.292 [0.7469]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Appendix 3: GRETL Results for U.K.

UK 2 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
```

```
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.122374
  test statistic: tau_c(1) = -3.97806
  asymptotic p-value 0.001534
  1st-order autocorrelation coeff. for e: -0.010
  lagged differences: F(2, 303) = 3.992 [0.0194]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.145725
  test statistic: tau_c(1) = -3.8342
  asymptotic p-value 0.002587
  1st-order autocorrelation coeff. for e: -0.018
  lagged differences: F(2, 303) = 10.751 [0.0000]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1994:02-2019:11 (T = 310)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
  ------------------------------------------------------------
  const           −0.0641312    0.0174438    −3.676    0.0003    ***
  Actual_spread    0.228496     0.0199115    11.48     1.28e-025 ***

Mean dependent var  −0.016137   S.D. dependent var   0.355680
Sum squared resid    27.38320   S.E. of regression   0.298172
R-squared            0.299504   Adjusted R-squared   0.297230
Log-likelihood      −63.74132   Akaike criterion     131.4826
Schwarz criterion    138.9558   Hannan-Quinn         134.4701
rho                  0.758987   Durbin-Watson        0.481803

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 307
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.161252
  test statistic: tau_c(2) = -4.08767
  asymptotic p-value 0.005318
  1st-order autocorrelation coeff. for e: -0.012
  lagged differences: F(2, 304) = 12.671 [0.0000]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

UK 3 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Averagespread

Augmented Dickey-Fuller test for Averagespread
including 2 lags of (1-L)Averagespread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.127001
  test statistic: tau_c(1) = -3.79081
  asymptotic p-value 0.003017
  1st-order autocorrelation coeff. for e: -0.009
  lagged differences: F(2, 303) = 5.814 [0.0033]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.070536
  test statistic: tau_c(1) = -3.85561
  asymptotic p-value 0.002398
  1st-order autocorrelation coeff. for e: -0.033
  lagged differences: F(2, 303) = 4.609 [0.0107]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1994:02-2019:11 (T = 310)
Dependent variable: Averagespread

                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const           −0.0601512    0.0205666    −2.925    0.0037    ***
  Actual_spread    0.603144     0.0273909    22.02     3.33e-065 ***

Mean dependent var   0.096953   S.D. dependent var   0.544029
Sum squared resid    35.52616   S.E. of regression   0.339624
R-squared            0.611540   Adjusted R-squared   0.610279
Log-likelihood      −104.0940   Akaike criterion     212.1879
Schwarz criterion    219.6611   Hannan-Quinn         215.1754
rho                  0.653225   Durbin-Watson        0.689342

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 307
```

```
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.226679
  test statistic: tau_c(2) = -4.68275
  asymptotic p-value 0.0005685
  1st-order autocorrelation coeff. for e: -0.031
  lagged differences: F(2, 304) = 12.783 [0.0000]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

UK 4 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.145725
  test statistic: tau_c(1) = -3.8342
  asymptotic p-value 0.002587
  1st-order autocorrelation coeff. for e: -0.018
  lagged differences: F(2, 303) = 10.751 [0.0000]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.087283
  test statistic: tau_c(1) = -5.67173
  asymptotic p-value 7.084e-007
  1st-order autocorrelation coeff. for e: -0.007
  lagged differences: F(2, 303) = 0.526 [0.5914]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1994:02-2019:11 (T = 310)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio   p-value
  -------------------------------------------------------------
```

```
  const            0.146074     0.0468702     3.117    0.0020   ***
  Actual_spread    0.0154800    0.00250543    6.179    2.05e-09 ***

Mean dependent var   0.210044   S.D. dependent var   0.851889
Sum squared resid    199.5168   S.E. of regression   0.804849
R-squared            0.110276   Adjusted R-squared   0.107387
Log-likelihood      -371.5665   Akaike criterion     747.1330
Schwarz criterion    754.6062   Hannan-Quinn         750.1205
rho                  0.745097   Durbin-Watson        0.496236

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 307
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.178514
  test statistic: tau_c(2) = -4.35146
  asymptotic p-value 0.002076
  1st-order autocorrelation coeff. for e: -0.012
  lagged differences: F(2, 304) = 9.181 [0.0001]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

UK 5 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.096247
  test statistic: tau_c(1) = -3.56272
  asymptotic p-value 0.006542
  1st-order autocorrelation coeff. for e: -0.016
  lagged differences: F(2, 303) = 2.180 [0.1149]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
```

```
  estimated value of (a - 1): -0.0489566
  test statistic: tau_c(1) = -3.29692
  asymptotic p-value 0.01505
  1st-order autocorrelation coeff. for e: -0.029
  lagged differences: F(2, 303) = 5.566 [0.0042]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1994:02-2019:11 (T = 310)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
  ------------------------------------------------------------
  const           −0.0785448    0.0260705    −3.013    0.0028    ***
  Actual_spread    0.634781     0.0250182    25.37     1.92e-077 ***

Mean dependent var   0.235831   S.D. dependent var   0.708801
Sum squared resid    50.23695   S.E. of regression   0.403865
R-squared            0.676394   Adjusted R-squared   0.675344
Log-likelihood      −157.7986   Akaike criterion     319.5972
Schwarz criterion    327.0704   Hannan-Quinn         322.5847
rho                  0.755467   Durbin-Watson        0.487233

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 307
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.154014
  test statistic: tau_c(2) = -3.878
  asymptotic p-value 0.01061
  1st-order autocorrelation coeff. for e: -0.019
  lagged differences: F(2, 304) = 14.084 [0.0000]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

UK 10 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread


Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
```

```
  estimated value of (a - 1): -0.0489566
  test statistic: tau_c(1) = -3.29692
  asymptotic p-value 0.01505
  1st-order autocorrelation coeff. for e: -0.029
  lagged differences: F(2, 303) = 5.566 [0.0042]

Step 2: testing for a unit root in Actua_spread

Augmented Dickey-Fuller test for Actua_spread
including 2 lags of (1-L)Actua_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0272976
  test statistic: tau_c(1) = -2.35943
  asymptotic p-value 0.1535
  1st-order autocorrelation coeff. for e: -0.025
  lagged differences: F(2, 303) = 3.405 [0.0345]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1994:02-2019:11 (T = 310)
Dependent variable: Average_spread

                coefficient   std. error   t-ratio    p-value
  ------------------------------------------------------------
  const          −0.0830438    0.0213942    −3.882    0.0001    ***
  Actua_spread    0.687338     0.0141644    48.53     2.63e-146 ***

Mean dependent var   0.495250   S.D. dependent var   0.918333
Sum squared resid    30.14242   S.E. of regression   0.312834
R-squared            0.884330   Adjusted R-squared   0.883955
Log-likelihood      −78.62193   Akaike criterion     161.2439
Schwarz criterion    168.7170   Hannan-Quinn         164.2313
rho                  0.941785   Durbin-Watson        0.116851

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 307
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0688461
  test statistic: tau_c(2) = -3.5404
  asymptotic p-value 0.02902
  1st-order autocorrelation coeff. for e: -0.017
  lagged differences: F(2, 304) = 1.211 [0.2993]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0272976
  test statistic: tau_c(1) = -2.35943
  asymptotic p-value 0.1535
  1st-order autocorrelation coeff. for e: -0.025
  lagged differences: F(2, 303) = 3.405 [0.0345]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0195964
  test statistic: tau_c(1) = -2.12365
  asymptotic p-value 0.2354
  1st-order autocorrelation coeff. for e: -0.023
  lagged differences: F(2, 303) = 8.763 [0.0002]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1994:02-2019:11 (T = 310)
Dependent variable: Average_spread

                 coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const          −0.0284604    0.0180584    −1.576    0.1160
  Actual_spread   0.799022     0.00959120   83.31     2.68e-213 ***

Mean dependent var   0.841353   S.D. dependent var   1.256428
Sum squared resid    20.72787   S.E. of regression   0.259419
R-squared            0.957507   Adjusted R-squared   0.957369
Log-likelihood      −20.58149   Akaike criterion     45.16299
Schwarz criterion    52.63613   Hannan-Quinn         48.15044
rho                  0.941235   Durbin-Watson        0.120270

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 307
```

```
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0607566
  test statistic: tau_c(2) = -3.01916
  asymptotic p-value 0.1058
  1st-order autocorrelation coeff. for e: -0.016
  lagged differences: F(2, 304) = 0.293 [0.7460]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Model 1: OLS, using observations 1994:03-2019:11 (T = 309)
Dependent variable: d_Average_spread

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	−0.00100299	0.00459694	−0.2182	0.8274	
d_Actual_spread	0.955337	0.0180758	52.85	<0.0001	***

Mean dependent var	−0.005913	S.D. dependent var	0.256323
Sum squared resid	2.003811	S.E. of regression	0.080790
R-squared	0.900978	Adjusted R-squared	0.900655
F(1, 307)	2793.315	P-value(F)	3.4e-156
Log-likelihood	339.9639	Akaike criterion	−675.9278
Schwarz criterion	−668.4611	Hannan-Quinn	−672.9426
rho	0.016772	Durbin-Watson	1.964177

UK 30 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 307
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0226873
  test statistic: tau_c(1) = -2.22363
  asymptotic p-value 0.1979
  1st-order autocorrelation coeff. for e: -0.025
  lagged differences: F(2, 303) = 5.934 [0.0030]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 307
```

```
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0911727
  test statistic: tau_c(1) = -3.96606
  asymptotic p-value 0.001604
  1st-order autocorrelation coeff. for e: -0.003
  lagged differences: F(2, 303) = 2.777 [0.0638]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1994:02-2019:11 (T = 310)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const            0.989203     0.0814253    12.15     5.20e-028 ***
  Actual_spread   -0.00473901   0.00393909   -1.203    0.2299

Mean dependent var   0.964976   S.D. dependent var   1.390109
Sum squared resid    594.3199   S.E. of regression   1.389104
R-squared            0.004677   Adjusted R-squared   0.001446
Log-likelihood      -540.7520   Akaike criterion     1085.504
Schwarz criterion    1092.977   Hannan-Quinn         1088.491
rho                  0.982962   Durbin-Watson        0.033529

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 307
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0232219
  test statistic: tau_c(2) = -2.26194
  asymptotic p-value 0.392
  1st-order autocorrelation coeff. for e: -0.022
  lagged differences: F(2, 304) = 7.147 [0.0009]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Appendix 4: GRETL Results for France

France 2 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 248
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.151753
  test statistic: tau_c(1) = -4.27924
  asymptotic p-value 0.0004776
  1st-order autocorrelation coeff. for e: -0.015
  lagged differences: F(2, 244) = 3.486 [0.0322]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 248
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.135886
  test statistic: tau_c(1) = -4.09104
  asymptotic p-value 0.001003
  1st-order autocorrelation coeff. for e: -0.007
  lagged differences: F(2, 244) = 0.426 [0.6534]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1999:01-2019:11 (T = 251)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const           −0.0348696    0.00920000   −3.790    0.0002    ***
  Actual_spread    0.588771     0.0187959    31.32     2.38e-088 ***

Mean dependent var   0.146355   S.D. dependent var   0.251398
Sum squared resid    3.198017   S.E. of regression   0.113329
R-squared            0.797597   Adjusted R-squared   0.796784
Log-likelihood       191.3931   Akaike criterion    −378.7863
Schwarz criterion   −371.7354   Hannan-Quinn        −375.9488
rho                  0.774663   Durbin-Watson        0.452201

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 248
```

```
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.159134
  test statistic: tau_c(2) = -3.68764
  asymptotic p-value 0.01902
  1st-order autocorrelation coeff. for e: 0.002
  lagged differences: F(2, 245) = 8.049 [0.0004]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

France 3 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Averagespread

Augmented Dickey-Fuller test for Averagespread
including 2 lags of (1-L)Averagespread
sample size 248
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.142112
  test statistic: tau_c(1) = -4.23136
  asymptotic p-value 0.0005785
  1st-order autocorrelation coeff. for e: -0.013
  lagged differences: F(2, 244) = 1.410 [0.2461]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 248
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.102611
  test statistic: tau_c(1) = -3.60709
  asymptotic p-value 0.005655
  1st-order autocorrelation coeff. for e: -0.009
  lagged differences: F(2, 244) = 0.634 [0.5313]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1999:01-2019:11 (T = 251)
Dependent variable: Averagespread

                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const           −0.0612679    0.0106256    −5.766    2.39e-08  ***
  Actual_spread    0.600810     0.0157700    38.10     7.21e-106 ***
```

```
Mean dependent var   0.227078   S.D. dependent var   0.308161
Sum squared resid    3.476326   S.E. of regression   0.118157
R-squared            0.853571   Adjusted R-squared   0.852983
Log-likelihood       180.9208   Akaike criterion    -357.8416
Schwarz criterion   -350.7907   Hannan-Quinn        -355.0041
rho                  0.832047   Durbin-Watson        0.335493

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 248
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.151116
  test statistic: tau_c(2) = -4.04358
  asymptotic p-value 0.006174
  1st-order autocorrelation coeff. for e: 0.009
  lagged differences: F(2, 245) = 5.615 [0.0041]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

France 5 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Avearge_spread

Augmented Dickey-Fuller test for Avearge_spread
including 2 lags of (1-L)Avearge_spread
sample size 248
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.115501
  test statistic: tau_c(1) = -3.81761
  asymptotic p-value 0.002744
  1st-order autocorrelation coeff. for e: -0.009
  lagged differences: F(2, 244) = 0.586 [0.5574]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 248
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0684707
  test statistic: tau_c(1) = -2.93553
  asymptotic p-value 0.04137
  1st-order autocorrelation coeff. for e: -0.010
  lagged differences: F(2, 244) = 0.499 [0.6080]
```

```
Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1999:01-2019:11 (T = 251)
Dependent variable: Avearge_spread

                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const            −0.150271    0.0194837    −7.713    2.96e-013 ***
  Actual_spread     0.620181    0.0181431    34.18     5.11e-096 ***

Mean dependent var   0.393865   S.D. dependent var   0.423819
Sum squared resid    7.888425   S.E. of regression   0.177990
R-squared            0.824334   Adjusted R-squared   0.823628
Log-likelihood       78.08351   Akaike criterion    −152.1670
Schwarz criterion   −145.1161   Hannan-Quinn        −149.3296
rho                  0.864322   Durbin-Watson        0.271917

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 248
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.128103
  test statistic: tau_c(2) = -3.77981
  asymptotic p-value 0.01441
  1st-order autocorrelation coeff. for e: -0.002
  lagged differences: F(2, 245) = 2.248 [0.1078]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

France 10 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 248
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0684707
  test statistic: tau_c(1) = -2.93553
  asymptotic p-value 0.04137
  1st-order autocorrelation coeff. for e: -0.010
  lagged differences: F(2, 244) = 0.499 [0.6080]

Step 2: testing for a unit root in Actual_spread
```

```
Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 248
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0463418
  test statistic: tau_c(1) = -2.52733
  asymptotic p-value 0.1089
  1st-order autocorrelation coeff. for e: -0.016
  lagged differences: F(2, 244) = 2.124 [0.1218]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1999:01-2019:11 (T = 251)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const            -0.238742    0.0314221    -7.598    6.09e-013 ***
  Actual_spread     0.706633    0.0176786    39.97     2.49e-110 ***

Mean dependent var   0.877382   S.D. dependent var   0.620460
Sum squared resid    12.97702   S.E. of regression   0.228290
R-squared            0.865164   Adjusted R-squared   0.864622
Log-likelihood       15.61170   Akaike criterion    -27.22340
Schwarz criterion   -20.17249   Hannan-Quinn        -24.38594
rho                  0.896056   Durbin-Watson        0.208013

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 248
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0922982
  test statistic: tau_c(2) = -3.1416
  asymptotic p-value 0.0803
  1st-order autocorrelation coeff. for e: -0.001
  lagged differences: F(2, 245) = 1.439 [0.2393]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

France 20 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 248
```

```
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0463418
  test statistic: tau_c(1) = -2.52733
  asymptotic p-value 0.1089
  1st-order autocorrelation coeff. for e: -0.016
  lagged differences: F(2, 244) = 2.124 [0.1218]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 248
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0393672
  test statistic: tau_c(1) = -2.32423
  asymptotic p-value 0.1643
  1st-order autocorrelation coeff. for e: -0.019
  lagged differences: F(2, 244) = 1.962 [0.1428]

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1999:01-2019:11 (T = 251)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
  ------------------------------------------------------------
  const            −0.261042    0.0264402    −9.873    1.29e-019 ***
  Actual_spread     0.889912    0.0117290    75.87     4.06e-174 ***

Mean dependent var   1.579498   S.D. dependent var   0.816712
Sum squared resid    6.913796   S.E. of regression   0.166632
R-squared            0.958539   Adjusted R-squared   0.958373
Log-likelihood       94.63415   Akaike criterion    −185.2683
Schwarz criterion   −178.2174   Hannan-Quinn        −182.4308
rho                  0.919530   Durbin-Watson        0.154019

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 248
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0722772
  test statistic: tau_c(2) = -2.8526
  asymptotic p-value 0.1496
  1st-order autocorrelation coeff. for e: -0.001
  lagged differences: F(2, 245) = 1.110 [0.3313]

There is evidence for a cointegrating relationship if:
```

```
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Model 1: OLS, using observations 1999:02-2019:11 (T = 250)
Dependent variable: d_Average_spread

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	0.000624611	0.00406172	0.1538	0.8779	
d_Actual_spread	0.944611	0.0171517	55.07	<0.0001	***

Mean dependent var	−0.000320	S.D. dependent var	0.233124
Sum squared resid	1.022829	S.E. of regression	0.064221
R-squared	0.924416	Adjusted R-squared	0.924111
F(1, 248)	3033.126	P-value(F)	4.4e-141
Log-likelihood	332.6265	Akaike criterion	−661.2529
Schwarz criterion	−654.2100	Hannan-Quinn	−658.4183
rho	−0.144080	Durbin-Watson	2.282486

France 30 Year Bond Regression Result Analysis

```
Step 1: testing for a unit root in Average_spread

Augmented Dickey-Fuller test for Average_spread
including 2 lags of (1-L)Average_spread
sample size 248
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0424071
  test statistic: tau_c(1) = -2.42111
  asymptotic p-value 0.1358
  1st-order autocorrelation coeff. for e: -0.018
  lagged differences: F(2, 244) = 2.149 [0.1188]

Step 2: testing for a unit root in Actual_spread

Augmented Dickey-Fuller test for Actual_spread
including 2 lags of (1-L)Actual_spread
sample size 248
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0384233
  test statistic: tau_c(1) = -2.30214
  asymptotic p-value 0.1713
  1st-order autocorrelation coeff. for e: -0.030
  lagged differences: F(2, 244) = 2.215 [0.1114]
```

```
Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 1999:01-2019:11 (T = 251)
Dependent variable: Average_spread

                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const            -0.253552    0.0303391    -8.357    4.56e-015 ***
  Actual_spread     0.926924    0.0125654    73.77     3.33e-171 ***

Mean dependent var   1.823863   S.D. dependent var   0.853122
Sum squared resid    7.961553   S.E. of regression   0.178813
R-squared            0.956244   Adjusted R-squared   0.956069
Log-likelihood       76.92546   Akaike criterion    -149.8509
Schwarz criterion   -142.8000   Hannan-Quinn        -147.0135
rho                  0.945507   Durbin-Watson        0.109121

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 2 lags of (1-L)uhat
sample size 248
unit-root null hypothesis: a = 1

  test without constant
  model: (1-L)y = (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0518325
  test statistic: tau_c(2) = -2.41671
  asymptotic p-value 0.3168
  1st-order autocorrelation coeff. for e: -0.002
  lagged differences: F(2, 245) = 0.773 [0.4627]

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

Model 1: OLS, using observations 1999:02-2019:11 (T = 250)
Dependent variable: d_Average_spread

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	−3.58983e-05	0.00371595	−0.009661	0.9923	
d_Actual_spread	0.957211	0.0158104	60.54	<0.0001	***

Mean dependent var	−0.000660	S.D. dependent var	0.232927
Sum squared resid	0.856108	S.E. of regression	0.058754
R-squared	0.936629	Adjusted R-squared	0.936374
F(1, 248)	3665.485	P-value(F)	1.4e-150
Log-likelihood	354.8679	Akaike criterion	−705.7358
Schwarz criterion	−698.6928	Hannan-Quinn	−702.9012
rho	−0.127996	Durbin-Watson	2.255632

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