The impact of the term spread in US monetary policy from 1870 – 2013.

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1. Introduction

Over the years, central banks have sought to maintain an efficient monetary policy in order to keep price stability and economic development under control despite the different cycles. For this reason, modeling the term structure of interest rates, based on the Expectations Hypothesis of Term Structure (EHTS here after), is viewed as crucial to determining the impact of monetary policies and the transmission mechanism, playing an important role in macroeconomic predictions and in portfolio analysis (Li and Davis, 2017) or stimulating economic activity (Igan *et al.*, 2017) and promoting higher earnings for the firms in the economy (Ioannidis and Kontonikas, 2008); thus, changes in short-term interest rates usually impact on long-term interest rates, and if this occurs, we can conclude that the monetary policy is effective (Holmes *et al.* 2015). Moreover, the EHTS is accepted as a predictive instrument (Mankiw and Miron (1986); Poole *et al.* (2002) or Adrian and Estrella (2008)) or because it has deep implications for monetary policy (e.g., Weber and Wolters (2012, 2013). Indeed, when monetary policy is effective, changes in short-term policy interest rates should impact long-term ones. Furthermore, attending to the difference in the relationship between short and long-term interest rates with different maturities, i.e., the term spread or the slope of the yield curve, contain significant information on future changes in short-term rates. In this respect, the term spread is an important determinant of the predictive power of the current monetary policy, which is influenced in turn by current economic activity. So, the term spread includes expectations of future activity (Estrella, 2005). In fact and concerning this latter idea, Estrella and Hardouvelis (1990; 1991) evidenced that the yield curve may be used as a predictor of real growth in consumption, investment, and aggregate GNP, as well as NBER-dated recessions, i.e., this power to control is due to the term spread offering significant information regarding the effects of shocks in the long run. Thus, one can assume that the term spread is a leading indicator of growth and recessions. In this sense, the correct modelling of the term spread will be a key in as much as its degree of persistence would mark the considerations and the implications relative to the monetary policy and its subsequent impact to the economy. In this line, some authors expose that, depending on its integration degree, a long memory spread would offer adequate forecasting power at longer horizons (Baillie and Bollerslev, 1994) and, more importantly, this would have implications for the controllability of interest rates (see Cassola and Morana (2008), Hassler and Nautz (2008) or Cömert, (2012)).

According to this idea, the treatment of both short- and long-term interest rates may permit us to compare the properties of these time series and the behaviour of the term spread as an term structure of interest rates control, jointly. Thus, this work revises recent US economic history (since 1870) in order to check how the major economic events impact on the macroeconomic time series, which may have intense and long-lasting effects, representing the long-term development of an economy, such as interest rates. Focusing on the U.S. economy, we can appreciate different shocks into its economy across the time (Darne and Charles, 2011). The historical US interest dates have suffered many variations and shocks since the 19Th century, such as different 'panics' by the end of 19th century, World War I (1914), the Great Depression (1929), World War II (1939), the oil price crises in 1973 and 1978 and/or the subprime mortgage crisis (2007)[1] and its aftermath (see Gil-Alana *et al.* (2017) or Egea and Hierro (2019).

[1] Among others, those events will be deeply explained in the following section.

In this sense, the analysis of the possible relationship between short- and long-term interest rates have been conducted twofold. On the one hand, a group of studies uses unit root and cointegration tests to analyze whether shocks permanently affect the interest rates but, unfortunately, they possess low power and complicate inference about persistence (Neely and Rapach, 2008). On the other hand, other studies consider whether interest rates are fractionally integrated, which gives more flexibility and accuracy relative to persistence and, depending the integration degree, the features of the persistence will be different, i.e., they could follow stationary or nonstationary but mean-reverting process. Additionally, regarding the spread resulting the difference of short- versus long-term rates, some authors support that the degree of integration would be different from $I(0)$ (Strohsal and Weber (2014) or (Holmes *et al.* (2015), for instance), i.e., integrated in order $I(d)$. Thus, by using two very long span of databases, i.e., the *Jordà-Schularick-Taylor Macrohistory Database* and *Shiller's database,* aiming to explain whether the monetary authorities interventions would be more or less effective and how different impacts in the economy have affected both interest rates through the transmission mechanism. In addition, according to the FVECM, the spread has predicted power in the bearing of futures short-term rates. We also find that the long-term rates drive the long-run relationship, which may be a marker of the term spread persistence.

In sum, to the best of our knowledge, our approach, i.e., the Fractionally Cointegrated Vector Autorregressive (FCVAR) model (Johansen and Nielsen, 2012), lets us model and explore the fulfilment of the EHTS as a preliminary step of monetary policy effectiveness and the stationarity of the term spread, jointly. This methodology allows us to consider no-contemplative scenarios until now, which provides us tools for the implementation of policies. Finally, we show what is the driver between the short- and long-run interest rates relationship, which may give us a clue of how the path of monetary policy transmission is.

The rest of the paper is as follows. The next section presents a tour of recent US economic history and focuses briefly on the empirical literature; section 3 shows the methodology used in the paper. Then, section 4 discusses the empirical results and conclusions are shown in section 5, leading to some of the economic policy implications in section 6.

2. A brief review of monetary policy history

2.1 Monetary policy through the last century and a half

The effects of monetary policy over the last century and a half have been different due to the efforts of the Fed to maintain equilibrium between economic growth and market forces based on interest rates. For this reason, the distinction of diverse eras is necessary to support and explain the behaviour of the term structure and the Fed's actions regarding monetary policy using interest rates as a mechanism of control. In this sense, several authors have tried to show historical evidence of changes in monetary policy. Nonetheless, we focus on two relevant papers: Taylor (1999), which divides recent history into three main periods, and Darne and Charles (2011), which explains events. We follow an economic classification organization such as the National Bureau of Economic Research as well. Therefore, based on an in-depth depth review of the literature, we build a table that summarizes US monetary policy from recent history.

Aiming to provide a deep overview, Taylor (1999), in his study about the history of monetary policy, suggests different periods, which span from the end of the nineteenth century to the end of the twentieth century. The earlier period covers from 1879 to 1914 and follows the classical international gold standard era; the latter period extends from 1955 to 1997 and covers the era of Bretton Woods, when the exchange rate was fixed, and the modern flexible exchange era. In this paper, Taylor (1999) also argues about the type of Fed actions in the last years of that period because this policy rule is different from that applied by the gold standard, Bretton Woods or the early part of the flexible exchange rate era. But, as is well known, various events in recent history played a significant role in monetary policy and the treatment of interest rates. Thus, Darne and Charles (2011) identified several episodes that help to understand and explain changes in US monetary policy; we use these to refine the different periods proposed by Taylor (1999).

The early period – The gold standard

The backgrounds of these episodes are defined by the economic cycles that have marked the measures in different ways. Following the National Bureau of Economic Research (NBER hereafter) dating cycles, we start with the end of the Civil War that devastated the USA, which links with the beginning of the dataset used in this paper, i.e., 1870. Following Kindleberger (2000), at this time, there were financial difficulties due to the fact that debts were very high, and the objective of the administration was to sell Treasury gold to pay off the national debt, stabilize the dollar, and improve the economy. In 1873, the 'Panic of 1873' and Long Depression occurred, prompted by a drop in silver demand and subsequent downward pressure on the value of silver. For this reason, the US government moved to the gold standard; silver prices fell, and the domestic money supply was also reduced. The perception of instability in US monetary policy caused investors to withdraw from long-term obligations, particularly long-term bonds (Bordo and Kydland, 1995). After a period of economic expansion came the 'Panic of 1893', where silver was undervalued due to overproduction and the U.S. Treasury was forced to borrow $65 million in gold to support the gold standard. In response, foreign investors sold American stocks to obtain American funds supported by gold. As a result of the retraction of market liquidity in the 'Panic of 1907', a commission was established to investigate the crisis and propose future solutions, leading to the creation of the Federal Reserve System. Due to the entrance of the USA into World War I, financial inflation was high due to huge gold imports from the European belligerents who bought war material (Bordo and Haubrich, 2004).

Pre-World War II and the road to the end of XX century

In 1928, the stability and progress of the economy were threatened, so the Fed initiated a tight monetary policy in order to avoid a stock market bubble. This tight policy led to the stock market crash of October 1929 and was the beginning of the Great Depression (Orphanides, 2003). This period is characterized by the repeated failures of the Federal Reserve System to balance the monetary collapse (Friedman and Schwartz, 1963). The contraction came to an end because linkage with the gold standard was broken and there was a program of reflation for Treasury gold and silver (Bordo and Haubrich, 2004). Before World War II, in the New Deal period, there was another depression due to the application of different economic measures, but the tight monetary policy carried out by the Federal Reserve was a crucial measure.

By the end of World War II, the USA and other countries joined a new international monetary system, the Bretton Woods system. It involved a much less direct link to gold as a nominal anchor than had existed during either the inter-war or pre-war periods of the gold standard. As is well known, after the war, investment in the arms industry brought subsequent periods of recession, highlighted by the post-Korean War period, in which the Federal Reserve changed to a more restrictive monetary policy because of fears of inflation and the formation of an economic bubble. Between 1968 and 1970, the Bretton Woods system began collapsing due to the inappropriate policies of its members, evasion of capital controls, and the abandonment of the responsibility to maintain price stability (Bordo, 1993). The US government tried to finance social programs and the Vietnam War, using an expansionary monetary policy. This led to the recession of 1970, where the Federal Reserve raised interest rates, i.e., monetary tightening. After the 1973 oil crisis, the Fed increased interest rates to solve the problem of stagflation (Bernanke *et al.* 1997); the early 1980s were characterized by of the raising of interest rates to fight inflation by the Federal Reserve under the direction of Paul Volcker. Campbell and Clarida (1987) explain the shocks that occurred in the 1980s as a federal budget deficit.

The early 2000s

In the early 2000s, the longest growth period in the history of the US ended owing to a fall in investment caused by the collapse of the dot-com bubble and the September 11th attacks. This situation was reversed by the implementation of painful fiscal adjustment and also through the cost of the Afghanistan and Iraq wars (Ventura and Kraay, 2007). Finally, by the end of 2007, the subprime mortgage market collapsed and quickly spread to the rest of the world. The US government responded with an unprecedented bank bailout and fiscal stimulus package. The NBER declared the recession over more than a year after the end date (June 2009).

Figure 1 shows the *Jordà-Schularick-Taylor Macrohistory Database* as a synthesis of all previously explained cycles, with the grey bands determining the cycle moments provided by NBER and the short- and long-term interest rates.

Figure 1. Time series plot for *Jordà-Schularick-Taylor Macrohistory Database*

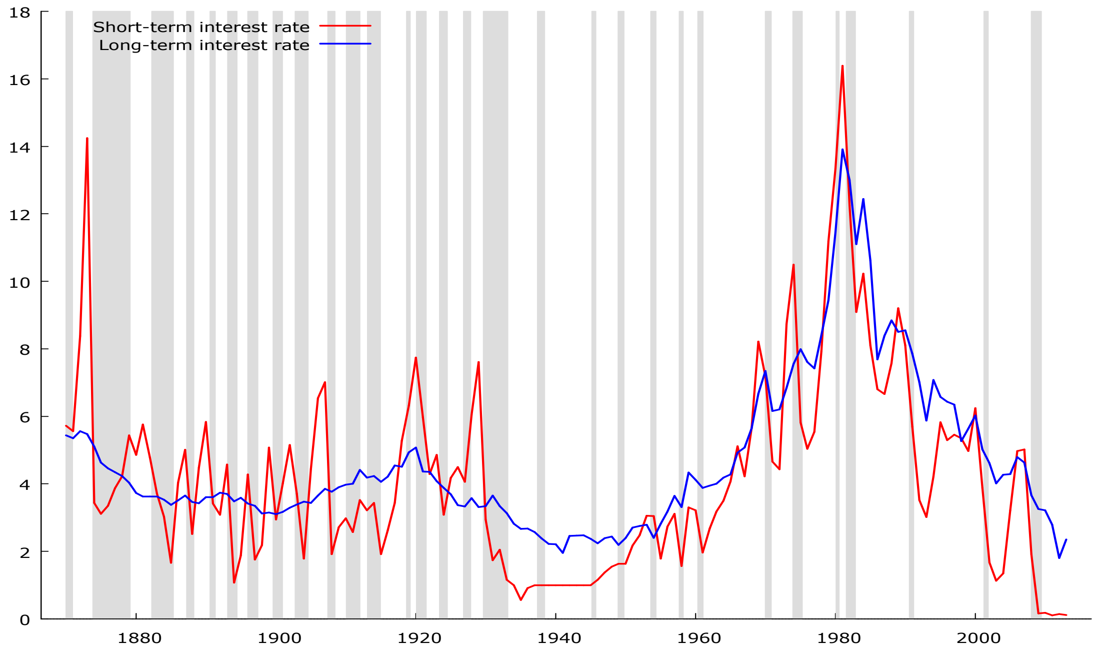
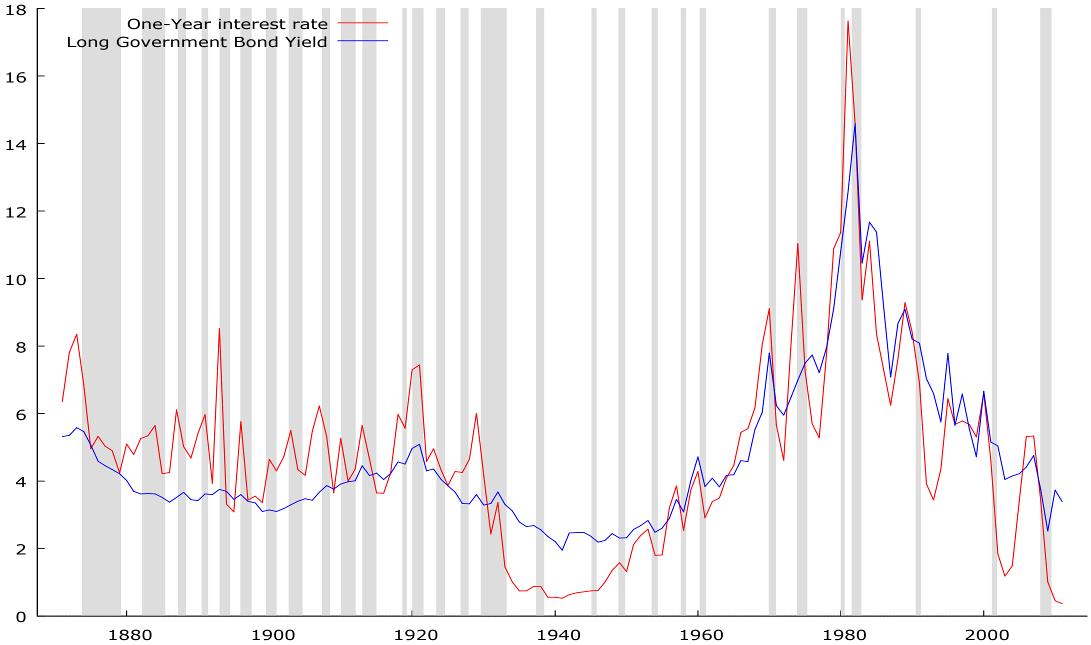


Figure 2 corresponds to *Shiller's database* and shows another similar synthesis for the events explained before. Also, the grey bands explain the cycle moments and are provided by NBER. Both databases will be explained in a later section.

Figure 2. Time series plot for *Shiller's database*



Interest rates allow economists and policy makers to predict cycles, which is crucial in the study of yield curves to forecast the behaviour of the term structure of interest rates. For this reason, the EHTS plays an important role in the linkage among short- and long-term rates. Adrian and Estrella (2008) reveal the predictive power of the yield curve so that an inverted yield curve signals a recession; meanwhile, a positive sloped yield curve is often a harbinger of inflationary growth.

Aiming to clarify the proposed events by several authors and sources, in table 1, we show a summary of all events cited previously in a novel contribution in the literature review. For the elaboration of this table, we have used the information provided in Darne and Charles (2011) and different studies, and the dates are checked with the dates provided by the NBER.

Table 1: Summary of events

Reference	Date	Event	Reason	Economic Measure
NBER; Kindleberger (2000)	1870	Post-USA Civil War	Very high debts	Treasury gold was sold to pay and stabilize the dollar
Bordo and Kydland (1995)	1873	'Panic of 1873'	Downward pressure on the silver value	The USA moved to gold standard
Friedman and Schwartz (1963); Bordo and Haubrich (2004)	1893	'Panic of 1893'	Overproduction of silver	The government borrow $65M in gold to support gold standard
Darne and Charles (2011)	1907	'Panic of 1907'	Retraction of market liquidity	Creation of the Federal Reserve system
Bordo and Haubrich (2004); Darne and Charles (2011)	1914 – 1918	World War I	High financial inflation	Tight central bank policies around the world
Darne and Charles (2011)	1928	Developing market bubble		Tight monetary policy
Friedman and Schwartz (1963); Orphanides (2003); Bordo and Haubrich (2004)	1929 – 1933	Great Depression	Failures of Federal Reserve system to balance the monetary collapse	The linkage with the gold standard was broken and program to reflation of Treasury gold and silver

Bordo and Haubrich (2004)	Pre-World War II	New Deal	Depression of the economy	Tight monetary policy
Bordo (1993)	Post-World War II		A much less direct link to gold as a nominal anchor than in previous periods.	Joining to Bretton Woods system
Darne and Chares (2011)	1950 – 1957	Post-Korean War	Inflation scare and bubble forming	Fed changed to a restrictive monetary policy
Bordo (1993)	1968	Bretton Woods system collapse	Inappropriate policies	Abandonment of this monetary system
Bordo and Haubrich (2004); Darne and Charles (2011)	1968 – 1971	Vietnam War	Financing social programs and Vietnam War	Expansionary monetary policy
Bernanke, Gertler and Watson (1997)	1973	Oil crisis	Stagflation caused by shocks in oil prices	Rising of interest rates
Campbell and Clarida (1987); Bordo and Haubrich (2004); Darne and Charles (2011)	End of 1970's and beginning 1980's	Volcker's direction	Fear to inflation; Federal budget deficit	Rising of interest rates by Fed.
Ventura and Kraay (2007)	Beginning of 2000's	Dot-com bubble and September 11th attacks		A painful fiscal adjustment due to the cost of Afghanistan and Iraq wars.
NBER	2007	Subprime mortgage crisis		Fiscal stimulus and bank bailout

Notes: Own elaboration

2.2. The Expectations Hypothesis of the Term Structure. How does EHTS affect monetary policy?

Studies concerning the term structure of interest rates have tried to evaluate the impact and how they are affected by the monetary policy of Central Banks. However, changes in the economy could affect the EHTS, so if a variation in short-term policy impacts on the long term, monetary policy is effective (Holmes et al, (2015)).

The EHTS is the most influential theory of term structure relations, and it has been studied as a way to show the relationship between short- and long-term rates. This hypothesis establishes that an average of the current and expected short-term rates determines long-term rates and the spread; differences in long- and short-term rates implies crucial information on future changes in short-term rates. So, the potential effectiveness of monetary policy is revealed by this relationship, which consists of the control of short-term policy rates by central banks (Bernanke and Blinder, 1992). Two papers in the literature, Fama (1984) and Fama and Bliss (1987), explain that the long-term rate is an unbiased predictor of future short-term rates[2]. Another implication of the EHTS is that the spread between the long-term rate and the short-term rate is an unbiased predictor of future short-run changes in the long-term rates, as Mankiw (1986), Campbell and Shiller (1987; 1991) and Campbell (1995) evidenced in their works.

From the contrast of this hypothesis shown by the studies above, studies have further focused their efforts on testing the EHTS and its economic implications in the USA or providing evidence of the forecasting power of the term structure. In this literature, mixed empirical evidence has been shown. This controversy is motivated by several reasons, such as the data selected, the techniques applied and the time period studied. Regarding the technique for testing the EHTS, we find, as an initial example, the study proposed by

[2] These works use the terms forward rate for the long-term rate and spot rate for the short-term rate.

Mankiw and Miron (1986), which related 3-month and 6-month rates and longer-term rates in order to find evidence of predictive ability of interest rates before the establishment of the Federal Reserve in the marketplace. For this reason, we show below different studies that treat the EHTS in different contexts.

On one hand, from a technical perspective, we find in support of EHTS several studies that used the cointegration concept of Engle and Granger (1987), such as Campbell and Shiller (1987), which examined the statistical significance of the EHTS in the January 1959 to October 1983 period. Hamilton (1988) used a Markov Switching model in order to explain the changes in regime for short- and long-term rates of US Treasury Bills for the January 1961 – March 1987 period. Hall *et al.* (1992) used the same variables with a different time series (they selected the period from January 1970 to December 1988) to support the EHTS using a cointegration. For its part, Shea (1992) selected data for the period December 1951 to February 1987 in order to determine that the interest maintains a long-term relationship; therefore, the spread would not have a tendency to increase or decrease over time. Engsted and Targgaard (1994) tested the implications of the EHTS on US term structure, finding that for the period January 1952 to February 1987, the zero-sum restriction on the cointegration vectors implied that the EHTS cannot be rejected following a variation of the Vector Error Correction Model (VECM hereafter), i.e., the threshold VECM. Moreover, Longstaff (2000) also used cointegration techniques, concretely the Vector Autoregressive (VAR) model, in a daily sample of extreme short-term rate and longer-term rates supporting the EHTS. In addition, Poole and Rasche (2000) and Poole *et al.* (2002) demonstrated that the market could anticipate changes in the FED's target during the period October 1988 through February 2000 using the federal funds rate. Hansen and Seo (2002) and Seo (2003) found roughly consistent results with the term structure prediction in the period that they chose (January 1952 to December 1992 and January 1960 to December 1999, respectively). Diebold *et al.* (2006) verified the EHTS in certain periods but not in the entire sample. Using another methodology such as the Autoregressive Conditional Heteroskedasticity (GARCH), Mili *et al.* (2012) explain specific interest rates dynamics in order to show the nonlinearities in the relationship between interest rates in the daily period from July 2001 to April 2011. For its part, Weber and Wolters (2012; 2013) applied the VECM in the US term structure in order to contribute an economic explanation of the deviations from EHTS in a similar data sample. Also, Kishor and Marfatia (2013) showed that the FF futures rate is cointegrated with the 3-month T-bill rate, and they move together in the long run in a daily sample that spans from May 1989 to June 2008. More recently, Holmes *et al.* (2015) supports that the EHTS holds in the long run, i.e., short-run policy changes effects on long-term rates for the period October 1993 until April 2015.

On the other hand, there is evidence against the EHTS, such as Sarno *et al.* (2007), which rejects the EHTS when short maturities from 1952 to 2003 are used. Thornton (2005) and Guidolin and Thornton (2010) tested the EHTS, determining less ability to forecast short-term rates, which has deep implications for policy makers; thus, conventional theory of the term structure of interest rates is threatened, and Bulkley *et al.* (2011; 2015) evidenced the failure of EHTS using Treasury securities in a similar monthly sample that starts in 1952.

More importantly, several studies have treated the spread between long- and short-term interest rates in the sense that this spread contains information about the term structure. These studies have focused on different regions in the world, but in the case of the USA, the work of Strohsal and Weber (2014) and Holmes *et al.* (2015) supports the EHTS; however, the degree of integration of the spread would be different from $I(0)$. Previously, Cömert (2012) related overnight interest rates and long-term rates in the US from 1983 to 2007 and presented evidence that the Fed has been gradually losing its control over long-term interest rates.

In sum, despite the initial controversy, this literature has shown that it is possible to establish a relationship between short- and long-term rates across the last century and a half in The USA. It has also addressed the importance of the spread between interest rates as a tool to determine the efficiency of monetary policy and forecasting power. Finally, unlike the studies previously considered, which have analysed the cointegration and spread, to the best of our knowledge, our approach is the only one that makes it possible to analyse both jointly. Hence, our econometric method permits us to test the existence of a long-run relationship between the interest rates selected and the persistence of the spread based on a new approach in the existing literature, a Fractionally Cointegrated Vector Autoregressive (FCVAR) model provided by Johansen and Nielsen (2012); this model makes it possible to avoid the problems with the axioms of traditional cointegration associated with rigidity.

3. Methodology

Our econometric strategy is based on obtaining and analyzing at a yearly frequency the model estimation; we then perform statistical tests of fractional cointegration and weak exogeneity based on the fundamental equation of the EHTS in an econometric context in order to explain possible monetary policy efficiency.

The EHTS model

The essential equation of the EHTS of a $k > 1$ period bond R_t (i.e., long-term interest rate) is equal to an average of current and expected r_t (i.e., short-term interest rates) set of a $k \leq 1$ period plus a constant term that could vary with the maturity of the rates. The relationship can be expressed in the following form:

$$R_t = \frac{1}{k} \sum_{i=0}^{k-1} E_t[r_{t+n}] + \pi_t^*, \qquad (1)$$

where π_t^* is a possible stationary term and E_t is the expectations operator at time t for the evolution of short-term interest rates driving the longer-term interest rate. In order to test the EHTS in the context of cointegration theory, the linear mode is:

$$R_t = c + \beta r_t + \varepsilon_t \qquad (2)$$

Agreeing with Campbell and Shiller (1987), R_t and r_t should be non-stationary and related through a cointegration relationship with parameters (1, -1), i.e., a one-to-one relation, β = 1. These imply that β_R and β_r are the cointegrated constants, and its combination is a stationary process, and the spread of the interest rate could revert to the mean. If the spread is stationary, the long- and short-term rates are driven by a common stochastic trend and do not allow arbitrage opportunities because market forces adjust to correct any temporary disequilibrium. As the EHTS suggests, the interest rate spread is an optimal forecast[3] of future changes in long-term interest rates.

In this paper, the fractionally cointegrated vector autoregressive (FCVAR) model allows us to study the long-run equilibrium relationship between long- and short-term interest rates. This model allows fractional processes of order d that cointegrate to order $d - b$; conducting our analysis using a bivariate fractional cointegration approach, we consider that the standard unit root and cointegration test might be too restrictive (*I(1)/I(0)*

[3] Baillie and Bollerslev (1994) discovered that a cointegrating relationship may not be precisely $I(0)$, implying that a fractionally cointegrated relationship may generate noticeable gains in forecast accuracy only within the context of a longer-term forecast.

dichotomy). In the FCVAR model, the error correction term (the spread when EHTS is supported) is different from *I(0)*; i.e., this assessment is not restricted (the integration order could be different from zero and thus show a long-memory process), rejecting the general assumption that the spread is *I(0)* and could be an *I*(*d*) process. More general *I*(*d*)-type specification has been adopted, considering the possibility of fractional orders of integration – cointegration without these values is unrestricted. We note that traditional cointegration has limitations, so we consider that the shocks on our interest rates could be persistent, following a long memory process in the residuals of the cointegrating relationship that exists; thus, a slow reversion towards the long-run equilibrium can take place. A fractional cointegration approach allows us to capture the relationships between the short- and long-term interest rates by considering that the spread could follow a fractional process *I(d – b)*; this is a long memory process and contrary to traditional cointegration, which forces this process to be *I(0).* According to Table 1 in Tkacz (2001), when *(d – b) = 0*, the term spread follows a stationary process and the shock duration is short-lived[4], meaning that there is a high degree of controllability of interest rates by the Fed. If *0 < (d – b) < 0.5*, there is a stationary process, and the shock duration is long-lived so, the Fed see how its controllability of interest rates is decreased; and finally, if *0.5 < (d – b) < 1*, the spread follows a non-stationary process, although it is mean-reverting and the shock duration is long-lived, being the worst scenario for policy implementations because the controllability of interest rates is very low. In this sense, for policy implementation, the traditional controversy attending the cointegration of interest rates or the behavior of the spread is rejected in favor the rise of new scenarios (Table 2) where is possible to check how would be the degree of controllability of the interest rates according to the order of integration of the error correction term (the term spread) once the EHTS is confirmed, i.e., the effectiveness of monetary policy is reduced as the persistence of the term spread increases (Busch and Nautz, 2010).

Table 2. Policy implementations scenarios

	Order of integration of the error correction term (ECT)		
	I(*d* – *b*) = I(0)	**I(0) < I(*d* – *b*) < I(0.5)**	**I(0.5) < I(*d* – *b*) < I(1)**
EHTS confirmed	High degree of controllability of interest rates.	Low degree of controllability of interest rates.	Very low degree of controllability of interest rates.

Notes: The shaded area corresponds to the best scenario for policy implementations. As *β = 1,* the ECT is assumed as the spread between both interest rates.

Fractional cointegration model – FCVAR methodology

This model is provided by Johansen (2008a, 2008b) and developed in Johansen and Nielsen (2012) and Nielsen and Popiel (2016); it has the advantage of being used for stationary and non-stationary time series. Our objective is to study the EHTS under fractional cointegration conditions.

To introduce the FCVAR model, we introduce the fractional difference operator to the CVAR model, which is Δ and the fractional lag operator is $\Delta = (1 - \mathrm{L})$. Replacing lag operators by their fractional counterparts Δ^b and $\Delta^b = (1 - \mathrm{L}_b)$ and applying $Y_t = \Delta^{d-b} X_t$, such that:

$$\Delta^{b} \mathrm{Y_t} = \alpha\beta' \mathrm{L_b} \mathrm{Y_t} + \sum_{i=1}^{k} \Gamma_i \, \Delta^{b} \mathrm{L_b^i} \mathrm{Y_t} + \varepsilon_t. \quad (3)$$

Applying $\mathrm{Y_t} = \Delta^{d-b} \mathrm{X_t}$, we obtain the following FCVAR model:

[4] This means that a shock would show a slow return towards the long-run equilibrium.

$$\Delta^d X_t = \alpha\beta' L_b \Delta^{d-b} X_t + \sum_{i=1}^{k} \Gamma_i \Delta^d L_b^i X_t + \varepsilon_t. \quad (4)$$

As usual, ε_t is a p-dimensional i.i.d. variable with mean zero and covariance matrix Ω. The parameters α and β are p x r matrices, where $0 \le r \le p$. The columns in matrix β are the cointegrating vectors, and $\beta' X_t$ assumes the existence of a common stochastic trend, which is integrated to order d, and the short-term parts from the long-run equilibrium are integrated to order *d – b*. The speed of the adjustment to the equilibrium coefficients is reflected in α. Thus, $\alpha\beta'$ is the long-run adjustment, and Γ_i represents the short-run dynamics of the variables.

There are two additional parameters in the FCVAR model compared with the CVAR model. The parameter *d* represents the order of fractional integration of the observable time series. The parameter *b* determines the degree of fractional cointegration, that is, the reduction in fractional integration order of $\beta' X_t$ compared to X_t itself. The relevant ranges for *b* are (0, 1/2), in which case the equilibrium errors are fractional of order greater than 1/2 and are therefore non-stationary although mean reverting, and (1/2, 1], in which case the equilibrium errors are fractional of order less than 1/2 and are stationary (Dolatabadi et al., 2015). Note that for $d = b = 1$, the FCVAR model is reduced to the CVAR model, which is thus nested in the FCVAR model as a special case. Johansen and Nielsen (2012) show that the maximum likelihood estimators $(b, \alpha, \Gamma_i, \dots, \Gamma_k)$ are asymptotically normal and that the maximum likelihood estimator of (β, ρ) is asymptotically mixed normal when $b > 1/2$ and asymptotically normal when $b < 1/2$. The important implication is that the standard asymptotic inference can be applied to all these parameters.

We now determine the number of stationary cointegrating relations following the hypotheses of the rank test based on a series of LR tests. In the FCVAR model, we test the hypothesis $H_0\colon \mathrm{rank}(\Pi) = r$ against the alternative $H_1\colon \mathrm{rank}(\Pi) = p$ for r = 0, 1, ... "estimated" rank is then the first non-rejected value in the sequence of tests. Being $L(d, b, r)$is the profile likelihood function given a rank r, where (α, β, Γ) have been reduced by rank regression (see Johansen and Nielsen, 2012). The asymptotic distributions of these LR test statistics are non-standard and are derived in Johansen and Nielsen (2012). We use the P-values obtained from computer programs made available by MacKinnon and Nielsen (2014) based on their numerical distribution. Maximizing the profile likelihood distribution under both hypotheses, the LR test statistics are now $LR_t(q)$. The asymptotic distribution of $LR_t(q)$ depends on the parameter *b* and on $q = n - r$. MacKinnon and Nielsen (2014) based on their numerical distribution functions, provide asymptotic critical values of the LR rank test. In the case of "weak cointegration", i.e., $0 < b < 1/2$, $LR_t(q)$ has a standard asymptotic distribution $LR_t(q) \xrightarrow{D} \chi^2(q^2)$.

The specification in (4) is the so-called restricted constant version of the model by Johansen and Nielsen (2012), which is also used by Dolatabadi et al. (2016). Deterministic trends may be assumed in the FCVAR model in several ways. Johansen and Nielsen (2012) considered the insertion of the restricted constant term ρ in the long-run cointegrating relation. Dolatabadi et al. (2016) suggested an unrestricted constant ξ as the linear trend of the fractionally integrated processes. The following specification shows a more general form:

$$\Delta^d X_t = \alpha L_b \Delta^{d-b}(\beta' X_t + \rho') + \textstyle\sum_{i=1}^{k} \Gamma_i \Delta^d L_b^i X_t + \xi + \varepsilon_t, \quad (5)$$

where ρ is denoted as the restricted constant term, i.e., the mean level of equilibrium relation, and ξ is the unrestricted constant term that generates a deterministic trend in the levels of the variables (Dolatabadi *et al*., 2016).

Therefore, the FCVAR model allows simultaneous modelling of the long-run equilibria, the adjustment reactions to deviations from the equilibria and the short-run dynamics of the system. Johansen and Nielsen (2012) and Nielsen and Popiel (2016) provide estimation and inference explanations for the model, and the latter study specifies MATLAB computer programs for the calculation of estimators and test statistics.

When the VAR model encounters the case of $d = b = 1$ (CVAR), the error correction term is integrated of order $(d - b)$, which is $I(0)$ in this case. However, in the fractional cointegration, these axioms are relaxed because $(d - b) = 0$, which means that the error correction term shows short-run stationary behaviour, or $(d - b) > 0$, which in turn means that there is a long memory process and that the error correction term will revert in the long run.

According to the latter study, fractional cointegration implies a FVECM such as:

$$\begin{pmatrix}\Delta R_t\\ \Delta r_t\end{pmatrix} = \begin{pmatrix}\alpha_R\\ \alpha_r\end{pmatrix}(R_{t-1} - \beta r_{t-1} - c) + \sum_{i=1}^{n}\Gamma_i\begin{pmatrix}\Delta R_{t-i}\\ \Delta r_{t-i}\end{pmatrix} + \begin{pmatrix}v_{1t}\\ v_{2t}\end{pmatrix} \tag{6}$$

With adjustment parameters α, cointegration coefficients β, restricted constant (c), lag length (n) and errors v. The Γ_i are 2 x 2 parameter matrices in the short-run dynamics. The adjustment coefficients α_R and α_r capture the speed of adjustment of R_t and r_t toward equilibrium. Additionally, according to EHTS, the absolute values of the estimates of α_R are much smaller than α_r; we suggest that the correction in the equation for the short term of interest rates exceeds the long-run equilibrium, i.e., the spread defined by the difference between long-term and short-term interest rates.

Permanent-Transitory (PT) decomposition in the FCVAR model

According to the Gonzalo and Granger (1995) Permanent-Transitory decomposition, $X_t = (R_t, r_t)'$, where R_t and r_t represent the long-term rate and short-term rate, respectively. In the Permanent-Transitory decomposition, X_t can be decomposed into a transitory (stationary) part, $\beta' X_t$, and a permanent part, $W_t = \alpha'_\perp X_t$, where $\alpha'_\perp \alpha = \alpha' \alpha_\perp = 0$. W_t is the common permanent component of X_t, and it is interpreted as the dominant rate, where the information that does not affect W_t will not have a permanent effect on X_t. We focus on the key parameter $\alpha_\perp$ in order to know which parameter (short- and long-term rate) contributes to the common trend. Following the mirror hypothesis, the linear hypothesis on $\alpha_\perp$ can also be tested directly on $\alpha_\perp$or alternatively on α itself using the values of LR tests in each hypothesis, and critical values can be taken from the χ^2 distribution for testing. For example, to test the hypothesis that the dominant rate is the long-term rate, i.e., $\alpha_\perp = (0, a)'$, we can equivalently test the mirror hypothesis H_0: $\alpha = (\gamma, 0)'$. Similarly, to test the hypothesis that the dominant rate is the short-term, i.e., $\alpha_\perp = (a, 0)'$, we test the mirror hypothesis H_1: $\alpha = (0, \gamma)'$(see Dolatabadi *et al.* (2015), which first combined the FCVAR with Permanent-Transitory decomposition).

An interpretation of the coefficient α is that an adjustment coefficient measures how disequilibrium errors could be affected in current changes in X_t. Under this interpretation, we wonder whether any coefficients in α are zeros, i.e., the variable in question is weakly exogenous. For example, under the hypothesis H_1, the parameter $\alpha = 0$ such that the short-term rate does not react to the disequilibrium error, i.e., the transitory component, implying that the short-term rate is the main contributor to the common trend.

In order to determinate the magnitude of each variable in the long-run, we use the Component Share (CS), as Baillie *et al.* (2002) note that since $\alpha'\alpha_{\perp} = 0$, it may also be expressed in terms of the elements of the error correction vector α. To interpret this, we let $\alpha = (\alpha_1, \alpha_2)'$ and $\alpha_{\perp}\alpha = (\alpha_{\perp,1}, \alpha_{\perp,2})'$. Afterwards, $\alpha'_{\perp}\alpha = \alpha_{\perp,1}\alpha_1 + \alpha_{\perp,2}\alpha_2 = 0$ implies that $\alpha_{\perp,1} = -\alpha_{\perp,2}\alpha_2/\alpha_1$, so Component Share (CS) may be expressed as

$$CS_1 = \frac{\alpha_2}{\alpha_2 - \alpha_1}, CS_2 = \frac{-\alpha_1}{\alpha_2 - \alpha_1} \quad (7)$$

4. Data and results

4.1. Data description

To study the long-run dynamics of term structure, we need a dataset as long as it allows us to check if the Fed has kept interest rates under control in recent history. Furthermore, we choose two different databases, and we use short- and long-term interest rates. One of them is provided by the *Jordà-Schularick-Taylor Macrohistory Database*, which covers 17 advanced economies from 1870 to 2013 on an annual basis. It includes 25 real nominal variables, but among these, we have selected financial variables such as short- and long-term interest rates for the USA[5]. The other data base selected is available in Chapter 26 from Shiller's book *Market Volatility* (1989) and is revised and updated from Robert Shiller's website. This set is formed with One-Year interest rate and Long Government Bond Yield (10-years of maturity) and is useful in order to examine long-run historical trends, as it begins in 1871 and finishes in 2011; our purpose, as we said previously, is the study of the term structure behaviour and monetary policy across time according to EHTS.

Table 3. Main statistics for both database

	Mean	Median	Min	Max	Standard deviation
Short-term rate	4.181	3.615	0.100	16.390	2.895
Long-term rate	4.635	3.921	1.802	13.911	2.272
One-Year interest rate	4.715	4.620	0.365	17.630	2.793
Long Government Bond Yield	4.654	3.980	1.950	14.590	2.246

Notes: From 1870 to 2013 for two first rows and from 1871 to 2011 for the last two rows.

We study the essential statistics as a preliminary procedure to know the data. In table 3, we show both databases selected for our empirical issue as explained previously. In this table, we combine the short- and long-term interest rates from *Jordà-Schularick-Taylor Macrohistory Database* and the One-Year interest rate and Long Government Bond Yield from Shiller's website. This table also shows that these statistics are very similar for both databases when short- and long-term rates are compared, so it could be a prelude to our results.

4.2. Econometric Strategy

The purpose of the present study is to test the existence of EHTS based on the treatment of two historical databases for US interest rates explained in the next subsection applying different tests. The first step, in difference to previous empirical studies regarding the EHTS, will reside in checking the fractional cointegration, i.e., if the FCVAR model is more appropriate than the standard cointegration. If we accept this step, we move to a second step, which involves the estimation of β under the hypothesis that the cointegrating vector is (1, -1), which allows us to consider the error term as the term spread. Continuing

[5] The short-term interest rates references to a maturity of 3 months; meanwhile, the long-term is 10-year. For more details, visit *http://www.macrohistory.net/data/*

with that restriction, i.e., the cointegrating vector is (1, -1), we estimate the adjustment coefficients under a Fractional Vector Error Correction Model (FVECM). These adjustment coefficients would provide us information about the Permanent-Transitory decomposition. Finally, with the aim of knowing if the spread is a long memory process, we will establish the order of integration or degree of spread persistence as the difference between order of integration (*d*) and strength of cointegration (*b*). Table 4 performs a summary of the econometrical strategy and the order of the proposed results.

Table 4. Strategy of Empirical Research

	Procedure	Hypotheses
Step 1	H_1^d: Is the fractional cointegration more appropriate than traditional cointegration?	Is there a fractional cointegration?
Step 2	H_1^β: Cointegrating vector is (1, -1)	Is the EHTS supported?
Step 3	$H_1^\beta \cap H_{1\perp}^{\alpha_{long/short}} \equiv H_1^\beta \cap H_1^{\alpha_{long/short}}$(mirror): Long-term rate and/or short-term rate has a permanent component in the common trend	What interest rate dominates the term structure?
Step 4	H_1^{d-b}: Is the spread a long memory process?	How is the degree of controllability of interest rates?

4.3. Univariate analysis

Before the application of the FCVAR model, in a preliminary step, we estimate the order of fractional integration of the historical interest rates. In order to motivate a fractionally cointegrated model, we consider univariate results observing long memory, and then we proceed to the estimation of the fractional parameter *d* for each univariate series, with results presented in table 5. Although the semiparametric log-periodogram regression method proposed by Geweke and Porter-Hudak (1983) is the most widely used, the method was modified and further developed by Robinson (1995) and has been analyzed by Velasco (1999) and Phillips and Shimotsu (2002) among others. These three columns are semiparametric log-periodogram regression estimates from Geweke and Porter-Hudak (1983) computed with bandwidths $m = T^{0.5}$, $m = T^{0.6}$, and $m = T^{0.7}$. The estimates are consistent with the joint estimates presented later. As we can see in table 5, the values for *d* are similar when we check it in the same time slot, i.e., if this test is applied on short- or long-term rates. We can observe as the values of *d* decrease when we pass from a bandwidth $m = T^{0.5}$ to $m = T^{0.6}$, and then, these values begin to increase again when bandwidth $m = T^{0.7}$. For shorter-term interest rates, the values of *d* are always between 0.5 and 1, which means that these processes are stationary and becoming mean-reverting values. The same occurs for longer-term interest rates, which gets values of around 1. In other words, these values suggest that the fractional cointegration is more appropriate to our approach[6].

Table 5. Univariate analysis. Geweke and Porter-Hudak (GPH) estimates

	$m = T^{0.5}$	$m = T^{0.6}$	$m = T^{0.7}$
	d	*d*	*d*
Short-term rate	0.838 (0.246)	0.564 (0.193)	0.608 (0.125)
Long-term rate	1.138 (0.264)	0.970 (0.167)	1.080 (0.131)
One-Year interest rate	0.884 (0.252)	0.551 (0.167)	0.616 (0.125)
Long Government Bond Yield	1.129 (0.137)	1.006 (0.104)	1.055 (0.108)

[6] To test the presence of unit roots, estimates were obtained from first-differenced data, as the original series may exceed 0.5, and the test requires that results are limited to an interval of $-0.5 < d < 0.5$ while adding 1 to obtain the proper estimates of d. According to the literature, the bandwidth size ranges from 0.25 to 0.8. For our study, the three bandwidths selected are valued at 0.4, 0.5 and 0.6

Notes: GPH denotes the Geweke and Porter-Hudak semiparametric log-periodogram regression estimator. Standard errors are given in parenthesis below estimates of *d*. The sample size is 144 for *Jordà-Schularick-Taylor Macrohistory Database*, i.e. Short and long term rates and 141 for Shiller's Database, i.e. One-Year interest rate and Long Government Bond Yield respectively.

4.4. Cointegration analysis

This subsection is devoted to steps 1 to 4 contained in table 4. First, under the Bayesian Information Criteria (BIC), we establish the optimal lag length for better accuracy in our estimation under the assumptions of the FCVAR model; there is a chance that the lag length selected would be different in each database studied. As can be observed, when we attend to *Jordà-Schularick-Taylor Macrohistory Database*, the optimal lag length is 1; meanwhile, for the Shiller's database, it is 1 as well[7]. Once the lag length is determined, we proceed to the first step, which reveals our premise about the capability of fractional cointegration in our estimation. For this, we test the cointegrating rank, evidencing that the number of cointegrating vectors is one in both databases. Subsequently, when the rank test is finalized, we test hypothesis H_1^d, which tests whether fractional cointegration is more appropriate than traditional cointegration (the CVAR model), i.e., the null hypothesis is $d = 1$, and its rejection implies that the FCVAR model is more suitable than traditional cointegration. Accordingly, by assuming *I(1)* cointegration or an *I(0)* VAR model, we may be mis-specifying the model estimates, parameters, test restrictions and implied dynamics, such as the term spread. In our case, as we can see at the bottom of table 6, we can continue our estimation under the fractional cointegration premises.

Table 6. Rank test and Fractional Cointegration test

	Jordà-Schularick-Taylor	*Shiller's*
Optimal lag length	1	1
Rank test		
0	26.610 (0.000)	13.836 (0.008)
1	6.133 (0.013)	2.991 (0.252)
$\hat{d}$	0.758 (0.103)	1.041 (0.094)
$\hat{b}$	0.384 (0.198)	0.556 (0.187)
H_1^d	8.130 (0.004)	7.974 (0.005)

Notes: In this table is shown the estimations for each database in different columns. It also shows the values of LR Statistics and the p-values are in brackets. For the parameters *d* and *b* we show their values and the standard deviations values are in parenthesis. The significance level is set to 10% for exclusion following Jones *et al.* (2014). The sample size is 144 for *Jordà-Schularick-Taylor Macrohistory Database* and 141 for Shiller's Database.

The next issue consists in the study of the long-run equilibrium between the short- and long-term interest rates. The estimated values are shown in table 7. It can be observed that parameter β is close to 1.[8] Observing that the EHTS implies that the series are cointegrated but the cointegrating vector between each variable is restricted in (1,-1), H_1^{β}, we must test the existence of this vector. Using an LR test as we can see in table 7, we do not reject this parameter restriction, concluding that the EHTS could not be rejected. This result reveals that in the last century, long-term interest rates are determined by short-term interest rates. Nonetheless, despite this result being well-known in the previous

[7] The lag length values are shown in table A1 in the appendix.

[8] In every estimation, we check the residuals for serial correlation using a multivariate Ljung-Box Q-test, $Q_{\hat{\varepsilon}}$ with h = 12 lags. The results show no evidence of serial correlation of the residuals in every estimation, and the Ljung-Box Q-test shows no signs of misspecification, which indicates that the model is well specified (see table A2 in appendix).

literature, this is the first time that a fractional cointegration is applied to confirm this relationship and that the database spans a long range of time.

Table 7. $Estimates\ of\ \beta$ and H_1^{β}: Is the EHTS supported?

	Jordà-Schularick-Taylor	*Shiller's*
Vector $\boldsymbol{\beta}$	1.000 -1.087	1.000 -0.992
$\boldsymbol{H_1^{\beta}}$	0.290 (0.590)	0.003 (0.957)

Notes: In this table is shown the estimations for each database in different columns. It also shows the values of LR Statistics and the p-values are in brackets. The significance level is set to 10% for exclusion following Jones *et al.* (2014). The sample size is 144 for *Jordà-Schularick-Taylor Macrohistory Database* and 141 for Shiller's Database.

The next step consists in the estimation of the FVECM (see equation 5); the significance of the adjustment coefficients in the joint hypothesis $H_1^{\beta} \cap H_1^{\alpha_i}$ is tested as shown in table 8. Using an LR test, we find that only the coefficients associated to short-term rates (α_r) are significant, which implies that the spread has a prediction power in the behavior of the futures short-term rates, which is consistent with EHTS. Finally, as expected, the adjustment coefficients of the short-term rate are positive, which is extra evidence in support of the EHTS; conversely, the adjustment coefficients of the long-term rates are much smaller in magnitude than short-term rates although insignificantly different from zero (this result is according to the results obtained by Hansen and Seo (2002)).

Finally, we decompose the FVECM in order to see which interest rate has a permanent component in the common trend. This is potentially useful information for the design and adjustment of monetary policy. To do this, we follow the methodology provided by Gonzalo and Granger (1995), i.e., the Permanent-Transitory decomposition, to establish the common trend in order to determine whether the long-term rate or short-term rate drives the common trend. In our case, both short-term rates do not contribute to the long run because the parameter α_r is different than zero. On the other hand, the parameter $\alpha_R = 0$, such that both long-term rates are weakly exogenous, being the permanent component, and this implies that this rate drives the common trend, i.e., this indicates that long-term rates are basis in the US monetary policy as a main tool through the effectiveness of the policies implementation. This can also be interpreted as proportions of short- and long-term contributions to the common trend. As we can appreciate at the bottom of table 8, in both databases, the longer-term rates contribute around 100% in the common trend.

Table 8. $H_1^{\beta} \cap H_1^{\alpha_i}$: What interest rate drives the term structure?

	Jordà-Schularick-Taylor	*Shiller's*
$\boldsymbol{H_1^{\beta} \cap H_{1\perp}^{\alpha_{long/short}} \equiv H_1^{\beta} \cap H_1^{\alpha_{short/long}}}$	0.005 (0.945)	0.415 (0.520)
$\boldsymbol{H_1^{\beta} \cap H_{1\perp}^{\alpha_{short/long}} \equiv H_1^{\beta} \cap H_1^{\alpha_{long/short}}}$	18.808 (0.000)	10.584 (0.001)
$\boldsymbol{\alpha_R}$	0.014	-0.127
$\boldsymbol{\alpha_r}$	2.436	1.408
$\boldsymbol{\alpha_{R\perp}}$	1.006	0.917
$\boldsymbol{\alpha_{r\perp}}$	-0.006	0.083

Notes: In this table is shown the estimations for each database in different columns. It also shows the values of LR Statistics and the p-values are in brackets. The significance level is set to 10% for exclusion following Jones *et al.* (2014). The sample size is 144 for *Jordà-Schularick-Taylor Macrohistory Database* and 141 for Shiller's Database. $\alpha_{R\perp}$ and $\alpha_{r\perp}$ are normalized such that the two elements add to one.

In the last step, as the cointegrating vector is (1, -1), we can interpret the difference *(d – b)*[9] as the order of integration of the spread, that is, the degree of persistence (H_1^{d-b}). As we can see in table 9, there is two-way evidence in the knowledge of this difference. On the one hand, clearly the order of integration of the spread is distinctly higher than zero and then exhibits a long-memory process. On the other hand, both databases follow a stationary process, and thus, the duration of the shock is long-lived. This result could be in line with the results that Weber and Wolters (2012) and Holmes *et al.* (2015) proposed in their studies regarding the controllability of the interest rates and, subsequently, the effectiveness of the monetary policy and the transmission mechanism is reduced.

Table 9. H_1^{d-b}: How is the degree of controllability of interest rates?

	Jordà-Schularick-Taylor	*Shiller's*
$\boldsymbol{H_1^{d-b}}$	0.374	0.485

Notes: In this table is shown the estimations for each database in different columns. It also shows the values of LR Statistics and the p-values are in brackets. The significance level is set to 10% for exclusion following Jones *et al.* (2014). The sample size is 144 for *Jordà-Schularick-Taylor Macrohistory Database* and 141 for Shiller's Database.

5. Summary of results

The role of central banks according to monetary policy through recent history implies the application of different economic measures to fight market inefficiency in the form of economic cycles. For this reason, the treatment of the term structure, i.e., the grouping and checking of short- and long-term interest rate behavior due to the term structure of interest rates, has always been viewed as crucial to assess the impact of monetary policy and its transmission mechanism.

Analyzing two historical databases with a recent methodology, i.e., the fractionally cointegrated vector autoregressive (FCVAR) model, our analysis is robust and capable of taking both the cointegration among short- and long-term interest rates and the long memory of the spread, jointly providing us the opportunity to reject the apriorism of the incompatibility of interest rates being cointegrated and the term spread non-stationary. Overall, we additionally propose a complete overview concerning the last and half century monetary policy events, aiming to clarify the proposed events by several authors and sources, in addition to a novel econometric approach that would give a better understanding of this hypothesis and approach to a more appropriate term structure of interest rates modeling.

The results provided by both databases evidence robustness in the results in accordance with EHTS; i.e., the spread between the short-term rates and long-term rates of the term structure was found to be an optimal predictor of future short rates. Importantly, we find evidence that the term spread shows a long memory process, in particular a stationary process, in contrast to the usual assumption of I(0). According to the P-T decomposition, a shock in the long-term rate will have a permanent (long-run) effect on the short-term rate and long-term rate, but a shock in the short-term rate, with no movement in the long-term rate, is completely transitory. In addition, we found that the long-term rate maintains fixed with no change in the short-term rate, so this change will affect the term spread $(\mathrm{R_t} - \mathrm{r_t})$ only through $\mathrm{z_t}$ (transitory component) and therefore will only have transitory effects. In summary, we evince that the short-term rate does not contribute to the long-run, so the long-term rate is the dominant rate.

[9] According to our methodology, *d* and *b* denote the fractional order of integration of the explanatory variables and the strength of cointegration, respectively.

6. Policy implications

In this paper, we use two data sets on interest rates involving long spans of data of the US economy which has not been stressed in the literature previously, providing a robustness for the results obtained which allows us to assess the effectiveness of monetary policy under non-contemplative scenarios until now. As the EHTS is supported, i.e., long-term interest rates are averages of expected future short-term rates, and hence, the monetary policy is effective because the transmission mechanism propitiates that, changes in short-term rates, affect long-term rates. Furthermore, the long-term rates are key elements for macroeconomic conditions, such as saving or investment. According to our results, the US monetary policy throughout the period analyzed has viewed long-term rates as a driver of the term structure. This may be an indicator that the Fed has employed long-term interest rates as a tool in order to develop and carry out its policies, such as to keep under control the loans and the public debt emissions. Attending to this, policymakers should monitor long-term rates carefully in assessing the contemporary state of the economy, by using short-term rates and focusing on spending, production or prices (Bernanke, 2006). Even though we mentioned that the behavior of long-term rates reflects current or future economic situation, the implications for policy may be quite different for example, when low or falling long-term rates reflect investor expectations of future economic weakness, which may be an economic recession indicator.

Otherwise, attending to the difference between short- and long-term rates, that is the term spread or the slope of the yield curve that contains significant information on future changes in the macroeconomic conditions, could be an instrument of the monetary policy to affect the real economy. In this paper, we show long memory in the term spread with an order of integration below 0.5 and, thereby follows a stationary process; denoting deep implications for monetary policy. Firstly, the long- and short-term rates are driven by a common stochastic trend and do not allow arbitrage opportunities because market forces adjust to correct any temporary disequilibrium. Secondly, a long memory spread holds adequate forecasting power at longer horizons (Baillie and Bollerslev, 1994). Thirdly, this could be an indicator that the Fed already has control over term structure but keeping the attention on the interest rates because the persistence of the spread implies a diminishing controllability of interest rates along the yield curve as Cömert (2012) or Balduzzi *et al.* (1998) suggest. As mentioned, given that the term spread is long memory, the interest rates reversion, after a shock, to its equilibrium is slower so, in order to achieve its economic objectives, such as higher investment or growth, monetary authorities need to be more active. In fact, the lasting impact of shocks would impede the transparency of policy signals and the Fed's impact on long-term rates (Busch and Nautz, 2010). Nonetheless, focusing on the implications in the short-run, as the persistence increases, policy makers are not required to frequently change the interest rates to affect the economy, i.e., policies need to be made and then wait to recover the equilibrium status before another policy. In contrast, attending to the long-run, policies must be more active and changing frequently. Definitively, although the fulfillment of the EHTS denotes an effectiveness of the monetary policy, the term spread persistence indicates a weakness, i.e., the authorities do not have a full control over the interest rates and its transmission mechanism, making it difficult to apply a correct and quick implementation of the policies due to the fact that the throwback to equilibrium is slower than in full controllability, pointing out the difficulties of the monetary policy in promoting economic growth through the monetary policy (Gil-Alana *et al*. (2017).

Overall, across the last century and a half, there were wars, economic crises and/or changes in economic policies in the USA. In this respect, the results lead us to conclude that, although the EHTS is fulfilled, monetary policy, regarding the interest rate channel, these years in the United States have not been fully efficient and, therefore, the transmission mechanism has not been either. Consequently, policy makers should look for alternative paths. Nonetheless, the creation of a figure such as the Federal Reserve is endorsed.

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Appendix

Table A1. Bayesian Information Criterion. Lag length selection

Lags	*Jordà-Schularick-Taylor*	*Shiller's*
1	**879.60**	**840.95**
2	891.09	854.76
3	902.60	853.38
4	906.64	882.61
5	918.50	857.11
6	920.48	851.96

Notes: Bold indicates lag order selected

Table A2. Ljung-Box Q-test

	Jordà-Schularick-Taylor	***Shiller's***
$Q_{\hat{\varepsilon}}$	45.798 (0.564)	39.667 (0.798)

Notes: Following Jones *et al.* (2014), the significance level is set to 10% for exclusion. *P*-values are in parenthesis below LR test values.