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An Analysis of the Daily Changes in US Treasury Security Yields

by

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ABSTRACT

This paper analyzes the dynamics of long-term US Treasury security yields from a Keynesian perspective using daily data. Keynes held that the short-term interest rate is the main driver of the long-term interest rate. In this paper, the daily changes in long-term Treasury security yields are empirically modeled as a function of the daily changes in the short-term interest rate and other important financial variables to test Keynes's hypothesis. The use of daily data provides a long time series. It enables the extension of earlier Keynesian models of Treasury security yields that relied on quarterly and monthly data. Models based on higher-frequency daily data from financial markets—such as the ones presented in this paper—can be valuable to investors, financial analysts, and policymakers because they make it possible for a real-time fundamental assessment of the daily changes in long-term Treasury security yields based on a wide range of financial variables from a Keynesian perspective. The empirical findings of this paper support Keynes's view by showing that the daily changes in the short-term interest rate are the main driver of the daily changes in the long-term interest rate on Treasury securities. Other financial variables, such as the daily changes in implied volatility of equity prices and the daily changes in the exchange rate, are found to have some influence on Treasury yields.

KEYWORDS: Treasury Securities; Government Bond Yields; Long-Term Interest Rate; Short-Term Interest Rate; Monetary Policy; US Government Debt

JEL CLASSIFICATIONS: E43; E50; E60; G10; G12

I. INTRODUCTION

Motivation

Understanding the daily changes in the long-term interest rate on US Treasury securities is an important theoretical and empirical topic. It is a relevant issue for macroeconomic theorists and policymakers interested in monetary transmission mechanisms and the effects of monetary policy, market volatility, inflationary pressures, financial conditions, Treasury debt management and operations, and government debt and deficits ratios on the government bond market. It is also a relevant and practical concern for investors and portfolio managers interested in understanding the dynamics of Treasury security yields for strategic and tactical asset allocation and in making investment decisions concerning duration, convexity, speculation, and delta hedging.

John Maynard Keynes (1930, 352–64) argued that the central bank's actions have a decisive influence on the long-term interest rate. He claimed that the central bank's policy rate sets the short-term interest rate. In turn, the short-term interest rate has a large and consequential influence on the long-term interest rate for Treasury securities.

This paper examines whether Keynes's claim holds true by empirically analyzing the effects of the daily changes in the short-term interest rate on the daily changes in the long-term interest rate on Treasury securities, after accounting for several important factors, such as the daily changes in volatility in the equity markets, energy prices and commodity indexes, and the exchange rate. The empirical findings reported in this paper support Keynes's contention.

The daily changes in long-term Treasury security yields are empirically modeled in this paper. The use of daily data provides many observations over a long period of time. This enables the extension of earlier Keynesian models of Treasury security yields that relied on quarterly and monthly data, such as Akram and Li (2016, 2017, forthcoming), to include high-frequency data from financial markets. Akram and Das (2014, 2015, 2017, 2019) have also modeled government bond yields for other countries and regions, including Japan, India, and the eurozone, using quarterly and monthly data. However, these studies did not use daily data.

Models based on higher-frequency data from financial markets, such as those presented in this paper, can be valuable to investors, financial analysts, and policymakers because such modeling makes it possible for a real-time fundamental assessment of the daily changes in long-term Treasury security yields based on a wide range of financial variables.

Relation to Debates in the Literature

This paper contributes to the ongoing debates on the dynamics of government bond yields. The literature on government bond yields contains many substantial but unresolved debates. The two main schools of thought represent neoclassical and Keynesian views.

The neoclassical school is based on the loanable funds view of the interest rate. It holds that: (1) government bond yields depend on the demand and supply of funds in the capital market; and (2) an increase (decrease) in government debt and deficit ratios leads to higher (lower) government bond yields. The neoclassical view is represented in Ardagna, Caselli, and Lane (2007), Baldacci and Kumar (2010), Do, Hoshi, and Okimoto (2011), Elmendorf and Mankiw (1998), Hansen and İmrohoroğlu (2013), Horioka, Nomoto, and Tera-Hagiwara (2014), Hoshi and Ito (2013, 2014), Lam and Tokuoka (2011), Paccagnini (2016), Poghosyan (2014), Reinhart and Rogoff (2009), Tokuoka (2012), and others. This view originates from the classic works of Eugene von Bohm-Bawerk, Gustav Cassel, Irving Fisher, Frank Taussig, and Alfred Marshall.[3]

Keynes maintained that interest rates have psychological and sociological foundations in a world characterized by ontological uncertainty (Davidson 2015). The Keynesian school is based on the liquidity preference view of the interest rate as articulated in Keynes ([1936]2007). Keynes believed that the central bank's actions are the main drivers of the long-term interest rate. Moreover, some followers of Keynes have argued that for countries with monetary sovereignty, an increase (decrease) in government debt and deficit ratios may not necessarily lead to higher (lower) government bond yields. The Keynesian perspective is represented in Akram (2014), Akram and Das (2014, 2015, 2017, 2019), Akram and Li (2016, 2017, 2018, forthcoming), Kregel (2011), Lavoie (2014), Wray (2012), and others. Simoski (2019) has analyzed government bond yields in several Latin American countries, including Brazil and Mexico, from

[3] Citations to these classics are available in Akram and Das (2019) and Simoski (2019).

a Keynesian vantage point. The Keynesian perspective derives from Keynes (1930, [1936] 2007), who relied on the statistical regularities first analyzed in Riefler (1930). The Keynesian perspective on interest rates and monetary operations, and their relation to fiscal policy, is further developed in Lerner (1947), Wray (2012), and Lavoie (2014). Some New Keynesian economists, such as Sims (2013), have independently arrived at similar conclusions. This paper is aligned with the Keynesian perspective, as it finds that the daily changes in the short-term interest rate are the key determinant of the long-term interest rate, though other variables (such as implied volatility in equity markets and the exchange rate) also do matter.

Whereas the existing literature has relied primarily on quarterly and occasionally monthly data to model the dynamics of government bond yields—since most macroeconomic variables are available in quarterly or monthly formats—this paper advances the discussion and empirical analysis of government bond yields by using high-frequency daily data. Only a small number of macroeconomics papers on US Treasury security yields use high-frequency daily data, such as Bollerslev, Cai, and Song (2000) and Gürkaynak, Sack, and Wright (2007). Indeed, this is the first paper to use daily data in analyzing bond yields from a Keynesian perspective. Examining the empirics of the daily changes in Treasury bond yields from a Keynesian perspective is a new and important extension of the literature.

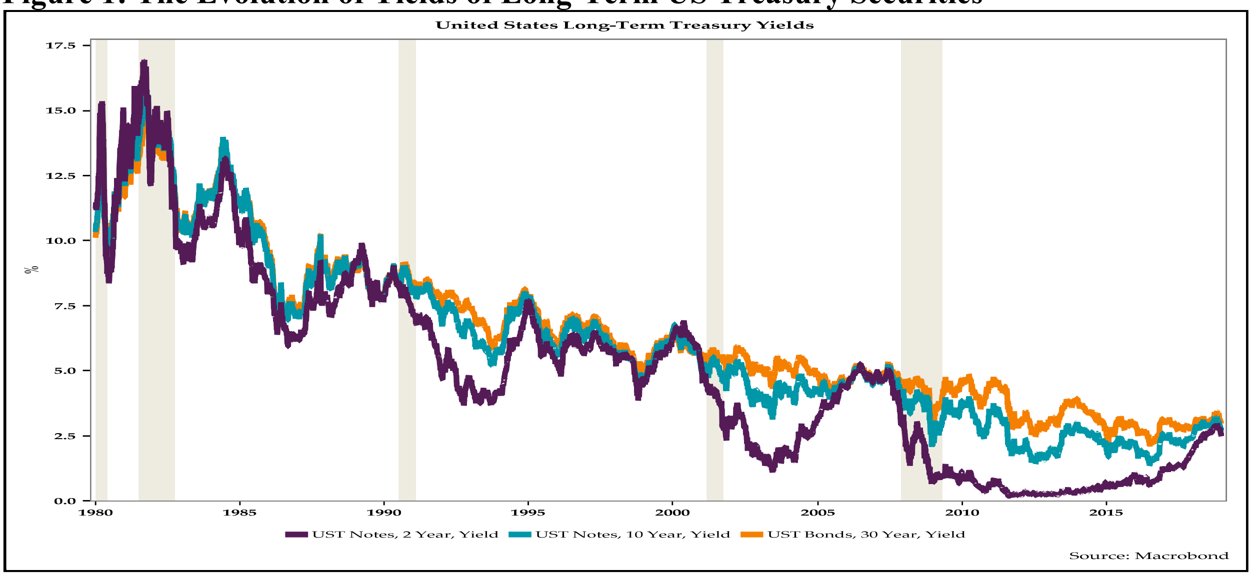
Outline of the Paper

This paper is organized as follows. Section II provides an overview of the evolution of US Treasury security yields and key financial variables. Section III discusses the data, undertakes unit root tests, describes the econometric methodology, and reports the empirical findings. Section IV concludes with a summary of the findings and their relevance to debates in economic theory and policy. The appendix has numerous scatterplots that illustrate the relationship between the short-term interest rate and the long-term interest rate for Treasury securities of varying maturity tenors.

II. THE EVOLUTION OF US TREASURY YIELDS AND KEY FINANCIAL VARIABLES

Figure 1 shows the evolution of long-term Treasury security yields. Treasury yields have declined over the past decades with the secular fall in observed headline and core inflation. (The shaded areas in the figures are recessions, as designated by the National Bureau of Economic Research). The decline in Treasury yields has continued since the turn of the century. This decline in Treasury yields has been further reinforced since the global financial crisis as the Federal Reserve—the central bank of the United States—lowered its policy rate and undertook a massive expansion of its balance sheet with large-scale asset purchases and various credit and liquidity programs to provide financial stability, restore confidence in the financial system, and support financial institutions deemed too big to fail.

Figure 1: The Evolution of Yields of Long-Term US Treasury Securities



This paper models the dynamics of the daily changes in the long-term Treasury yield as a function of the daily changes in the short-term interest rate and other variables. A careful look at the evolution and coevolution of these variables can provide an understanding of the drivers of the long-term interest rate and the underlying relationships among the macroeconomic and financial variables that are key drivers of long-term Treasury security yields.

Figure 2 displays the evolution of the federal funds effective rate and the short-term interest rate, as measured by the yield of 3-month Treasury bills. The Federal Reserve's main policy rate is the federal funds target rate. The Federal Reserve seeks to target the rate at which reserves are traded between financial institutions that are members of the Federal Reserve system. The federal funds effective rate is the actual rate at which the central bank's reserves are traded among banks. The figure shows that the yield of the 3-month Treasury bill is usually very close to the federal funds effective rate. Moreover, the changes in the 3-month Treasury bill's yield moves in lockstep with the changes in the federal funds effective rate. Since the yield of Treasury bills is very close to the federal funds target rate and the market for Treasury bills is more important than that of the federal funds reserve, it is appropriate to model the Keynesian view in which the yield of the Treasury bill is the main short-term interest rate that is relevant for the Treasury securities market. Keynes's thesis that a higher (lower) short-term interest rate will increase (decrease) the long-term interest rate can be operationalized in terms of analyzing the effects of the 3-month Treasury bills' yield on the yield of long-term Treasury securities.

Figure 2: The Evolution of the Federal Funds Effective Rate and the Short-term Interest Rate

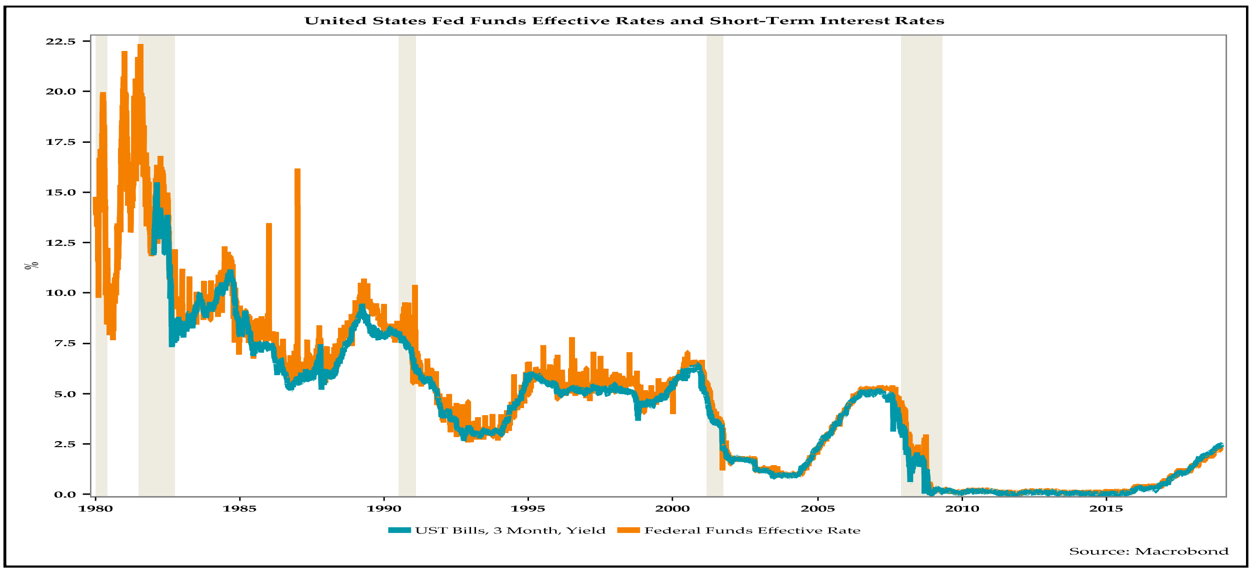


Figure 3 presents the evolution of implied volatility from equity markets. Two key measures of such volatility are used here. The Chicago Board Options Exchange (CBOE) volatility index (VIX) is a measure of the implied volatility of the S&P 500 index, while the CBOE Nasdaq 100 volatility index (VXN) is a measure of the implied volatility of the Nasdaq. Implied volatility from the equity markets provides useful information about investor sentiment, outlook, and risk assessment in financial markets and the broader economy. Increased volatility in equity markets should lower yields if investors seek safety in Treasury securities at times of turmoil and heightened risk aversion in the financial markets.

Figure 3: The Evolution of the Measures of Implied Volatility from Equity Markets

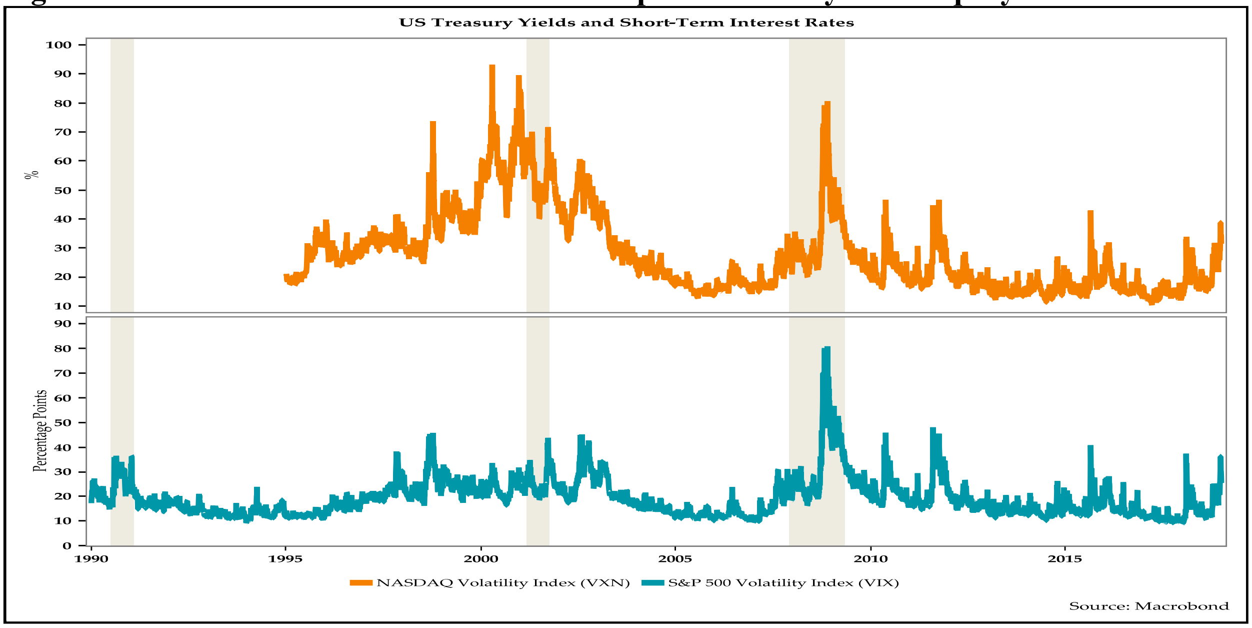


Figure 4 exhibits the evolution of crude oil prices, as measured by two different crude oil price benchmarks. Crude oil prices can be useful because they provide information about inflationary pressure emanating from energy inputs. Crude oil prices also provide insights about growth in the global economy and the outlook for global effective demand. They can also be an indicator of economic and political risks, particularly related to conditions in the major crude oil–producing areas. Higher crude oil prices should increase Treasury yields if investors regard higher crude oil prices as a harbinger of inflationary pressures and strong effective demand in the global economy.

Figure 4: The Evolution of Crude Oil Prices

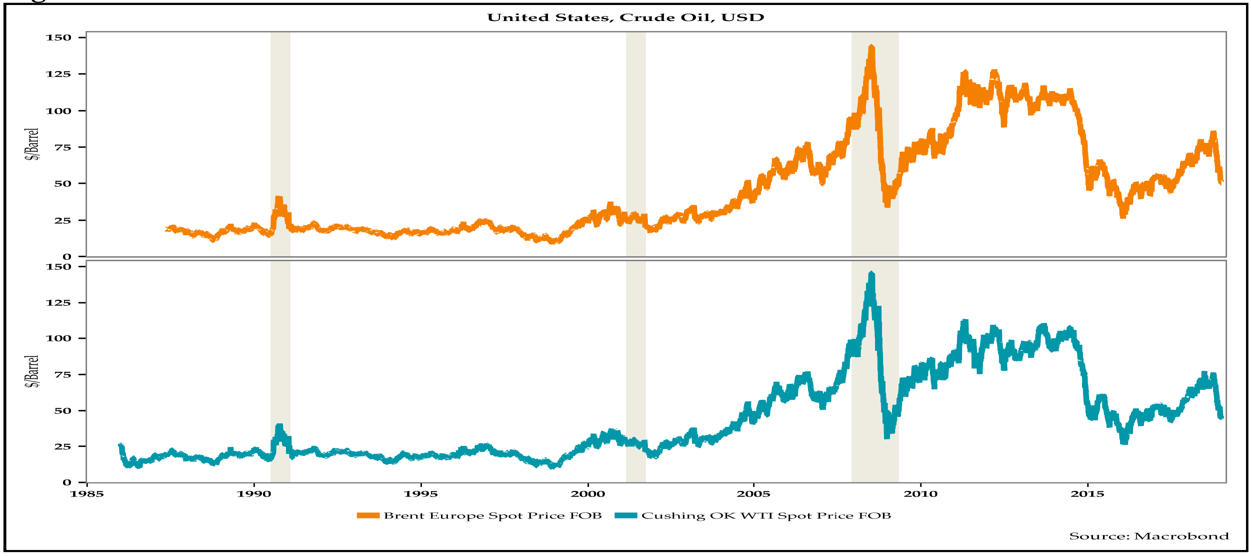


Figure 5 shows the evolution of the commodity (price) index, and the prices for copper and gold. Commodity prices provide propitious cues about global inflationary pressures in the pipeline and aggregate demand. Hence, investors will pay close attention to the behavior of commodity prices, particularly those related to energy, food, industrial goods, and precious metals. Higher commodity prices could be a leading indicator of inflationary pressures. Hence, higher commodity prices should increase Treasury yields, as investors seek to be compensated for higher expected inflation. It is useful to examine whether copper and gold prices have any effect on Treasury yields.

Figure 5: The Evolution of the Commodity Index and Copper and Gold Prices

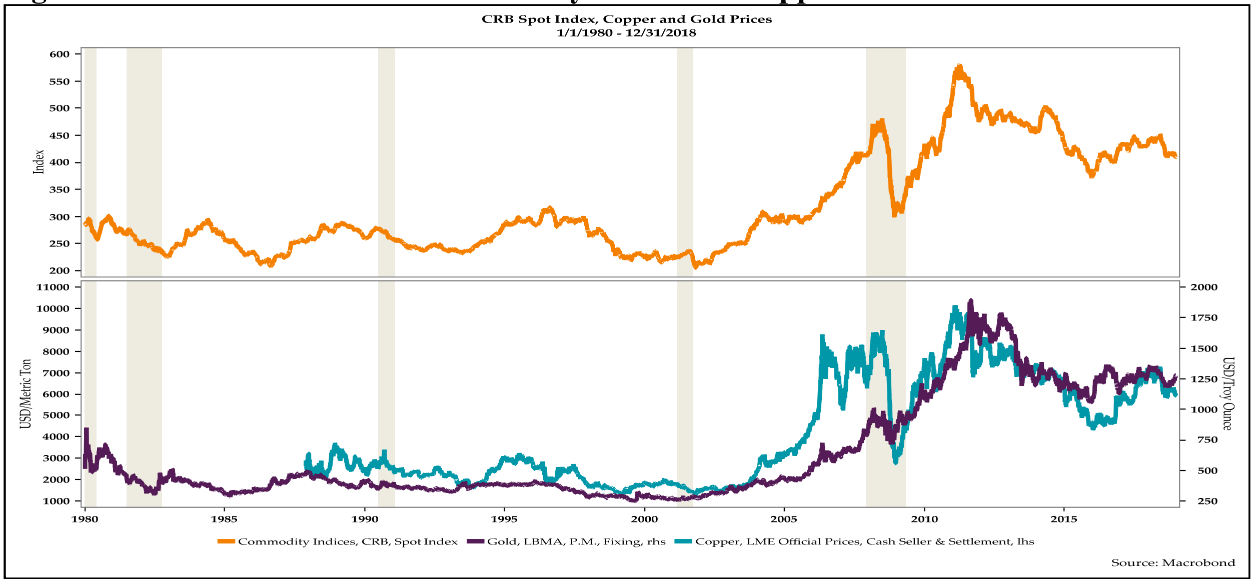
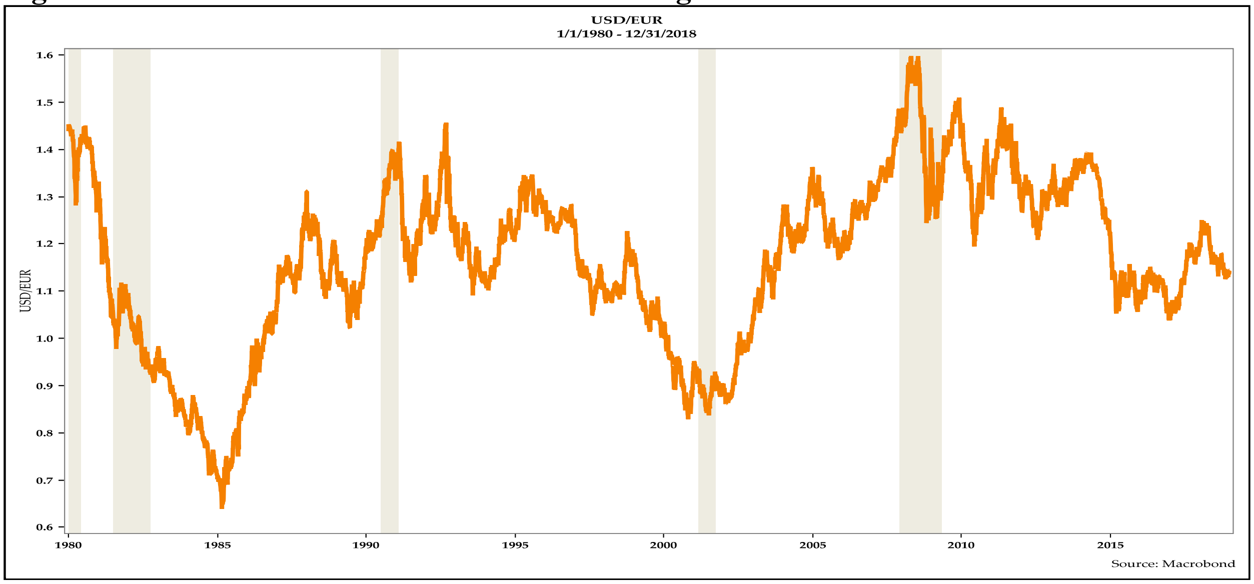


Figure 6 shows the evolution of the value of the US dollar (USD) against the euro (EUR), as represented in the USD/EUR exchange rate. The USD/EUR exchange rate is expressed in terms of dollar per euro, which means that a rise is a depreciation of the dollar with respect to the euro, while a decline is an appreciation of the dollar with respect to the euro. The data for the USD/EUR exchange rate prior to the launch of the euro are constructed based on the dollar exchange rates of the currencies of those countries that joined the eurozone at its launch. The currency value can provide clues to investor confidence and sentiments, as well as to financial flows. These factors have a bearing on Treasury securities. A depreciation (appreciation) of the dollar implies that foreign investors find Treasury securities cheaper (expensive) relative to foreign government bonds. This would increase (decrease) the demand for Treasury securities. Hence, Treasury yields will decline (rise).

Figure 6: The Evolution of the USD/EUR Exchange Rate



Several scatterplots are provided in the appendix. These scatterplots show: (1) the correlation between the yields of Treasury securities of various maturity tenors and the yields of the 3-month Treasury bills; and (2) the correlation between the year-over-year change in the yields of Treasury securities of various maturity tenors and the year-over-year change in the yields of the 3-month Treasury bills.

These scatterplots reveal certain intriguing patterns. First, there is a strong positive correlation between the yields of long-term Treasury securities and Treasury bills. Second, there is also a positive correlation between the year-over-year percentage point changes in the yields of Treasury securities and Treasury bills, but it is less closely correlated than the previously mentioned correlation. Third, the strong positive correlation between the yields of long-term Treasury securities and Treasury bills declines as the maturity tenor of Treasury securities increases. Fourth, the positive correlation between year-over-year percentage point changes in the yields of Treasury securities and Treasury bills also declines as the maturity tenor of Treasury securities rises.

III. DATA, UNIT ROOT TESTS, ECONOMETRIC MODELS, AND EMPIRICAL FINDINGS

Table 1 summarizes the data used in this paper. The first column lists the variables and gives the variable names. The second column describes the data and gives the date range for the data. The third column lists the frequency of the data. The final column gives the sources of the data.

Table 1: Definition and Source of the Variables

Variable labels	Data description	Frequency	Sources
Short-term interest rate			
TB3M	Treasury bills, 3-month, yield, %; 1/4/1982–12/31/2018	Daily	Macrobond
US Treasury security yields			
UST2Y	Treasury securities, 2-year, yield, %; 1/1/1990–12/31/2018	Daily	Macrobond
UST3Y	Treasury securities, 3-year, yield, %; 1/1/1990–12/31/2018	Daily	Macrobond
UST5Y	Treasury securities, 5-year, yield, %; 1/1/1990–12/31/2018	Daily	Macrobond
UST7Y	Treasury securities, 7-year, yield, %; 1/1/1990–12/31/2018	Daily	Macrobond
UST10Y	Treasury securities, 10-year, yield, %; 1/1/1990–12/31/2018	Daily	Macrobond
UST30Y	Treasury securities, 30-year, yield, %; 1/1/1990–12/31/2018	Daily	Macrobond
Volatility			
VIX	S&P 500 volatility index (VIX), close; 1/2/1990–12/31/2018	Daily	Chicago Board Options Exchange; Macrobond
VXN	Nasdaq volatility index (VXN), close; 1/3/1995–12/31/2018	Daily	Chicago Board Options Exchange; Macrobond
Energy prices, commodity prices, and indexes			
CRB	Commodity indexes, CRB, spot index, USD; 1/1/1980–12/31/2018	Daily	Commodity Research Bureau; Macrobond
GOLD	Gold, P.M., fixing, USD; 1/1/1980–12/31/2018	Daily	London Bullion Market Association; Macrobond
COPPER	Copper, official price, cash seller & settlement, USD; 11/20/1987–12/31/2018	Daily	London Metal Exchange; Macrobond
OIL1	Crude oil, Cushing OK WTI spot price FOB, USD; 1/2/1980–12/31/1980	Daily	Energy Information Administration; Macrobond
OIL2	Crude oil, Brent Europe spot price FOB, USD 5/20/1987–12/31/2018	Daily	Energy Information Administration; Macrobond
Currency			
DOLLAR	FX spot rate, USD/EURO; 1/1/1980–12/31/2018	Daily	Macrobond

Models and Equations

The following equations ([1] to [3]) are estimated to examine the relationship between the short-term interest rate and the long-term interest rate on Treasury securities of various maturity tenors:

[1] $\Delta UST = F(\Delta STIR, \Delta VOL)$

[2] $\Delta UST = F(\Delta STIR, \Delta VOL, \Delta COM, \Delta FX)$

[3] $\Delta UST = F(\Delta STIR, \Delta VOL, \Delta OIL, \Delta FX)$

where UST is the yields on US Treasury securities of different tenors, including 2-year (UST2Y), 3-year (UST3Y), 5-year (UST3Y), 7-year (UST7Y), 10-year (UST10Y), and 30-year (UST30Y). Short-term interest rate (STIR) is the yield on 3-month Treasury bills (TB3M). Two variables are used for measures of volatility (VOL). The first one is the S&P 500 volatility index (VIX) and the second one is the Nasdaq volatility index (VXN). CRB spot index (CRB), gold price index (GOLD), and the official price of copper (COPPER) are included in different equations for commodity prices (COM). West Texas Intermediate (WTI) spot price (OIL1) and Brent Europe spot price (OIL2) are used for oil prices. The potential impact of foreign exchange (FX) on UST is represented by the spot rate between the US dollar and the euro (DOLLAR). The notation Δ represents the day-to-day changes in the above-mentioned variables.

The behavioral equations ([4] to [15]) estimated in this paper take the following general forms:

[4] $\Delta UST_i = F(\Delta TB3M, \Delta VIX)$

[5] $\Delta UST_i = F(\Delta TB3M, \Delta VIX, \Delta CRB, \Delta DOLLAR)$

[6] $\Delta UST_i = F(\Delta TB3M, \Delta VIX, \Delta GOLD, \Delta DOLLAR)$

[7] $\Delta UST_i = F(\Delta TB3M, \Delta VIX, \Delta COPPER, \Delta DOLLAR)$

[8] ΔUST_i=F(ΔTB3M, ΔVIX, ΔOIL1, ΔDOLLAR)

[9] ΔUST_i=F(ΔTB3M, ΔVIX, ΔOIL2, ΔDOLLAR)

[10] ΔUST_i=F(ΔTB3M, ΔVXN)

[11] ΔUST_i=F(ΔTB3M, ΔVXN, ΔCRB, ΔDOLLAR)

[12] ΔUST_i=F(ΔTB3M, ΔVXN, ΔGOLD, ΔDOLLAR)

[13] ΔUST_i=F(ΔTB3M, ΔVXN, ΔCOPPER, ΔDOLLAR)

[14] ΔUST_i=F(ΔSTIR, ΔVXN, ΔOIL1, ΔDOLLAR)

[15] ΔUST_i=F(ΔTB3M, ΔVXN, ΔOIL2, ΔDOLLAR)

where i=2-year, 3-year, 5-year, 7-year, 10-year, and 30-year maturity tenors. Daily data on relevant variables are used. Data on ΔVIX and ΔVXN are available from January 3, 1990 and December 18, 1995, respectively. Hence, the time period starts either on January 3, 1990 or on December 18, 1995. Regressions that include ΔVIX as an independent variable have 10,590 observations, while regressions that include ΔVXN as an independent variable have 8,415 observations.

The final step of the analysis involves using the longest possible dataset to examine the relationship between the long-term interest rate on Treasury securities of various tenors and the short-term interest rate. Because of the data availability, ΔTB3M, ΔCRB, ΔGOLD, and ΔDOLLAR are independent variables in the regressions. The full dataset runs from January 4, 1982 to December 31, 2018. Therefore, these regressions include 13,511 observations. The following equations ([16] to [18]) are estimated using the full sample period:

[16] $\Delta UST_i = F(\Delta TB3M)$

[17] $\Delta UST_i = F(\Delta TB3M, \Delta CRB, \Delta DOLLAR)$

[18] $\Delta UST_i = F(\Delta TB3M, \Delta GOLD, \Delta DOLLAR)$

where i=2-year, 3-year, 5-year, 7-year, 10-year, and 30-year maturity period.

Empirical Findings

Since this study deals with a long time series, the first step is to examine if the variables follow the unit root process. Both Augmented Dickey-Fuller (ADF) (Dickey and Fuller 1979, 1981) and Phillips-Perron (PP) (Phillips and Perron 1988) tests are used in the paper. Results from three different versions (specifically, without either constant or trend, only with constant but no trend, and with both constant and trend) of ADF and PP tests are presented in tables 2 and 3.

Table 2: Augmented Dickey-Fuller Tests

Variable	ADF			
	No Trend or Intercept	With Intercept	With Trend and Intercept	Time Period
ΔUST2Y	-63.250***	-63.263***	-63.282***	1/2/1990 to 12/31/2018
ΔUST3Y	-85.612***	-85.620***	-85.628***	1/2/1990 to 12/31/2018
ΔUST5Y	-63.567***	-63.577***	-63.580***	1/2/1990 to 12/31/2018
ΔUST7Y	-63.243***	-63.253***	-63.254***	1/2/1990 to 12/31/2018
ΔUST10Y	-85.709***	-85.717***	-85.714***	1/2/1990 to 12/31/2018
ΔUST30Y	-86.921***	-86.930***	-86.925***	1/2/1990 to 12/31/2018
ΔTB3M	-16.832***	-16.879***	-17.283***	1/2/1990 to 12/31/2018
ΔVIX	-31.214***	-31.212***	-31.211***	1/2/1990 to 12/31/2018
ΔVXN	-34.521***	-34.518***	-34.516***	1/3/1995 to 12/31/2018
ΔCRB	-29.765***	-29.777***	-29.774***	1/2/1990 to 12/31/2018
ΔGOLD	-87.276***	-87.285***	-87.282***	1/2/1990 to 12/31/2018
ΔCOPPER	-91.901***	-91.898***	-91.892***	1/2/1990 to 12/31/2018
ΔOIL1	-91.022***	-91.017***	-91.013***	1/2/1990 to 12/31/2018
ΔOIL2	-84.443***	-84.439***	-84.435***	1/2/1990 to 12/31/2018
ΔDOLLAR	-86.396***	-86.391***	-86.387***	1/2/1990 to 12/31/2018

Notes: 1) The null hypothesis of the ADF test is that the series contains unit roots.
2) *** represents statistical significance at the 1 percent level.

Table 3: Phillips-Perron Tests

Variable	PP			
	No Trend or Intercept	With Intercept	With Trend and Intercept	Time Period
ΔUST2Y	-86.019***	-86.024***	-86.021***	1/2/1990 to 12/31/2018
ΔUST3Y	-85.628***	-85.633***	-85.638***	1/2/1990 to 12/31/2018
ΔUST5Y	-85.880***	-85.889***	-85.892***	1/2/1990 to 12/31/2018
ΔUST7Y	-85.848***	-85.848***	-85.849***	1/2/1990 to 12/31/2018
ΔUST10Y	-85.702***	-85.717***	-85.714***	1/2/1990 to 12/31/2018
ΔUST30Y	-87.027***	-87.042***	-87.037***	1/2/1990 to 12/31/2018
ΔTB3M	-77.616***	-77.632***	-77.682***	1/2/1990 to 12/31/2018
ΔVIX	-105.266***	-105.257***	-105.250***	1/2/1990 to 12/31/2018
ΔVXN	-34.521***	-34.518***	-34.516***	1/3/1995 to 12/31/2018
ΔCRB	-88.674***	-88.627***	-88.624***	1/2/1990 to 12/31/2018
ΔGOLD	-87.291***	-87.300***	-87.297***	1/2/1990 to 12/31/2018
ΔCOPPER	-91.903***	-91.898***	-91.893***	1/2/1990 to 12/31/2018
ΔOIL1	-91.088***	-91.082***	-91.079***	1/2/1990 to 12/31/2018
ΔOIL2	-84.552***	-84.547***	-84.543***	1/2/1990 to 12/31/2018
ΔDOLLAR	-86.396***	-86.390***	-86.391***	1/2/1990 to 12/31/2018

Notes: 1) The null hypothesis of the PP test is that the series contains unit roots.
2) *** represents statistical significance at the 1 percent level.

Test results suggest that the null hypothesis of the unit root is rejected at less than the 1 percent level for all variables. Therefore, it is reasonable to conjecture that these variables are stationary, i.e., I(0).

In the following step, equations [4] to [15] are estimated using the ordinary least squares (OLS) technique. In these equations, ΔVIX is included as an independent variable. Results are reported in table 4. Not surprisingly, in all equations the short-term interest rate has the strongest influence on the Treasury security yields. The coefficient of ΔTB3M is always positive and significant at the 1 percent level. The size of this variable shows a declining trend from 0.5 to 0.2 with the rise of the tenor of Treasury securities. It shows that the changes in the current short-term interest rate have a strong effect on the yields of Treasuries securities of a shorter maturity tenor than on the yields of Treasury securities of a long maturity tenor. In essence, the influence of the daily changes of the short-term interest rate is much higher at the front end of the Treasury yield curve than at the back end of the Treasury yield curve. As expected, the daily changes in volatility are negatively associated with the daily changes in Treasury yields. The daily changes in prices of commodities, copper, and oil exhibit a positive relationship with the daily changes in Treasury yields. Coefficients of these variables are always significant at the 1 percent level. This implies that an increase in inflationary pressure is associated with higher bond yields. The coefficient of the daily changes in the gold price index is negative and significant in three out of six equations. This suggests that higher gold prices—which often rise when investors are concerned about the state of effective demand and inflation risks—lead to lower bond yields, as investors also seek safety in Treasury securities. The coefficient of the daily changes in the dollar exchange rate is negative and significant at the 1 percent level in all six equations. This implies that the depreciation of the US dollar reduces the yields on Treasury securities. The depreciation of the dollar makes Treasury securities cheaper relative to foreign government bonds in terms of foreign currency. Hence, this increases the demand for Treasury securities, as they become cheaper to overseas investors. This results in higher prices and lower Treasury yields.

In the next step of the analysis, two robustness tests—namely the Breusch-Godfrey Lagrange multiplier (LM) test and the Harvey heteroskedasticity test—are applied to examine if the results suffer from any serial correlation or heteroskedasticity. Results, given in table 5, show that there is evidence of serial correlation in only one out of 36 equations estimated in this paper. However, results for heteroskedasticity are rather mixed. There is no evidence of the presence of heteroskedasticity in 23 out of 36 equations.

Table 4: Ordinary Least Squares Results (with ΔVIX) (time period: 01/03/1990 to 12/31/2018)

	Eq.	ΔTB3M	ΔVIX	ΔCRB	ΔGOLD	ΔCOPPER	ΔOIL1	ΔOIL2	ΔDOLLAR	Const	R^2
ΔUST2Y	4	0.466***	-0.005***	-	-	-	-	-	-	-0.000	0.198
	5	0.458***	-0.004***	0.002***	-	-	-	-	-0.804***	-0.000	0.210
	6	0.460***	-0.005***	-	-0.000	-	-	-	-0.722***	-0.000	0.208
	7	0.459***	-0.005***	-	-	0.000***	-	-	-0.776***	-0.000	0.209
	8	0.458***	-0.005***	-	-	-	0.002***	-	-0.776***	-0.000	0.209
	9	0.458***	-0.005***	-	-	-	-	0.002***	-0.786***	-0.000	0.210
ΔUST3Y	4	0.446***	-0.005***	-	-	-	-	-	-	-0.000	0.167
	5	0.437***	-0.005***	0.003***	-	-	-	-	-0.837***	-0.000	0.180
	6	0.441***	-0.005***	-	-0.000	-	-	-	-0.711***	-0.000	0.177
	7	0.439***	-0.005***	-	-	0.000***	-	-	-0.790***	-0.000	0.178
	8	0.437***	-0.005***	-	-	-	0.003***	-	-0.815***	-0.000	0.180
	9	0.438***	-0.005***	-	-	-	-	0.003***	-0.824***	-0.000	0.181
ΔUST5Y	4	0.402***	-0.006***	-	-	-	-	-	-	-0.000	0.133
	5	0.393***	-0.005***	0.003***	-	-	-	-	-0.748***	-0.000	0.144
	6	0.397***	-0.006***	-	-0.000	-	-	-	-0.574***	-0.000	0.139
	7	0.395***	-0.006***	-	-	0.000***	-	-	-0.700***	-0.000	0.141
	8	0.391***	-0.006***	-	-	-	0.005***	-	-0.750***	-0.000	0.147
	9	0.393***	-0.006***	-	-	-	-	0.005***	-0.750***	-0.000	0.146
ΔUST7Y	4	0.346***	-0.006***	-	-	-	-	-	-	-0.000	0.104
	5	0.338***	-0.006***	0.003***	-	-	-	-	-0.615***	-0.001	0.114
	6	0.342***	-0.006***	-	-0.000***	-	-	-	-0.412***	-0.000	0.1089
	7	0.340***	-0.006***	-	-	0.000***	-	-	-0.572***	-0.000	0.111
	8	0.335***	-0.005***	-	-	-	0.006***	-	-0.631***	-0.000	0.120
	9	0.338***	-0.006***	-	-	-	-	0.006***	-0.627***	-0.000	0.118
ΔUST10Y	4	0.297***	-0.006***	-	-	-	-	-	-	-0.000	0.089
	5	0.290***	-0.005***	0.003***	-	-	-	-	-0.502***	-0.001	0.098
	6	0.294***	-0.006***	-	-0.000**	-	-	-	-0.318***	-0.000	0.092
	7	0.292***	-0.005***	-	-	0.000***	-	-	-0.462***	-0.001	0.095
	8	0.287***	-0.005***	-	-	-	0.006***	-	-0.529***	-0.001	0.107
	9	0.290***	-0.005***	-	-	-	-	0.006***	-0.523***	-0.000	0.104
ΔUST30Y	4	0.203***	-0.005***	-	-	-	-	-	-	-0.000	0.058
	5	0.199***	-0.004***	0.003***	-	-	-	-	-0.195**	-0.001	0.066
	6	0.203***	-0.005***	-	-0.000**	-	-	-	-0.010***	-0.000	0.059
	7	0.201***	-0.004***	-	-	0.000***	-	-	-0.152**	-0.001	0.062
	8	0.195***	-0.004***	-	-	-	0.007***	-	-0.237***	-0.001	0.080
	9	0.198***	-0.004***	-	-	-	-	0.006***	-0.218***	-0.000	0.073

Note: *** and ** represent statistical significance at the 1 percent and 5 percent level, respectively.

Table 5: Robustness Tests (with ΔVIX)

	Eq. 4	Eq. 5	Eq. 6	Eq. 7	Eq. 8	Eq. 9
			Breusch-Godfrey serial correlation LM Test			
ΔUST2Y	0.000	0.454	0.332	0.466	0.428	0.447
ΔUST3Y	1.022	0.082	0.147	0.071	0.093	0.068
ΔUST5Y	1.996	0.690	0.823	0.558	0.616	0.581
ΔUST7Y	3.322	1.796	1.933	1.410	1.576	1.497
ΔUST10Y	4.882**	3.273	3.626	2.648	2.964	2.857
ΔUST30Y	0.675	0.270	0.551	0.093	0.094	0.095
			Harvey heteroskedasticity test			
ΔUST2Y	2.428	1.900	2.381**	1.740	2.261	2.446
ΔUST3Y	2.063	2.654**	1.464	2.422**	1.657	1.642
ΔUST5Y	5.134***	2.946***	2.174	2.793**	2.435**	2.650**
ΔUST7Y	1.521	1.355	1.408	1.382	1.469	1.208
ΔUST10Y	1.075	1.591	2.483**	2.521**	2.110	2.328
ΔUST30Y	2.336	3.032**	2.283	2.798**	2.927**	2.295

Note: *** and ** represent statistical significance at the 1 percent and 5 percent level, respectively

In the next set of equations (i.e., [10] to [15]), ΔVIX is replaced by ΔVXN. Results from these regressions, displayed in table 6, are very similar to what were found earlier. As before, ΔTB3M has the strongest influence on the daily changes in Treasury yields. The magnitude of the coefficient of ΔTB3M lies between 0.1 and 0.4. The coefficient on ΔVXN is always negative and statistically significant at the 1 percent level. Coefficients for the daily change in commodities, copper, and oil are positive and significant, while the coefficient of the daily changes in the gold price is negative and significant in most equations. Finally, the coefficient of the daily change in the dollar exchange rate is negative and significant in all but five equations. Robustness tests, shown in table 7, suggest that there is no evidence of serial correlation (at least at the 5 percent level) in any equation, though heteroskedasticity is sometimes present.

Table 6: Ordinary Least Squares Results (with ΔVXN) (time period: 12/18/1995–12/31/2018)

	Eq.	ΔTB3M	ΔVXN	ΔCRB	ΔGOLD	ΔCOPPER	ΔOIL1	ΔOIL2	ΔDOLLAR	Const	R^2
ΔUST2Y	10	0.377***	-0.006***	-	-	-	-	-	-	-0.000	0.165
	11	0.371***	-0.005***	0.002***	-	-	-	-	-0.790***	-0.000	0.177
	12	0.373***	-0.006***	-	-0.000	-	-	-	-0.651***	-0.000	0.167
	13	0.372***	-0.005***	-	-	0.000***	-	-	-0.766***	-0.000	0.176
	14	0.371***	-0.005***	-	-	-	0.002***	-	-0.753***	-0.000	0.176
	15	0.371***	-0.005***	-	-	-	-	0.002***	-0.768***	-0.000	0.176
ΔUST3Y	10	0.364***	-0.006***	-	-	-	-	-	-	-0.000	0.144
	11	0.357***	-0.006***	0.003***	-	-	-	-	-0.840***	-0.000	0.156
	12	0.360***	-0.006***	-	-0.000**	-	-	-	-0.637***	-0.000	0.153
	13	0.359***	-0.006***	-	-	0.000***	-	-	-0.792***	-0.000	0.154
	14	0.356***	-0.006***	-	-	-	0.003***	-	-0.811***	-0.000	0.156
	15	0.357***	-0.006***	-	-	-	-	0.003***	-0.825***	-0.000	0.156
ΔUST5Y	10	0.323***	-0.007***	-	-	-	-	-	-	-0.000	0.117
	11	0.316***	-0.007***	0.003***	-	-	-	-	-0.173***	-0.000	0.127
	12	0.319***	-0.007***	-	-0.000***	-	-	-	-0.425***	-0.000	0.123
	13	0.318***	-0.007***	-	-	0.000***	-	-	-0.658***	-0.000	0.124
	14	0.319***	-0.006***	-	-	-	0.004***	-	-0.712***	-0.000	0.129
	15	0.315***	-0.007***	-	-	-	-	0.004***	-0.714***	-0.000	0.129
ΔUST7Y	10	0.276***	-0.007***	-	-	-	-	-	-	-0.000	0.094
	11	0.269***	-0.006***	0.003***	-	-	-	-	-0.583***	-0.000	0.104
	12	0.273***	-0.007***	-	-0.000*	-	-	-	-0.254**	-0.000	0.100
	13	0.271***	-0.007***	-	-	0.000***	-	-	-0.533***	-0.000	0.101
	14	0.265***	-0.006***	-	-	-	0.005***	-	-0.600***	-0.000	0.109
	15	0.268***	-0.006***	-	-	-	-	0.005***	-0.597***	-0.000	0.107
ΔUST10Y	10	0.234***	-0.007***	-	-	-	-	-	-	-0.000	0.085
	11	0.301***	-0.006***	0.003***	-	-	-	-	-0.436***	-0.000	0.093
	12	0.232***	-0.007***	-	-0.000***	-	-	-	-0.133	-0.000	0.088
	13	0.230***	-0.006***	-	-	0.000***	-	-	-0.391***	-0.000	0.090
	14	0.224***	-0.006***	-	-	-	0.005***	-	-0.466***	-0.000	0.100
	15	0.226***	-0.006***	-	-	-	-	0.005***	-0.458***	-0.000	0.097
ΔUST30Y	10	0.153***	-0.005***	-	-	-	-	-	-	-0.000	0.057
	11	0.149***	-0.005***	0.003***	-	-	-	-	-0.093	-0.001	0.066
	12	0.152***	-0.005***	-	-0.000***	-	-	-	0.210**	-0.000	0.060
	13	0.151***	-0.005***	-	-	0.000***	-	-	-0.042	-0.000	0.062
	14	0.144***	-0.005***	-	-	-	0.006***	-	-0.142	-0.000	0.078
	15	0.147***	-0.005***	-	-	-	-	0.005***	-0.117	-0.000	0.071

Note: *** and ** represent statistical significance at the 1 percent and 5 percent level, respectively.

Table 7: Robustness Tests (with ΔVXN)

	Eq. 10	Eq. 11	Eq. 12	Eq. 13	Eq. 14	Eq. 15
	Breusch-Godfrey serial correlation LM test					
ΔUST2Y	2.055	3.819	3.152	3.898**	3.621	3.616
ΔUST3Y	0.265	1.154	1.005	1.211	1.006	1.031
ΔUST5Y	0.057	0.051	0.048	0.105	0.036	0.032
ΔUST7Y	0.238	0.005	0.002	0.008	0.009	0.011
ΔUST10Y	1.005	0.448	0.452	0.218	0.505	0.515
ΔUST30Y	0.034	0.117	0.004	0.117	0.015	0.010
	Harvey heteroskedasticity test					
ΔUST2Y	2.709	6.886***	5.114***	6.739***	6.422***	6.398***
ΔUST3Y	1.470	2.883**	1.523	2.856**	2.289	2.036
ΔUST5Y	2.479	1.004	0.554	1.248	1.449	1.205
ΔUST7Y	0.991	0.457	0.510	1.108	0.725	0.925
ΔUST10Y	0.241	0.755	0.775	0.550	0.610	0.276
ΔUST30Y	1.518	1.049	0.553	1.557	1.218	1.500

Note: *** and ** represent statistical significance at the 1 percent and 5 percent level, respectively**.**

The results from estimating equations [16] to [18] are presented in table 8. The full dataset is used for these regressions. The results are consistent with the earlier results. Both ΔTB3M and ΔCRB have positive and statistically significant effects on the daily changes of Treasury yields. The coefficients of ΔGOLD and ΔDOLLAR are negative when these coefficients are statistically significant. Robustness tests, provided in table 9, show that the estimated equations are mostly free from the problems of serial correlation and heteroskedasticity.

Table 8: Ordinary Least Squares Results (time period: 01/04/1982 to 12/31/2018)

	Eq.	ΔTB3M	ΔCRB	ΔGOLD	ΔDOLLAR	Const	R^2
ΔUST2Y	16	0.498***	-	-	-	-0.001	0.303
	17	0.493***	0.002***	-	-0.729***	-0.001	0.311
	18	0.494***	-	-0.000	-0.631***	-0.001	0.309
ΔUST3Y	16	0.469***	-	-	-	-0.001	0.255
	17	0.464***	0.003***	-	-0.767***	-0.001	0.264
	18	0.465***	-	-0.000	-0.640***	-0.001	0.261
ΔUST5Y	16	0.423***	-	-	-	-0.001	0.200
	17	0.418***	0.004***	-	-0.654***	-0.001	0.209
	18	0420***	-	-0.000**	-0.485***	-0.001	0.204
ΔUST7Y	16	0.382***	-	-	-	-0.001	0.164
	17	0.378***	0.004***	-	-0.527***	-0.001	0.171
	18	0.380***	-	-0.000**	-0.338***	-0.001	0.166
ΔUST10Y	16	0.348***	-	-	-	-0.001	0.149
	17	0.345***	0.004***	-	-0.419***	-0.001	0.156
	18	0.346***	-	-0.001*	-0.251***	-0.001	0.150
ΔUST30Y	16	0.277***	-	-	-	-0.001	0114
	17	0.275***	0.003***	-	-0.110	-0.001	0.120
	18	0.277***	-	-0.000*	0.045	-0.001	0.114

Note: ***, **, and * represent statistical significance at the 1 percent, 5 percent, and 10 percent level, respectively.

Table 9: Robustness Tests

	Eq. 16	Eq. 17	Eq. 18
	Breusch-Godfrey serial correlation LM test		
ΔUST2Y	0.183	0.651	0.519
ΔUST3Y	0.753	0.391	0.432
ΔUST5Y	1.526	0.944	1.045
ΔUST7Y	1.936	1.493	1.494
ΔUST10Y	1.970	1.525	1.649
ΔUST30Y	0.221	0.113	0.221
	Harvey heteroskedasticity test		
ΔUST2Y	1.997	3.057**	2.203
ΔUST3Y	2.246	0.989	1.215
ΔUST5Y	1.615	1.131	0.856
ΔUST7Y	0.907	1.011	0.984
ΔUST10Y	0.088	2.230	2.651**
ΔUST30Y	0.151	2.024	1.121

Note: *** and ** represent statistical significance at the 1 percent and 5 percent level, respectively

IV. CONCLUSION

The empirical findings reported in this paper have important implications for economic theory and public policy.

First, the findings provide evidence that the Federal Reserve's actions on the federal funds target rate and other monetary policy actions have a decisive effect on the daily change in long-term Treasury security yields, primarily through the daily change in yield on the 3-month Treasury bill. Second, it shows that the other key drivers of the long-term interest rate are the daily changes in volatility in the equity market, the index of commodity prices, crude oil prices, and the exchange rate of the dollar. Third, the empirical analysis presented holds for Treasury securities of various maturity tenors. This means that the Federal Reserve's federal funds target rate and other monetary policy actions have an effective influence on the shape of the yield curve through the daily changes in the short-term interest rate, even after accounting for several key macroeconomic and financial variables. Fourth, the analysis shows daily changes in the long-term interest rate can be explained quite well without government fiscal variables. Fifth, modeling the daily changes in the long-term interest rate based on the analysis of high-frequency macroeconomic and financial variables can be useful for policymakers and investors because it provides a fundamental perspective that can complement models based on quarterly and monthly data. In essence, the findings of this paper support Keynes's view that the central bank's policy actions have a decisive influence on the long-term interest rate of Treasury securities through the central bank's influence on the short-term interest rate.

These findings are relevant to current policy debates regarding low and negative interest rates, the monetary policy transmission mechanism, central bank operations, the fiscal theory of price, the effects of elevated government deficit and debt ratios on the yields of Treasury securities, fiscal sustainability in countries with their own currencies, and financial stability. These issues have been discussed in Bindseil (2004), Elmendorf and Mankiw (1998), Fullwiler ([2008]2017), Lavoie (2014), Reinhard and Rogoff (2009), Sims (2013), and Wray (2012) from different theoretical perspectives. These debates are relevant for not only for the United States but also for other advanced economies, such as Japan and the United Kingdom, that have witnessed the perpetuation of low and negative interest rates in recent years. Empirical analysis of the drivers of the daily changes in long-term Treasury security yields, such as those conducted here, can inform these theoretical and policy discussions, even amid divergence of theoretical perspectives. In future research, it would be useful to model the dynamics of daily changes of the long-term interest rate on government bonds for other advanced economies and key emerging markets to determine whether Keynes's perspective holds.

REFERENCES

Akram, T. 2014. "The Economics of Japan's Stagnation." *Business Economics* 49(3): 156–75.

Akram, T., and A. Das. 2014. "Understanding the Low Yields of the Long-Term Japanese Sovereign Debt." *Journal of Economic Issues* 48(2): 331–40.

———. 2015. "A Keynesian Explanation of Indian Government Bond Yields." *Journal of Post Keynesian Economics* 38(4): 565–87.

———. 2017. "The Dynamics of Government Bond Yields in the Eurozone." *Annals of Financial Economics* 12(3): 1750011-1-1750011-18.

———. 2019. "The Long-run Determinants of Indian Government Bond Yields." *Asian Development Review* 36(1): 168–205.

Akram, T., and H. Li. 2016. "The Empirics of Long-term US Interest Rates." Levy Economics Institute Working Paper 863. Annandale-on-Hudson, NY: Levy Economics Institute of Bard College.

———. 2017. "What Keeps Long-Term U.S. Interest Rates So Low?" *Economic Modelling* 60: 380–90.

———. 2018. "The Dynamics of JGBs' Nominal Yields." Levy Economics Institute Working Paper 906. Annandale-on-Hudson, NY: Levy Economics Institute of Bard College.

———. Forthcoming. "An Inquiry Concerning Long-Term U.S. Interest Rates Using Monthly Data." *Applied Economics*.

Ardagna, S., F. Caselli, and T. Lane. 2007. "Fiscal Discipline and the Cost of Public Debt Service: Some Estimates for OECD Countries." *The B.E. Journal of Macroeconomics* 7(1): 1–33.

Baldacci, E., and M. Kumar. 2010. "Fiscal Deficits, Public Debt, and Sovereign Bond Yields." IMF Working Paper No. 10/184. Washington, DC: International Monetary Fund.

Bindseil, U. 2004. *Monetary Policy Implementation: Theory, Past, and Present*. Oxford and New York: Oxford University Press.

Bollerslev, T., J. Cai, and F. M. Song. 2000. "Intraday Periodicity, Long Memory Volatility, and Macroeconomic Announcement Effects in the US Treasury Bond Market." *Journal of Empirical Finance* 7(1): 37–55.

Davidson, P. 2015. *Post Keynesian Theory and Policy: A Realistic Analysis of the Market Oriented Capitalist Economy*. Cheltenham, UK, and Northampton, MA: Edward Elgar.

Dickey, D. A., and W. A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association* 74(366): 427–31.

———. 1981. "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root." *Econometrica* 49(4): 1057–72.

Doi, T., T. Hoshi, and T. Okimoto. 2011. "Japanese Government Debt and Sustainability of Fiscal Policy." *Journal of the Japanese and International Economies* 25(4): 414–33.

Elmendorf, D. W., and N. G. Mankiw. 1998. "Government Debt." NBER Working Paper No. 6470. Cambridge, MA: National Bureau of Economic Research.

Fullwiler, S. T. (2008) 2017. "Modern Central Bank Operations: The General Principles." In Louis-Philippe Rochon and Sergio Rossi (eds.), *Advances in Endogenous Money Analysis*. Northampton, MA: Edward Elgar.

Gruber, J. W., and S. B. Kamin. 2012. "Fiscal Positions and Government Bond Yields in OECD Countries." *Journal of Money, Credit, and Banking* 44(8): 1563–87.

Gürkaynak, R. S., B. Sack, and J. H. Wright. 2007. "The US Treasury Yield Curve: 1961 to the Present." *Journal of Monetary Economics* 54(8): 2291–304.

Hansen, G., and S. İmrohoroğlu. 2013. "Fiscal Reform and Government Debt in Japan: A Neoclassical Perspective." *Review of Economic Dynamics* 21: 201–24.

Horioka, C. Y., T. Nomoto, and A. Terada-Hagiwara. 2014. "Why Has Japan's Massive Government Debt Not Wreaked Havoc (Yet)?" *The Japanese Political Economy* 40(2): 3–23.

Hoshi T., and T. Ito. 2013. "Is the Sky the Limit? Can Japanese Government Bonds Continue to Defy Gravity?" *Asian Economic Policy Review* 8(2): 218–47.

———. 2014. "Defying Gravity: Can Japanese Sovereign Debt Continue to Increase Without a Crisis?" *Economic Policy* 29(77): (January) 5–44.

Keynes, J. M. 1930. *A Treatise on Money, Vol. II: The Applied Theory of Money*. London: Macmillan.

———. (1936) 2007. *The General Theory of Employment, Interest, and Money*. New York: Palgrave Macmillan.

Kregel, J. 2011. "Was Keynes' Monetary Policy *À Outrance* in the *Treatise*, A Forerunner of ZIRP and QE? Did He Change His Mind in the *General Theory*?" Levy Economics Institute Policy Note 2011/4. Annandale-on-Hudson, NY: Levy Economics Institute of Bard College.

Lam, R. W., and K. Tokuoka. 2011. "Assessing the Risks to the Japanese Government Bond (JGB) Market." *Journal of International Commerce, Economics and Policy* 4(1): 1350002-1-1350002-15.

Lavoie, M. 2014. *Post-Keynesian Economics: New Foundations.* Cheltenham, UK and Northampton, MA: Edward Elgar.

Lerner, A. P. 1947. "Money as a Creature of the State." *American Economic Review* 37(2): 312–17.

Macrobond. Various years. Macrobond subscription services (accessed June 28, 2019).

Paccagnini, A. 2016. "The Macroeconomic Determinants of the US Term Structure during the Great Moderation." *Economic Modelling* 52(A): 216–25.

Phillips, P. C. B., and P. Perron. 1988. "Testing for a Unit Root in Time Series Regression." *Biometrika* 75(2): 335–46.

Poghosyan, T. 2014. "Long-Run and Short-Run Determinants of Sovereign Bond Yields in Advanced Economies." *Economic Systems* 38(1): 100–14.

Reinhart, C. M., and K. S. Rogoff. 2009. *This Time is Different: Eight Centuries of Financial Folly*. Princeton, NJ: Princeton University Press.

Riefler, W. W. 1930. *Money Rates and Money Markets in the United States*. New York and London: Harper & Brothers.

Simoski, S. 2019. "A Keynesian Exploration of the Determinants of Government Bond Yields for Brazil, Colombia, and Mexico." Master of Science thesis, Levy Economics Institute of Bard College. Annandale-on-Hudson, NY: Bard College. Available at: https://digitalcommons.bard.edu/levy_ms/16

Sims, C. A. 2013. "Paper Money." *American Economic Review* 103(2): 563–84.

Tokuoka, K. 2012. "Intergenerational Implications of Fiscal Consolidation in Japan." IMF Working Paper No. 12/197. Washington DC: International Monetary Fund.

Wray, L. R. 2012. *Modern Money Theory: A Primer on Macroeconomics for Sovereign Monetary Systems*. New York: Palgrave Macmillan.

APPENDIX: SCATTERPLOTS

Figure A1: Scatterplot of the Yields of 2-year Treasury Securities and 3-month Treasury Bills

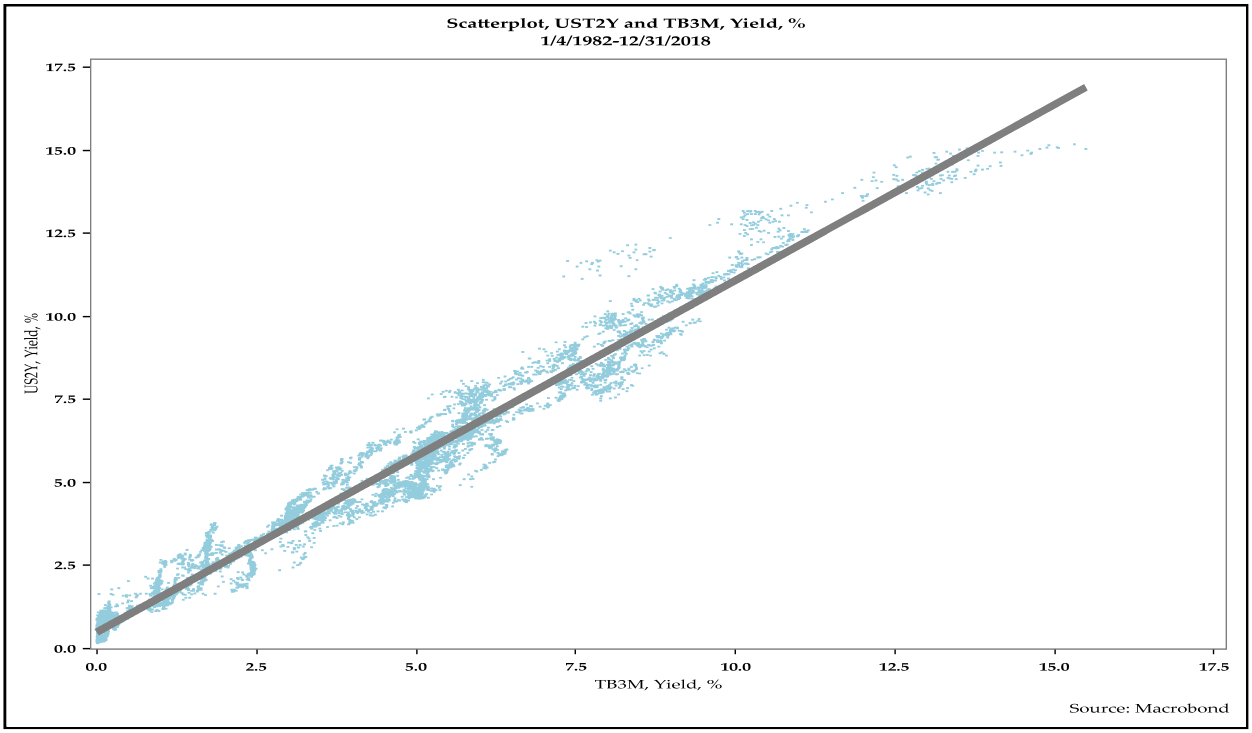


Figure A2: Scatterplot of Year-over-Year Percentage Point Changes in the Yields of 2-year Treasury Securities and 3-month Treasury Bills

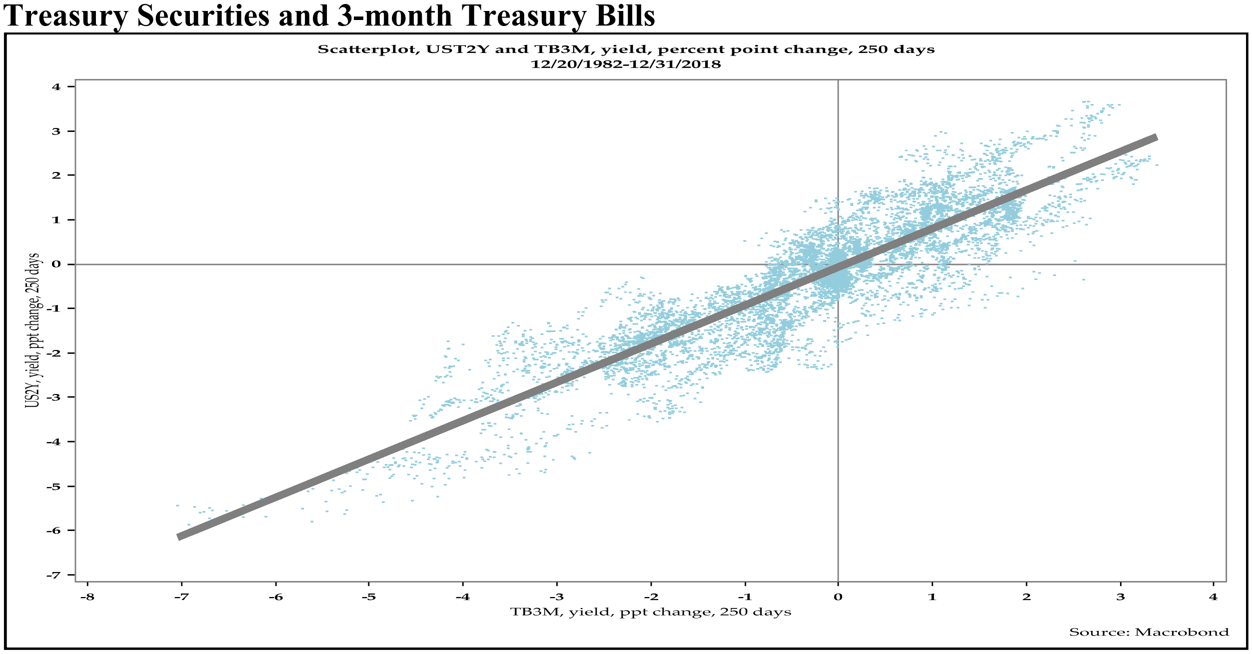


Figure A3: Scatterplot of the Yields of 3-year Treasury Securities and 3-month Treasury Bills

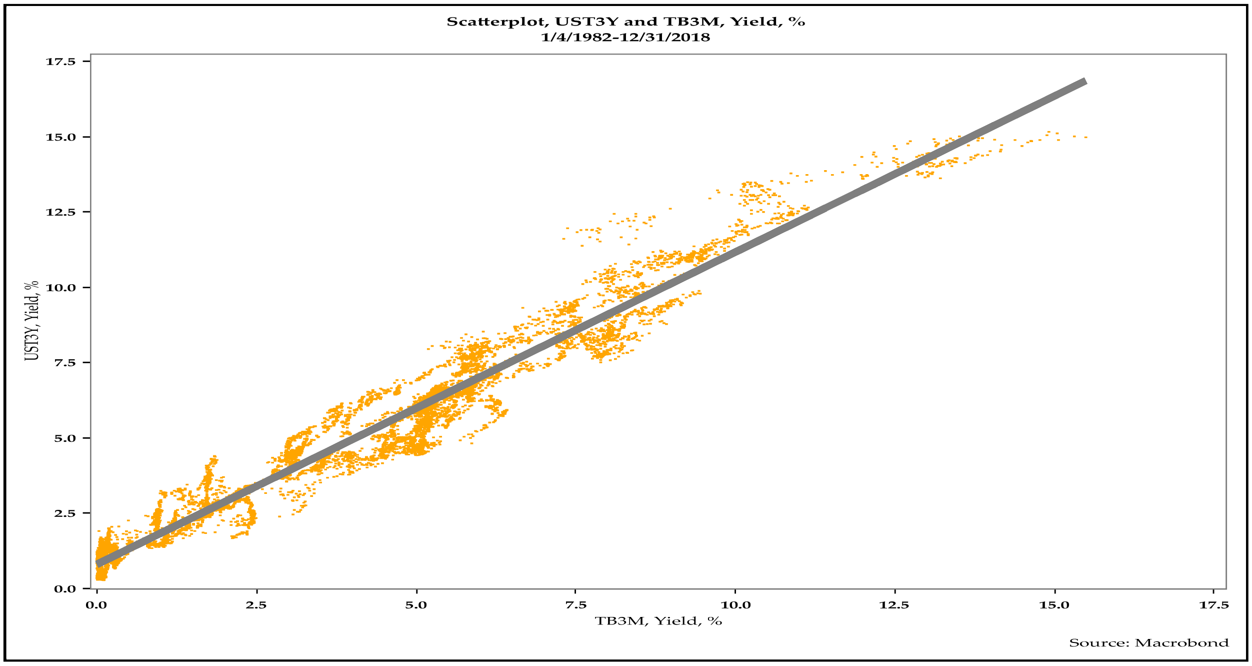


Figure A4: Scatterplot of Year-over-Year Percentage Point Changes in the Yields of 3-year Treasury Securities and 3-month Treasury Bills

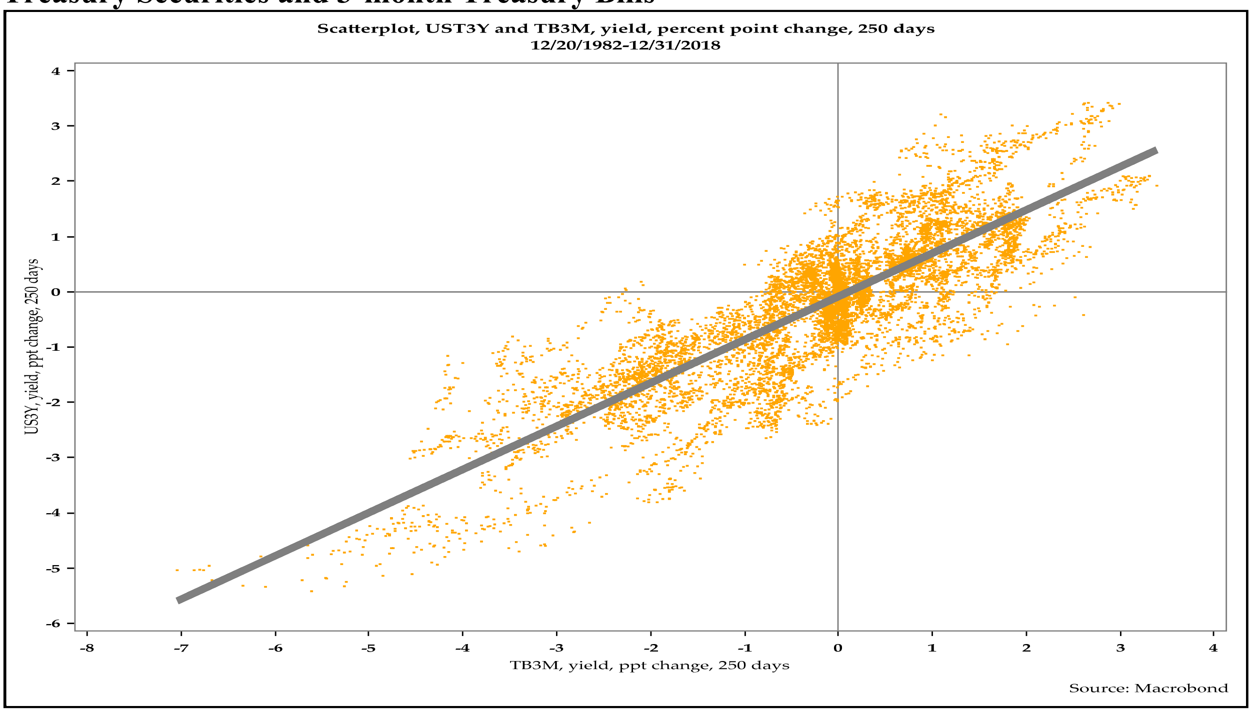


Figure A5: Scatterplot of the Yields of 5-year Treasury Securities and 3-month Treasury Bills

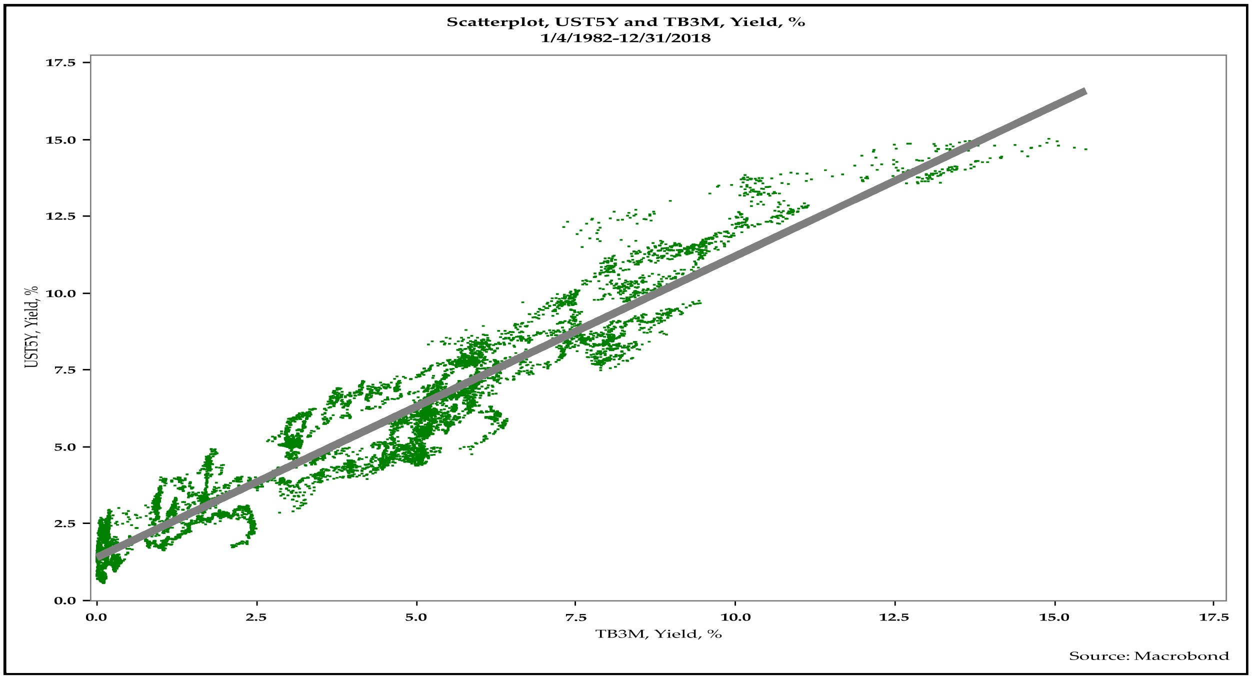


Figure A6: Scatterplot of Year-over-Year Percentage Point Changes in the Yields of 5-year Treasury Securities and 3-month Treasury Bills

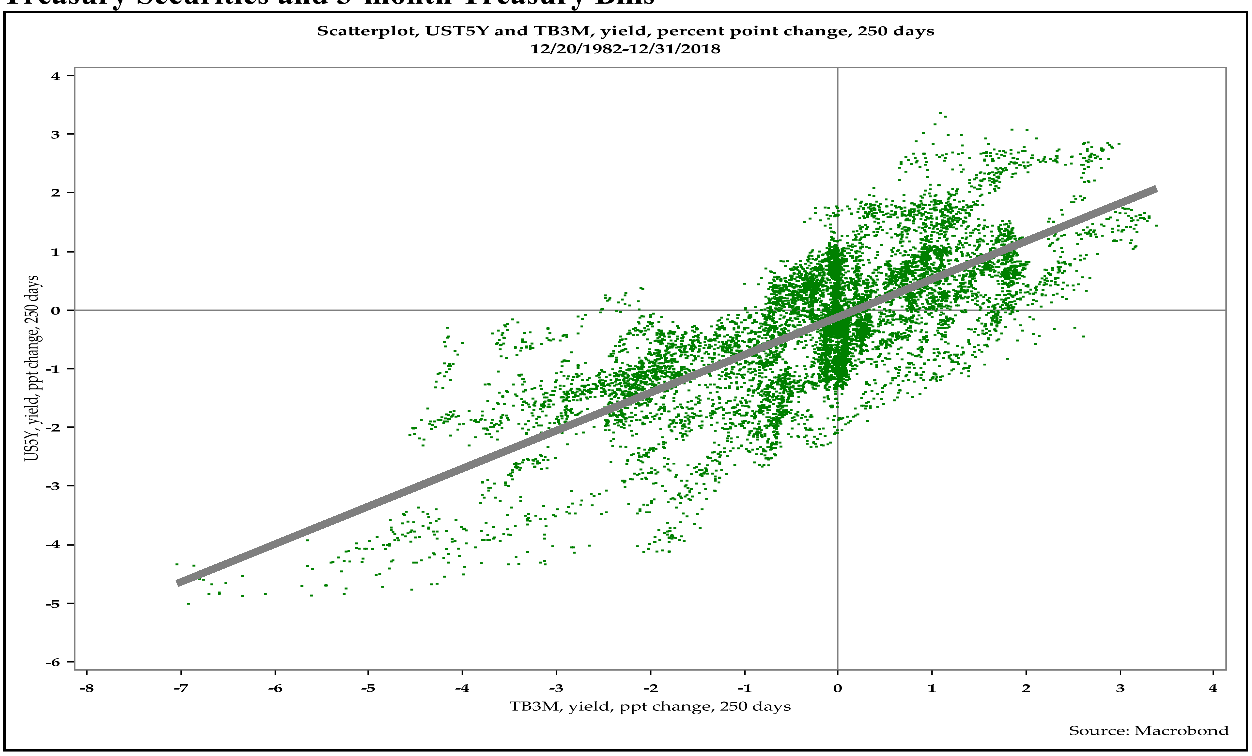


Figure A7: Scatterplot of the Yields of 7-year Treasury Securities and 3-month Treasury Bills

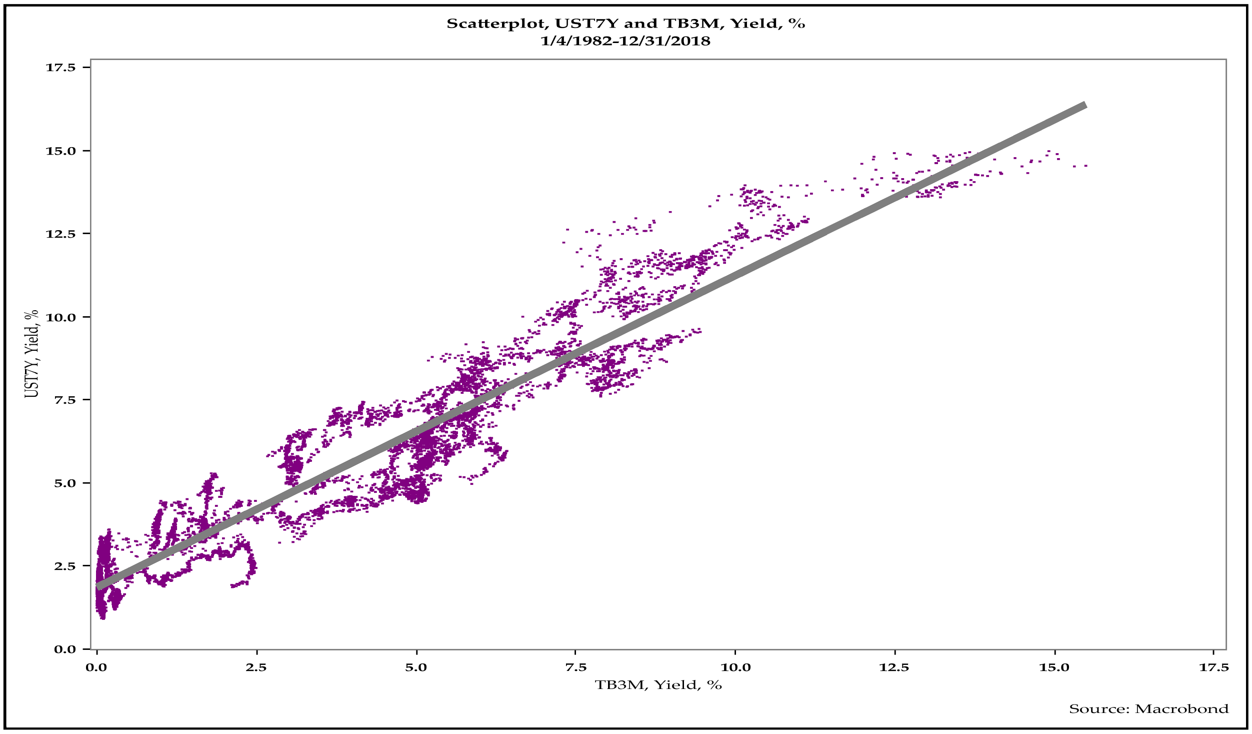


Figure A8: Scatterplot of Year-over-Year Percentage Point Changes in the Yields of 7-year Treasury Securities and 3-month Treasury Bills

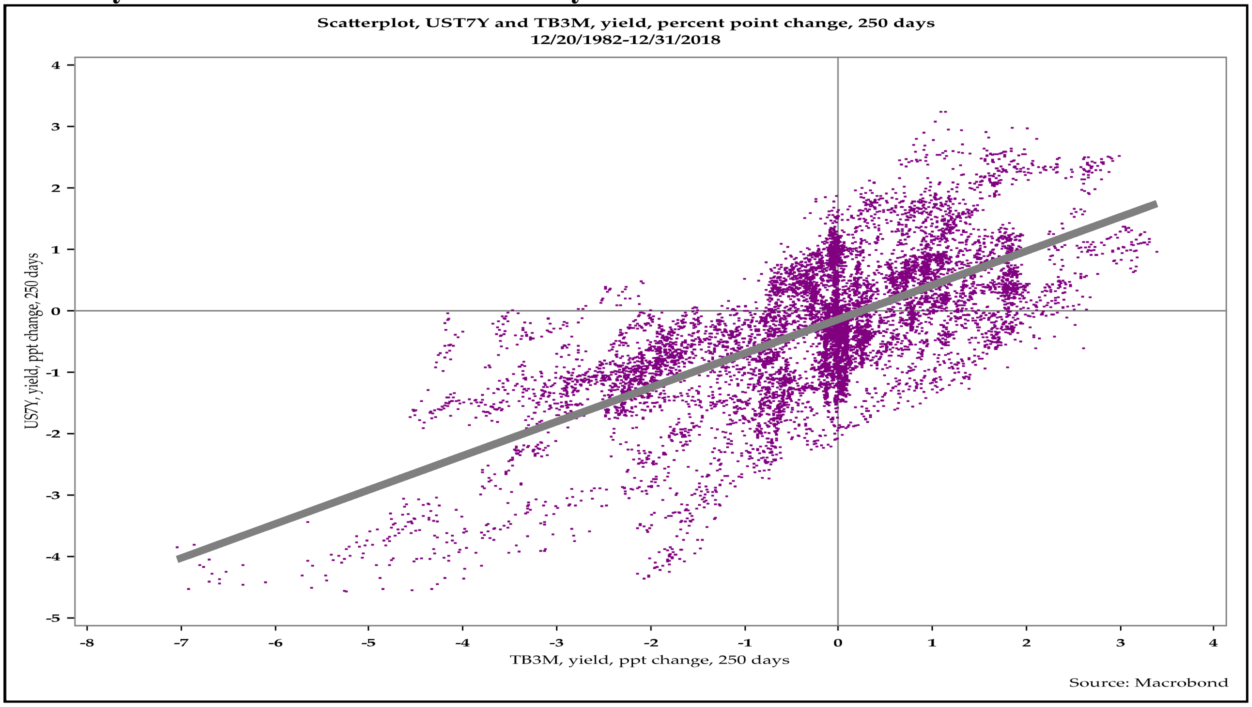


Figure A9: Scatterplot of the Yields of 10-year Treasury Securities and 3-month Treasury Bills

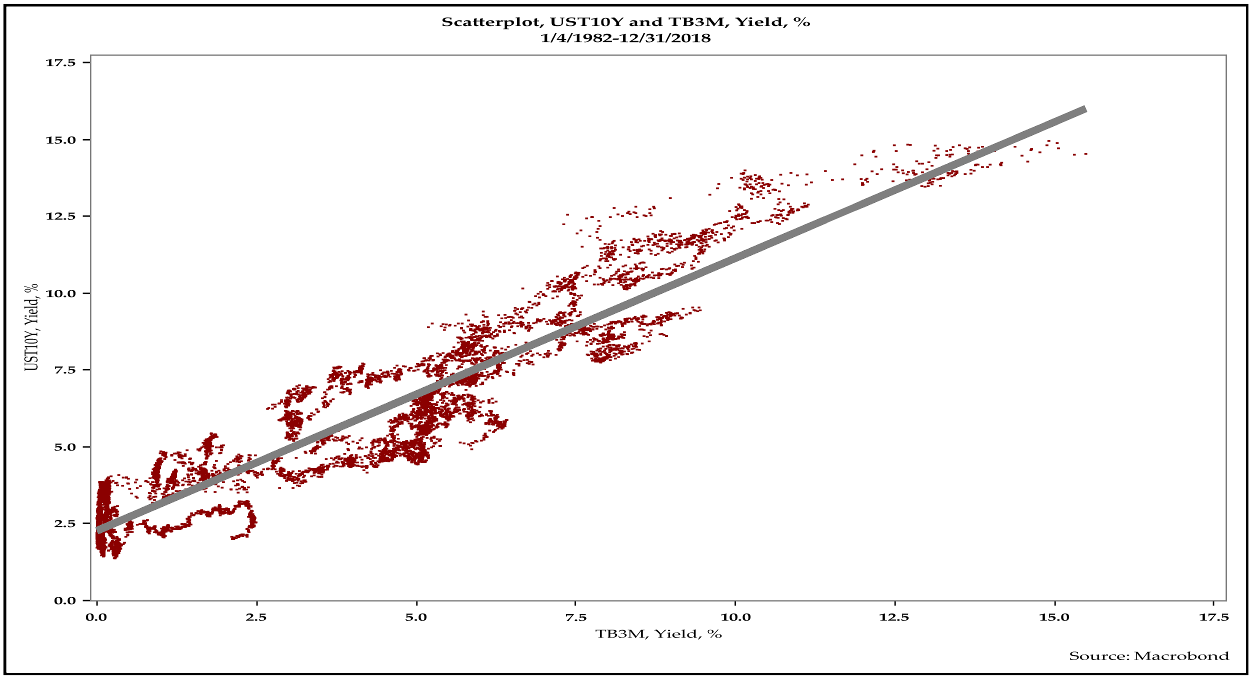


Figure A10: Scatterplot of Year-over-Year Percentage Point Changes in the Yields of 10-year Treasury Securities and 3-month Treasury Bills

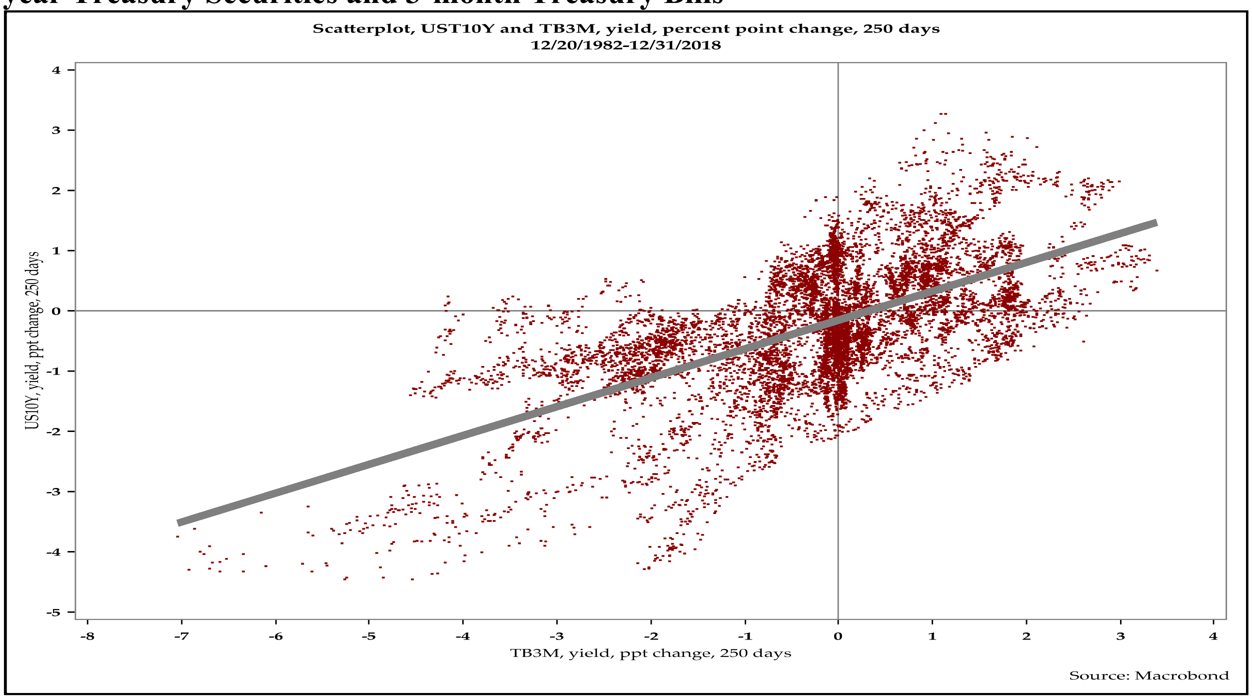


Figure A11: Scatterplot of the Yields of 30-year Treasury Securities and 3-month Treasury Bills

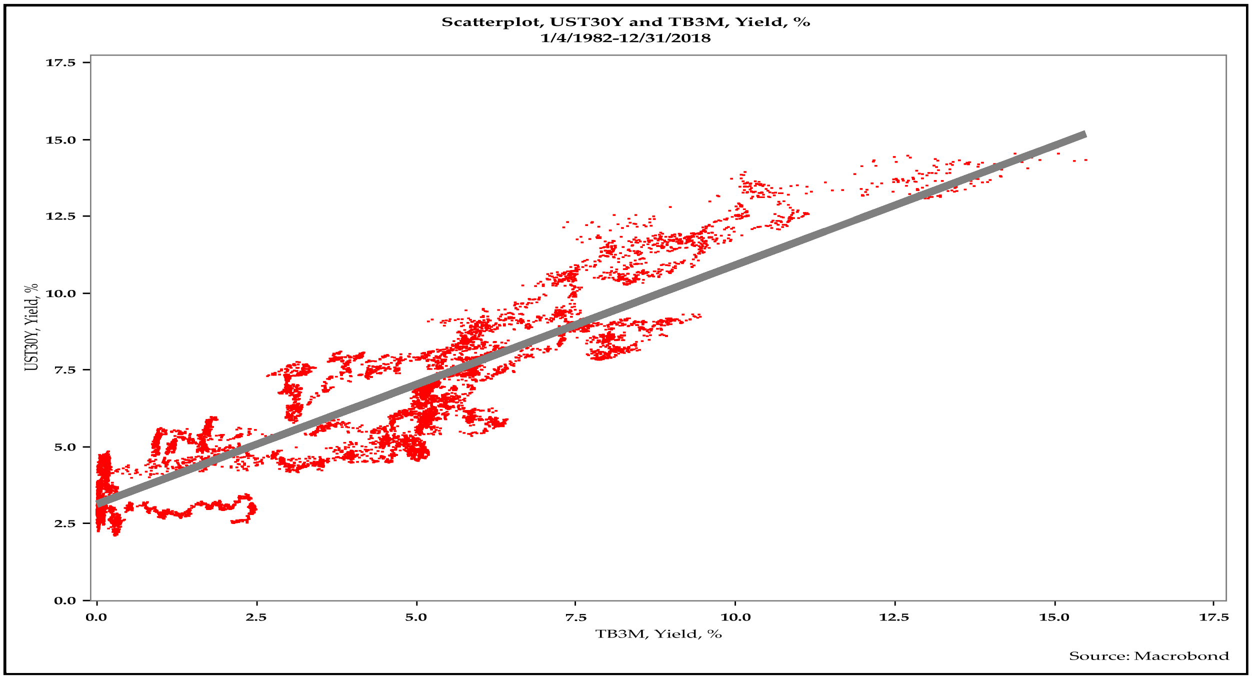


Figure A12: Scatterplot of Year-over-Year Percentage Point Changes in the Yields of 30-year Treasury Securities and 3-month Treasury Bills