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The Dynamics of Monthly Changes in US Swap Yields: A Keynesian Perspective

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ABSTRACT

John Maynard Keynes (1930) asserted that the central bank sways the long-term interest rate through the influence of its policy rate on the short-term interest rate. Recent empirical research shows that Keynes's conjecture holds for long-term Treasury yields in the United States. This paper investigates whether Keynes's conjecture also holds for the monthly changes in US long-term swap yields by econometrically modeling its dynamics using an autoregressive distributed lag (ARDL) approach. The econometric modeling reveals that there is statistically significant effect on the monthly changes in the Treasury bill rate on the monthly changes in swap yields of different maturity tenors after controlling for a host of macroeconomic and financial control variables. The findings from the econometric models that are estimated render a perspicacious Keynesian perspective on key policy questions and contemporary debates in macroeconomics and finance.

KEYWORDS: Interest Rate Swaps; Swap Yields; Short-Term Interest Rate; Monetary Policy; Federal Reserve; John Maynard Keynes

JEL CODES: E43; E50; E58; E60; G10; G12

INTRODUCTION

US-dollar-denominated interest rate swaps play a vital role in the US fixed income markets. As of second half of 2021, the notional value of outstanding US dollar interest rate swaps amounted to a bit more than $134.6 trillion, while the gross market value of dollar-denominated interest swaps amounted to nearly $1.8 trillion, according to the Bank for International Settlements (2022). While there is considerable discussion of many aspects of interest rate swaps, there is a clear lack of empirical literature on the modeling of dollar-denominated interest rate swap yields in terms of key macroeconomic and financial variables. This paper is a part of an effort, initiated in Akram and Mamun (2022), to address the lacuna regarding the macroeconomic and financial determinants of interest rate swap yields.

The existing literature in economics and quantitative finance have attempted to model swap yields as they relate to credit and liquidity conditions, rather than fundamental macroeconomic factors. The lack of any systematic attempts at empirically modeling the dynamics of swap yields based on macroeconomic and financial variables is a crucial gap in the existing literature. This paper specifically examines whether the short-term interest rate influences interest rate swap yields of different maturity tenors, after controlling for some key macroeconomic and financial factors. John Maynard Keynes's (1930) views on interest rate dynamics inspires an examination of the relationship between the swap yield and the short-term interest rate.

Keynes (1930) argued that the central bank's policy rate and other instruments of monetary policy exert an enormous influence over the long-term interest rate on gilt-edged securities via the short-term interest rate. His views on the relationship between the short-term interest rate and the long-term interest rate were based both on his theoretical insights on the workings of financial markets and investor behavior, as well as empirical regularities as documented in Riefler's (1930) statistical analysis of bond yields in the United States and Keynes's own observations of similar trends in the United Kingdom. In recent years, Akram and Li (2017, 2020), Deleidi and Levrero (2021), and Gabrisch (2022) have shown that Keynes's conjecture holds for long-term US Treasury yields.

In this paper, the dynamics of dollar-denominated interest rate swap yields are examined to test whether the short-term interest rate has an influence on swaps yields of different maturity tenors after controlling for core inflation, the growth of industrial production, the change in the log of the equity price index, the log of the exchange rate, and the log of implied volatility of the equity market. By examining the relationship between the short-term interest rate and the swap yields of different maturity tenors, this paper will reveal whether Keynes's conjecture extends to not just to government bond yields but also to interbank interest rate swap yields.

Outline

This paper is organized as follows. Section II gives a brief primer on interest rate swaps. It also provides an overview of the literature on interest rate swaps. Section III develops a simple model that ties the interest rate swap yields to macroeconomic factors, including the short-term interest rate. Section IV describes the evolution of interest rate swap yields in the United States with reference to the macroeconomic milieu. Section V presents the data sources used in the paper, explains the variables, and displays summary statistics and unit root and stationary tests. Section VI reports the results of our econometric modeling of swap yields. Section VII concludes with reflections on the policy implications of the empirical results.

SECTION II: A PRIMER ON INTEREST RATE SWAPS AND A SHORT REVIEW OF THE LITERATURE

An interest rate swap is a simultaneous selling and purchasing of cash flows. An interest rate swap between two firms can be illustrated as follows: Firm A needs a $1 million floating rate loan, whereas firm B needs a $1 million fixed rate loan. However, firm B has a comparative advantage in a floating rate loan, whereas firm A has a comparative advantage in a fixed rate loan. Each firm borrows in the market where they have a comparative advantage. Hence, firm A borrows $1 million in fixed rate, while firm B borrow $1 million in floating rate. The firms then decide to exchange the interest payments with each other.

An interest rate swap constitutes an exchange of cash flow streams based on certain interest rates. Typically, for a plain vanilla swap, it is an exchange between a stream of fixed interest rate payments and a stream of floating interest rate payments, both in the same currency. The interest payments are based on the same notional principal. The floating rate is usually tied to some benchmark money market rate. The maturity of interest rate swaps varies but are usually between two to thirty years. The fixed rate payer is known as the buyer of the swaps, whereas the floating rate payer is known as the seller of the swap.

Interest rate swap terms are usually set such that the present value of the counterparty's payment is equal to the present value of the payment to be received. The initial value of the swap contract should be zero. The counterparty choosing to pay the fixed rate and the counterparty choosing to pay the floating rate each believe that they will gain. Their assumptions are based on their needs and their expectations of the level and changes in the interest rates during the tenor of the swap.

A Short Review of the Literature on Interest Rate Swaps

Bicksler and Chen (1986) and Wall and Pringle (1988) provide an economic analysis of interest rate swaps and their use in business and finance for liability transformation and asset transformation. Corb (2012) surveys the concepts underlying interest rate swaps and provides a lucid explanation of various topics concerning swaps, including risk characteristics, usage, and pricing. Swaps can be used for active liability management and hedging interest rate risks, as well as for speculating on directional views of future interest rates. Loeys (1985) has argued that interest rate swaps are useful for corporations and financial institutions for managing interest rate risks. Whittaker (1987) explains regulatory and policy issues concerning interest rate swaps. Kuprianov (1993) summarizes the importance of interest rate swaps in corporate finance. Studies of the use of interest rate swaps in corporations provide some valuable insights. For example, Chernenko and Faulkender (2011) examine nonfinancial firms' use of derivatives, such as interest rate swaps. They report that hedging of interest rate risk is concentrated among high-investment firms, which is consistent with costly external finance. They also report that firms appear to use interest rate swaps to manage earnings and engage in speculation. Li and Mao (2003) show that fixed rate swap payers generally have lower credit ratings, a higher leverage ratio, a higher percentage of floating rate loans, and are more likely to use bank loans than floating rate swap payers. Duffie and Huang (1996) develop a model that ties the credit quality of a corporation to the swap yield, while Duffie and Singleton (1997) present a multifactor model of the term structure of interest rate swaps yields. Even though the literature on interest rate swaps is vast, the relationship between the short-term interest rate and the long-term swap yields has not been yet explored and econometrically modeled. Keynes's insight that the long-term interest rate moves largely in tandem with the short-term interest rates provides a solid foundation for scrutinizing the dynamics of long-term swap yields from a fundamental macroeconomic and financial perspective and econometrically modeling such dynamics.

SECTION III: A SIMPLE MODEL OF SWAP YIELD

A simple model of the swap yield is introduced here. The model draws on Akram (2021, 2022a, 2022b). Whereas those models operationalize Keynes's view that the short-term interest rate is the main driver of the long-term interest rate on government bonds, the model presented here relates the dynamics of the swap yield to the short-term interest rate and other key macroeconomic and financial variables.

The long-term interbank swap yield is S_{LT}. The short-term interest rate is r_{ST}. The central bank's policy rate is r_{CB}. The core inflation is π, while the central bank's core inflation target is $\bar{\pi}$. Z_1, Z_2, Z_3 are distinct Weiner processes. The parameters of the models are: $a_1, a_2, b_1, b_2, c_1, c_2$.

The model is expressed in the follow three equations:

$$\boldsymbol{dS_{LT}(t) = (a_1 r_{ST}(t) + a_2 \pi(t))dt + a_3\sqrt{r_{ST}(t)}dZ_1} \qquad \textbf{[1]}$$

$$\boldsymbol{dr_{ST}(t) = b_1(r_{CB}(t) - r_{ST}(t))dt + b_2\sqrt{r_{ST}(t)}dZ_2} \qquad \textbf{[2]}$$

$$\boldsymbol{d\pi(t) = c_1(\bar{\pi} - \pi(t))dt + c_2\sqrt{\pi(t)}dZ_3} \qquad \textbf{[3]}$$

Equation [1] connects the dynamics of the interbank swap yield to the short-term interest rate, inflation, and a Weiner process adjusted by the short-term interest rate. Equation [2] tethers the dynamics of the short-term interest rate to: (i) the difference between the central bank's policy rate and (ii) the short-term interest rate and a Weiner process adjusted by the short-term interest rate. Equation [3] relates the dynamics of core inflation to: (i) the difference between the central bank's core inflation target and core inflation and (ii) a Weiner process adjusted by core inflation. Note that the each of the Weiner processes described in the above equations are independent and distinct from one another.

The above model can be readily extended to fuse other pertinent macroeconomic and financial variables, such as the growth of industrial production, the logarithm of the equity price index, the logarithm of the exchange rate, and the logarithm of the volatility of financial market, if these are regarded as having critical influence on the swap yield of different maturity tenors.

In the empirical part of the paper, the autoregressive distributed lag (ARDL) approach is used to econometrically model the dynamics of dollar-denominated swap yield and examine its relationship to the short-term interest rate, while controlling for the effects of other key macroeconomic and financial variables.

SECTION IV: THE EVOLUTION OF INTEREST RATE SWAP YIELDS AND ITS MACROECOMIC MILEU

Macroeconomic and financial market conditions have substantial influence on swap yields, as can be seen in this brief outline of US economic and financial variables. The Federal Reserve's monetary policy exerts considerable impact on swap yields via the short-term interest rate.

Figure 1 shows the evolution of outstanding US-dollar-denominated interest rate swaps. It gives both the notional value of outstanding interest rate swaps and the gross market value. The notional value of US-dollar-denominated swaps has risen from nearly \$14 trillion in 2000 to \$135 trillion in 2021, while the gross market value rose from \$0.4 trillion in 2000 to \$1.8 trillion in 2021.[1] The notional value of outstanding dollar-denominated interest rate swaps rose steadily from 2000 to 2008, but it remained steady in the years following. However, the gross market value of dollar-denominated swaps peaked at $10.4 trillion in 2008 and has steadily declined from 2011 to 2021.

Figure 1. The Evolution of Outstanding US-dollar-denominated Interest Rate Swaps, 2000–21

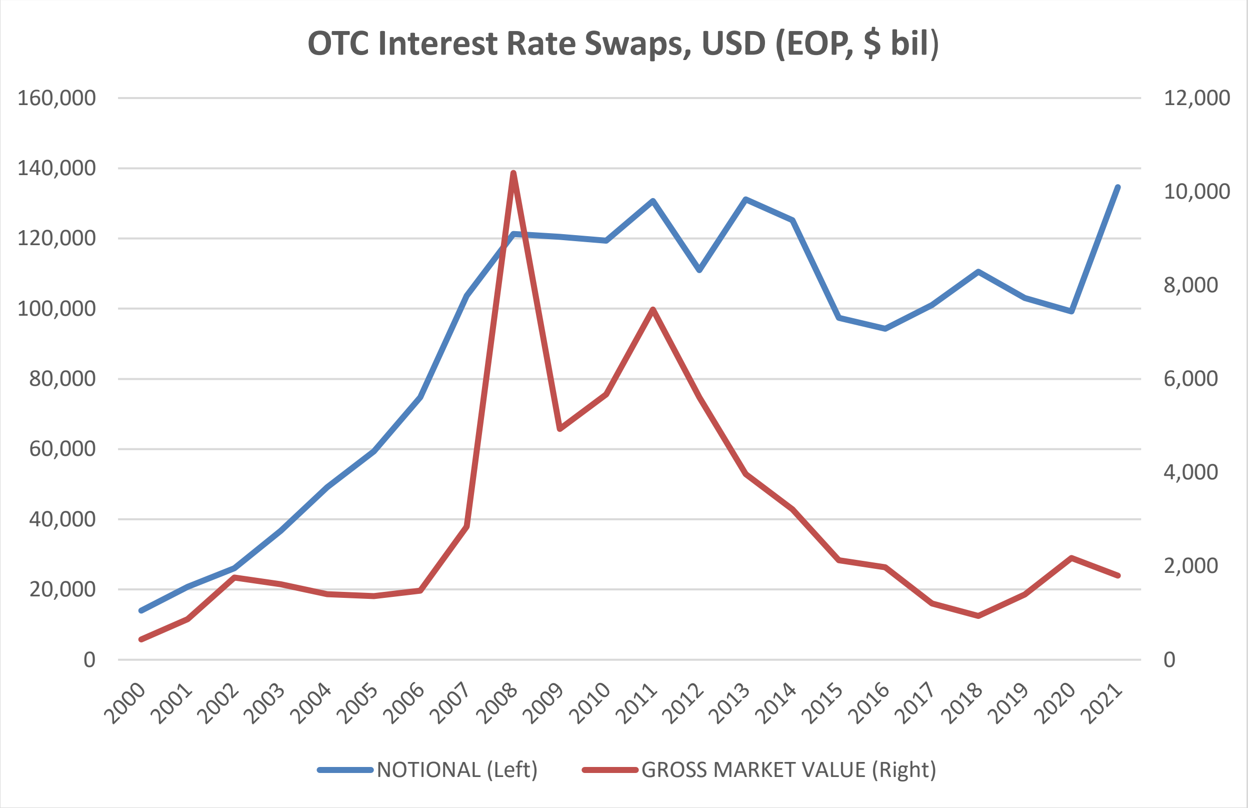

Figure 2 displays the evolution of swap yields of different maturity tenors, while figure 3 exhibits the coevolution 10-year swaps and the short-term interest rate. Swap yields declined from the beginning of 2011 to mid-2012 but rose from late 2012 to early 2014 followed by a decline until mid-2016. Swap yields began to decline and preceded the decline in the short-term interest rate from late 2016 to mid-2020. Swap yields from mid-2020 to the end of the period rose, while the short-term interest rate began to rise in late 2021.

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[1] All figures are in current (nominal) US dollars.

Figure 2. The Evolution of Swap Yields in the United States, 2011M1–2022M3

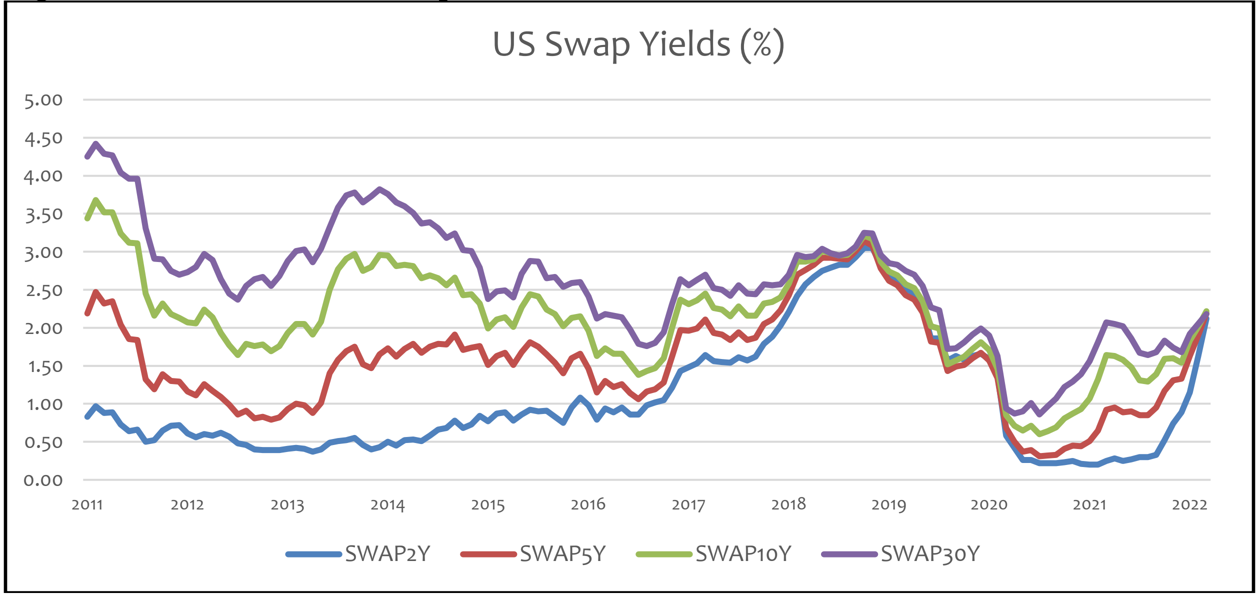


Figure 3. The Coevolution of the 10-year Swap Yield and the 3-month Treasury Bill Rate, 2011M1–2022M3

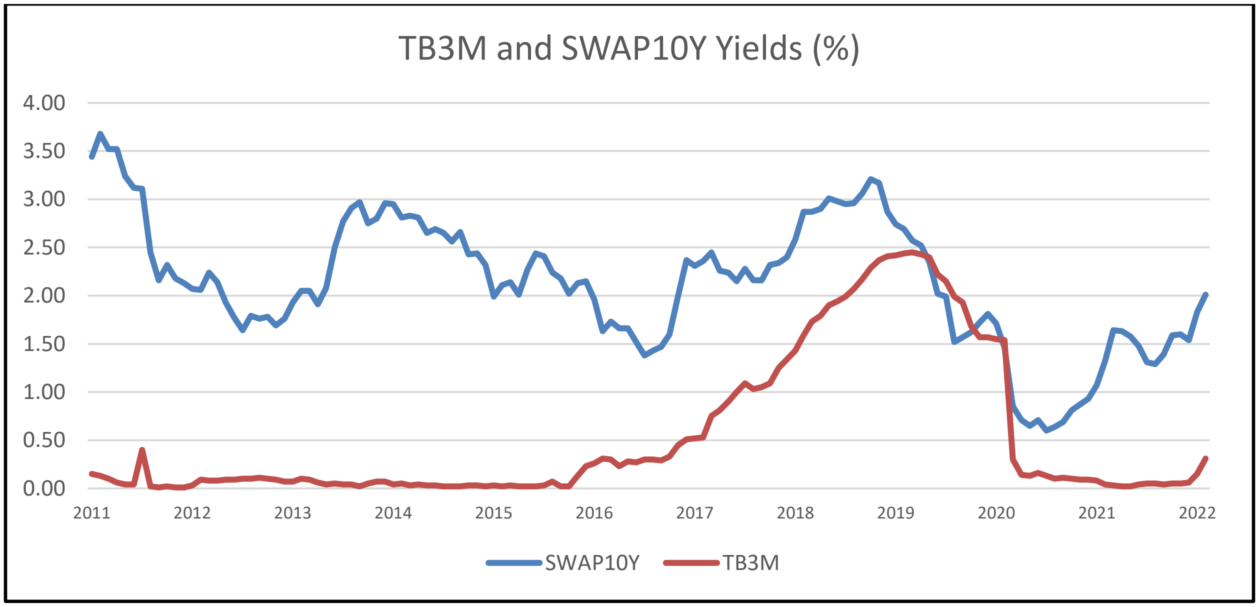


Figure 4 traces the coevolution of 10Y swap yields and the core personal consumer expenditure (PCE) inflation. The figure would suggest that there is no tight connection between swap yields and core inflation.

Figure 4. The Coevolution of the 10-year Swap Yield and Core PCE Inflation, 2011M1–2022M3.

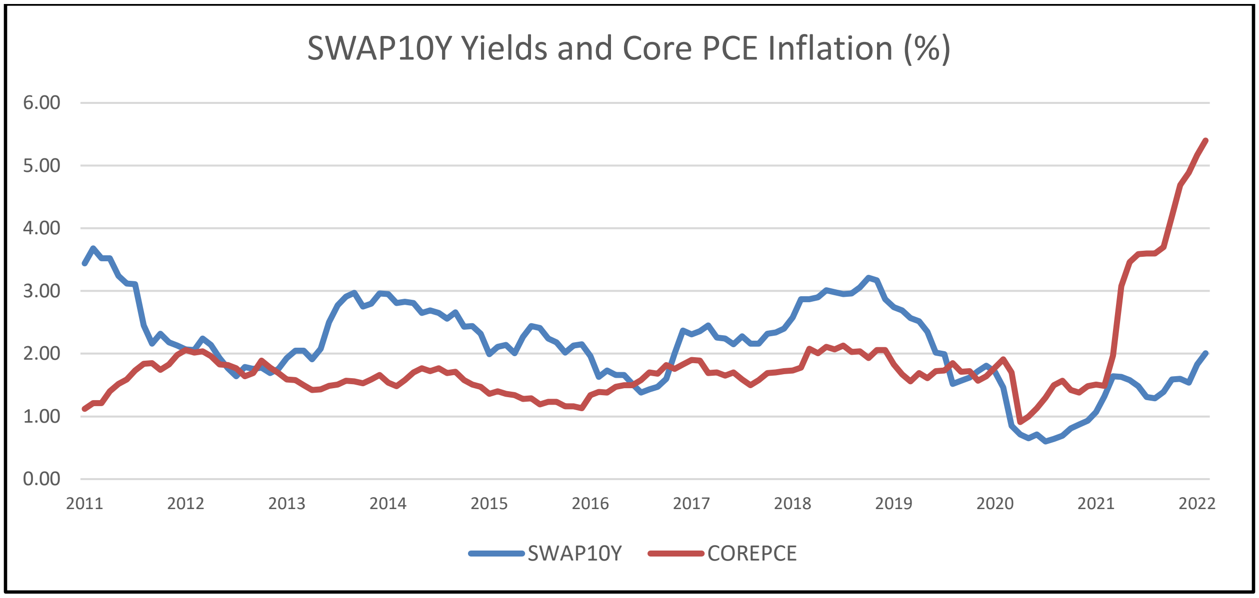


Figure 5 exhibits the evolution of the S&P500 index. The stock market has risen throughout the period under consideration. The rise in the S&P500 index was steady between 2011 and 2019. The S&P500 fell in March 2020 but it recovered in the following months and exceeded the previous peak by the late summer of 2020. The rise peaked at the end of 2021, and the S&P500 began to decline beginning in 2022.

Figure 5. The Evolution of the SP500 Index, 2011M1–2022M3

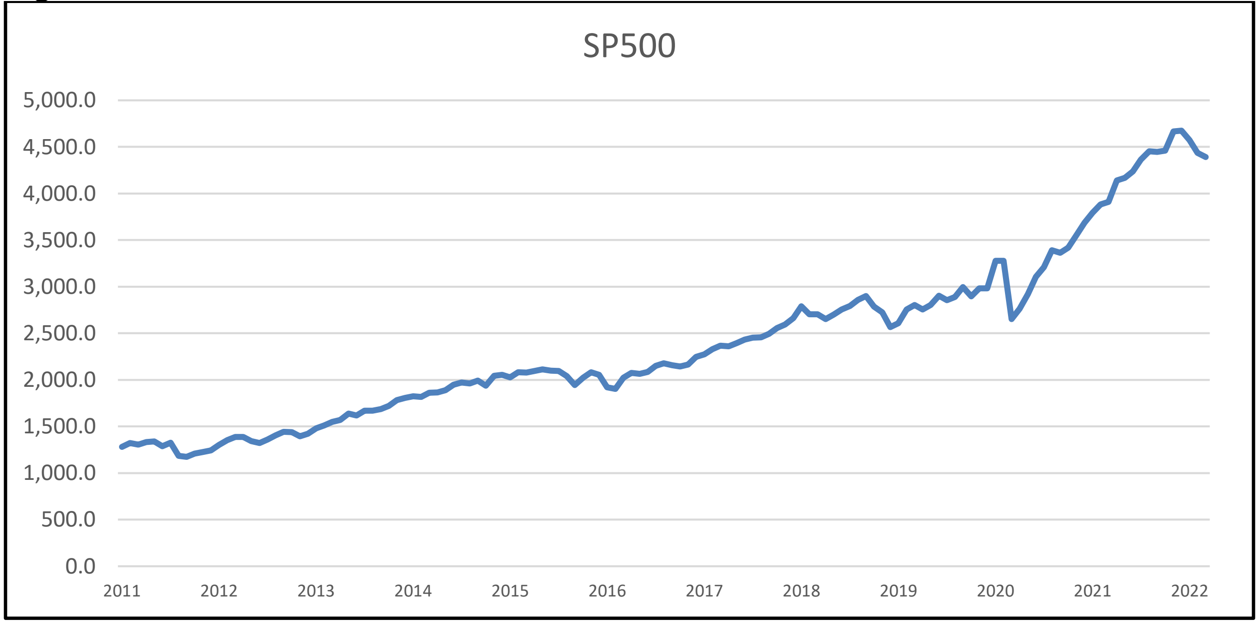


Figure 6 exhibits the evolution of the exchange rate of the US dollar against the euro. Here an increase in the exchange rate indicates a deprecation of the dollar, while a decrease in the exchange rate indicates an appreciation of the dollar.

Figure 6. The Evolution of the US-dollar Exchange Rate, EURUSD, $/€, 2011M1–2022M3.

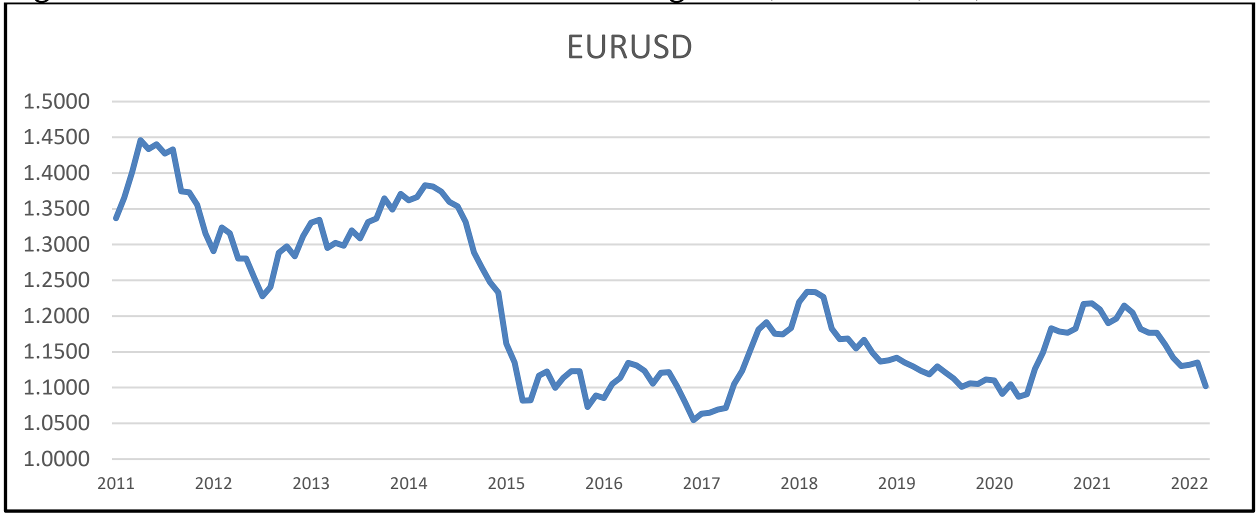
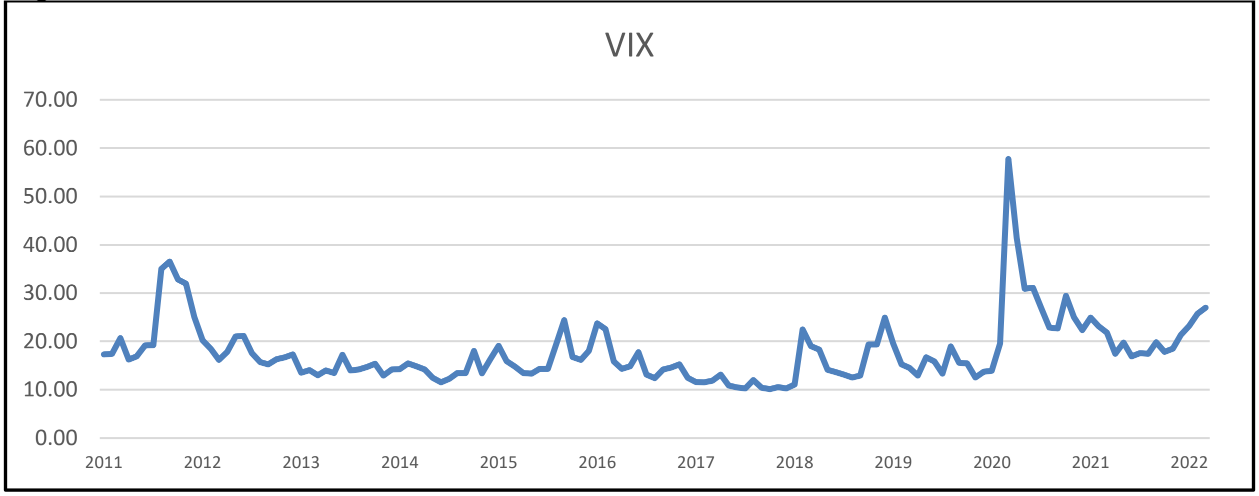


Figure 7 illustrates the evolution of the Chicago Board Options Exchange Volatility Index (VIX). The VIX is a measure of implied volatility. It is derived from real-time, mid-quote prices of call and put options of the S&P 500 index. The VIX rose notably in September of 2011 and remained high until the end of the year. The VIX stayed within a range of 10 to 25 from 2012 to 2019. In March 2020, with the onset of the global pandemic, the VIX rose sharply. It began to decline in the following month and normalized to less than 20 by March 2021. However, by the end of 2021, it began rising again and continued its increase as the Russian military operations started in February 2022.

Figure 7. The Evolution of the VIX, 2011M1–2022M3.



SECTION V: DATA DESCRIPTION, UNIT ROOT TESTS, AND STATIONARY TESTS

Table 1 provides a summary of the variables used in the paper. The first column lists the variable names. The second column gives the data description and the date range for the data. The third column enumerates the data frequency and indicates whether high frequency data have been converted to low frequency data. The final column provides the source of the data.

The short-term interest variables are 3- and 6-month Treasury bills. The interest rate swaps are of 2-, 5-, 10- and 30-year terms. Several controls variables, including inflation rates, industrial production index, two major exchange rates, two major US stock indices, and a market volatility measure, are also used. The financial control variables are in the (natural) $\log_e(.)$ form.

Table 1. Summary of the Data

Variables	Data description, date range	Frequency	Sources
Short-term interest rates			
TB3M	Treasury bill, 3 month, %, bid yield at constant maturity, January 2011–March 2022	Daily; converted to monthly	Federal Reserve Board
TB6M	Treasury bill, 6 month, %, bid yield at constant maturity, January 2011–March 2022	Daily; converted to monthly	Federal Reserve Board
Long-term swap rates			
SWAP2Y	Interest rate swap, 2 year vs. 3 month float, %, mid-rate, January 2011–March 2022	Daily; converted to monthly	Tullet Prebon Information
SWAP5Y	Interest rate swap, 5 year, vs. 3 month float, %, mid-rate, January 2011–March 2022	Daily; converted to monthly	Tullet Prebon Information
SWAP10Y	Interest rate swap, 10 year vs. 3 month float, %, mid-rate, January 2011 — March 2022	Daily; converted to monthly	Tullet Prebon Information
SWAP30Y	Interest rate swap, 30 year, vs. 3 month float, %, mid-rate, January 2011 — March 2022	Daily; converted to monthly	Tullet Prebon Information
Inflation			
COREPCE	Personal consumer expenditure less food & energy: chain price index, seasonally adjusted, % change, y/y, 2012 = 100, January 2011–March 2022	Monthly	Bureau of Economic Analysis
CORECPI	Consumer price index all items less food, and energy, not seasonally adjusted, % change, y/y, 1982-1984 = 100, January 2011–March 2022	Monthly	Bureau of Labor Statistics
Economic activity			
IPYOY	Industrial production, index, % change, y/y, seasonally adjusted, 2017 = 100, January 2011–March 2022	Monthly	Federal Reserve Board
Financial variables			
YEN	Exchange rate, Japanese yen per US dollar, ¥/$, January 2011–March 2022	Daily; converted to monthly	Federal Reserve Board
EURO	Exchange rate, US dollar per euro, $/€, January 2011–March 2022	Daily; converted to monthly	Federal Reserve Board
DIJA	Stock price index, Dow Jones: 30 industrial stocks, average price close, January 2011–March 2022	Daily; converted to monthly	*Wall Street Journal*
SP500	Standard & Poor's 500 composite index, January 2011–March 2022	Daily; converted to monthly	Standard and Poor's
VIX	Chicago Board of Exchange (CBOE), market volatility index, January 2011–March 2022	Daily; converted to monthly	*Wall Street Journal*

The summary statistics of all the variables are reported in table 2A and table 2B. Table 2A displays the summary statistics of the variables, while table 2B provides the summary statistics of the first differences of the variables. The longer-term swap rates and stock market indices are not normally distributed. However, all variables are normally distributed when converted to first-difference.

Table 2.A: Summary Statistics of the Variables

	Obs	Mean	Std. Dev.	Max	Min	Skewness	Kurtosis	JB	Probability
SWAP2Y	134	1.05	0.77	3.05	0.20	1.13	3.23	28.56	0.00
SWAP5Y	134	1.56	0.66	3.14	0.31	0.31	2.79	2.41	0.30
SWAP10Y	134	2.13	0.67	3.68	0.60	-0.18	2.74	1.09	0.58
SWAP30Y	134	2.58	0.77	4.42	0.86	-0.04	2.93	0.07	0.97
TB3M	134	0.55	0.78	2.45	0.01	1.35	3.28	41.38	0.00
TB6M	134	0.61	0.80	2.54	0.04	1.30	3.17	37.67	0.00
COREPCE	134	1.83	0.76	5.40	0.91	2.91	11.84	625.56	0.00
CORECPI	134	2.13	0.85	6.41	0.95	2.95	12.66	715.30	0.00
IPYOY	134	0.96	4.31	17.81	-17.69	-0.57	8.76	192.78	0.00
LNYEN	134	4.64	0.13	4.82	4.34	-1.08	2.97	25.82	0.00
LNEURO	134	0.19	0.09	0.37	0.05	0.47	1.96	10.85	0.00
LNDIJA	134	9.89	0.33	10.49	9.32	0.11	1.94	6.54	0.04
LNSP500	134	7.71	0.36	8.45	7.07	0.14	2.28	3.36	0.19
LNVIX	134	2.83	0.31	4.06	2.32	1.01	4.54	35.92	0.00

Note: LN = Natural log = Log$_e$(.).

Table 2.B: Summary Statistics of the First Differences of the Variables

	Obs	Mean	Max	Min	Std. Dev.	Skewness	Kurtosis	JB	Probability
ΔSWAP2Y	133	0.01	0.47	-0.80	0.13	-1.66	13.91	720.68	0.00
ΔSWAP5Y	133	0.00	0.39	-0.66	0.16	-0.67	4.95	30.95	0.00
ΔSWAP10Y	133	-0.01	0.42	-0.66	0.17	-0.55	4.73	23.18	0.00
ΔSWAP30Y	133	-0.02	0.37	-0.69	0.17	-0.88	5.23	44.68	0.00
ΔTB3M	133	0.00	0.36	-1.24	0.13	-6.24	59.76	18714.27	0.00
ΔTB6M	133	0.00	0.31	-1.21	0.13	-6.36	62.96	20820.06	0.00
ΔCOREPCE	133	0.03	1.11	-0.79	0.17	1.45	17.06	1142.47	0.00
ΔCORECPI	133	0.04	1.31	-0.66	0.21	2.32	14.74	883.01	0.00
ΔIPYOY	133	0.02	15.96	-12.35	2.23	1.60	28.90	3774.27	0.00
ΔLNYEN	133	0.00	0.07	-0.04	0.02	0.79	4.41	24.90	0.00
ΔLNEURO	133	0.00	0.04	-0.06	0.02	-0.34	3.65	4.98	0.08
ΔLNDIJA	133	0.01	0.11	-0.23	0.04	-2.44	17.95	1370.40	0.00
ΔLNSP500	133	0.01	0.09	-0.21	0.03	-2.47	16.58	1157.36	0.00
ΔLNVIX	133	0.00	1.08	-0.37	0.20	1.69	9.77	317.60	0.00

Note: Δ is the first-difference of the variable

Table 3A displays the results of the unit root tests, stationary, and the stationary tests for these variables. The unit root tests are conducted using the automated Dickey-Fuller (ADF) tests (Dickey and Fuller 1979, 1981) and the Phillips Perron tests (Phillips and Perron 1988), while the stationarity tests are conducted using Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) tests (Kwiatkowski et al. 1992). The test results are mixed in table 3A, with most variables nonstationary at the level.

Table 3.A: Unit Root and Stationarity Tests of the Variables

	ADF Unit Root Tests (H_0: Nonstationary)			PP Unit Root Tests (H_0: Nonstationary)			KPSS Tests (H_0: Stationarity)	
	None	**Intercept**	**Trend**	**None**	**Intercept**	**Trend**	**Intercept**	**Trend**
SWAP2Y	– 0.28	– 1.54	– 1.91	– 0.48	– 1.47	– 1.72	0.35*	0.17**
SWAP5Y	– 0.91	– 2.14	– 2.08	– 0.77	– 2.05	– 1.94	0.14	0.14*
SWAP10Y	– 1.35	– 2.92**	– 2.66	– 1.18	– 2.49	– 2.34	0.45*	0.08
SWAP30Y	– 1.53	– 2.82*	– 3.03	– 1.45	– 2.36	– 2.53	0.89***	0.05
TB3M	– 0.88	– 1.22	– 1.12	– 1.05	– 1.38	– 1.33	0.45*	0.16**
TB6M	– 0.77	– 1.28	– 1.36	– 0.96	– 1.45	– 1.53	0.46*	0.17**
COREPCE	1.05	0.01	– 0.48	2.27	2.18	1.40	0.46*	0.15**
CORECPI	1.13	– 0.72	– 1.50	2.05	1.62	0.86	0.51**	0.14*
IPYOY	– 2.38**	– 2.41	– 2.40	– 3.01***	– 3.10**	– 3.04	0.16	0.07
LNYEN	1.13	– 1.54	– 1.69	1.14	– 1.51	– 1.62	0.80***	0.28***
LNEURO	– 1.53	– 1.74	– 2.13	– 1.34	– 1.65	– 2.17	0.85***	0.20**
LNDIJA	2.67	– 0.36	– 3.45**	4.15	– 0.05	– 3.43**	1.42***	0.06
LNSP500	3.47	– 0.05	– 2.78	3.96	0.16	– 2.68	1.39***	0.11
LNVIX	– 0.19	– 3.73***	– 3.80**	0.30	– 3.57***	– 3.64**	0.28	0.23***

Note: Significance levels: *** for 1 percent, ** for 5 percent and * for 10 percent

Table 3B presents the unit root and the stationarity tests for the first differences of the variables. All the ADF unit root tests indicate that the null hypothesis of nonstationarity can be rejected at the 1 percent level of significance for the first differences of all variables. The PP tests also reject the null hypothesis of nonstationary at the 1 percent level for all first-differenced variables. The KPSS tests show that the null hypothesis of stationarity cannot be rejected for the first differences of these variables (except for the two measurements for inflation).

Table 3.B: Unit Root and Stationarity Tests of the First Differences of the Variables

	ADF Unit Root Tests (H_0: Nonstationary)			PP Unit Root Tests (H_0: Nonstationary)			KPSS Tests (H_0: Stationarity)	
	None	Intercept	Trend	None	Intercept	Trend	Intercept	Trend
ΔSWAP2Y	– 6.29***	– 6.29***	– 6.32***	– 6.49***	– 6.49***	– 6.68***	0.10	0.10
ΔSWAP5Y	– 8.32***	– 8.29***	– 8.38***	– 8.47***	– 8.44***	– 8.52***	0.12	0.10
ΔSWAP10Y	– 8.30***	– 8.29***	– 8.37***	– 8.32***	– 8.29***	– 8.37***	0.12	0.08
ΔSWAP30Y	– 7.92***	– 7.95***	– 8.01***	– 7.92***	– 7.95***	– 8.01***	0.11	0.06
ΔTB3M	– 9.69***	– 9.66***	– 9.64***	– 9.96***	– 9.93***	– 9.91***	0.14	0.12*
ΔTB6M	– 8.43***	– 8.41***	– 8.37***	– 8.71***	– 8.69***	– 8.65***	0.11	0.10
ΔCOREPCE	– 4.68***	– 4.80***	– 5.08***	– 7.15***	– 7.31***	– 7.43***	0.45*	0.21**
ΔCORECPI	– 3.13***	– 3.30**	– 3.41*	– 5.51***	– 5.49***	– 5.29***	0.48**	0.22***
ΔIPYOY	– 5.57***	– 5.53***	– 5.57***	– 9.18***	– 9.12***	– 9.20***	0.10	0.05
ΔLNYEN	– 8.29***	– 8.38***	– 8.37***	– 8.33***	– 8.34***	– 8.32***	0.12	0.08
ΔLNEURO	– 8.74***	– 8.77***	– 8.74***	– 8.90***	– 8.90***	– 8.86***	0.06	0.05
ΔLNDIJA	– 11.18***	– 11.71***	– 11.68***	– 11.18***	– 12.59***	– 12.62***	0.07	0.05
ΔLNSP500	– 10.34***	– 9.70***	– 9.70***	– 10.31***	– 11.16***	– 11.24***	0.08	0.05
ΔLNVIX	– 12.07***	– 12.03***	– 12.00***	– 16.91***	– 16.87***	–18.46***	0.18	0.11

Note: Significance levels: *** for 1 percent, ** for 5 percent and * for 10 percent

SECTION VI: ECONOMETRIC MODELS AND EMPIRICAL FINDINGS

The autoregressive distributed lag approach (ARDL) is applied for the estimation of short-term relationships between the short-term interest rate and the swap rate. The basic form of an ARDL regression model is:

$$\Delta y_t = \beta_0 + \beta_1 \Delta y_{t-1} + ...+ \beta_k \Delta y_{t-p} + \alpha_0 \Delta x_t + \alpha_1 \Delta x_{t-1} + ... + \alpha_q \Delta x_{t-q} + \varepsilon_t$$

where y and x are the swap yield and Treasury bill rate respectively and ε_t is a random “disturbance” term. The main results with different swap term rates and 3-months Treasury bills rate are presented in table 4. The core PCE inflation and growth in industrial production at their first difference are presented as controls in the first models for all swap rates. Then the model is expanded to other the control variables by adding a measurement of stock return (ΔLNSP500), the percent change in the euro–dollar exchange rate (ΔLNEURO), and the percent change in market volatility (ΔLNVIX). The control variables aim to adjust for any macroeconomic impact on the interbank swap rates.

The ARDL approach is used to econometrically model the dynamics of swap yields rather than another approach for several important reasons. First, the autoregressive conditional heteroscedasticity Lagrange multiplier (ARCH-LM) tests on the ordinary least squares (OLS) model of swap and Treasury rates are conducted and the results of these tests indicated that there is no ARCH effect present in US Treasury bills and swap rates except for 2-year swap rates (see Appendix A for the detailed results). Second, the traditional vector autoregressive (VAR) and vector error correction models (VECM) are also applied. However, the Granger causality tests did not show any two-way directional relationship between swap and Treasury rates. Similarly, the VECM did not reveal any converging models for the short-term interest rates and swap yields of different maturity tenors. Lastly, tests for structural breaks did not yield any significant results. Based on the evaluation of these findings, the ARDL approach appears to be most germane for the analysis of the dynamics of swap yields.

The 3-month Treasury rate at the first difference has a positive relationship with all the different terms of the swap rates. The size of the impact is diminished the higher the maturity tenor of the swaps. This finding supports the hypothesis that Keynesian inferences on the influence of the short-term interest rate can be extended to interbank swap rates. Furthermore, the short-term Treasury rate impacts the swap rates with a one-period lag. However, the impact is negative and pronounced for higher term lengths. Keynes did not remark on the lead-lag structure of the influence of the short-term interest rate on the long-term interest rate. However, these findings do not in any manner contradict the Keynesian view that the short-term interest rate has an important and decisive influence on swap rates. Furthermore, the lagged swap rates are very good predictors of current rates.

Table 4: ARDL (p, q) Model (with ΔTB3M)

	ΔSWAP2Y	**ΔSWAP2Y**	**ΔSWAP5Y**	**ΔSWAP5Y**	**ΔSWAP10Y**	**ΔSWAP10Y**	**ΔSWAP30Y**	**ΔSWAP30Y**
Main Equation								
ΔTB3M	0.59*** (0.00)	0.53*** (0.00)	0.57*** (0.00)	0.43*** (0.00)	0.54*** (0.00)	0.37*** (0.00)	0.55*** (0.00)	0.39*** (0.00)
ΔTB3M(-1)	–0.17** (0.04)	–0.16 (0.12)	–0.17 (0.10)		–0.21* (0.06)		–0.27*** (0.00)	–0.16** (0.05)
ΔSWAP_Y(-1)	0.34** (0.01)	0.39*** (0.00)	0.24** (0.01)	0.25*** (0.00)	0.29*** (0.00)	0.29*** (0.00)	0.36*** (0.00)	0.37*** (0.00)
ΔCOREPCE	0.07 (0.33)	0.05 (0.49)	0.06 (0.52)	0.04 (0.72)	–0.009 (0.92)	–0.04 (0.69)	–0.06 (0.50)	–0.08 (0.38)
ΔIPYOY	–0.002 (0.56)	–0.001 (0.69)	0.0001 (0.99)	–0.003 (0.63)	0.002 (0.66)	–0.001 (0.81)	0.002 (0.61)	–0.0003 (0.96)
ΔLNSP500		–0.15 (0.83)		0.55 (0.54)		0.62 (0.50)		0.50 (0.55)
ΔLNEURO		–0.08 (0.87)		0.09 (0.90)		0.69* (0.37)		1.36* (0.07)
ΔLNVIX		–0.10 (0.30)		–0.09 (0.51)		–0.14 (0.37)		–0.17 (0.26)
Intercept	0.001 (0.89)	0.003 (0.77)	–0.01 (0.62)	–0.01 (0.54)	–0.01 (0.49)	–0.01 (0.45)	–0.02 (0.42)	–0.01 (0.43)
Model Information								
Obs	132	132	132	132	132	132	132	132
Adj R^2	0.51	0.51	0.29	0.30	0.25	0.27	0.29	0.35
AIC	– 1.89	– 1.87	– 1.11	– 1.12	– 0.90	– 0.93	– 0.98	– 1.05
Diagnostic Tests								
Joint significance F-Test	27.94 (0.00)	17.91 (0.00)	11.61 (0.00)	8.88 (0.00)	9.53 (0.00)	8.06 (0.00)	11.92 (0.00)	10.03 (0.00)
Serial correlation Durbin-Watson Statistic	1.98	1.98	1.93	1.91	1.95	1.92	1.96	2.00
Serial correlation Breusch-Godfrey LM Test	0.65 (0.52)	0.67 (0.52)	0.42 (0.66)	0.21 (0.81)	0.24 (0.79)	0.22 (0.80)	0.09 (0.90)	0.20 (0.82)
Heteroskedasticity Breusch-Pagan-Godfrey test	1.02 (0.41)	1.13 (0.35)	0.40 (0.85)	1.50 (0.17)	0.79 (0.56)	2.51 (0.02)	0.87 (0.50)	2.24 (0.03)
Normality test Jarque-Bera statistic	3.63 (0.16)	1.48 (0.48)	0.58 (0.75)	0.15 (0.93)	0.41 (0.81)	0.87 (0.65)	1.01 (0.60)	1.18 (0.55)
Stability diagnostic Ramsey RESET Test	1.59 (0.21)	2.07 (0.13)	1.49 (0.23)	2.53 (0.08)	1.62 (0.20)	3.81 (0.02)	0.61 (0.54)	3.45 (0.03)

Note: All vars are in diff, *p*-values are in parenthesis. BG LM and Ramsey RESET tests are with 2 lags.

Most of the controls variable, such as core PCE inflation, the growth of the industrial production, the percentage change in the stock price index, the euro–dollar exchange rate, and the percentage change in market volatility, did not yield any meaningful relationship with the swap rate, but it is still useful to examine whether these have any impact whatsoever.

Other diagnostic tests are also presented in table 4. There are no serial correlations in these models based on (1) the Durbin Watson test and (2) Breusch and Godfrey LM test. The Jarque-Bera tests indicate the error terms have the skewness and kurtosis matching a normal distribution. The regression errors are homoscedastic (except for two cases). In addition, the Ramsey RESET tests indicate the general specifications of the models are correct. The cumulative sum (CUMSUM) and the cumulative sum of squares (CUMSUMQ) tests for parameter stability are presented in appendix B. These tests show that the time-series models developed are stable over time and without any structural breaks. The Ljung-Box Q-statistics and their p-values as part of the correlogram for these models are provided in appendix C. The Q-statistics consistently failed to reject the null hypothesis of no autocorrelation.

A robustness check with the impact of the 6-month Treasury bill rate (instead of the 3-month Treasury bill rate) on the different term swap rates is undertaken in appendix D. A set of different control variables, such as the first difference of core CPI for an inflation measurement, stock return of the Dow-Jones industrial average index, and percent change in the yen–dollar exchange rate, are also utilized to check whether the results hold. The regression using the 6-month Treasury bill rate showed a similar positive relationship with the swap rates as shown in the table 4 results. Lastly, the ARCH-LM tests of the models in table 4 are displayed in appendix E. Similar to the ARCH-LM tests in the OLS models (appendix A), there is no evidence of heteroscedastic residuals (i.e., does not exhibit ARCH effects) except for 2-year swap rates.

SECTION VII: CONCLUSION

The empirical findings of the paper have bearing on macroeconomic theory and policy, particularly concerning monetary policy and financial market regulations, asset allocation, and risk management. The findings clearly show that the Federal Reserve’s decisions regarding the fed funds target rate and other monetary policy matters exert a marked effect on the swap yields of different maturity tenors through the monthly changes in the short-term interest rate. An increase (decrease) in the short-term interest rate tends to be associated with a concomitant increase (decrease) in the long-term swap yield. The effect is most pronounced at the front end of the swap yield curve. Monthly changes in most control variables have hardly any discernable effect on the monthly changes in the swap yield. This supports that case that the short-term interest rate is the key driver of long-term swap yields of different maturity tenors after controlling for assorted factors. These empirical findings bolster the case that the Federal Reserve does and can exert substantive influence on financial markets and in particular its actions sway the pricing of fixed income securities and derivatives, including interest rate swaps through monetary policy actions (Bindseil 2004; Fullwiler [2008] 2017).

The results obtained from the empirical modeling of swap yields shows the important influence of the short-term interest rate on the swap yields of different maturity tenors, after controlling for several key macroeconomic and financial variables, such as core inflation, the growth of industrial production, the log of the equity price index, the log of the exchange rate, and the log of the implied volatility of the equity index. The results suggest that the Federal Reserve's monetary policy, through the effects of the feds funds target rate (range) on the short-term interest rate and other actions, influence the dollar-denominated swap yields. This is a substantive finding given the wide-ranging influence of swap yields on financial intermediation, the banking industry, nonfinancial corporate borrowing and lending, capital markets, financial institutions, financial stability, and the real economy.

The empirical findings extends John Maynard Keynes's conjecture that the central bank influences not just the long-term interest rate on government securities but also the long-term swap yield. It reveals the ability of the central bank to influence the interbank interest rate, borrowing and lending rates, financial intermediation, and the financial system. The findings concerning the dynamics of US-dollar-denominated swap yields is not just relevant for US financial markets but also for understanding the dynamics of swap yields in other major financial markets. These findings could advance the empirical modeling of swap yields based on fundamental macroeconomic and financial factors.

This paper fulfils a critical lacuna in the empirical literature on the swap yield, as most often in the existing literature in economics and quantitative finance, the swap yield is empirically modeled merely as a function of the Treasury yield of the same maturity tenor and a spread, rather than the underlying macro and financial factors. The approach used here can prove to be fruitful in further investigations of swap yield dynamics.

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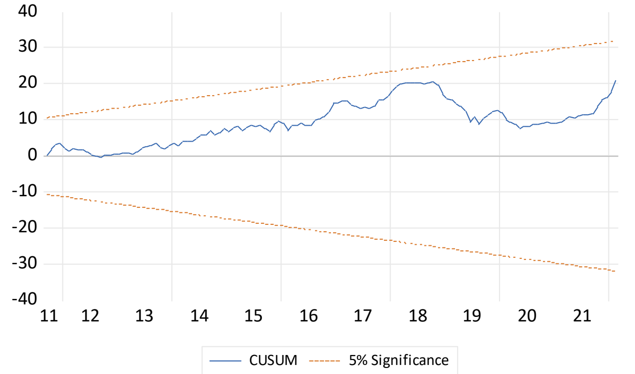
Appendix A: ARCH LM test

Models	**ΔSWAP2Y**	**ΔSWAP5Y**	**ΔSWAP10Y**	**ΔSWAP30Y**	**ΔSWAP2Y**	**ΔSWAP5Y**	**ΔSWAP10Y**	**ΔSWAP30Y**
	ΔTB3M				**ΔTB6M**			
Lags	**Panel One**							
1	3.79 (0.05)	2.95 (0.09)	5.64 (0.02)	4.69 (0.03)	10.61 (0.00)	0.11 (0.74)	1.74 (0.19)	4.21 (0.04)
4	2.30 (0.06)	1.05 (0.39)	2.01 (0.09)	1.66 (0.16)	3.39 (0.01)	0.14 (0.97)	0.76 (0.55)	1.88 (0.12)
8	2.41 (0.02)	0.89 (0.53)	1.07 (0.39)	0.49 (0.86)	2.81 (0.01)	0.48 (0.87)	0.83 (0.58)	0.48 (0.86)
12	1.89 (0.04)	0.97 (0.48)	0.93 (0.52)	0.48 (0.92)	2.28 (0.01)	0.73 (0.72)	0.73 (0.72)	0.40 (0.96)
	Panel Two							
1	3.83 (0.05)	0.73 (0.39)	2.52 (0.11)	2.27 (0.13)	1.62 (0.20)	0.00 (0.94)	1.19 (0.27)	2.38 (0.12)
4	2.28 (0.06)	0.40 (0.81)	1.13 (0.36)	1.24 (0.30)	1.51 (0.20)	0.02 (0.99)	0.54 (0.70)	1.07 (0.37)
8	2.45 (0.02)	0.55 (0.82)	1.01 (0.43)	0.95 (0.47)	1.46 (0.18)	0.44 (0.89)	0.87 (0.55)	0.81 (0.60)
12	1.93 (0.04)	0.69 (0.75)	0.93 (0.52)	0.97 (0.48)	1.66 (0.09)	0.65 (0.80)	0.88 (0.57)	0.96 (0.49)

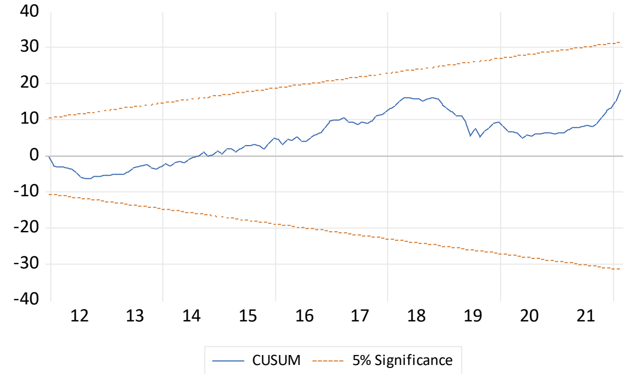
Note: OLS model includes the change in the short-term interest rate (ΔTB3M, ΔTB6M) and the controls (namely ΔCOREPCE and ΔIPYOY in panel one and ΔCOREPCE, ΔIPYOY, ΔLNSP500, ΔLNEURO, and ΔLNVIX in panel two). *p*-values are in parenthesis.

Appendix B.1: CUMSUM for ARDL (p, q) Model (with ΔTB3M)

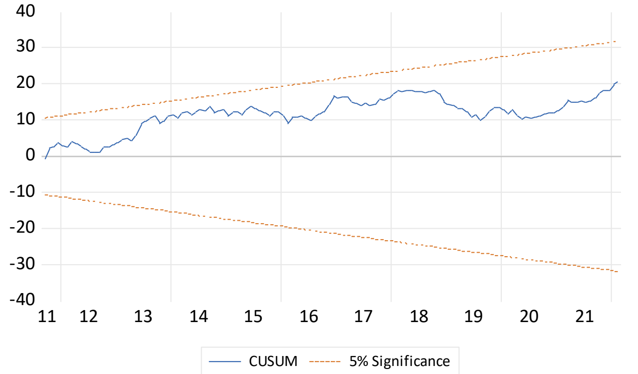
ΔSWAP2Y Base Model



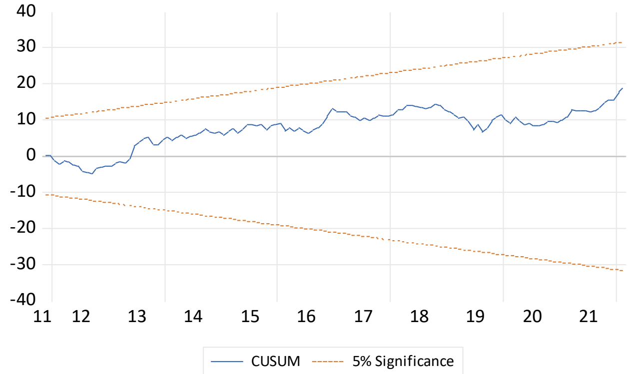
ΔSWAP2Y Extended Model



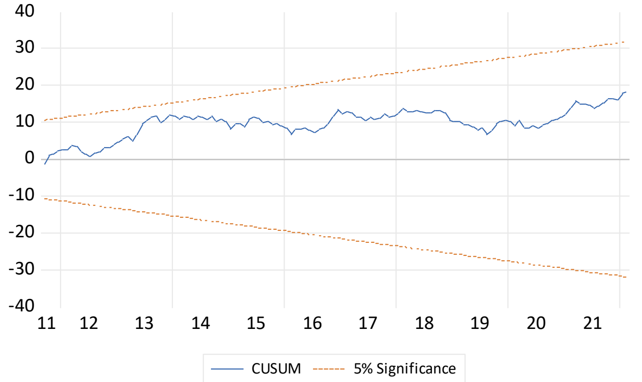
ΔSWAP5Y Base Model



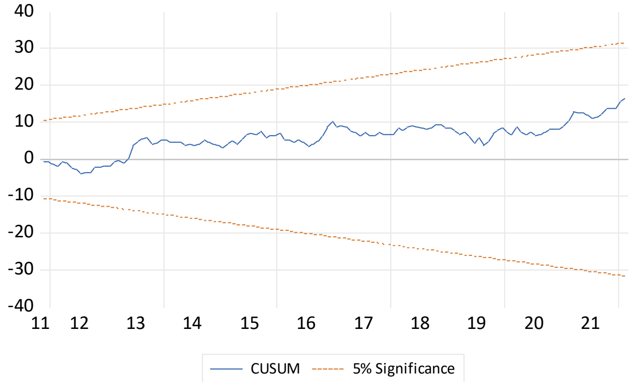
ΔSWAP5Y Extended Model



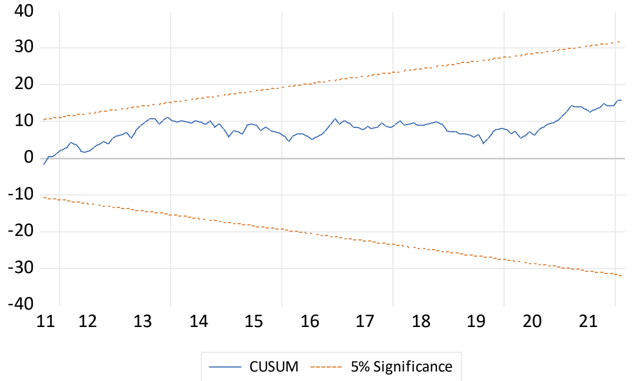
ΔSWAP10Y Base Model



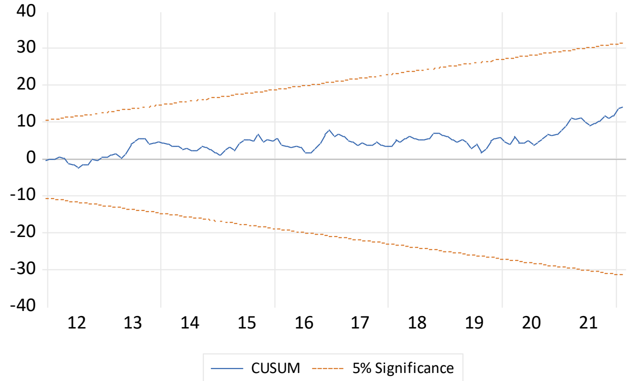
ΔSWAP10Y Extended Model



ΔSWAP30Y Base Model



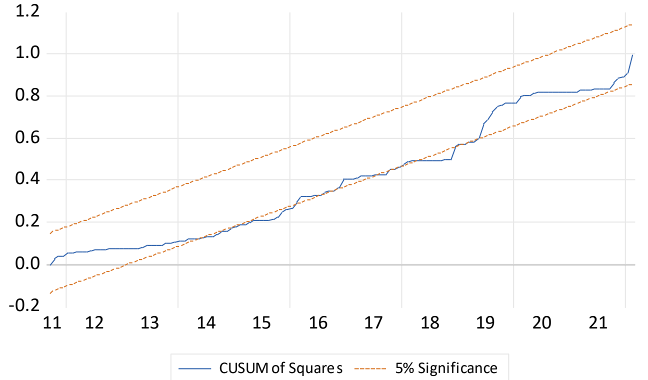
ΔSWAP30Y Extended Model



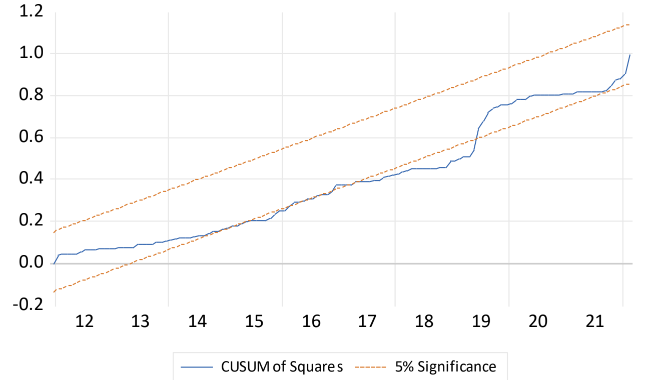
Note: ARDL (p, q) models include the change in the short-term interest rate (ΔTB3M) and the controls (namely ΔCOREPCE and ΔIPYOY in the base model and ΔCOREPCE, ΔIPYOY, ΔLNSP500, ΔLNEURO, and ΔLNVIX in the extended model).

Appendix B.2: CUMSUMSQ for ARDL (p, q) model (with ΔTB3M)

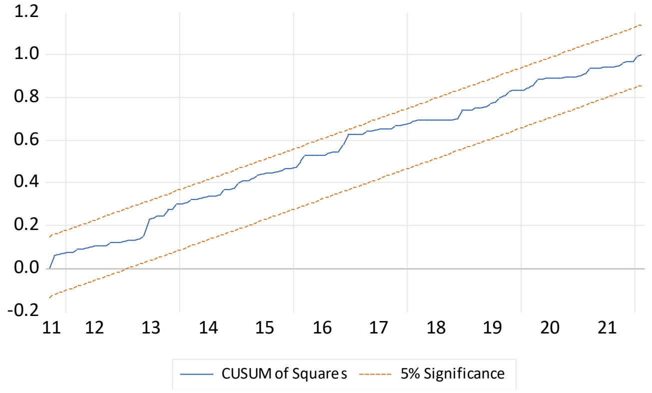
ΔSWAP2Y Base Model



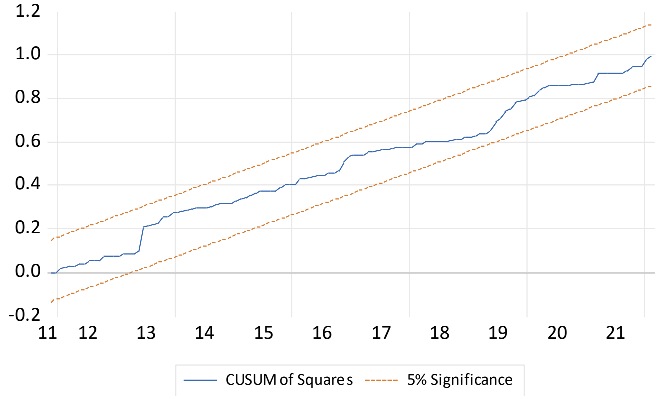
ΔSWAP2Y Extended Model



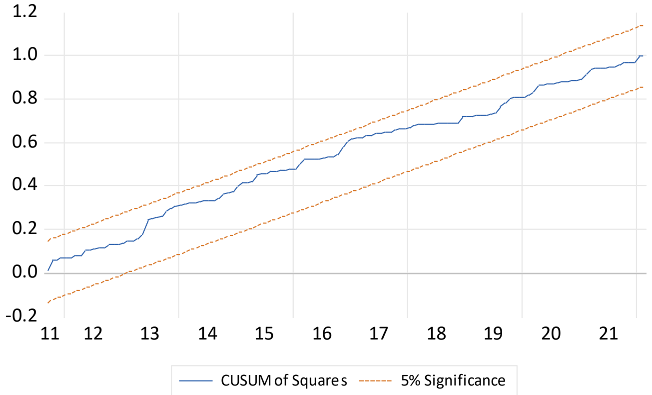
ΔSWAP5Y Base Model



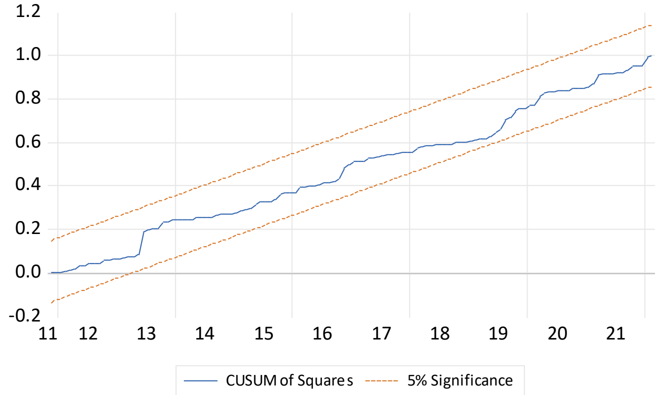
ΔSWAP5Y Extended Model



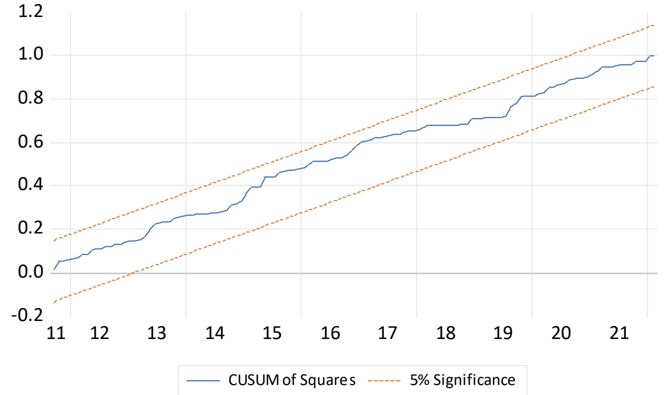
ΔSWAP10Y Base Model



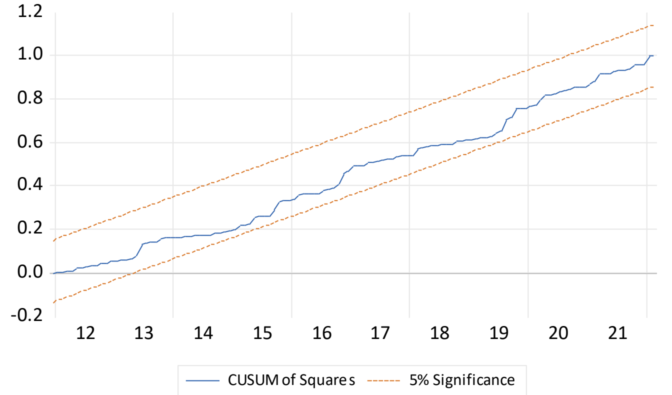
ΔSWAP10Y Extended Model



ΔSWAP10Y Base Model



ΔSWAP30Y Extended Model



Note: ARDL (p, q) models include the change in the short-term interest rate (ΔTB3M) and the controls (namely ΔCOREPCE and ΔIPYOY in the base model and ΔCOREPCE, ΔIPYOY, ΔLNSP500, ΔLNEURO, and ΔLNVIX in the extended model).

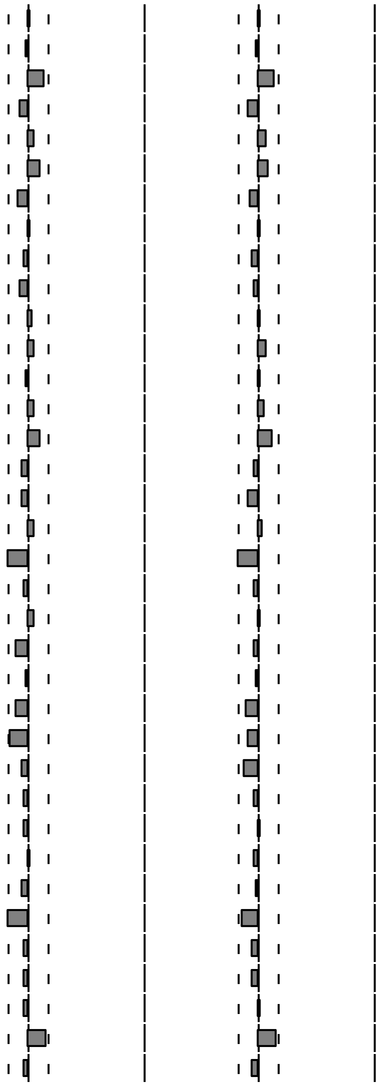
Appendix C: Correlogram – Q -Stat ARDL (p, q) models with ΔTB3M

Table C.1: ΔSWAP2Y = Φ^1(C, ΔTB3M, ΔCOREPCE, ΔIPYOY)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.037	-0.037	0.1875	0.665
		2	0.080	0.079	1.0613	0.588
		3	0.055	0.061	1.4774	0.687
		4	0.009	0.007	1.4891	0.829
		5	-0.011	-0.020	1.5062	0.912
		6	0.093	0.088	2.7127	0.844
		7	-0.091	-0.085	3.8972	0.792
		8	0.004	-0.016	3.8990	0.866
		9	0.052	0.057	4.2834	0.892
		10	-0.123	-0.114	6.4905	0.773
		11	-0.012	-0.025	6.5111	0.837
		12	0.063	0.069	7.0874	0.852
		13	0.020	0.055	7.1493	0.894
		14	0.023	0.012	7.2281	0.926
		15	0.066	0.046	7.8790	0.929
		16	-0.009	0.017	7.8908	0.952
		17	-0.078	-0.114	8.8281	0.946
		18	0.032	0.004	8.9914	0.960
		19	-0.049	-0.016	9.3741	0.967
		20	-0.074	-0.087	10.237	0.964
		21	0.063	0.052	10.867	0.965
		22	-0.043	0.001	11.160	0.972
		23	-0.016	0.005	11.199	0.981
		24	-0.065	-0.093	11.883	0.981
		25	-0.070	-0.055	12.705	0.980
		26	0.042	0.074	13.001	0.984
		27	0.025	-0.015	13.108	0.989
		28	-0.024	-0.010	13.206	0.992
		29	-0.058	-0.061	13.793	0.992
		30	-0.116	-0.146	16.107	0.982
		31	-0.027	-0.007	16.238	0.986
		32	-0.137	-0.122	19.548	0.959
		33	-0.073	-0.060	20.505	0.956
		34	-0.017	-0.010	20.560	0.966
		35	0.061	0.089	21.233	0.968
		36	-0.088	-0.057	22.657	0.959

*Probabilities may not be valid for this equation specification.

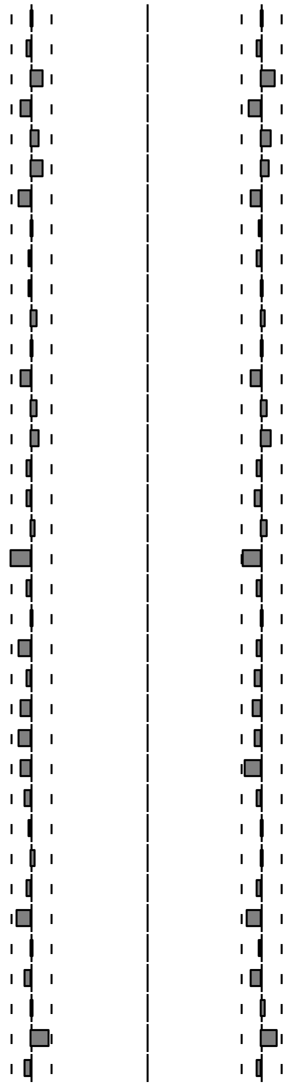
Table C.2: ΔSWAP5Y = Φ^1(C, ΔTB3M, ΔCOREPCE, ΔIPYOY)



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.022	0.022	0.0642	0.800
		2	-0.018	-0.018	0.1062	0.948
		3	0.142	0.143	2.8700	0.412
		4	-0.078	-0.087	3.7171	0.446
		5	0.057	0.069	4.1664	0.526
		6	0.114	0.088	5.9912	0.424
		7	-0.084	-0.068	6.9965	0.429
		8	0.024	0.011	7.0768	0.528
		9	-0.032	-0.057	7.2216	0.614
		10	-0.069	-0.033	7.9101	0.638
		11	0.039	0.013	8.1276	0.702
		12	0.055	0.067	8.5802	0.738
		13	-0.020	-0.004	8.6395	0.800
		14	0.062	0.050	9.2187	0.817
		15	0.112	0.120	11.127	0.744
		16	-0.049	-0.048	11.499	0.778
		17	-0.058	-0.089	12.021	0.799
		18	0.059	0.035	12.553	0.817
		19	-0.186	-0.181	17.943	0.526
		20	-0.028	-0.032	18.068	0.583
		21	0.046	0.023	18.402	0.623
		22	-0.109	-0.030	20.327	0.563
		23	-0.015	-0.023	20.362	0.620
		24	-0.113	-0.114	22.467	0.551
		25	-0.166	-0.095	27.037	0.354
		26	-0.056	-0.124	27.562	0.380
		27	-0.043	-0.031	27.870	0.418
		28	-0.025	-0.001	27.980	0.466
		29	-0.006	-0.035	27.986	0.519
		30	-0.053	-0.017	28.469	0.546
		31	-0.179	-0.154	34.090	0.321
		32	-0.048	-0.050	34.500	0.349
		33	-0.035	-0.062	34.717	0.386
		34	-0.026	0.018	34.839	0.428
		35	0.161	0.167	39.584	0.273
		36	-0.046	-0.061	39.981	0.298

*Probabilities may not be valid for this equation specification.

Table C.3: ΔSWAP10Y = Φ^1(C, ΔTB3M, ΔCOREPCE, ΔIPYOY)



	AC	PAC	Q-Stat	Prob*
1	0.018	0.018	0.0452	0.832
2	-0.031	-0.031	0.1758	0.916
3	0.114	0.115	1.9504	0.583
4	-0.092	-0.099	3.1243	0.537
5	0.081	0.096	4.0292	0.545
6	0.104	0.080	5.5370	0.477
7	-0.110	-0.091	7.2422	0.404
8	0.003	-0.012	7.2435	0.511
9	-0.022	-0.035	7.3156	0.604
10	-0.016	0.018	7.3537	0.692
11	0.064	0.031	7.9604	0.717
12	-0.007	0.003	7.9669	0.788
13	-0.096	-0.083	9.3439	0.747
14	0.059	0.054	9.8594	0.772
15	0.082	0.090	10.872	0.762
16	-0.043	-0.046	11.156	0.800
17	-0.032	-0.063	11.316	0.840
18	0.035	0.055	11.510	0.871
19	-0.178	-0.164	16.469	0.626
20	-0.025	-0.046	16.568	0.681
21	0.022	0.002	16.642	0.733
22	-0.101	-0.045	18.270	0.690
23	-0.039	-0.062	18.523	0.729
24	-0.083	-0.071	19.656	0.716
25	-0.111	-0.065	21.681	0.654
26	-0.083	-0.146	22.838	0.642
27	-0.058	-0.031	23.396	0.664
28	-0.018	0.001	23.451	0.710
29	0.034	0.017	23.648	0.746
30	-0.046	-0.040	24.013	0.771
31	-0.129	-0.118	26.931	0.676
32	0.015	-0.018	26.970	0.719
33	-0.064	-0.084	27.697	0.728
34	-0.007	0.027	27.705	0.769
35	0.165	0.139	32.655	0.582
36	-0.050	-0.044	33.108	0.607

*Probabilities may not be valid for this equation specification.

Table C.4: $\Delta SWAP30Y = \Phi^1(C, \Delta TB3M, \Delta COREPCE, \Delta IPYOY)$

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.012	0.012	0.0196	0.889
		2	-0.036	-0.037	0.2007	0.905
		3	0.071	0.072	0.8872	0.829
		4	-0.125	-0.129	3.0439	0.551
		5	0.067	0.080	3.6780	0.597
		6	0.089	0.072	4.7995	0.570
		7	-0.063	-0.045	5.3612	0.616
		8	0.005	-0.012	5.3647	0.718
		9	0.002	0.005	5.3652	0.801
		10	-0.007	0.015	5.3731	0.865
		11	0.078	0.056	6.2736	0.855
		12	-0.032	-0.038	6.4271	0.893
		13	-0.121	-0.110	8.6125	0.802
		14	0.046	0.043	8.9320	0.835
		15	0.025	0.037	9.0287	0.876
		16	-0.040	-0.045	9.2755	0.902
		17	-0.015	-0.054	9.3113	0.930
		18	0.006	0.042	9.3162	0.952
		19	-0.117	-0.102	11.456	0.908
		20	-0.056	-0.080	11.944	0.918
		21	0.028	0.020	12.073	0.938
		22	-0.067	-0.046	12.786	0.939
		23	-0.077	-0.094	13.741	0.934
		24	-0.058	-0.059	14.298	0.940
		25	-0.086	-0.068	15.513	0.929
		26	-0.094	-0.129	16.993	0.909
		27	-0.020	-0.024	17.062	0.930
		28	0.019	0.033	17.125	0.946
		29	0.058	0.045	17.704	0.950
		30	-0.065	-0.080	18.446	0.951
		31	-0.057	-0.035	19.013	0.955
		32	0.058	0.035	19.605	0.958
		33	-0.102	-0.112	21.462	0.939
		34	0.016	0.020	21.509	0.953
		35	0.137	0.118	24.950	0.896
		36	-0.070	-0.065	25.858	0.894

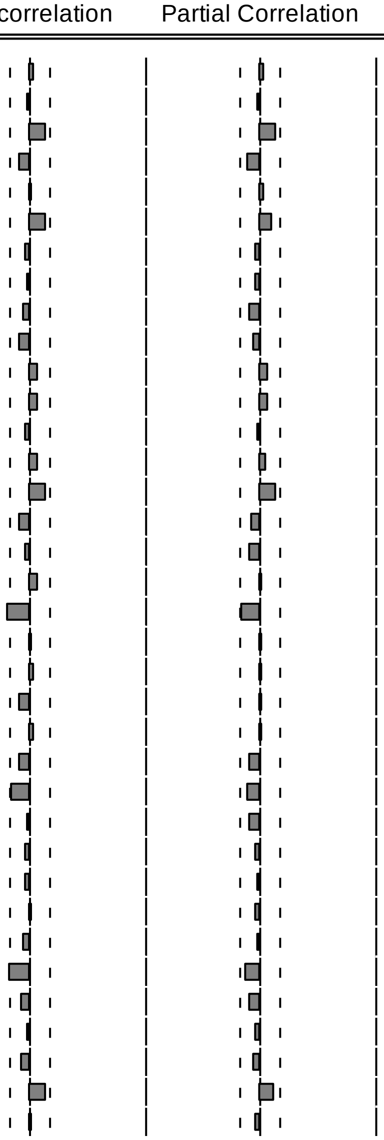
*Probabilities may not be valid for this equation specification.

Table C.5: ΔSWAP2Y = Φ^2(C, ΔTB3M, ΔCOREPCE, ΔIPYOY, ΔLNSP500, ΔLNEURO, ΔLNVIX)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.040	-0.040	0.2150	0.643
		2	0.082	0.080	1.1260	0.570
		3	0.079	0.086	1.9866	0.575
		4	0.005	0.005	1.9904	0.738
		5	-0.042	-0.056	2.2316	0.816
		6	0.119	0.109	4.2035	0.649
		7	-0.058	-0.043	4.6857	0.698
		8	-0.039	-0.056	4.9010	0.768
		9	0.066	0.055	5.5295	0.786
		10	-0.168	-0.156	9.6376	0.473
		11	0.013	0.011	9.6625	0.561
		12	0.070	0.078	10.394	0.581
		13	0.022	0.056	10.463	0.656
		14	0.006	0.010	10.469	0.727
		15	0.084	0.038	11.524	0.715
		16	-0.053	-0.019	11.950	0.747
		17	-0.085	-0.116	13.049	0.733
		18	0.020	-0.017	13.112	0.785
		19	-0.061	-0.024	13.691	0.801
		20	-0.045	-0.054	14.007	0.830
		21	0.059	0.057	14.565	0.844
		22	-0.031	0.017	14.717	0.874
		23	0.007	0.040	14.726	0.904
		24	-0.068	-0.103	15.480	0.906
		25	-0.088	-0.090	16.763	0.890
		26	0.068	0.086	17.539	0.892
		27	0.013	-0.023	17.566	0.916
		28	-0.029	-0.018	17.713	0.933
		29	-0.041	-0.053	18.009	0.944
		30	-0.111	-0.128	20.144	0.913
		31	-0.038	0.017	20.392	0.927
		32	-0.140	-0.144	23.867	0.849
		33	-0.059	-0.047	24.500	0.857
		34	-0.048	-0.050	24.921	0.872
		35	0.040	0.036	25.209	0.889
		36	-0.072	-0.009	26.153	0.886

*Probabilities may not be valid for this equation specification.

Table C.6: ΔSWAP5Y = Φ²(C, ΔTB3M, ΔCOREPCE, ΔIPYOY, ΔLNSP500, ΔLNEURO, ΔLNVIX)



	AC	PAC	Q-Stat	Prob*
1	0.031	0.031	0.1333	0.715
2	-0.021	-0.022	0.1951	0.907
3	0.142	0.144	2.9699	0.396
4	-0.096	-0.108	4.2392	0.375
5	0.011	0.028	4.2571	0.513
6	0.135	0.111	6.8245	0.337
7	-0.045	-0.028	7.1067	0.418
8	-0.022	-0.029	7.1778	0.518
9	-0.051	-0.085	7.5579	0.579
10	-0.097	-0.061	8.9328	0.538
11	0.067	0.071	9.5826	0.568
12	0.080	0.074	10.529	0.570
13	-0.035	-0.023	10.709	0.635
14	0.068	0.049	11.393	0.655
15	0.136	0.149	14.203	0.510
16	-0.089	-0.071	15.404	0.495
17	-0.042	-0.087	15.673	0.547
18	0.067	0.024	16.372	0.567
19	-0.191	-0.165	22.098	0.279
20	-0.008	-0.001	22.108	0.335
21	0.038	0.008	22.344	0.380
22	-0.086	-0.004	23.522	0.373
23	0.028	0.023	23.646	0.424
24	-0.093	-0.092	25.067	0.402
25	-0.162	-0.108	29.428	0.246
26	-0.017	-0.084	29.476	0.290
27	-0.049	-0.048	29.880	0.320
28	-0.032	-0.009	30.055	0.361
29	0.018	-0.042	30.113	0.408
30	-0.051	-0.008	30.561	0.437
31	-0.179	-0.125	36.188	0.239
32	-0.076	-0.083	37.202	0.242
33	-0.015	-0.025	37.245	0.280
34	-0.077	-0.055	38.318	0.280
35	0.142	0.125	41.972	0.194
36	-0.004	-0.030	41.975	0.228

*Probabilities may not be valid for this equation specification.

Table C.7: ΔSWAP10Y = Φ^2(C, ΔTB3M, ΔCOREPCE, ΔIPYOY, ΔLNSP500, ΔLNEURO, ΔLNVIX)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.029	0.029	0.1125	0.737
		2	-0.040	-0.041	0.3300	0.848
		3	0.105	0.108	1.8515	0.604
		4	-0.086	-0.095	2.8630	0.581
		5	0.030	0.047	2.9854	0.702
		6	0.105	0.084	4.5371	0.604
		7	-0.090	-0.078	5.6811	0.577
		8	-0.066	-0.068	6.3046	0.613
		9	-0.055	-0.072	6.7456	0.664
		10	-0.053	-0.021	7.1500	0.711
		11	0.097	0.092	8.5320	0.665
		12	0.047	0.037	8.8645	0.714
		13	-0.104	-0.087	10.463	0.656
		14	0.058	0.057	10.973	0.688
		15	0.123	0.130	13.256	0.583
		16	-0.078	-0.078	14.173	0.586
		17	0.011	-0.041	14.192	0.653
		18	0.053	0.042	14.621	0.688
		19	-0.177	-0.129	19.502	0.425
		20	0.011	0.003	19.522	0.488
		21	0.008	-0.022	19.532	0.551
		22	-0.071	-0.018	20.341	0.562
		23	0.013	-0.006	20.371	0.619
		24	-0.043	-0.014	20.669	0.658
		25	-0.084	-0.058	21.843	0.645
		26	-0.042	-0.111	22.138	0.681
		27	-0.074	-0.062	23.057	0.682
		28	-0.042	-0.024	23.363	0.715
		29	0.067	0.024	24.123	0.723
		30	-0.047	-0.036	24.503	0.749
		31	-0.140	-0.115	27.916	0.626
		32	-0.033	-0.073	28.104	0.664
		33	-0.051	-0.042	28.563	0.688
		34	-0.056	-0.037	29.135	0.705
		35	0.161	0.109	33.852	0.523
		36	0.016	0.018	33.898	0.569

*Probabilities may not be valid for this equation specification.

Table C.8: ΔSWAP30Y = Φ^2(C, ΔTB3M, ΔCOREPCE, ΔIPYOY, ΔLNSP500, ΔLNEURO, ΔLNVIX)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.009	-0.009	0.0103	0.919
		2	-0.030	-0.030	0.1312	0.937
		3	0.053	0.053	0.5172	0.915
		4	-0.098	-0.099	1.8497	0.763
		5	0.027	0.029	1.9503	0.856
		6	0.078	0.070	2.7995	0.834
		7	-0.077	-0.066	3.6428	0.820
		8	-0.070	-0.080	4.3489	0.824
		9	-0.048	-0.055	4.6744	0.862
		10	-0.072	-0.057	5.4228	0.861
		11	0.106	0.095	7.0516	0.795
		12	0.056	0.045	7.5166	0.822
		13	-0.126	-0.116	9.8910	0.703
		14	0.039	0.029	10.123	0.753
		15	0.086	0.102	11.241	0.735
		16	-0.069	-0.060	11.969	0.746
		17	0.041	-0.016	12.226	0.786
		18	0.008	0.005	12.235	0.835
		19	-0.107	-0.060	14.034	0.782
		20	-0.003	-0.026	14.035	0.829
		21	-0.021	-0.026	14.107	0.865
		22	-0.024	-0.013	14.197	0.894
		23	-0.019	-0.052	14.257	0.919
		24	0.004	0.039	14.261	0.941
		25	-0.035	-0.020	14.462	0.953
		26	-0.081	-0.139	15.548	0.946
		27	-0.042	-0.049	15.842	0.956
		28	-0.025	-0.006	15.947	0.967
		29	0.097	0.067	17.549	0.953
		30	-0.070	-0.094	18.387	0.952
		31	-0.077	-0.070	19.416	0.948
		32	0.008	-0.015	19.428	0.960
		33	-0.105	-0.098	21.382	0.941
		34	-0.018	-0.037	21.440	0.954
		35	0.156	0.111	25.891	0.868
		36	0.009	0.014	25.905	0.893

*Probabilities may not be valid for this equation specification.

Appendix D: Additional Regressions: ARDL (p, q) Model (with ΔTB6M and a set of alternative control variables)

	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP10Y	ΔSWAP30Y	ΔSWAP30Y
Main Equation								
ΔTB6M	0.73*** (0.00)	0.61*** (0.00)	0.62*** (0.00)	0.40*** (0.00)	0.54*** (0.00)	0.31*** (0.00)	0.56*** (0.00)	0.27*** (0.01)
ΔTB6M(-1)	–0.11 (0.15)						–0.22*** (0.00)	
ΔSWAP_Y(-1)				0.23*** (0.00)				
ΔSWAP_Y(-2)				–0.03 (0.59)				
ΔSWAP_Y(-3)				0.17** (0.01)				
ΔSWAP_Y(-4)				–0.12* (0.07)				
ΔCORECPI	0.05 (0.23)	0.06 (0.20)	–0.007 (0.90)	0.01 (0.85)	–0.08 (0.20)	–0.04 (0.37)	–0.11 (0.05)	–0.09 (0.09)
ΔIPYOY	–0.004 (0.26)	–0.006 (0.11)	0.0001 (0.97)	–0.004 (0.30)	0.001 (0.64)	–0.0005 (0.90)	0.004 (0.23)	–0.002 (0.72)
ΔLNDJIA		0.69 (0.04)		1.60 (0.00)		1.49 (0.02)		1.55 (0.02)
ΔLNYEM		1.39 (0.00)		2.59 (0.00)		2.79 (0.00)		2.12* (0.00)
ΔLNVIX		0.03 (0.54)		0.12 (0.21)		0.05 (0.68)		–0.01 (0.94)
Intercept	–0.001 (0.83)	–0.008 (0.31)	–0.005 (0.71)	–0.02 (0.05)	–0.01 (0.58)	–0.03 (0.03)	–0.01 (0.50)	–0.03 (0.02)
Model Information								
Obs	133	133	133	133	133	133	133	133
Adj R^2	0.62	0.68	0.30	0.50	0.23	0.41	0.27	0.44
AIC	– 2.06	– 2.21	– 1.13	– 1.44	– 0.89	– 1.14	– 0.95	– 1.19
Diagnostic Tests								
Joint Significance F-Test	44.30 (0.00)	41.09 (0.00)	15.36 (0.00)	14.30 (0.00)	10.84 (0.00)	14.24 (0.00)	10.75 (0.00)	15.62 (0.00)
Serial Correlation Durbin-Watson Stat	1.97	1.80	1.88	1.85	1.89	1.88	1.96	1.84
Serial Correlation Breusch-Godfrey LM Test	0.27 (0.76)	0.70 (0.50)	0.46 (0.63)	0.80 (0.45)	0.67 (0.51)	0.76 (0.47)	0.67 (0.51)	1.48 (0.23)
Heteroskedasticity Breusch-Pagan-Godfrey Test	0.91 (0.48)	1.68 (0.12)	0.48 (0.75)	2.09 (0.03)	0.27 (0.89)	3.71 (0.00)	0.17 (0.97)	5.13 (0.00)
Normality Test Jarque-Bera Stat	1.12 (0.57)	0.96 (0.62)	7.65 (0.02)	21.76 (0.00)	15.53 (0.00)	14.44 (0.00)	27.70 (0.00)	1.18 (0.55)
Stability Diagnostic Ramsey RESET Test	7.85 (0.00)	12.82 (0.00)	7.85 (0.00)	5.34 (0.01)	0.70 (0.50)	3.57 (0.03)	0.51 (0.60)	2.10 (0.13)

Note: all vars are in diff, *p*-values are in parenthesis. BG LM and Ramsey RESET tests are with 2 lags.

Appendix E: ARCH LM Test with ARDL (p, q) Models (with ΔTB3M)

Models	**ΔSWAP2Y**	**ΔSWAP5Y**	**ΔSWAP10Y**	**ΔSWAP30Y**
Lags	**Panel One**			
1	9.33 (0.00)	0.68 (0.41)	1.80 (0.18)	2.39 (0.12)
4	3.67 (0.01)	0.46 (0.76)	1.26 (0.29)	1.95 (0.32)
8	2.69 (0.01)	0.92 (0.50)	1.03 (0.41)	0.48 (0.87)
12	2.15 (0.02)	0.82 (0.63)	0.77 (0.68)	0.41 (0.96)
Lags	**Panel Two**			
1	9.56 (0.00)	0.07 (0.79)	0.003 (0.95)	0.09 (0.77)
4	3.92 (0.00)	0.14 (0.97)	0.35 (0.84)	0.30 (0.88)
8	2.43 (0.02)	0.54 (0.82)	0.82 (0.59)	0.50 (0.85)
12	2.11 (0.02)	0.62 (0.82)	0.74 (0.71)	0.39 (0.96)

Note: ARDL (p, q) models (from table 4) include the change in the short-term interest rate (ΔTB3M) and the controls (namely ΔCOREPCE and ΔIPYOY in panel one for the basic model and ΔCOREPCE, ΔIPYOY, ΔLNSP500, ΔLNEURO, and ΔLNVIX in panel two for the extended model); *p*-values are in parenthesis.