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An Analysis of UK Swap Yields

Tanweer Akram
Citibank

Khawaja Mamun
Sacred Heart University

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by

Tanweer Akram*
Citibank

and

Khawaja Mamun
Sacred Heart University

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Corresponding author: Tanweer Akram, tanweer_akram@hotmail.com; Khawaja Mamun, mamun@sacredheart.edu

Levy Economics Institute
P.O. Box 5000
Annandale-on-Hudson, NY 12504-5000
http://www.levyinstitute.org

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ABSTRACT

John Maynard Keynes argued that the central bank influences the long-term interest rate through the effect of its policy rate on the short-term interest rate. However, Keynes's claim was confined to the behavior of the long-term government bond yield. This paper investigates whether Keynes's claim holds for the yields of spread products and over-the-counter financial derivatives by econometrically modeling the dynamics of the pound sterling–denominated long-term interest rate swap yield. It uses the generalized autoregressive conditional heteroskedasticity (GARCH) modeling approach to examine the relationship between the month-over-month changes in the short-term swap yield and the month-over-month change in the long-term swap yield, while controlling for several key macroeconomic and financial variables. The month-over-month change in the short-term interest rate has a positive and statistically significant effect on the month-over-month change in the long-term swap yield. This finding reinforces Keynes's conjecture concerning the central bank's influence over the long-term interest rate. The investigation's empirical findings and their policy implications are discussed from a Keynesian perspective.

KEYWORDS: Interest Rate Swaps; Swap Yields; Interest Rates; Bank of England; John Maynard Keynes

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

SECTION I: INTRODUCTION

In the *Treatise on Money*, John Maynard Keynes (1930) argued that the central bank influences the long-term interest rate through the effect of its policy rate on the short-term interest rate. Keynes held that the central bank's policy rate determines the short-term interest rate. In turn, the short-term interest rate, along with a central bank's other monetary policy actions, affects the long-term interest rate on government bonds. Keynes's conjecture about the relationship between the short-term interest rate and the long-term government bond yield is supported in recent empirical literature, such as Akram and Li (2017, 2020a), Deleidi and Levrero (2021), Gabrisch (2022), and Li and Su (2021). Akram and Li (2020b) report that there is a tight connection between the short-term interest rate and the long-term interest rate of gilts in the United Kingdom.

Keynes's claim about the connection between the short-term interest rate and the long-term interest rate was confined to the behavior of gilt-edged securities, that is, the long-term government bond yield. Given the finding about the tight connection between the short-term interest rate and the long-term gilt yield in the United Kingdom, it raises an obvious question—whether Keynes's conjecture is applicable to long-term pound sterling (GBP)–denominated spread products and over-the-counter (OTC) financial derivatives, such as interest rate swaps.

This paper investigates if Keynes's claim holds for the GBP-denominated long-term interest rate swap yield. It econometrically models the dynamics of GBP-denominated long-term swap yields. It examines whether there is a relationship between the short-term interest rate and the long-term swap yield. It is shown that the change in the short-term interest rate has a decisive influence over the change in the long-term swap yield, after controlling for other macroeconomic and financial factors, such as the change in core inflation, change in the growth of industrial production, percentage change in the equity index, and percentage change in the GBP's exchange rate.

Interest rate swaps play a vital role in the global financial and derivatives markets. As of 2021, the total outstanding interest rate swaps in all currencies amounted to almost $400 trillion in notional terms and $8 trillion in gross market value. The total amount of outstanding GBP-denominated interest rate swaps is substantial. Interest rate swaps denominated in GBP amounted to more than $47.4 trillion in notional terms and around $1.2 trillion in gross market value in 2021 (Bank for International Settlements 2022). Hence, GBP-denominated interest rate swaps constituted a nearly 12 percent share of total outstanding interest rate swaps in notional terms and a 15 percent share of total outstanding interest rate swaps in gross market value. The consequential share of GBP-denominated interest rate swaps in the total amount of interest rate swaps in all currencies undoubtedly reflects the continuing importance of the United Kingdom and the City of London in global financial markets and the role of the GBP in global finance, despite the relative demise of the UK's economic role in the global system. It also underscores the need to examine and econometrically model the dynamics of GBP-denominated interest rate swap yields. Recently, there has been a concerted effort to econometrically model interest rate swap yields from a Keynesian viewpoint, such as Akram and Mamun (2022a, 2022b). This paper extends that endeavor to model the dynamics of GBP-denominated interest rate swap yields.

There is a voluminous literature on interest rate swaps. Corb (2012) furnishes a detailed explanation of swaps, while Bicksler and Chen (1986), Remolona and Wooldbridge (2003), and Smith Jr., Smithson, and Wakeman (1988) provide valuable information about the use of interest rate swaps in business and finance. Some empirical literature models the dynamics of swap yields, such as Duffie and Huang (1996), Duffie and Singleton (1997), and Kim and Koppenhaver (1993). However, the empirical modeling of swap dynamics has not related the long-term swap yield to the current short-term interest rate. Most economic modelers have decomposed the long-term swaps yield of a certain maturity tenor as consisting of the long-term Treasury yield of the same maturity tenor and a corresponding swap spread. Modelers, such as Lekkos and Milas (2001), then tend to zero in on explaining what drives the corresponding swap spread. This approach, however, raises the question: What drives Treasury yields? In contradistinction to the standard approach, in this current paper the month-over-month change in the long-term swap yield is econometrically modeled in such a way that it is directly related to the current short-term interest rate and several macroeconomic and financial variables. The benefit of this approach is that it relates the long-term swap yield to fundamental macroeconomic and financial variables. It also appraises whether Keynes's conjecture is applicable to the long-term interest rate swap yield.

Outline

This paper proceeds as follows. Section II concisely reprises Keynes's views on the behavioral determinants of the long-term interest rate. Section III provides the macroeconomic context surrounding the evolution of GBP-denominated interest rate swap yields. Section IV describes the data and data sources. It also provides the summary statistics, unit root tests, and stationary tests of the variables. Section V reports the empirical findings of the econometric models. Section VI concludes.

SECTION II: KEYNES'S VIEW OF THE DETERMINANTS OF THE LONG-TERM INTEREST RATE

Keynes maintained that monetary policy drives the long-term interest rate through the short-term interest rate. Kregel (2011) succinctly summarized Keynes's views on the relationship between the short-term interest rate and the long-term interest rate.

Keynes (2007 [1936], 165–209, 222–244) resolutely rejected the loanable funds view of the interest rate. Instead, he believed that interest rates have a basis in human psychology and behavior, social conventions, and institutions. Liquidity preference, in a world characterized by uncertainty, is the foundation for the interest rate. Hence, for Keynes, the interest rate is a return for the willingness to give up cash or bank money, rather than a return for saving or patience. Mott (2010) argued that Kalecki's principle of increasing risk—which is based on the notion that the greater the investment, the higher the danger to wealth in the event of failure or adverse shock—provides an economic and financial rationale for firms and households to stay liquid beyond just individual psychology, preferences, or idiosyncrasies.

In the standard model of quantitative finance and rational expectations, the long-term interest rate is a function of the current short-term interest rate and the expected path of the future short-term interest rates or forward rates. In the standard model, the scope of the current short-term interest rate for influencing the long-term interest rate is limited. In contrast to the standard model, Keynes (1930, II: 352–62) identifies several reasons why the current short-term interest rate has a decisive influence on the long-term interest rate. He draws on various technical aspects of financial markets, institutional characteristics of financial institutions, investors' expectations, herding behavior, and the fundamental uncertainty that prevents investors from having well-formulated mathematical expectations about the future.

First, Keynes notes that there is an institutional reason for the short-term and long-term interest rate to generally move together. When the short-term interest rate is lower (higher) than the long-term interest rate, it is profitable to borrow (lend) on a long-term basis. When the short-term interest is low (high), investors are willing to shift to (shift out of) long-term bonds. This causes long-term bonds to rally (sell-off) as investors reallocate their portfolio.

Second, the need to generate income from financial assets causes the short-term and long-term interest rate to move together.

Third, investors have limited knowledge about the future. Hence, for the most part, it is not actually possible for investors to have well-defined mathematical expectations about the economic and financial outlook due to uncertainty. Since investors cannot assign probability weights to the path of future interest rates, investors in practice resort to "the apparent certainties of the short period, however deceptive" (Keynes 1930, II: 361). Investors' decisions are usually "oversensitive … to the near future" because of the lack of knowledge about the more-distant future. Keynes believes investors are compelled to take a cue from current conditions regarding "trends further ahead."

Fourth, interest rate and asset price dynamics are reinforced by the herding and crowd psychology of investors. Keynes (1930, II: 357–58) remarked that "as long as a crowd can be relied on to act in a certain way, even if it is misguided, it will be to the advantage of the better-informed professional to act in the same way—a short period ahead." He insisted that most investors succumb to "the preys and hope and fears aroused by transient events" and the mob psychology that fosters herding.

These factors constitute the psychological, social, conventional, and institutional basis on which the central bank's current policy rate and monetary policy exert their influence on the long-term interest rate via the short-term interest rate. Thus, Keynes (1930, II: 315) claimed: "The influence of the short-term rate of interest on the long-term rate is much greater than anyone … would have expected."

Keynes (1930, II: 363) understood the crucial importance of the central bank's policy rate, asserting that "[t]here is no reason to doubt the ability of a Central Bank to make its short-term rate of interest effective in the market." He emphasized that "[t]he efficacy of the Bank-rate for the management of a managed money was a great discovery… its application in varying conditions were not clearly understood—and have not been clearly understood … down to this day" (Keynes 1930, I: 17). His views were based not just on his own observations of the gilts market in the United Kingdom but also on the then-recently available empirical studies of money markets and capital markets in the United States carried out by W. W. Riefler (1930). Keynes approvingly quoted Riefler's own summary of the findings of these studies: "[T]he surprising fact is not that [long-term] bond yields are relatively stable in comparison to short-term [interest] rates, but they have reflected fluctuations in short-term [interest] rates so strikingly and to a such a considerable extent" (Riefler 1930, 123; cited in Keynes 1930, II: 354–55).

Keynes ([1936] 2007, 202–3) understood the power of the central bank and its limitations. He realized that "[t]he short-term interest rate is easily controlled by the monetary authority," but "the long-term [interest] rate may be more recalcitrant." However, he asserted that "[i]f the monetary authority were prepared to deal both ways on the specified terms in debt of all maturities, and … in debts of varying degrees of risks, the relationship with the complex rate of interest and the quantities of the money would be direct" (Keynes [1936] 2007, 205). He noted: "A complex offer by the central bank to buy and sell at stated prices gilt-edged bonds of all maturities, in place of the single bank rate for short-term bills, is the most important practical improvement that can be made in the technique of monetary management" (Keynes [1936] 2007, 206).

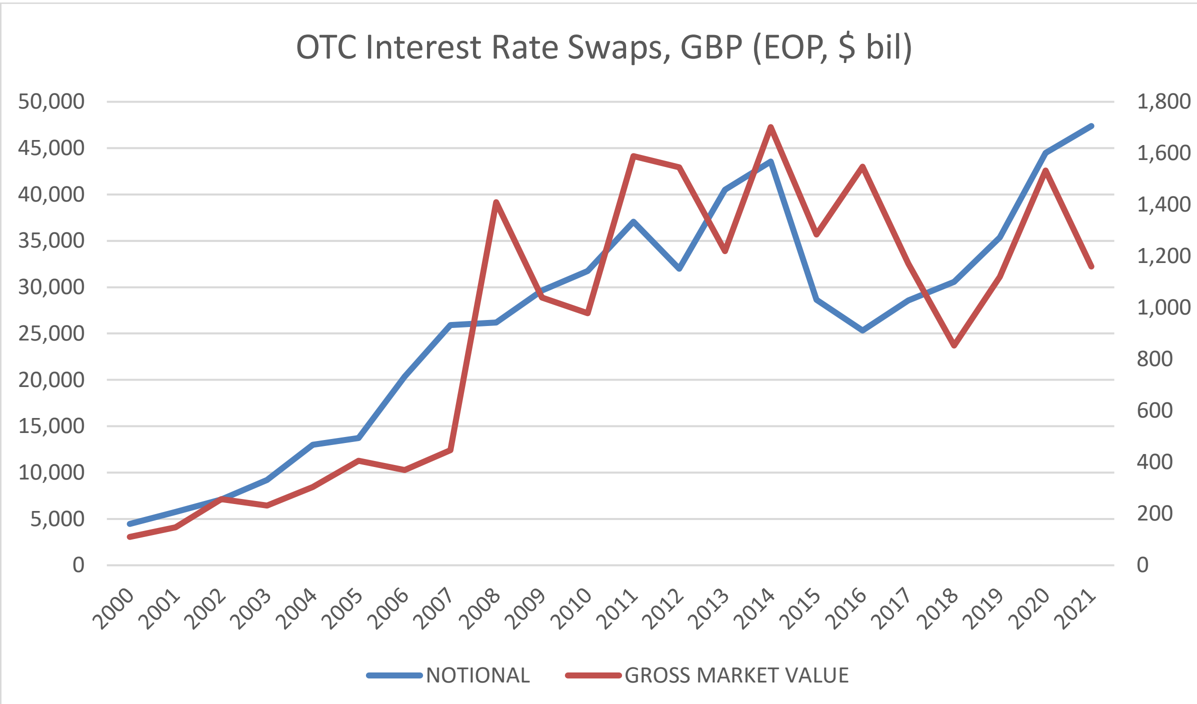
The inquiry into the relationship between the short-term interest rate and the long-term interest rate has a distinguished pedigree, as this topic interested J. R. Hicks, Roy Harrod, George Shackle, Nicholas Kaldor, and Michal Kalecki (Toporowski 2022). For example, Kalecki (1954, 73) maintained that "the long-term [interest] rate is determined by anticipation of the short-term [interest] rate based on past experience and by the estimates of the risk involved in the possible depreciation of a long-term asset." As cited in Toporowski (2022, 16), Kalecki (1933, 97) had also noted that "changes in the rate of interest are determined by the mechanism of the business cycle, rather than determining it." However, it was Keynes who assiduously articulated the central bank's determinate role in influencing the long-term interest rate through the short-term interest rate arising from its setting the policy rate and other monetary policy actions.

In recent years there has been a marked increase in the number of empirical studies examining the relationship between short-term and long-term interest rates from a Keynesian perspective. Akram (2021a, 2021b) recapitulates the Keynesian perspective on interest rate dynamics and develops a simple model that links the short-term interest rate and the long-term government bond yield. However, empirical studies of the long-term interest rate swap yield are still at a nascent stage. Thus, an investigation into whether Keynes's conjecture with respect to the relationship between the short-term interest rate and long-term interest rate holds for GBP-denominated interest rate swap yields in the context of the UK's macroeconomic and financial circumstances is germane. It is relevant for both economic theory and policy.

SECTION III: THE MACROECONOMIC CONTEXT OF THE EVOLUTION OF GBP-DENOMINATED INTEREST RATE SWAP YIELDS

As of 2021, the notional value of GBP-denominated interest rate swaps was US$47.4 trillion, while their gross market value was $1.2 trillion. Figure 1 illustrates the evolution of outstanding GBP-denominated interest rate swaps. During the 2000–21 period, the notional value of outstanding GBP interest rate swaps rose steadily from less than $4.5 trillion in 2000 to $47.4 trillion in 2021, even though there were several years when the notional value declined. GBP interest rate swaps' gross market values rose sharply in 2007–8 amid the global financial crisis. However, between 2009 and 2021 their gross market value fluctuated in the range of $1.0 trillion to $1.6 trillion.

Figure 1. The Evolution of Outstanding GBP Interest Rate Swaps, 2000–21



Source: Bank for International Settlements

Figure 2 exhibits the evolution of the yields of swaps of different maturity tenors.[1] Swap yields have declined over time. However, the yields of different maturity tenors showed co-movement over last three decades. Typically, the swap yield curve is positively sloped. Hence, the 10-year swap yield is usually higher than the 5-year swap yield, and the 5-year swap yield is usually higher than the 2-year swap yield.

[1] Sources for the relevant data for Figures 2–6 are listed in Table 1.

Figure 2. The Evolution of Swap Yields in the United Kingdom, 1990M1–2022M3

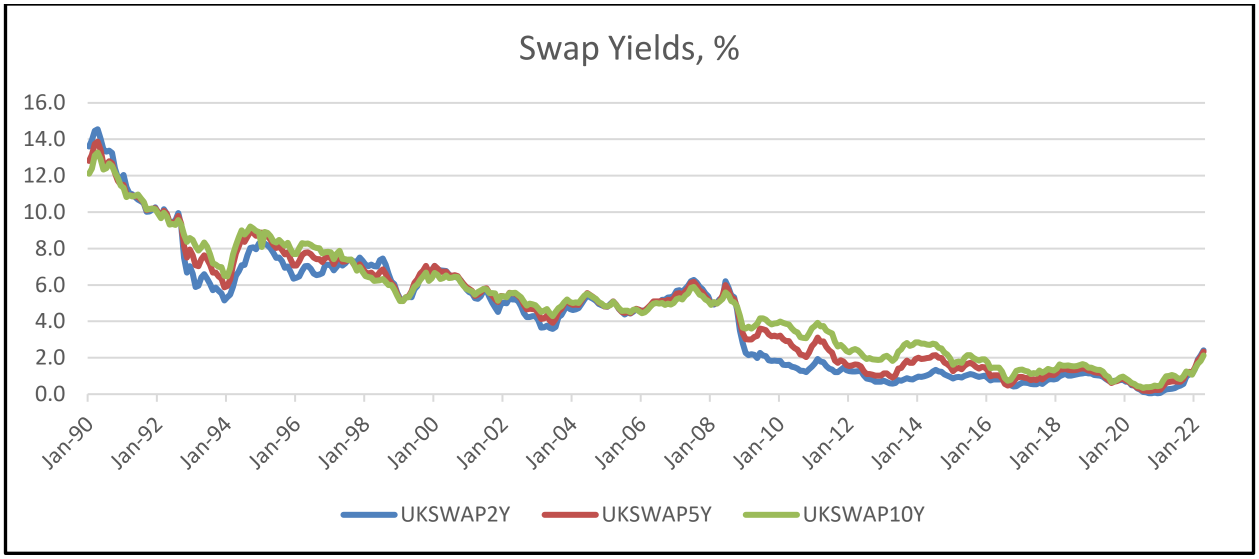


Figure 3 displays the coevolution of the 10-year swap yield and the 3-month London interbank offer rate (LIBOR) during the period. Throughout the early 1990s, LIBOR was higher than the 10-year swap yield, though it was lower than the 10-year swap yield during the remainder of the period. It shows that most of the time the long-term swap yield and short-term interest rate moved in lockstep. There are clearly times when the LIBOR changes notably while the 10-year swap yield remains steady.

Figure 3. The Coevolution of the 10Y Swap Yield and the 3-month LIBOR, 1990M1–2022M3

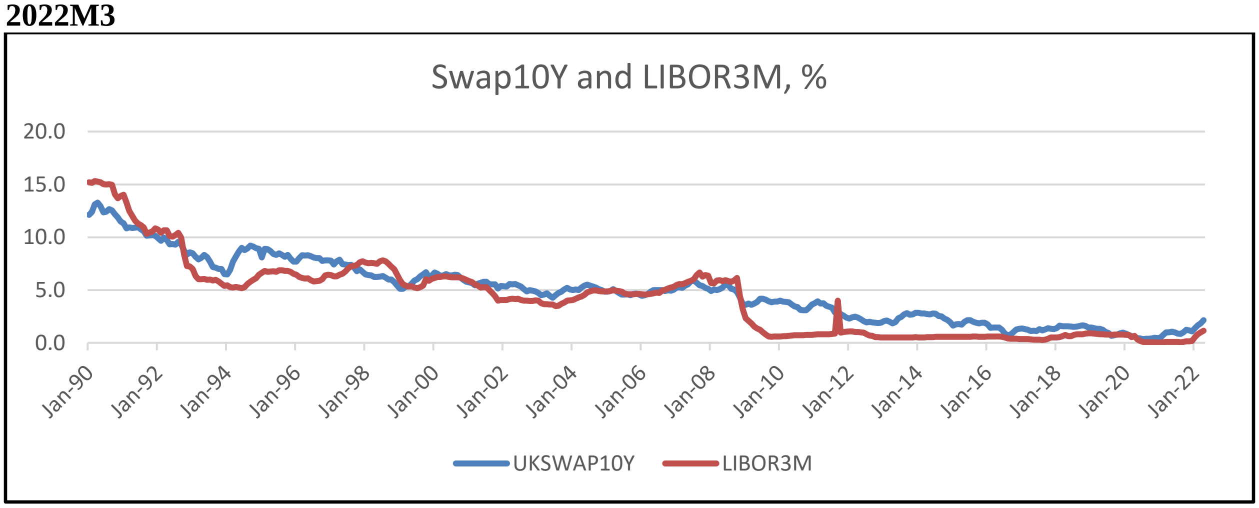


Figure 4 shows the coevolution of the 10-year swap yield and core inflation. These usually move together and are positively correlated. Nevertheless, there are also times when swap yields and inflation move in the opposite direction, such as during the recession of the early 1990s, the tightening of monetary policy in the late 1990s, and in the aftermath of the global financial crisis in 2009–10.

Figure 4. The Coevolution of the 10Y Swap Yield and Core Consumer Price Index (CPI) Inflation, 1990M1–2022M3

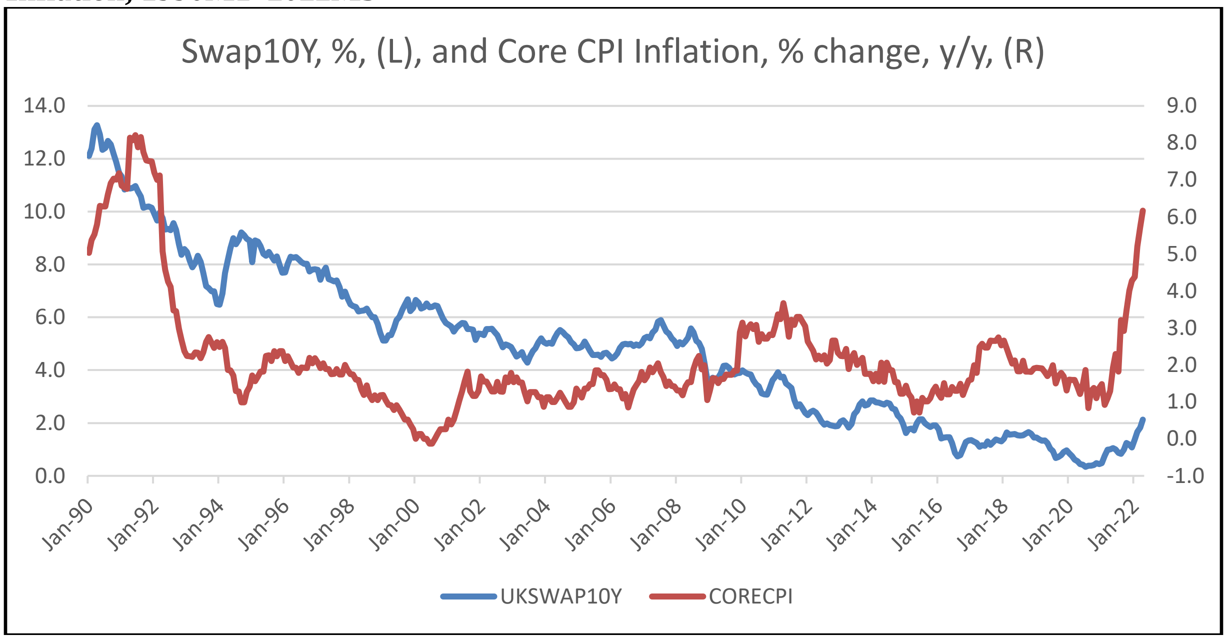


Figure 5. The Evolution of the *Financial Times* Stock Exchange 100 (FTSE100) Index, 1990M1–2022M3

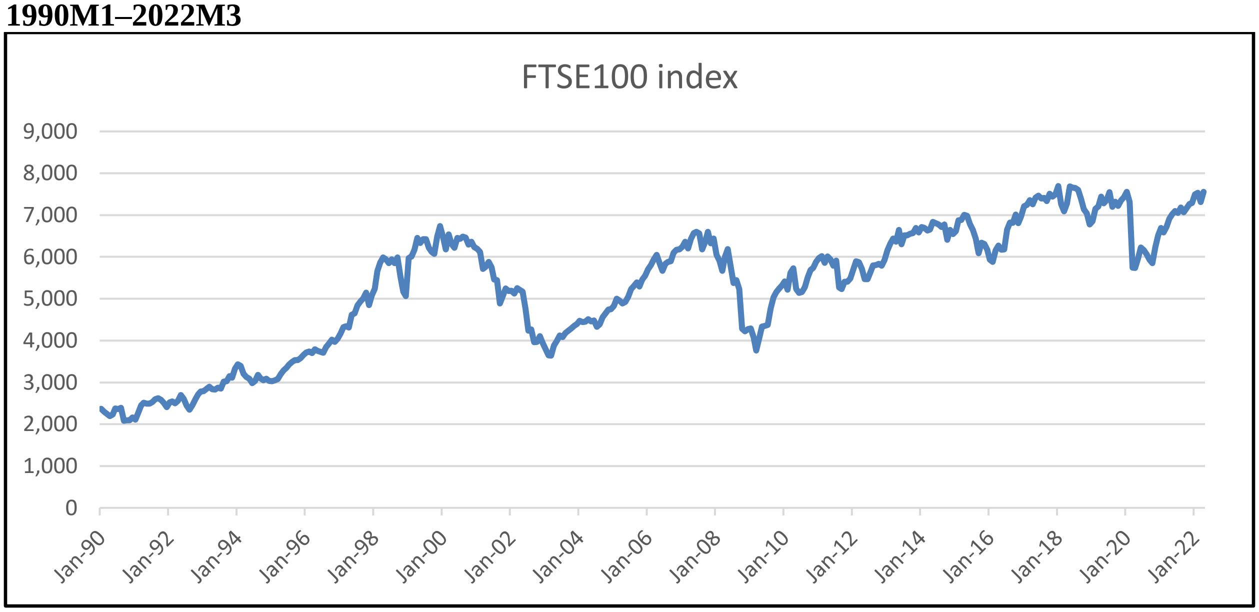
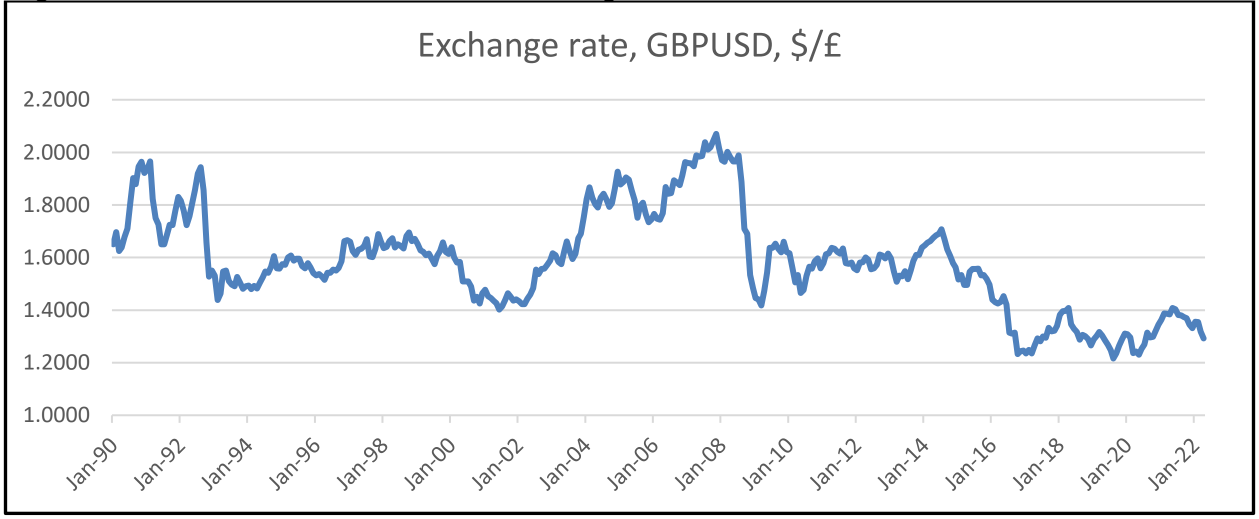


Figure 5 lays out the evolution of the *Financial Times* Stock Exchange 100 (FTSE100) Index, which is the United Kingdom's stock price index. It shows that the index rose during the period, though there have been episodes of declines during periods of recession and economic slowdown associated with the tech bubble in 2000, the global financial crisis in 2008, and the global pandemic in 2020.

Figure 6 displays the evolution of the GBP's exchange rate against the US dollar ($/£). The GBP has ranged from $1.2/£ to slightly above $2.0/£. The GBP was trading between $1.6/£ and $1.8/£ in the beginning of the 1990s but depreciated to a range between $1.4/£ and $1.7/£ until late 2002. It started appreciating in late 2003 and rose to a bit more than $2.0/£ by late 2007. The GBP depreciated markedly during the global financial crisis. The following year it hovered around $1.6/£. It began to depreciate in late 2014 and was approaching $1.4/£ around the time of the Brexit referendum in June 2016, falling to near $1.2/£ afterward. Between early 2016 and early 2022, it traded in the range of $1.2/£ to $1.4/£.

Figure 6. The Evolution of the GBP Exchange Rate, $/£, 1990M1–2022M3



SECTION IV: DATA DESCRIPTION, SUMMARY STATISTICS, AND UNIT ROOT AND STATIONARITY TESTS

Table 1, below, provides a summary of the data used in this paper. The first column lists the variables. The second column gives the data description and date range. The third column provides the frequency of the data and indicates whether the data has been converted from high frequency data to monthly frequency. The final column furnishes the data sources.

The data consist of long-term swap yields, the short-term interest rate, inflation, economic activity, and financial variables. The long-term swap yields are of 2-, 5-, and 10-year terms, while the short-term interest rate is the 3-month LIBOR. The inflation measures are the year-over-year change in the headline and core consumer price (CPI) indexes. The year-over-year change in the industrial production index is used as a measure of economic activity. The financial variables are the spot exchange rate of the GBP against the US dollar and the FTSE100 Index. The data used are in monthly frequency from January 1990 to March 2022, consisting of 387 observations.

Table 1. Summary of the Data

Variables	Data description, date range	Frequency	Sources
Short-term interest rates			
LIBOR3M	London interbank offer rate, 3-month, %, January 1990–March 2022	Daily; converted to monthly	Intercontinental Exchange
Long-term swap rates			
SWAP2Y	Interest rate swap, 2-year, GBP, %, January 1990–March 2022	Daily; converted to monthly	Refinitiv
SWAP5Y	Interest rate swap, 5-year, GBP, %, January 1990–March 2022	Daily; converted to monthly	Refinitiv
SWAP10Y	Interest rate swap, 10-year, GBP, %, January 1990–March 2022	Daily; converted to monthly	Refinitiv
Inflation			
CORECPI	Consumer price index, all items excluding energy, food, and alcoholic beverages & tobacco, not seasonally adjusted, % change, y/y, January 1990–March 2022	Monthly	Office of National Statistics

Variables	Data description, date range	Frequency	Sources
CPI	Consumer price index, all items, not seasonally adjusted, % change, y/y, January 1990–March 2022	Monthly	Office of National Statistics
Economic activity			
IP	Industrial production, index, % change, y/y, seasonally adjusted, 2019 = 100, January 1990–March 2022	Monthly	Office of National Statistics
Financial variables			
GBP	Spot exchange rate, $/£, US dollars per British pound sterling, January 1990–March 2022	Daily; converted to monthly	Bank of England
FTSE100	Stock price index, London *Financial Times* 100, January 2, 1984 = 100, January 1990–March 2022	Daily; converted to monthly	*Financial Times*

Note: LNGBP = LN(GBP) and LNFTSE100 = LN(FTSE100), where LN(.) designates the natural logarithm of the variables.

Table 2A provides the summary statistics of the variables and table 2B displays the summary statistics of the first differences of the variables.

Table 2A. Summary Statistics of the Variables

Vars	Obs	Mean	Std Dev	Max	Min	Skewness	Kurtosis	J-B	Probability
SWAP2Y	386	4.33	3.31	14.55	0.05	0.66	3.01	28.12	0.00
SWAP5Y	386	4.65	3.16	13.87	0.17	0.53	2.70	19.87	0.00
SWAP10Y	386	4.89	3.01	13.27	0.34	0.52	2.69	19.22	0.00
LIBOR3M	386	4.14	3.61	15.32	0.03	0.92	3.74	63.27	0.00
CPI	386	2.44	1.70	8.51	-0.20	1.61	5.72	286.70	0.00
CORECPI	386	2.15	1.56	8.21	-0.13	2.18	7.83	682.78	0.00
IP	386	0.88	4.73	30.04	-25.50	0.20	10.66	948.23	0.00
LNFTSE100	386	8.52	0.34	8.95	7.64	-0.94	2.81	57.11	0.00
LNGBP	386	0.45	0.12	0.73	0.20	0.01	2.60	2.53	0.28

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

Vars	Obs	Mean	Std Dev	Max	Min	Skewness	Kurtosis	J-B	Probability
ΔSWAP2Y	385	-0.030	0.24	0.92	-1.79	-1.37	11.96	1412.6	0.00
ΔSWAP5Y	385	-0.028	0.22	0.80	-1.22	-0.41	5.97	152.9	0.00
ΔSWAP10Y	385	-0.027	0.20	0.82	-0.82	0.11	4.91	59.4	0.00
ΔLIBOR3M	385	-0.037	0.31	3.14	-3.03	-0.71	54.02	41900.7	0.00
ΔCPI	385	0.004	0.33	1.68	-2.41	-0.37	11.72	1230.7	0.00
ΔCORECPI	385	0.002	0.28	1.39	-2.05	-0.41	12.68	1517.9	0.00
ΔIP	385	0.003	2.66	26.28	-16.60	1.52	32.81	14437.8	0.00
ΔLNFTSE100	385	0.003	0.04	0.16	-0.24	-1.36	10.57	1040.6	0.00

ΔLNGBP	385	-0.001	0.02	0.06	-0.11	-0.99	6.50	259.5	0.00

Table 2A shows that the mean of the swap yield at the back end of the swap yield curve is greater than the mean of the swap yield at the front and middle of the curve.

Table 3A exhibits the variables' unit root and stationarity tests. Table 3B shows the unit root and stationarity tests of the variables in their first difference.

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

Variables at Level	ADF Unit Root Tests (H_0: Nonstationary)			KPSS Tests (H_0: Stationarity) tests	
	None	Intercept	Trend	Intercept	Trend
SWAP2Y	– 3.33***	– 3.45**	– 3.90**	2.13***	0.13*
SWAP5Y	– 3.58***	– 3.33**	– 4.05**	2.22***	0.13*
SWAP10Y	– 2.98***	– 2.54	– 3.67*	2.24***	0.20**
LIBOR3M	– 4.01***	– 3.46*	– 3.07	1.98***	0.13*
CPI	– 0.71	– 2.02	– 1.46	0.39*	0.22***
CORECPI	– 1.47	– 2.66	– 2.13	0.45*	0.31***
IP	– 3.17***	– 3.38**	– 3.44**	0.16	0.11
LNFTSE100	– 1.35	– 2.03	– 2.47	1.68***	0.24***
LNGBP	– 1.03	– 2.15	– 2.71	0.87***	0.31***

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

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

	ADF Unit Root Tests (H_0: Nonstationary)			KPSS Tests (H_0: Stationarity) tests	
	None	Intercept	Trend	Intercept	Trend
ΔSWAP2Y	– 8.49***	– 8.64***	– 8.92***	0.31	0.06
ΔSWAP5Y	– 9.22***	– 12.76***	– 13.02***	0.29	0.05
ΔSWAP10Y	– 14.59***	– 14.77***	– 14.89***	0.24	0.04
ΔLIBOR3M	– 19.21***	– 19.44***	– 19.68***	0.31	0.07
ΔCPI	– 4.38***	– 4.34***	– 4.69***	0.31	0.08
ΔCORECPI	– 5.26***	– 5.24***	– 5.65***	0.28	0.05
ΔIP	– 12.28***	– 12.26***	– 12.24**	0.03	0.03
ΔLNFTSE100	– 17.21***	– 17.30***	– 17.30***	0.11	0.05
ΔLNGBP	– 15.22***	– 15.22***	– 15.20***	0.06	0.03

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

The unit root tests in Table 3A and Table 3B consist of augmented Dickey–Fuller (ADF) tests with three different assumptions in the test equation. The null hypothesis of the ADF tests is that the unit root is present. The tables also report the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests with two different assumptions in the test equation. The null hypothesis of the KPSS tests is that the time series is stationary. Both ADF and KPSS tests in Table 3A imply that most variables are nonstationary. However, after taking the first difference, both ADF and KPSS tests imply that all first differenced variables are stationary, as reported in Table 3B.

SECTION V: ECONOMETRIC MODELS AND EMPIRICAL FINDINGS

Based on the findings from the ADF and the KPSS tests, three sets of models are proposed for econometrically examining the dynamics of the GBP-denominated interest rate swap yield: (1) simple models, (2) basic models, and (3) extended models. In the simple models, the change in the long-term swap yield is solely a function of the change in the short-term interest rate. In the basic models, the change in the long-term swap yield is a function of the change in the short-term interest rate and two control variables, namely, the change in core inflation and change in the growth of industrial production. In the extended model, the change in the long-term swap yield is a function of the change in the short-term interest rate and four control variables, namely, the change in core inflation, change in the growth of industrial production, percentage change in the equity index, and percentage change in the exchange rate. The three sets of models are represented in the equations given below.

Simple Models

ΔSWAP2Y = F^1(ΔLIBOR3M)

ΔSWAP5Y = F^2(ΔLIBOR3M)

ΔSWAP10Y = F^3(ΔLIBOR3M)

Basic Models

ΔSWAP2Y = F^4(ΔLIBOR3M, ΔCORECPI, ΔIP)

ΔSWAP5Y = F^5(ΔLIBOR3M, ΔCORECPI, ΔIP)

ΔSWAP10Y = F^6(ΔLIBOR3M, ΔCORECPI, ΔIP)

Extended Models

ΔSWAP2Y = F^7(ΔLIBOR3M, ΔCORECPI, ΔIP, ΔLNFTSE, ΔLNGBP)

ΔSWAP5Y = F^8(ΔLIBOR3M, ΔCORECPI, ΔIP, ΔLNFTSE, ΔLNGBP)

ΔSWAP10Y = F^9(ΔLIBOR3M, ΔCORECPI, ΔIP, ΔLNFTSE, ΔLNGBP)

The autoregressive conditional heteroskedasticity–Lagrange multiplier (ARCH–LM) test is conducted on the ordinary least square (OLS) regressions of the above sets of models. The

ARCH–LM tests reveal that the residuals of the OLS models exhibit conditional heteroskedasticity (the ARCH effect). Table 4 presents the results of the OLS regressions from the above three sets of models. The results of the ARCH-LM tests of the simple, basic, and extended models are displayed in three different panels in Table 4.

Table 4. ARCH-LM Test

Models	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP10Y
	Panel One		
Lags	**Simple Models**		
1	35.71 (0.00)	38.51 (0.00)	63.36 (0.00)
4	10.47 (0.00)	13.18 (0.00)	21.13 (0.00)
8	5.18 (0.00)	6.57 (0.00)	10.23 (0.00)
12	3.55 (0.04)	4.44 (0.00)	9.03 (0.00)
	Panel Two		
Lags	**Basic Models**		
1	37.50 (0.00)	41.84 (0.00)	63.37 (0.00)
4	10.91 (0.00)	13.95 (0.00)	22.05 (0.00)
8	5.36 (0.00)	6.84 (0.00)	10.62 (0.00)
12	3.66 (0.00)	4.61 (0.00)	9.50 (0.00)
	Panel Three		
Lags	**Extended Models**		
1	24.29 (0.00)	25.38 (0.00)	59.34 (0.00)
4	8.71 (0.00)	10.63 (0.00)	22.99 (0.00)
8	4.43 (0.00)	5.51 (0.00)	11.05 (0.00)
12	3.11 (0.00)	3.60 (0.00)	9.56 (0.00)

Note: OLS models include the change in the short-term interest rate (ΔLIBOR3M) in panel one. The controls (ΔCORECPI, ΔIP) are added in panel two and (ΔCORECPI, ΔIP, ΔLNFTSE100, ΔLNGBP) are added in panel three. All panels also include an AR(1) term; *p*-values are in parenthesis.

The null hypothesis of the ARCH–LM test is that there is no conditional heteroskedasticity. The tests clearly reject the null hypothesis of no conditional heteroskedasticity. Based on the finding that ARCH effects are present in the OLS regressions of the above sets of models, the generalized autoregressive conditional heteroskedasticity (GARCH) approach, developed by

Engle (1982, 2001) and Bollerslev (1986), is deemed as the most suitable one for modeling the dynamics of the month-over-month change in the GBP-denominated long-term interest rate swap yield.

GARCH(1,1) models the variance by forming a weighted average of a long-term average, the forecasted variance from the last period (the GARCH term), and information about volatility observed in the previous period (the ARCH term). Furthermore, GARCH(1,1) models capture the volatility clustering present in GBP-denominated swap yields.

The following three sets of GARCH(1,1) models are estimated. The models' equations are given below.

Simple Models

ΔSWAP2Y = Φ^1(C, ΔLIBOR3M); variance equation

ΔSWAP5Y = Φ^2(C, ΔLIBOR3M); variance equation

ΔSWAP10Y = Φ^3(C, ΔLIBOR3M); variance equation

Basic Models

ΔSWAP2Y = Φ^4(C, ΔLIBOR3M, ΔCORECPI, ΔIP); variance equation

ΔSWAP5Y = Φ^5(C, ΔLIBOR3M, ΔCORECPI, ΔIP); variance equation

ΔSWAP10Y = Φ^6(C, ΔLIBOR3M, ΔCORECPI, ΔIP); variance equation

Extended Models

ΔSWAP2Y = Φ^7(C, ΔLIBOR3M, ΔCOREPCPI, ΔIP, ΔLNFTSE100, ΔLNGBP); variance equation

ΔSWAP5Y = Φ^8(C, ΔLIBOR3M, ΔCOREPCPI, ΔIP, ΔLNFTSE100, ΔLNGBP); variance equation

ΔSWAP10Y = Φ^9(C, ΔLIBOR3M, ΔCOREPCPI, ΔIP, ΔLNFTSE100, ΔLNGBP); variance equation

All models also include an autoregressive term with one lag (that is, AR(1)).

The results from the GARCH(1,1) models, including several diagnostic tests, are exhibited in Table 5.

The coefficient of the short-term interest rate (LIBOR3M) is always positive, economically important, and statistically significant in all these models. This suggests the change in the short-term interest rate strongly affects the swap yield. Similar empirical patterns relating the short-term interest rate and the long-term swap yield are reported for the Chilean peso and the US dollar denominated interest rate swaps (Akram and Manun 2022a, 2022b) The effect is larger for the 5-year swap yields compared to the 2-year and 10-year swap yields, while the effect is the smallest for the 10-year swap yields. The effect of the change in the short-term interest rate declines in the extended models (that is, with more control variables) for longer maturity swaps (5-year and 10-year swaps).

Table 5. GARCH(1,1) Model

	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP10Y	ΔSWAP10Y
					Mean Equation				
Intercept	–0.01 (0.38)	–0.01 (0.44)	–0.003 (0.64)	–0.02 (0.15)	–0.02 (0.14)	–0.01 (0.21)	–0.02 (0.10)	–0.02* (0.09)	–0.02 (0.10)
ΔLIBOR3M	0.24*** (0.00)	0.23*** (0.00)	0.33*** (0.00)	0.39*** (0.00)	0.39*** (0.00)	0.33*** (0.00)	0.19*** (0.00)	0.18*** (0.00)	0.12*** (0.00)
ΔCORECPI		0.02 (0.15)	0.02** (0.02)		0.02 (0.47)	0.02 (0.45)		0.03 (0.25)	0.04 (0.19)
ΔIP		0.001 (0.67)	0.002 (0.26)		0.002 (0.69)	0.001 (0.77)		0.001 (0.71)	0.001 (0.79)
ΔLNFTSE100			–0.38*** (0.00)			–0.11 (0.51)			–0.03 (0.89)
ΔLNGBP			1.81*** (0.00)			1.34*** (0.00)			1.46*** (0.00)
AR(1)	0.37*** (0.00)	0.38*** (0.00)	0.34*** (0.00)	0.35*** (0.00)	0.35*** (0.00)	0.33*** (0.00)	0.26*** (0.00)	0.26*** (0.00)	0.24*** (0.00)
					Variance Equation				
INTERCEPT	0.01** (0.02)	0.01** (0.02)	0.005* (0.06)	0.004 (0.19)	0.001*** (0.00)	0.003* (0.08)	0.003*** (0.00)	0.003*** (0.00)	0.002*** (0.00)
ARCH(-1)	0.27*** (0.00)	0.27*** (0.00)	0.29*** (0.00)	0.42*** (0.00)	0.41*** (0.00)	0.33*** (0.00)	0.21*** (0.00)	0.21*** (0.00)	0.15*** (0.00)
GARCH(-1)	0.63*** (0.00)	0.63** (0.00)	0.58*** (0.00)	0.50*** (0.00)	0.49*** (0.00)	0.59*** (0.00)	0.71*** (0.00)	0.71*** (0.00)	0.79*** (0.00)
					Model Information				
OBS	385	385	385	385	385	385	385	385	385
ADJ R^2	0.30	0.29	0.32	0.12	0.12	0.19	0.08	0.08	0.10
AIC	– 0.73	– 0.72	– 0.82	– 0.70	– 0.70	– 0.72	– 0.64	– 0.64	– 0.62
					Diagnostic Tests				
ARCH LM	0.51	0.54	0.53	0.72	0.69	0.50	1.12	1.18	0.73

(12 lags)	(0.91)	(0.89)	(0.90)	(0.73)	(0.76)	(0.92)	(0.34)	(0.30)	(0.72)
DW Stat	1.95	1.96	2.11	2.19	2.18	2.08	2.05	2.05	1.99
JQB	365.32*** (0.00)	463.74*** (0.00)	277.28*** (0.00)	2.92 (0.23)	3.28 (0.19)	1.08 (0.58)	6.36** (0.04)	6.19** (0.04)	2.06 (0.36)

Note: All variables are in first difference, *p*-values are in parenthesis. ***, **, and * imply statistical significance at the 1 percent, 5 percent, and 10 percent level, respectively. Models with ΔSWAP2Y include a linear time trend, as the 2-year swap yield exhibits linearly increasing conditional variances.

In the extended model, the coefficient for the percentage change in the GBP spot exchange is also statistically significant at the 1 percent level. It is positively correlated with the swap yield. This indicates that an appreciation of the GBP leads to a higher interbank swap yield, after controlling for other variables in the models.[2]

The increase (decrease) in core inflation is associated with an increase (decrease) in the swap yield, but it is not statistically significant. Likewise, an increase (decrease) in the growth of industrial production has a positive (negative) effect on the swap yield, but it is also not statistically significant.

In the extended model, the coefficient for the percent change in the FTSE equity index has a negative sign. It is statistically significant in the model for the 2-year swap yield but not so for the 5-year and 10-year swap yields.

The adjusted R^2 and the Akaike information criteria (AIC) for the simple models are not markedly different from the basic and extended models. This gives credence to the notion that the change in the short-term interest rate rules the roost. The consistency of similar results in all three sets of models evinces that the change in the short-term interest rate is the main driver of the change in the swap yield.

The ARCH and GARCH terms in the variance equation are positive and statistically significant in all the models. The ARCH and GARCH coefficients in the variance equation summed up to be 0.88 or above. This indicates the persistence of volatility in the errors. In other words, the process mean reverts very slowly (Engle 2001).

[2] However, it must be said that during the sterling crisis of 2022, when both the short-term interest rate and the long-term gilt yield rose while the GBP depreciated, the swap yields rose (Luhnow, Thomas, and Colchester 2022). Clearly the effect of a higher short-term interest rate on the swap yield dominated over the GBP's deprecation.

Results from several postestimation diagnostic tests vindicate the modeling approach and the models' results. ARCH-LM tests (at 12 lags) on the three sets of models failed to reject the absence of the ARCH effect. This implies that the models correctly address the conditional heteroskedasticity. The results of additional ARCH-LM tests with different lags for the three sets of GARCH(1,1) models are provided in Table A1 in Appendix A. In most of these models, the results of the ARCH–LM tests fail to reject the absence of the ARCH effect. The Durbin–Watson statistic indicates there is no serial correlation in the error terms in these models. The correlograms of Q-statistics and the correlograms of squared residuals of the extended models are displayed in Appendix B. The correlograms of the Q-statistics show that the mean equations in these models are correctly specified and there are no remaining serial correlations. The correlograms of squared residuals display that there are no remaining ARCH effects in the variance equations. These findings elucidate that these models and the variance equations are correctly specified. The Jarque–Bera tests imply that errors in most of these models are normally distributed.

Several alternate specifications are also estimated to assess the robustness of the findings. Models with ΔCPI instead of ΔCORECPI, as a measure of the change in inflation, are used in the estimated model in Appendix C. The results are very similar to the ones in Table 5. Lastly, several alternative specifications based on higher-order GARCH, namely GARCH(1,2), GARCH(2,1), and GARCH(2,2), are estimated in Appendix D. The alternative specifications also show the strong and positive effect of the short-term interest rate on the long-term swap yield. This provides additional evidence that the change in the short-term interest rate affects the change in the long-term swap yield.

SECTION VI: CONCLUSION

The empirical results obtained here are relevant to both macroeconomic theory and policy. The findings show that an increase (decrease) in the short-term interest rate is associated with an increase (decrease) in the long-term swap yield, after controlling for various macroeconomic factors, such as the change in inflation, change in the growth of industrial production, percentage change in the equity index, and percentage change in the exchange rate. These findings imply that the Bank of England's (BoE) policy rate decisions exert a marked effect on the interest rate swap yield via the monthly change in the short-term interest rate. The effect is most pronounced in the middle of the swap yield curve, but it is also discernable in both the front and back end of the curve.

In the variance equations, both the ARCH and GARCH terms are positive and significant. The positive and statistically significant ARCH coefficient implies that a volatility shock in the current month feeds into the next month's volatility. The positive and statistically significant GARCH coefficient indicates a large shock (either positive or negative) will lead to a large variance forecast for a long period of time.

This paper's findings corroborate Keynes's conjecture regarding the importance of the central bank's influence on the long-term interest rate via the short-term interest rate. This paper shows that the BoE's influence on the long-term interest rate is not just confined to the gilt-edged Treasury bond's yield but also extends to the long-term swap yield across the swap yield curve. These findings are aligned with similar empirical patterns observed in recent research on the dynamics of the long-term interest rate swap yield denominated in US dollars and other currencies.

The key policy implication of the findings discussed here is that the BoE exerts enormous influence on financial markets. The influence of the BoE's policy rate decisions is not just confined to the short-term interest rate and the long-term gilts yield, but also extends to the long-term swap yield. However, the question of whether the BoE should or should not use its ability to influence the change in the swap yield is separate from its operational ability to do so. That depends on the BoE's goals, targets, legal and political mandates, and the financial, economic, and social consequences of its policy rate decisions on the complex of interest rates, including long-term gilts yields and swap yields.

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APPENDIX A: ARCH–LM TEST AFTER GARCH(1,1)

Table A1. ARCH–LM Test after GARCH(1,1)

Models	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP10Y
Panel One			
Lags	**Simple Models**		
1	1.43 (0.23)	4.45 (0.03)	8.27 (0.00)
4	1.05 (0.38)	1.45 (0.21)	2.50 (0.04)
8	0.64 (0.75)	1.01 (0.43)	1.53 (0.14)
12	0.51 (0.91)	0.72 (0.73)	1.12 (0.34)
Panel Two			
Lags	**Basic Models**		
1	1.91 (0.17)	4.75 (0.03)	8.50 (0.00)
4	1.14 (0.33)	1.52 (0.20)	2.59 (0.03)
8	0.67 (0.72)	0.96 (0.47)	1.61 (0.12)
12	0.54 (0.89)	0.69 (0.76)	1.18 (0.30)
Panel Three			
Lags	**Extended Models**		
1	0.61 (0.44)	3.61 (0.06)	4.96 (0.03)
4	0.90 (0.46)	1.24 (0.29)	1.51 (0.20)
8	0.75 (0.65)	0.70 (0.69)	1.01 (0.43)
12	0.53 (0.90)	0.50 (0.92)	0.73 (0.72)

Note: GARCH(1,1) model includes the change in the short-term interest rate (ΔLIBOR3M) in panel one. The controls (ΔCORECPI, ΔIP) are added in panel two and (ΔCORECPI, ΔIP, ΔLNFTSE100, ΔLNGBP) are added in panel three. All panels also include an AR(1) term; *p*-values are in parenthesis.

APPENDIX B: CORRELOGRAMS FOR THE EXTENDED MODEL

Figure B1. GARCH(1,1) Extended Model: ΔSWAP2Y Correlogram of Standardized Residuals (Q-Statistics)

Sample (adjusted): 1990M03 2022M03
Q-statistic probabilities adjusted for 1 ARMA term

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.038	0.038	0.5728	
		2	-0.064	-0.066	2.1757	0.140
		3	0.043	0.048	2.8881	0.236
		4	0.089	0.081	5.9697	0.113
		5	0.055	0.055	7.1561	0.128
		6	-0.094	-0.091	10.666	0.058
		7	-0.050	-0.045	11.646	0.070
		8	0.036	0.017	12.146	0.096
		9	0.036	0.029	12.659	0.124
		10	-0.056	-0.040	13.908	0.126
		11	-0.011	0.011	13.956	0.175
		12	0.007	-0.009	13.975	0.234
		13	-0.003	-0.015	13.979	0.302
		14	0.017	0.024	14.092	0.367
		15	-0.038	-0.028	14.671	0.401
		16	-0.066	-0.068	16.408	0.355
		17	-0.043	-0.049	17.150	0.376
		18	-0.001	-0.002	17.150	0.444
		19	0.021	0.029	17.335	0.500
		20	-0.047	-0.031	18.230	0.507
		21	-0.145	-0.134	26.783	0.141
		22	0.021	0.014	26.966	0.172
		23	0.022	-0.008	27.157	0.205
		24	0.010	0.034	27.200	0.248
		25	-0.061	-0.035	28.738	0.230
		26	0.031	0.040	29.137	0.258
		27	0.065	0.020	30.877	0.233
		28	0.009	0.002	30.909	0.275
		29	0.036	0.059	31.441	0.298
		30	-0.033	-0.034	31.903	0.324
		31	0.009	-0.021	31.938	0.370
		32	-0.034	-0.054	32.430	0.396
		33	-0.044	-0.039	33.236	0.407
		34	0.037	0.047	33.829	0.427
		35	0.046	0.056	34.725	0.433
		36	-0.033	-0.041	35.201	0.459

*Probabilities may not be valid for this equation specification.

Figure B2. GARCH(1,1) Extended Model: ΔSWAP5Y Correlogram of Standardized Residuals (Q-Statistics)

Sample (adjusted): 1990M03 2022M03
Q-statistic probabilities adjusted for 1 ARMA term

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.043	0.043	0.7074	
		2	-0.097	-0.099	4.4018	0.036
		3	0.013	0.022	4.4641	0.107
		4	0.058	0.047	5.7819	0.123
		5	-0.005	-0.006	5.7901	0.215
		6	-0.131	-0.122	12.501	0.029
		7	-0.009	0.000	12.535	0.051
		8	-0.060	-0.088	13.954	0.052
		9	-0.054	-0.045	15.115	0.057
		10	0.024	0.028	15.350	0.082
		11	0.064	0.057	17.000	0.074
		12	0.010	0.002	17.041	0.107
		13	-0.005	0.009	17.050	0.148
		14	-0.002	-0.025	17.052	0.197
		15	0.034	0.016	17.515	0.230
		16	-0.049	-0.056	18.472	0.239
		17	-0.088	-0.073	21.604	0.156
		18	0.047	0.051	22.501	0.166
		19	-0.011	-0.019	22.549	0.209
		20	-0.002	0.019	22.550	0.258
		21	-0.136	-0.136	30.127	0.068
		22	0.030	0.024	30.495	0.082
		23	0.111	0.068	35.560	0.034
		24	0.005	0.012	35.568	0.046
		25	-0.036	-0.032	36.102	0.054
		26	-0.005	-0.003	36.114	0.070
		27	-0.002	-0.041	36.117	0.090
		28	-0.010	0.002	36.159	0.112
		29	-0.012	-0.014	36.223	0.137
		30	0.009	0.006	36.254	0.166
		31	-0.010	0.003	36.300	0.198
		32	-0.096	-0.077	40.192	0.125
		33	-0.006	-0.025	40.208	0.151
		34	0.073	0.048	42.493	0.125
		35	0.026	0.018	42.772	0.144
		36	-0.009	0.010	42.808	0.171

*Probabilities may not be valid for this equation specification.

Figure B3. GARCH(1,1) Extended Model: ΔSWAP10Y Correlogram of Standardized Residuals (Q-Statistics)

Sample (adjusted): 1990M03 2022M03
Q-statistic probabilities adjusted for 1 ARMA term

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.034	0.034	0.4582	
		2	-0.088	-0.090	3.4896	0.062
		3	-0.012	-0.006	3.5483	0.170
		4	0.039	0.032	4.1370	0.247
		5	0.001	-0.003	4.1379	0.388
		6	-0.113	-0.108	9.1495	0.103
		7	-0.054	-0.047	10.311	0.112
		8	-0.032	-0.050	10.724	0.151
		9	-0.056	-0.066	11.981	0.152
		10	0.035	0.038	12.468	0.188
		11	0.081	0.072	15.060	0.130
		12	0.027	0.018	15.349	0.167
		13	0.022	0.028	15.545	0.213
		14	-0.015	-0.025	15.637	0.269
		15	0.031	0.014	16.019	0.312
		16	-0.046	-0.054	16.871	0.327
		17	-0.067	-0.049	18.681	0.286
		18	0.032	0.043	19.109	0.322
		19	-0.006	-0.002	19.123	0.384
		20	-0.080	-0.067	21.766	0.296
		21	-0.048	-0.040	22.721	0.303
		22	0.020	-0.007	22.886	0.350
		23	0.078	0.047	25.381	0.279
		24	-0.022	-0.023	25.581	0.321
		25	0.006	0.017	25.597	0.374
		26	-0.047	-0.073	26.531	0.380
		27	-0.034	-0.039	27.021	0.408
		28	0.017	0.007	27.145	0.456
		29	-0.041	-0.048	27.837	0.473
		30	0.000	0.010	27.837	0.527
		31	-0.055	-0.044	29.097	0.512
		32	-0.055	-0.052	30.380	0.498
		33	0.062	0.040	32.031	0.465
		34	-0.014	-0.044	32.120	0.511
		35	0.042	0.044	32.887	0.522
		36	0.023	0.009	33.108	0.560

*Probabilities may not be valid for this equation specification.

Figure B4. GARCH(1,1) Extended Model: ∆SWAP2Y Correlogram of Standardized Residuals Squared (Q-Statistics)

Sample (adjusted): 1990M03 2022M03
Included observations: 385 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.040	0.040	0.6173	0.432
		2	-0.027	-0.029	0.9076	0.635
		3	-0.043	-0.040	1.6176	0.655
		4	0.069	0.072	3.4762	0.482
		5	-0.057	-0.066	4.7517	0.447
		6	-0.001	0.006	4.7523	0.576
		7	0.015	0.018	4.8413	0.679
		8	-0.024	-0.036	5.0648	0.751
		9	-0.023	-0.010	5.2699	0.810
		10	0.007	0.005	5.2918	0.871
		11	-0.026	-0.033	5.5683	0.901
		12	0.015	0.023	5.6560	0.932
		13	-0.018	-0.022	5.7869	0.954
		14	-0.028	-0.032	6.1080	0.964
		15	-0.028	-0.018	6.4230	0.972
		16	-0.028	-0.037	6.7481	0.978
		17	0.012	0.015	6.8081	0.986
		18	-0.017	-0.019	6.9196	0.991
		19	0.018	0.015	7.0576	0.994
		20	0.023	0.025	7.2758	0.996
		21	0.006	-0.002	7.2913	0.997
		22	-0.053	-0.049	8.4264	0.996
		23	-0.039	-0.037	9.0397	0.996
		24	-0.019	-0.025	9.1868	0.997
		25	-0.027	-0.030	9.4806	0.998
		26	-0.042	-0.039	10.208	0.998
		27	0.017	0.013	10.326	0.998
		28	-0.006	-0.012	10.340	0.999
		29	-0.020	-0.023	10.509	0.999
		30	-0.002	0.001	10.510	1.000
		31	-0.020	-0.035	10.673	1.000
		32	-0.010	-0.010	10.717	1.000
		33	-0.005	-0.005	10.725	1.000
		34	-0.052	-0.064	11.888	1.000
		35	0.029	0.038	12.235	1.000
		36	-0.036	-0.050	12.782	1.000

*Probabilities may not be valid for this equation specification.

Figure B5. GARCH(1,1) Extended Model: ΔSWAP5Y Correlogram of Standardized Residuals Squared (Q-Statistics)

Sample (adjusted): 1990M03 2022M03
Included observations: 385 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.097	0.097	3.6297	0.057
		2	-0.040	-0.049	4.2402	0.120
		3	0.013	0.022	4.3015	0.231
		4	-0.020	-0.026	4.4645	0.347
		5	-0.047	-0.041	5.3180	0.378
		6	0.007	0.014	5.3362	0.501
		7	0.009	0.003	5.3662	0.615
		8	0.004	0.005	5.3741	0.717
		9	0.021	0.018	5.5440	0.785
		10	-0.020	-0.026	5.7055	0.839
		11	-0.004	0.003	5.7136	0.892
		12	0.016	0.015	5.8221	0.925
		13	-0.030	-0.032	6.1738	0.940
		14	0.026	0.035	6.4461	0.954
		15	-0.018	-0.030	6.5700	0.969
		16	0.063	0.074	8.1647	0.944
		17	0.046	0.030	9.0238	0.940
		18	-0.021	-0.025	9.2012	0.955
		19	0.002	0.012	9.2025	0.970
		20	0.001	-0.005	9.2029	0.980
		21	0.119	0.131	15.032	0.821
		22	0.053	0.031	16.177	0.807
		23	-0.046	-0.052	17.053	0.807
		24	0.013	0.027	17.123	0.843
		25	-0.028	-0.039	17.452	0.865
		26	0.026	0.052	17.728	0.885
		27	0.050	0.047	18.758	0.879
		28	0.034	0.014	19.235	0.891
		29	-0.048	-0.045	20.181	0.887
		30	-0.042	-0.044	20.917	0.890
		31	-0.010	0.004	20.958	0.913
		32	-0.040	-0.032	21.642	0.917
		33	-0.006	-0.015	21.660	0.935
		34	-0.004	-0.001	21.666	0.950
		35	-0.027	-0.040	21.981	0.958
		36	0.066	0.076	23.827	0.940

*Probabilities may not be valid for this equation specification.

Figure B6. GARCH(1,1) Extended Model: ΔSWAP10Y Correlogram of Standardized Residuals Squared (Q-Statistics)

Sample (adjusted): 1990M03 2022M03
Included observations: 385 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.113	0.113	4.9625	0.026
		2	-0.025	-0.038	5.2096	0.074
		3	-0.008	-0.000	5.2329	0.156
		4	-0.033	-0.034	5.6620	0.226
		5	-0.040	-0.033	6.2903	0.279
		6	-0.054	-0.048	7.4234	0.283
		7	0.017	0.026	7.5307	0.376
		8	-0.034	-0.044	7.9869	0.435
		9	-0.015	-0.007	8.0723	0.527
		10	0.019	0.015	8.2131	0.608
		11	0.044	0.038	8.9735	0.624
		12	0.012	-0.000	9.0292	0.700
		13	0.029	0.030	9.3672	0.745
		14	0.007	-0.004	9.3847	0.806
		15	-0.084	-0.080	12.222	0.662
		16	-0.071	-0.050	14.249	0.580
		17	-0.009	0.004	14.280	0.647
		18	0.034	0.033	14.755	0.679
		19	-0.035	-0.043	15.247	0.707
		20	0.058	0.063	16.616	0.678
		21	0.068	0.042	18.484	0.618
		22	-0.026	-0.038	18.771	0.659
		23	-0.046	-0.042	19.643	0.663
		24	0.032	0.039	20.076	0.692
		25	0.050	0.041	21.101	0.687
		26	0.044	0.055	21.892	0.695
		27	-0.035	-0.043	22.402	0.717
		28	-0.020	-0.007	22.576	0.754
		29	-0.031	-0.022	22.983	0.777
		30	-0.048	-0.039	23.937	0.775
		31	-0.056	-0.069	25.275	0.755
		32	0.082	0.095	28.116	0.664
		33	0.043	0.024	28.898	0.672
		34	0.054	0.052	30.116	0.659
		35	-0.048	-0.071	31.086	0.658
		36	0.056	0.087	32.409	0.640

*Probabilities may not be valid for this equation specification.

APPENDIX C: GARCH(1,1) MODEL WITH ΔCPI

Table C1. GARCH(1,1) Model (with ΔCPI)

	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP10Y	ΔSWAP10Y
Mean Equation									
Intercept	–0.01 (0.38)	–0.008 (0.55)	–0.002 (0.80)	–0.02 (0.15)	–0.02 (0.12)	–0.01 (0.17)	–0.02 (0.10)	–0.02 (0.09)	–0.02* (0.09)
ΔLIBOR3M	0.24*** (0.00)	0.22*** (0.00)	0.37*** (0.00)	0.39*** (0.00)	0.39*** (0.00)	0.34*** (0.00)	0.19*** (0.00)	0.19*** (0.00)	0.12*** (0.00)
ΔCPI		0.04 (0.01)	0.04*** (0.00)		0.03 (0.18)	0.04 (0.13)		0.04 (0.17)	0.05* (0.09)
ΔIP		0.00 (0.79)	0.002 (0.21)		0.001 (0.73)	0.001 (0.84)		0.001 (0.75)	0.001 (0.84)
ΔLNFTSE100			–0.48*** (0.00)			–0.11 (0.48)			–0.03 (0.85)
ΔLNGBP			1.83*** (0.00)			1.35*** (0.00)			1.50*** (0.00)
AR(1)	0.37*** (0.00)	0.38*** (0.00)	0.34*** (0.00)	0.35*** (0.00)	0.34*** (0.00)	0.33*** (0.00)	0.26*** (0.00)	0.25*** (0.00)	0.23*** (0.00)
Variance Equation									
Intercept	0.01** (0.02)	0.01 (0.02)	0.01** (0.03)	0.004 (0.19)	0.005*** (0.00)	0.004*** (0.00)	0.003*** (0.00)	0.003*** (0.00)	0.002*** (0.00)
ARCH(-1)	0.27*** (0.00)	0.26*** (0.00)	0.34*** (0.00)	0.42*** (0.00)	0.42*** (0.00)	0.35*** (0.00)	0.21*** (0.00)	0.22*** (0.00)	0.16*** (0.00)
GARCH(-1)	0.63*** (0.00)	0.62** (0.00)	0.55*** (0.00)	0.50*** (0.00)	0.48*** (0.00)	0.56*** (0.00)	0.71*** (0.00)	0.70*** (0.00)	0.78*** (0.00)
Model Information									
Obs	385	385	385	385	385	385	385	385	385
ADJ R^2	0.30	0.29	0.30	0.11	0.12	0.19	0.08	0.08	0.11
AIC	– 0.73	– 0.73	– 0.83	– 0.70	– 0.70	– 0.72	– 0.64	– 0.64	– 0.66
Diagnostic Tests									
ARCH LM (12 lags)	0.51 (0.91)	0.57 (0.87)	0.49 (0.92)	0.72 (0.73)	0.68 (0.77)	0.49 (0.92)	1.12 (0.34)	1.13 (0.33)	0.71 (0.74)
DW Stat	1.95	1.96	2.18	2.19	2.18	2.09	2.05	2.05	1.99
JQB	365.32*** (0.00)	420.43*** (0.00)	298.10*** (0.00)	2.92 (0.23)	3.54 (0.17)	1.02 (0.60)	6.36** (0.04)	8.00** (0.02)	2.43 (0.30)

Note: All variables are in first difference, *p*-values are in parenthesis. ***, **, and * imply statistical significance at the 1 percent, 5 percent, and 10 percent levels, respectively. Models with ΔSWAP2Y include a linear time trend, as the 2-year swap yield exhibits linearly increasing conditional variances.

APPENDIX D: ADDITIONAL GARCH(p,q) MODELS

Table D1. GARCH(1,2) Model

	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP10Y	ΔSWAP10Y
					Mean Equation				
Intercept	–0.01 (0.43)	–0.01 (0.49)	–0.005 (0.59)	–0.02 (0.15)	–0.02 (0.14)	–0.01 (0.19)	–0.02* (0.08)	–0.02* (0.07)	–0.02 (0.10)
ΔLIBOR3M	0.24*** (0.00)	0.23*** (0.00)	0.35*** (0.00)	0.39*** (0.00)	0.39*** (0.00)	0.32*** (0.00)	0.19*** (0.00)	0.19*** (0.00)	0.13*** (0.00)
ΔCORECPI		0.02 (0.14)	0.02* (0.06)		0.02 (0.47)	0.02 (0.50)		0.04 (0.22)	0.04 (0.18)
ΔIP		0.001 (0.70)	0.002 (0.30)		0.001 (0.69)	0.001 (0.71)		0.002 (0.65)	0.001 (0.72)
ΔLNFTSE100			–0.39*** (0.00)			–0.14 (0.44)			–0.06 (0.78)
ΔLNGBP			1.82*** (0.00)			1.47*** (0.00)			1.41*** (0.00)
AR(1)	0.37*** (0.00)	0.38*** (0.00)	0.33*** (0.00)	0.35*** (0.00)	0.35*** (0.00)	0.34*** (0.00)	0.26*** (0.00)	0.25*** (0.00)	0.23*** (0.00)
					Variance Equation				
Intercept	0.01** (0.04)	0.01** (0.03)	0.006* (0.05)	0.004 (0.19)	0.005*** (0.00)	0.003** (0.01)	0.003*** (0.00)	0.003*** (0.00)	0.002** (0.01)
ARCH(-1)	0.30*** (0.00)	0.30*** (0.00)	0.55*** (0.00)	0.42*** (0.00)	0.41*** (0.00)	0.36*** (0.00)	0.24*** (0.00)	0.24*** (0.00)	0.20*** (0.00)
GARCH(-1)	0.40* (0.09)	0.36 (0.16)	0.47*** (0.00)	0.49*** (0.01)	0.49** (0.01)	0.31 (0.10)	0.36 (0.15)	0.32 (0.19)	0.27 (0.26)
GARCH(-2)	0.16 (0.40)	0.18 (0.37)	0.07 (0.51)	0.001 (0.99)	0.002 (0.99)	0.26 (0.10)	0.30*** (0.15)	0.33 (0.11)	0.45** (0.04)
					Model Information				
Obs	385	385	385	385	385	385	385	385	385
Adj R^2	0.30	0.29	0.31	0.12	0.12	0.20	0.08	0.08	0.11
AIC	– 0.73	– 0.72	– 0.82	– 0.70	– 0.69	– 0.71	– 0.64	– 0.64	– 0.66
					Diagnostic Tests				
ARCH LM (12 lags)	0.49 (0.92)	0.51 (0.91)	0.51 (0.91)	0.72 (0.74)	0.68 (0.77)	0.27 (0.99)	0.78 (0.67)	0.82 (0.63)	0.53 (0.90)
DW Stat	1.96	1.97	2.12	2.19	2.18	2.07	2.05	2.04	1.99
JQB	578.40*** (0.00)	304.12*** (0.00)	323.57*** (0.00)	2.89 (0.23)	3.26 (0.19)	0.89 (0.64)	4.78* (0.09)	4.44 (0.11)	1.83 (0.30)

Note: All variables are in first difference, *p*-values are in parenthesis. ***, **, and * imply statistical significance at the 1 percent, 5 percent, and 10 percent levels, respectively. Models with ΔSWAP2Y include a linear time trend, as the 2-year swap yield exhibits linearly increasing conditional variances.

Table D2. GARCH(2,1) Model

	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP10Y	ΔSWAP10Y
Mean Equation									
Intercept	–0.01 (0.44)	–0.01 (0.52)	–0.004 (0.61)	–0.02 (0.15)	–0.02 (0.14)	–0.01 (0.20)	–0.02* (0.06)	–0.02* (0.08)	–0.02* (0.05)
ΔLIBOR3M	0.25*** (0.00)	0.24*** (0.00)	0.35*** (0.00)	0.39*** (0.00)	0.39*** (0.00)	0.32*** (0.00)	0.19*** (0.00)	0.19*** (0.00)	0.18*** (0.00)
ΔCORECPI		0.02 (0.13)	0.02** (0.04)		0.02 (0.47)	0.02 (0.49)		0.05* (0.07)	0.05* (0.06)
ΔIP		0.001 (0.72)	0.002 (0.29)		0.001 (0.69)	0.001 (0.73)		0.002 (0.52)	0.002 (0.61)
ΔLNFTSE100			–0.39*** (0.00)			–0.11 (0.53)			0.11 (0.55)
ΔLNGBP			1.82*** (0.00)			1.45*** (0.00)			1.40*** (0.00)
AR(1)	0.38*** (0.00)	0.38*** (0.00)	0.33*** (0.00)	0.35*** (0.00)	0.35*** (0.00)	0.33*** (0.00)	0.25*** (0.00)	0.28*** (0.00)	0.26*** (0.00)
Variance Equation									
Intercept	0.01** (0.04)	0.01* (0.06)	0.005* (0.06)	0.004** (0.01)	0.005** (0.01)	0.002** (0.02)	0.002** (0.02)	0.003*** (0.00)	0.003*** (0.00)
ARCH(-1)	0.32*** (0.00)	0.32*** (0.00)	0.53*** (0.00)	0.42*** (0.00)	0.41*** (0.00)	0.35*** (0.00)	0.25*** (0.00)	0.26*** (0.00)	0.25*** (0.00)
ARCH(-2)	–0.09 (0.34)	–0.11 (0.29)	–0.04 (0.71)	–0.001 (0.99)	–0.001 (0.99)	–0.10 (0.33)	–0.13 (0.10)	–0.26*** (0.00)	–0.25*** (0.00)
GARCH(-1)	0.66*** (0.00)	0.67** (0.00)	0.59*** (0.00)	0.50*** (0.00)	0.49*** (0.00)	0.69*** (0.00)	0.82*** (0.00)	0.99*** (0.00)	0.98*** (0.00)
Model Information									
Obs	385	385	385	385	385	385	385	385	385
Adj R^2	0.30	0.29	0.31	0.12	0.12	0.20	0.08	0.08	0.09
AIC	– 0.73	– 0.72	– 0.82	– 0.70	– 0.69	– 0.71	– 0.64	– 0.67	– 0.70
Diagnostic Tests									
ARCH LM (12 lags)	0.51 (0.91)	0.52 (0.90)	0.52 (0.90)	0.72 (0.73)	0.68 (0.77)	0.33 (0.98)	0.66 (0.79)	0.75 (0.70)	0.53 (0.89)
DW Stat	1.97	1.98	2.12	2.19	2.18	2.06	2.03	2.10	2.07
JQB	581.68 (0.00)	506.66 (0.00)	303.86 (0.00)	2.90 (0.21)	3.26 (0.19)	0.80 (0.67)	4.23 (0.12)	2.52 (0.28)	2.24 (0.32)

Note: All variables are in difference, *p*-values are in parenthesis. ***, **, and * imply statistical significance at the 1 percent, 5 percent, and 10 percent levels, respectively. Models with ΔSWAP2Y include a linear time trend, as the 2-year swap yield exhibits linearly increasing conditional variances.

Table D3. GARCH(2,2) Model

	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP10Y	ΔSWAP10Y
Mean Equation									
Intercept	–0.01 (0.46)	–0.01 (0.52)	–0.004 (0.62)	–0.02 (0.14)	–0.02 (0.14)	–0.01 (0.19)	–0.02 (0.10)	–0.02* (0.08)	–0.02* (0.05)
ΔLIBOR3M	0.25*** (0.00)	0.24*** (0.00)	0.30*** (0.00)	0.39*** (0.00)	0.39*** (0.00)	0.32*** (0.00)	0.11*** (0.00)	0.11*** (0.00)	0.19*** (0.00)
ΔCORECPI		0.02 (0.13)	0.02 (0.12)		0.02 (0.48)	0.02 (0.51)		0.03 (0.22)	0.05* (0.06)
ΔIP		0.001 (0.71)	0.002 (0.14)		0.001 (0.68)	0.001 (0.71)		0.002 (0.69)	0.002 (0.59)
ΔLNFTSE100			–0.33*** (0.00)			–0.14 (0.47)			0.10 (0.59)
ΔLNGBP			1.81*** (0.00)			1.47*** (0.00)			1.42*** (0.00)
AR(1)	0.38*** (0.00)	0.39*** (0.00)	0.34*** (0.00)	0.35*** (0.00)	0.35*** (0.00)	0.34*** (0.00)	0.33*** (0.00)	0.33*** (0.00)	0.26*** (0.00)
Variance Equation									
Intercept	0.01 (0.41)	0.01 (0.36)	0.002** (0.03)	0.006 (0.56)	0.01 (0.52)	0.003 (0.14)	0.002** (0.01)	0.003** (0.01)	0.004*** (0.00)
ARCH(-1)	0.32*** (0.00)	0.32*** (0.00)	0.34*** (0.00)	0.43*** (0.00)	0.42*** (0.00)	0.36*** (0.00)	0.25*** (0.00)	0.24*** (0.00)	0.25*** (0.00)
ARCH(-2)	0.07 (0.81)	–0.08 (0.74)	–0.14 (0.22)	0.11 (0.89)	0.12 (0.88)	–0.01 (0.98)	–0.27*** (0.00)	–0.27*** (0.00)	–0.25*** (0.00)
GARCH(-1)	0.54 (0.54)	0.51 (0.51)	1.26*** (0.00)	0.16 (0.94)	0.14 (0.94)	0.32 (0.60)	1.38*** (0.00)	1.32*** (0.00)	0.93*** (0.00)
GARCH(-2)	0.08 (0.86)	0.10 (0.80)	–0.43*** (0.00)	0.18 (0.86)	0.18 (0.84)	0.26 (0.51)	–0.37** (0.02)	–0.31* (0.08)	0.05 (0.77)
Model Information									
Obs	385	385	385	385	385	385	385	385	385
Adj R^2	0.30	0.29	0.32	0.11	0.12	0.20	0.09	0.09	0.09
AIC	– 0.72	– 0.72	– 0.82	– 0.69	– 0.69	– 0.71	– 0.69	– 0.68	– 0.64
Diagnostic Tests									
ARCH LM (12 lags)	0.49 (0.92)	0.51 (0.90)	0.61 (0.83)	0.62 (0.82)	0.58 (0.86)	0.27 (0.99)	0.82 (0.63)	0.20 (0.90)	0.55 (0.88)
DW Stat	1.97	1.98	2.05	2.19	2.18	2.07	2.11	2.11	2.08
JQB	596.85 (0.00)	520.81 (0.00)	267.83 (0.00)	2.66 (0.26)	2.96 (0.23)	0.89 (0.64)	0.06 (0.97)	6.19 (0.04)	2.29 (0.32)

Note: All variables are in first difference, *p*-values are in parenthesis. ***, **, and * imply statistical significance at the 1 percent, 5 percent, and 10 percent levels, respectively. Models with ΔSWAP2Y include a linear time trend, as the 2-year short-term swap yield exhibits linearly increasing conditional variances.