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Euro Interest Rate Swap Yields: A GARCH Analysis

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The dataset is available for replication: The dataset used in the empirical part of this paper is available upon request to *bona fide* researchers for the replication and verification of the results.
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ABSTRACT

This paper models the month-over-month change in euro-denominated (EUR) long-term interest rate swap yields. It shows that the change in the short-term interest rate has an economically and statistically significant effect on the change in EUR swap yields of different maturity tenors, after controlling for various macroeconomic and financial variables, such as the month-over-month change in inflation or core inflation and the growth of industrial production, and the percentage change in the equity price index, the exchange rate, and the size of the European Central Bank's (ECB) balance sheet. It uses a generalized autoregressive conditional heteroskedasticity (GARCH) approach to model the dynamics of the monthly change in EUR swap yields and their volatility. The results of the estimated models of EUR swap yields of different maturity tenors extend the Keynesian view that the central bank's monetary policy actions have a decisive influence on long-term government bond yields and long-term market interest rates, primarily through their effects on the current short-term interest rate.

KEYWORDS: Euro Swaps; Interest Rate Swaps; Short-Term Interest Rate; Monetary Policy; European Central Bank (ECB); Generalized Autoregressive Conditional Heteroskedasticity (GARCH)

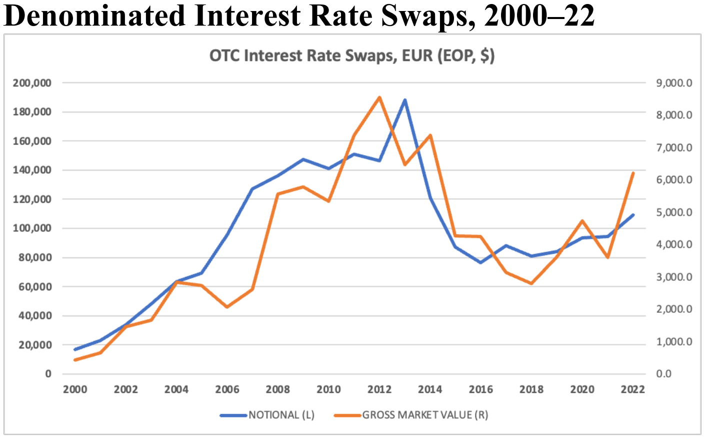
JEL CLASSIFICATIONS: E43; E50; E60; G10; G12

SECTION I: INTRODUCTION

Euro-denominated (EUR) interest rate swaps play a substantial role in global financial markets. Figure 1, below, shows the evolution of the gross market value and notional value of outstanding over-the-counter (OTC) EUR interest rate swaps. As of 2022, the gross market value of EUR swaps was $6.2 trillion, according to the Bank for International Settlements (2023); the notional value was $109.4 trillion during the same period. EUR swaps constitute about 27 percent by gross market value and 47 percent by notional value of total outstanding interest rate swaps in all currencies.

Remolana and Wooldridge (2003) provide background information about the emergence and evolution of the EUR swap market, which they describe as "one of the largest and most liquid financial markets." The growth of the EUR swap market has been driven by both hedging and speculative positioning activity. They argue that, in the euro zone, the government bond market's fragmented characteristics and financial market shocks in the late 1990s have prompted investors to shift to EUR swaps in lieu of government securities. There is a wide range of participants in the EUR swaps market and a recent study (Fontana et al. 2019) brings out some of its more interesting features, such as that: (1) the EUR swap market is highly standardized, (2) it is concentrated around a group of major dealers, but there are also some core intermediaries and central counterparties, (3) banks are involved in all segments of the swap market, while non-banks tend to be active in niche specialization, and (4) there is considerable variation in transaction prices.

Figure 1: The Gross Market Value and Notional Market Value of Outstanding Euro-Denominated Interest Rate Swaps, 2000–22



This paper econometrically models EUR long-term interest rate swap yields based on fundamental macroeconomic and financial variables. It shows that the change in the short-term interest rate has an economically and statistically significant effect on the change in EUR swap yields of different maturity tenors, after controlling for various macroeconomic and financial variables. EUR swaps have a consequential role in global and European financial markets, but there has not been any previous attempt to model their yields from a Keynesian vantage point.

John Maynard Keynes (1930) claimed that the central bank's monetary policy actions have a decisive role in setting the long-term government bond yield through the short-term interest rate. Econometric models of the dynamics of EUR swap yields from a Keynesian perspective can illuminate the following issues: (1) the role and effectiveness of the European Central Bank's (ECB) monetary policy, its transmission mechanism, and the effects of monetary policy on market interest rates; (2) the effects of overall macroeconomic and financial conditions on swap yields; and (3) the relationship between the short-term interest rate and the long-term market swap yield. The economic modeling of the long-term swap yield as a function of the short-term interest rate, after controlling for relevant macroeconomic and financial factors, can also help evaluate whether Keynes's (1930) assertion that the central bank exerts influence on the long-term interest rate extends to OTC derivatives, such as EUR swaps.

This paper is a continuation of a larger project to determine the relationship between currency swap yields and short-term target interest rates. In this regard, Akram and Mamun (2023a, 2023b, 2023c, 2023d, 2023e, forthcoming) have shown that such relationships exist to various degrees for advanced Western countries (United States, United Kingdom), emerging countries (China, India, and Chile), and the advanced economy in Asia (Japan). The euro zone also presents an interesting case study, as the euro is a relatively newer currency. In addition, the currency operates in a geographic (but not political) union that has adopted a single currency. Thus, it is important to examine the Keynesian conjecture's relevance for a unique currency derivative.

The paper proceeds as follows. Section II reviews the relevant literature. Section III provides an overview of the evolution of EUR swap yields in the context of the euro zone's economic and financial conditions. Section IV describes the data; it also provides the results of unit root and stationary tests pertaining to the data. Section V presents the econometric models developed to investigate the dynamics of EUR swap yields. It reports and then interprets the findings. Section VI elaborates on the policy implications of these findings. Section VII summarizes and concludes.

SECTION II: A BRIEF REVIEW OF THE LITERATURE

The Keynesian perspective on interest rate dynamics has a distinguished pedigree. Kregel (2011) has shown that Keynes's (1930) assertion on the relationship between the short-term interest rate and long-term interest rate on gilt-edged securities (government bonds) was based on: (1) Riefler's (1930) statistical analysis of US interest rates in the 1920s and (2) his own shrewd observations of the behavior of interest rates in the UK during the same period.

In recent years, there has been a spate of studies demonstrating that Keynesian views are well grounded in the data. The key finding of the empirical analysis is that the long-term government bond yield is tethered to the short-term interest rate. Fullwiler (2006, [2008] 2017) holds that the Fed can always set its policy rate and, if needed, can directly target other interest rates. Atesoglu (2003–4) finds evidence of positive cointegration and pass-through from the fed funds rate to the prime rate, while his subsequent study (Atesoglu 2005) is based on a vector-error correction model that evinces a cointegration relation and unidirectional causality from the fed funds rate to the long-term interest rate. Payne (2006–7) reports that there is empirical support for the view that the causality runs from the fed funds rate to the fixed mortgage rate. This finding is also supported by Cook (2008), who shows that there is a substantial pass-through from the fed funds rate to the 30-year fixed mortgage rate in the US. Deleidi and Levrero (2020) report that the Fed's monetary policy affects various long-term market interest rates—such as the 10-year Treasury note yield and Moody's Aaa Corporate Bond Yield—and the Fed can also set the short-term policy rate. Akram and Li (2020a) evince that the short-term interest rate is the main driver of the long-term Treasury yield, while the rate of core inflation and the pace of economic activity also have an effect.

There are several studies on interest rate dynamics from a Keynesian perspective using data from countries and regions other than the US. These studies bear testimony to similar empirical regularities. Akram and Li (2020b) summarize Japan's interest rate dynamics in the past decades and show that the Bank of Japan's low policy rate, which led to a low current short-term interest rate, kept long-term Japanese government bond yields low. Simoski (2019) finds that, in some key Latin American countries—namely Brazil, Colombia, and Mexico—the current short-term interest rate is the primary driver of the long-term government bond yield. Vinod, Chakraborty, and Karun (2014) report that in India, monetary policy—along with inflation expectations and volatility in capital flows—affects the long-term interest rate, while the fiscal deficit has no discernible effects. Several multi-country studies have corroborated these patterns in other financial markets. Gabrisch (2021) provides evidence tying the short-term interest rate to the long-term interest rate in six financial markets. Kim (2020, 2021) has undertaken two panel-data studies demonstrating that, for countries with monetary sovereignty, the respective central bank's decisions affect the long-term interest rate, and are largely independent of government debt ratios and investors' sentiment.

Lavoie (2014, 186–88, 232–34) has rendered a useful summary of both the theoretical foundation of the Keynesian perspective on interest rate dynamics and the empirical research that assesses its scope. His survey of the empirical literature shows that the debate on the direction of causality has not been resolved. For example, Pollin (1991, 2008) has maintained that market forces, rather than the central bank's policy actions, drive market interest rates. Li and Su (2021) report that the relation between the short-term interest rate and the long-term interest rate is asymmetric: while the long-term interest rate non-linearly Granger causes the short-term interest rate, the short-term interest rate does not Granger cause the long-term interest rate, in most subsamples. However, they do find that in the UK and Japan, there is bidirectional Granger causality between the short-term interest rate and long-term interest rate. Rahimi, Lavoie, and Chu (2016) find evidence of bidirectional causality between the short-term interest rate and long-term interest rate. Moreover, in the most recent business cycles, they observe that the fed funds rate in the US and the overnight rate in Canada Granger cause the long-term interest rate significantly. Rahimi, Chu, and Lavoie (2017) apply a rolling window strategy to discern the bidirectional Granger causality between the fed funds rate and the 10-year Treasury yield in the

US. It should be noted that Granger causality tests merely reveal temporal precedence, while the underlying dynamics regarding the relationship between the short-term interest rate and long-term interest rate, after controlling for other factors, would have to be empirically modeled and theoretically analyzed. Akram (2021, 2023) has articulated some simple Keynesian models that link the long-term government bond yield to the short-term interest rate. These models are amenable to the empirical modeling of the dynamics of the long-term swap yield from a Keynesian perspective.

Whilst there is a voluminous and insightful literature on interest rate swaps, there has not been any specific study of EUR swap yields from a Keynesian perspective. Nevertheless, a brief look at the relevant literature on swaps is required both to acquaint ourselves with the existing literature and to highlight why an econometric investigation of the dynamics of the EUR swap yields from a Keynesian perspective is deemed necessary and may provide a perceptive analysis. Bicksler and Chen (1986), Chernenko and Faulkender (2011), Corb (2012), Cortes (2003), Kim and Koppenhaver (1993), Miron and Swanwell (1992), Ron (2000), Sadr (2009), Sawyer (2011), Smith Jr., Smithson, and Wakeman (1988), Visvanathan (1998), and Zhou (2002) have rendered valuable primers and studies on the applications and features of interest rate swaps in business and finance.

There are also several important studies that initiated the empirical modeling of swap yields and especially swap spreads, such as Duffie and Huang (1996), Duffie and Singleton (1997), and Lekkos and Milas (2001). However, these important pioneering studies of swap yields and swap spreads did not investigate the vital role of macroeconomic and financial factors on swap yields. Duffie and Huang (1996) connected swap yields to credit quality, while Duffie and Singleton (1997) modeled swap yields in terms of credit and liquidity factors. Consistent with this literature, Sun, Sundaresen, and Wang (1993) relate swap yields to swap dealers' credit ratings rather than to their macroeconomic underpinnings. Lekkos and Milas (2001) have examined the effect of government bond yields on swap spreads and found that swap spreads in the front end of the swap yield curve are procyclical, whereas those in the back end of the swap yield curve are countercyclical. Cortes (2003) explicates swap spreads in terms of government bond issues, the slope of the Treasury yield curve, risk and liquidity premiums, and mortgage repayment hedging but fails to consider the pivotal role of the central bank. Klingler and Sundaresan (2019) have analyzed swap yields and swap spreads in terms of the aggregated funding status of benefit plans. While these studies have yielded some valuable insights, the absence of macroeconomic and financial variables in their empirical analysis of swap yields, as well as the omission of the vital role of the central bank's monetary policy, are fatal and lamentable flaws in the literature.

Fortunately, quite recently, this gap in the empirical literature concerning the modeling of swap yields is gradually being redressed for swaps denominated in several hard currencies and a few emerging-market currencies. Akram and Mamun (2023a, 2023b, 2023c, 2023d, 2023e, forthcoming) have modeled swap yields in terms of macroeconomic and financial factors. They have specifically investigated the relationship between the current short-term interest rate and the long-term swap yield. These studies have examined the behavior of the yield of interest rate swaps denominated in the US dollar (USD), Japanese yen (JPY), British pound sterling (GBP), Chinese yuan (CNY), Indian rupee (INR), and Chilean peso (CLP). The current paper is part of the same nascent research program, extending the series to EUR swaps and European financial markets. While the results of these recent studies show that the short-term interest rate has a statistically significant and economically meaningful effect on the long-term swap yields in most financial markets, it is not definitive that this empirical regularity would always and necessarily hold in every financial market. Clearly, there is a need to refine and extend the nascent scholarship through the empirical modeling of swaps denominated in various other currencies used in financial markets. Thus, a study that econometrically models the behavior of EUR swaps is warranted.

SECTION III: THE MACROECONOMIC BACKDROP TO THE EVOLUTION OF EURO SWAP YIELDS

Before engaging in the statistical analysis of the data and econometrically modeling EUR swap yield dynamics, it is helpful to start with an overview of the macroeconomic and financial variables within the study period.

Figure 2, below, depicts the evolution of interest rate swaps during the study period. From the start of the study period in 2000 to mid-2005, swap yields generally trended down with a brief period of reversal between late 2001 and mid-2002. Between late 2002 and mid-2008, swap yields rose. During the global financial crisis, swap yields declined sharply from mid-2008 until mid-2009, rising again somewhere between mid-2010 and early 2011. But, with the onset of the European debt crisis, swap yields again declined markedly and continued on that trend with occasional reversals. During the period that the ECB pursued low, near-zero, and negative policy rates, swap yields declined sharply. Swap yields declined further and stayed low during the great lockdown associated with the start of the global pandemic. However, by late 2021, swap yields started rising in anticipation of higher policy rates and higher short-term interest rates. As the ECB raised its policy rates in 2022, swap yields surged markedly. By the end of the study period, swap yields were quite elevated in comparison to the preceding several years.

Figure 2: The Evolution of Interest Rate Swap Yields, 2000M01–2023M08

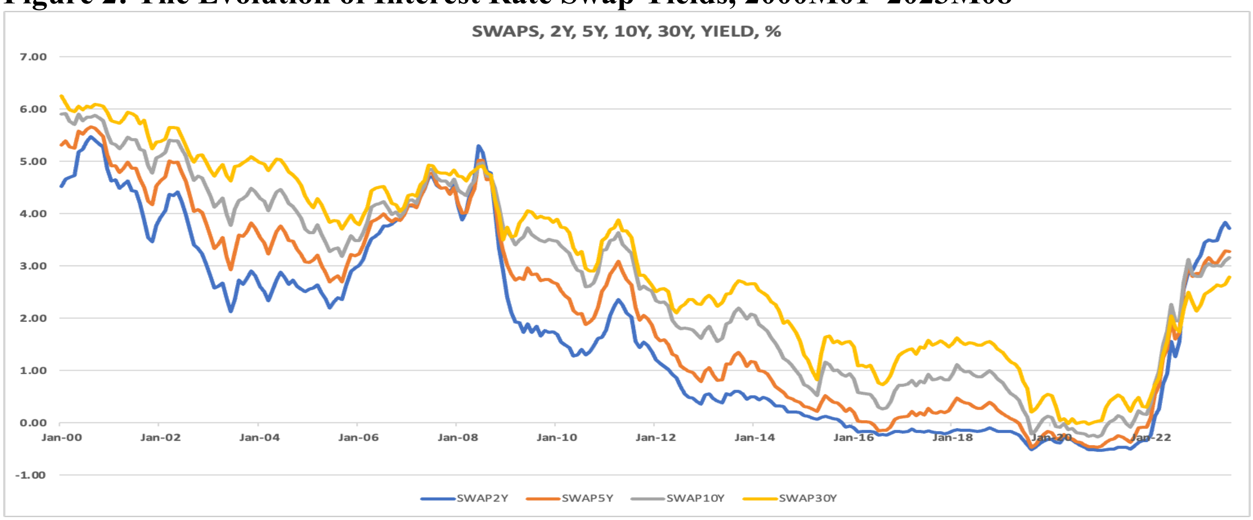


Figure 3 displays the coevolution of the 10-year swap yield and the 3-month Euribor rate. It shows that the 10-year swap yield and the short-term interest rate tend to move in tandem, though they do diverge occasionally. Hence, it is no surprise that the 10-year swap yield is strongly and positively correlated with the short-term interest rate. In the first year of the study period, the 10-year yield and the short-term interest rate were moving in opposite directions, but in the periods thereafter, this anomaly ceased to be the case. As the short-term interest rate declined notably from early 2001 to mid-2003, the 10-year swap yield also fell. Between

September 2003 and September 2005, the short-term interest rate was stable, at around 2.1 percent, but the swap yield declined. However, in the following three years, as the short-term interest rate rose, the 10-year swap yield increased in tandem. The short-term interest rate declined sharply during the global financial crisis, as did the 10-year swap yield, but by less and much more gradually. Subsequently, during the rest of the study period, the 10-year swap yield moved essentially in lockstep with the short-term interest rate. By late 2012, the short-term interest rate was hovering close to zero; meanwhile, the 10-year swap yield tended to decline overall, though on some occasions, it rose moderately. Between mid-2015 and mid-2022, the short-term interest rate was negative; during this period, the 10-year swap yield fell even more. Indeed, from late 2019 until early 2021, the 10-year swap yield also fell into negative territory. However, by early 2022, the 10-year swap yield began to rise. As the short-term interest rate started rising in April 2022, the 10-year swap yield did so as well. Near the end of the study period, both the short-term interest rate and the 10-year swap yield had risen, but the short-term interest rate exceeded the 10-year swap yield by slightly more than 60 basis points.

Figure 3: The Coevolution of 10-year Swap Yield and 3-month Euribor Rate 2000M01–2023M08

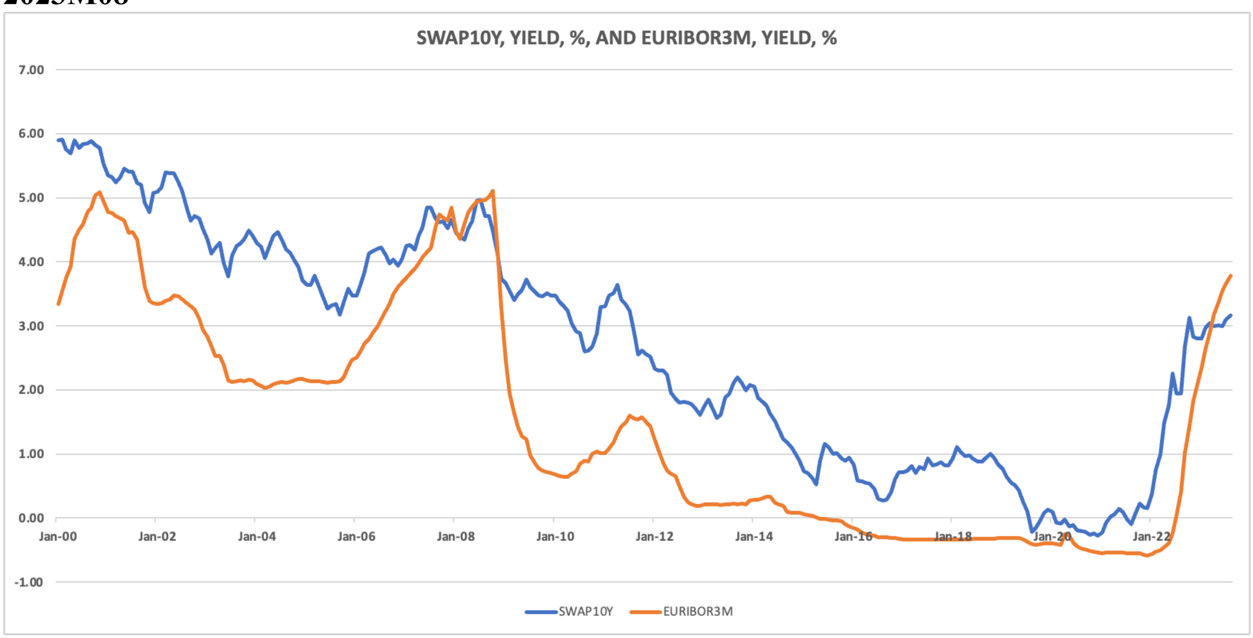


Figure 4 shows the coevolution of the 10-year swap yield and core inflation. The 10-year swap yield and core inflation have a positive, but not particularly strong correlation. Between 2000 and 2019, core inflation ranged between 0.7 percent to 2 percent, while swap yields declined from nearly 6 percent to near zero; some even turned slightly negative during that period. During the second half of 2020, inflation declined noticeably, but by 2021, inflation was surging. Core inflation had surged to more than 5.6 percent in early 2023, while 10-year swap yields had risen notably along with higher short-term interest rates and an increase in inflationary pressure. By the end of the study period, core inflation was below its peak, but the 10-year swap yield remained elevated and appeared to be rising.

Figure 4: The Coevolution of the 10-year Swap Yield and Core Inflation, 2000M01–2023M08

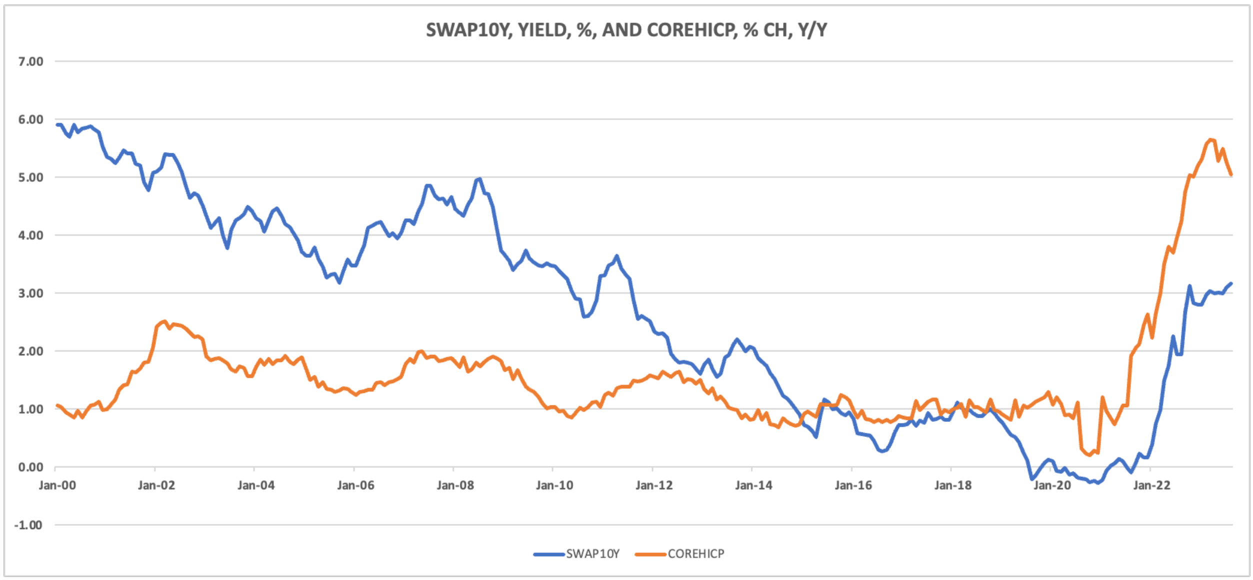


Figure 5 traces the growth of industrial production in the euro zone during the study period. The growth of industrial production is a useful indicator of overall economic activity. Even though industrial production tends to be more volatile than overall economic activity, it is positively correlated with economic activity. A growth (decline) in industrial production usually conveys a growth (decline) in overall activity. During the study period, the year-over-year growth in industrial production averaged slightly more than 0.9 percent per month. Most episodes of a decline in industrial production—such as between March 2001 to October 2001, May 2008 to July 2009, and January 2020 to April 2020—were associated with a recession in the euro zone. However, there were also periods in which industrial production continued to decline, even when the euro zone was no longer in a recession but either the zone was recovering from a recession or overall growth was feeble, such as between October 2011 to September 2013. It is noteworthy that industrial production was declining in the euro zone from January 2023 to the end of the study period in August 2023.

Figure 5: The Growth in Industrial Production, 2000M01–2023M08

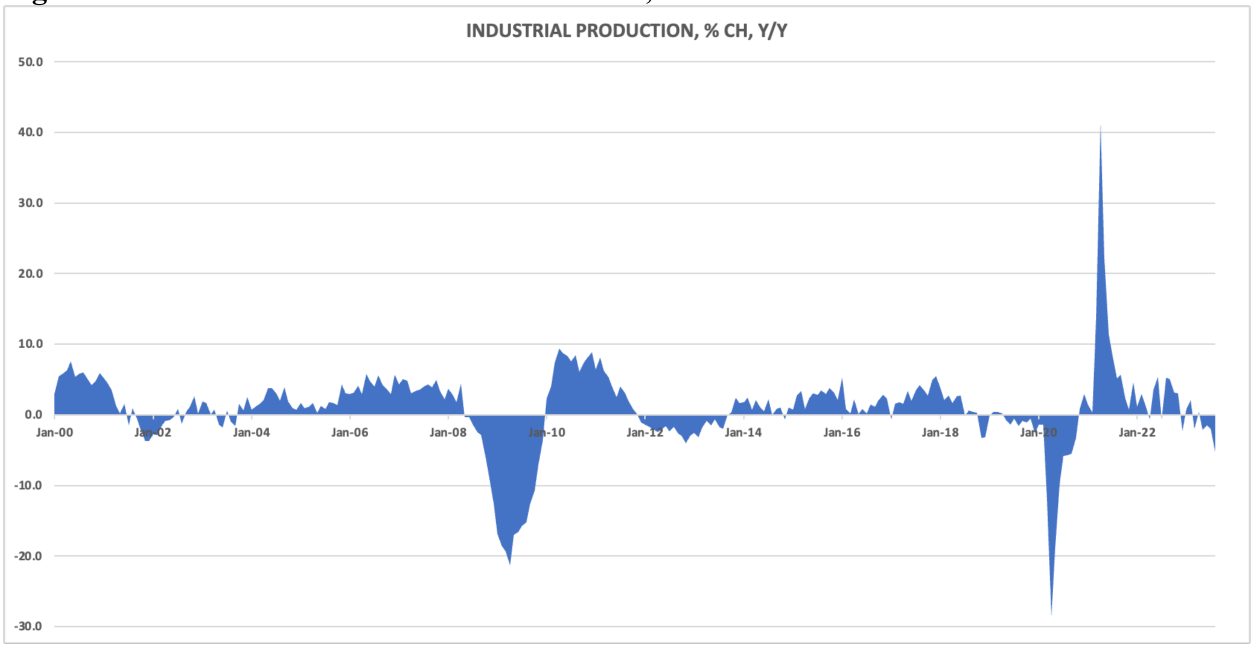


Figure 6 displays the evolution of the two key equity indexes, namely the EURO STOXX 50 index and the FTSE Euro 100 index. The equity indexes, which tend to move together, fell from their peak at the beginning of the study period in early 2000 and bottomed out in March 2003. Subsequently, they gradually rose until the advent of the global financial crisis in late 2007. The equity indexes again hit bottom in March 2009 before beginning a steady recovery that continued until the shutdown at the beginning of the global pandemic. Between February 2020 and April 2020, the equity index fell sharply, but began to recover as pandemic restrictions were eased. Recovery continued until late 2021. There was a correction in the equity markets from early to late 2022, followed by a recovery that continued until mid-2023, with some corrections near the very end of the study period.

Figure 6: The Evolution of Key Equity Indexes, 2000M01–2023M08

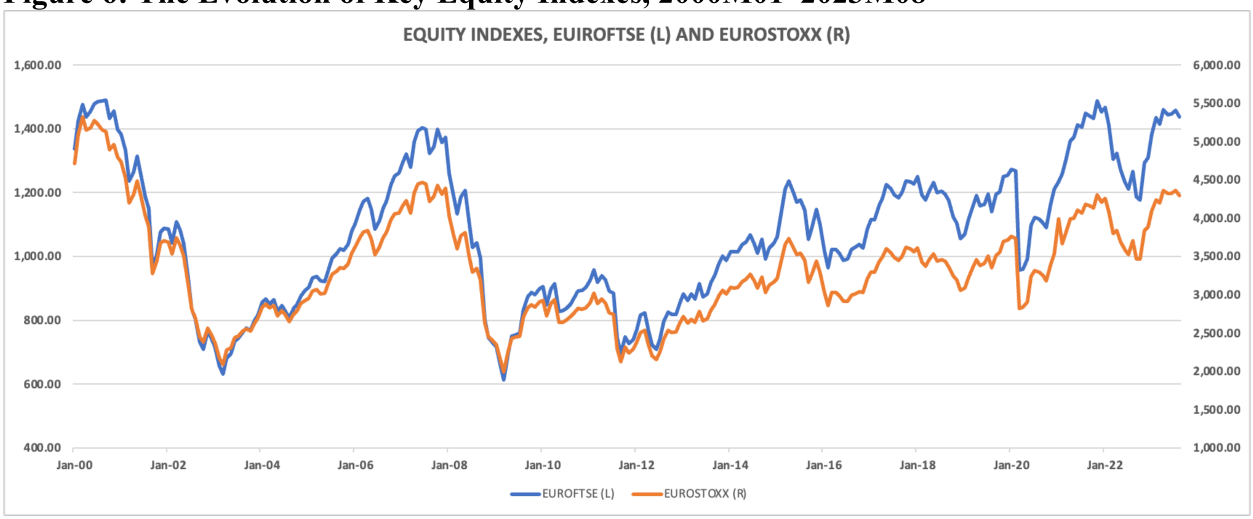


Figure 7 shows the evolution of the nominal effective exchange rate and the euro–dollar (EURUSD) exchange rate. At the turn of the twenty-first century, the euro was at a parity with the US dollar. After a brief period of depreciation against the dollar, it regained parity by November 2002, and underwent a steady appreciation until the beginning of 2005. The euro resumed appreciating: starting at $1.20 in late 2005 and reaching nearly $1.60 by mid-2008. Between mid-2008 and early 2015, the euro traded somewhere between $1.60 and $1.23; however, it deteriorated sharply in early 2014 from $1.40 to around $1.08 in April 2015. The euro remained stable at around $1.08 until April 2017. The currency ranged between $1.22 and $1.07 between April 2017 and mid-2022, but depreciated in the following months until reaching parity in October 2022. Thereafter the euro reversed course and began to appreciate; between March 2023 and the end of the study period, the euro was fairly stable, trading at around $1.10.

Figure 7: The Evolution of the Nominal Effective Exchange Rate and the EURUSD Exchange Rate, 2000M01–2023M08

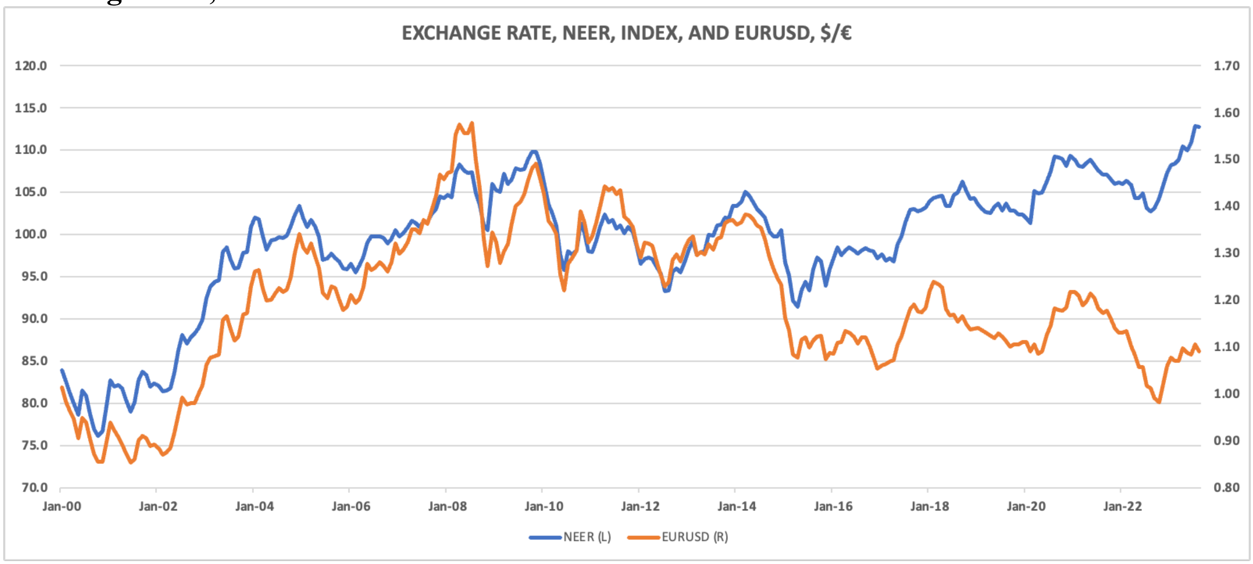
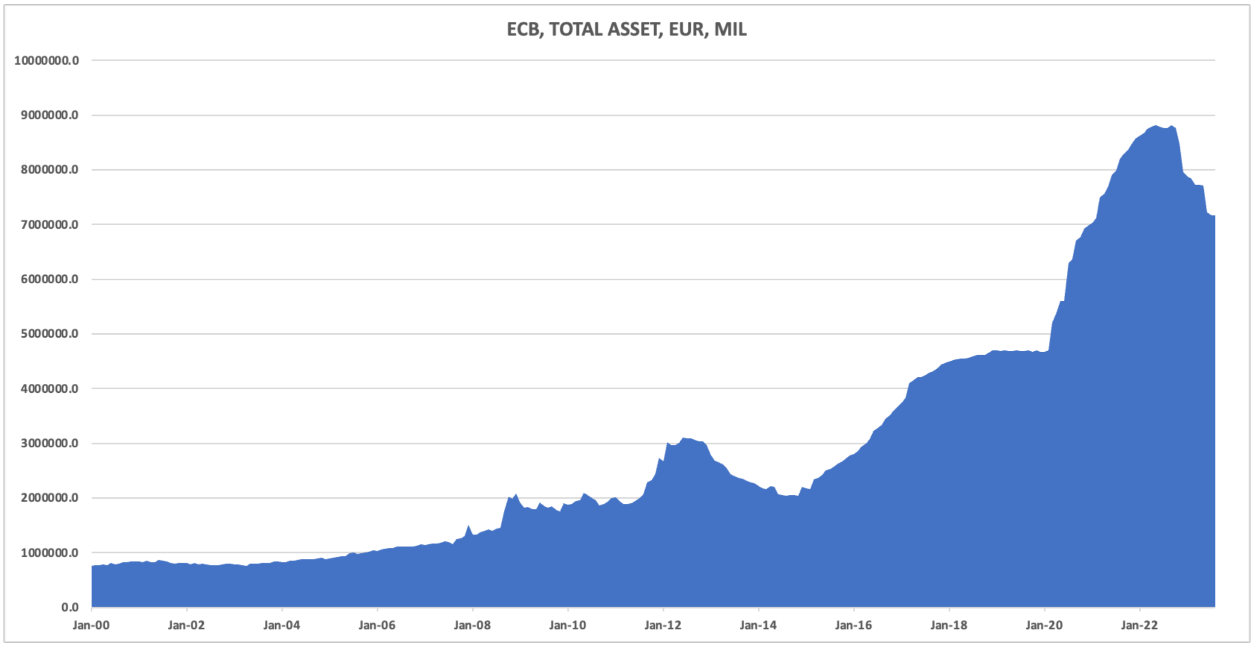


Figure 8 traces the evolution of the total assets on the ECB's balance sheet. At the start of the study period, the ECB's total assets amounted to a bit more than €760 billion, rising to €1.4 trillion by August 2008. In response to the global financial crisis, the ECB expanded its balance sheet, which increased to €1.9 trillion by January 2009. The balance sheet was essentially unchanged between January 2009 and August 2011, however, in response to the crisis in the euro zone's periphery (when the government bond yields of several euro countries, such as Portugal, Ireland, Italy, Greece, and Spain, spiked markedly), the ECB expanded its balance sheet and, by May 2012, it amounted to €3 trillion. Subsequently, the ECB shrank its balance sheet (falling to €2 trillion by August 2014) but soon reversed course due to slow growth and low inflation. By early 2019, the ECB's total assets stood at nearly €4.7 trillion. The balance sheet stabilized for the next 12 months, but in response to the global pandemic, the ECB engaged in a marked increase in its balance sheet through various large-scale asset purchase programs and assorted measures to provide liquidity and credit facilities. In March 2020, the ECB increased its balance sheet to €5.2 trillion and the expansion continued unabated until September 2022, when it peaked at €8.8 trillion. Thereafter, it again began to shrink its balance sheet, and, by the end of the study period in August 2023, the balance sheet had shrunk to less than €7.2 trillion.

Figure 8: The Evolution of the ECB's Balance Sheet, Total Assets, 2000M01–2023M08



SECTION IV: DATA DESCRIPTIONS AND UNIT ROOT AND STATIONARITY TESTS

Table 1 summarizes the data used in the paper. The first column displays the labels of the variables. The second column gives a description and date range for the data. The third column provides the data's frequency and indicates whether high-frequency data have been converted to lower-frequency data. The final column catalogs the data sources. For interest rate swaps, the yields of swaps of 2-year, 5-year, 10-year, and 30-year tenors are used. Short-term interest rates are obtained from 3-month and 6-month euro interbank offer rates (EBOR3M, EBOR6M). Two measures of inflation are used. The first is total inflation, based on the year-over-year percentage change in the harmonized index of consumer prices, seasonally and working day adjusted (SWDA). The second is core inflation, based on the year-over-year percentage change in the harmonized index of consumer prices excluding energy, food, and alcohol, SWDA. Economic activity is measured by the year-over-year percentage change in industrial production, SWDA. Two different indices of stock prices are used: the FTSE Euro 100 index and the EURO STOXX 50 index. Two different exchange rates are obtained, namely, the EURUSD exchange rate and the nominal effective exchange rate of the euro. Finally, the ECB's total assets are used for measuring its balance sheet.

The monthly time-series data starts in January 2000 and ends in May 2023, covering 281 months of observations. Several high-frequency daily data have been converted to monthly data. For a few variables, the natural logarithm (LN) is used because the first difference of the natural logarithm provides the percentage change of that variable.

Table 1: Variables and the Data

Variable label	Description, date range	Frequency	Sources
Swap yields			
SWAP2Y	Interest rate swap, 2-year, EUR, % January 2000–August 2023	Daily; converted to monthly	Refinitiv
SWAP5Y	Interest rate swap, 5-year, EUR, % January 2000–August 2023	Daily; converted to monthly	Refinitiv
SWAP10Y	Interest rate swap, 10-year, EUR, %, January 2000–August 2023	Daily; converted to monthly	Refinitiv
SWAP30Y	Interest rate swap, 30-year, EUR, %, January 2000–August 2023	Daily; converted to monthly	Refinitiv
Short-term interest rates			
EBOR3M	3-month euro interbank offer rate (EURIBOR), average, %, January 2000–August 2023	Daily; converted to monthly	European Central Bank
EBOR6M	6-month euro interbank offer rate (EURIBOR), average, %, January 2000–August 2023	Daily; converted to monthly	European Central Bank
Inflation			
HICP	Harmonized index of consumer prices, % change, y/y, SDWA, January 2000–August 2023	Monthly	European Central Bank
CHICP	Harmonized index of consumer prices, excluding energy, food, and alcohol, %, change, y/y, SWDA, January 2000–August 2023	Monthly	European Central Bank
Economic activity			
IPYOY	Industrial production: % change, y/y, SWDA, January 2000–August 2023	Monthly	Statistical Office of the European Communities
Financial market			
EFTSE	FTSE Euro 100 index, stock price index, close price, January 2000–August 2023	Daily; converted to monthly	*Financial Times*
ESTOXX	EURO STOXX 50, stock price index, close price, January 2000–August 2023	Daily; converted to monthly	STOXX Limited
Exchange rate			
EURUSD	Exchange rate, \$/€, average, January 2000–August 2023	Daily; converted to monthly	European Central Bank

Variable label	Description, date range	Frequency	Sources
NEER	Nominal effective exchange rate, January 2000–August 2023	Daily; converted to monthly	JPMorgan
Central bank balance sheet			
ECB	European Central Bank, total assets, end of period, million, euro (€) January 2000–August 2023	Monthly	European Central Bank

The summary statistics of all variables in their level and at first difference are presented in Tables 2A and 2B, respectively. The average of the swap yields increases with maturity levels, as longer maturity represents a higher risk. Similarly, the average of the EBOR3M is slightly lower than the average of the longer-term EBOR6M. The coefficient of variance (CV), measured as the ratio of standard deviation to the mean, shows that higher-tenor swap yields have lower volatility.[1] The skewness of the yields of swaps of lower tenors and short-term interest rates is positive and thus exhibits a slightly longer tail on the right. However, the yields of longer-tenor swaps exhibit negative skewness, albeit very small in size. The kurtosis for swap yields and short-term interest rates is below three, displaying a platykurtic distribution with short tails (that is, fewer outliers). The Jarque-Bera tests in Table 2A suggest the hypothesis that the variables are normally distributed can be rejected.

Table 2A: Summary Statistics of the Variables

Variables	Obs.	Mean	Std. Dev.	Max.	Min	Skewness	Kurtosis	J-B	Prob.
SWAP2Y	281	1.76	1.81	5.47	-0.53	0.35	1.77	23.43	0.00
SWAP5Y	281	2.16	1.84	5.66	-0.47	0.14	1.66	21.93	0.00
SWAP10Y	281	2.66	1.81	5.91	-0.27	-0.002	1.71	19.62	0.00
SWAP30Y	281	3.03	1.78	6.25	-0.03	-0.0003	1.78	17.56	0.00
EBOR3M	281	1.47	1.78	5.11	-0.58	0.56	1.97	27.06	0.00
EBOR6M	281	1.58	1.77	5.22	-0.55	0.51	1.96	24.75	0.00
HICP	281	2.08	1.84	10.65	-0.62	2.30	9.77	785.74	0.00
CHICP	281	1.52	0.89	5.64	0.21	2.67	11.48	1174.38	0.00
IPYOY	281	0.92	5.90	41.47	-28.64	-0.21	15.00	1689.02	0.00
LNEFTSE	281	6.95	0.21	7.31	6.42	-0.28	2.19	11.25	0.00
LNESTOXX	281	8.10	0.26	10.86	7.60	4.16	45.33	21791.24	0.00
LNEURUSD	281	0.17	0.14	0.46	-0.16	-0.44	2.79	9.60	0.01
LNNEER	281	4.59	0.08	4.70	4.33	-1.40	4.46	116.21	0.00
LNECB	281	14.58	0.76	15.99	13.54	0.25	1.91	16.92	0.00

[1] The measurement of the coefficient of variances is not reported in table 2A and table 2B. The results are available upon request.

Table 2B shows the summary statistics of all the variables at their first difference. The means of the variables at their first difference values are very small. The short-term interest rates and swap yields are more volatile at their first difference. The skewness of the swap yields is positive and thus shows a slightly longer tail on the right. However, the short-term interest rates exhibit negative skewness, indicating longer tails on the left side of the distributions. All swap yields and short-term interest rates are leptokurtic, showing longer and fatter tails. In particular, the percentage change in the EURO STOXX 50 index and the ECB's total assets exhibits unusually high kurtosis. This indicates they have very long tails. None of the variables, except for the EURUSD exchange rate, have a normal distribution according to the Jarque-Bera test. The exceptionally large percentage change in industrial production shows a slowdown in March 2020, indicating the pandemic's impact on European industries, followed by a significant increase exactly a year later, in March 2021, as the lockdown subsided.

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

Variables	Obs.	Mean	Std. Dev.	Max.	Min	Skewness	Kurtosis	J-B	Prob.
ΔSWAP2Y	280	-0.0004	0.17	0.98	-0.73	0.40	8.95	420.53	0.00
ΔSWAP5Y	280	-0.01	0.17	0.87	-0.64	0.72	6.64	178.58	0.00
ΔSWAP10Y	280	-0.01	0.16	0.72	-0.40	0.81	5.15	84.69	0.00
ΔSWAP30Y	280	-0.01	0.15	0.50	-0.50	0.19	4.39	24.36	0.00
ΔEBOR3M	280	0.0001	0.15	0.61	-0.95	-1.85	16.30	2224.79	0.00
ΔEBOR6M	280	0.0004	0.15	0.76	-0.93	-1.54	16.13	2121.50	0.00
ΔHICP	280	0.015	0.31	1.65	-1.63	0.03	8.43	343.54	0.00
ΔCHICP	280	0.015	0.16	0.96	-0.79	1.12	12.45	1101.67	0.00
ΔIPYOY	280	-0.02	3.21	27.81	-19.25	1.24	30.41	8838.02	0.00
ΔLNEFTSE	280	0.0003	0.05	0.13	-0.28	-1.53	9.02	531.53	0.00
ΔLNESTOXX	280	-0.0003	0.20	2.29	-2.32	-0.18	124.34	171785.20	0.00
ΔLNEURUSD	280	0.0002	0.02	0.07	-0.08	0.00	3.51	3.01	0.22
ΔLNNEER	280	0.0001	0.01	0.05	-0.04	0.33	4.21	22.07	0.00
ΔLNECB	280	0.01	0.03	0.19	-0.12	1.48	10.62	779.63	0.00

The unit root and stationarity tests are displayed in Tables 3A and 3B. Table 3A exhibits the unit root tests of the variables at their level. Both the augmented Dickey-Fuller (ADF) unit root tests (Dickey and Fuller 1979, 1981) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) stationarity tests (Kwiatkowski et al. 1992) are shown. The null hypotheses for the ADF and KPSS tests are different. The ADF test looks for the presence of a unit root (that is, nonstationarity), while the

KPSS test detects stationarity in the data. The unit root tests in Table 3A indicate that most of the variables are nonstationary, with two notable exceptions, namely, the growth in industrial production and the EURO STOXX 50 index, which shows the presence of stationarity in both tests.

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

Variables at Level	ADF Unit Root Tests (H_0: Unit Root)			KPSS Tests (H_0: Stationarity) tests	
	None	Intercept	Trend	Intercept	Trend
SWAP2Y	-1.38	-1.66	-0.36	1.45***	0.17**
SWAP5Y	-1.60	-1.78	-0.40	1.61***	0.18**
SWAP5Y	-1.68	-1.81	-0.54	1.70***	0.15**
SWAP30Y	-1.73	-1.72	-1.21	1.82***	0.13*
EURO3M	-1.52	-1.94	-1.43	1.42***	0.14*
EURO6M	-1.49	-1.98	-1.47	1.39***	0.14*
HICO	-0.72	-2.42	-2.33	0.19	0.18**
CHICP	0.25	-1.65	-1.29	0.18	0.19**
IPYOY	-3.83***	-3.89**	-3.89**	0.05	0.05
LNEFTSE	-0.08	-2.33	-2.82	0.39*	0.19**
LNESTOXX	-0.20	-4.48***	-4.45***	0.21	0.21**
LNEURUSD	-1.14	-2.11	-2.00	0.39*	0.38***
LNNEER	0.99	-2.25	-2.57	0.94***	0.23***
LNECB	4.28	-0.33	-2.90	1.89***	0.14*

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

Table 3B exhibits the unit root and stationarity tests of the variables in their first difference. All the variables become stationary at their first difference in both ADF and KPSS tests. However, the KPSS tests for short-term interest rates weakly rejected the null hypothesis of stationarity. The overall picture, though, supports stationarity at the first difference.

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

Variables at Level	ADF Unit Root Tests (H_0: Unit Root)			KPSS Tests (H_0: Stationarity) tests	
	None	Intercept	Trend	Intercept	Trend
ΔSWAP2Y	-10.30***	-10.29***	-10.48***	0.32	0.12*
ΔSWAP5Y	-11.55***	-11.55***	-11.74***	0.36*	0.13*
ΔSWAP5Y	-11.79***	-11.80***	-11.98***	0.34	0.13*
ΔSWAP30Y	-12.27***	-12.31***	-12.41***	0.26	0.09
ΔEURO3M	-6.20***	-6.19***	-6.34***	0.20	0.11
ΔEURO6M	-6.14***	-6.13***	-6.28***	0.23	0.11
ΔHICO	-6.04***	-6.04***	-5.93***	0.10	0.05
ΔCHICP	-4.35***	-4.43***	-4.58***	0.38*	0.18**
ΔIPYOY	-7.53***	-7.51***	-7.50***	0.01	0.01
ΔLNEFTSE	-13.59***	-13.57***	-13.63***	0.14	0.04
ΔLNESTOXX	-27.30***	-27.25***	-27.22***	0.12	0.04
ΔLNEURUSD	-12.15***	-12.13***	-12.17***	0.15	0.05
ΔLNNEER	-13.02***	-13.07***	-13.06***	0.08	0.06
ΔLNECB	-6.37***	-6.92***	-6.93***	0.08	0.05

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

SECTION V: EMPIRICAL MODELS AND FINDINGS

Based on the findings of the ADF and KPSS tests, other traditional time series tests—such as Granger causality and Johansen cointegration tests—were conducted. However, these tests did not exhibit any bidirectional relationship between the short-term interest rate and the swap yields of different maturity tenors. Following these conventional tests, the autoregressive conditional heteroskedasticity (ARCH) Lagrange multiplier (LM) tests on ordinary least square (OLS) regressions of swap-yield models were untaken. The ARCH-LM tests can ascertain whether an ARCH framework is a suitable approach for econometrically modeling swap-yield dynamics. These models, and their generalized version (GARCH), are specifically designed to model and forecast conditional variances. In ARCH and GARCH models, the variance of the dependent variable is a function of the past values of the dependent variable and the independent variables. This allows the analyst to model volatility over time, which is particularly useful for understanding the dynamics of financial markets. ARCH models were introduced by Engle (1982) and GARCH by Bollerslev (1986) and Taylor (1986).[2]

The results from the ARCH-LM tests are given in Table 4. The tests show the presence of the ARCH effect in OLS regression models of the month-over-month change in the swap yields of different maturity tenors for more than one lag. These results clearly indicate that ARCH-type models will be useful for estimating the relationship between the month-over-month change in the swap yield and the month-over-month change in the short-term interest rate in the euro zone, after controlling for other factors by modeling the volatility.

[2] For additional background information, including the econometric theory and some applications, see Bollerslev, Chou, and Kroner (1992); Bollerslev, Engle, and Nelson (1994); and Bollerslev and Mikkelsen (1996). These three papers provide comprehensive surveys of ARCH and GARCH models and their applications.

Table 4: ARCH LM Test

Models	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP30Y
Panel one				
Lags	**Models with CHICP and IPYOY**			
1	3.70 (0.05)	1.56 (0.21)	1.24 (0.27)	1.34 (0.25)
4	13.39 (0.00)	26.91 (0.00)	17.17 (0.00)	5.34 (0.00)
8	7.06 (0.00)	14.70 (0.00)	10.88 (0.00)	2.95 (0.00)
12	4.86 (0.00)	10.25 (0.00)	7.83 (0.00)	2.74 (0.00)
Panel two				
Lags	**Models with CHICP, IPYOY PLUS others**			
1	19.04 (0.00)	4.35 (0.04)	2.16 (0.14)	2.81 (0.09)
4	15.40 (0.00)	24.69 (0.00)	20.60 (0.00)	5.01 (0.00)
8	8.11 (0.00)	12.77 (0.00)	10.90 (0.00)	2.79 (0.00)
12	5.46 (0.00)	8.65 (0.00)	8.18 (0.00)	2.76 (0.00)

Note: The OLS model includes the change in the short-term interest rate (ΔEBOR3M) and the controls (ΔCHICP, ΔIP) in panel one and some additional controls (ΔLNEURUSD and ΔLNECB) in panel two. All panels also include an AR(1) term. *p*-values are in parenthesis.

Hence, a standard GARCH(1,1) model is used here to econometrically analyze the dynamics of the swap yield:

$$Y_t = \beta_0 + \beta_1 X_t + \varepsilon_t \qquad [1]$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \gamma_1 \sigma_{t-1}^2 \qquad [2]$$

Here, the current volatility of the error term is explained by the long-run average variance (α_0), the past values of the shocks, and the history of volatility. The swap yields of different maturities against three-month and six-month short-term interest rates are estimated in two different models.

The first set of models is based on the month-over-month change in the short-term interest rate (ΔEBOR3M, ΔEBOR6M), core inflation rate or inflation (ΔCHICP, ΔHICP), and the growth in industrial production (ΔIP). The second set of models is based not just on the month-over-month change in the short-term interest rate, inflation or core inflation, and the growth in industrial production, but also includes additional control variables, namely, the percentage changes in the equity index (ΔLNESTOXX, ΔLNEFSTE), the exchange rate (ΔLNEURUSD, ΔLNNEER), and the ECB's total assets (ΔLNECB).

The main results for GARCH(1,1) models are presented in Tables 5A and 5B. An autoregressive term, AR(1), is added to address autocorrelation in the models.

In the mean equation in Table 5A, the effect of the ΔEURO3M on all different maturities of swap yields is positive and statistically significant. Furthermore, the effect of the three-month interbank offer rate declines with a higher tenure of the swaps. The effects of core inflation and percentage change of industrial production on the swap yields of different maturity tenors are not statistically significant. Among the other control variables, the percentage change in the equity price index has a negative and statistically significant effect on the change in the swap yields of higher maturity tenors only. This implies that a rise (fall) in the equity price index is associated with a decrease (increase) in the swap yield of maturities with a tenor greater than five years. The results also show that the percentage change in the exchange rate of the euro against the US dollar has a positive and statistically significant effect on ΔSWAP2Y and ΔSWAP5Y. Lastly, the percentage change in ECB's total assets only positively affects the two-year and five-year swap yields. The AR(1) term has a positive and statistically significant effect on the swap yield of all four maturity tenors.

Table 5A: GARCH (1,1) Model with EBOR3M

	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP10Y	ΔSWAP30Y	ΔSWAP30Y
Mean equation								
Intercept	0.001 (0.88)	0.005 (0.22)	0.001 (0.70)	0.01 (0.72)	–0.04 (0.65)	–0.03 (0.72)	–0.13 (0.12)	–0.11 (0.16)
ΔEBOR3M	0.72*** (0.00)	0.78*** (0.00)	0.56*** (0.00)	0.62*** (0.00)	0.34*** (0.00)	0.35*** (0.00)	0.19** (0.01)	0.21** (0.01)
ΔCHICP	0.001 (0.68)	0.01 (0.54)	0.02 (0.63)	0.02 (0.53)	0.02 (0.73)	0.02 (0.68)	0.03 (0.68)	0.02 (0.77)
ΔIP	–0.0004 (0.95)	–0.0002 (0.96)	–0.004 (0.71)	–0.0001 (0.84)	0.001 (0.62)	0.0005 (0.72)	0.004 (0.14)	0.003 (0.15)
ΔLNESTOXX		0.03 (0.35)		0.04 (0.13)		0.04*** (0.00)		–0.04*** (0.00)
ΔLNEURUSD		0.57*** (0.00)		1.05*** (0.00)		0.28 (0.57)		0.27 (0.63)
ΔLNECB		–0.18*** (0.00)		–0.21 (0.18)		–0.10 (0.71)		–0.36 (0.28)
AR(1)	0.19*** (0.00)	0.21*** (0.00)	0.30*** (0.00)	0.32*** (0.00)	0.26*** (0.00)	0.27*** (0.00)	0.20** (0.04)	0.19* (0.06)
Variance equation								
Intercept	0.0001 (0.18)	0.0001 (0.21)	0.001 (0.20)	0.001* (0.06)	0.004** (0.01)	0.004** (0.02)	0.004*** (0.00)	0.004** (0.02)
ARCH(-1)	0.54*** (0.00)	0.58*** (0.00)	0.24** (0.01)	0.30*** (0.00)	0.17** (0.04)	0.18** (0.05)	0.16* (0.09)	0.16* (0.09)
GARCH(-1)	0.62*** (0.00)	0.60** (0.00)	0.75*** (0.00)	0.69*** (0.00)	0.63*** (0.00)	0.63*** (0.00)	0.64*** (0.00)	0.65*** (0.00)
Model information								
Obs	279	279	279	279	279	279	279	279
Adj R^2	0.41	0.41	0.26	0.25	0.19	0.18	0.12	0.13
AIC	– 1.88	– 1.93	– 1.25	– 1.27	– 1.55	– 1.14	– 1.09	– 1.09
Diagnostic tests								
ARCH LM (12 lags)	0.63 (0.82)	0.78 (0.67)	0.91 (0.54)	0.60 (0.84)	1.48 (0.13)	1.35 (0.19)	1.19 (0.29)	1.47 (0.13)
DW Stat	1.89	1.91	2.03	2.01	1.94	1.93	1.93	1.92
JQB	55.02 (0.00)	29.68 (0.00)	20.25 (0.00)	7.98 (0.02)	11.93 (0.00)	12.02 (0.00)	19.70 (0.00)	16.30 (0.00)

Note: All vars are in diff, *p*-values are in parenthesis. ***, **, * implies statistical significance at 1 percent, 5 percent, and 10 percent, respectively.

The parameters in the variance equation are statistically significant. The significant ARCH coefficient implies that a volatility shock in the current month feeds into the next month's volatility. The significant GARCH coefficient indicates that a large shock (either positive or negative) will lead to a large variance in the forecast for an extended period of time. The sum of the ARCH and GARCH coefficients measures the rate at which the volatility effect fades over time. Since the sum is high, the shocks to the conditional variance are persistent and clustered over time.[3]

Table 5B shows that the six-month short-term interest rate has much the same effect as that of the three-month short-term interest rate on the swap yields of different maturity tenors presented in Table 5A. However, the effect of ΔEBOR6M on the different swap yields is larger than that of ΔEBOR3M (given in Table 5A). Different control variables are used in Table 5B to ascertain the robustness of the findings. Total inflation is used instead of core inflation; the percentage change in the EFTSE 100 equity index is used instead of EUROSTOXX; and ΔLNNEER is used instead of ΔLNEURUSD for the percentage change in the exchange rate.

In Table 5B, among the control variables, the change in inflation exhibits a weak positive effect on some of the swap yields of different maturity tenors. The percentage change in the EFTSE 100 equity index also shows a positive and statistically significant impact on swap yields with a five-year maturity or longer. Like the percentage change in EURUSD, the percentage change in the nominal effective exchange rate only has an effect on swaps for lower tenors. The percentage change in the ECB's total assets has no statistically significant effect on the swap yields. The effect of the AR(1) term is always positive and statistically significant, similar to that in Table 5A.

Similar to the results from the GARCH(1,1) models in Table 5A, the ARCH and GARCH coefficients in the variance equation are also both statistically significant in Table 5B. In addition, the sum of the two coefficients is closer to one for the higher-maturity swap models.[4] This, again, indicates strong evidence of the persistence and clustering of the variance of the error terms over time. The positive and statistically significant ARCH coefficient implies that a volatility shock today feeds into the next month's volatility. The positive and statistically significant GARCH coefficient indicates that a large shock (either positive or negative) will lead to a large variance in the forecast for a long period of time.

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[3] The sum of the ARCH and GARCH coefficients is more than one for two-year swaps, indicating an unstable volatility persistence over time.

[4] Similar to in Table 5A, the sum of the ARCH and GARCH coefficients for the two-year swap yields is more than one.

Table 5B: GARCH (1,1) Model with EBOR6M

	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP10Y	ΔSWAP30Y	ΔSWAP30Y
Mean equation								
Intercept	–0.002 (0.64)	–0.003 (0.61)	–0.002 (0.93)	–0.0005 (0.97)	–0.04 (0.59)	–0.07 (0.51)	–0.15 (0.13)	–0.09 (0.18)
ΔEBOR6M	0.99*** (0.00)	0.95*** (0.00)	0.73*** (0.00)	0.73*** (0.00)	0.42*** (0.00)	0.38** (0.02)	0.24** (0.03)	0.23*** (0.00)
ΔHICP	0.02 (0.14)	0.02 (0.15)	0.06** (0.03)	0.06** (0.02)	0.07* (0.05)	0.06 (0.13)	0.08* (0.06)	0.05 (0.25)
ΔIP	–0.0001 (0.87)	–0.0002 (0.59)	–0.0001 (0.90)	–0.001 (0.26)	–0.001 (0.91)	–0.004 (0.80)	0.003 (0.15)	0.001 (0.58)
ΔLNEFTSE		0.14 (0.19)		0.22 (0.12)		0.36 (0.12)		0.76*** (0.37)
ΔLNNEER		0.96** (0.01)		1.96*** (0.00)		0.70 (0.45)		0.77 (0.37)
ΔLNECB		–0.17 (0.11)		–0.18 (0.26)		–0.10 (0.74)		–0.34 (0.14)
AR(1)	0.26*** (0.00)	0.26*** (0.00)	0.30*** (0.00)	0.32*** (0.00)	0.23*** (0.00)	0.22** (0.04)	0.16 (0.14)	0.13 (0.17)
Variance equation								
Intercept	0.0001 (0.15)	0.0001 (0.13)	0.001* (0.07)	0.001** (0.03)	0.003*** (0.00)	0.003* (0.06)	0.004** (0.01)	0.004** (0.01)
ARCH(-1)	0.48** (0.01)	0.51** (0.02)	0.26*** (0.00)	0.31*** (0.00)	0.16** (0.04)	0.17 (0.15)	0.13 (0.14)	0.21* (0.06)
GARCH(-1)	0.66*** (0.00)	0.63** (0.00)	0.72*** (0.00)	0.69*** (0.00)	0.65*** (0.00)	0.62*** (0.00)	0.68*** (0.00)	0.58*** (0.00)
Model information								
Obs	279	279	279	279	279	279	279	279
Adj R^2	0.53	0.55	0.37	0.37	0.28	0.28	0.18	0.20
AIC	– 2.12	– 2.15	– 1.40	– 1.43	– 1.24	– 1.25	– 1.15	– 1.20
Diagnostic tests								
ARCH LM (12 lags)	1.10 (0.36)	1.05 (0.40)	1.04 (0.41)	0.94 (0.50)	1.43 (0.15)	1.26 (0.24)	1.39 (0.17)	1.32 (0.21)
DW Stat	2.01	2.04	2.08	2.10	1.98	1.99	1.98	1.91
JQB	54.06 (0.00)	48.24 (0.00)	13.35 (0.00)	6.49 (0.04)	13.65 (0.00)	19.13 (0.00)	18.14 (0.00)	13.45 (0.00)

Note: All vars are in diff, *p*-values are in parenthesis. ***, **, * implies statistical significance at 1 percent, 5 percent, and 10 percent, respectively.

The results of postestimation diagnostic tests are in the bottom part of Tables 5A and 5B. The ARCH-LM tests show that the GARCH(1,1) models accounted for all the ARCH effects.[5] The models do not have any autocorrelation problems based on the Durbin-Watson test statistics and

[5] The ARCH-LM tests with other lags are available upon request.

correlograms.[6] The Jarque-Bera test reveals that the standardized residuals are not normally distributed. However, this does not alter the main findings reported in the paper.

As a part of the robustness check, models with different lags of GARCH were also estimated. In particular, GARCH(2,1), GARCH(1,2), and GARCH(2,2) models have been estimated. The results of these estimates are displayed in Appendix A. In all the models, the effect of the change in the short-term interest rate on the swap yields of different maturities is virtually identical. All control variables also exhibit very similar results to Tables 5A and 5B. The GARCH(2,1) model in Table A.1 shows insignificant results for ARCH(-1), but ARCH(-2) and GARCH(-1) estimates in the variance equation present positive and statistically significant values. Similar estimates for the first and second lags of ARCH in the GARCH(2,2) model are provided in Table A.3. The estimates for the second lag of GARCH of the variance equation in both GARCH(1,2) and GARCH(2,2) models mostly exhibit negative and statistically significant results as expected, compared to the positive, significant estimates of the first lag.

SECTION VI: POLICY IMPLICATIONS OF THE FINDINGS FROM THE ESTIMATED MODELS

The findings show that the ECB, the euro zone's central bank, can exert influence on market interest rates, such as long-term swap yields. Its influence on long-term swap yields of different maturity tenors is asserted through the effect on the policy rates: (1) the interest rate on the main refinancing operations (MRO), which provides the bulk of the banking system's liquidity in the euro zone; (2) the rate on the deposit facility, which banks may use to make overnight deposits with the euro system; and (3) the rate on the marginal lending facility (which offers overnight credit to banks from the euro system) on the short-term interest rate. The short-term interest rate's pronounced effect on long-term swap yields of various maturity tenors implies that the ECB has considerable sway over the euro zone's financial system and financial markets because monetary policy measures affect market rates, such as EUR swap yields, which matters (directly

[6] The correlograms (autocorrelations and partial autocorrelations) of the standardized residuals from the estimated GARCH(1,1) models are also available upon request. The correlograms show that there is no remaining autocorrelation in the mean equation and that the models chosen are correctly specified.

or indirectly) for the borrowing costs and lending rates for households, small businesses, large corporations, and the public sector, including parastatals, local and regional governments, and sovereign governments. While the findings of previous research, such as Akram and Das (2017), show that the ECB's monetary policy actions influence the long-term government bond yields in the euro zone, the models estimated here show that the ECB's monetary policy also influences market interest rates on OTC products, such as swaps, after controlling for the effects of other macroeconomic and financial factors.

SECTION VII: CONCLUSION

The econometric models estimated in this paper reveal that the month-over-month change in the short-term interest rate has a statistically significant and economically meaningful and positive effect on the month-over-month change in swap yields of different maturity tenors. The effect is greater in the front end of the swap yield curve than at its back end. Nevertheless, the positive effect of the month-over-month change in the short-term interest rate applies to the month-over-month change in swap yields across the whole swap yield curve, even if the effects vary across the swap yield curve. Two different models of the month-over-month change in the long-term swap yields of several different tenors are estimated and divulge similar results. Moreover, alternative choices of independent variables are used to confirm that the results obtained are quite robust and not sensitive to the choice of variables.

The findings imply that monetary policy matters for market interest rates, such as swap yields, and that the ECB's monetary policy actions influence borrowing costs and lending rates critical for households, firms, and governments. The findings of the paper suggest that Keynes's view about the relationship between the short-term interest rate and long-term interest rate is well-supported for EUR swap yields. Recent econometric studies of swaps and government bonds denominated in various hard currencies (such as USD, JPY, GBP) and several emerging market currencies (such as CNY, INR, and CLP), which are cited earlier, have found that there is a clear relationship between the short-term interest rate and long-term interest rate, not just on government bonds but also private fixed-income securities, such as swaps. This study shows that the positive relationship between short-term interest rates and long-term swap yields applies to EUR swaps. Hence, this study reiterates and reinforces the empirical support for Keynes's assertion that the central bank plays a crucial role in setting the long-term interest rate via the short-term interest rate. The empirical regularity observed in various financial markets for swaps denominated in other currencies holds for EUR swaps and the financial markets in the euro zone. It shows Keynes's assertion applies not just to government yields but also to long-term market interest rates, such as EUR swap yields, in concordance with resemblant findings for USD, GBP, JPY, CNY, CLP, and INR swap yields, as reported in previous studies.

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APPENDIX A

Table A.1: GARCH (2,1) Model with EBOR3M

	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP10Y	ΔSWAP30Y	ΔSWAP30Y
Mean equation								
Intercept	0.001 (0.87)	0.004 (0.19)	0.01 (0.60)	0.01 (0.59)	–0.03 (0.79)	–0.03 (0.80)	–0.11** (0.03)	–0.09* (0.09)
ΔEBOR3M	0.68*** (0.00)	0.75*** (0.00)	0.52*** (0.00)	0.57*** (0.00)	0.35*** (0.00)	0.35*** (0.00)	0.19** (0.01)	0.21*** (0.00)
ΔCHICP	0.001 (0.33)	0.01 (0.23)	0.03 (0.42)	0.03 (0.32)	0.01 (0.80)	0.01 (0.79)	0.03 (0.48)	0.03 (0.58)
ΔIP	0.0001 (0.84)	0.0002 (0.65)	0.004 (0.72)	0.0002 (0.85)	0.001 (0.59)	0.001 (0.65)	0.004 (0.11)	0.004* (0.08)
ΔLNESTOXX		0.01 (0.82)		0.05** (0.05)		0.04*** (0.00)		0.04*** (0.00)
ΔLNEURUSD		0.59*** (0.00)		0.79 (0.11)		0.05 (0.92)		–0.32 (0.57)
ΔLNECB		–0.19*** (0.00)		–0.18 (0.31)		–0.06 (0.98)		–0.19 (0.41)
AR(1)	0.20*** (0.00)	0.21*** (0.00)	0.31*** (0.00)	0.32*** (0.00)	0.31*** (0.00)	0.31*** (0.00)	0.24*** (0.00)	0.25*** (0.00)
Variance equation								
Intercept	0.0001* (0.09)	0.0001 (0.20)	0.002** (0.04)	0.001* (0.07)	0.001** (0.01)	0.01** (0.03)	0.01*** (0.00)	0.005** (0.02)
ARCH(-1)	0.35 (0.12)	0.37 (0.12)	0.03 (0.77)	0.08 (0.62)	0.02 (0.77)	0.02 (0.77)	0.02 (0.59)	0.002 (0.96)
ARCH(-2)	0.31 (0.15)	0.31 (0.16)	0.33*** (0.00)	0.29** (0.01)	0.22*** (0.00)	0.22*** (0.00)	0.31** (0.02)	0.35** (0.03)
GARCH(-1)	0.52*** (0.00)	0.52** (0.00)	0.57*** (0.00)	0.59*** (0.00)	0.43** (0.01)	0.42** (0.04)	0.36** (0.01)	0.40** (0.01)
Model information								
Obs	279	279	279	279	279	279	279	279
Adj R^2	0.41	0.41	0.26	0.25	0.19	0.18	0.12	0.12
AIC	– 1.89	– 1.93	– 1.28	– 1.28	– 1.78	– 1.63	– 1.13	– 1.12
Diagnostic tests								
ARCH LM (12 lags)	0.58 (0.85)	0.73 (0.72)	0.73 (0.72)	0.62 (0.82)	1.05 (0.40)	1.07 (0.39)	1.17 (0.30)	1.21 (0.27)
DW Stat	1.90	1.93	2.07	2.04	2.00	2.00	2.02	2.01
JQB	68.83 (0.00)	43.73 (0.00)	23.21 (0.00)	15.49 (0.00)	10.01 (0.01)	10.87 (0.00)	8.81 (0.01)	7.48 (0.02)

Note: All vars are in diff, *p*-values are in parenthesis. ***, **, * implies statistical significance at 1 percent, 5 percent, and 10 percent, respectively.

Table A.2: GARCH (1,2) Model with EBOR3M

	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP10Y	ΔSWAP30Y	ΔSWAP30Y
Mean equation								
Intercept	0.001 (0.91)	0.005 (0.13)	0.003 (0.86)	–0.003 (0.75)	–0.11*** (0.00)	–0.10*** (0.00)	–0.14 (0.53)	–0.16 (0.13)
ΔEBOR3M	0.69*** (0.00)	0.76*** (0.00)	0.56*** (0.00)	0.66*** (0.00)	0.26*** (0.00)	0.24*** (0.00)	0.19*** (0.00)	0.21** (0.01)
ΔCHICP	0.01 (0.52)	0.01 (0.28)	0.02 (0.48)	0.03 (0.49)	–0.01 (0.76)	0.002 (0.95)	–0.03 (0.59)	–0.03 (0.69)
ΔIP	0.0001 (0.92)	0.0002 (0.63)	0.0004 (0.65)	0.0005 (0.75)	–0.0005 (0.86)	–0.001 (0.80)	0.004 (0.15)	0.004 (0.11)
ΔLNESTOXX		0.01 (0.78)		0.01 (0.81)		0.03 (0.62)		0.04*** (0.00)
ΔLNEURUSD		0.59*** (0.00)		1.15*** (0.00)		–0.05 (0.88)		0.14 (0.80)
ΔLNECB		–0.21*** (0.00)		–0.10 (0.54)		0.08 (0.71)		–0.30 (0.39)
AR(1)	0.20*** (0.00)	0.22*** (0.00)	0.31*** (0.00)	0.37*** (0.00)	0.27*** (0.00)	0.27*** (0.00)	0.21 (0.15)	0.19** (0.04)
Variance equation								
Intercept	0.0001 (0.13)	0.0001 (0.10)	0.001 (0.14)	0.002*** (0.00)	0.005*** (0.01)	0.005*** (0.00)	0.004 (0.19)	0.003 (0.11)
ARCH(-1)	0.41** (0.01)	0.34** (0.01)	0.17** (0.05)	0.16*** (0.00)	0.15*** (0.00)	0.15*** (0.00)	0.13 (0.39)	0.11 (0.19)
GARCH(-1)	1.00*** (0.00)	1.16*** (0.00)	1.24*** (0.00)	1.55*** (0.00)	1.06*** (0.00)	1.09*** (0.00)	1.15*** (0.00)	1.22*** (0.00)
GARCH(-2)	–0.29** (0.01)	–0.40*** (0.00)	–0.43* (0.05)	–0.68*** (0.00)	–0.51*** (0.00)	–0.54*** (0.00)	–0.48*** (0.00)	–0.50*** (0.00)
Model information								
Obs	279	279	279	279	279	279	279	279
Adj R^2	0.41	0.41	0.26	0.23	0.18	0.18	0.13	0.14
AIC	– 1.88	– 1.94	– 1.26	– 1.34	– 1.21	– 1.20	– 1.11	– 1.11
Diagnostic tests								
ARCH LM (12 lags)	0.52 (0.90)	0.63 (0.82)	0.85 (0.59)	0.43 (0.95)	2.87 (0.00)		1.09 (0.37)	1.41 (0.16)
DW Stat	1.90	1.94	2.05	2.09	1.96	1.96	1.96	1.93
JQB	59.05 (0.00)	36.45 (0.00)	19.50 (0.00)	8.97 (0.01)	14522.17 (0.00)		14.56 (0.00)	10.64 (0.00)

Note: All vars are in diff, *p*-values are in parenthesis. ***, **, * implies statistical significance at 1 percent, 5 percent, and 10 percent, respectively.

Table A.3: GARCH (2,2) Model with EBOR3M

	ΔSWAP2Y	ΔSWAP2Y	ΔSWAP5Y	ΔSWAP5Y	ΔSWAP10Y	ΔSWAP10Y	ΔSWAP30Y	ΔSWAP30Y
Mean equation								
Intercept	0.00003 (0.99)	0.01 (0.11)	0.005 (0.85)	0.01 (0.67)	–0.04 (0.12)	–0.04 (0.39)	–0.10* (0.06)	–0.10 (0.14)
ΔEBOR3M	0.68*** (0.00)	0.75*** (0.00)	0.52*** (0.00)	0.57*** (0.00)	0.42*** (0.00)	0.41*** (0.00)	0.19*** (0.00)	0.20*** (0.00)
ΔCHICP	0.01 (0.33)	0.02 (0.19)	0.03 (0.42)	0.03 (0.33)	–0.03 (0.40)	–0.03 (0.43)	–0.05 (0.35)	–0.04 (0.47)
ΔIP	0.0001 (0.83)	0.0002 (0.59)	0.0004 (0.68)	0.0003 (0.77)	–0.0004 (0.91)	–0.0001 (0.97)	0.004 (0.12)	0.005 (0.10)
ΔLNESTOXX		0.01 (0.79)		0.05 (0.13)		0.04 (0.57)		0.04*** (0.00)
ΔLNEURUSD		0.59*** (0.00)		0.77* (0.06)		–0.09 (0.72)		–0.33 (0.56)
ΔLNECB		–0.21*** (0.00)		–0.21 (0.24)		0.06 (0.80)		–0.15 (0.55)
AR(1)	0.20*** (0.00)	0.22*** (0.00)	0.33*** (0.00)	0.33*** (0.00)	0.32*** (0.00)	0.33*** (0.00)	0.26*** (0.00)	0.26*** (0.00)
Variance equation								
Intercept	0.0001 (0.18)	0.0001 (0.35)	0.002 (0.16)	0.001 (0.12)	0.01*** (0.00)	0.01*** (0.00)	0.01*** (0.00)	0.01*** (0.00)
ARCH(-1)	0.34 (0.16)	0.30 (0.20)	–0.01 (0.90)	0.01 (0.93)	–0.01 (0.77)	–0.01 (0.87)	–0.002 (0.93)	–0.01 (0.74)
ARCH(-2)	0.19 (0.52)	0.12 (0.79)	0.33** (0.02)	0.30** (0.03)	0.20*** (0.00)	0.22** (0.01)	0.24*** (0.00)	0.25** (0.02)
GARCH(-1)	0.83*** (0.00)	1.03 (0.10)	0.85*** (0.00)	0.94*** (0.00)	0.88*** (0.00)	0.85*** (0.00)	0.79*** (0.00)	0.82*** (0.00)
GARCH(-2)	–0.20 (0.24)	–0.33 (0.37)	–0.24 (0.14)	–0.29** (0.03)	–0.44** (0.01)	–0.39** (0.02)	–0.38*** (0.00)	–0.37*** (0.00)
Model information								
Obs	279	279	279	279	279	279	279	279
Adj R^2	0.41	0.41	0.26	0.25	0.18	0.18	0.12	0.12
AIC	– 1.88	– 1.93	– 1.28	– 1.28	– 1.22	– 1.21	– 1.13	– 1.13
Diagnostic tests								
ARCH LM (12 lags)	0.52 (0.90)	0.61 (0.84)	0.74 (0.71)	0.54 (0.88)			0.84 (0.60)	0.89 (0.55)
DW Stat	1.91	1.94	2.09	2.06	1.99	2.01	2.05	2.04
JQB	68.35 (0.00)	42.47 (0.00)	22.78 (0.00)	15.30 (0.00)			10.57 (0.00)	9.73 (0.00)

Note: All vars are in diff, *p*-values are in parenthesis. ***, **, * implies statistical significance at 1 percent, 5 percent, and 10 percent, respectively.