Working Paper No. 1051

Euro Interest Rate Swap Yields: Some ARDL Models

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May 2024

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The authors thank participants at various workshops for their valuable comments. **Disclaimer:** The authors' institutional affiliations are provided solely for identification purposes. Views expressed are merely those of the authors. The standard disclaimer holds. **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. **Note:** Some passages in this paper are taken from the same authors' following publication with minor changes: Akram, T., and K. Mamun. 2023. "Euro Interest Rate Swap Yields: A GARCH Analysis." Levy Institute Working Paper No. 1034. Annadale-on-Hudson, NY: Levy Economics Institute of Bard College.

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ISSN 1547-366X

ABSTRACT

This paper examines the dynamics of euro-denominated (EUR) long-term interest rate swap yields. It shows that the short-term interest rate has an economically and statistically significant effect on EUR swap yields of different maturity tenors, after controlling for various key macroeconomic variables. It presents several autoregressive distributive lag (ARDL) models of the dynamics of EUR swap yields. The estimated econometric models of EUR swap yields of different maturity tenors imply that the European Central Bank (ECB) exerts substantial influence on interest rate swap yields, primarily through the effect of its actions on the current short-term interest rate. Examining the case of EUR interest rate swaps, the findings of the paper lend additional credence to John Maynard Keynes's hypothesis concerning the ability of a central bank to influence long-term market interest rates.

KEYWORDS: Euro Swaps; Interest Rate Swaps; Short-Term Interest Rate; Monetary Policy; European Central Bank (ECB); Autoregressive Distributed Lag (ARDL)

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

SECTION I: INTRODUCTION

This paper econometrically models the behavior of euro-denominated (EUR) interest rate swap yields from a Keynesian perspective by applying the autoregressive distributive lag (ARDL) approach to modeling EUR swap yields. Interest rate swaps play a vital role in global financial markets, including EUR financial markets, both in the euro zone and elsewhere. As of 2022, the gross market value of EUR interest rate swaps was more than $6.2 trillion (USD), according to the Bank for International Settlements (BIS 2023), while their notional value was nearly $110 trillion during the same period. Considering all currencies, EUR interest rate swaps constitute about one-third by gross market value and almost half by the notional value of total outstanding interest rate swaps.

In recent years, there has been a spate of studies establishing the relevance of the Keynesian perspective on the dynamics of interest rate swap yields denominated in various currencies, including the US dollar (USD), British pound sterling (GBP), Japanese yen (JPY), Chinese yuan (CNY), Indian rupee (INR), and Chilean peso (CLP). Akram and Mamun (2023a, b, c, d, e; 2024, forthcoming) have modeled swap yields in terms of macroeconomic and financial factors. These studies have shown that the short-term interest rate has a decisive influence on swap yields, in concordance with John Maynard Keynes's (1930, [1936] 2007) view that the central bank's monetary policy exerts an influence on long-term interest rates via the short-term interest rate. Keynes's views on the behavior of long-term interest rates were supported by empirical regularities discerned by Riefler (1930). Regarding the behavior of EUR swap yields, Akram and Mamun (2023e) have recently shown that the *change* in EUR swap yields is influenced by the *change* in the short-term interest rate, after controlling for assorted macroeconomic variables. This paper, however, examines whether the same relationship holds for the *level* of EUR interest rate swap yields. It associates the *level* of the current short-term interest rate with the *level* of swap yields, holding various key macroeconomic variables constant. Thus, it extends the literature to assess the robustness of Keynes's conjecture and specifically whether it applies to the *level* of EUR swaps.

The literature on interest rate swaps is vast. For relevant primers on different aspects of interest rate swaps, readers can consult Bicksler and Chen (1986), Chernenko and Faulkender (2011), Corb (2012), Flavell (2010), Miron and Swannell (1992), Ron (2000), Sadr (2009), Sawyer (2011), Visvanathan (1998), and Zhou (2002). However, there is a dearth of empirical modeling of swap yields from a macroeconomic perspective. The pioneering empirical modeling of swap yields and especially swap spreads, such as Sun, Sundaresan, and Wang (1993), Duffie and Huang (1996), Duffie and Singleton (1997), Kim and Koppenhaver (1993), and Lekkos and Milas (2001), focuses on mainly credit quality and the liquidity factors that influence swap yields, rather than their macro-financial determinants. More recently, 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 about the behavior of swap yields, the absence of macroeconomic and financial variables in the empirical analysis—while also omitting the vital role of the central bank's monetary policy—has been a clear chasm in the literature. The Keynesian perspective on swap yields draws on models, such as Akram (2022, 2023), that tether the long-term government bond yield to the short-term interest rate, filling a critical lacuna in the literature.

There have been a few perceptive studies of the EUR swap market. Remolona and Wooldridge (2003) provide some useful background about the emergence and evolution of the EUR swap market. The EUR swap market's growth has been driven by both hedging and speculative positioning activity. They argue that, in the euro zone, the government bond markets' 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. A recent study (Fontana et al. 2019) highlights fascinating stylized features: (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 nonbank financial institutions tend to be active in niche specialization, and (4) there is considerable variation in transaction prices. While these studies have unmasked some important features of EUR swaps, the econometric modeling of EUR swaps from the Keynesian perspective is still at a formative stage, but such papers can provide a vista that can be useful to policymakers, investors, and risk managers.

The paper proceeds as follows. Section II describes the data and furnishes unit root and stationarity tests to evaluate the time series properties of the data. Section III presents the estimated econometric models and analyzes the findings of these models. Section IV concludes by reflecting on the policy implications of the empirical findings.

SECTION II: 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- and 6-month euro interbank offer rates (EBOR3M, EBOR6M). Two measures of inflation are utilized in the analysis. 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 (NEER) of the euro. Finally, the European Central Bank's (ECB) total assets are used to measure its balance sheet.

The monthly time series data starts in January 2000 and ends in September 2023, covering 285 months of observations. Several high-frequency daily data have been converted to monthly data. For a few variables, their 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–September 2023	Daily; converted to monthly	Refinitiv
SWAP5Y	Interest rate swap, 5-year, EUR, % January 2000–September 2023	Daily; converted to monthly	Refinitiv
SWAP10Y	Interest rate swap, 10-year, EUR, %, January 2000–September 2023	Daily; converted to monthly	Refinitiv
SWAP30Y	Interest rate swap, 30-year, EUR, %, January 2000–September 2023	Daily; converted to monthly	Refinitiv
Short-term interest rates			
EBOR3M	3-month euro interbank offer rate (EURIBOR), average, %, January 2000–September 2023	Daily; converted to monthly	European Central Bank
EBOR6M	6-month euro interbank offer rate (EURIBOR), average, %, January 2000–September 2023	Daily; converted to monthly	European Central Bank
Inflation			
HICP	Harmonized index of consumer prices, % change, y/y, SDWA, January 2000–September 2023	Monthly	European Central Bank
CHICP	Harmonized index of consumer prices, excluding energy, food, and alcohol, %, change, y/y, SWDA, January 2000–September 2023	Monthly	European Central Bank
Economic activity			
IPYOY	Industrial production: % change, y/y, SWDA, January 2000–September 2023	Monthly	Statistical Office of the European Communities
Financial market			
EFTSE	FTSE Euro 100 index, stock price index, close price, January 2000–September 2023	Daily; converted to monthly	*Financial Times*
ESTOXX	EURO STOXX 50, stock price index, close price, January 2000–September 2023	Daily; converted to monthly	STOXX Limited
Exchange rate			
EURUSD	Exchange rate, $/€, average, January 2000–September 2023	Daily; converted to monthly	European Central Bank
NEER	Nominal effective exchange rate, January 2000–September 2023	Daily; converted to monthly	JPMorgan
Central bank balance sheet			
ECB	European Central Bank, total assets, end of period, million, euro (€) January 2000–September 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 yield increases with the maturity levels, as a longer maturity represents a higher risk. Similarly, the average of the 6-month euro interbank offer rate (EBOR6M) is slightly higher than the average of the shorter-term, 3-month euro interbank offer rate (EBOR3M). The coefficient of variance (CV), measured as the ratio of standard deviation to the mean, shows that higher-term rates have lower volatility.[1] The skewness of the yields of swaps of all tenors (except the 10-year term) and the short-term interest rates are positive and thus exhibit a slightly longer tail on the right. The yield of the 10-year swaps exhibits negative skewness, albeit very small in size. The kurtosis for swap yields and short-term interest rates is below 3.0, displaying a platykurtic distribution with short tails (that is, fewer outliers). The Jarque-Bera tests in Table 2A suggest that the hypothesis that the variables are normally distributed can be rejected, a typical characteristic of time series variables.

Table 2A: Summary Statistics of the Variables

Variables	Obs.	Mean	Std. Dev.	Max.	Min	Skewness	Kurtosis	J-B	Prob.
SWAP2Y	285	1.79	1.82	5.47	-0.53	0.32	1.74	23.71	0.00
SWAP5Y	285	2.18	1.83	5.66	-0.47	0.12	1.66	21.83	0.00
SWAP10Y	285	2.67	1.80	5.91	-0.27	-0.01	1.73	19.26	0.00
SWAP30Y	285	3.03	1.77	6.25	-0.03	0.01	1.80	17.13	0.00
EBOR3M	285	1.50	1.79	5.11	-0.58	0.52	1.91	26.98	0.00
EBOR6M	285	1.61	1.78	5.22	-0.55	0.47	1.89	24.91	0.00
HICP	285	2.12	1.86	10.65	-0.62	2.19	9.13	675.03	0.00
CHICP	285	1.57	0.98	5.64	0.23	2.52	9.80	850.43	0.00
IPYOY	285	0.85	5.89	41.47	-28.64	-0.19	14.92	1689.48	0.00
LNEFTSE	285	6.95	0.21	7.31	6.42	-0.28	2.18	11.74	0.00
LNESTOXX	285	8.10	0.26	10.86	7.60	4.07	44.41	21150.30	0.00
LNEURUSD	285	0.17	0.14	0.46	-0.16	-0.42	2.78	8.80	0.01
LNNEER	285	4.59	0.08	4.73	4.33	-1.35	4.43	110.64	0.00
LNECB	285	14.60	0.77	15.99	13.54	0.23	1.87	17.72	0.00

Table 2B shows the summary statistics of all the variables at their first difference. The means of 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 yield 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 sides of the distributions. All swap yields and short-term interest rates are leptokurtic, showing longer and fatter tails. In particular, the

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

percentage change of the EURO STOXX 50 index exhibits unusually high kurtosis, indicating very long tails for the stock index. All the variables, except the EURUSD exchange rate, do not 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 impact of the COVID-19 pandemic on euro zone industries, followed by a large increase exactly a year later in March 2021.

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

Variables	Obs.	Mean	Std. Dev.	Max.	Min	Skewness	Kurtosis	J-B	Prob.
ΔSWAP2Y	284	-0.003	0.98	-0.73	0.17	0.39	8.92	421.19	0.00
ΔSWAP5Y	284	-0.01	0.87	-0.64	0.17	0.71	6.66	182.06	0.00
ΔSWAP10Y	284	-0.01	0.72	-0.40	0.15	0.80	5.16	85.58	0.00
ΔSWAP30Y	284	-0.01	0.50	-0.50	0.15	0.17	4.39	24.37	0.00
ΔEBOR3M	284	0.002	0.61	-0.95	0.15	-1.86	16.29	2254.31	0.00
ΔEBOR6M	284	0.002	0.76	-0.93	0.15	-1.55	16.21	2180.57	0.00
ΔHICP	284	0.01	1.64	-1.62	0.32	0.00	7.99	294.25	0.00
ΔCHICP	284	0.01	0.95	-0.80	0.16	0.81	11.65	917.41	0.00
ΔIPYOY	284	-0.03	27.81	-19.25	3.18	1.29	31.24	9518.19	0.00
ΔLNEFTSE	284	0.0002	0.13	-0.28	0.05	-1.54	9.12	554.71	0.00
ΔLNESTOXX	284	-0.0004	2.29	-2.32	0.20	-0.18	126.11	179339.20	0.00
ΔLNEURUSD	284	0.0002	0.07	-0.08	0.02	0.00	3.51	3.09	0.21
ΔLNNEER	284	0.00	0.05	-0.04	0.01	0.32	4.20	21.83	0.00
ΔLNECB	284	0.01	0.19	-0.12	0.03	1.45	10.56	774.63	0.00

The unit root and stationarity tests are displayed in Tables 3A and 3B, respectively. Table 3A exhibits the unit root tests of the variables at the level. Both the augmented Dickey-Fuller (ADF) unit root tests and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) stationarity tests are shown. The null hypotheses for the ADF and KPSS tests are different. The ADF test examines for the presence of a unit root (that is, nonstationarity), while the KPSS test detects stationarity in the data. The unit root tests indicate that most of the variables are nonstationary in Table 3A, with two notable exceptions, namely, the growth of industrial production and the EURO STOXX stock price index, which show some presence of stationarity in both types of 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)	
	None	Intercept	Trend	Intercept	Trend
SWAP2Y	-1.28	-1.59	-0.25	1.34***	0.19**
SWAP5Y	-1.52	-1.74	-0.24	1.54***	0.20**
SWAP10Y	-1.61	-1.80	-0.34	1.66***	0.18**
SWAP30Y	-1.66*	-1.74	-0.83	1.80***	0.15**
EURO3M	-1.46	-1.90	-1.29	1.31***	0.16**
EURO6M	-1.46	-1.96	-1.41	1.27***	0.16**
HICP	-0.34	-1.73	-1.67	0.22	0.19**
CHICP	-0.41	-2.65*	-2.57	0.22	0.21**
IPYOY	-3.89***	-3.92***	-3.92**	0.04	0.04
LNEFTSE	-0.10	-2.34	-2.87	0.43*	0.19**
LNESTOXX	-0.21	-4.47***	-4.47***	0.22	0.22***
LNEURUSD	-1.17	-2.09	-1.99	0.38*	0.38***
LNNEER	1.03	-2.20	-2.58	0.98***	0.23***
LNECB	2.39	-0.37	-2.90	1.92***	0.13*

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

Table 3B shows the unit root and stationarity tests of the variables in their first difference. All of the variables become stationary at their first difference in the ADF test. However, the KPSS tests—for some swap yields in the middle of the swap yield curve—weakly rejected the null hypothesis of stationarity. Based on these tests, it is postulated that the overall picture supports stationarity at the first difference.

Table 3B: 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)	
	None	Intercept	Trend	Intercept	Trend
ΔSWAP2Y	-10.41***	-10.39***	-10.60***	0.35	0.13*
ΔSWAP5Y	-11.63***	-11.63***	-11.84***	0.39*	0.13*
ΔSWAP10Y	-11.85***	-11.87***	-12.06***	0.38*	0.13*
ΔSWAP30Y	-12.32***	-12.34***	-12.47***	0.31	0.10
ΔEURO3M	-6.27***	-6.26***	-6.41***	0.23	0.11
ΔEURO6M	-6.23***	-6.22***	-6.37***	0.25	0.12
ΔHICP	-6.23***	-6.25***	-6.25***	0.05	0.03
ΔCHICP	-5.04***	-5.03***	-4.95***	0.21	0.11
ΔIPYOY	-7.49***	-7.48***	-7.46***	0.02	0.02
ΔLNEFTSE	-13.69***	-13.67***	-13.72***	0.13	0.04
ΔLNESTOXX	-27.49***	-27.44***	-27.41***	0.11	0.04
ΔLNEURUSD	-12.24***	-12.22***	-12.27***	0.16	0.05
ΔLNNEER	-13.10***	-13.14***	-13.13***	0.08	0.06
ΔLNECB	-6.40***	-6.90***	-6.89***	0.07	0.06

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

SECTION III: EMPIRICAL MODELS AND FINDINGS

The ARDL cointegration technique is an appropriate approach for modeling the dynamics of macroeconomic variables with variables that are integrated of different orders: I(0), I(1), or a combination of both. This approach is robust when there is a long-run relationship between the underlying variables. Based on the unit root and stationarity tests undertaken above, which show that the variables under consideration are a combination of I(0) and I(1), the ARDL approach is applied for modeling the EUR interest rate swap yields.

The main results are displayed in Tables 4 and 5. Models for swap yields of all four maturity tenors are estimated. The swap yields are modeled as a function of the short-term interest rate, inflation or core inflation, the growth of industrial production, the month-over-month percentage change in the equity price index, the month-over-month percentage change in the exchange rate, and the month-over-month percentage change in the ECB's balance sheet.

Table 4 shows estimations using the 3-month euro interbank offer rate, which is the main variable of interest. The shorter swap yield models exhibit ARDL (2,2) lags. The 3-month euro interbank rate has a longer lag for the 30-year swap model. In all models with four different maturity tenors of swaps, the 3-month euro interbank offer rate affects the swap yield positively and significantly. In particular, a 100-basis point increase in the 3-month euro interbank offer rate increases swap yields by 94 basis points for 2-year term swap yields and 31 basis points for the 30-year term, indicating that the effect declines with higher maturity terms for the swaps, where short-term rates have less impact on longer-term swap yields. In addition, the models show significant lagged effects of the 3-month euro interbank offer rate at various lags on the different maturities of swap yields. The models also exhibit up to two lagged dependent variables that affect the swap yields for all maturities.

The long-term relationship between the 3-month euro interbank offer rate and the swap yield is also examined. The long-run relationships at different maturities are significant and do not vary much from the front end to the back end of the EUR swap yield curve. In particular, the long-term relationship varies from the 2-year maturity term to the 30-year maturity, respectively, from

87 to 77 basis points. The rate of adjustment—for any shock to the long-run relationship between the 3-month euro interbank offer rate and the swap yield—is very long and differs significantly for different maturities, dissipating in around 12.5–33.3 months. Among the control variables, core inflation and the growth of industrial production have a positive but weak effect on the swap yield. A higher level of core inflation is associated with a higher swap yield. Likewise, a rise in industrial production is associated with a higher swap yield.

Post-model information and diagnostics tests are presented in the bottom panel of Table 4. The adjusted R^2 shows a high degree of explanation for variances in the swap yield by the 3-month Treasury bill rate and its lags, as well as the autoregressive variables. The Akaike Information Criterion (AIC) also shows a good fit for all models. The joint-significance tests for all models show a strong rejection of the insignificance of the regressors. The Durbin-Watson statistics and Breusch-Godfrey LM tests indicate there is no serial correlation in the error terms in these modes. The Breusch-Pagan-Godfrey heteroskedasticity tests fail to reject the null hypothesis of homoscedasticity in all models, indicating no presence of heteroskedasticity. The Jarque-Bera tests indicate that the error terms are normally distributed in all models for all swap term lengths. The Ramsey RESET tests indicate that all the models are well specified. The CUSUM and CUSUMSQ tests showed that all the models are stable in both intercept and regression error variances; these models for all four maturity terms are available upon request.

Table 4: ARDL (p, q) Model (with EBOR3M and CORE HICP)

	SWAP2Y (2,2)	SWAP5Y (2,2)	SWAP10Y (2,2)	SWAP30Y (2,3)
	Main equation			
EBOR3M	0.94*** (0.00)	0.74*** (0.00)	0.51*** (0.00)	0.31*** (0.00)
EBOR3M(-1)	–1.29*** (0.00)	–1.16*** (0.00)	–0.82*** (0.00)	–0.35** (0.04)
EBOR3M(-2)	0.41*** (0.00)	0.45*** (0.00)	0.34*** (0.00)	–0.16 (0.42)
EBOR3M(-3)				0.22** (0.03)
SWAP*i*Y(-1)	1.16*** (0.00)	1.22*** (0.00)	1.25*** (0.00)	1.20*** (0.00)
SWAP*i*Y(-2)	–0.24** (0.01)	–0.25*** (0.00)	–0.28*** (0.00)	–0.23*** (0.00)
CORE HICP	0.01 (0.32)	0.02 (0.33)	0.01 (0.26)	0.01 (0.25)
IPYOY	0.001 (0.61)	0.001 (0.50)	0.001 (0.46)	0.002 (0.22)
ΔLNEXSTOXX	0.07** (0.02)	0.06** (0.01)	0.05** (0.01)	0.07** (0.02)
ΔLNEURUSD	0.25 (0.59)	0.13 (0.78)	0.02 (0.95)	0.35 (0.47)
ΔLNECB	–0.59** (0.02)	–0.34 (0.15)	–0.24 (0.32)	–0.55* (0.07)
Intercept	0.02 (0.44)	0.01 (0.52)	0.02 (0.44)	0.03 (0.24)
	Cointegrating relationship			
Long-term coefficient	0.87*** (0.00)	0.77*** (0.00)	0.73*** (0.00)	0.77*** (0.00)
Rate of adjustment	–0.08*** (0.00)	–0.04*** (0.00)	–0.03*** (0.00)	–0.03*** (0.00)
	Model information			
Obs.	283	283	283	282
Adj R^2	0.99	0.99	0.99	0.99
AIC	– 1.23	– 1.06	– 1.11	– 1.09
	Diagnostic tests			
Joint significance F-test	5581.62 (0.00)	4775.01 (0.00)	4807.35 (0.00)	4115.17 (0.00)
Serial correlation Durbin-Watson stat	2.01	1.98	1.97	2.00
Serial correlation Breusch-Godfrey LM test	0.29 (0.75)	1.91 (0.15)	2.16 (0.14)	0.52 (0.60)
Heteroskedasticity Breusch-Pagan-Godfrey test	6.30 2(0.00)	7.02 (0.00)	5.64 (0.00)	1.77 (0.06)
Normality test Jarque-Bera stat	401.87 (0.00)	129.02 (0.00)	56.35 (0.00)	24.97 (0.00)
Ramsey RESET test	3.78 (0.02)	1.16 (0.31)	0.28 (0.77)	0.24 (0.79)

Note: *p*-values are in parenthesis. ***, **, and * implies statistical significance at 1 percent, 5 percent, and 10 percent, respectively. BG LM is with 2 lags and Ramsey RESET test is fitted with 2 terms.

Table 5 shows models with 6-month euro interbank rate (instead of the 3-month euro interbank rate) on different swap-yield maturities. The lags of the ARDLs are similar to the models with the 3-month euro interbank rate. The model also examines the robustness of Table 4's results using different control variables, such as total inflation rate instead of core inflation, FTSE Euro 100 Index instead of EURO STOXX Index, and nominal effective exchange rate instead of euro–dollar exchange rate. The results are very similar to those presented in Table 4. The impact of the 6-month euro interbank rate on different maturities of swap yields is generally larger than the 3-month rates. The one-lag impact of the euro interbank rate on swap yields is negative and followed by a positive second-lag impact. Similar to the results in Table 4, the autoregressive lags are positive in the first lag and negative in the second; the autoregressive lags exhibit an identical impact on the swap yields.

The long-term relationship for models with the 6-month euro interbank rates is positive and a little higher than the 3-month rate. However, the rate of adjustment to a shock to the long-term relationship is very similar for both the 3- and 6-month rates on swap yields. Among the control variables, inflation and growth in industrial production have no impact, while the percentage change in the FTSE Euro Index affects the different maturities of swap yields positively. The percentage increase in the nominal effective exchange rate has a positive effect on swap yield, but it is not statistically significant. A percent increase in the ECB's total assets has a negative effect on swap yields, but it is not always statistically significant.

Similar to the post-estimation results reported in Table 4, the models displayed in Table 5 for different maturities of swap yields and the 6-month euro interbank rate also show a good fit as per the adjusted R^2 and AIC. The Durbin-Watson test and Breusch-Godfrey tests show the presence of no serial correlation. The Breusch-Pagan-Godfrey heteroskedasticity test also yields no support for nonconstant standard deviation in the error term. The Jarque-Bera test exhibits a similar conclusion as in Table 4. Ramsey RESET tests suggest that the estimated models are specified correctly. The CUSUM and CUSUMSQ tests for the models in Table 5 are available upon request.

Table 5: ARDL (p, q) Model (with EBOR6M and HICP)

	SWAP2Y (2,2)	SWAP5Y (2,2)	SWAP10Y (2,2)	SWAP30Y (2,3)
	Main equation			
EBOR6M	1.12*** (0.00)	0.91*** (0.00)	0.64*** (0.00)	0.38*** (0.00)
EBOR6M(-1)	–1.56*** (0.00)	–1.45*** (0.00)	–1.05*** (0.00)	–0.44** (0.02)
EBOR6M(-2)	0.52*** (0.00)	0.57*** (0.00)	0.43*** (0.00)	–0.19 (0.38)
EBOR6M(-3)				0.27** (0.02)
SWAP*i*Y(-1)	1.11*** (0.00)	1.21*** (0.00)	1.24*** (0.00)	1.18*** (0.00)
SWAP*i*Y(-2)	–0.19** (0.02)	–0.25*** (0.00)	–0.27*** (0.00)	–0.21*** (0.00)
HICP	0.01 (0.25)	0.01 (0.31)	0.01 (0.27)	0.01 (0.22)
IPYOY	0.003 (0.78)	0.0003 (0.76)	0.0002 (0.83)	0.001 (0.32)
ΔLNEFTSE	0.58** (0.01)	0.42* (0.06)	0.30 (0.21)	0.69*** (0.00)
ΔLNNEER	1.11* (0.06)	0.93 (0.16)	0.50 (0.48)	0.71 (0.36)
ΔLNECB	–0.47** (0.02)	–0.24 (0.19)	–0.18 (0.38)	–0.47* (0.06)
Intercept	0.01 (0.60)	0.01 (0.52)	0.02 (0.37)	0.02 (0.36)
	Cointegrating relationship			
Long-term coefficient	0.92*** (0.00)	0.86*** (0.00)	0.80*** (0.00)	0.89*** (0.00)
Rate of adjustment	–0.08*** (0.00)	–0.04*** (0.00)	–0.03*** (0.00)	–0.03*** (0.00)
	Model information			
Obs.	283	283	283	282
Adj R^2	0.99	0.99	0.99	0.99
AIC	– 1.61	– 1.28	– 1.23	– 1.19
	Diagnostic tests			
Joint significance F-test	8165.70 (0.00)	5931.54 (0.00)	5415.38 (0.00)	4567.79 (0.00)
Serial correlation Durbin-Watson stat	1.99	2.00	2.00	2.02
Serial correlation Breusch-Godfrey LM test	0.004 (0.99)	1.80 (0.17)	1.78 (0.12)	0.58 (0.56)
Heteroskedasticity Breusch-Pagan-Godfrey test	8.62 (0.00)	9.55 (0.00)	6.90 (0.00)	2.23 (0.01)
Normality test Jarque-Bera stat	319.49 (0.00)	145.35 (0.00)	71.76 (0.00)	42.21 (0.00)
Ramsey RESET test	1.25 (0.29)	0.37 (0.69)	0.17 (0.85)	0.43 (0.65)

Note: *p*-values are in parenthesis. ***, **, and * implies statistical significance at 1 percent, 5 percent, and 10 percent, respectively. BG LM is with 2 lags and Ramsey RESET test is fitted with 2 terms.

SECTION IV: CONCLUSION

The econometric models estimated in this paper reveal that the short-term interest rate has a statistically significant and economically meaningful positive effect on the *level* of swap yields across the EUR swap yield curve. The effect is greater on the front end of the swap yield curve than on its back end. Nevertheless, the positive effect of the short-term interest rate applies to swap yields across the whole EUR swap yield curve, though the effects vary across the yield curve. Moreover, alternative choices of independent variables show that the findings are quite robust and that the results are not dependent on 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 that are critical for households, firms, and governments. The paper's findings suggest that Keynes's views about the relationship between the short-term interest rate and long-term interest rate holds for EUR swap yields. Recent econometric studies of swaps and government bonds denominated in various hard currencies (such as USD, JPY, and GBP) and several emerging market currencies (such as CNY, INR, and CLP), some of which were 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 on private fixed-income securities, such as swaps.

Akram and Mamun's (2023e) recent study has shown that a *change* in the short-term interest rate affects the monthly change in EUR swap yields, while this study confirms that the positive relationship between short-term interest rates and long-term swap yields applies to the *level* of 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 that Keynes's assertion applies not just to long-term government bond yields but also to long-term market interest rates, such as EUR swap yields. The findings reported in this study are very much in concordance with the empirical patterns observed elsewhere and reported in previous studies for USD, GBP, JPY, CNY, CLP, and INR swap yields.

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