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The Role of Eonia in the Dynamics of Short-Term Interbank Rates

Summary: To signal monetary policies and market expectations, we apply a fractionally cointegrated vector autoregressive (FCVAR) model, aiming to analyse the expectations hypothesis of term structure (EHTS), persistence in the Euro OverNight Index Average (Eonia) spread and permanent-transitory decomposition using a novel approach. We use a monthly frequency sample for the 3-month Euribor rate and Eonia rate, covering the period from January 1999 to February 2019. The results obtained confirm the EHTS and show evidence of a high persistence of the spread, which means that shocks may impede effectiveness in monetary policy and that the European Central Bank (ECB) loses control over interest rates. Additionally, according to permanent-transitory decomposition, we determine that the Eonia rate has a permanent component and thus dominates the common trend in the cointegration system. In sum, if the ECB wants to keep the interbank market interest rates under control, it must contemplate the evolution of the Eonia rate.

Key words: Eonia rate, Long memory and fractional cointegration, Euribor rate, Persistence of interest rates, Permanent-transitory decomposition.

JEL: C22, E52, G15.

Interest rates play an important role in the monetary policy defined by central banks, joining the short- and longer-term interest rates to predict the behaviour of the financial markets and the economy. In particular, the term structure has long been established as reflecting economic agents' anticipation of future events and an indicator for policy makers, as evidenced by the volume of academic literature over the past century dealing with the term structure (see Kenneth R. Vetzal 1994, for a survey).

According to this framework, the financial environment is competitive, and the term structure should move in assembly with the predictions of the expectations hypothesis of term structure (EHTS); thus, returns respond to international market forces, and considering the term structure of interest rates has always been viewed as crucial to assess the impact of monetary policy and its transmission mechanism. Indeed, Ben S. Bernanke and Alan S. Blinder (1992) supported that this relationship between short- and longer-term interest rates implies that their spread contains significant information on future changes in short-term rates and plays an important role in the potential effectiveness of monetary policy. Filippo Cossetti and Francesco Guidi (2009) denote that the actions of the European Central Bank (ECB) in monetary policy do not have substantial effects on the yield curve, and Dieter Nautz and Jan Scheithauer (2011) indicate that the monetary policy design determines the strength of the relation between the overnight rate and the central bank's policy rate.

In this context, we apply the fractionally cointegrated vector autoregressive (FCVAR) model combined with permanent-transitory (PT) decomposition (Jesus Gonzalo and Clive W. J. Granger 1995). We test for the existence of a long-run relationship between short- and long-term interest rates, as combined spread persistence, and also provide evidence that interest rate has the dominant position in the common trend. The paper is structured as follows. Section 1 presents the literature selected. Section 2 introduces the data selected and the econometric strategy as well as the methodology used to determine the results, which are shown in Section 3. Finally, in Section 4, we summarize and establish the conclusions.

1. Literature Review

This body of literature has been supported by the EHTS, which consists of the study of this linkage among overnight rates and short-term rates to explain the monetary policy in the Eurozone, establishing that longer-term interest rates are determined by the expected short-term rates plus a constant term and thus that both interest rates show a long-run relationship (see John Y. Campbell and Robert J. Shiller 1987). In other words, if the EHTS is confirmed, the spread is a predictor of the changes in the relationship (N. Gregory Mankiw, Stephen M. Goldfeld, and Shiller 1986; Campbell and Shiller 1991; Campbell 1995). In this sense, the vast literature has focused on the study of the EHTS, assuming that the spread follows a stationary process as a condition to contrast this issue. Nevertheless, there are authors who have countered this assumption about the possible non-stationarity or persistence of the spread but obviating the existence of the EHTS.

In this regard, Bernanke and Blinder (1992) supported that this relationship among short- and longer-term interest rates implies that their spread contains significant information on future changes in short-term rates and plays an important role in the potential effectiveness of monetary policy, which consists of the control of the short-term policy rate by central banks; the economy is affected by monetary impulses through long-term interest rate movements. More recently, Uwe Hassler and Nautz (2008) have revealed an important result: they expose that if the persistence of the Euro OverNight Index Average (Eonia) spread is too high, it means that the central bank would lose control over interest rates due to the perdurable impact of shocks, avoiding the signalling role of the Eonia rate. For its part, Cossetti and Guidi (2009) denote that the actions of the ECB in monetary policy do not have substantial effects on the yield curve. Tobias Linzert and Sandra Schmidt (2011) analyse how a reduction in liquidity could alleviate pressure on the Eonia spread according to the monetary policy designed, and Nautz and Scheithauer (2011) indicate that the monetary policy design determines the strength of the relation between the overnight rate and the central bank's policy rate. In this line of research, the linkage among short-term interbank interest rates in European banks, i.e., the Eonia and the 3-month Euribor rates, to study the persistence of the spread due to the importance of market expectations of the European monetary policy attitude in the near future, has been recently established by Ansgar Belke, Joscha Beckmann, and Florian Verheyen (2013). Furthermore, according to Go Tamakoshi and Shigeyuki Hamori (2014), the Eonia rate plays a crucial role in signalling the target of monetary policy, while the Euribor rate provides outstanding interest rates for various financial products, i.e., the 3-month Euribor rate is used because it has been a focus in recent studies of interbank money markets. Finally, Achim Hauck and Ulrike Neyer (2014) explain how the Eurosystem's liquidity measures to reactivate the interbank market could conflict with aims from the monetary policy perspective and financial stability perspective. Our empirical setup for the analysis of the dynamics in the relationship between the overnight rate and the short-term interest rates is given. Carla Soares and Paulo M. M. Rodrigues (2013) warn that changes in official interest rates impact banks' funding costs and bank loans' interest rates. In this sense, they also support that given that central bank reference rates are transmitted along the yield curve and other asset prices, the central bank can influence investment and consumption decisions and, ultimately, consumer prices. Furthermore, bearing in mind the dynamics between these two interest rates is of crucial importance for the implementation of monetary policy by the ECB since one of its main objectives is to influence the interest rates in the short-term in the interbank money market (Hassler and Nautz 2008).

According to the previous scenario, one of the main results regarding these policy implications of spread persistence has been shown by Nuno Cassola and Claudio Morana (2008), Hassler and Nautz (2008), and Nautz and Scheithauer (2011) in Europe. They reveal that the Eonia spread is I(0) before but fractionally integrated with long memory when the order of fractional integration d has increased to approximately 0.25. Since $d < 0.5$, the Eonia is still under the ECB's control. Additionally, the increased persistence of the Eonia spread suggests that the degree of controllability of the Eonia spread may have declined, while Ulrike Busch and Nautz (2010) estimated a long memory process and found that the persistence of deviations in longer-term money market rates from the European Central Bank's policy rate has decreased, implying that monetary policy has become more effective in controlling interest rates. Overall, in relation to having control of monetary policy, another strand of the literature has focused on PT decomposition (Gonzalo and Granger 1995) to explain the information contained in the common trend, which is useful in the long-run and for expectations about the course of government policies, i.e., to identify and estimate the common trend that drives the cointegrating relation between the interest rates. One first application of this methodology is by Rik W. Hafer, Ali M. Kutan, and Su Zhou (1997), who demonstrated that German term structure occupies a dominant position in the future European Monetary Union (EMU).

The FCVAR model has been employed in reference to financial markets and political economics. Massimiliano Caporin, Angelo Ranaldo, and Paolo Santucci de Magistris (2013) applied the FCVAR model on high and low prices to predict stock prices. For its part, Eduardo Rossi and Santucci de Magistris (2013) applied this methodology to study the relationship between spot and futures markets, and Maggie E. C. Jones, Morten Ørregaard Nielsen, and Michał Ksawery Popiel (2014) checked the fractional long-run relationship between Canadian political support and macrovariables. Additionally, Sepideh Dolatabadi, Nielsen, and Ke Xu (2016) and Dolatabadi et al. (2018) applied the FCVAR model for the analysis of price discovery in commodity markets, and more recently, Leandro Maciel (Forthcoming) modelled and forecasted daily high and low asset prices. Few studies in the literature have addressed the application of this methodology in the interest rates. Such studies are Mirko Abbritti et al. (2018), who studied the US term premium under fractional cointegration conditions, and Luis A. Gil-Alana and Hector Carcel (Forthcoming), who performed the same for exchange rates. This methodology is useful in that it allows us to test for cointegration between interest rates of different maturities and spread stationarity simultaneously, unlike what is possible with the traditional cointegration method; with the traditional method, different studies have executed this exercise separately.

This paper is novel in this body of literature in that it recognizes that the premises of standard cointegration testing (I(1)/I(0) dichotomy) time series variables, integrated at order one and comoved at order zero, are too restrictive, i.e., linear combinations of I(1) non-stationary processes are I(0) stationary. In this sense, the empirical literature has shown that many economic and financial time series hold long-range dependence in the autocorrelation function but do not precisely exhibit a unit root process, i.e., the long memory process. For this reason and according to our research, we reject traditional cointegration assumptions that all interest rates cannot move away from one another for long periods of time and that they are unit roots or I(1); they follow dichotomy I(0)/I(1), such that they follow a fractional process I(d). We also discard the notion that the error term follows a stationary process, I(0) (in line with Gabriel Pérez Quirós and Hugo Rodríguez Mendizábal 2006 or Nautz and Christian J. Offermanns 2007, who assume that the Eonia spread is stationary) in cases of the cointegration of both variables. In turn, the rigidity of the traditional approach is overcome in favour of allowing for the series to be cointegrated, and the error term does not necessarily need to be I(0); for example, we allow for the error term to be cointegrated in order I(d – b), unlike other techniques, which assume that the error term is I(0). To the best of our knowledge, the relationship between shorter- and longer-term interest rates follows a I(0)/I(1) process; however, fractional cointegration may refute this assumption such that, in the presence of a unitary long-run relationship between interest rates with different maturities, shocks that affect this cointegration relationship can be long-lived and even non-stationary. Indeed, the study of the long-run relationship and the behaviour of the error term may be analysed jointly, which is one of the main advantages of this methodology. Therefore, our new approach uses the FCVAR model developed by Søren Johansen and Nielsen (2012) and Nielsen and Popiel (2016), which is an expansion of the traditional cointegrated vector autoregressive (CVAR) model proposed by Johansen (1995), enabling us to establish the number of equilibrium relations *via* cointegrating rank testing to estimate memory parameters, long-run cointegrating relations with adjustment parameters, and short-run lagged dynamics. In this respect, our purpose is to analyse the dynamics of the short-term side of the yield curve, i.e., the relationship between Eonia rate and short-term interbank rates (Euribor rate) as well as the repercussion that the behaviour of the spread between both interest rates may affect the monetary policy and its implications simultaneously. Overall, the FCVAR model allows for several scenarios not considered until now to be determined. Finally, using PT decomposition, we provide evidence that the interest rate has the dominant position in the common trend.

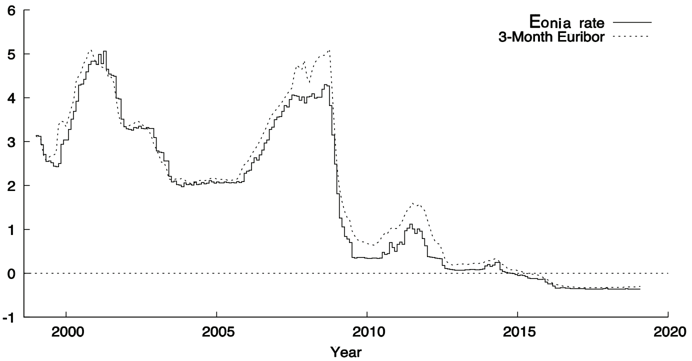
2. Data and Econometric Approach

For our empirical analysis, we employ a monthly sample of short-term interest rates of the Eurozone over the period from January 1999 (this is the date that the euro currency was introduced) to February 2019 (totaling 242 observations for each interest rate series). The data correspond to the 3-month Euribor (R_t) interest rate and Eonia (r_t) rate measured in percentages. Euribor is the rate at which euro interbank term deposits are offered by one prime bank to another prime bank within the EMU zone and is based on market criteria that include those banks that adequately reflect the diversity of the euro money market. Meanwhile, the Eonia rate is the 1-day interbank interest rate for the Eurozone, and it is computed as a weighted average of all overnight unsecured lending transactions in the interbank market. In other words, it is the rate at which banks provide loans to each other with a duration of one day. Therefore, the Eonia rate could be considered the 1-day Euribor rate. The data are collected from the Eurostat (2017)[1] website. First, it should be noted that these interest rates were chosen because, following the study by Tamakoshi and Hamori (2014), on the one hand, the ECB Governing Council is responsible for regulating the official interest rates in the Eurozone, which operates as a benchmark for interbank market interest rates. This agrees with the first step of the monetary policy transmission mechanism (Cossetti and Guidi 2009). According to the EHTS, the long-term interest rate should reflect the contemporary level of the very short- or short-term interest rate and its expectations over the maturity of the long-term investment. Consequently, it is the shortest maturity interest rate, i.e., the overnight interest rate, and the expectations on this rate that establish the remaining interest rates. It is important to appreciate how the Eurosystem stimuluses the market interest rate, i.e., the Eonia rate plays a benchmark role in the Eurozone (Soares and Rodrigues 2013). In this sense, the Eonia rate not only contains information on market expectations about the position of monetary policy in the near future but also anchors interest rates of greater maturity, and as it has been contended, the ECB influences short-term rates such as the 3-month Euribor rate by monitoring the Eonia rate, which should shift nearby main refinancing operations (MRO). Furthermore, Cossetti and Guidi (2009) show that the Eonia rate is highly correlated with the monetary policy rate, i.e., the Eonia rate could be a proxy for the monetary policy rate. On the other hand, Euribor rates are also important because they provide leading interest rates for various financial products, including interest and futures rate swaps. Euribor rates, such as the 3- and 6-month Euribor rate, which are widely used as an index for interest rates on bank loans in several Eurozone countries, are influenced by expectations of shorter-term interest rates and by liquidity and credit risk premium. Therefore, a change in official interest rates may affect the funding costs of banks and interest rates of bank loans.

As a preview of the variables selected, Figure 1 presents a graphical analysis of the time series dynamics plotted for the Eonia rate and 3-month Euribor rate. This plot shows a similar behavior in both variables that could confirm our subsequent results. In fact, the fluctuations in the Eonia rate suggest liquidity conditions that are

[1] **Eurostat.** 2017. Eurostat Products Datasets. http://ec.europa.eu/eurostat/product?code=IRT_ST_M&mode=view (accessed March 31, 2017).

temporarily relaxed or restrictive on the money market. Table 1 shows the descriptive analysis associated with each interest rate. Both rates show similar values for the different measures. For instance, in terms of volatility, as we can see, both interest rates exhibit a very similar behavior.



Source: Own elaboration.

Figure 1 Time Series Plotted for Used Variables

Table 1 Descriptive Statistics for the Options Data

	Mean	Median	Minimum	Maximum	Standard deviation
3-month Euribor rate	1.835	1.985	-0.330	5.110	1.726
Eonia rate	1.626	1.535	-0.360	5.060	1.676

Notes: The data sample covers from January 1999 to February 2019.

Source: Own elaboration.

Our empirical procedure consists of several steps. On the one hand, we apply the FCVAR model proposed by Johansen (2008a, b) and Johansen and Nielsen (2012), aiming to contrast the EHTS and the possible existence of spread persistence. On the other hand, we study PT decomposition (Gonzalo and Granger 1995) to determine which interest rate drives the common trend.

To test the EHTS in the context of cointegration theory, the commonly linear model is as follows:

$$R_t = c + \beta r_t + \varepsilon_t. \tag{1}$$

According to Campbell and Shiller (1987), R_t and r_t should be non-stationary and related through a cointegration relationship with parameters (1, -1). These results imply that β_R and β_r are the cointegrated constants and that their combination is a stationary process, and the spread of the interest rate follows a mean-reverting process. If the spread is stationary, the short- and long-term rates are driven by a common stochastic trend and do not allow for arbitrage opportunities because market forces adjust to correct any temporary disequilibrium.

2.1 FCVAR Model

The model is a generalization of Johansen's (1995) CVAR model to allow for fractional processes of order d that cointegrate to order $d - b$. This model has the advantage of being used for stationary and non-stationary time series and is presented by Johansen (2008a, b) and further developed by Johansen and Nielsen (2012) and Nielsen and Popiel (2016).

As always, ε_t is p-dimensional independent and identically distributed with a mean of zero and covariance matrix Ω. The parameters α and β are p x r matrices, where $0 \leq r \leq p$. In matrix β, the columns are the cointegrating relationships, and $\beta' X_t$ assumes the existence of a common stochastic trend, which is integrated of order d, and the short-term parts from the long-run equilibrium are integrated of order $d - b$; however, if $d - b < 1/2$, then it is asymptotically a zero-mean stationary process. The coefficients in α correspond to the speed of adjustment until equilibrium. Therefore, $\alpha\beta'$ is the long-run adjustment, ρ' is the restricted constant term, Γ_i represents the short-run behaviour of the variables, and the fractional difference operator introducing persistence in the model is Δ. Meanwhile, the fractional lag operator is $\Delta = (1 - L)$. Replacing lags operators with their fractional counterparts Δ^b and $\Delta^b = (1 - L_b)$, we obtain the final model:

$$\Delta^d X_t = \alpha\beta' L_b \Delta^{d-b} X_t + \sum_{i=1}^{k} \Gamma_i \Delta^b L_b^i Y_t + \varepsilon_t. \quad (2)$$

When the vector autoregressive (VAR) model is in the case of $d = b = 1$ (CVAR), X_t is integrated of order d, and b means the strength of the cointegrating relationships (as the value of b is higher, the persistence is lower in the cointegrating relationships). The error correction term (ECT) is integrated of order $(d - b)$, that is, I(0) in this case. However, in fractional cointegration, these axioms are relaxed because $(d - b) = 0$, i.e., the ECT shows a short-run stationary behaviour, or $(d - b) > 0$, i.e., there is a long memory process, and the ECT will revert in the long-run.

Johansen and Nielsen (2012) show that the maximum likelihood estimators (d, α, Γ_i, …, Γ_k) are asymptotically normal and that the maximum likelihood estimator of (β, ρ) is asymptotically mixed normal.

To determine the number of stationary cointegrating relations, we follow the hypotheses in the rank test based on a series of likelihood-ratio (LR) tests. In the FCVAR model, we test the hypothesis H_0: $rank(\Pi) = r$ against the alternative H_1: $rank(\Pi) = p$. $L(d, b, r)$ is the profile likelihood function given a rank r, where (α, β, Γ) have been reduced by rank regression (see Johansen and Nielsen 2012), and the profile likelihood function given rank r is $L(d, r)$, where the parameters (α, β, ρ, Γ) have been excluded.

Maximizing the profile likelihood distribution under both hypotheses, the LR test statistics are now $LR_t(q)$. The asymptotic distribution of $LR_t(q)$ depends on the parameter b and on $q = n - r$. James G. MacKinnon and Nielsen (2014), based on their numerical distribution functions, provide asymptotic critical values (CV) of the LR rank test. In the case of "weak cointegration", i.e., $0 < b < 1/2$, $LR_t(q)$ has a standard asymptotic distribution, $LR_t(q) \xrightarrow{D} \chi^2(q^2)$.

According to the existing literature, cointegration implies a fractional vector error correction model (FVECM) such as the following:

$$\begin{pmatrix}\Delta R_t \\ \Delta r_t\end{pmatrix} = \begin{pmatrix}\alpha_R \\ \alpha_r\end{pmatrix}(R_{t-1} - \beta r_{t-1} - c) + \sum_{i=1}^{n} \Gamma_i \begin{pmatrix}\Delta R_{t-i} \\ \Delta r_{t-i}\end{pmatrix} + \begin{pmatrix}w_{1t} \\ w_{2t}\end{pmatrix}, \quad (3)$$

with adjustment parameters α, cointegration coefficient β, restricted constant (c), lag length (n) and errors w. Γ_i are 2 x 2 parameter matrices in the short-run dynamics. The adjustment coefficients α_R and α_r capture the speed of adjustment of R_t and r_t towards equilibrium.

2.2 PT Decomposition in the FCVAR Model

According to Gonzalo and Granger's (1995) PT decomposition, we let $X_t = (R_t, r_t)'$, where R_t and r_t denote the 3-month Euribor rate and Eonia rate, respectively. In PT decomposition, X_t can be decomposed into a transitory (stationary) part, $\beta' X_t$, and a permanent part, $W_t = \alpha'_\perp X_t$, where $\alpha'_\perp \alpha = \alpha' \alpha_\perp = 0$. W_t is the common permanent component of X_t, and it is interpreted as the dominant rate, where the information that does not affect W_t will not have a permanent effect on X_t. To determine which parameter contributes to each market (Eonia and Euribor), we attend to the key parameter $\alpha_\perp$. Following the mirror hypothesis, the linear hypothesis on $\alpha_\perp$ can also be tested directly on $\alpha_\perp$ or alternatively on α itself using the values of the LR tests in each hypothesis, and critical values can be taken from the χ^2 distribution for testing. For example, to test the hypothesis that the dominant rate is the 3-month Euribor rate, i.e., $\alpha_\perp = (0, a)'$, we can equivalently test the mirror hypothesis, H_0: $\alpha = (\gamma, 0)'$. Similarly, to test the hypothesis that the dominant rate is the Eonia rate, i.e., $\alpha_\perp = (a, 0)'$, we test the mirror hypothesis, H_1: $\alpha = (0, \gamma)'$ (see Dolatabadi et al. 2018, which first combined the FCVAR model with PT decomposition).

An interpretation of coefficient α is that an adjustment coefficient measures how disequilibrium errors could be affected by current changes in X_t. Under this interpretation, we wonder whether any coefficients in α are zeros, i.e., the variable in question is weakly exogenous. For example, under hypothesis H_1, parameter $\alpha = 0$, such that the Eonia rate does not react to the disequilibrium error, i.e., the transitory component, implying that the Eonia rate is the main contributor to the common trend.

To determine the proportion, i.e., the component share (CS) that each parameter has in the long-run relationship, we follow Richard T. Baillie et al. (2002), who notice that since $\alpha' \alpha_\perp = 0$, it may also be expressed in terms of the elements of the error correction vector α. To interpret this, we let $\alpha = (\alpha_1, \alpha_2)'$ and $\alpha_\perp \alpha = (\alpha_{\perp,1}, \alpha_{\perp,2})'$. Afterwards, $\alpha'_\perp \alpha = \alpha_{\perp,1}\alpha_1 + \alpha_{\perp,2}\alpha_2 = 0$ implies that $\alpha_{\perp,1} = -\alpha_{\perp,2}\alpha_2/\alpha_1$, and thus, CS may be expressed as:

$$CS_1 = \frac{\alpha_2}{\alpha_2 - \alpha_1}, \; CS_2 = \frac{-\alpha_1}{\alpha_2 - \alpha_1}. \quad (4)$$

In this respect, the CS for Variable 1 reflects how sensitive Variable 2 is relative to Variable 1, and *vice versa*.

Finally, in Table 2, we present the strategy followed in our empirical research. Using this strategy, we also show the questions that we try to answer from an econometric approach based on the previously developed methodology. In this sense, the first step is testing the existence of a long-run relationship between the Eonia rate and the 3-month Euribor rate, and we study whether fractional cointegration is more appropriate than standard cointegration. In the second step, we study the possible relation one to one, i.e., the cointegrating vector (1, -1); this is the existence of the EHTS. The next step consists of analyzing the adjustment coefficients; in the fourth step, we examine the fractional cointegration degree (persistence of the Eonia spread). The last step consists of applying PT decomposition to determine which interest rates "drive" the common trend.

Table 2 Strategy of Empirical Research

	Procedure	Hypotheses
Step 1	Fractional cointegration?	$\boldsymbol{H_1^d}$: Is the fractional cointegration more appropriate than traditional cointegration?
Step 2	Estimation of β	$\boldsymbol{H_1^\beta}$: Cointegrating vector is (1, -1).
Step 3	Estimation of adjustment coefficients (α_R, α_r)	$\boldsymbol{H_1^\beta} \cap \boldsymbol{H_1^{\alpha_i}}$: Euribor and/or Eonia are weakly exogenous under the restriction of the cointegrating vector (1, -1).
Step 4	Degree of spread persistence, i.e., order of integration ($d - b$)	$\boldsymbol{H_1^{d-b}}$: Is the spread a long memory process?
Step 5	PT decomposition	$\boldsymbol{H_1^\beta} \cap \boldsymbol{H_{1\perp}^{\alpha_{EUR/Eon}}} \equiv \boldsymbol{H_1^\beta} \cap \boldsymbol{H_1^{\alpha_{Eon/EUR}}}$ **(mirror):** Euribor and/or Eonia has a permanent component in the common trend.

Source: Own elaboration.

3. Results

As a preliminary step, we estimate the order of fractional integration of the interest rates. To motivate an FCVAR model, we first discuss the univariate results, observing long memory, and then, we proceed with the estimation of the fractional parameter d for each univariate series; the results are presented in Table 3. The three columns are semiparametric log-periodogram regression estimates from John Geweke and Susan Porter-Hudak (1983), computed with bandwidths $m = T^{0.4}$, $m = T^{0.5}$, and $m = T^{0.6}$. Although the semiparametric log-periodogram regression proposed by Geweke and Porter-Hudak (1983) is the most used, this method was modified and further developed by Peter M. Robinson (1995) and has been analysed by Carlos Velasco (1999) and Katsumi Shimotsu and Peter C. B. Phillips (2002), among others. The estimates are consistent with the joint estimates presented later. As we can see in Table 3, the values for d increase as the bandwidth increases, becoming a mean-reverting value of approximately 1. To test the presence of unit roots, the estimates were obtained using first-differenced data because the original series might be above 0.5, and this test requires that the results are limited to the interval $-0.5 < d < 0.5$, then adding 1 to obtain the proper estimates of d. We can also see that both results – those for the Eonia rate and 3-month Euribor rate – are very similar and in line with the results shown later.

Table 3 Univariate Analysis, Geweke Porter-Hudak (GPH) Estimates

	$m = T^{0.4}$ d	$m = T^{0.5}$ d	$m = T^{0.6}$ d
Eonia rate	0.745 (0.343)	1.028 (0.204)	1.337 (0.188)
3-month Euribor rate	0.652 (0.201)	1.130 (0.191)	1.199 (0.129)

Notes: GPH denotes the Geweke and Porter-Hudak semiparametric log-periodogram regression estimator. Standard errors are given in parenthesis beneath the estimates of d. The sample size is 242.

Source: Own elaboration.

This section presents the results obtained corresponding to the study of a fractional cointegration analysis from a multivariate perspective. First, in Table 4, the lag length selected under the Bayesian information criterion (BIC) is one; as we can see, there is evidence that the number of cointegrating vectors is also one for the Akaike information criterion (AIC).

Table 4 Lag Length Selection and Rank Test

Lags	**AIC**		**BIC**	
1	**-842.07**		**-800.20**	
2	-835.93		-780.11	
3	-835.11		-765.33	
4	-832.68		-748.95	
5	-837.73		-740.04	
6	-834.53		-722.89	
Rank	***LR*-statistics**	**CV 1%**	**CV 5%**	**CV 10%**
0	20.462	24.151	19.342	17.065
1	9.586	11.461	7.895	6.303

Notes: Bold indicates lag length order selected. The bottom of the table shows the *LR*-statistics and critical values. The sample size is 242.

Source: Own elaboration.

In the first step, we also reveal that fractional cointegration is more appropriate than traditional cointegration (H_1^d = 0.089), as shown in Table 5. To verify the EHTS, we follow the next approach. First, aiming to estimate the long-run relationship between long- and short-term rates, it can be observed that parameter β is close to 1. As we cannot reject the hypothesis that the cointegrating vector is (1, -1) (H_1^{β}), the EHTS is supported by this result, and thus, we can interpret the difference between the 3-month Euribor rate and the Eonia rate as the spread, i.e., $(R_t - r_t)$.

Analogously and even more importantly, in Table 5, we show a very interesting result about the spread persistence (Step 4); thus, we can explain the difference $(d - b)$ as the order of integration of the spread. Hypothesis H_1^{d-b} determines the degree of spread persistence, which reaches a value of 0.705. According to Table 1 in Greg Tkacz (2001), when $(d - b) = 0$, the spread follows a stationary process, and the shock duration is short-lived, i.e., this means that a shock would show a slow return towards the long-run equilibrium. If $0 < (d - b) < 0.5$, there is a stationary process, and the shock duration is long-lived; finally, if $0.5 < (d - b) < 1$, the spread follows a non-stationary process, although it is mean-reverting, and the shock duration is long-lived. This implies a long memory process, and the series demonstrates stationary but mean-reverting behavior with long-lived shock duration. As we have previously warned, the results could allow us to study the persistence of the spread due to the importance of the market expectations related to European monetary policy attitude in the near future. In this sense, according to Cassola and Morana (2008) and Hassler and Nautz (2008), if the ECB wants to direct Eonia, the order of integration of the Eonia spread should be less than 0.5. Therefore, in the latter study, the authors used another short-term rate, i.e., the key policy rate. However, in our case, we obtain a higher value than that proposed by them, which implies that there is a loss in the control of these monetary policies. In addition, our results have been obtained, including a larger time horizon, which covers a period that spans until today. In sum, Table 6 summarizes all of the abovementioned scenarios, describing the new scenarios not considered until now.

Table 5 Fractional Cointegration Test and Results

Hypothesis	LR-statistics	p-value
H_1^d	2.894	0.089
	Cointegrating vector	(1.000, -1.019)
	$\hat{d}$	1.413 (0.134)
	$\hat{b}$	0.708 (0.145)
Hypothesis	**LR-statistics**	**p-value**
H_1^{β}	0.134	0.714
H_1^{d-b}	0.705	

Notes: The top of the table shows the LR-statistics and p-values. Standard errors are in parenthesis below values of $\hat{d}$ and $\hat{b}$. Following Jones, Nielsen, and Popiel (2014), the significance level is set to 10% for exclusion. The sample size is 242.

Source: Own elaboration.

Table 6 Policy Implementations Scenarios

	Order of integration of the ECT		
Value of β	**$I(d-b) = I(0)$**	**$I(0) < I(d-b) < I(0.5)$**	**$I(0.5) < I(d-b) < I(1)$**
β = 1	The policies duration is **short-lived**.	The policies duration is **long-lived**.	The ECT follows a **non-stationary** process, although mean-reverting and policies durations are **long-lived**.

Notes: The shaded area corresponds to the best scenario for policy implementations. As β = 1, the ECT is assumed as the spread between both interest rates.

Source: Own elaboration.

The next step, according to the existing cointegration literature, consists of testing the significance of the adjustment coefficients in the joint hypothesis, $H_1^{\beta} \cap H_1^{\alpha_i}$, using an LR test, and we find that only the coefficients associated with short-term rates (α_{Eon}) are significant (Table 7), which implies that the spread has a prediction power in the behaviour of the future short-term rates, which is consistent with the EHTS.

Table 7 FVECM Results under Constrained Parameter (1, -1)

Hypothesis	LR-statistics	p-value
$H_1^{\beta} \cap H_1^{\alpha_{EUR}} \equiv H_1^{\beta} \cap H_1^{\alpha_{\perp Eon}}$	10.732	0.001
$H_1^{\beta} \cap H_1^{\alpha_{Eon}} \equiv H_1^{\beta} \cap H_1^{\alpha_{\perp EUR3}}$	0.922	0.337
α_{EUR}	-0.723	
α_{Eon}	0.160	
Component share		
$CS_{EUR}(\alpha_{\perp EUR})$	0.181	
$CS_{Eon}(\alpha_{\perp Eon})$	0.819	

Notes: In the field of hypothesis we reference the mirror hypothesis. The top of the table shows the *LR*-statistics and *p*-values. Following Jones, Nielsen, and Popiel (2014), the significance level is set to 10% for exclusion. The sample size is 242. $\alpha_{\perp EUR3}$ and $\alpha_{\perp Eon}$ are normalized such that the two elements add to one.

Source: Own elaboration.

Finally, in Step 5, referring to Table 7, where the mirror hypothesis is shown, we decompose the common trend to determine if the 3-month Euribor rate or Eonia rate drives the common trend. In our case, the 3-month Euribor rate does not contribute to the long-run rate because the parameter α_{EUR} is not zero. On the other hand, the parameter $\alpha_{Eon} = 0$, such that the Eonia rate is weakly exogenous, is a permanent component, which implies that this rate drives the common trend. Thus, movements in the Eonia rate can precipitate a change in the 3-month Euribor rate until a new common trend is established. This finding conforms to previous empirical findings proposed by Cossetti and Guidi (2009) and Tamakoshi and Hamori (2014), who support the existence of a long-run relationship between both interest rates.

Regarding PT decomposition, a shock in the Eonia rate will have a permanent (long-run) effect on Eonia and Euribor, but a shock in the 3-month Euribor rate, with no movement in the Eonia rate, is completely transitory. In addition, we found that the Eonia rate remains fixed at any change in the 3-month Euribor rate, so this change will affect the spread $(R_t - r_t)$ only through z_t (transitory component) and, therefore, will only have transitory effects. In sum, we show that the 3-month Euribor rate does not contribute to the long-run rate, so the Eonia rate is the dominant rate. This can also be interpreted as both interest rates contributing to the common trend. As we can see in the bottom of Table 7, where the component share is presented, common trend proportions are estimated at 18.1% and 81.9% for the 3-month Euribor rate and Eonia rate, respectively. Thus, we find that the Eonia rate dominates in the common trend.

4. Conclusions

It is well known that the Eonia rate plays a crucial role in signaling the target of monetary policy, while the Euribor rate provides outstanding interest rates for various financial products. In this sense, we first aimed to contrast the usefulness of monetary policies through the relationship between 3-month Euribor interest rate and the Eonia rate. Our approach using the Eonia rate could be used in the ECB's policy. In this context, Cossetti and Guidi (2009), among others, warn that the Eonia rate marks the first step of the monetary policy transmission process, and they show that the Eonia rate is highly correlated with the monetary policy rate, i.e., the Eonia rate could be a proxy of it. To complete our empirical strategy, we have analysed the Eonia spread using a novel approach, i.e., we use a FCVAR model to determine the long-run relation between these two interest rates and to find monetary policy evidence according to the persistence of the Eonia spread. We also analysed the effect of monetary policy using PT decomposition.

Accordingly, the Eonia rate acts as a useful tool for the implementation of monetary policy, which would allow for checking the correct functioning of the monetary policy transmission mechanism. In this respect, the proposal of Soares and Rodrigues (2013), who warn about the usefulness of the 3-month Euribor to contrast the real effects of changes in rates on the real economy, is recalled. Essentially, the measure of a short-term rate *versus* a very short-term rate would allow for testing the validity of the EHTS; the EHTS argues that different types of maturities are related to each other. Regarding this, the FCVAR model is the only technique that permits the testing of the relationship between interest rates with different maturities, which could be long memory and even non-stationary, providing a novel set of results on this topic. In addition to measuring the long-run relationship and its characteristics, by using PT decomposition, the interest rate that drives the relationship is known.

Overall, our primary results support that the EHTS is confirmed, denoting a long-run relationship between the Eonia rate and the 3-month Euribor. Subsequently, and even more importantly, the spread between the Eonia rate and 3-month Euribor rate follows a non-stationary but mean-reverting process, which shows that any shock over this would be long-lived. In other words, any shock affecting this relationship will involve more extensive adjustment processes over time. The greater persistence in money market rates may further indicate that it is more difficult for monetary policy signals to be transmitted along the money market yield curve. If policy spreads are highly persistent, the lasting impact of shocks may impede the transparency of policy signals and, thus, the central bank's impact on longer-term rates, implying a gradual loss of control power over interest rates by the ECB. Thus, our political recommendation derived from these results warns that, although the ECB has monetary policy tools linked to interest rates, the transmission mechanism of these policies is not guaranteed to be immediate. Indeed, the analysis of PT decomposition reveals that the Eonia rate is the dominant rate in the relationship, i.e., it drives the common trend. This result has an important implication for policy makers because if the ECB wants to keep the interest rate under control, it must contemplate the evolution of the Eonia rate.

Going forward, future research concerning this topic might be concerned with the implications of the implementation of Quantitative Easing by the ECB in 2015. However, central banks can use rates to promote lending and prevent inflation by reducing rates. Nevertheless, the results of this measure would be very different from those of conventional credit expansion policy. In this sense, Anthony F. Herbst, Joseph S. K. Wu, and Chi Pui Ho (2014) asseverate that, after the global financial crisis, this issue occurred, known as a "reserve trap".

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