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The Interaction between American and European IRS Interest Rates

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Abstract

European interest rates movements are affected by various internal and external factors. This paper studies the link between European and American short- and long-term interest rates. In particular, we consider the forward interest rates coming from euro and dollar IRS term structures. The econometric techniques employed are co-integration, Granger-causality, OLS and GMM. Our results indicate that European remote settlement forward and long-term interest rates are primarily driven by US rates and confirm that the causality acts mainly from the US to the Eurozone. This was true even during the recent periods of European Central Bank quantitative easing. These factors weaken the ECB's ability to intervene. In fact, we found the impact of American monetary policy on long-term interest rates to be also relevant for European bonds.

Keywords: forward interest rates; euro and dollar; cointegration; causality; dynamic.

JEL classification: C51; E47; E58.

"… we have to keep in mind that there are all kinds of influences on these [interest] rates, some of which have to do with our own euro area economy and some of which have to do with external factors."
Mario Draghi[1]

1. INTRODUCTION

This paper is based on the widespread belief and widely acknowledged fact, confirmed by Mario Draghi, that when one market is integrated with another, the first market is strongly influenced by the monetary, financial, and economic policies and conditions of relevance of the second.

The aim of this paper is to analyse the presence of different links and integration between certain financial markets, and to quantify them. In particular, it presents the links between the implied forward European and American Interest Rate Swaps (IRS) from 2000 to 2016, and evaluates the ability of the European Central Bank (ECB) to steer the euro interest rates of the European market for both short-and long-term maturities. Our research

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will mainly evaluate the forward interest rates, as explained in detail in Section 5. However, it is important to note at this stage that implied forward rates constitute a key tool for investigating the properties of long-term interest rates.

According to our base model, euro implied forward interest rates can be explained by a weighted mean of the yields of the following two alternative investments: (i) the euro spot rate, and (ii) the corresponding forward interest rates in dollars.

The "settlement" or "delivery" date is fundamental: if the settlement date is close in time, the euro forward interest rate will be mainly influenced by expectations on euro short-term spot rate, which is linked to the future policy rate (Repo, the official Euro interest rate). If the settlement date is far in time, the implied forward euro interest rate is particularly affected by the corresponding forward dollar interest rate.

Our analysis is conducted in several steps. After the literature review (Section 2), an example of the problem (Section 3) and a description of the databank used in the analysis (Section 4), we describe a theoretical model showing euro market interest rate behaviour (Section 5). Next we identify the degree of integration of all variables, and evaluate whether any equilibrium relations can explain the euro interest rate (Section 6). In order to do this, we apply Johansen 's co-integration method to sets of alternative variables. Third, we test whether European rates are mainly influenced by American rates or vice versa, using Granger's causality test between American and European interest rates (Section 7). Fourth, we counter the problem of endogeneity by looking for instruments to apply to the American interest rate changes in GMM dynamic estimations of the corresponding European yields (Section 8). Finally, we use Ordinary Least Squares (OLS) and Generalized Method of Moments (GMM) to verify forward American interest rate endogeneity / exogeneity, and to estimate dynamic relationships between American and European interest rates (Section 9). A final discussion about stability and some consequences of our results are reported in Section 10 and Section 11.

The co-integration result shows that European forward interest rates with forward settlement date from five years onward have a very strong link with American forward rates, and that the Repo coefficient is not always significantly different from zero. For close settlement dates, the equilibrium level of European rates seems not to be influenced by the American forward rates, but both Repo and the Eurozone bank liquidity exert a major impact. The results of the Granger causality test show that American forward rates "Granger cause" European rates and not vice versa. However, the results of the exogeneity test applied to dynamic relationships suggest that forward American interest rates are not completely exogenous to European ones, but in any case, when settlement dates are distant, changes in American interest rates exert a very strong impact on changes in European interest rates. Of course, the strong influence of the US market makes the impact of ECB policy relatively weaker.

2. LITERATURE REVIEW

Unfortunately, there are few articles on this topic. Solnik (1974), studied market integration from the risk point of view. They expanded the traditional CAPM to become an International Asset Pricing Model. Solnik (1974) found that prices depend on market integration; they indirectly influence and are influenced by foreign market general behaviour of overseas markets /the overseas market. Their market structure model implies that the securities are priced according to international systematic risk, but it confirms strong dependence on national factors. Canova and De Nicolò (2000) analyzed the interdependencies among existing international asset returns, real activity, and inflation. They discovered that shocks originating in the US have important real and informational effects that are not observed for shocks originating in other economies. Nominal stock returns are correlated to inflation only in the USA. The US yield curve makes it possible to predict both domestic and foreign inflation, although not to predict all foreign interest rates. Responses of real and financial variables are insignificant in modifying the exchange rate. Bruneau and Jondeau (1999) examined the causal links between long-term interest rates in Germany, France, and the US, finding long-term mutual causality between US and German rates (where US rates have a large and significant effect on the German rate but not vice versa) and the rates between the German and French markets. Their analysis methods are: Error Correction Model (ECM), neutrality analysis, and long-run causality. Landschoot (2008) found that US dollar yield spreads are closely affected by changes in the level and the slope of the default-free term structure, the stock market return and volatility. Euro yield spreads are strongly affected by the US level and slope. This confirms the dominance of US interest rates in the corporate bond markets. Rosa (2008) studied Federal Reserve and ECB communication strategies, analysing the effect of monetary policy decisions on European and American yield curves. He found that the response of American long-maturity interest rates to the Fed's unexpected statements is larger than the reaction of the same European structure to ECB announcements. In particular, the surprise component of the Fed's monetary policy also has an impact on the movements of European interest rates, and the Fed influences European interest rates of all maturities. On the other hand, ECB monetary policy has no statistically significant effect on US interest rates. Neri and Nobili (2010) considered how changes in the federal funds rate introduced by the US Federal Reserve affect the euro-zone economy. The international transmission mechanism was found to work through movements in the exchange rate, commodity prices, short-term interest rates, and the trade balance. Ciner (2011) used a frequency domain method and decomposed test statistics into short-term and long-term causality measures. He found significant linkages between international interest rates. Egorov *et al.* (2011) studied the joint term structure of interest rates in the United States and the European Union. They found that a new four-factor model with two common and two local factors captures the joint term structure dynamics in the US and the EU. Altavilla *et al.* (2014) quantified the financial and macroeconomic impact of OMT (Outright Monetary Transactions) advertisements on two-year government bond yields of four European countries. OMT announcements have no impact in France and Germany, whereas Italy and Spain saw two-year government bond yields decrease by about two percentage points. Georgoutsos and Kouretas (2016) used data on interest rates from the U.S. dollar-Libor, GBP-Libor, and Euro-Libor markets with maturities ranging from 7 days to 12 months. Their main findings were (i) they did not find the rank of the cointegration space suggested by their methodology; (ii) their estimated coefficients did not suffer from instabilities in recursive estimations. Eross *et al.* (2016) analysed the interaction between the LIBOR-OIS spread, euro fixed-float OIS swap rate and the three-month US-German bond spread. They found that liquidity shocks propagating within the interbank market are useful in forecasting benchmark interest movements.

This brief literature review shows first that there is in fact a close link between American and European interest rates, and that generally the direction of causality is from the USA to the Eurozone, although not all researchers agree on this. Second, short and long-term interest rates behave differently. Our suggestion is, however, that considering interest rates with the same characteristics helps to diminish ambiguity, and a reduction in the number of explanatory variables simplifies all relations. Moreover, the heterogeneity between short and long-term maturities is better analysed by considering the implicit forward interest rate, rather than just the spot interest rate. For these reasons, our analysis is based on the American and euro interest rate swaps (IRS).

3. THE PROBLEM

The focus of this paper is to show how American interest rates influence European rates. Figures no. 1 and no. 2 present the differences between the behaviour of euro short-term (spot) interest rates and of forward rates with a distant settlement date.

Short-term interest rates are strongly influenced by the official Repo and negatively influenced by bank liquidity. In the case of a distant settlement date, the forward rate, in Figure no. 2 represented by the seven- to ten-year forward Eurirs (European Interest Rate Swap), appears neither slightly connected to Repo nor connected at all to liquidity, but follows the path of the correspondent American forward IRS (interest rate swap) return.

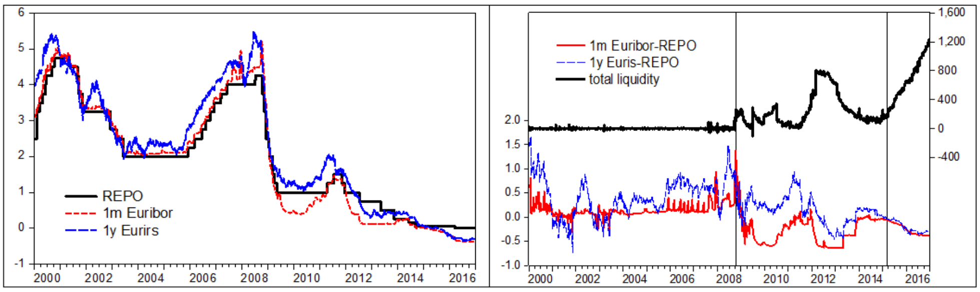


Figure no. 1 – Repo, bank liquidity and European short-term interest rates

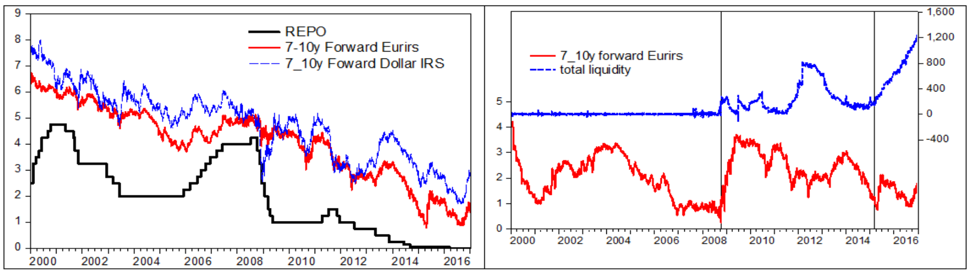


Figure no. 2 – Repo, bank liquidity, and Euro and dollar forward interest rates with distant settlement

We attempt, therefore, to answer the following questions:

- *What type of connections and integration exist between the European and American financial markets?*
- *Are European rates influenced by American rates, and thus by the decisions of the Fed, or is the opposite true*?
- *Can the ECB influence the interest rates of the market for both short-and long-term maturities?*
- *Is the European forward interest rate dynamic stable? And are GMM more efficient than OLS?*

4. DATA SET

In this research on the link between European and American markets, we considered the following daily time series data: Eurirs, dollar IRS, the correspondent euro and US forward interest rates[2], Repo, Eurozone bank liquidity, USA Treasury Bills, German bund, dummies for Fed and ECB meetings[3]. The database includes daily data including maturity from one month to 30 years, over the period from 1 January 2000 to 31 December 2016. EViews 9.5 is used as an econometrics tool. Table no. 1 shows the sources of all series, and the symbols used in this paper.

Table no. 1 – Sources of variables and their symbols used in this paper

Symbol	Definition	Source	URL
Repo	Repo	ECB	www.ecb.int
R_{km}	k-month Euribor	Euribor, EMMI	www.emmi-benchmarks.eu
Risk3	3-month Euribor Risk	Spread Euribor-Eurepo (when Eurepo was not available, risk was proxied by a constant)	Eurepo series has been discontinued
Liq	Total bank liquidity	ECB: corresponds to current account – reserve requirements + deposit facility	http://www.ecb.int/stats/monetary/res/html/index.en.html see: csv data (zipped)
$R_{€,N}$	N-year maturity Euris	Numis, Intercontinental exchange (ICE)	https://www.theice.com/marketdata/reports/180
$F_{€,k\text{-}h}$	implicit forward Euris yields with settlement in year *t+k* and expiring in year *t+h*	(our computation from $R_{€,N}$)	
$R_{\$,N}$	N-year dollar IRS	Numis, Intercontinental exchange (ICE)	
$F_{\$,k\text{-}h}$	implicit forward dollar IRS yield with settlement year in *t+k* and expiring year in *t+h*	(our computation from $R_{\$N}$)	
$RTB_{\$,N}$	N-year Treasury bonds	Fed	https://www.federalreserve.gov/datadownload/Choose.aspx?rel=H15
$FTB_{\$,k\text{-}h}$	implicit forward Treasury bonds yield with settlement year in *t+k* and expiring year in *t+h*	(our computation from $RTB_{\$N}$)	
$Bund_{10}$	10y German Bund	Bundesbank	http://www.bundesbank.de/Navigation/EN/Statistics/Time_series_databases/Macro_economic_time_series/its_details_value_node.html?tsId=BBK01.WT1010

Internet pages: last access on 31-08-2017

5. THE MODEL

According to the theory of efficient market behaviour, a market is in equilibrium when all information is properly exploited and similar asset yields tend to be equal. The behaviour of long-term rates can be explained by means of the most important alternatives on the basis of this theory.

Given a risk-free bond with duration *N*, one potential alternative consists of buying a security of maturity 1 and, simultaneously, *n-1* futures of duration 1 and settlement in *t*+1, ..., *t*+*N*-1.

$$NR_{N,t} = (R_t+F_{t+1}+\ldots+ F_{t+N-1}) \quad (1)$$

$$R_{N,t} = (R_t+F_{t+1}+\ldots+ F_{t+N-1})/N \quad (2)$$

The yield on a long-term asset with yield to maturity R_N corresponds to the average of the short-term spot interest rate *R* and a set of forward interest rates $F_{t+k,t+h}$, with settlement in $t+k$ and expiring in $t+h$. We thus concentrate our analysis to the determinants of the interest rate in the forward/future market. For the sake of simplicity we consider here only one-period maturities, i.e. $h=k+1$, and indicate the future rate as F_{t+k}.

The characteristics of long-term interest rates are derived by aggregating the interest rates of the different forward settlements. The main markets considered in this analysis are Eurirs (Interest rate swap on Euro) and dollar IRS (interest rate swaps on dollars). These markets are very important for the banking sector, and have a very low degree of risk, and thus give the advantage that it is not necessary to take into account the influence of risk on interest rates.

At the same time, the main alternatives to a euro interest forward with settlement on day $t+k$ ($F_{€,t+k}$) are: an equivalent American *1*-year interest rate future with settlement at $t+k$ ($F_{\$,t+k}$) and a spot one-year maturity asset purchased in t+k ($R_{€,t+k}$)

According to the arbitrage and efficiency conditions, the following relation can therefore be considered valid, at least as a first approximation

$$F_{€,t+k} \cong q_{1k}\,(F_{€,t+k}+E_t[C_{t+k}]) + q_{2k}\,E[R_{€,t+k}] \quad (3)$$

where q_{1k} and q_{2k} are the weights of the two alternatives (with $q_{1k}+q_{1k}$ probably of the order of 1), and where $E[C_{t+k}]$) is the expected euro/dollar exchange rate appreciation from $t+k$ to $t+k+1$.

Assuming that the exchange rate from $t+k$ and $t+k+1$ follows a sort of random path with $E_t[C_{t+k}]\cong 0$, (3) can be simplified as:

$$F_{€,t+k} \cong q_{1k}\,F_{€,t+k} + q_{2k}\,E_t[R_{€,t+k}] \quad (4)$$

The error in prediction of the spot rate becomes greater the more distant is settlement day *k*, while the error in predicting C_{t+k} is relatively constant. Thus weight q_{1k} increases when *k* increases, and the opposite holds for for q_{2k}, since greater weight corresponds to the lower risk alternative.

When considering short maturities or the nearest settlement dates, the spot and forward euro interest rates are mainly connected to the Repo, since q_{1k} becomes “very small” compared to q_{2k}. Short-term Repo expectations however depend on its present value, since Repo is “integrated” of order 1 (i.e. strongly persistent). The other relevant explanatory variable is, of course, bank liquidity, which plays a key role in determining the spread between Repo and market interest rates:

$$F_{€,t+k} \cong q_{2k}\,E_t[R_{€,t+k}] \cong E_t[\text{Repo + liquidity effect}] \quad (5)$$

When forward rates have a very distant settlement date, the corresponding dollar forward rate is the main explanatory variable. The expected policy interest rate tends, in the very long-run, to a sort of "constant", given by the two percent value of ECB inflation target plus the long-term Eurozone growth. Today's monetary policy is not relevant for long-term expectations, since, in the long run, it can change considerably. Equation 6 represents this:

$$F_{€,t+k} \cong q_{1k} F_{€,t+k} + \text{constant} \tag{6}$$

6. COINTEGRATION RESULTS

Preliminary unit root tests showed that interest rate variables are I(1) (i.e. first order integrated). The results obtained by the Augmented Dickey-Fuller test as well by the other tests available in Eviews are quite consistent.

After confirming that variables are I(1), we used the Johansen cointegration test to investigate the equilibrium relations between American and European markets.

Johansen's method was used in order to detect whether an equilibrium exists between European forward rates, Repo, and bank total liquidity (Liq) or, alternatively, between European forward interest rates, Repo, and the corresponding American forward IRS.

Three variables ($R_€$, Repo and Liq for near settlements, or $F_€$, Repo and $F_\$$ for distant settlements) were in fact sufficient to find cointegration equilibrium, so it was not necessary to consider all the four variables together.

The optimum number of lags was investigated by means of the usual tests (Table no. 2). Results suggest that the optimal number is usually from two to four.

Table no. 2 – Optimal number of lags

	Lag order selection criteria			Lag exclusion test (joint)			
	AIC	SC	HQ	1%	5%	10%	ns
$R_{€,1m}$, Repo, Liq	8	4	8	3	-	-	4
$R_{€,12m}$, Repo, Liq	8	4	8	3	-	-	4
$F_{€,1-2}$, Repo, Liq	8	3	4	3	-	-	4
$F_{€,2-3}$, Repo, Liq	8	3	4	3	-	-	4
$F_{€,2-3}$, Repo, $F_{\$,2-3}$	4	3	3	3	-	-	4
$F_{€,3-5}$, Repo, $F_{\$,3-5}$	4	3	3	3	-	-	4
$F_{€,5-7}$, Repo, $F_{\$,5-7}$	4	3	3	3	-	-	4
$F_{€,7-10}$, Repo, $F_{\$,7-10}$	6	2	3	2	-	3	4
$F_{€,10-30}$, Repo, $F_{\$,10-30}$	4	2	4	2	-	3	4

Notes: Period 2000-2016, daily data. AIC: Akaike information criterion: SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

Cointegration results are reported in Table no. 3, and lags correspond to those suggested by the SC test. Using between 2 and 4 lags, results change only slightly. Combinations of variables not reported here are not cointegrated.

Table no. 3 – Johansen Cointegration Test and Equilibrium

Variables	Lags	No. of CE(s):	Coefficients		
			Repo	US interest rate	Tot.liq/1000
$R_{€,1m}$, Repo, Liq	4	1***	1.0929 (0.0256)***	-	-0.4797 (0.1370)***
$R_{€,12m}$, Repo, Liq	4	1***	1.0675 (0.0511)***	-	-0.2148 (0.2810)
$F_{€,1-2}$, Repo, Liq	3	1***	0.9754 (0.0501)***	-	-0.9645 (0.2739)***
$F_{€,2-3}$, Repo, Liq	3	1**	0.9001 (0.0903)***	-	-1.3780 (0.4940)**
$F_{€,2-3}$, Repo, $F_{\$,2-3}$	3	1*** (^	9.3515 (1.5985)***	-8.3738 (1.2837)***	-
$F_{€,3-5}$, Repo, $F_{\$,3-5}$	3	1*** (^	-0.9690 (0.3061)**	2.2532 (0.2762)***	-
$F_{€,5-7}$, Repo, $F_{\$,5-7}$	3	1***	-0.2166 (0.12372)***	1.4338 (0.1246)***	-
$F_{€,7-10}$, Repo, $F_{\$,7-10}$	2	1***	-0.0660 (0.088)	1.1846 (0.099)***	-
$F_{€,10-30}$, Repo, $F_{\$,10-30}$	2	1***	0.0170 (0.058)	1.1156 (0.066)***	-

*Notes: Period 2000-2016, daily data. In brackets: coefficient standard deviations; (^ = No clear economic results. *** and ** indicate 1% and 5% probability of significance respectively*

For short-term maturities and near settlements, equilibria exists only between euro-interest rates, Repo, and Liquidity, with liquidity having a negative impact on euro-interest rates. For average settlement, results are not clear. For very distant settlements, forward Eurirs are mainly connected to the corresponding American forward IRS, with Repo not significant. The remainder of the paper refers *to distant settlements* because this is the our case of interest.

7. GRANGER CAUSALITY TESTS

It is widely recognized that many spurious correlations can be found in econometric estimations, and also that co-integration refers to equilibrium relations without providing a clear answer on the causal relationship between European and American rates. We thus used the Granger Causality Test to verify the connection between these variables.

"Granger causality" does not however mean "causality" in its common sense; "*x Granger causes y*" does not imply that *y* is the effect or the result of *x*. The Granger approach checks only how much of the current *y* can be explained by past values of *x*, by testing whether lagged values of *x* can make the explanation of *y* better. So *y* is said to be Granger-caused by *x* if *x* helps in predicting *y* (i.e. if the coefficients on the lagged *x*'s are statistically significant).

Our results, reported in Table no. 4, show that American forward rates "Granger-cause" European rates, but not vice-versa. See in particular the SC test. This holds at least for the most distant settlement dates, those between seven and 10 years and between 10 and 30 years.

Table no. 4 - Granger causality test between euro and US forward rates (levels).

Forward rates	Lags	Probability		Results from 'Granger causality'	
		Euro rates 'do not cause' US rates	US rates 'do not cause' Euro rates	Euro rates cause US rates	US rates cause Euro rates
5-7	2(a)	0.1188	0.0000	NO/YES	YES
	3(b)	0.0014	0.0000		
	4(c)	0.0010	0.0000		
7-10	2(a)	0.1502	0.0000	NO	YES
	3(b)	0.1853	0.0000		
	4(c)	0.1886	0.0000		
10-30	2(a)	0.0519	0.0000	NO	YES
	3(b)	0.1405	0.0000		
	4(c)	0.0282	0.0000		

Notes: Period: 2000-2016, daily data; (a)= automatically chosen lags; (b) = SC and HQ tests; (c)= LR, FPE and AIC tests.

8. EXOGENOUS INSTRUMENTS

Granger causality is just one of the methods of analysing causality, but it is not appropriate for detecting a clear relationship between two contemporaneous variables. We therefore expanded our analysis to a dynamic model considering the link between contemporary variations in $F_{€,h-k,t}$, $Repo_t$ and $F_{\$,h-k,t}$. The European forward Eurirs changes is our dependent variable, and the contemporaneous values of $\Delta Repo_t$ and $\Delta F_{\$,h-h,t}$ are included in the regression. In this case, estimators like General Method of Moments (GMM) should be employed instead of OLS, but GMM require the use of efficient "instruments" for the suspected endogenous variables, in our case $\Delta F_{\$,h-k,t}$ (this problem does not regard $\Delta Repo_t$, the ECB's exogenous policy rate).

In selecting appropriate instruments, we first used the change in the Treasury bond forward rate $\Delta FTB_{\$,h-k,t}$. American Treasury bonds (TB) are quoted in the late afternoon, while IRS bonds are priced in the morning in London, exactly at the same time as Eurirs. Movements of treasury Bonds interest rates on day *t*-1 ($\Delta FTB_{\$,h-k,t-1}$) thus tend to anticipate part of the change of American IRS's on day t, but they should not be influenced by Eurirs on day t. Other instruments, relevant on Fed meeting days, are surprises in monetary policy. In particular, surprises about the new official interest rate, and surprises about its future expected path, often related to the Fed's official communications. The former surprise can be measured by the monthly Libor interest rate change $\Delta R_{\$,1m,t+1}$), This latter type of surprise can be approximated by the change in the spread between 1-6 month forward Libor $\Delta(6R_{\$,6m.t+1}$ - $R_{\$,1m,t+1})/5$-$\Delta R_{\$,1m,t+1}$) and the monthly interest rate $\Delta R_{\$,1m,t+1.}$ (see Rosa and Verga, 2007; Rosa, 2013). Here, changes on day t+1 are considered rather than changes on t, because the impact of Fed's decision on $R_{\$,1m}$ and $R_{\$,6m}$ is known with a lag of one day (Libor is quoted in the morning, Fed's meeting are taken in the afternoon).

Table no. 5 reports a group of OLS equations for the American $\Delta F_{\$,h-h,t}$, based on the instruments to be applied change in our GMM estimations. In this analysis we considered the entire sample from 2000 to 2016, but the "last days" of the reserve requirements period were eliminated, since on those days markets are particularly unstable and volatile.

Those regressions correspond to the so-called "marginal equations" in the procedures on exogeneity of Engle and Hendry (1993), and include the instrument variables described above and their lags. Since ΔFTB treasury bond forward rates are very volatile, we found the use of a weighted mean of the three settlement interest rates to be often more efficient (Table no. 5).

Table no. 5 – "Marginal equations" of American forward interest rate changes

Dependent variable	$\Delta F_{\$,5\text{-}7,t}$	$\Delta F_{\$,7\text{-}10,t}$	$\Delta F_{€\$,10\text{-}30,t}$
equation	(1)	(2)	(3)
const	-0.0008	-0.0008	-0.0010
$(2\Delta FTB_{\$,5\text{-}7,t-1}+\Delta FTB_{\$,7\text{-}10,t-1}+\Delta FTB_{\$,10\text{-}30,t-1})/4$	0.6736***	-	-
$(\Delta FTB_{\$,5\text{-}7,t-1}+2\Delta FTB_{\$,7\text{-}10,t-1}+\Delta FTB_{\$,10\text{-}30,t-1})/4$	-	0.7252***	-
$(\Delta FTB_{\$,5\text{-}7,t-1}+\Delta FTB_{\$,7\text{-}10,t-1}+2\Delta FTB_{\$,10\text{-}30,t-1})/4$	-	-	0.5700***
$\Delta FTB_{\$,5\text{-}7,t-2}$	0.2249***	-	-
$(\Delta FTB_{\$,5\text{-}7,t-2}+2\Delta FTB_{\$,7\text{-}10,t-2}+\Delta FTB_{\$,10\text{-}30,t-2})/4$	-	0.2747***	-
$(\Delta FTB_{\$,5\text{-}7,t-2}+\Delta FTB_{\$,7\text{-}10,t-2}+2\Delta FTB_{\$,10\text{-}30,t-2})/4$	-	-	0.1619***
$\Delta FTB_{\$,5\text{-}7,t-3}$	0.1101***	-	-
$(\Delta FTB_{\$,5\text{-}7,t-3}+2\Delta FTB_{\$,7\text{-}10,t-3}+\Delta FTB_{\$,10\text{-}30,t-3})/4$	-	0.1272***	-
$(\Delta FTB_{\$,5\text{-}7,t-3}+\Delta FTB_{\$,7\text{-}10,t-3}+2\Delta FTB_{\$,10\text{-}30,t-3})/4$	-	-	0.0965***
$\Delta F_{\$,h\text{-}k,t-1}$	-0.4169***	-0.4240***	-0.3114***
$\Delta F_{\$,h\text{-}k,t-2}$	-0.2015***	-0.2031***	-0.1414***
$\Delta F_{\$,h\text{-}k,t-2}$	-0.0687***	-0.0848***	-0.0681***
$\Delta R_{\$,1m,t} \times Fed\_meeting_{t-1}$	0.2091***	0.1791***	0.1441**
$[(6\Delta R_{\$,6m,t} - \Delta R_{\$,1m,t})/5-\Delta R_{\$,1m,t}]\times Fed\_meeting_{t-1}$	0.1821***	0.1320***	0.0729***
Adj R-squared	**0.2149**	**0.2302**	**0.1879**
DW	**2.0439**	**2.0234**	**2.0284**
observations	**4232**	**4232**	**4104**

*Notes: Period 2000-2016, daily data, excluding last days of maintenance period of required reserves; HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 10.0000); *** and ** indicate 1% and 5% probability of significance respectively. Fed_meeting is a dummy with value 1 on meeting days*

All regressors are significant, which suggests that they are probably valid instruments in our GMM estimations of Euro rate dynamics.

9. EURO INTEREST RATE DYNAMIC EQUATIONS

In order to complete the study of the relevance of American on distant settlement forward rates on the same euro rates, we considered the dynamic relationship of the European interest rates. As indicated in Tables no. 2 to 5, our analysis is limited to the forward Eurirs with settlements of five to seven, seven to ten, and 10 to 30 years. Equations were estimated by means of an "error correction scheme". The dependent variable is the European forward interest rate changes, and equations are of this type:

$$\Delta F_{€,h\text{-}k,t} = a_0 + \alpha_{10}\Delta F_{\$,h\text{-}k,t} + \alpha_{20}\Delta Repo_t + b_0 F_{€,h\text{-}k,t-1} + b_1 F_{\$,h\text{-}k,t-1} + b_2 Repo_{t-1} + \alpha_{01} F_{€,h\text{-}k,t+1} \quad \alpha_{11}\Delta F_{\$,h\text{-}k,t+1} + \alpha_{21}\Delta Repo_{t-1} + \alpha_{31}\Delta Liq_{t-1} + \alpha_{02} F_{€,h\text{-}k,t-1} + \alpha_{12}\Delta F_{\$,h\text{-}k,t-2} + \alpha_{22}\Delta Repo_{t-1} + \alpha_{32}\Delta Liq_{t-2} + \dots$$

As an alternative to estimating $b_0 F_{€,h\text{-}k,t-1} + b_1 F_{\$,h\text{-}k,t-1} + b_3 Repo_{t-1}$, it would be possible to introduce the residuals of the corresponding cointegration vectors as regressors. We preferred however to estimate all single parameters b_0, b_1 and b_2 in our dynamic equation

(”direct method”). Results obtained by both methods are, anyway, very similar. (Details are available on request.) Bank liquidity variations were introduced among regressors because they might influence the European forward rate dynamic, although liquidity did not appear in the cointegration equilibrium.

Table no. 3 already suggested that the optimal number of lags is 2, 3, or 4 for variables expressed in levels. The error correction model is based on variation lags, but a variation contains one lag ($\Delta x_t = x_t - x_{t-1}$), so the corresponding optimal number of lags is 1, 2 or 3. We therefore started from three lags and dropped one coefficient at a time from our regressions, starting from the least significant, until all coefficients remained significant at least at 10 percent of probability. Once again, estimations considered the entire sample from 2000 to 2016, but the “last days” of the reserve requirements period were eliminated, since on those days markets are particular unstable. The first three equations were estimated by OLS to make a comparison with GMM results.

When non-significant variables were eliminated, changes in Repo were no longer among the regressors, apart from its value on t. The same occurred with liquidity changes: in the very few cases that lags remained significant, their sign was wrong and we eliminated the variable. Eventually, two lags of our variables were found to be sufficient for all regressions. Final results are reported in Table no. 6, equations (1)-(3).

Table no. 6 – Dynamic equations of euro $\Delta F_{€,h\text{-}k,t\text{-}1}$

Method	**OLS**	**OLS**	**OLS**	**GMM**	**GMM**	**GMM**
Dependent variable	$\Delta F_{€,5\text{-}7,t}$	$\Delta F_{€,7\text{-}10,t}$	$\Delta F_{€,10\text{-}30,t}$	$\Delta F_{€,5\text{-}7,t}$	$\Delta F_{€,7\text{-}10,t}$	$\Delta F_{€,10\text{-}30,t}$
equation	(1)	(2)	(3)	(4)	(5)	(6)
const	-0.0042	-0.0025	-0.0051	-0.0052*	-0.0024	-0.0019
$\Delta F_{\$,h\text{-}k,t}$	0.2643***	0.2563***	0.2935***	0.4446***	0.3986***	0.4105***
$\Delta Repo_t$	-0.0421**	-0.0681**	-	-0.0351*	-	-
$F_{€,h\text{-}k,t\text{-}1}$ (β_1)	-0.0041***	-0.0065***	-0.0090***	-0.0047***	-0.0062***	-0.0081***
$F_{\$,h\text{-}k,t\text{-}1}$ (β_2)	0.0035**	0.0051***	0.0076**	0.0040**	0.0048***	0.0058*
$Repo_{t\text{-}1}$ (β_3)	0.0014*	0.0019**	0.0022**	0.0020**	0.0021**	0.0033***
$\Delta F_{€,h\text{-}k,t\text{-}1}$	-0.2366***	-0.2366***	-0.1610***	-0.2586***	-0.2112***	-0.1737***
$\Delta F_{\$,h\text{-}k,t\text{-}1}$	0.2067***	0.2194***	0.2048***	0.2111***	0.2064***	0.2000***
$\Delta F_{€,h\text{-}k,t\text{-}2}$	-0.0874***	-0.0396*	-0.0551**	-0.0821***	-	-0.0543**
$\Delta F_{\$,h\text{-}k,t\text{-}2}$	0.0909***	0.0606***	0.0744***	0.0955***	0.2064***	0.0801***
Adj R-squared	0.2247	0.2083	0.1589	0.1604	0.1689	0.1423
DW	2.0457	2.0209	2.0502	2.0137	2.0804	2.0319
observations	4232	4232	4105	4232	4232	4104

*Notes: Period 2000-2016, daily data, excluding last days of maintenance period of required reserves. OLS: HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 10.0000). GMM: Generalized Method of Moments; Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed bandwidth = 10.0000); Standard errors & covariance computed using HAC weighting matrix (Bartlett kernel, Newey-West fixed bandwidth = 10.0000). ***, ** and * indicate 1%, 5% and 10% probability level of significance respectively.*

The results suggest that changes in US forward IRS always exert a positive impact on Eurirs changes, while past values of Eurirs changes have a negative effect on the present Eurirs variations. Consistently with the cointegration results, the coefficients β_3 of $Repo_{t-1}$ are smaller and often less significant than the corresponding coefficients β_2 of $F_{\$,h\text{-}k,t\text{-}1}$,. The most relevant variables impacting on forward Eurirs movements are therefore forward

American IRS. Coefficients of both the level of American IRS and Repo on *t*-1 are positive, while the coefficients of Eurirs level are negative. When the Eurirs forward rate is above its equilibrium level, it falls on the following day, indicating that equilibrium market is stable. The DW is close to two, i.e. no first order residual autocorrelation is significant. The coefficients β_1 of $F_{€,h-k,t-1}$ seems similar to $-(\beta_2+\beta_3)$.

Equations (4)-(6) of Table no. 6 report the corresponding equations estimated by GMM, while the corresponding "IV diagnostic and test" for GMM instruments are reported in Table no. 7. The comments on equations (4)-(6) are the same as those of OLS regresssiones and are therefore not repeated.

Table no. 7 – IV diagnostic and test

H0 Hypothesis			**5-7**	**7-10**	**10-30**	
$\Delta FTB_{\$,h-k,t-1}$ weighted mean is a valid instrument	Instrument Orthogonality C Test		0.7082	0.8396	0.6154	YES
$\Delta R_{\$,1m,t} \times Fed\_meeting_{t-1}$ is a valid instrument			0.8579	0.2790	0.9189	YES
$[(6\Delta R_{\$,6m,t} - \Delta R_{\$,1m,t})/5 - \Delta R_{\$,1m,t}] \times Fed\_meeting_{t-1}$ is a valid instrument			0.8286	0.1795	0.7245	YES
$\Delta F_{\$,h-k,t}$ is exogenous	Endogeneity Test	Difference in J-stats	0.0000	0.0000	0.0028	NO
Instruments are weak	Cragg-Donald F-stat	Stock-Yogo (relative bias):	<5%	<5%	<5%	NO
		Stock-Yogo (size):	<10%	<10%	<10%	NO

The analysis about the "goodness" of our instruments (coming from Table no. 5 plus all preditermined variable in OLS regressions) is satisfactorry: the probabilities of our main instruments of being valid are much greater than 10%, and the hypothesis of weak instruments is always rejected.

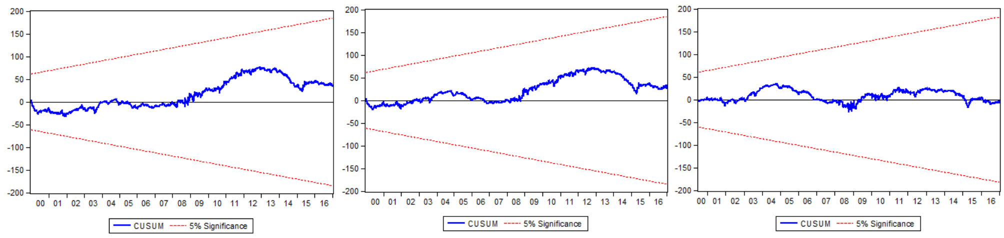
It is interesting to note, however, that even the hypothesis of $\Delta F_{\$,h-k,t}$ exogeneity is rejected, and therefore GMM estimations are preferable to OLS since OLS coefficients are biased, parameters obtained by both GMM and OLS are similar, even if GMM coefficients are usually greater. OLS biases should therefore be not too large.

10. OBSERVATIONS ABOUT STABILITY

Many tests are available to investigate parameter stability, but the aim of this paper is to briefly examine the behaviour of our regression through time.

Figure no. 3 reports the CUSUM test applied to Equations (4)-(6) of Table no. 6.

All curves lie well within the two five percent confidence limits, and the relations seem fairly stable, at least according to this particular test.



$\Delta F_{€,5\text{-}7}$ $\Delta F_{€,7\text{-}10}$ $\Delta F_{€,10\text{-}30}$

Figure no. 3 – CUSUM test of Equations (4)-(6) of Table no. 6

The stability of our equations was also tested by means of "dynamic(ex-ante) forecasts". We estimated equations (2) and (5) of Table no. 6 each equation using only a subset of data and forecast the remaining data by means of a dynamic forecast. Endogenous variables in the equations were built by iteration and all parameters were set the same as those estimated for the first subset.

The dynamic forecast reported in Figure no. 4 starts in October 2008 and covers the entire period of ECB Quantitave Easing, i.e. intervention made to alleviate the various crises hitting the Eurozone 2008-2016.

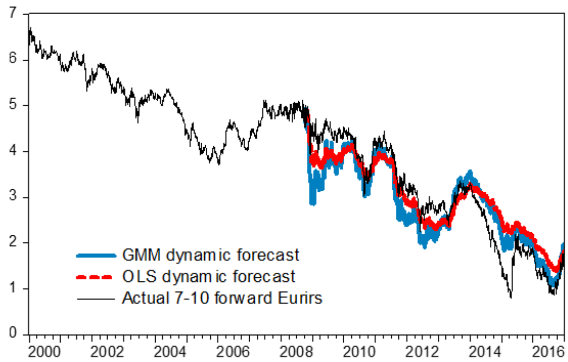
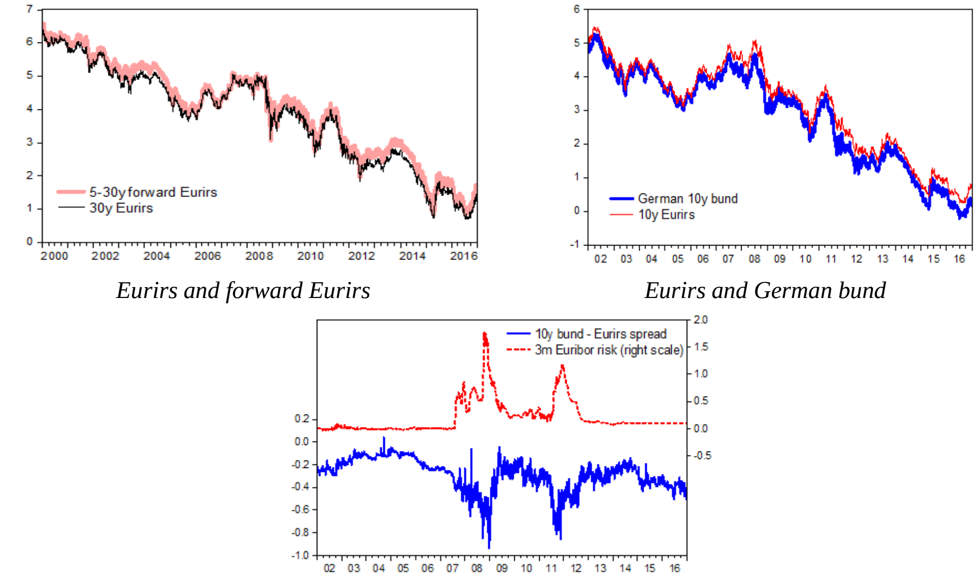


Figure no. 4 – Actual values and dynamic forecast of $\Delta F_{€,7\text{-}10,t}$

Both GMM and OLS dynamic forecasts appear to be able to explain the actual dependent variables, even though both central banks made numerous changes in monetary policy in those years.

After confirming that from 5 years settlement onwards, forward euro interest rates are heavily influenced by the corresponding American rates, it is possible to come back the original IRS yields to maturity: they simply correspond to the mean of their forward rate components. We also found that, settlement dates more distant at least than 5 years, forward Eurirs are strongly influenced by the American correspondent rates. This hinders ECB in controlling long-term interest rates by means of Repo and liquidity. For example, the very important 30 year Eurirs, corresponding to a mean of forward rates with an overwhelming weight of distant settlement dates, is very close to the 10-30 year forward rate (Figure no. 5) where the influence on American rates is particular strong. In other words, what ECB does has almost no impact on this long-run maturity.



Eurirs and forward Eurirs *Eurirs and German bund*

German bunds-Eurirs and Euribor risk

Figure no. 5 – Comparison between Eurirs, forward Eurirs, German bund and Euribor risk

This is very important, since not only is Eurirs one of the most important benchmarks in deciding bank loan long term fixed interest rates, but also because sovereign bond yields too are connected to it, even though other variables affect the spreads between sovereign bond yields and Eurirs. For example, Figure no. 5 shows clearly that the 10 year German bund is closely connected to 10 year Eurirs, although there is a spread between the two rates. The difference between the bund rate and Eurirs is negative, and the spread widens when risk in interbank Euribor market is high (Figure no. 5). Other euro-countries show slightly different results, but the strong relevance of Eurirs to treasury bonds remains.

11. CONCLUSIONS

We have found that the explanatory variables relevant in explaining short-term spot rates and forward Eurirs interest rates with near settlements are markedly different from those relevant for long-term spot interest rates and for distant settlements forward returns. The former are strongly influenced by ECB's official rate and liquidity operations. The latter are strongly connected to their American corresponding rates. This is consistent with the theoretical model presented in Section 5.

We also tested the causality between European and American interest rates, and the main finding is that Granger causality acts from the US to the EU.

Dynamic regressions are consistent with economic theory, and for distant settlements forward interest rates confirm that American interest rates closely influence European ones, although American interest rates are far from exogenous.

Many aspects of the research, however, deserve to be examined more thoroughly. For example:

- Is it possible to find more efficient instruments to improve GMM?
- What other variables can be used to clarify the relationship between European and American interest rates?
- What exactly is the role of expectations and central bank communications in the links between the two markets?
- How does this relationship in the long-term influence the relationship between their respective stock markets and other assets?
- What instrument would be appropriate to estimate the inverse relation, i.e. the influence of euro on American interest rates?

To conclude our analysis, it is apparent that the ability of the ECB to control long-term rates is weakened by the overwhelming influence of the corresponding US rates. Our results in fact show that even during the period of ECB Quantitative Easing, the relationship between the long-term interest rates did not change a great deal. For the same reasons, European implied forward interest rates are not good indicators of European short-term interest rate expectations when settlements are distant.

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Notes

[1] Mario Draghi, President of the ECB, Frankfurt am Main, 9 January 2014, introductory statement to the press conference.
[2] We assume that futures and forward implicit rates are perfectly substituted. The forward rates are constructed with the formula: $F_{k\text{-}h} = (h\,R_h - k\,R_k) / (h\text{-}k)$. With both Eurirs and dollar IRS data, there is no practical difference between results of this formula or its better known alternative $\{[(1+ R_h/100)^h / (1+ R_k/100)^k]^{1/(h-k)}-1]\}*100$, the difference being only in their third decimal digit. We also employed zero-coupon equivalent of Eurirs and dollar IRS instead of usual IRS interest rates. All econometric results from zero-coupon, however, are very similar to the ones we reported in the paper. Our procedure has the advantage that it is possible to pass by forward rates to spot long-term rates by simply averaging the corresponding forward rates.
[3] Fed and ECB meetings are two dummies built by putting 1 on the day of a monetary policy committee meeting and 0 elsewhere.

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