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VOLATILITY SPILLOVER AND CONTAGION EFFECTS BETWEEN EURODOLLAR FUTURE AND ZERO COUPONS MARKETS: EVIDENCE FROM ITALY

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Abstract:
This paper examines the time-varying conditional correlations between the Eurodollar futures market and the zero coupons of Banca Fideuram. We apply a bivariate dynamic conditional correlation (DCC) GARCH model in order to capture potential contagion effects between the markets for the period 2005-2017. Empirical results reveal contagion during the under-investigation period regarding the twenty-one bivariate models, showing that the Eurodollar futures market has a major impact on the zero coupons of Banca Fideuram. Findings have crucial implications for policymakers who provide regulations for the above-mentioned derivative markets.

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INTRODUCTION

This paper investigates the potential volatility spillover and contagion effects (Dimitriou, Kenourgios & Simos 2013) of the Eurodollar futures market and the zero coupons of Banca Fideuram. We consider the zero coupons of Banca Fideuram ending from 2018 to 2033. By employing a bivariate DCC-GARCH model, we show significant volatility spillover effects (Sehgal, Ahmad & Deisting 2015; Li & Giles 2015; Aboura & Chevallier 2015; Antonakakis, Floros & Kizys 2016). Moreover, we use the definition of contagion as suggested by Forbes and Rigobon (2002). They defined contagion as a significant increase in cross-market linkages after a shock. Dynamic conditional correlations reveal contagion effects (Dimitriou & Kenourgios 2015; Sensoy & Hacihasanoglu 2015) in sub-periods between the Eurodollar futures market and all the zero coupons of Banca Fideuram.

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The motivation for this paper is analyzed as follows. Firstly, there is no other empirical research investigating the conditional second moments of the distribution between the Eurodollar futures market and the zero coupons of Banca Fideuram. Secondly, the potential existence of contagion between the Eurodollar futures market and the zero coupons of Banca Fideuram provides new evidence for financial theory. Thirdly, the under-investigation period is of great importance, since it entails major economic crises i.e., the financial crisis of 2008.

The paper is organized as follows. Section 2 presents the literature review and Section 3 provides the data characteristics. Section 4 provides the methodology. Section 5 shows the empirical results. The last section provides the conclusion.

LITERATURE REVIEW

There are numerous empirical studies investigating the spillovers among different future and financial markets (Mensi *et al* 2013; Kavussanos et al 2014; Li *et al* 2014; Antonakakis and Kizys 2015; Du and He 2015; Ewing and Malik 2016; Bagchi 2017; Roy and Roy 2017; Ma *et al* 2019; Tsiaras and Simos 2020; Tsiaras 2020, Tsiaras 2020).

Mensi et al (2013) find evidence of spillovers between the S&P 500 and commodity price indices for energy, food, gold, and beverages over the turbulent period from 2000 to 2011.

Kavussanos et al (2014) examine the existence of spillover effects between commodity and freight markets for the period 2006-2009. By using different GARCH models, they show the existence of spillovers effects.

Li et al (2014) show potential spillovers and dynamic conditional correlations between spot and forward tanker freight markets. By using a multivariate GARCH model, they examine the period from 2006 to 2011.

Antonakakis and Kizys (2015) find evidence of volatility spillover effects between commodity and FOREX markets: crude oil, gold, silver, platinum, CHF/USD, GBP/USD, EUR.USD. They investigate the period 1987 to 2014.

Du and He (2015) found evidence of significant spillover between crude oil and stock markets using daily data of the S&P 500 stock index and West Texas Intermediate (WTI). Based on their results, they supported the existence of positive risk spillovers from stock to crude oil markets and negative spillovers from crude oil to stock markets.

Ewing and Malik (2016) examine the volatility of oil and US stock market prices incorporating structural breaks using daily data from 1996 to 2013. By employing univariate and bivariate GARCH models, they find no volatility spillovers between the two markets.

Bagchi (2017) investigates the dynamic relationship between crude oil price volatility and stock markets in the emerging economies like BRIC (Brazil, Russia, India and China) countries. By using a AR-APARCH model, he finds evidence of positive and negative relationships between the under-investigation markets.

Roy and Roy (2017) show the financial contagion in Indian commodity derivative markets vis-à-vis bond, FOREX, gold, and stock markets. They applied a multivariate DCC-GARCH model for the period 2006-2016.

Ma *et a*l (2019) examine the inter-connectedness between WTI oil price returns and the returns of listed firms in the US energy sector for the period 2008-2018.

They show that, although idiosyncratic information is mostly independent of oil shocks, individual energy stock returns do respond to WTI price movements.

Tsiaras and Simos (2020) prove the spillover effects among S&P 500, four national equity markets and the respective FOREX markets for the period from 2010 to 2018.

Tsiaras (2020) investigates and proves the spillovers between JPY/USD, KRW/USD, EUR/USD and INR/USD futures markets for the period 2014-2019. In our paper, we provide empirical evidence of spillover effects between major future FOREX market and Zero Coupons derivative markets.

To the best of our knowledge, there is no previous empirical evidence providing evidence of spillover effects between the under-investigation market.

DATA CHARACTERISTICS

We use daily data for Eurodollar futures market (DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE) and sixteen zero coupons of Banca Fideuram (BANCA FIDEURAM ZERO CPN. 2018, BANCA FIDEURAM ZERO CPN. 2019, BANCA FIDEURAM ZERO CPN. 2020, BANCA FIDEURAM ZERO CPN. 2021, BANCA FIDEURAM ZERO CPN. 2022, BANCA FIDEURAM ZERO CPN. 2023, BANCA FIDEURAM ZERO CPN. 2024, BANCA FIDEURAM ZERO CPN. 2025, BANCA FIDEURAM ZERO CPN. 2026, BANCA FIDEURAM ZERO CPN. 2027, BANCA FIDEURAM ZERO CPN. 2028, BANCA FIDEURAM ZERO CPN. 2029, BANCA FIDEURAM ZERO CPN. 2030, BANCA FIDEURAM ZERO CPN. 2031, BANCA FIDEURAM ZERO CPN. 2032 and BANCA FIDEURAM ZERO CPN. 2033). We downloaded data from the Datastream database. We set the period from January 4, 2005 to December 11, 2017 (3375 observations). We use the market returns generated by the equation $r_t = \log(p_t) - \log(p_{t-1})$, where p_t is the price of future market on day t and p_{t-1} is the price of future market on day $t-1$.

In tables 1, 2, 3 and 4 we see the summary statistics for the markets returns. BANCA FIDEURAM ZERO CPN. 2032 exhibits the highest mean value (0,00023071). Based on the highest maximum (0,077701), the second minimum (-0,066133) and the second highest std. deviation (0,0095707) values, BANCA FIDEURAM ZERO CPN. 2032 presents the largest fluctuations among all the markets. Additionally, all market returns are negatively skewed, except the cases of BANCA FIDEURAM ZERO CPN. 2018, BANCA FIDEURAM ZERO CPN. 2019, BANCA FIDEURAM ZERO CPN. 2020 and BANCA FIDEURAM ZERO CPN. 2021. Furthermore, we observe that all market returns show excess kurtosis. In addition, Jarque-Bera statistic results indicate the rejection of the null hypothesis of normality for all market returns. ADF (Dickey and Fuller 1979) test results reject the null hypotheses of unit root at 1% level, showing that the daily market returns appropriate for further testing.

Table 1 *- Summary Statistics of the Daily Market Logarithmic Returns*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE	BANCA FIDEURAM ZERO CPN. 2018	BANCA FIDEURAM ZERO CPN. 2019	BANCA FIDEURAM ZERO CPN. 2020	BANCA FIDEURAM ZERO CPN. 2021
Mean	-3.62e-005	0.00014653	0.00016334	0.00017082	0.00017633
Minimum	-0.034722	-0.034328	-0.037916	-0.032092	-0.036549
Maximum	0.032842	0.052911	0.057069	0.057384	0.059144
Std. Deviation	0.0058591	0.0040629	0.0042757	0.0050665	0.0054361
Skewness	-0.0067747	0.56365***	0.59049***	0.66735***	0.23680***
t-Statistic	0.16075	13.374	14.011	15.835	5.6187
p-Value	0.87229	8.5689e-041	1.3378e-044	1.7961e-056	1.9243e-008
Excess Kyrtosis	2.4752***	16.889***	16.837***	13.692***	9.9221***
t-Statistic	29.374	200.43	199.81	162.49	117.75
p-Value	1.1804e-189	0.00000	0.00000	0.00000	0.00000
Jarque-Bera	861.58***	40293***	40062***	26614***	13876***
p-Value	8.1273e-188	0.00000	0.00000	0.00000	0.00000
ADF Test	-34.0035***	-36.1749***	-35.1774***	-35.273***	-35.4105***

Table 2 *- Summary Statistics of the Daily Market Logarithmic Returns*

	BANCA FIDEURAM ZERO CPN. 2022	BANCA FIDEURAM ZERO CPN. 2023	BANCA FIDEURAM ZERO CPN. 2024	BANCA FIDEURAM ZERO CPN. 2025
Mean	0.0001646	0.00018798	0.0002024	0.00020046
Minimum	-0.036124	-0.051395	-0.048579	-0.045075
Maximum	0.059525	0.047033	0.049644	0.052734
Std. Deviation	0.0058674	0.0062433	0.0066364	0.0066885
Skewness	-0.14823***	-0.10383***	-0.23445***	-0.17699***
t-Statistic	3.5171	2.4636	5.5629	4.1996
p-Value	0.00043625	0.013754	2.6528e-008	2.6742e-005
Excess Kyrtosis	11.316***	8.4188***	6.8660***	6.0796***
t-Statistic	134.29	99.909	81.481	72.149
p-Value	0.00000	0.00000	0.00000	0.00000
Jarque-Bera	18021***	9973.1***	6660.3***	5215.4***
p-Value	0.00000	0.00000	0.00000	0.00000
ADF Test	-35.3086***	-34.3199***	-35.7359***	-34.922***

Table 3 *- Summary Statistics of the Daily Market Logarithmic Returns*

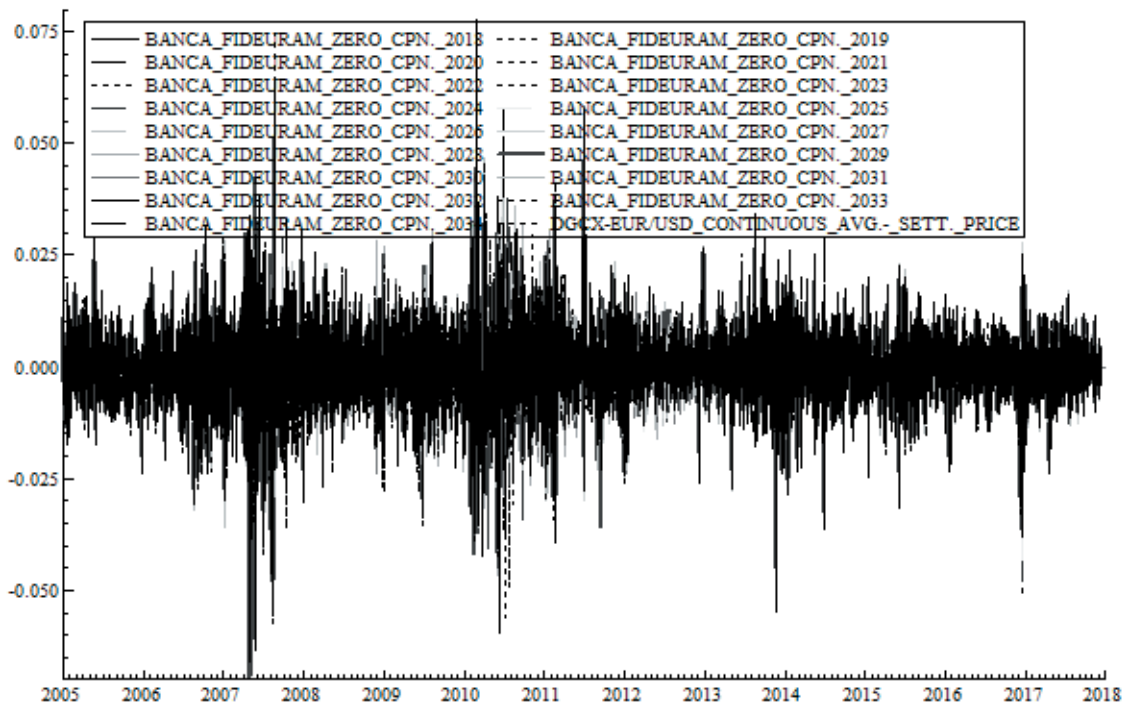
	BANCA FIDEURAM ZERO CPN. 2026	**BANCA FIDEURAM ZERO CPN. 2027**	**BANCA FIDEURAM ZERO CPN. 2028**	**BANCA FIDEURAM ZERO CPN. 2029**
Mean	0.00020225	0.00020596	0.00020595	0.00021448
Minimum	-0.056538	-0.057316	-0.056162	-0.06922
Maximum	0.058081	0.046397	0.049962	0.051293
Std. Deviation	0.0071898	0.0076207	0.0081711	0.0084838
Skewness	-0.18968***	-0.28312***	-0.31747***	-0.40512***
t-Statistic	4.2871	6.7177	7.5328	9.6126
p-Value	1.8099e-005	1.8466e-011	4.9673e-014	7.0759e-022
Excess Kyrtosis	6.4695***	5.4861***	5.1496***	5.6284***
t-Statistic	76.775	65.105	61.111	66.794
p-Value	0.00000	0.00000	0.00000	0.00000
Jarque-Bera	5904.1***	4277.5***	3785.8***	4547.1***
p-Value	0.00000	0.00000	0.00000	0.00000
ADF Test	-34.5052***	-35.2119***	-35.0801***	-35.9567***

Table 4 *- Summary Statistics of the Daily Market Logarithmic Returns*

	BANCA FIDEURAM ZERO CPN. 2030	**BANCA FIDEURAM ZERO CPN. 2031**	**BANCA FIDEURAM ZERO CPN. 2032**	**BANCA FIDEURAM ZERO CPN. 2033**
Mean	0.00021384	0.00021572	0.00023071	0.00022541
Minimum	-0.062678	-0.055032	-0.066133	-0.064688
Maximum	0.059321	0.076138	0.077701	0.074629
Std. Deviation	0.0087642	0.0092783	0.0095707	0.0097384
Skewness	-0.20305***	-0.069956**	-0.15964***	-0.14954***
t-Statistic	4.8178	1.6599	3.7878	3.5482
p-Value	1.4516e-006	0.096938	0.00015197	0.00038786
Excess Kyrtosis	5.6736***	5.0302***	5.8516***	5.4135***
t-Statistic	67.330	59.694	69.443	64.244
p-Value	0.00000	0.00000	0.00000	0.00000
Jarque-Bera	4549.9***	3560.9***	4829.5***	4133.8***
p-Value	0.00000	0.00000	0.00000	0.00000
ADF Test	-34.9155***	-34.9721***	-35.1153***	-34.9907***

Figure 1 graphs the logarithmic returns for DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE, BANCA FIDEURAM ZERO CPN. 2018, BANCA FIDEURAM ZERO CPN. 2019, BANCA FIDEURAM ZERO CPN. 2020, BANCA FIDEURAM ZERO CPN. 2021, BANCA FIDEURAM ZERO CPN. 2022, BANCA FIDEURAM ZERO CPN. 2023, BANCA FIDEURAM ZERO CPN. 2024, BANCA FIDEURAM ZERO CPN. 2025, BANCA FIDEURAM ZERO CPN. 2026, BANCA FIDEURAM ZERO CPN. 2027, BANCA FIDEURAM ZERO CPN. 2028, BANCA FIDEURAM ZERO CPN. 2029, BANCA FIDEURAM ZERO CPN. 2030, BANCA FIDEURAM ZERO CPN. 2031, BANCA FIDEURAM ZERO CPN. 2032 and BANCA FIDEURAM ZERO CPN. 2033. Based on the virtual observation of the graph, we see time varying levels of fluctuations, indicating the presence of heteroskedasticity and appropriate the use of the DCC-GARCH model.

Figure 1 *- Actual Series of the Logarithmic Returns of the Markets.*



METHODOLODY

In the first stage, we generate the daily logarithmic returns:

$$y_t = \mu + \varepsilon_t \text{, with } t = 1,\ldots,T \quad (1)$$

where μ is constant $y_t = \mu + \varepsilon_t$ and ε_t is standardized residuals, defined as follows:

$$\varepsilon_t = \sqrt{h_t}\, u_t \text{, where } \varepsilon_t \sim N(0, H_t) \text{ and } u_t \text{ are i.i.d.} \quad (2)$$

where u_t is standardized errors and h_t is conditional variance depending on h_t and ε_t for each market lagged one period, generated by the univariate GARCH(1,1) model (Bollerslev 1986):

$$h_t = \omega + a\varepsilon_{t-1}^2 + bh_{t-1} \tag{3}$$

where ω is constant, a and b are ARCH and GARCH effects·

In the second stage, we employ the Engle (2002) representation of the bivariate GARCH model inorder to estimate the bivariate conditional variance matrix ($\mathbf{H}_t$ is N x N matrix, with N the number of markets, *i = 1*,…,N) as follows:

$$H_t = D_t R_t D_t \tag{4}$$

D_t is the conditional variance matrix given by:

$$D_t = \text{diag}\left(h_{11t}^{\frac{1}{2}} \ldots h_{NNt}^{\frac{1}{2}} \right) \tag{5}$$

$\mathbf{R}_t$ is the condition correlation matrix of N x N dimension, and is defined, as follows:

$$R_t = (\rho_{iit}) = \text{diag}(q_{11,t}^{-\frac{1}{2}} \ldots q_{NN,t}^{-\frac{1}{2}}) Q_t \text{diag}(q_{11,t}^{-\frac{1}{2}} \ldots q_{NN,t}^{-\frac{1}{2}}) \tag{6}$$

where the N x N symmetric positive definite matrix $Q_t = \left(q_{ii,t} \right)$ is given by:

$$Q_t = \left(1-\alpha-\beta\right)\overline{Q} + \alpha u_{t-1} u'_{t-1} + \beta Q_{t-1} \tag{7}$$

$\overline{Q}$ i s the N x N unconditional variance matrix of u_t, and α and β are nonnegative scalar parameters, satisfying $\alpha + \beta < 1$.

EMPIRICAL RESULTS

In this section, we present the empirical results generated by the multivariate DCC-GARCH model. Sub-section 5.1 shows the results of the univariate GARCH model, while in sub-section 5.2 we analyze the results of the multivariate DCC-GARCH model. In sub-section 5.3, we report an analysis of the generated Dynamic Conditional Correlations (DCCs).

RESULTS OF THE UNIVARIATE GARCH (1,1) MODEL

Tables 5, 6, 7 and 8 show the estimated values for mean equation and univariate GARCH (1,1) model. We observe statistically significant μ for all the market returns, except the case of DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE. Additionally, empirical results report statistically significant ω for all the market returns. Moreover, ARCH (a) and GARCH (b) terms are highly significant for all the markets returns.

Table 5 *- Estimates of Univariate GARCH (1,1) Model*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE	BANCA FIDEURAM ZERO CPN. 2018	BANCA FIDEURAM ZERO CPN. 2019	BANCA FIDEURAM ZERO CPN. 2020	BANCA FIDEURAM ZERO CPN. 2021
constant *(μ)*	0.0000377	0.0000221*	0.0000702***	0.0001333***	0.0001804***
t-Statistic	0.4768	1.517	3.051	3.603	3.624
p-Value	0.6335	0.1294	0.0023	0.0003	0.0003
constant *(ω)*	0.050450*	0.001737*	0.005068*	0.016843*	0.040020*
t-Statistic	1.107	1.288	1.370	1.464	1.478
p-Value	0.2683	0.1979	0.1708	0.1433	0.1394
ARCH *(α)*	0.037845***	0.114787***	0.099745***	0.081683***	0.070081***
t-Statistic	7.898	4.879	3.732	3.699	3.345
p-Value	0.0000	0.0000	0.0002	0.0002	0.0008
GARCH *(b)*	0.964238***	0.896551***	0.908039***	0.922360***	0.931229***
t-Statistic	227.3	49.48	42.07	48.76	48.81
p-Value	0.0000	0.0000	0.0000	0.0000	0.0000

Table 6 *- Estimates of Univariate GARCH (1,1) Model*

	BANCA FIDEURAM ZERO CPN. 2022	BANCA FIDEURAM ZERO CPN. 2023	BANCA FIDEURAM ZERO CPN. 2024	BANCA FIDEURAM ZERO CPN. 2025
constant *(μ)*	0.0002175***	0.0002566***	0.0002897***	0.0003358***
t-Statistic	3.763	3.874	3.815	4.154
p-Value	0.0002	0.0001	0.0001	0.0000
constant *(ω)*	0.062064*	0.117230*	0.181788*	0.373052**
t-Statistic	1.628	1.878	1.656	1.990
p-Value	0.1036	0.0604	0.0978	0.0466
ARCH *(α)*	0.064147***	0.066864***	0.060533***	0.074506***
t-Statistic	3.509	4.691	3.863	3.808
p-Value	0.0005	0.0000	0.0001	0.0001
GARCH *(b)*	0.935513***	0.931312***	0.935657***	0.917570***
t-Statistic	54.52	65.63	55.49	41.82
p-Value	0.0000	0.00000	0.0000	0.0000

Table 7 *- Estimates of Univariate GARCH (1,1) Model*

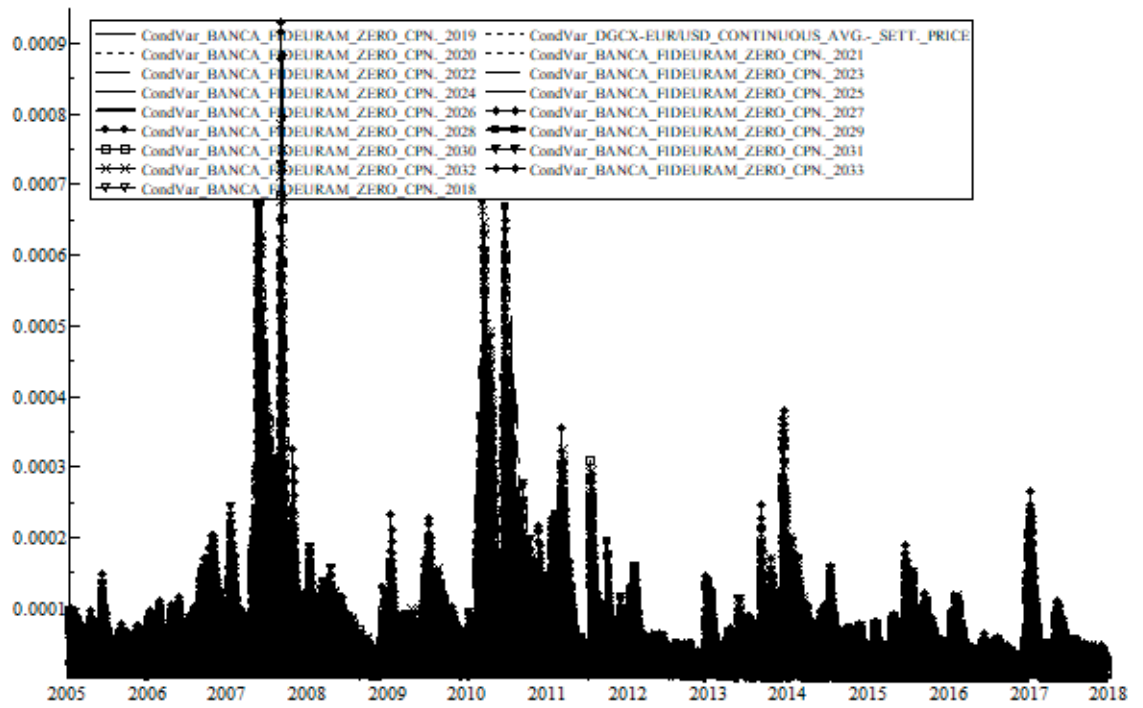
	BANCA FIDEURAM ZERO CPN. 2026	**BANCA FIDEURAM ZERO CPN. 2027**	**BANCA FIDEURAM ZERO CPN. 2028**	**BANCA FIDEURAM ZERO CPN. 2029**
constant *(μ)*	0.0003728***	0.0003899***	0.0003379***	0.000410***
t-Statistic	4.199	4.145	3.702	3.874
p-Value	0.0000	0,0000	0.0002	0.0001
constant *(ω)*	0.585090***	0.865811***	0.803986***	1.664445***
t-Statistic	2.282	2.165	2.104	2.049
p-Value	0.0225	0.0304	0.0354	0.0406
ARCH *(α)*	0.078349***	0.086326***	0.075854***	0.101611***
t-Statistic	4.625	4.194	4.193	3.700
p-Value	0.0000	0.0000	0.0000	0.0002
GARCH *(b)*	0.910445***	0.898462***	0.911873***	0.874166***
t-Statistic	44.88	34.42	40.40	23.27
p-Value	0.0000	0.0000	0.0000	0.0000

Table 8 *- Estimates of Univariate GARCH (1,1) Model*

	BANCA FIDEURAM ZERO CPN. 2030	**BANCA FIDEURAM ZERO CPN. 2031**	**BANCA FIDEURAM ZERO CPN. 2032**	**BANCA FIDEURAM ZERO CPN. 2033**
constant *(μ)*	0,000423***	0.000457***	0.000462***	0.000448***
t-Statistic	3.785	3.884	3.786	3.596
p-Value	0.0002	0.0001	0.0002	0.0003
constant *(ω)*	1.354293**	1.555353***	1.497339***	1.648639***
t-Statistic	1.903	2.129	2.453	2.399
p-Value	0.0571	0.0334	0.0142	0.0165
ARCH *(α)*	0.083461***	0.088127***	0.080689***	0.082399***
t-Statistic	3.603	4.198	4.700	4.553
p-Value	0.0003	0.0000	0.0000	0.0000
GARCH *(b)*	0.898062***	0.893645***	0.902314***	0.899750***
t-Statistic	28.59	31.76	40.47	37.88
p-Value	0.0000	0.0000	0.0000	0.0000

In figure 2, we observe the behavior of conditional variances for DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE, BANCA FIDEURAM ZERO CPN. 2018, BANCA FIDEURAM ZERO CPN. 2019, BANCA FIDEURAM ZERO CPN. 2020, BANCA FIDEURAM ZERO CPN. 2021, BANCA FIDEURAM ZERO CPN. 2022, BANCA FIDEURAM ZERO CPN. 2023, BANCA FIDEURAM ZERO CPN. 2024, BANCA FIDEURAM ZERO CPN. 2025, BANCA FIDEURAM ZERO CPN. 2026, BANCA FIDEURAM ZERO CPN. 2027, BANCA FIDEURAM ZERO CPN. 2028, BANCA FIDEURAM ZERO CPN. 2029, BANCA FIDEURAM ZERO CPN. 2030, BANCA FIDEURAM ZERO CPN. 2031, BANCA FIDEURAM ZERO CPN. 2032, and BANCA FIDEURAM ZERO CPN. 2033. We see strongly volatile conditional variances for all the market returns over time. Additionally, results indicate a common movement of conditional volatilities.

Figure 2 *- Conditional Variances of the Univariate GARCH (1,1) Model.*



RESULTS OF THE BIVARIATE DCC-GARCH (1,1) MODEL, DIAGNOSTIC TESTS AND SELECTED INFORMATION CRITERIA

Tables 9, 10, 11 and 12 present the results of the bivariate DCC model estimations. We observe that the average CORij is statistically significant for the pairs of markets: DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2027, DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2029 and DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2032. Furthermore, we see statistically significant α and $\boldsymbol{\beta}$ parameters, indicating strong ARCH and GARCH effects for all the pairs of market returns (Efimova and Serletis 2014; Li and Giles 2014; Sehgal and Ghosh 2016; Chang *et al* 2018; Sun *et al* 2019; Sukhonpitumart *et al* 2020; Yu *et al* 2020; Belhassine 2020). Additionally, we provide the estimates of the degrees of freedom (v) and of the log-likelihood.

Table 9 *- Estimates of the Bivariate DCC-GARCH (1,1) Model, Degrees of Freedom, Log-likelihood*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2018	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2019	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2020	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2021
Average CORij	-0.028369	-0.029169	-0.26245	-0.028106
t-Statistic	-0.7921	-0.8427	-0.7534	-0.7739
p-Value	0.4284	0.3995	0.4513	0.4390
alpha *(α)*	0.008466***	0.010216***	0.008200***	0.008050***
t-Statistic	3.041	3.571	3.473	3.449
p-Value	0.0024	0.0004	0.0005	0.0006
beta *(β)*	0.983542***	0.979266***	0.983939***	0.984555***
t-Statistic	179.9	185.2	226.1	240.0
p-Value	0.0000	0.0000	0.0000	0.0000
degrees of freedom *(df)*	5.730267***	5.875022***	6.500954***	6.450702***
t-Statistic	12.31	12.45	12.39	12.46
p-Value	0.0000	0.0000	0.0000	0.0000
log-likelihood	28728.993	28046.932	27161.298	26627.008

Table 10 *- Estimates of the Bivariate DCC-GARCH (1,1) Model, Degrees of Freedom, Log-likelihood*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2022	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2023	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2024	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2025
Average CORij	-0.032175	-0.029485	-0.026158	-0.030716
t-Statistic	-0.9473	-0.8569	-0.7185	-0.8789
p-Value	0.3435	0.3915	0.4725	0.3795
alpha *(α)*	0.007305***	0.008021***	0.008913***	0.007824***
t-Statistic	3.280	3.461	3.563	3.340
p-Value	0.0010	0.0005	0.0004	0.0008
beta *(β)*	0.984699***	0.983735***	0.982894***	0.984395***
t-Statistic	233.1	245.0	215.6	216.9
p-Value	0.0000	0.0000	0.0000	0.0000
degrees of freedom *(df)*	6.448894***	6.700370***	6.856377***	7.074205***
t-Statistic	12.41	11.73	11.79	12.19
p-Value	0.0000	0.0000	0.0000	0.0000
log-likelihood	26326.015	26048.641	25727.520	25603.802

Table 11 *- Estimates of the Bivariate DCC-GARCH (1,1) Model, Degrees of Freedom, Log-likelihood*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2026	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2027	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2028	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2029
Average CORij	-0.021714	-0.036694*	-0.020921	-0.034145*
t-Statistic	-0.6194	-1.080	-0.6453	-1.064
p-Value	0.5357	0.2803	0.5188	0.2872
alpha *(α)*	0.007685***	0.007194***	0.006878***	0.007204***
t-Statistic	3.413	3.301	3.168	3.132
p-Value	0.0006	0.0010	0.0015	0.0018
beta *(β)*	0.984614***	0.985149***	0.985076***	0.984160***
t-Statistic	243.9	253.2	243.3	213.3
p-Value	0.0000	0.0000	0.0000	0.0000
degrees of freedom *(df)*	6.853648***	6.925275***	7.264400***	7.044709***
t-Statistic	12.27	11.90	11.70	11.62
p-Value	0.0000	0.0000	0.0000	0.0000
log-likelihood	25334.343	25132.457	24870.512	24754.147

Table 12 *- Estimates of the Bivariate DCC-GARCH (1,1) Model, Degrees of Freedom, Log-likelihood*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2026	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2027	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2028	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2029
Average CORij	-0.030906	-0.029990	-0.036048*	-0.029070
t-Statistic	-0.9881	-0.9409	-1.147	-0.8904
p-Value	0.3232	0.3468	0.2513	0.3733
alpha *(α)*	0.007099***	0.007192***	0.006640***	0.007193***
t-Statistic	3.039	2.999	3.031	3.168
p-Value	0.0024	0.0027	0.0025	0.0015
beta *(β)*	0.983747***	0.984130***	0.984981***	0.984612***
t-Statistic	209.6	196.7	222.6	214.6
p-Value	0.0000	0.0000	0.0000	0.0000
degrees of freedom *(df)*	7.029137***	7.042781***	6.986029***	7.010423***
t-Statistic	11.65	11.62	11.84	12.00
p-Value	0.0000	0.0000	0.0000	0.0000
log-likelihood	24602.282	24394.485	24298.304	24222.677

In tables 13, 14, 15, and 16, we report the results of the diagnostic tests and information criteria. $x^2(4)$ statistic results suggest that the null hypothesis of no spillovers is rejected at 1% significance level. Ljuing-Box test results (Hosking, 1980; Li-McLeod, 1983) provide evidence of no serial autocorrelation, suggesting the absence of misspecification errors of the estimated multivariate GARCH model. Moreover, the estimated AIC and SIC information criteria are presented.

Table 13 *- Diagnostic Tests and Information Criteria*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2018	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2019	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2020	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2021
x^2 **(4)**	8610.8**	7362.6**	1550.4**	1156.0**
p-Value	0.0000	0.0000	0.0000	0.0000
Hosking (50)	202.361	221.370	211.544	219.100
p-Value	0.4400240	0.1432761	0.2743670	0.1687156
Hosking² (50)	171.515	166.338	226.453	230.384
p-Value	0.9133156	0.9506138	0.0808038	0.0571307
Li-McLeod (50)	202.575	221.452	211.587	219.146
p-Value	0.4358555	0.1424173	0.2736908	0.1681628
Li-McLeod² (50)	172.026	166.843	226.539	230.334
p-Value	0.9087771	0.9476324	0.0802170	0.0573922
Akaike	0.002067	0.002187	0.002342	0.002436
Schwarz	0.023842	0.023961	0.024117	0.024211

Table 14 *- Diagnostic Tests and Information Criteria*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2022	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2023	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2024	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2025
x^2 **(4)**	1970.3**	2510,7**	1463.2**	688.23**
p-Value	0.0000	0.0000	0.0000	0.0000
Hosking (50)	221.416	202.490	204.207	195.549
p-Value	0.1427906	0.4375132	0.4043224	0.5756642
Hosking² (50)	201.280	181.741	194.714	191.925
p-Value	0.4217686	0.7901022	0.5527005	0.6082992
Li-McLeod (50)	221.507	202.618	204.279	195.733
p-Value	0.1418376	0.4350033	0.4029490	0.5720145
Li-McLeod² (50)	201.571	182.022	194.924	192.107
p-Value	0.4161116	0.7857841	0.5484897	0.6046953
Akaike	0.002489	0.002537	0.002594	0.002616
Schwarz	0.024263	0.024312	0.024369	0.024390

Table 15 *- Diagnostic Tests and Information Criteria*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2026	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2027	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2028	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2029
x^2 **(4)**	850.54**	1487.7**	688.45**	11490144.8**
p-Value	0.0000	0.0000	0.0000	0.0000
Hosking (50)	189.425	189.649	198.376	191.851
p-Value	0.6931695	0.6890983	0.5191595	0.6479014
Hosking² (50)	210.468	205.508	211.294	218.450
p-Value	0.2587621	0.3423628	0.2460402	0.1520976
Li-McLeod (50)	189.609	189.939	198.546	192.042
p-Value	0.6898251	0.6856063	0.5157553	0.6442619
Li-McLeod² (50)	210.356	205.489	211.277	218.314
p-Value	0.2605135	0.3427115	0.2463003	0.1536092
Akaike	0.002663	0.002698	0.002744	0.002765
Schwarz	0.024438	0.024473	0.024519	0.024539

Table 16 *- Diagnostic Tests and Information Criteria*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2030	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2031	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2032	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2033
x^2 **(4)**	1615.6**	1320.5**	1265,8**	898,61**
p-Value	0.0000	0.0000	0.0000	0.0000
Hosking (50)	188.043	187.970	205.352	203.574
p-Value	0.7179321	0.7192047	0.3826575	0.4164732
Hosking² (50)	207.557	202.431	192.019	197.642
p-Value	0.3063950	0.3995570	0.6064352	0.4938025
Li-McLeod (50)	188.272	188.175	205.438	203.,681
p-Value	0.7138843	0.7155944	0.3810407	0.4144023
Li-McLeod² (50)	207.483	202.369	192.069	197.676
p-Value	0.3076582	0.4007574	0.6054549	0.4931197
Akaike	0.002791	0.002828	0.002845	0.002858
Schwarz	0.024566	0.024603	0.024619	0.024633

Figures 3 and 4 plot the conditional covariances for all the pairs of market returns during the whole period. We observe a tremble trend for all the conditional covariances. Additionally, conditional covariances seem to be extremely volatile.

Figure 3 *- Conditional Covariances of the Bivariate DCC-GARCH (1,1) Model.*

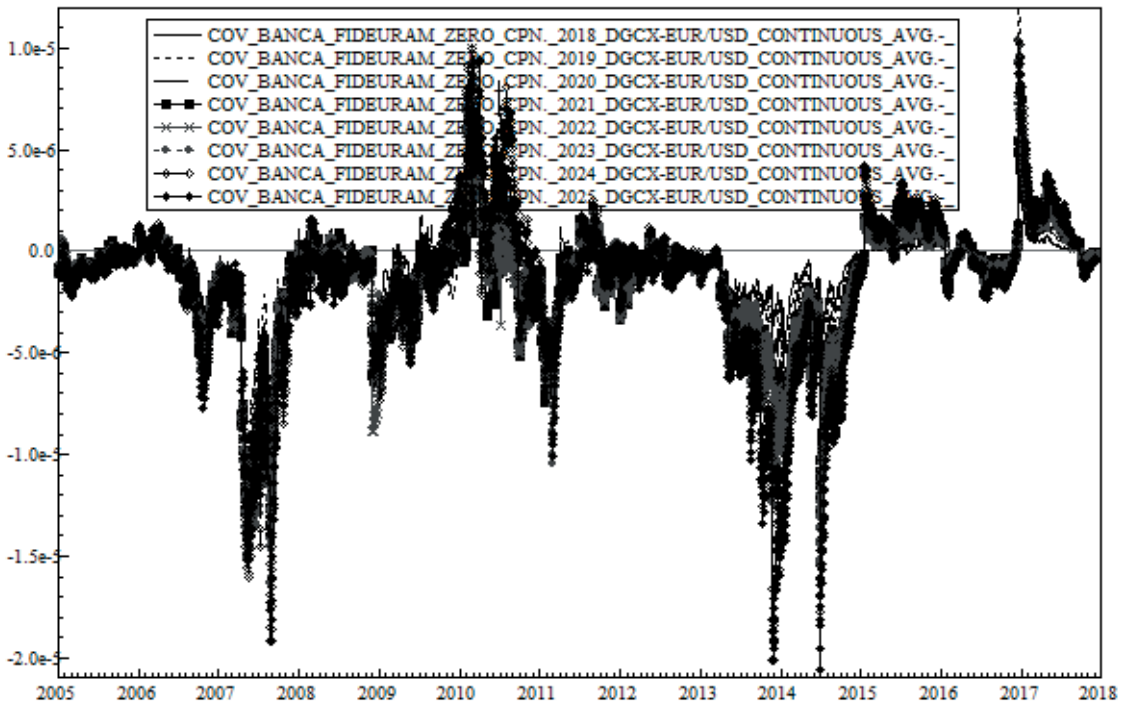
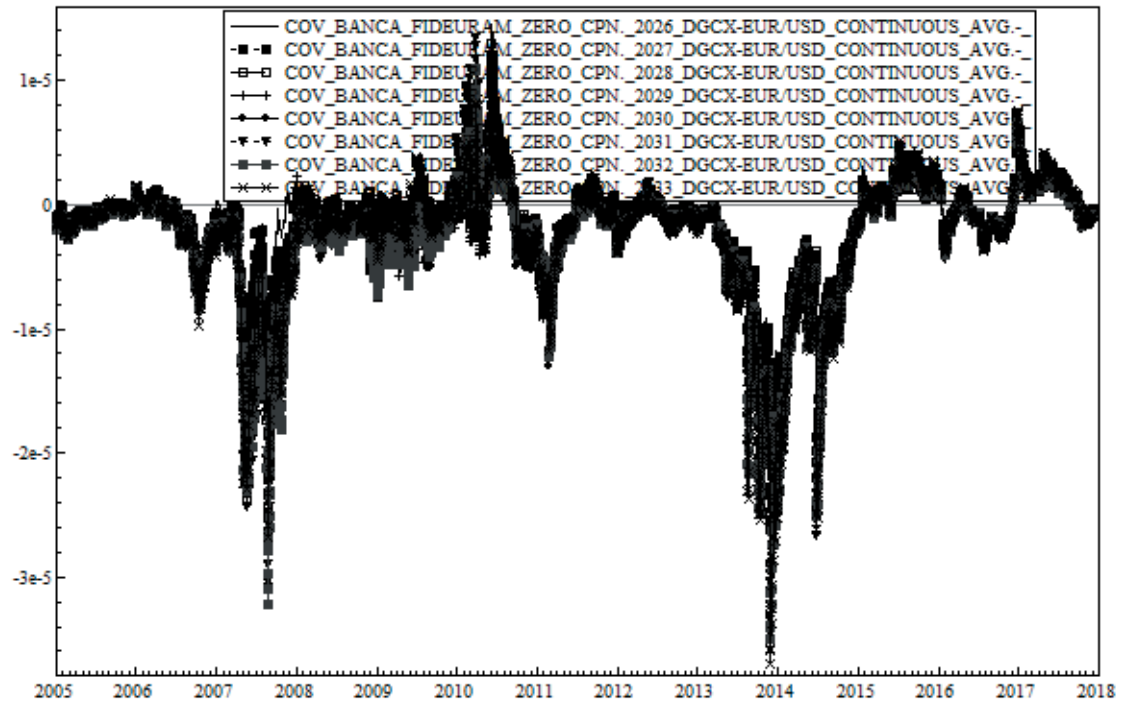


Figure 4 *- Conditional Covariances of the Bivariate DCC-GARCH (1,1) Model.*



ANALYSIS OF THE DYNAMIC CONDITIONAL CORRELATIONS (DCCS)

Tables 17, 18, 19 and 20 show the descriptive statistics of the dynamic conditional correlations (DCCs) of the twenty-one pairs of markets generated by Equation 5. We observe the highest mean value (0,29828) for the pair of markets DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2028. The highest std. deviation value for the pair of markets DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2019 indicates that the specific DCC experiences larger fluctuations. The statistically significant Skewness, Excess Kyrtosis and the Jarque-Bera test statistics indicate that the DCCs for all the pairs of markets are not normally distributed.

Table 17 *- Statistical Properties of the Multivariate GARCH-DCC's*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2018	**DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2019**	**DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2020**	**DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2021**
Mean	-0.039373	-0.042172	-0.03832	-0.043446
Minimum	-0.35803	-0.36773	-0.33772	-0.33122
Maximum	0.16949	0.19866	0.15557	0.13102
Std. Deviation	0.086969	0.088029	0.083352	0.081366
Skewness	-0.66274***	-0.59605***	-0.77505***	-0.86371***
p-Value	1.0141e-055	2.0647e-045	1.5787e-075	2.4504e-093
Excess Kyrtosis	0.77644***	0.67404***	0.74112***	0.71865***
p-Value	3.1330e-020	1.2544e-015	1.4292e-018	1.4835e-017
Jarque-Bera	331.84***	263.73***	415.13***	492.25***
p-Value	8.7272e-073	5.3801e-058	7.1627e-091	1.2891e-107
Akaike	0.002791	0.002828	0.002845	0.002858
Schwarz	0.024566	0.024603	0.024619	0.024633

Table 18 *- Statistical Properties of the Multivariate GARCH-DCC's*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2022	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2023	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2024	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2025
Mean	-0.044479	-0.036367	-0.03233	-0.043351
Minimum	-0.29975	-0.32593	-0.32002	-0.31119
Maximum	0.13255	0.15368	0.16649	0.1375
Std. Deviation	0.075008	0.078369	0.086434	0.079562
Skewness	-0.59792***	-0.61477***	-0.61657***	-0.70375***
p-Value	1.0982e-045	3.3949e-048	1.8166e-048	1.3480e-062
Excess Kyrtosis	0.46461***	0.67357***	0.40503***	0.70271***
p-Value	3.5133e-008	1.3114e-015	1.5354e-006	7.4775e-017
Jarque-Bera	231.46***	276.40***	236.91***	348.03***
p-Value	5.4935e-051	9.5830e-061	3.6013e-052	2.6732e-076

Table 19 *- Statistical Properties of the Multivariate GARCH-DCC's*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2026	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2027	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2028	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2029
Mean	-0.033146	-0.042371	-0.032106	-0.042044
Minimum	-0.29929	-0.28349	-0.25206	-0.2736
Maximum	0.11153	0.092663	0.10489	0.096035
Std. Deviation	0.077377	0.071889	0.0673	0.069413
Skewness	-0.96329***	-0.95533***	-0.87138***	-0.93736***
p-Value	1.2552e-115	9.3446e-114	5.7226e-095	1.3692e-109
Excess Kyrtosis	0.93473***	0.91733***	0.87606***	1.0724***
p-Value	1.3611e-028	1.3410e-027	2.5739e-025	4.2329e-037
Jarque-Bera	644.83***	631.70***	535.03***	655.95***
p-Value	9.4906e-141	6.7291e-138	6.5873e-117	3.6472e-143

Table 20 *- Statistical Properties of the Multivariate GARCH-DCC's*

	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2030	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2031	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2032	DGCX-EUR/USD CONTINUOUS AVG.- SETT. PRICE - BANCA FIDEURAM ZERO CPN. 2033
Mean	-0.038035	-0.037904	-0.043152	-0.037287
Minimum	-0.25894	-0.26307	-0.25104	-0.25792
Maximum	0.095731	0.10924	0.097284	0.10538
Std. Deviation	0.065429	0.06739	0.064469	0.068924
Skewness	-0.87481***	-0.79454***	-0.86477***	-0.92264***
p-Value	1.0575e-095	2.7998e-079	1.4595e-093	3.0921e-106
Excess Kyrtosis	0.87804***	0.90575***	1.0857***	1.0885***
p-Value	2.0112e-025	6.0021e-027	5.4860e-038	3.5911e-038
Jarque-Bera	538.89***	470.47***	586.42***	645.45***
p-Value	9.5881e-118	6.8992e-103	4.5696e-128	6.9584e-141

Figures 5 and 6 present the pair-wise Dynamic Conditional Correlations (DCCs). We observe strong co-movements for all DCCs. DCCs have positive values in sub-periods, indicating the existence of contagion, implying the specific correlations risky for any investor. Furthermore, we can notice the effects of major economic events on the DCC graphs as we see that the lines are bouncing above and beyond, *i.e.* (a) the bankruptcy of Lehman Brothers (14/09/2008), (b) the European Central Bank announcement of an aggressive money-creation program, printing more than one trillion new euros (22/01/2015), (c) Black Monday (24/08/2015), and (d) the United Kingdom referendum (23/06/2016), among others.

Figure 5 *- Dynamic Conditional Correlations for All the Pairs of Markets Generated by the Bivariate DCC-GARCH (1,1) Model.*

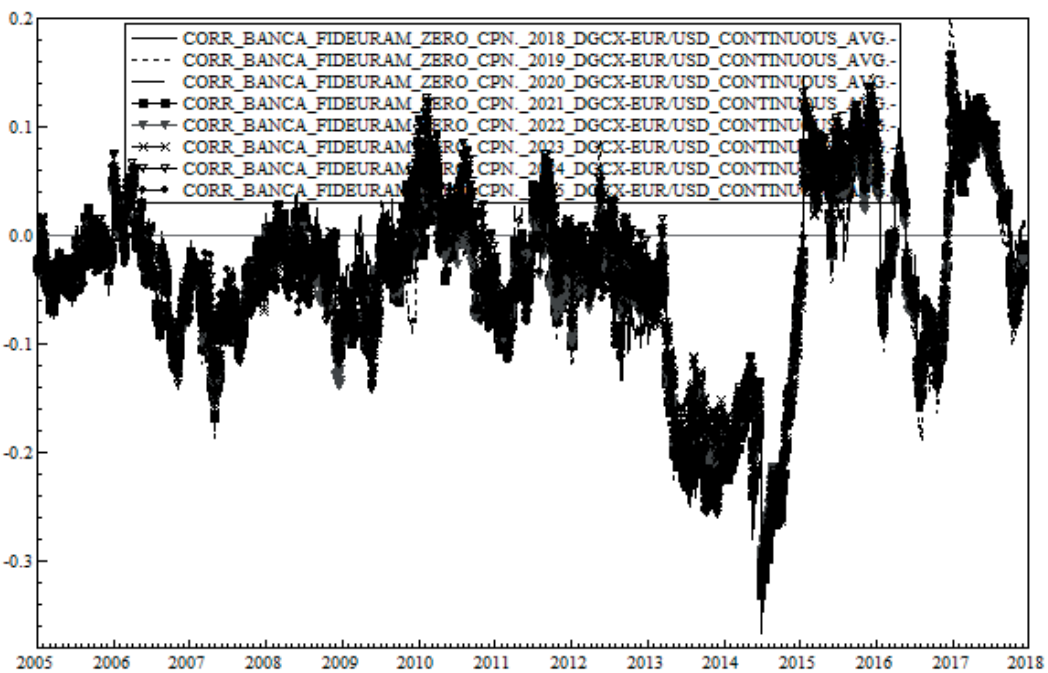
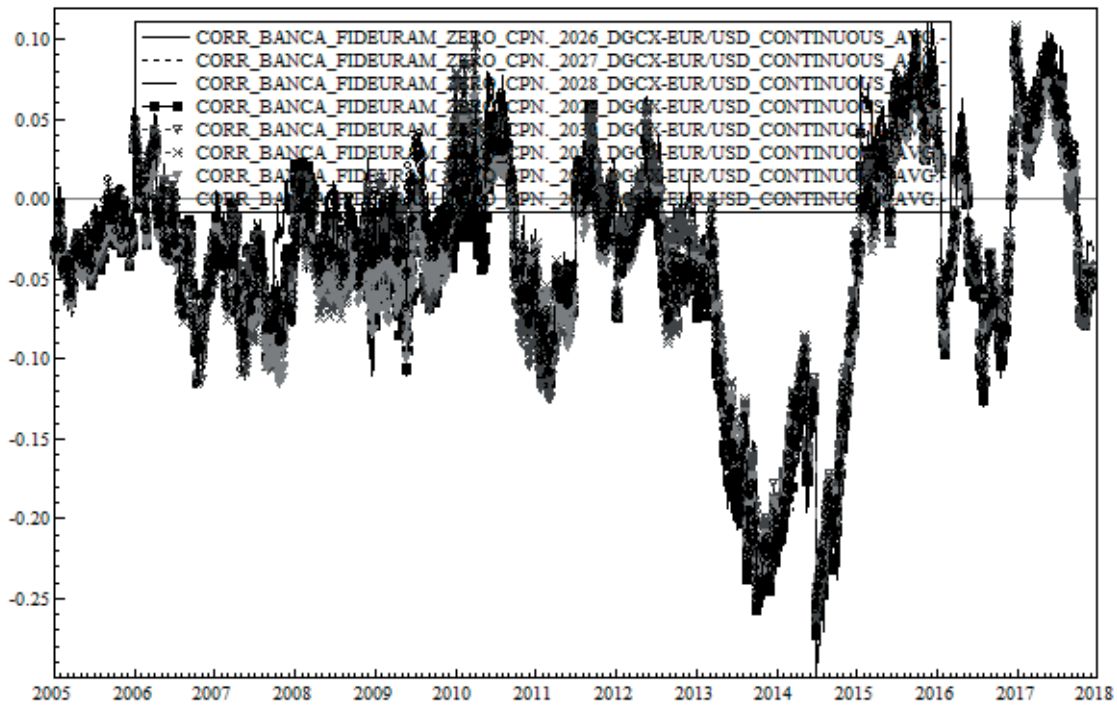


Figure 6 *- Dynamic Conditional Correlations for All the Pairs of Markets Generated by the Bivariate DCC-GARCH (1,1) Model.*



CONCLUSIONS

This paper investigates the potential volatility spillovers effects and the existence of contagion effects of the Eurodollar futures market and sixteen zero coupons of Banca Fideuram by employing a bivariate DCC-GARCH model. We set the under-investigation period from 2005 until 2017. To the best of our knowledge, this is the first empirical study investigating volatility spillovers between the Eurodollar futures market and the zero coupons of Banca Fideuram.

The main empirical results are summarized as follows. Based on the descriptive statistics, BANCA FIDEURAM ZERO CPN. 2032 returns present the largest fluctuations compared to the rest markets. Furthermore, results of the bivariate DCC-GARCH model indicate strong evidence of volatility spillover effects. DCCs analysis shows evidence of strong co-movements for all the pairs of markets. Additionally, DCCs reveal contagion for all the pairs of markets in sub-periods. The empirical results are of interest to policymakers, who provide regulations for the under-investigation derivative markets, as well as to market-makers.

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PRELIVANJE NESTABILNOSTI I EFEKAT ZARAZE IZMEĐU TRŽIŠTA EVRO DOLARSKIH FJUČERSA I BEZKUPONSKIH OBVEZNICA: DOKAZI IZ ITALIJE

Rezime:

Ovaj rad ispituje vremenski različite uslovne korelacije između terminskog tržišta Eurodollar i nula kupona Banca Fideuram. Primenjujemo GARCH model bivarijantne dinamičke uslovne korelacije (DCC) kako bismo zabeležili potencijalne efekte zaraze između tržišta za period 2005-2017. Empirijski rezultati otkrivaju zarazu tokom istražnog perioda u vezi sa dvadeset i jednim bivarijantnim modelom, pokazujući da tržište futura Eurodollar ima veliki uticaj na nulte kupone Banca Fideuram. Nalazi imaju presudne implikacije za kreatore politika koji pružaju propise za gore navedena tržišta derivata.

Ključne reči:

DCC-GARCH model,
buduće tržište EURODOLLAR,
nula kupona,
finansijska zaraza, dinamičke uslovne korelacije.

Klasifikacija jela:

C58, C61, G11, G15.