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The impact of the Brexit referendum on British and European Union bank shares: a cross-correlation analysis with national indices

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Abstract

Besides the possible political and geostrategic impact, the Brexit referendum and the respective citizens' decision had immediate economic impacts such as the decrease in GDP growth and the impact on exchange rates. Furthermore, the fact that London is one of Europe's financial centres would surely have an impact on this sector, with the banking sector as a particular case to be studied, due to its importance in society, both for firms and private individuals. In this paper, we analyse a wide range of banks in the European Union, in order to understand if they are now more correlated with national indices and with the Eurostoxx 600, a general index of the Eurozone. The results show that Eurozone banks generally decreased their effect on national indices, but some evidence of increasing correlation with the Eurostoxx was detected in the short run. Therefore, the European Central Bank should focus attention on this particular sector. Regarding non-Eurozone countries, they increased their correlation with national indices and decreased it with the Eurostoxx. This last result could be interesting, suggesting that monetary authorities could have the possibility of dealing easily with possible economic shocks.

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1. Introduction

After the Eurodebt crisis, Ferreira (2016) studied the impact of that crisis on European Union (EU) bank shares, namely how the returns of those shares changed their relation with the respective national indices. Using detrended cross-correlation analysis (DCCA) and its correlation coefficient, he found that many banks had increased correlation levels with the respective stock market, meaning that banks came to have more influence on stock markets than in the past. With these results, the author concluded that potential devaluations of bank shares could have a future impact on national indices. This kind of analysis shows the importance of being aware of how such events have an impact on stock markets, even more so if the events have a direct influence on financial markets, something which has gained relevance in recent years.

In mid-2016, the European Union faced another problem, although of a different nature: the UK referendum where British citizens decided to leave the European Union, a process that has come to be known as Brexit. Although not directly related to financial issues, this decision had an instant impact on the financial sector. For example, the FTSE-100, the main UK stock market, fell more than 3% on the day after the referendum. The banking sector, in particular, also suffered with this decision: Barclays lost about 17,7% of its value on that same day, the Royal Bank of Scotland about 18% and Lloyds Bank more than 21%.

Fear of the possibility of financial exit flows due to the uncertainty of the Brexit process explains the situation. Moreover, that uncertainty would also have consequences at a macroeconomic level in general, in variables like growth, trade or foreign direct investment, or in particular sectors like agriculture or energy, among others (see, for example, Boulanger and Phillipidis, 2015, Ebell and Warren, 2016, Dhingra et al. 2017a, 2017b, Gudgin et al., 2018, McCann 2018, Ziv et al., 2018, Bulmer and Quaglia, 2018).

Specifically for financial services, authors such as Howarth and Quaglia (2017), Armour (2017), Rehman and Posta (2018), Lavery et al. (2018) or Hall and Wójcik (2018) use approaches to analyse consequences more directed towards the geostrategy of financial services. Now, with increased distance from the referendum episode, and the existence of enough data, it is possible to start the analysis we propose in this paper: to analyse the consequences of Brexit for financial markets.

Over time, the UK's financial integration with other EU countries increased, as stated, for example, by Ayuso and Blanco (2001), Rangvid (2001), Yang et al. (2003), even when the Eurozone was created and the UK authorities decided not to adopt the common currency and also during the Eurodebt crisis (Bekaert et al. 2013 or Ferreira et al., 2018). This increased integration, even in those contexts, means that the UK maintained strong links with the EU which, according to theory, could enhance the well-being of all an economy's agents (see, for example, Bekaert et al. 2005). So, despite the impacts of Brexit on the financial sector due to the importance of the UK in the EU context in this particular sector (Howarth and Quaglia, 2017), other consequences could arise for the community as a whole. It will also be important for political decision-makers to know those connections, in order to analyse possible solutions.

In order to attain the objectives of the paper, we use an approach similar to that of Ferreira (2016): the correlation coefficient based on detrended cross-correlation analysis (DCCA) to evaluate how Brexit influenced the cross-correlation pattern of bank share returns with national indices and with a general EU index (the Eurostoxx 600). Evaluation of the cross-correlation's evolution is based on the $\Delta\rho$DCCA proposed by Silva et al. (2016), with the considered break being the date of the Brexit referendum (23rd June 2016). The analysis is

performed for all Eurozone and non-Eurozone banks for which data is available. The ΔρDCCA was also used, for example, by Wang et. al (2017), who used multi-scale methods to analyse the possibility of a contagion effect between several world stock markets during the subprime crisis.

The remainder of the paper is organized as follows: Section 2 presents the data and methodology. Section 3 describes the results, split in Eurozone and non-Eurozone banks. Section 4 concludes.

2. Data and methodology

In this study, we analyze evolution of the correlation between banks' share returns and the corresponding country's index, considering the Brexit referendum as a break date. The sample data start on 19th June 2014 and end on 28th June 2018, comprising a total of 1030 observations, split in two sub-samples with 23rd June 2016 as the break (each sub-sample having 515 observations).

Regarding banks, the objective was to use the same banks as in the study by Ferreira (2016). At the time, 39 banks from 13 different countries were used for Eurozone countries, while in non-Eurozone countries the sample had 24 banks from 8 countries. The sample analysed in this paper is slightly reduced. Regarding the Eurozone, one Italian bank ceased to exist, a Portuguese and a Spanish bank were sold (and so were no longer quoted in the respective stock markets) and two Maltese banks now have no information about quotations. So we use a total of 34 banks from the same 13 countries. Regarding non-Eurozone banks, no data was found for the two Bulgarian banks but a Polish bank was added to the analysis. Here, we used 23 banks from 7 different countries. The full sample of countries and the respective code used in this paper are presented in Table 1. Besides using each national index to analyse how each bank relates to the respective national index, we also analyse evolution of each bank's correlation with the Eurostoxx 600, aiming to determine whether the Eurozone as a whole is more or less exposed to banks following Brexit.

Table 1. Indices and shares.

Eurozone banks		**Non-Eurozone banks**	
***Index*/**Share	**Code**	***Index*/**Share	**Code**
ATX – Austria	***AUT00***	***PX – CzechRepublic***	***CZE00***
Erste Group Bank	AUT01	Komercni Banka	CZE01
Raiffeisen Bank	AUT02	Erste Group Bank	CZE02
BEL20 – Belgium	***BEL00***	***OMX20 – Denmark***	***DEN00***
KBC Group	BEL01	Danske Bank	DEN01
OMX Helsinki – Finland	***FIN00***	Nordea Bank	DEN02
Nordea Bank	FIN01	Jyske Bank	DEN03
CAC40 – France	***FRA00***	***BUX – Hungary***	***HUN00***
BNP Paribas	FRA01	OTP Bank	HUN01
Societe Generale	FRA02	FHB	HUN02
Credit Agricole	FRA03	***WIG20 – Poland***	***POL00***
Natixis	FRA04	PKO Bank	POL01
DAX30 – Germany	***GER00***	BANK Pekao	POL02
Deutsche Bank	GER01	Bank Zachodni	POL03

Eurozone banks		Non-Eurozone banks	
***Index*/**Share	**Code**	***Index*/**Share	**Code**
Commerzbank	GER02	MBank	POL04
ATHEX – Greece	***GRE00***	Alior Bank SA	POL05
Alpha Bank	GRE01	***BET – Romania***	***ROM00***
National Bank of Greece	GRE02	Banca Transilvania	ROM01
Eurobank Ergasias	GRE03	BRD Group	ROM02
Bank of Piraeus	GRE04	***OMX30 – Sweden***	***SWE00***
ISEQ – Ireland	***IRE00***	Nordea Bank	SWE01
Bank of Ireland	IRE01	Swedbank	SWE02
MIB30 – Italy	***ITA00***	Handelsbanken	SWE03
Intesa Sanpaolo	ITA01	SEB	SWE04
Unicredit	ITA02	***FTSE100 – UK***	***UK00***
Unione di Banche Italiane	ITA03	Lloyds	UK01
Mediobanca	ITA04	HSBC	UK02
Banca Popolaredi Milano	ITA05	Royal Bank Scotland	UK03
Banca PPO Emilia Romagna	ITA06	Standard Chartered	UK04
Banca Monte dei Paschi	ITA07	Barclays	UK05
Banca Mediolanum	ITA08		
AEX – Netherlands	***NET00***		
Ing Groep	NET01		
PSI20 – Portugal	***POR00***		
BCP	POR01		
IBEX35 – Spain	***SPA00***		
Banco Santander	SPA01		
BBVA	SPA02		
Caixabank	SPA03		
Banco Sabadell	SPA04		
Bankinter	SPA05		
CSE – Cyprus	***CYP00***		
Bank of Cyprus	CYP01		
Hellenic Bank	CYP02		
MSE – Malta	***MAL00***		
Bank of Valletta	MAL01		
HSBC Bank Malta	MAL02		

Based on the index/share value (S_t), we calculate the return rate (r_t), as is usual, by the difference of logarithms between consecutive values, i.e.

$$r_t = \ln(S_t) - \ln(S_{t-1}). \quad (1)$$

We use detrended cross-correlation analysis (DCCA) to study long-range cross-correlation between time series. DCCA was created by Podobnik and Stanley (2008), and is calculated as follows: i) considering the data given by x_k and y_k with $k = 1,\ldots,t$ equidistant observations, the first step of DCCA is the integration of both series, calculating new series given by

$$x(t) = \sum_{k=1}^{t} x_k \text{ and } y(t) = \sum_{k=1}^{t} y_k \quad (2)$$

ii) those series, with *N* observations, are divided into boxes of equal length, *n*. Afterwards, we divide them into *N-n* overlapping boxes and in each box the local trend is calculated with ordinary least squares ($\tilde{x}_k$and$\tilde{y}_k$); iii) then, the detrended series is calculated, obtaining the difference between original values and the trend; iv) next, we calculate the covariance of the residuals in each box given by

$$f^2_{DCCA} = \frac{1}{n-1}\sum_{k=1}^{i+n}(x_k - \tilde{x}_k)(y_k - \tilde{y}_k) \quad (3)$$

v) finally, the detrended covariance is calculated summing all *N-n* boxes of size *n*, given by

$$F^2_{DCCA}(n) = \frac{1}{N-n}\sum_{i=1}^{N-n} f^2_{DCCA} \quad (4)$$

The process is repeated for different length boxes finding the relationship between the DCCA fluctuation function and *n*, to find the long-range cross correlation$F_{DCCA}(n)$ given by the power law$F_{DCCA}(n) \sim n^{\lambda}$. The λ exponent could be interpreted as follows: a λ greater than 0.5 means persistent long-range cross-correlations; values lower than 0.5 mean anti-persistent cross-correlation.

Based on the DCCA exponent and on the values of the detrended fluctuation analysis (DFA), Zebende (2011) created the DCCA correlation coefficient given by

$$\rho_{DCCA} = \frac{F^2_{DCCA}}{F_{DFA\{x\}}F_{DFA\{y\}}} \quad (5)$$

This coefficient quantifies the long-range correlation between two different variables, and has the general properties of one correlation coefficient:$-1 \leq \rho_{DCCA} \leq 1$.If$\rho_{DCCA} = 0$ there is no cross-correlation between series, while a positive or negative value means, respectively, evidence of cross-correlation or anti cross-correlation. This correlation is debated in Zebende et al. (2013), and its efficiency is shown in Kristoufek (2014). We also analyse the significance of that coefficient testing the equality to zero, according to the procedures of Podobnik et al. (2011). The literature shows several applications of the DCCA with financial data. Using data from banks, the only study found is the one by Ferreira (2016) cited above.

It is usual to adopt correlation measures to analyse the relationship between financial assets. The DCCA has the ability to capture not only linear relationships (like other traditional measures such as the Pearson correlation) but also non-linear relationships, making its correlation coefficient a more general measure. Other non-linear methodologies also present this advantage, such as mutual information (proposed by Shannon, 1948, and testable according to Dionísio et al., 2004) or the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model proposed by Bollerslev (1986) and the respective evolutions. The DCCA can provide information for different time scales, which allows, for example, different results for different time horizons (both short and long ones). This feature gives us the possibility of having more complete conclusions, which is an advantage when compared with other measures.

3. Results

The main objective of this paper is to find out if Brexit had any effect on cross-correlations between bank share returns and the national indices and with the Eurostoxx 600 returns. In order to distinguish possible results between Eurozone and non-Eurozone banks, we divide the analysis in two different sub-sections. As our main objective is to analyse how Brexit affected the cross-correlations, and due to space constraints, we just show the results for the

ΔρDCCA. So descriptive statistics and the results for DCCA correlation coefficients before and after Brexit are not presented but can be supplied on request.

3.1. Eurozone banks

We started calculating the DCCA and the respective correlation coefficient for each bank and for national indices. Based on the analysis of statistical significance proposed by Podobnik et al. (2011), and considering the relationship between banks and national indices, in the period before Brexit all the calculated correlation coefficients are significant at least at a 5% level. After Brexit, one Maltese Bank just has significant correlations for smaller time scales (the Lombard Bank, for $n \leq 7$) and the Italian Banca Monte dei Paschi has significant correlations just for $7 \leq n \leq 28$. The remaining banks have significant correlations for all time scales.

Based on $\Delta\rho_{DCCA} = \rho_{after}-\rho_{before}$, it is possible to determine whether after Brexit banks became more or less correlated with the respective national index, which could be a sign that index is more or less exposed to this particular financial sector. The results for Eurozone banks are presented in Figure 1. In the figure it is possible to identify the correlation between each bank share return and the respective national index. For example, in the last panel, for MAL02 we have the correlation of HSBC Bank Malta returns with the Maltese index. Each inverse triangle represents the correlation coefficient for each time scale. Being negative means that the correlation decreased after the decision of the Brexit referendum, while if it is positive the correlation increased (as happens, for example, for CYP01). In these two cases the behavior was the same over all the considered time scales (in this study we used time scales from 4 to 119). The interpretations are similar for the remaining figures.

Analysis of Figure 1 reveals very interesting results. Almost all banks have decreased correlation after Brexit, meaning that national indices are less exposed to this particular sector. This highlights the important work of the European Central Bank in making the financial sector more robust. The Greek banking sector as a whole, which had increased correlation, remains a problem: these results show that now the Greek stock market is more exposed to an eventual bank crisis than in the past. The same increased correlation is also clearly seen in one of the Cypriot banks and less so in one Maltese bank. Both German banks have a slight increase in correlation, but just for lower time scales (i.e., in the short run). At the time of publishing Ferreira (2016), a statistical test for ΔρDCCA was not yet available. The author made a t-test for the mean of the ΔρDCCA, which could give an idea of the general behaviour but does not allow direct comparison for each length box, which is now available with the test proposed by Guedes et al. (2018a, 2018b). The critical values of that test are presented in Table I, for the case of N = 500 (consistent with our samples) and for the different time scales presented in the original study.

Table I: Critical values of $\Delta\rho_{DCCA}$ with 90%, 95% and 99% of confidence level (CL) for N = 500 (Guedes et al., 2018a, 2018b)

	n = 4	n = 8	n = 16	n = 32	n = 64
CL = 90%	0.0017	0.0016	0.0016	0.0016	0.0016
CL = 95%	0.0021	0.0019	0.0019	0.0019	0.0019
CL = 99%	0.0027	0.0025	0.0024	0.0024	0.0025

The tightness of the critical values of these studies makes them difficult to detect in the Figure but allows us to conclude on rejection of the null for the ΔρDCCA (because most of the values are outside the bounds which are limited by the critical values).

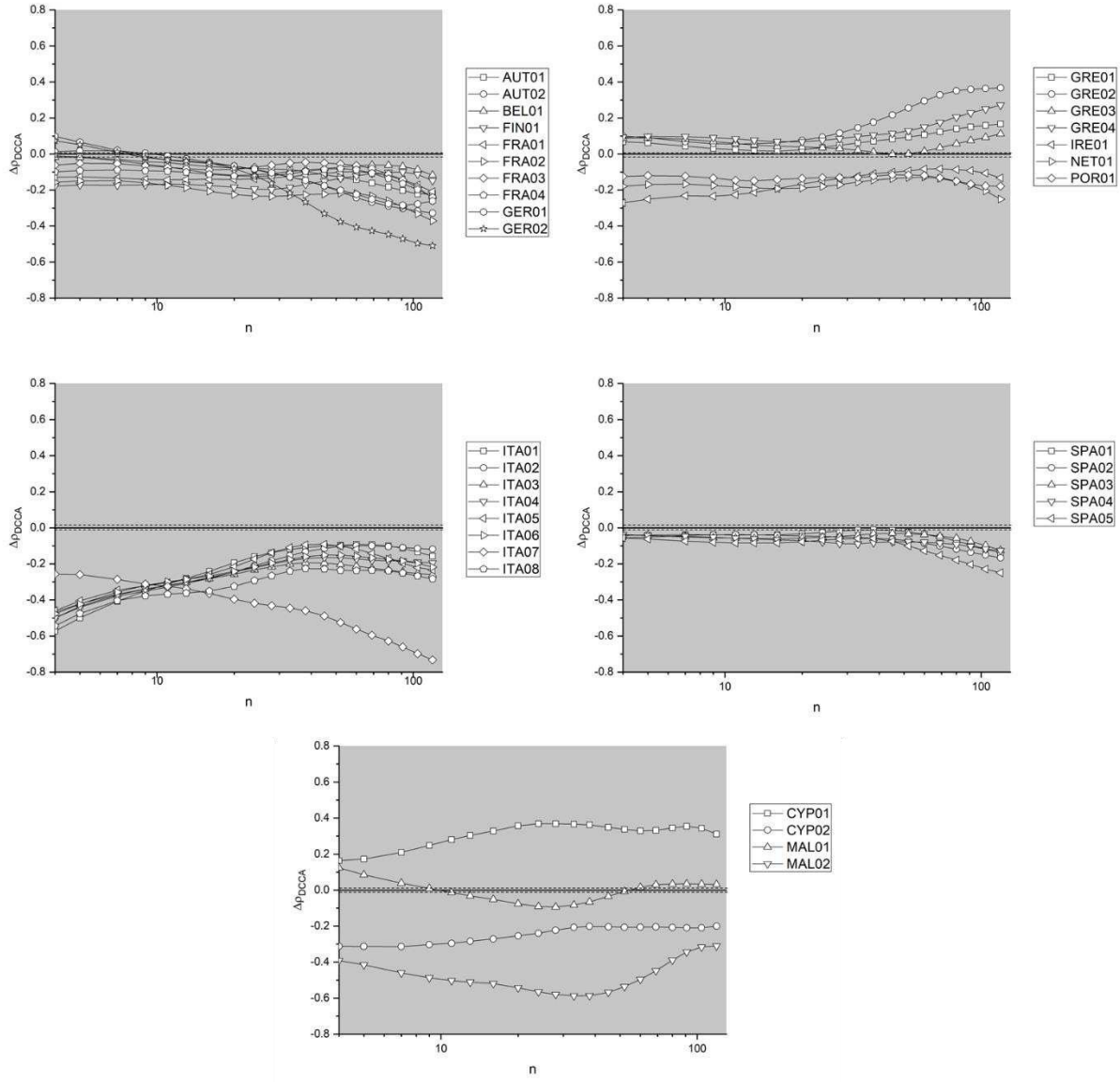

Figure 1. ΔρDCCA for Eurozone banks and the respective national index, as a function of *n* (days). Dashed lines are the critical values of the test developed by Guedes et al. (2018a, 2018b).

Besides analysing the relationship with each national index, we study how bank share returns are correlated with the Eurostoxx 600 returns, an index including major Eurozone firms, with the results in Figure 2.

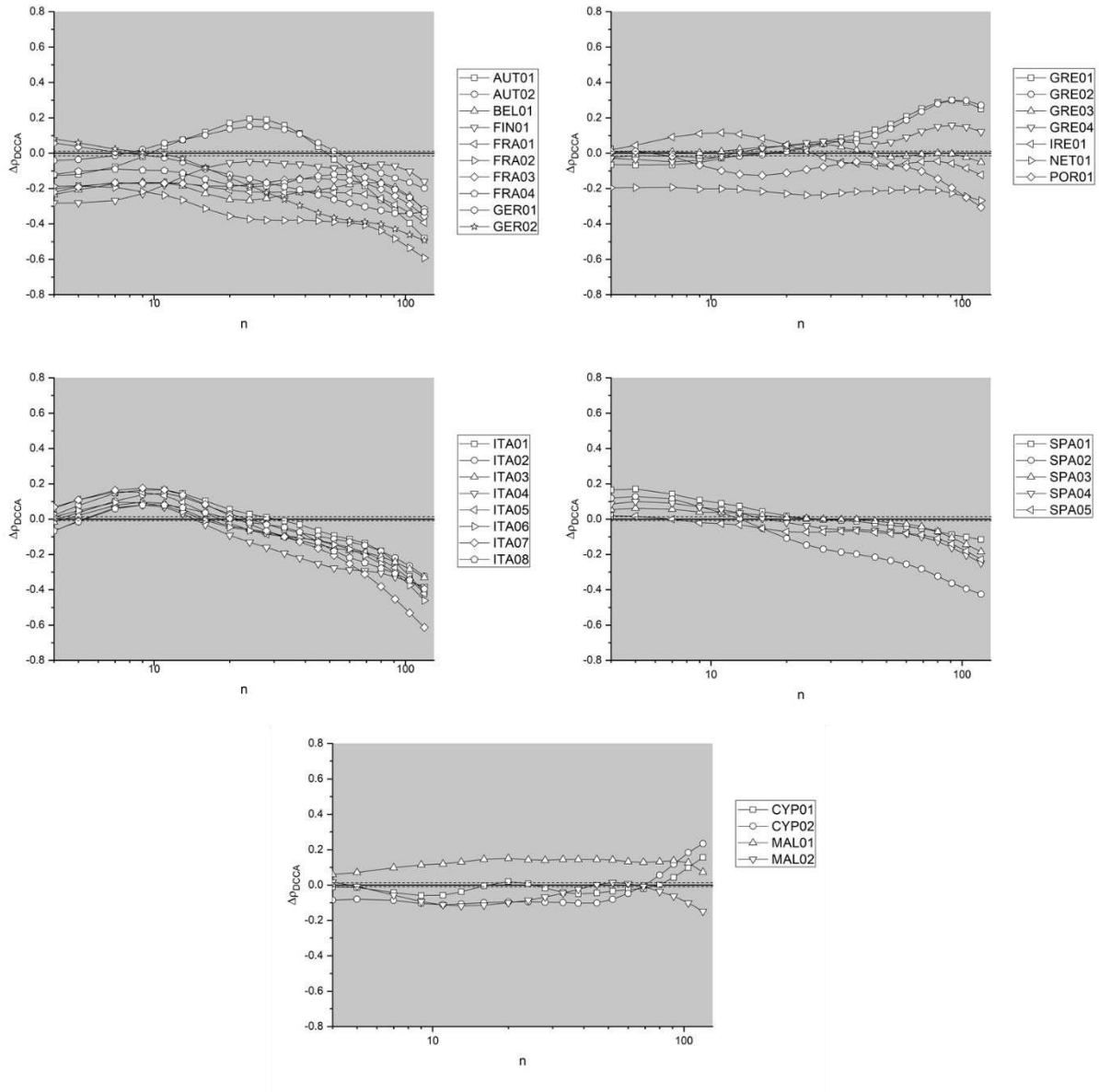

Figure 2. ΔρDCCA for Eurozone banks and the Eurostoxx 600, as a function of *n* (days). Dashed lines are the critical values of the test developed by Guedes et al. (2018a, 2018b).

Qualitatively, the results are not much different, although for small and medium time scales some more banks present more positive correlations: Austrian, most Italian, Irish and Spanish banks, besides those indicated in the previous analysis. This means that in the short run, the Eurostoxx 600 is more exposed now to the banking sector than national indices.

3.2. Non-Eurozone banks

We made a similar analysis for non-Eurozone banks, tracking for possible differences when compared with Eurozone ones. In this case, and regarding the significance of individual correlation coefficients before and after Brexit, there is stronger evidence of significant correlations. In the pre-Brexit period, just the Danish Jyske Bank had some time scales with non-significant correlations ($n \geq 104$) while post-Brexit this happened with the Hungarian FHB (for ≥ 33) and the British Barclays (for $n \geq 80$). Regarding the $\Delta\rho_{DCCA,}$ the results are

presented in Figure 3. For these countries, there is more evidence of increased exposure of national indices to the banking sector. It is noted that Danish and British markets show some sign of differences from the others, with closer behaviour than Eurozone countries. This is a regular result in other studies analysing financial integration in the EU (see, for example, Ferreira and Dionísio, 2015, Ferreira et al., 2016 or Ferreira and Kristoufek 2017).

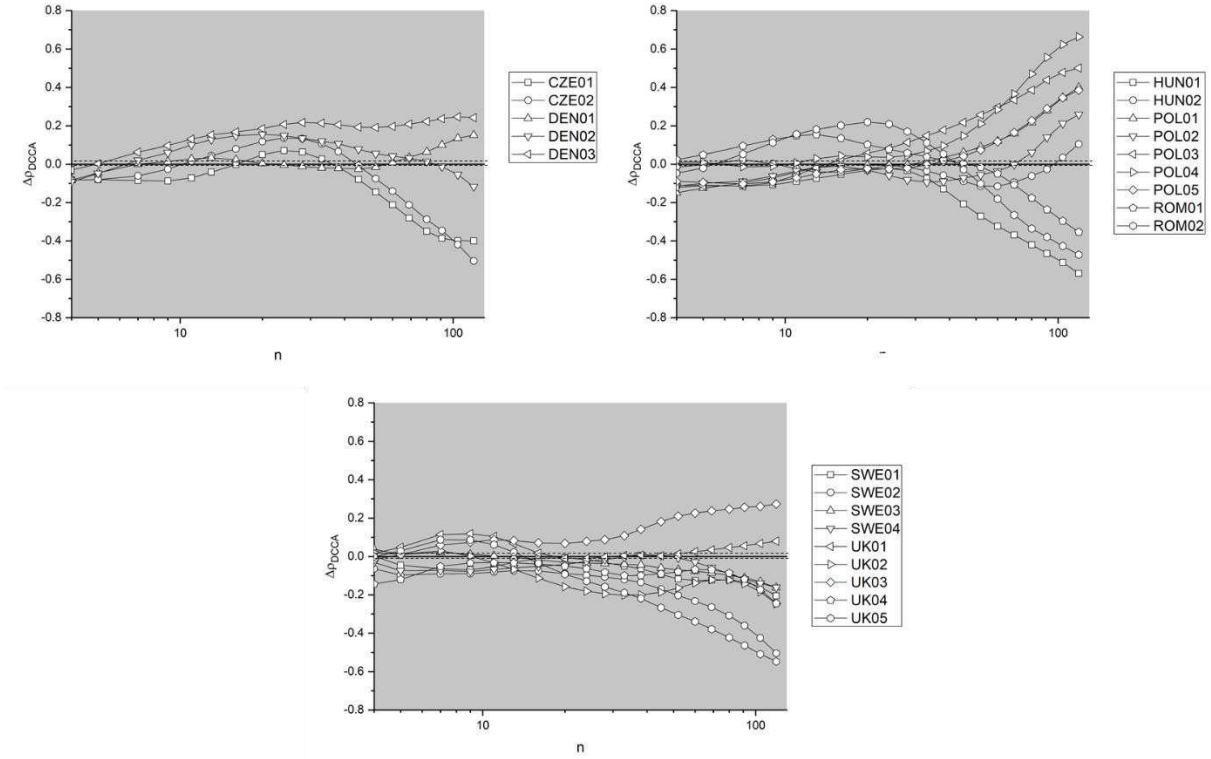

Figure 3. ΔρDCCA for non-Eurozone banks and the respective national index, as a function of *n* (days). Dashed lines are the critical values of the test developed by Guedes et al. (2018a, 2018b).

Figure 4 presents the results for the correlation between non-Eurozone banks and the Eurostoxx 600. In this case, most banks decreased their correlations with the Eurostoxx, meaning that they have less influence on that index. This is not a surprising result, since the Eurostoxx just has components from the Eurozone countries. However, it could be important for economic policy-makers, due to the possible connection with decreased financial integration, which could have disadvantages but also benefits for those countries.

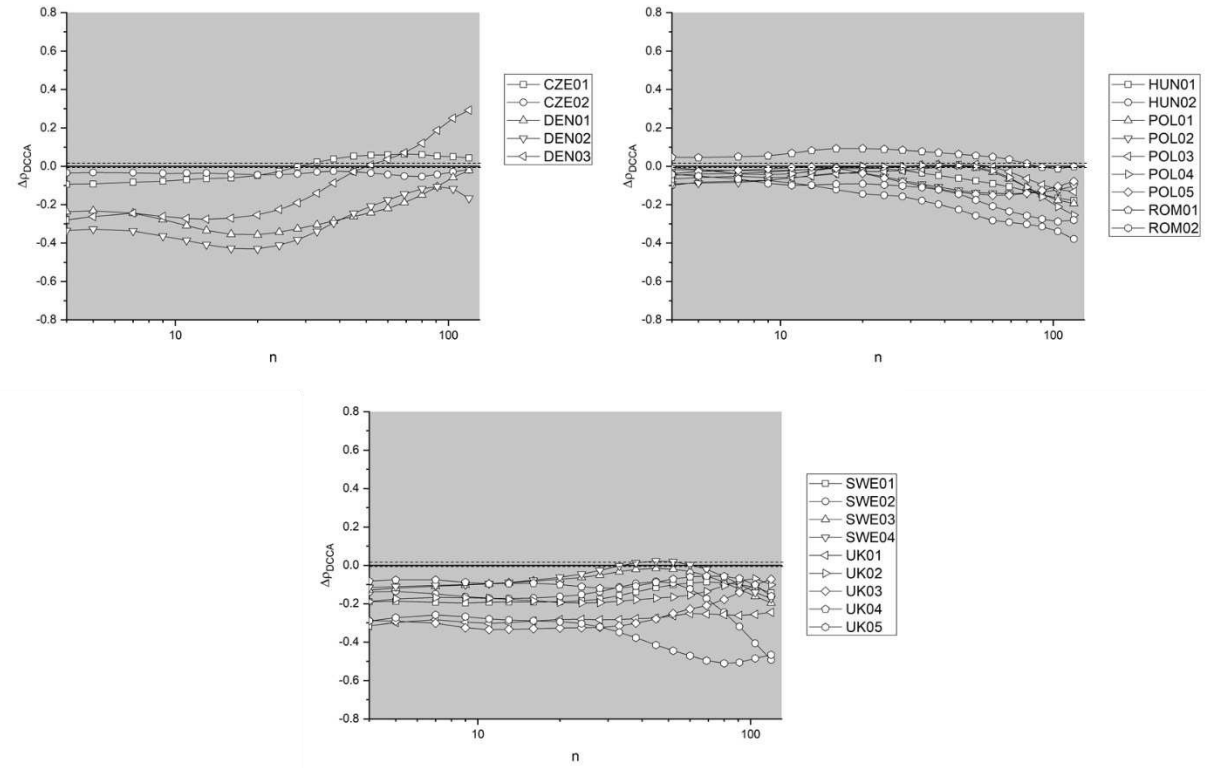

Figure 4. ΔρDCCA for non-Eurozone banks and the Eurostoxx 600, as a function of *n* (days). Dashed lines are the critical values of the test developed by Guedes et al. (2018a, 2018b).

4. Concluding remarks

After the Eurodebt crisis, which had consequences for the banking sector, namely possible increased exposure of national indices to bank shares, analysis of Brexit could give some insights into that behaviour. Following the work of Ferreira (2016), which effectively analysed the effects of the Eurozone crisis, this paper analyses the effects of Brexit, splitting the sample in Eurozone and non-Eurozone banks.

Considering Eurozone banks, most banks decreased their correlations with the respective national index, probably because economic issues are almost solved, but also because European Central Bank intervention, namely with macro-prudential regulation, could have some affects. However, when the correlation is measured with the Eurostoxx 600, in the short run (lower scales), it seems that in some cases that exposure to the banking sector increased. This could be an alert for the Central Bank to pay some attention to this sector. An important conclusion is that Greek banks seem to be the main ones with increased correlation.

Regarding non-Eurozone countries, their national indices' exposure to banks increased in several countries. As none of those countries experiences a debt crisis, it is not necessarily a problem, but could arouse economic and monetary authorities' attention for the future. When the difference in correlation is measured with the Eurostoxx, there is a clear decrease in correlation.

These results could lead to different conclusions, depending on the agents involved. For investors, the fact that bank share returns decreased their correlations could be used for portfolio diversification, if used complementarily with other shares with higher exposure.

For monetary authorities the results could serve as a warning for the future if correlations increase or represent a gain, in the particular case of Eurozone countries, because it would seem that political measures have had effect.

Finally, and specifically for non-Eurozone countries, decreased correlation with the Eurozone could also have consequences. Although needing confirmation for other sectors, because we are studying a particular one, this result could mean that the level of financial integration decreased over time. And if this could have negative consequences through preventing higher growth rates, it could also have a positive impact, namely the fact that in the case of asymmetric shocks, through the exchange rate, those countries would be able to face those shocks and mitigate possible crisis (which does not occur, for example, in Eurozone countries because they share a common currency).

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