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The relationship between oil prices and the Brazilian stock market

Paulo Ferreira [a,b,c,*], Éder Pereira [d,e], Marcus Silva [f]

[a] VALORIZA - Research Center for EndogenousResourceValorization, Portalegre, Portugal
[b] Instituto Politécnico de Portalegre, Portalegre, Portugal
[c] CEFAGE-UE, IIFA, Universidade de Évora, Largo dos Colegiais 2, 7000 Évora, Portugal
[d] Programa de Modelagem Computacional, SENAI Cimatec, Av. Orlando Gomes 1845, 41.650-010, Salvador, BA, Brazil
[e] Instituto Federal do Maranhão, Brazil
[f] Instituto Federal da Bahia, Brazil

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ABSTRACT

Crude oil remains a very important product not only because of its regular use, but also because it is a very important financial asset, influencing the economy as a whole. In this paper, we assess how WTI oil price shocks are related with the Brazilian economy as a whole, but also with each of the listed companies in Ibovespa, searching for the relationships with different economic activities. Based on the Detrended Cross-Correlation Analysis correlation coefficient, which allows us to analyse the impacts for different time scales, we conclude unsurprisingly that the most affected sectors are those most related with the use of oil. However, another important result is the significant correlation between oil price shocks and the returns of the financial sector, showing this particular sector's exposure to oil, i.e., this is one of the sectors most correlated with oil returns. This is relevant not only for investors but also for authorities, because possible future oil shocks could have a high impact on the Brazilian financial sector

1. Introduction and related literature

Oil is considered a strategic resource and is extremely relevant to a particular country or region, since its derivatives such as gasoline and diesel are used by most forms of transport, besides other uses in industry in products such as paraffin, asphaltic products, petrochemical naphtha, kerosene, polymers, solvents, fuel oils, lubricating oils among others. For many decades, oil was one of the major drivers of the international economy, reaching almost 50% of the world's primary energy consumption in the early 1970s. Although this share has been declining over time, accounting for about 43% of consumption, it should remain significant for decades.

Several studies identify different amounts of oil as responsible for all the electricity generated in the world, ranging from 7.5% to about 10% (see [1] and [2,3]), which is still a relevant amount. During World War II, about 90% of Brazil's oil was imported from the United States, showing Brazil's heavy dependence on North American oil [4]. An important milestone for the national oil industry was the founding of Petrobras (PetróleoBrasileiro S.A.) in 1953, which is a mixed-economy corporation in the conception of Decree-Law No. 200, dated 25th February, 1967.

In 1973, Brazil imported 78% of the oil consumed in the country. Reducing that dependence was a matter of survival for the country, which led the government to encourage Petrobras to increase its national oil production and develop

* Corresponding author at: CEFAGE-UE, IIFA, Universidade de Évora, Largo dos Colegiais 2, 7000 Évora, Portugal.
E-mail addresses: pferreira@ipportalegre.pt (P. Ferreira), eder.johnson@ifma.edu.br (É. Pereira), marcus.fisico@gmail.com (M. Silva).

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the Proálcool program, with the objective of using alcohol as fuel for transport. Brazil's dependence on the price of oil became evident with the oil price crisis in December 1973, when OPEC (Organization of Petroleum Exporting Countries) members gradually raised the price of oil [5]. In this context, the oil price shocks during the 1970s, together with the policy implemented by former US President Ronald Regan focused on raising interest rates, meant that part of the international capital migrated to the United States, affecting developing economies and contributing to Brazil entering an external crisis in the late 1970s and early 1980s, with the country remaining in recession until 1984.

More recently, when oil prices increased between 2003 and 2008, the Brazilian economy experienced a moment of accelerated economic growth. The fall in the price of oil in July 2014 and the appearance of political problems contributed to the biggest recession in Brazil's history, leading to a decline in two consecutive years (2015 and 2016) in the Brazilian economy [6]. Regarding the capital market, the main Brazilian stock index, Ibovespa, dropped from 53 500 points in June 2014 to 41 593 points in February 2016, while the price of WTI crude oil rose from 105.74 USD to 27.45 USD in the same period. Companies such as Petrobras showed a significant reduction in their market value.

Given the importance of the Brazilian economy in the world context and the importance of oil not only as a raw material but also as a financial asset, the objective of this paper is to analyse how oil price affects the Brazilian stock market. Furthermore, we will analyse not only the main Brazilian stock index (Ibovespa) but also each of the individual shares listed in that stock market. We will make the study using the correlation coefficient from the Detrended Cross-Correlation Analysis (DCCA), which enables us to identify the pattern of correlations in different time scales, allowing effects in the short and long run to be distinguished.

The literature contains many examples of studies analysing correlation patterns between oil and stock markets, based on the fact that oil can be understood as a substitute asset of stocks (see for example, [7]), but also because it can affect productive sectors differently, with different effects on them depending on the intensity of their use of oil. For example, Segal [8] finds that the increase in oil prices could affect the prices of other products, which could affect negatively the results of firms which are more dependent on oil or its derivatives. Besides the impact on share prices, oil price fluctuations affect macroeconomic variables such as inflation rates, GDP, unemployment and exchange rates.

Academic interest in the effects of oil prices goes back to the oil price shocks of the 1970s and since then the number of studies has multiplied. Many of them study the effect of oil prices on the stock markets of developed countries. For example, Kaul and Seyhun [9], Ferson and Harvey [10,11], Jones and Gautam [12], Sadorsky [13], El-Sharif et al. [14], Park and Ratti [15], Apergis and Miller [16], Abhyankar et al. [17], Moya-Martínez et al. [18] and Zhang [19] all analyse the impact of oil prices on developed stock markets.

Recently, with increased availability of data for more markets, it is usual to find analysis of the effects of oil prices on emerging markets: Hammoudeh and Aleisa [20], Hammoudeh et al. [21], Hammoudeh and Huimin [22], Arouri and Rault [23], Asteriou and Bashmakova [24], Zhu et al. [25], Fang and You [26] and Ghosh and Kanjilal [27]. Some studies include Brazil in the analysis. For example, Basher and Sadorsky [28] conclude that in Brazil, as in other emerging markets, the oil price has an impact on stock returns. Bhar and Nikolova [29] found no dependence between WTI crude oil and returns in Brazil. Contrarily, Reboredo [30], Mensi et al. [31] and Kayalar et al. [32] identified dependence between the oil price and stock returns, in several places.

An interesting result of the analysis of previous work is that conclusions about the connections between oil prices and stock markets are mixed. According to Ciner [33], this could be related with the use of linear methodologies, unable to detect some types of correlations. More recent studies, applying nonlinear techniques, are more likely to find significant linkages between oil and stock markets: Zhang [34], Aloui and Jammazi [35], Miller and Ratti [36], Filis et al. [37], Broadstock et al. [38], Wen et al. [39], Nguyen and Bhatti [40], Antonakakis and Filis [41] and Ferreira et al. [42]. The DCCA correlation coefficient, which is also used in Ferreira et al. [42], is included in the set of non-linear methodologies and is also able to study correlations in different time scales.

In this paper we are interested in analysing the correlations of oil prices with stock markets but for individual stocks, rather than the whole indices. The main objective is to find out if it is possible to distinguish between the different impacts, in different sectors, in the case of the Brazilian economy. The literature also contains some studies analysing the impact of the oil market on different productive sectors. For example, Huang et al. [7] find a direct effect of oil price on other oil stocks, in the case of the US stock market (corroborated later by Hammoudeh and Huimin [22]). Faff and Brailsford [43] analyse the Australian stock market, and found that some sectors are more affected by oil prices shocks (and not only firms in the oil and gas markets). Cong et al. [44] analyse the Chinese market, and unlike the previous study, just find evidence of correlations in the case of oil firms and in manufacturing industry. Elyasiani et al. [45], Arouri [46], Broadstock et al. [38], Zhang and Cao [47], Broadstock et al. [48], Wen et al. [39], and Yang et al. [49] are all in accordance, finding that oil price shocks have different impacts on different sectors.

Some studies distinguish between demand and supply industries and conclude that while in the case of demand industries, an increase in oil price has a positive impact on those industries, in the case of supply industries, the results are negative or non-existent, concluding that in industries on the demand side, increased oil prices have a positive impact (see, for example, Gogineni [50], Nandha and Faff [51] and Kilian and Park [52]). With a wider sample, Kang et al. [53] found that both kinds of sector are influenced by oil prices. Yang et al. [49] used multifractal DCCA and found a strong relationship between oil price and ten different sectors in the Chinese economy.

Our paper contributes to the literature by analysing a specific country and each of the shares listed in the main stock market index. The DCCA correlation coefficient is used not only to capture non-linear correlations but also to distinguish

between different time scales. Our main results point to a short run impact of oil price on the Brazilian stock market as a whole. For specific sectors of activity, those more related with oil are naturally more correlated with the oil price, but we also find that the financial sector is somewhat exposed to this particular asset.

The remainder of the paper is organized as follows: Section 2 presents the methodology and data used in this study; Section 3 describes the results; Section 4 concludes.

2. Methodology and data

Considering that financial markets can be understood as complex systems, we will use in this analysis a statistical physics methodology called detrended cross-correlation analysis (DCCA) and its correlation coefficient, to analyse the dependence between time series. This methodology was created by Podobnik and Stanley [54] and is performed as follows: (i) considering two time series, x_k and y_k, with $k = 1, \ldots, t$ equidistant observations, equidistant observations, it starts by integrating both series, i.e., calculating $(t) = \sum_{k=1}^{t} x_k$ and $y(t) = \sum_{k=1}^{t} y_k$; (ii) divide the whole samples into boxes of equal length, of dimension n, divide into N-n overlapping boxes and calculate, with ordinary least squares, the respective local trend ($\tilde{x}_k$ and $\tilde{y}_k$); (iii) calculate the detrended series, based on the difference between the original values and the previously identified trend; (iv) calculate the covariance of the residuals for each box, given by $f^2_{DCCA} = \frac{1}{n-1}\sum_{k=i}^{i+n}(x_k - \tilde{x}_k)(y_k - \tilde{y}_k)$; (v) obtain the detrended covariance given by $F^2_{DCCA}(n) = \frac{1}{N-n}\sum_{i=1}^{N-n} f^2_{DCCA}$. This process is repeated for all length boxes with the long-range cross correlation resulting in a power law given by: $F_{DCCA}(n) \sim n^{\lambda}$, where λ is the parameter of interest, quantifying the long-range power-law cross-correlations. The work of Podobnik et al. [55] proposes a test to quantify the long-range cross-correlations between two different time series.

To measure the degree of the correlation, the correlation coefficient created by Zebende [56] is used, given by $\rho_{DCCA} = \frac{F^2_{DCCA}}{F_{DFA\{x\}}F_{DFA\{y\}}}$, where DFA{x} and DFA{y} represent the DFA method for the series x and y, respectively (see [57], for a description of this method, which is just used indirectly in this calculation). This is an efficient correlation coefficient according to Kristoufek [58] and is tested according to the procedure proposed by Podobnik et al. [59]. Besides the properties of the correlation coefficient (see [60]), it can also give us information for different time scales, distinguishing between the short-run and long-run behaviour of the correlations.

As well as use of the DCCA correlation coefficient in studies involving oil and stock markets, some work studies the relationship between different financial assets, such as stock markets and exchange rates (see, for example, [61,62]), oil and exchange rates [63], or even analysing futures [64]. In this work, the authors propose a slightly different methodology called detrended partial cross-correlation analysis (DPXA), a generalization of DCCA but considering the existence of other common factors affecting both time series under analysis. Another variation of the DCCA is found in the work of Horvatic et al. [65]. Podobnik et al. [66] also use the DCCA to analyse financial markets, but in this case to assess the relationship between volume and price changes.

In this study we use data from the main Brazilian stock market index, Ibovespa, and the respective constituents, as well as the WTI Crude Oil price. Data was retrieved from Datastream, from 3rd January 2000 to 12th April 2019, a total of 5029 observations. Not all the shares are of the same size, so we matched the available size with the WTI series considering the same time span. From the total of 65 constituents of the stock index, at the moment of data retrieval, we excluded 6 of them due to reduced samples. Appendix A provides the list of shares used as well as the sector of activity and number of observations used for the analysis (Table A1).

3. Results

Before calculating the estimations of the DCCA correlation coefficients with oil, we calculated the descriptive statistics for the assets used, the results appearing in Appendix B (Table B1). There, just one share (MARFRIG FRIGORIFICOS) is seen to have a negative mean return, while the remainder have positive returns, despite the mean being very near to zero in some cases. Shares are relatively equally divided regarding skewness value (identifying whether positive shocks are more or less probable than negative ones), but it is noted that most of the assets have higher kurtosis than expected for normal distribution, which means that most of the distributions are leptokurtic, i.e., have fat tails (this is a common feature of financial assets).

We went on to calculate the DCCA correlations between each of the assets regarding the oil price. Fig. 1 shows the correlation coefficient between WTI oil and IBOVESPA returns. In general, the correlation levels are not high, although statistically significant for short time scales and marginally significant for medium time scales. For higher time scales the correlations are not significant, which means than in general, the Brazilian index is not excessively exposed to oil.[1]

However, the results vary for the different sectors of activity, as seen in Figs. 2–7, where the correlations between oil and each of the individual shares are presented, organized by different sectors.

Obviously, oil, gas and biofuels firms are more related with oil, with significant correlation over all the time scales. Other sectors which have higher correlations with oil returns are mining, pharmaceutical, real state, steel and metallurgy,

[1] Calculations were also made considering Brent oil as reference. The results are very similar, confirming the robustness of the analysis. Due to space constraints, we do not show all the figures in this paper, but the results of the correlations of Brent with Ibovespa and with Petrobras are presented in Appendix C (Figs. C1 and C2).

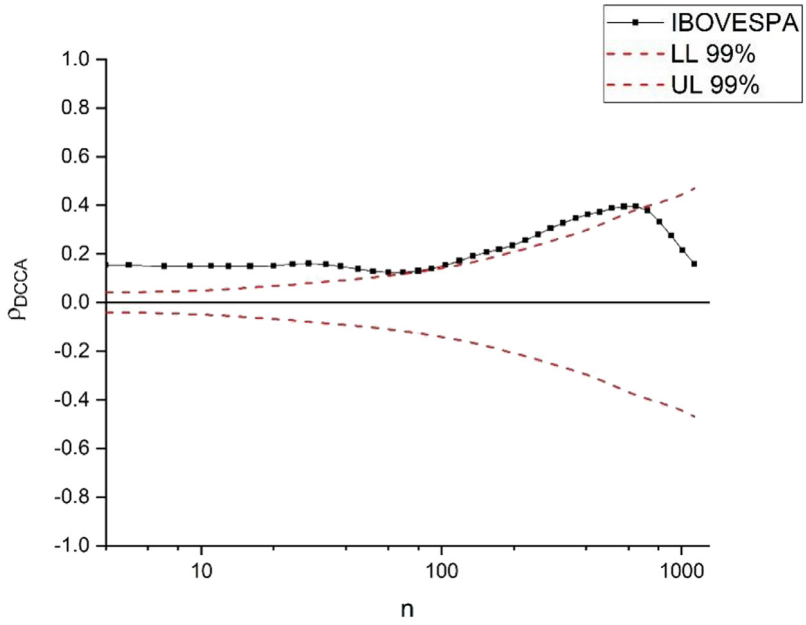

Fig. 1. DCCA correlation coefficient between oil returns and IBOVESPA returns, depending on time scale (in days). Dashed lines represent lower and upper critical values, to test hypotheses H0: $\rho_{DCCA} = 0$ and H1: $\rho_{DCCA} \neq 0$.

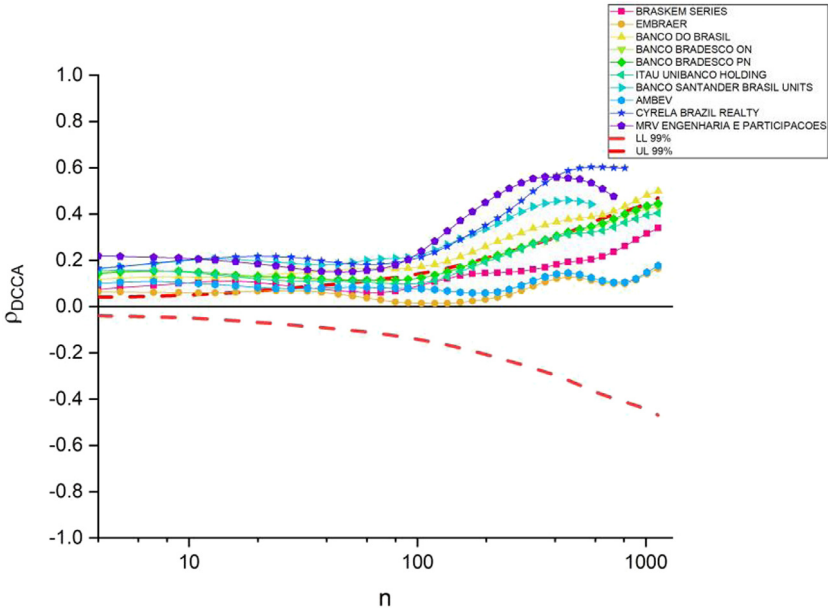

Fig. 2. DCCA correlation coefficient between oil and shares in the following economic sectors: Aviation Transport Material; Banking; Beverages; Building and engineering; Chemicals (depending on time scale - in days). Dashed lines represent lower and upper critical values, to test hypotheses H0: $\rho_{DCCA} = 0$ and H1: $\rho_{DCCA} \neq 0$.

food, building and engineering and car hire. One possible explanation for this result is that with the improvement in trade in the Brazilian economy, which is an exporter of crude oil, there has been an increase in domestic liquidity, reflecting an increase in the demand for Brazilian companies listed in the Brazilian stock index IBOVESPA. Additionally, this increase in domestic liquidity has led to an increase in the entire national production chain, which is well interconnected, and as the oil industry is one of the most central sectors [67], an increase in oil price causes an increase in demand for goods and inputs in the domestic industry, raising companies' profits in the medium term and, consequently, their market value.

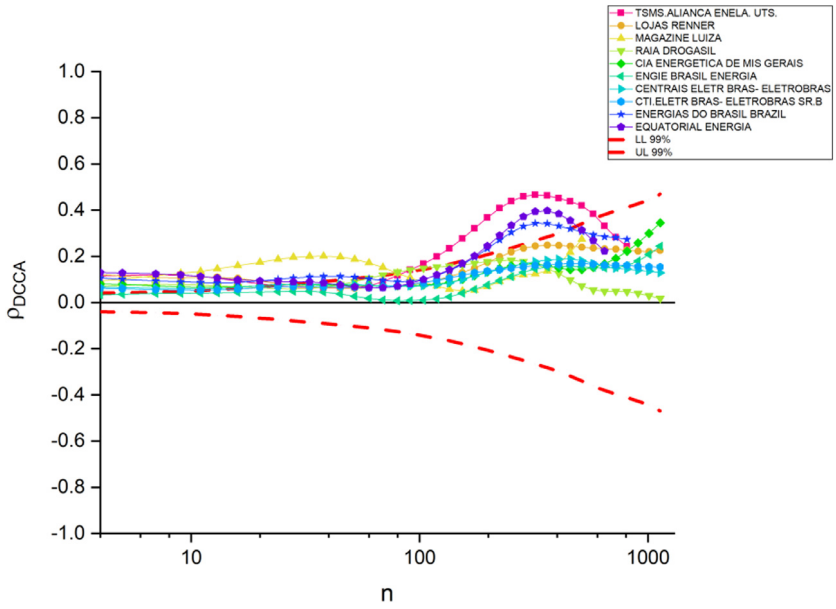

Fig. 3. DCCA correlation coefficient between oil and shares in the following economic sectors: Clothing commerce; Commerce (appliances and furniture); Commerce (drugstores), Electric power (depending on time scale - in days). Dashed lines represent lower and upper critical values, to test hypotheses H0: $\rho_{DCCA} = 0$ and H1: $\rho_{DCCA} \neq 0$.

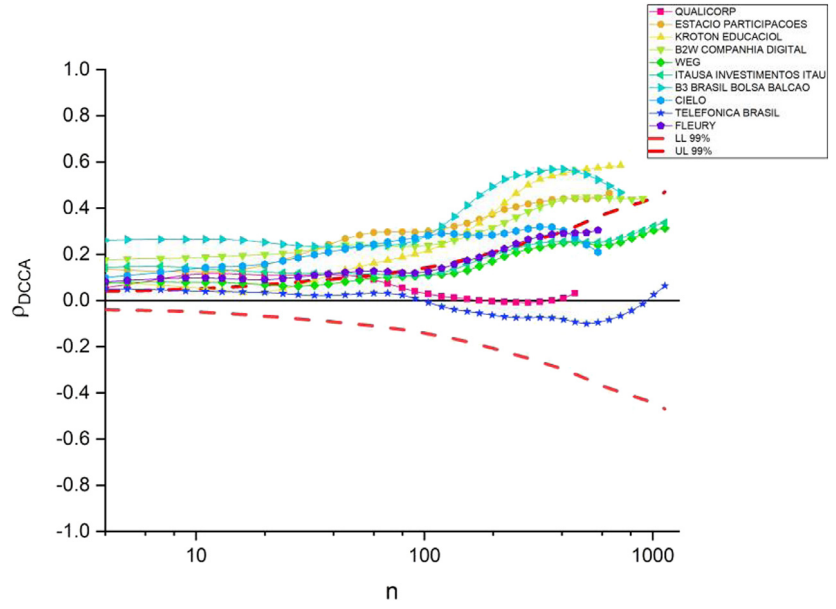

Fig. 4. DCCA correlation coefficient between oil and shares in the following economic sectors: Education; Electronic commerce; Equipment; Financial services; Fixed phone services; Health services (depending on time scale - in days). Dashed lines represent lower and upper critical values, to test hypotheses H0: $\rho_{DCCA} = 0$ and H1: $\rho_{DCCA} \neq 0$.

Another sector showing a statistically significant effect of correlations with oil is finance, both for general financial services and for banking in general. This means the financial sector is somewhat exposed to shocks in oil prices, since it has a relevant correlation with oil returns. So, possible future instability in oil prices could have a direct impact on the financial sector, which could be then extended to the whole economy. This kind of result is also in line with some previous evidence of a generalized increase of correlation in different market sectors, which is an increase of systemic risk (see, for example, [68]).

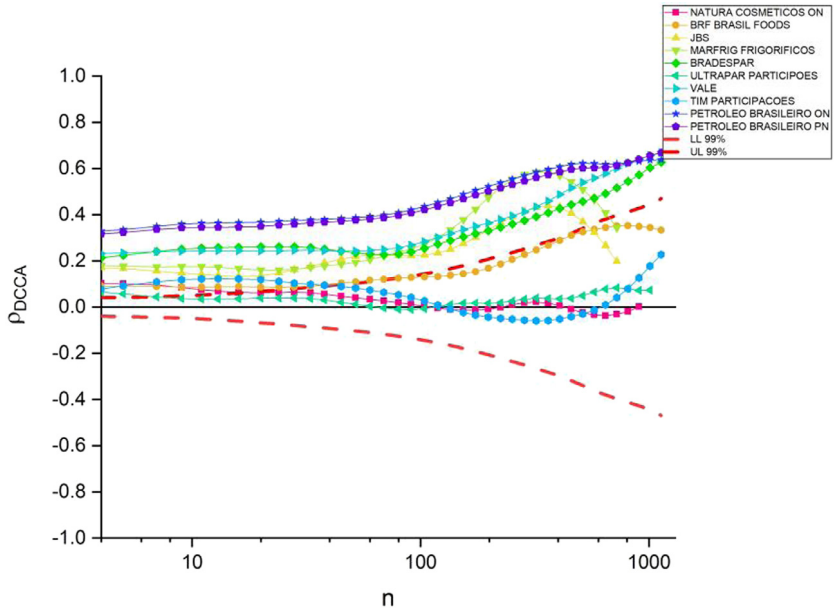

Fig. 5. DCCA correlation coefficient between oil and shares in the following economic sectors: Foods; Holding (diverse products/services); Mining; Mobile phone services; Oil, Gas and Biofuels; Personal Use and Cleaning Products (depending on time scale - in days). Dashed lines represent lower and upper critical values, to test hypotheses H0: $\rho_{DCCA} = 0$ and H1: $\rho_{DCCA} \neq 0$.

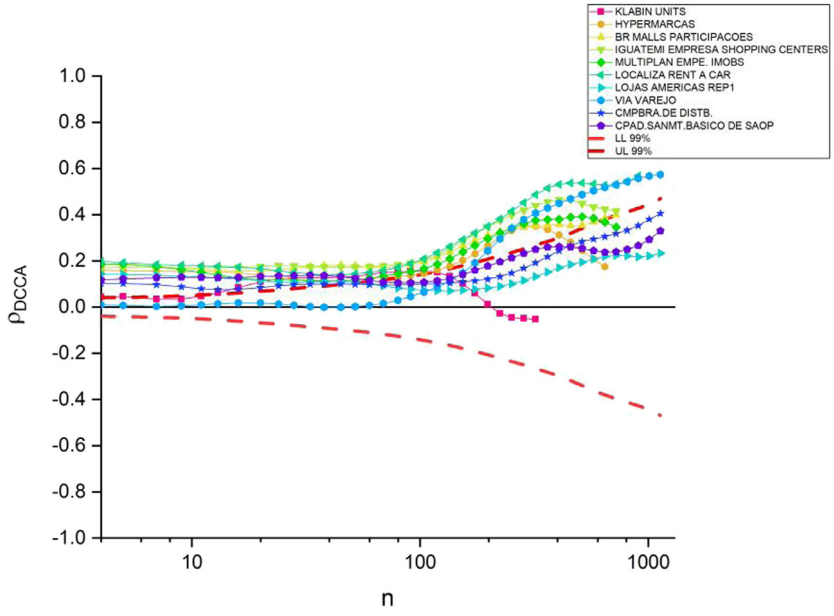

Fig. 6. DCCA correlation coefficient between oil and shares in the following economic sectors: Pharmaceutical; Real state; Car hire; Retail commerce; Water and sanitation; Wood and paper (depending on time scale - in days). Dashed lines represent lower and upper critical values, to test hypotheses H0: $\rho_{DCCA} = 0$ and H1: $\rho_{DCCA} \neq 0$.

On the contrary, the following sectors show low or non-significant effects: aviation transport material, beverages, chemicals, water and sanitation, equipment, commerce, mobile and fixed phone services and wood and paper. These are sectors with a distant relationship with oil, which could be interesting for portfolio design and management.

A very interesting result emerges in the electricity sector, which has some mixed results but in most time scales with non-significant correlations. Over time, the importance of electricity production and distribution originating in renewable sources is increasing, which could help to explain this result which is in line with the findings of Ferreira et al. [69].

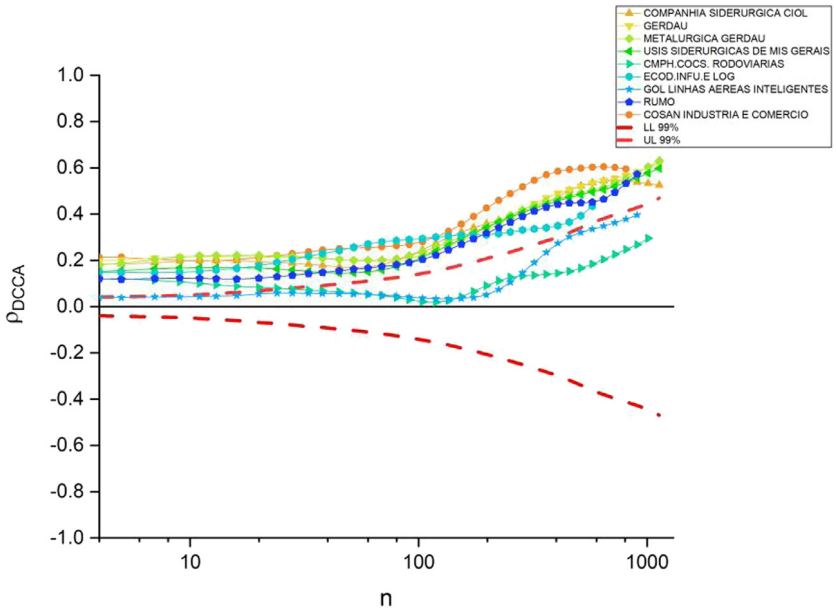

Fig. 7. DCCA correlation coefficient between oil and shares in the following economic sectors: Steel and Metallurgy, Transportation (depending on time scale - in days). Dashed lines represent lower and upper critical values, to test hypotheses H0: $\rho_{DCCA} = 0$ and H1: $\rho_{DCCA} \neq 0$.

4. Conclusions

With the objective of analysing the relationship between oil price and the Brazilian stock market index, we used the DCCA correlation coefficient not only for the whole market but also for each of the listed firms, trying to identify different patterns in the correlations, depending on the sector of activity.

For shorter time scales we found a significant correlation with the Brazilian stock index, although this vanishes for higher scales. The sample under analysis indicates that, in the long run, oil price does not have a significant impact on the index studied. However, the impact is not identical in all sectors. The correlation is higher in sectors that use oil or its derivatives in their activities. Other sectors with little relation to oil show low significance in their correlations.

Another important result concerns the statistical correlation between oil and stocks in the financial sector. Although not directly related to its activities, this particular sector's exposure to oil price shocks is very relevant, for example, for supervising authorities, because a possible oil price shock in the future could have an impact on the financial sector's performance.

Our results are also relevant for investors in their attempt to construct portfolios and for firm managers, who could have here some information about how their business is influenced (or not) by oil price.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

See Table A1.

Table A1
Shares used in the study and the respective sample dimension and activity sector.

Share	N	Activity sector
AMBEV ON	5104	Beverages
B2W COMPANHIA DIGITAL ON	3663	Electronic commerce
B3 BRASIL BOLSA BALCAO ON	2966	Financial services
BANCO BRADESCO ON	7639	Banking
BANCO BRADESCO PN	7639	Banking
BANCO DO BRASIL ON	7639	Banking
BANCO SANTANDER BRASIL UNITS	2483	Banking
BR MALLS PARTICIPACOES ON	3137	Real state
BRADESPAR PN	4872	Holding (diverse products/services)
BRASKEM PN SERIES 'A'	7634	Chemicals
BRF BRASIL FOODS ON	6464	Food
CENTRAIS ELETR BRAS- ELETROBRAS ON	7015	ElectricPower
CIA ENERGETICA DE MIS GERAIS PN	6633	ElectricPower
CIELO ON	2555	Financial Services
CMPBRA.DE DISTB. PN	6101	Retail commerce
CMPH.COCS. RODOVIARIAS ON	4485	Transportation
COMPANHIA SIDERURGICA CIOL ON	6705	Steel and Metallurgy
COSAN INDUSTRIA E COMERCIO ON	3496	Steel and Metallurgy
CPAD.SANMT.BASICO DE SAOP.ON	5703	Water and sanitation
CTI.ELETR BRAS- ELETROBRAS SR.B PN	7638	ElectricPower
CYRELA BRAZIL REALTY ON	3596	Building and engineering
ECOD.INFU.E LOG.ON	2357	Transportation
EMBRAER ON	6461	TransportEquipment
ENERGIAS DO BRASIL ON BRAZIL	3588	ElectricPower
ENGIE BRASIL ENERGIA ON	5444	ElectricPower
EQUATORIAL ENERGIA ON	2875	ElectricPower
ESTACIO PARTICIPACOES ON	2806	Education
FLEURY ON	2432	HealthServices
GERDAU PN	7639	Steel and Metallurgy
GOL LINHAS AEREAS INTELIGENTES PN	3862	Transportation
HYPERMARCAS ON	2866	Retail commerce
IGUATEMI EMPRESA SHOPPING CENTERS ON	3178	Real state
ITAU UNIBANCO HOLDING PN	6867	Banking
ITAUSA INVESTIMENTOS ITAU PN	6464	Financial Services
JBS ON	3142	Food
KLABIN UNITS	1362	Woodsandpaper
KROTON EDUCACIOL ON	3060	Education
LOCALIZA RENT A CAR ON	3625	Rent a car
LOJAS AMERICAS PN REP1 PN	7637	Commerce
LOJAS RENNER ON	5279	Retail commerce
MAGAZINE LUIZA ON	2075	Commerce (appliancesandfurniture)
MARFRIG FRIGORIFICOS ON	3076	Food
METALURGICA GERDAU PN	7624	Steel and Metallurgy
MRV ENGENHARIA E PARTICIPACOES ON	3060	Building and engineering
MULTIPLAN EMPE. IMOBS.ON	3056	Real state
NATURA COSMETICOS ON	3883	Personal Use and Cleaning Products
PETROLEO BRASILEIRO ON	7639	Oil, Gas and Biofuels
PETROLEO BRASILEIRO PN	7638	Oil, Gas and Biofuels
QUALICORP ON	2033	HealthServices
RAIA DROGASIL ON	5990	Commerce (drugstore)
RUMO ON	3859	Transportation
TELEFONICA BRASIL PN	5363	Fixe PhoneServices
TIM PARTICIPACOES ON	5364	Mobile PhoneServices
TSMS.ALIANCA ENELA. UTS.	3251	ElectricPower
ULTRAPAR PARTICIPOES ON	4259	Holding (diverse products/services)
USIS SIDERURGICAS DE MIS GERAIS A PN	7033	Steel and Metallurgy
VALE ON	6389	Mining
VIA VAREJO ON	5714	Retail commerce
WEG ON	5461	Equipments

Appendix B

See Table B1.

Table B1
Descriptive statistics for assets used.

Asset	Mean	Std. Dev.	Maximum	Minimum	Skewness	Kurtosis
AMBEV ON	0,0007	0,0176	0,1512	−0,1944	−0,055	10,086
B3 BRASIL BOLSA BALCAO ON	0,0001	0,0271	0,1682	−0,2259	0,057	7,060
BANCO DO BRASIL ON	0,0006	0,0268	0,1883	−0,2379	0,005	4,713
BANCO BRADESCO ON	0,0006	0,0215	0,1540	−0,1395	0,158	3,120
BANCO BRADESCO PN	0,0005	0,0221	0,1999	−0,1405	0,227	3,931
BRADESPAR PN	0,0003	0,0275	0,1538	−0,2808	−0,236	5,075
BRF BRASIL FOODS ON	0,0005	0,0211	0,2621	−0,2200	0,980	21,334
BRASKEM PN SERIES 'A'	0,0004	0,0265	0,1939	−0,2204	0,177	4,295
BR MALLS PARTICIPACOES ON	0,0003	0,0264	0,2243	−0,1992	0,406	8,924
B2W COMPANHIA DIGITAL ON	0,0002	0,0347	0,3477	−0,2319	0,444	6,641
CMPH.COCS. RODOVIARIAS ON	0,0005	0,0240	0,1799	−0,3102	−0,585	11,543
CIELO ON	0,0000	0,0195	0,1055	−0,1488	−0,130	3,567
CIA ENERGETICA DE MIS GERAIS PN	0,0002	0,0254	0,1638	−0,2368	−0,419	6,376
COSAN INDUSTRIA E COMERCIO ON	0,0003	0,0265	0,2061	−0,1588	−0,107	4,310
COMPANHIA SIDERURGICA CIOL ON	0,0003	0,0320	0,1967	−0,3784	−0,357	8,270
CYRELA BRAZIL REALTY ON	0,0004	0,0296	0,2893	−0,1981	0,104	6,663
ECOD.INFU.E LOG.ON	0,0000	0,0216	0,0880	−0,1600	−0,139	2,632
ENGIE BRASIL ENERGIA ON	0,0007	0,0239	0,3063	−0,1278	0,851	10,454
CENTRAIS ELETR BRAS- ELETROBRAS ON	0,0001	0,0307	0,4008	−0,3334	0,271	11,126
CTI.ELETR BRAS- ELETROBRAS SR.B PN	0,0001	0,0290	0,2782	−0,2242	0,185	5,779
EMBRAER ON	0,0002	0,0239	0,2029	−0,1828	−0,170	5,950
ENERGIAS DO BRASIL ON BRAZIL	0,0003	0,0200	0,1446	−0,1155	−0,071	3,193
EQUATORIAL ENERGIA ON	0,0007	0,0176	0,1280	−0,1681	−0,428	8,778
ESTACIO PARTICIPACOES ON	0,0004	0,0269	0,2525	−0,1993	0,031	8,265
FLEURY ON	0,0004	0,0183	0,1055	−0,0934	0,122	2,480
GERDAU PN	0,0004	0,0271	0,1689	−0,1614	0,042	2,495
METALURGICA GERDAU PN	0,0002	0,0276	0,1767	−0,2096	−0,055	4,116
GOL LINHAS AEREAS INTELIGENTES PN	0,0000	0,0368	0,4076	−0,2436	0,714	10,110
HYPERMARCAS ON	0,0004	0,0226	0,1918	−0,1538	0,051	5,883
IGUATEMI EMPRESA SHOPPING CENTERS ON	0,0002	0,0199	0,1306	−0,1580	−0,111	4,774
ITAUSA INVESTIMENTOS ITAU PN	0,0005	0,0215	0,2237	−0,1232	0,317	4,891
ITAU UNIBANCO HOLDING PN	0,0005	0,0221	0,2095	−0,1293	0,306	4,463
JBS ON	0,0003	0,0324	0,2409	−0,3761	−0,339	10,689
KLABIN UNITS	0,0002	0,0167	0,0631	−0,0666	0,075	0,738
KROTON EDUCACIOL ON	0,0002	0,0251	0,1352	−0,2129	−0,431	5,471
LOJAS AMERICAS PN REP1 PN	0,0007	0,0274	0,2475	−0,1719	0,266	5,739
LOJAS RENNER ON	0,0009	0,0324	1,0745	−0,9410	7,258	516,729
MAGAZINE LUIZA ON	0,0011	0,0357	0,3178	−0,1777	1,046	9,734
MARFRIG FRIGORIFICOS ON	−0,0003	0,0295	0,2451	−0,2855	−0,118	8,221
MRV ENGENHARIA E PARTICIPACOES ON	0,0001	0,0311	0,2884	−0,2455	−0,184	7,609
MULTIPLAN EMPE. IMOBS.ON	0,0003	0,0211	0,2677	−0,1770	0,493	13,583
TURA COSMETICOS ON	0,0004	0,0225	0,1367	−0,1478	0,232	2,815
CMPBRA.DE DISTB. PN	0,0002	0,0211	0,1419	−0,1147	0,123	2,669
PETROLEO BRASILEIRO ON	0,0004	0,0261	0,1497	−0,1615	0,035	3,858
PETROLEO BRASILEIRO PN	0,0003	0,0256	0,1509	−0,1715	−0,124	4,233
QUALICORP ON	0,0001	0,0246	0,1464	−0,3477	−1,649	23,975
RAIA DROGASIL ON	0,0013	0,0227	0,5447	−0,2286	5,403	102,239
RUMO ON	0,0005	0,0485	1,5540	−0,6653	8,515	298,473
LOCALIZA RENT A CAR ON	0,0009	0,0254	0,2374	−0,2080	0,000	8,633
BANCO SANTANDER BRASIL UNITS	0,0003	0,0205	0,1468	−0,1182	0,052	3,470
CPAD.SANMT.BASICO DE SAOP.ON	0,0003	0,0240	0,1554	−0,1608	−0,075	3,016
TSMS.ALIANCA ENELA. UTS.	0,0004	0,0190	0,1563	−0,1989	−0,375	13,521
TIM PARTICIPACOES ON	0,0002	0,0298	0,2619	−0,2574	−0,005	6,607
ULTRAPAR PARTICIPOES ON	0,0006	0,0191	0,7344	−0,1089	18,453	624,462
USIS SIDERURGICAS DE MIS GERAIS A PN	0,0003	0,0326	0,3065	−0,1760	0,301	4,271
VALE ON	0,0005	0,0252	0,1377	−0,2814	−0,278	6,662
TELEFONICA BRASIL PN	0,0000	0,0193	0,1354	−0,2061	−0,195	6,383
VIA VAREJO ON	0,0003	0,0352	0,4505	−0,8090	−1,811	84,817
WEG ON	0,0009	0,0205	0,3281	−0,3281	2,321	56,636
BRAZIL BOVESPA - TOT RETURN IND	0,0003	0,0172	0,1368	−0,1210	−0,112	4,227
Crude Oil	0,0002	0,0238	0,1641	−0,1709	−0,169	4,389

Appendix C

See Figs. C1 and C2.

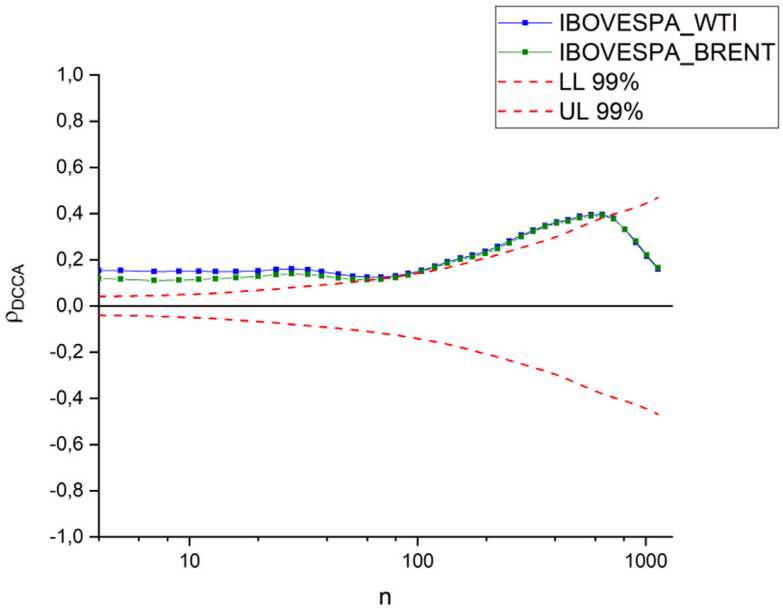

Fig. C1. DCCA correlation coefficient between IBOVESPA and two different oil prices (WTI and Brent), depending on time scale (in days). Dashed lines represent lower and upper critical values, to test hypotheses H0: $\rho_{DCCA} = 0$ and H1: $\rho_{DCCA} \neq 0$.

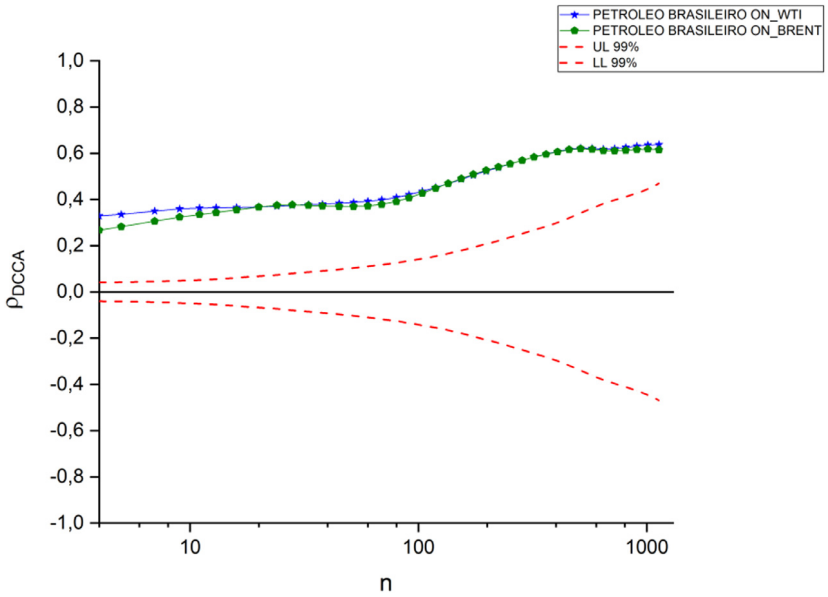

Fig. C2. DCCA correlation coefficient between PETROBRASand two different oil prices (WTI and Brent), depending on time scale (in days). Dashed lines represent lower and upper critical values, to test hypotheses H0: $\rho_{DCCA} = 0$ and H1: $\rho_{DCCA} \neq 0$.

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