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Measuring the dynamic cross-correlation and contagion effect between Brent crude and heating oil (US-Diesel) prices pre and during the Covid-19 outbreak

ITISE 2022

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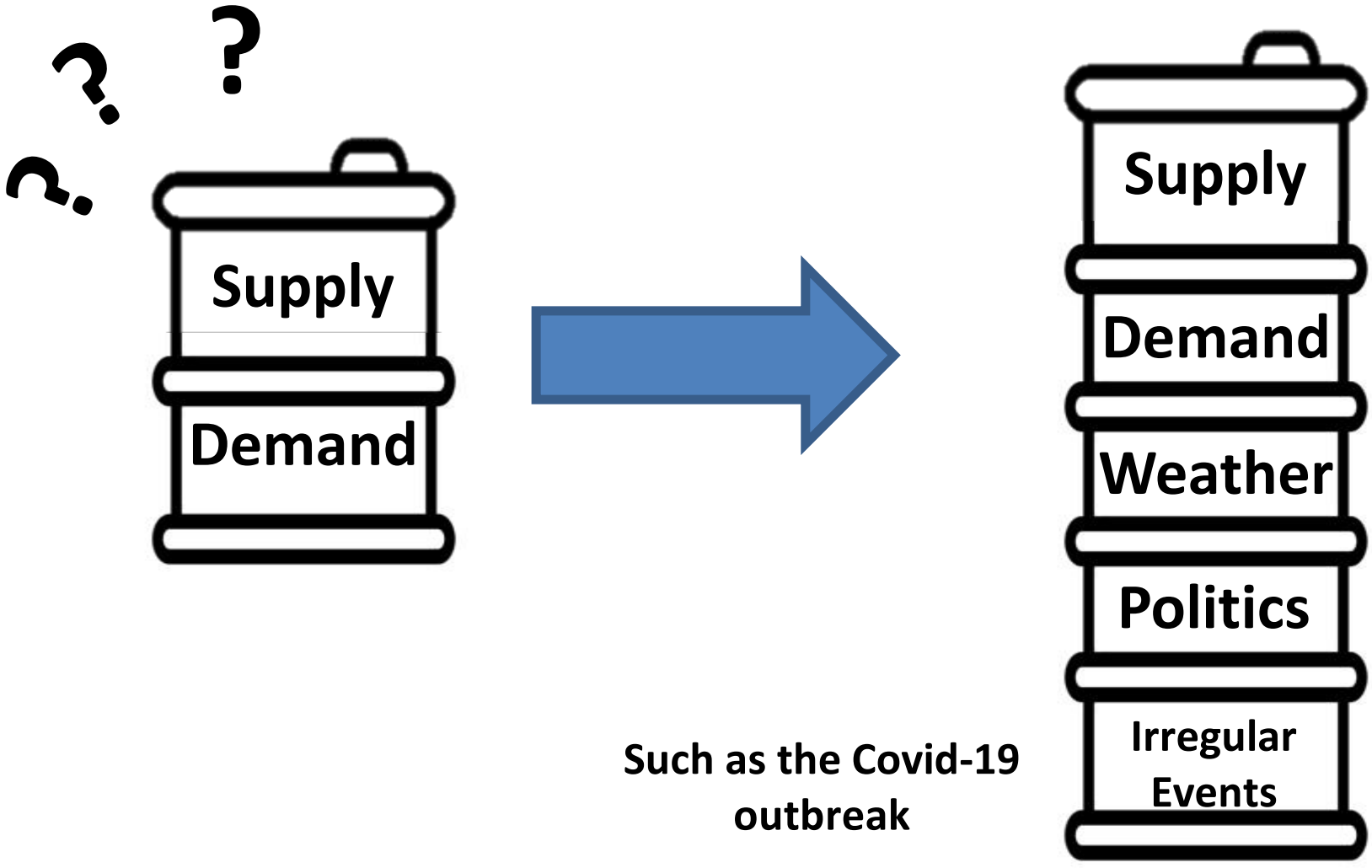
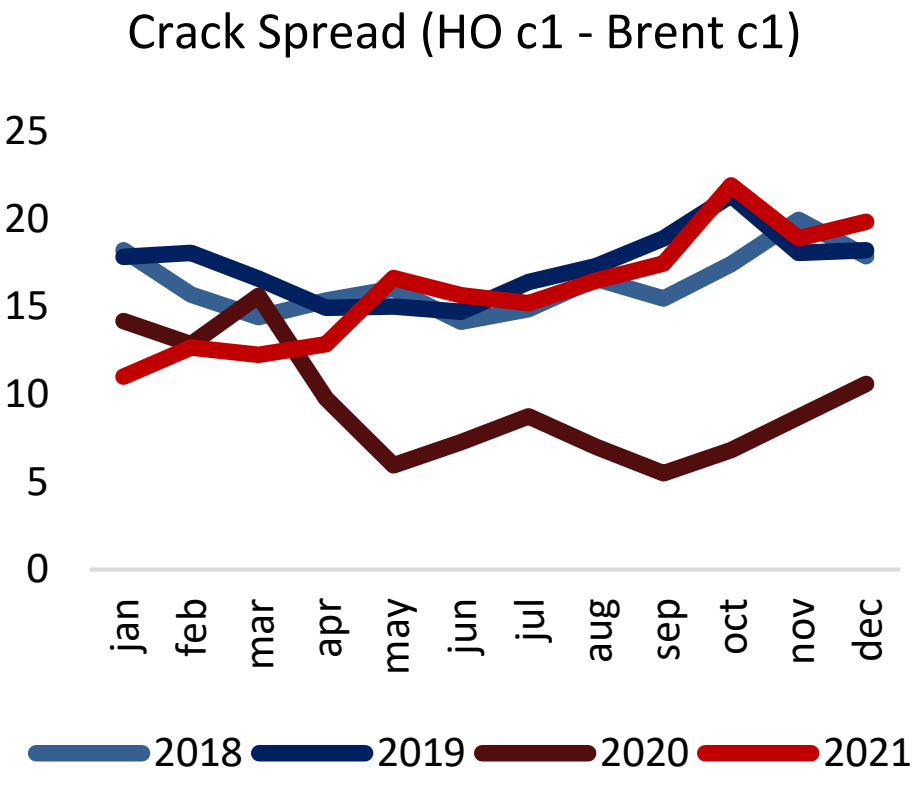
Crude Oil prices dynamics



Data characteristics

- Daily prices of futures contracts settlements (HO Nymex and Ice Brent);
- HO-Brent differential, also known as ’**crack-spread**’ can be applied as a representation of the **refinery margin**;
- Two periods: **P1** (Jan-18 to Dec-2019) and **P2** (Jan-20 to Dec-2021).



Methods – Detrended Cross-correlation Analysis

Considering two long-range cross-correlated TS y_i and $y_i^{'}$ of equal length N, the values can be approached in the integrated form:

$$Y_k = \sum_{i=1}^{k} y_i \tag{1}$$

$$Y_k^{'} = \sum_{i=1}^{k} y_i^{'} \tag{2}$$

where $k = 1, ..., N$. The entire TS are fractioned into $N - n$ overlapping boxes with $n+1$ values. The box starting at the position i and landing at the position $i + n$ is defined as the "local trend". Also, we can define the $\hat{Y_{k,i}}$ and $\hat{Y_{k,i}^{'}}(i \leq k \leq i + n)$ as the ordinate points of the linear least-squeres fit. For each box it is possible to calculate the covariance of the residual as follows:

$$f^2_{DCCA}(n, i) = \frac{1}{(n-1)} \sum_{k=i}^{i+n} (Y_k - \hat{Y_{k,i}})(Y_k^{'} - \hat{Y_{k,i}^{'}}) \tag{3}$$

Therefore, the detrended-covariance is calculate by summing over all overlapping $N - n$ boxes of size n as:

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

When a long-range cross-correlation appears between the two TS then $F_{DCCA} \sim n^{\lambda}$, where $\lambda \approx (H_{DFA} + H^{'}_{DFA})/2$. The λ exponent quantifies the long-range power-law correlations, but does not quantify the level of cross-correlation [45, 47, 28]. For this matter, Zebende [45] proposed the DCCA cross-correlation coefficient defined by:

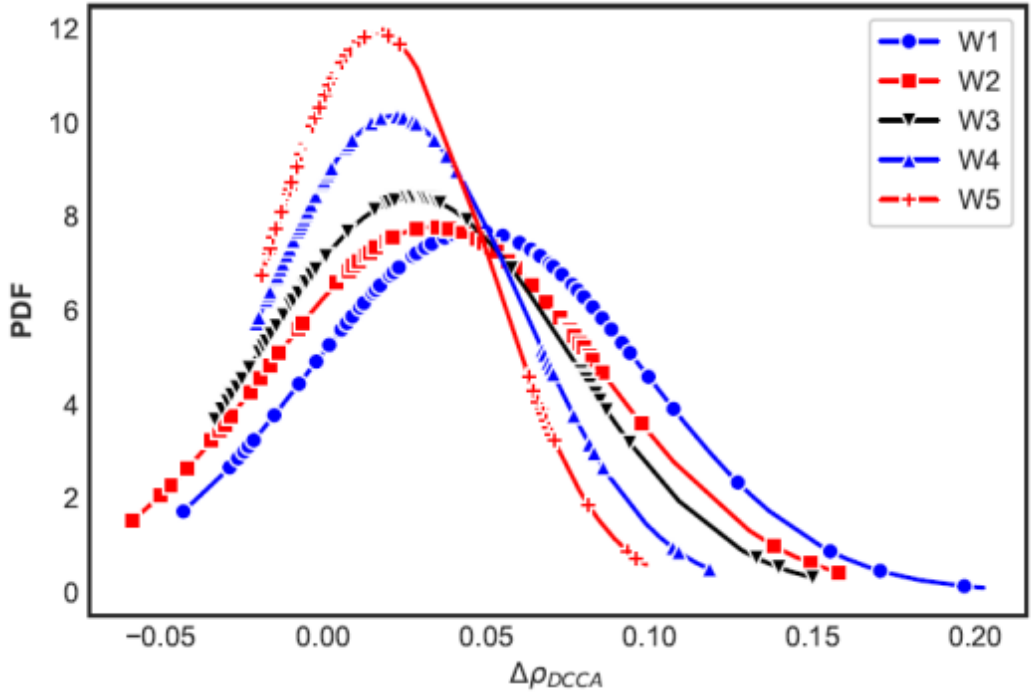
$$\rho_{DCCA} \equiv \frac{F^2_{DCCA}}{F_{DFA}\{y_i\} F_{DFA}\{y_i^{'}\}} \tag{5}$$

Methods – Rolling Window and Statistic Test

$$\Delta\rho_{DCCA}(n) = \rho_{DCCA}^{P_2}(n) - \rho_{DCCA}^{P_1}(n)$$

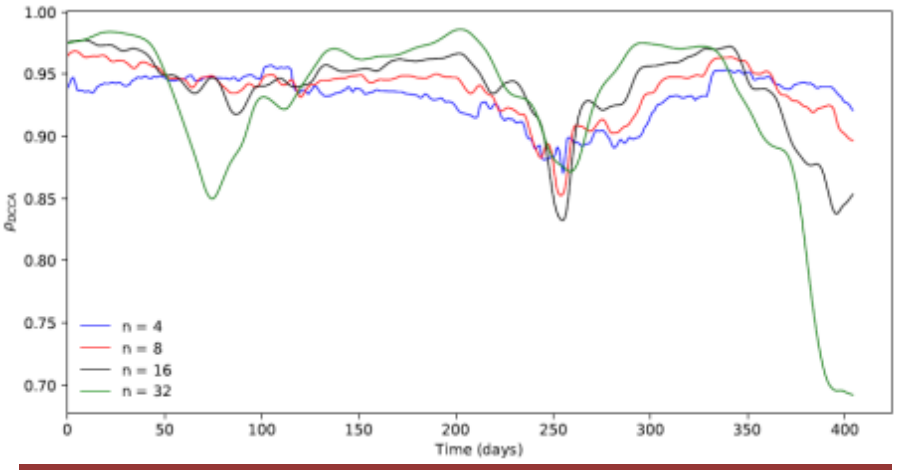
$H_0: \Delta\rho_{DCCA}(n) = \langle\Delta\rho_{DCCA}\rangle$ (contagion does not exists)

$H_1: \Delta\rho_{DCCA}(n) \neq \langle\Delta\rho_{DCCA}\rangle$ (contagion exists)



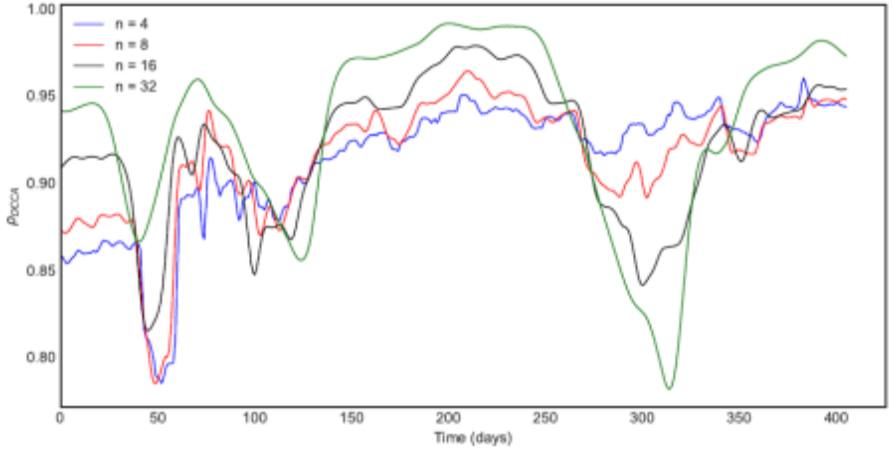
Results and Discussion - ρ_{dcca}

P1 – W2 (100 days)



- Prices showed a weaker relation during the beginning of 2019, which is not applied to larger sizes of W and it is an indication of **short-term** effects;

P2 – W2 (100 days)



- Loss of cross-correlation from March to April of 2020;
- Specific characteristics of the diesel market;
- Shorter window sizes are sensitive to short-term effects, which one can note during the year 2021 (Ida hurricane);
- This might suggest that short-term **supply shortages** of diesel in the US Gulf can affect the HO-Brent cross-correlation the same as a restricted demand period caused by COVID-19 (not captured by larger windows!)

Descriptive summary of ΔρDCCA for W1 to W5.

Statistics	n = 4	n = 8	n = 16	n = 32	n = 64
			W1 = 50		
Mean	0.0469	0.0478	0.0606	-	-
SD	0.0519	0.0585	0.0949	-	-
Skewness	0.7747	1.3477	2.7715	-	-
Kurtosis	0.4957	1.3932	9.5141	-	-
			W2 = 100		
Mean	0.0336	0.0314	0.0233	0.0012	-
SD	0.0513	0.0519	0.0492	0.0546	-
Skewness	0.3688	0.4340	-0.6524	-0.0903	-
Kurtosis	-0.3147	0.0274	0.0166	-0.3943	-
			W3 = 150		
Mean	0.0276	0.0289	0.0216	0.0033	-
SD	0.0475	0.0422	0.0330	0.0232	-
Skewness	0.8434	1.1727	1.3479	1.2184	-
Kurtosis	-0.0618	0.8768	2.4628	1.5078	-
			W4 = 200		
Mean	0.0213	0.0245	0.0197	0.0071	0.0062
SD	0.0393	0.0351	0.0261	0.0215	0.0199
Skewness	0.9908	1.3799	1.6650	1.4585	1.6720
Kurtosis	-0.3018	0.9029	2.9319	2.2209	1.8339
			W5 = 250		
Mean	0.0165	0.0211	0.0170	0.0030	-0.0043
SD	0.0335	0.0308	0.0242	0.0232	0.0310
Skewness	1.1137	1.3311	1.2920	-0.1065	-0.4814
Kurtosis	-0.2545	0.6427	1.8523	0.4632	0.8582

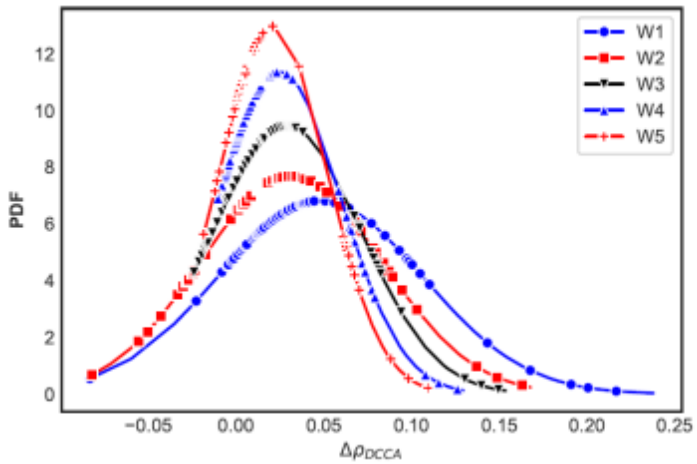
- As suggested by Guedes et al. [43], the observed **mean values are approximately close to zero** and the **standard deviation (SD) decreases for greater W sizes**. However, mostly skewness and kurtosis diverged from values observed from normal distributions, i.e., Kurtosis ≈ 3 and Skewness ≈ 0 for different combinations of n and W, which tends to affect the normality of the distributions.

Are they following a normal distribution?

Normality test of ΔρDCCA for W1 to W5.

Table 3: The *Brent – HO* Normality test of $\Delta\rho_{DCCA}$ for W1 to W5. Significance level of 95% (p-value< 0.05) rejects the null hypothesis of normality.

D'Agostino and Pearson's Normality Test					
Statistics	n = 4	n = 8	n = 16	n = 32	n = 64
			W1 = 50		
χ^2	24.1151	59.8950	171.8440	-	-
$p-value$	**5.80e-06**	**9.86e-14**	**4.84e-38**	-	-
			W2 = 100		
χ^2	6.7952	7.873	0.9515	9.0797	-
$p-value$	**0.0335**	**0.0195**	0.6214	**0.0107**	-
			W3 = 150		
χ^2	24.8080	46.5804	68.8323	54.3651	-
$p-value$	**4.10e-06**	**7.68e-11**	**1.13e-15**	**1.57e-12**	-
			W4 = 200		
χ^2	32.8813	57.2596	88.2648	72.4758	79.9174
$p-value$	**7.24e-08**	**3.68e-13**	**6.82e-20**	**4.43e-18**	**3.89e-20**
			W5 = 250		
χ^2	38.6335	52.6530	61.0372	2.7892	14.8160
$p-value$	**4.08e-09**	**3.69e-12**	**5.57e-14**	0.2479	**0.0010**



Significance test of ΔρDCCA for W1 to W5.

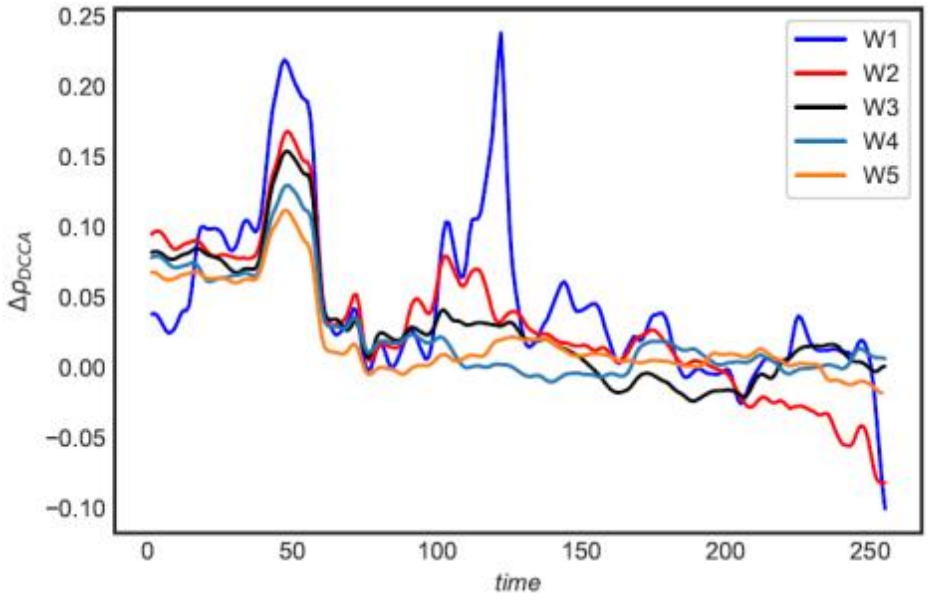
Table 4: The *Brent – HO* significance test of $\Delta\rho_{DCCA}$ for W1 to W5. Significance level of 95% (p-value< 0.05) rejects the null hypothesis of $\Delta\rho_{DCCA} = 0$.

T-test or Wilcoxon signed-rank test for significance at differences					
Statistics	n = 4	n = 8	n = 16	n = 32	n = 64
W1 = 50					
Statistic	W = 2924	W = 1744	W = 2325	-	-
$p - value$	**1.03e-29**	**6.42e-35**	**2.67e-32**	-	-
W2 = 100					
Statistic	W = 5951	W = 6600	t = 7.5491	W = 16146	-
$p - value$	**2.37e-18**	**2.73e-16**	**7.94e-13**	0.9683	-
W3 = 150					
Statistic	W = 7050	W = 4865	W = 4547	W = 15694	-
$p - value$	**6.16e-15**	**4.25e-22**	**2.90e-23**	0.6706	-
W4 = 200					
Statistic	W = 9763	W = 3956	W = 2472	W = 11748	W = 15046
$p - value$	**4.12e-08**	**1.62e-25**	**1.18e-31**	**0.0001**	0.3280
W5 = 250					
Statistic	W = 11094	W = 3623	W = 3942	t = 2.0720	W = 12846
$p - value$	**1.36e-05**	**7.81e-27**	**1.43e-25**	**0.0393**	**0.0043**

- One can note that **there is evidence of a contagion** predominance for time scales n < 32, which suggests short-term effects spillovers when comparing P1 and P2. However, there is **no strong evidence** of the contagion effect for values of n >= 32 days, which suggests that the market imbalances caused by the COVID-19 do not affect the HO-Brent cross-correlation in the long-term as much as the short-term.

ΔρDCCA for different time scales (n)

Example: n = 8 days



- Prevalence of ΔρDCCA(n) > 0 for the first 150 days of comparison;
- For every time scale (n) the correlations are shown to be lower during the beginning of P2 if compared to the same period in P1, besides the lower ΔρDCCA(n) at last 50 days of the curves indicate that the HO-Brent **fully recovered in terms of correlation after 200 days of the COVID-19 outbreak**.

Thank You!

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