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The Global Equity Market Reactions of the Oil & Gas Midstream and Marine Shipping Industries to COVID-19: An Entropy Analysis

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Abstract

This article quantifies the information flow between major equities in the Oil & Gas Midstream and Marine Shipping industries, on the basis of the effective transfer entropy methodology. In addition, the article provides the first analysis of investor fear and market expectations in these sectors, according to the Rényi entropy approach. The period of study was extended over five years to fully capture the pre/post-COVID situations. The entropy results reveal a major change in the underlying information flow pattern among equities in the Oil & Gas Midstream and Marine Shipping sectors in the aftermath of COVID-19. According to the new (post-COVID) paradigm, the stocks in the Oil & Gas Midstream and Integrated Freight & Logistics industries have gained momentum in occupying six of the ten positions within the list of the most influential equities in the market, in terms of information transmission. The disorder and randomness have decreased for over 89% of the studied equities, after virus outbreak. For the equities detected with high information-transmission standing, the Rényi entropy results indicate that investors more likely showed a higher level of future expectations and a lower level of fear regarding frequent market events within the post-COVID timeline.

Keywords: Marine Shipping; Logistics; Freight Transportation; COVID-19; Entropy.

1. Introduction

The world has witnessed a different scenery since the emergence of the Coronavirus (COVID-19). One such major change has been the implementation of worldwide Non-Pharmaceutical Interventions (NPI) – mainly in the form of mandatory quarantines, business closures, and international travel restrictions – in order to control the spread of the virus. Although proven effective in reducing the rate of virus transmission [1, 2], the implementation of such large-scale containment measures has had negative economic consequences [3] which varies depending on their scale and severity of implementation. Among the repercussions of NPI, the diminishing international trade [4] - caused jointly by reduced production and market demand- should logically impact the transportation industry, in a sequel. As a matter of fact, the disruption in the global supply chain resulting from the COVID-19 emergence drove the transportation industry to a near halt [5], particularly during the early months of the crisis.

A growing body of literature has focused on the impact of the COVID-19 issue on the marine transportation sector, in terms of performance [6-10] and equity market reactions [5]. For example, Xu et al. (2021) [6] conducted a

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structural equation modelling analysis of confirmatory factor analysis and path assessment to study the impact of COVID-19 on the transportation and logistics sectors in China, and found a statistically insignificant correlation between COVID-19 and ocean freight in that country. Verschuur et al. (2021) [10] conducted an investigation on a global level and used the empirical vessel tracking information - as a high-frequency indicator of economic activity - to study the impact of NPI measures on maritime trade and found worldwide port-level trade losses, following the COVID-19 emergence, for which the ports in China, the Middle East, and Western Europe were detected with the largest absolute losses. Furthermore, it was estimated that the reduction in maritime trade became as low as -9.6% in the first eight months of the crisis [10]. With regards to the equity market reactions, Kamal et al. (2021) [5] applied an event study methodology to assess the market reactions of selected shipping stocks (listed on the New York Stock Exchange (NYSE)) to several COVID-related news of optimistic and pessimistic nature. They found positive market reactions for marine transportation equities to the announcement of optimistic events, such as approval of the first COVID-19 vaccine or the proposal of economic stimulus plans, and adverse market reactions to pessimistic news [11-19]. However, the number of such investigations – linking COVID-19 and transportation equities-seem to be quite limited, compared to the existing bulk literature on the COVID-19 impacts on global equity markets [20-28]. As stock markets can be considered as a set of interconnected and correlated equities, it is conceivable that the internal force of the markets can be formed through the cumulative interactions of their listed firms [29-36].

As such, understanding the mutual information between equities should be important in analyzing the markets. However, such an information on connectivity (between equity participants) should be complemented by the information on the underlying directionality, in order to provide a complete image. Such a binary information set can be obtained by applying the concept of Transfer Entropy (TE), which is derived upon the formulation of conditional mutual information [37]. The transfer entropy methodology effectively quantifies the reduction in uncertainty – provided by past values of variables – in predicting the dependent variable, as it is conditioned on these past values, and is considered as a model-free statistic capable of measuring the time-directed transfer of information between stochastic variables as well as providing the asymmetric information transfer measures in multivariate distributions [37]. A number of previous investigations have applied the TE methodology to analyze the financial markets [11, 38, 39].

For instance, Golmohammadi & Fazelabdolabadi (2021) [11] mapped the information transfer paradigm between 2200 equities – globally distributed within major financial markets – for the periods before and after the COVID-19 outbreak. They report on drastic changes in major global equity markets in the aftermath of COVID-19 emergence, which was based on the changes in the underlying information flow pattern - derived from effective transfer entropy - within the markets studied [11] - Australia, Brazil, Canada, China, Germany, Iran, Japan, Qatar, Saudi Arabia, South Africa, South Korea, United Kingdom, and the United States. In addition, they report on substantial changes (nearly 70%) in the functionality of the market sectors – in terms of being a transmitter or receiver of information – encountered after COVID-19 emergence. Given the new circumstances that abound the global financial markets, it may be necessary to conduct an investigation to thoroughly understand the current standing of equities in the marine shipping and Oil & Gas midstream sectors. In this respect, the present work makes a two-fold contribution to the existing literature – providing the first information transfer map between equities in the marine shipping and Oil & Gas midstream sectors (in a cross-market domain) and quantifying the market expectations and investor fear for selected equities in these sectors.

2. Methods

Used as the main processing stream in the present work, the method of transfer entropy, originally proposed by Schreiber (2000) [40], quantifies the asymmetric dynamics of two processes, using the conditional block entropy [41]. If the entropy is considered as a proxy to measure the uncertainty level inherent in optimally encoding the independent draws of a discrete random variable, the formulation of transfer entropy would be based on the premise of Shannon entropy [42]. Assuming X as being a discrete random variable, with probability distribution function $p(x_t)$, the Shannon entropy, H_X, is defined as:

$$H_X = -\Sigma p(x_t) log_2\big(p(x_t)\big) \tag{1}$$

If the random variable X represents the event space of a time series, the sequence of its state outcomes until time t, with k back steps in time, becomes:

$$x_t{}^{(k)} = x_t, x_{t-1}, x_{t-2}, \dots, x_{t-k+1} \tag{2}$$

If we denote the probability of observing the variable in state x at time $t+1$ as $p\big(x_{t+1} \vee x_t^{(k)}\big) = p(x_{t+1} \vee x_t, \dots, x_{t-k+1})$ then the average number of bits needed to encode the output state of the variable in time $t+1$ with known $k$backstep values – the entropy of x_{t+1}- can be written as:

$$h_X(k) = -\Sigma p\big(x_{t+1}, x_t^{(k)}\big) log_2 p\big(x_{t+1} \vee x_t^{(k)}\big) = H_X\big(x_{t+1}, x_t^{(k)}\big) - H_X\big(x_t^{(k)}\big) \tag{3}$$

where the summation runs over all the possible values of $\left(x_{t+1}, x_t^{(k)}\right)$, for a fixed time t.

The value of the calculated entropy hence depends on the selection of the block length k- referred to as conditional block entropy – which decreases along the increase in the length of the block, as long as x_{t-k}contains more information to predictx_{t+1}than x_{t-k+1} [41].

For a bi-variate case, the value of transfer entropy can be obtained by accounting the deviation from the generalized Markov property. Considering a time series Y, the sequence of its observations until time t, with l back steps in time, can be taken as:

$$y_t{}^{(l)} = y_t, y_{t-1}, y_{t-2}, \ldots, y_{t-l+1} \tag{4}$$

An information flow from process Y to process X exists, if the information in $y_t^{(l)}$can be valuable in forecasting x_{t+1}, despite the information collected from $x_t^{(k)}$. The transfer entropy, $T_{Y\to X}(k,l)$, is then formulated by Schreiber (2000) [40] as Equation 5, to subtract the information already contained in $x_t^{(k)}$:

$$T_{Y\to X}(k,l) = \sum_{x,y} p\left(x_{t+1}, x_t^{(k)}, y_t^{(l)}\right) log_2 p\left(x_{t+1} \vee x_t^{(k)}, y_t^{(l)}\right) - \sum_x p\left(x_{t+1}, x_t^{(k)}\right) log_2 p\left(x_{t+1} \vee x_t^{(k)}\right) \tag{5}$$

$$T_{Y\to X}(k,l) = h_X(k) - h_{X,Y}(k.l) \tag{6}$$

where $h_{X,Y}(k.l)$denotes the conditional entropy of X, given the information of both $x_t^{(k)}$ and $y_t^{(l)}$ blocks.

The results of the transfer entropy may be subject to bias, due to small-sample effects. To correct for this bias, it is suggested [43] to compute the effective transfer entropy, $ETE_{Y\to X}(k,l)$, between the two processes. The effective transfer entropy is calculated by subtracting the value of transfer entropy obtained from Equation 5 from the value obtained after conducting a shuffling operation on process Y, $T_{Y_{shuffled}\to X}(k,l)$. The shuffling procedure entails taking random draws from the distribution of Y and re-arrangement of the selected set to generate a new time series, in order to destroy statistical dependencies between the two processes as well as the time series dependencies of Y [42]:

$$ETE_{Y\to X}(k,l) = T_{Y\to X}(k,l) - T_{Y_{shuffled}\to X}(k,l) \tag{7}$$

$T_{Y_{shuffled}\to X}(k,l) \to 0$ as the sample size increases and becomes non-zero in case small-sample effects exist.

The set of probability measures listed above are established over discretized values of the variables; therefore, the variables` data should be grouped into non-overlapping partitions, a priori. For this reason, the symbolic encoding scheme dominantly used would select the size of the bins, according to the 5% and 95% empirical quantiles of the data – $q_{[0.05]}$and $q_{[0.95]}$. As a result, the symbolically-encoded time series, s_t , takes the following form:

$$s_t = \begin{Bmatrix} 1 for y_t \le q_{[0.05]} \\ 2 for q_{[0.05]} < y_t < q_{[0.95]} \\ 3 for y_t \ge q_{[0.95]} \end{Bmatrix} \tag{8}$$

To account for frequent and rare events, signal complexities were assessed by incorporating the Rényi entropy (as Equation 9) for each time series considered.

$$RE_d = \frac{1}{1-d} log\left(\sum_i p_i^d\right) \tag{9}$$

where $d(d \ge 0)$ represents the order of Rényi entropy, which favors rare events when $d < 1$ and privileges frequents events as $d > 1$ [44]. The estimation of the probabilities in Equation 9 was made through the Gaussian kernel functions.

3. Data Description

The information used as input in the present study, is comprised of the closing daily prices of stocks of 70 companies, which presumably represent the main equities in the Oil & Gas Midstream and Marine Shipping sectors worldwide. The names of the companies selected are listed in Table 1. Such a name selection also ensures a cross-market inspection of the information transfer, as the equities are being traded in different financial markets. The input data was obtained from Yahoo Finance. The data was acquired for the time span between (2016-Aug-01 and 2021-Aug-01). This length was later divided into two periods, to account for prior/post-COVID timelines. The date used to set this division was taken to be 30-January-2020, on which the pandemic outbreak was officially declared by the World Health Organization [44].

Table 1. The list of companies considered

Index	Company Name	Yahoo ticker	Industry
1	Ardmore Shipping Corporation	ASC	Marine Shipping
2	A.P. Møller - Mærsk A/S	MAERSK-A.CO	Marine Shipping
3	Badaro No. 19 Ship Investment Company	155900.KS	Marine Shipping
4	Capital Product Partners L.P.	CPLP	Marine Shipping
5	COSCO Shipping Development Co., Ltd.	601866.SS	Marine Shipping
6	COSCO Shipping Holdings Co., Ltd.	601919.SS	Marine Shipping
7	Costamare Inc.	CMRE	Marine Shipping
8	Danaos Corporation	DAC	Marine Shipping
9	DHT Holdings, Inc.	DHT	Oil & Gas Midstream
10	Diana Shipping Inc.	DSX	Marine Shipping
11	Dorian LPG Ltd.	LPG	Oil & Gas Midstream
12	DSV Panalpina A/S	DSV.CO	Integrated Freight & Logistics
13	Dynagas LNG Partners LP	DLNG	Oil & Gas Midstream
14	Eagle Bulk Shipping Inc.	EGLE	Marine Shipping
15	Euronav NV	EURN	Oil & Gas Midstream
16	Euroseas Ltd.	ESEA	Marine Shipping
17	Evergreen Marine Corporation (Taiwan) Ltd.	2603.TW	Marine Shipping
18	Frontline Ltd.	FRO	Oil & Gas Midstream
19	GasLog Partners LP	GLOP	Oil & Gas Midstream
20	Genco Shipping & Trading Limited	GNK	Marine Shipping
21	Global Ship Lease, Inc.	GSL	Marine Shipping
22	Globus Maritime Limited	GLBS	Marine Shipping
23	Golar LNG Limited	GLNG	Oil & Gas Midstream
24	Golden Ocean Group Limited	GOGL	Marine Shipping
25	Hamburger Hafen und Logistik Aktiengesellschaft	HHFA.DE	Marine Shipping
26	Hapag-Lloyd Aktiengesellschaft	HLAG.DE	Marine Shipping
27	HMM Co.,Ltd	011200.KS	Marine Shipping
28	Höegh LNG Partners LP	HMLP	Oil & Gas Midstream
29	International Seaways, Inc.	INSW	Marine Shipping
30	Kawasaki Kisen Kaisha, Ltd.	9107.T	Marine Shipping
31	Kirby Corporation	KEX	Marine Shipping
32	KNOT Offshore Partners LP	KNOP	Marine Shipping
33	Kuehne + Nagel International AG	0QMW.IL	Integrated Freight & Logistics
34	Matson, Inc.	MATX	Marine Shipping
35	Mitsui O.S.K. Lines, Ltd.	9104.T	Marine Shipping
36	Navigator Holdings Ltd.	NVGS	Oil & Gas Midstream
37	Navios Maritime Holdings Inc.	NM	Marine Shipping
38	Navios Maritime Partners L.P.	NMM	Marine Shipping
39	Nippon Yusen Kabushiki Kaisha	601018.SS	Marine Shipping
40	Nippon Yusen Kabushiki Kaisha	9101.T	Marine Shipping
41	Nordic American Tankers Limited	NAT	Marine Shipping
42	Overseas Shipholding Group, Inc.	OSG	Oil & Gas Midstream
43	Pangaea Logistics Solutions, Ltd.	PANL	Marine Shipping
44	PBF Logistics LP	PBFX	Oil & Gas Midstream
45	Pyxis Tankers Inc.	PXS	Marine Shipping
46	Qatar Gas Transport Company Limited	QGTS.QA	Oil & Gas Midstream
47	Qatar Navigation Q.P.S.C.	QNNS.QA	Marine Shipping
48	Regional Container Lines Public Company Limited	RCL.BK	Marine Shipping
49	Safe Bulkers, Inc.	SB	Marine Shipping
50	SEACOR Marine Holdings Inc.	SMHI	Marine Shipping
51	Seanergy Maritime Holdings Corp.	SHIP	Marine Shipping
52	SFL Corporation Ltd.	SFL	Marine Shipping
53	Shanghai International Port (Group) Co., Ltd.	600018.SS	Marine Shipping

54	Sino-Global Shipping America, Ltd.	SINO	Integrated Freight & Logistics
55	Scorpio Tankers Inc.	STNG	Oil & Gas Midstream
56	Star Bulk Carriers Corp.	SBLK	Marine Shipping
57	StealthGas Inc.	GASS	Marine Shipping
58	Teekay Corporation	TK	Oil & Gas Midstream
59	Teekay LNG Partners L.P.	TGP	Oil & Gas Midstream
60	The National Shipping Company of Saudi Arabia	4030.SR	Marine Shipping
61	Tidewater Inc.	TDW	Oil & Gas Midstream
62	Transportation and Logistics Systems, Inc.	TLSS	Integrated Freight & Logistics
63	Trencor Limited	TRE.JO	Marine Shipping
64	Tsakos Energy Navigation Limited	TNP	Oil & Gas Midstream
65	Top Ships Inc.	TOPS	Marine Shipping
66	U-Ming Marine Transport Corporation	2606.TW	Marine Shipping
67	Wan Hai Lines Ltd.	2615.TW	Marine Shipping
68	Westshore Terminals Investment Corporation	WTE.TO	Marine Shipping
69	XPO Logistics, Inc.	XPO	Integrated Freight & Logistics
70	Yang Ming Marine Transport Corporation	2609.TW	Marine Shipping

4. Results and Discussion

The effective transfer entropy was calculated, for each pair of the listed stocks (Table 1) along the both directions - $X \rightarrow Y$ and $Y \rightarrow X$. For each state in a given pair, the calculations were attempted over the periods, before and after the COVID-19 outbreak. The selection for the lag orders – k and l-was taken as unity, which is an appropriate choice when analyzing the financial markets [42]. The number of shuffling operations performed was set to one hundred, to ensure efficient removal of bias from the established results. Figures 1 to 4 depict the computed results for the values of the effective transfer entropy for the companies considered. To ease its visual inspection, the results are presented separately for entries 1- 40 and 41-70 of the list (Table 1), as well as for the pre/post-COVID periods. With respect to the color interpretation of the results, a more positive number indicates more information transfer (from stock y to stock x) and zero is the case in which no information transfer has been detected, within the considered time span. The whole set of computed results for all the companies considered - including the transfer entropy, the effective transfer entropy and the corresponding statistical measures (standard deviations, p-values) – can be obtained from the corresponding author, upon reasonable request.

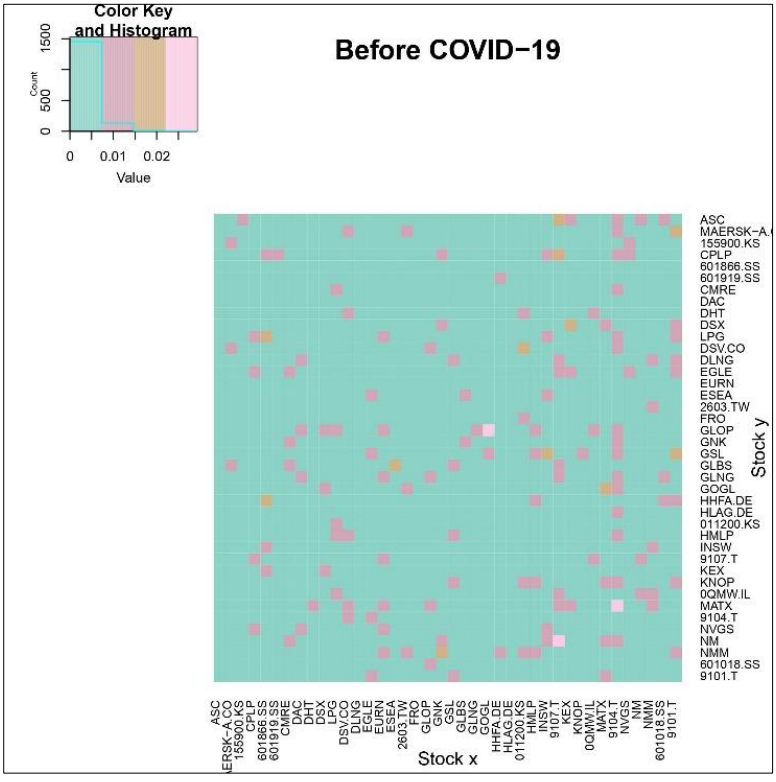

Figure 1. The information flow (effective transfer entropy) from stock y to stock x, for the companies 1 through 40 (listed in Table 1), before the COVID-19 outbreak

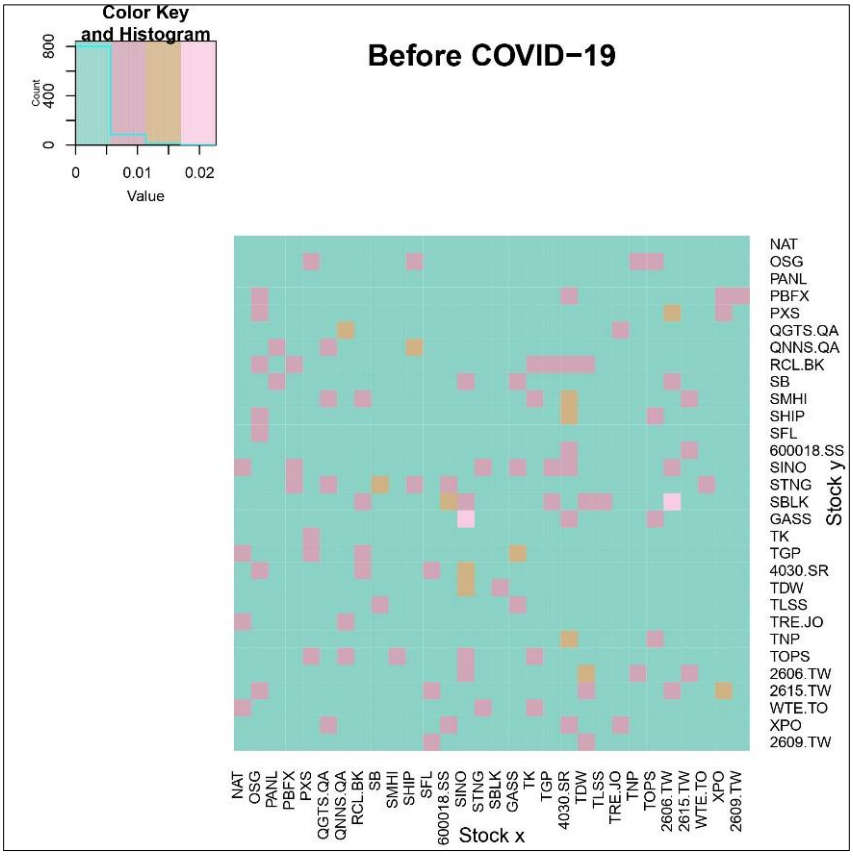

Figure 2. The information flow (effective transfer entropy) from stock y to stock x, for the companies 41 through 70 (listed in Table 1), before the COVID-19 outbreak

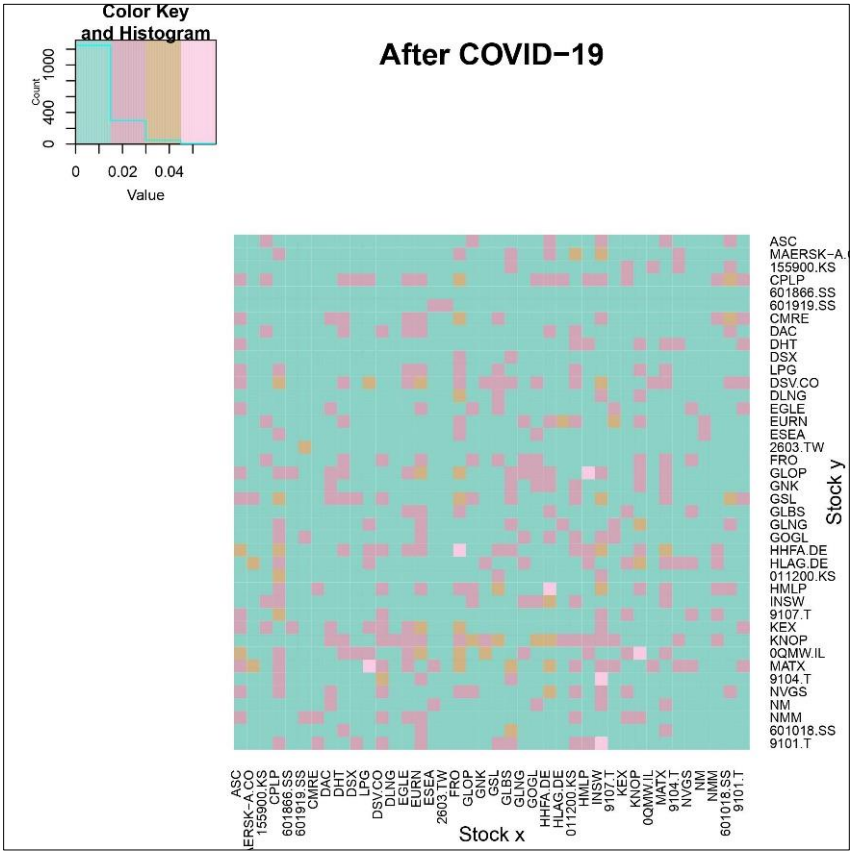

Figure 3. The information flow (effective transfer entropy) from stock y to stock x, for the companies 1 through 40 (listed in Table 1), after the COVID-19 outbreak

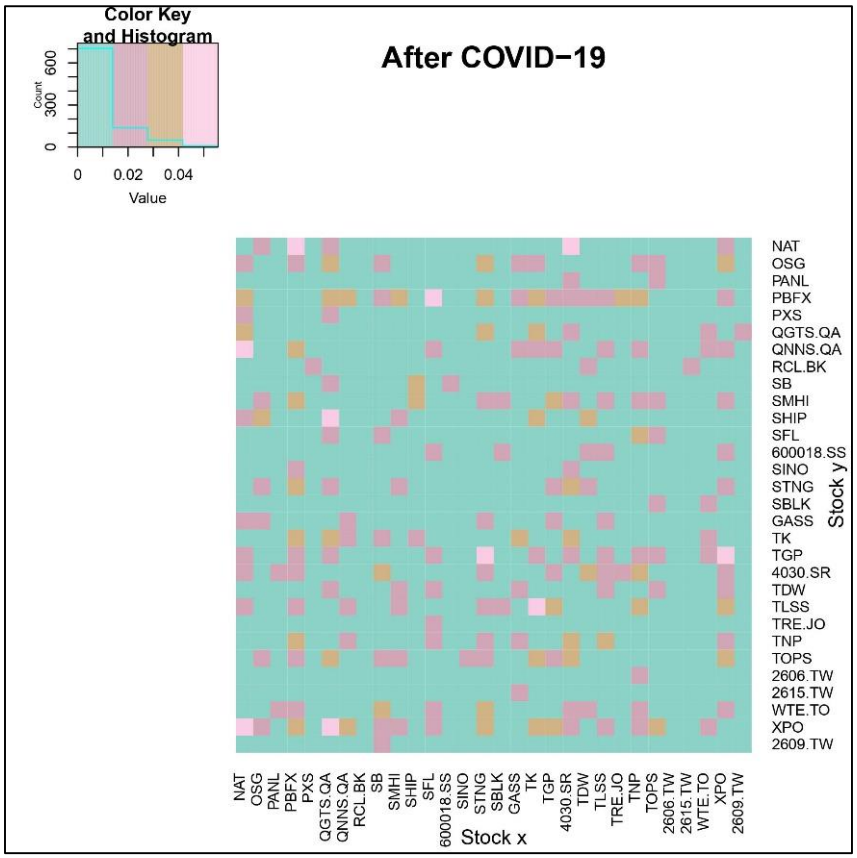

Figure 4. The information flow (effective transfer entropy) from stock y to stock x, for the companies 41 through 70 (listed in Table 1), after the COVID-19 outbreak

The effective transfer entropy results show the formation of a new information transfer paradigm, after COVID-19 emergence, among major equities in the Oil & Gas Midstream and Marine Shipping sectors. According to our results, the new price action of equities acts more sensitively to each other (with few exceptions) and the overall information transfer in the two sectors has increased after COVID-19 outbreak, even in the devised cross-market domain. Given the market capitalization of the selected equities, a general extension of this finding to the post-COVID status of these two sectors is plausible.

With respect to the information transmission, the market has seen an altered list of major players in the Oil & Gas Midstream and Marine Shipping sectors. As part of our analysis in the present paper, we have also studied the status of equities (in these sectors) with respect to their net information flow. An equity was then interpreted as being an information transmitter (receiver) if the net information outflow was positive (negative). In this context, a more positive net information outflow value rendered the equity as a holding a more influencing role in the market. Tables 2-3 list the main information transmitter equities in the Oil & Gas Midstream and Marine Shipping sectors, before and after COVID-19 respectively. As evident from the list, the Marine Shipping equities have lost grounds to other industries in the market, in the post-COVID timeline. This argument is based on the fact that six positions out of ten most influencing equities in these sectors were taken by the firms operating in the Oil & Gas Midstream and Integrated Freight & Logistics industries (Table 3) after COVID-19 emergence; namely, PBF Logistics LP; XPO Logistics, Inc; GasLog Partners LP; DSV Panalpina A/S; Transportation and Logistics Systems, Inc.; Kuehne + Nagel International AG.

Table 2. The main information transmitter equities, before COVID-19

Rank	Company name
1	Matson, Inc.
2	Navios Maritime Partners L.P.
3	Eagle Bulk Shipping Inc.
4	Tidewater Inc.
5	Star Bulk Carriers Corp.
6	Global Ship Lease, Inc.
7	Teekay LNG Partners L.P.
8	XPO Logistics, Inc.
9	Capital Product Partners L.P.
10	Navios Maritime Holdings Inc.

Table 3. The main information transmitter equities, after COVID-19

Rank	Company name
1	PBF Logistics LP
2	XPO Logistics, Inc.
3	KNOT Offshore Partners LP
4	Hamburger Hafen und Logistik Aktiengesellschaft
5	GasLog Partners LP
6	Matson, Inc.
7	DSV Panalpina A/S
8	Global Ship Lease, Inc.
9	Transportation and Logistics Systems, Inc.
10	Kuehne + Nagel International AG

In terms of market expectations and investor fear, the reactions have been mixed. Table 4 provides the net values of Rényi entropy for equities considered (Table 1), computed up to the order of 20. This net value was calculated as the Rényi entropy difference between the corresponding post/pre-COVID values. The results follow four distinct patterns, as described in Table 5.

Table 4. The net values of Rényi entropy for equities listed in Table 1

d	ASC	MAERSK-A.CO	155900.KS	CPLP	601866.SS	601919.SS	CMRE	DAC	DHT	DSX	LPG	DSV.CO	DLNG	EGLE	EURN
2	-0.6788	0.6720	-0.0493	-0.1386	-0.2403	-0.2582	-0.3363	-0.6484	-0.5781	-0.8912	-1.0757	-0.1201	0.0611	-0.9214	0.3546
3	-0.6868	0.6740	-0.0322	-0.1537	-0.2287	-0.2435	-0.3361	-0.6506	-0.5901	-0.8913	-1.0631	-0.1151	0.0860	-0.9276	0.3802
4	-0.6884	0.6681	-0.0192	-0.1662	-0.2182	-0.2311	-0.3369	-0.6502	-0.5970	-0.8886	-1.0551	-0.1128	0.1018	-0.9282	0.3924
5	-0.6887	0.6621	-0.0094	-0.1752	-0.2082	-0.2212	-0.3361	-0.6488	-0.6011	-0.8850	-1.0506	-0.1109	0.1120	-0.9279	0.3988
6	-0.6889	0.6579	-0.0016	-0.1816	-0.1994	-0.2137	-0.3339	-0.6473	-0.6037	-0.8811	-1.0479	-0.1091	0.1189	-0.9277	0.4024
7	-0.6891	0.6555	0.0046	-0.1863	-0.1918	-0.2078	-0.3309	-0.6458	-0.6055	-0.8773	-1.0461	-0.1075	0.1238	-0.9276	0.4045
8	-0.6894	0.6545	0.0097	-0.1898	-0.1853	-0.2032	-0.3275	-0.6445	-0.6069	-0.8738	-1.0449	-0.1060	0.1273	-0.9276	0.4058
9	-0.6899	0.6544	0.0140	-0.1925	-0.1799	-0.1996	-0.3241	-0.6433	-0.6079	-0.8706	-1.0440	-0.1047	0.1299	-0.9278	0.4066
10	-0.6904	0.6546	0.0175	-0.1947	-0.1752	-0.1967	-0.3208	-0.6423	-0.6087	-0.8677	-1.0433	-0.1035	0.1320	-0.9281	0.4071
11	-0.6909	0.6551	0.0204	-0.1964	-0.1712	-0.1944	-0.3177	-0.6415	-0.6093	-0.8652	-1.0427	-0.1024	0.1336	-0.9285	0.4074
12	-0.6915	0.6556	0.0229	-0.1979	-0.1677	-0.1924	-0.3148	-0.6407	-0.6099	-0.8628	-1.0422	-0.1015	0.1349	-0.9289	0.4075
13	-0.6920	0.6561	0.0251	-0.1991	-0.1647	-0.1908	-0.3122	-0.6401	-0.6103	-0.8608	-1.0418	-0.1006	0.1359	-0.9293	0.4075
14	-0.6926	0.6565	0.0269	-0.2001	-0.1620	-0.1894	-0.3099	-0.6395	-0.6107	-0.8589	-1.0414	-0.0998	0.1368	-0.9297	0.4075
15	-0.6931	0.6568	0.0284	-0.2009	-0.1597	-0.1882	-0.3078	-0.6390	-0.6110	-0.8572	-1.0411	-0.0991	0.1376	-0.9301	0.4074
16	-0.6936	0.6570	0.0298	-0.2017	-0.1576	-0.1871	-0.3059	-0.6386	-0.6112	-0.8557	-1.0408	-0.0985	0.1382	-0.9305	0.4073
17	-0.6941	0.6572	0.0310	-0.2023	-0.1557	-0.1862	-0.3042	-0.6382	-0.6115	-0.8543	-1.0405	-0.0980	0.1388	-0.9309	0.4072
18	-0.6946	0.6573	0.0320	-0.2029	-0.1540	-0.1854	-0.3027	-0.6378	-0.6117	-0.8531	-1.0402	-0.0975	0.1393	-0.9313	0.4071
19	-0.6951	0.6574	0.0329	-0.2034	-0.1525	-0.1847	-0.3013	-0.6375	-0.6119	-0.8519	-1.0399	-0.0970	0.1397	-0.9317	0.4069
20	-0.6955	0.6574	0.0337	-0.2039	-0.1511	-0.1840	-0.3001	-0.6372	-0.6120	-0.8509	-1.0397	-0.0966	0.1401	-0.9320	0.4068

d	ESEA	2603.TW	FRO	GLOP	GNK	GSL	GLBS	GLNG	GOGL	HHFA.DE	HLAG.DE	011200.KS	HMLP	INSW	9107.T
2	-0.0294	-0.9770	-1.0645	-0.1719	-0.0075	-0.0746	-0.5744	-0.8612	-0.8747	-0.1452	-0.3016	-1.7171	0.3408	-0.2256	-1.1076
3	-0.0537	-0.9732	-1.0994	-0.1937	-0.0226	-0.0937	-0.6026	-0.8521	-0.9236	-0.1342	-0.3198	-1.7440	0.3574	-0.1946	-1.0807
4	-0.0693	-0.9692	-1.1165	-0.2095	-0.0306	-0.1130	-0.6132	-0.8461	-0.9459	-0.1212	-0.3339	-1.7570	0.3668	-0.1812	-1.0612
5	-0.0783	-0.9665	-1.1270	-0.2213	-0.0344	-0.1276	-0.6173	-0.8415	-0.9577	-0.1110	-0.3444	-1.7654	0.3734	-0.1740	-1.0470
6	-0.0840	-0.9652	-1.1343	-0.2306	-0.0360	-0.1380	-0.6188	-0.8378	-0.9646	-0.1036	-0.3523	-1.7718	0.3785	-0.1694	-1.0362
7	-0.0878	-0.9646	-1.1397	-0.2380	-0.0366	-0.1454	-0.6192	-0.8349	-0.9690	-0.0981	-0.3585	-1.7770	0.3825	-0.1660	-1.0278
8	-0.0906	-0.9645	-1.1441	-0.2441	-0.0366	-0.1510	-0.6190	-0.8324	-0.9720	-0.0941	-0.3635	-1.7813	0.3857	-0.1634	-1.0210
9	-0.0926	-0.9647	-1.1476	-0.2492	-0.0363	-0.1552	-0.6185	-0.8304	-0.9740	-0.0911	-0.3676	-1.7850	0.3882	-0.1612	-1.0153
10	-0.0943	-0.9650	-1.1505	-0.2535	-0.0359	-0.1586	-0.6181	-0.8286	-0.9755	-0.0887	-0.3710	-1.7882	0.3903	-0.1593	-1.0106
11	-0.0956	-0.9655	-1.1529	-0.2572	-0.0354	-0.1613	-0.6176	-0.8271	-0.9767	-0.0868	-0.3738	-1.7910	0.3921	-0.1577	-1.0065
12	-0.0967	-0.9661	-1.1550	-0.2603	-0.0348	-0.1635	-0.6171	-0.8258	-0.9775	-0.0853	-0.3762	-1.7935	0.3936	-0.1562	-1.0030

13	-0.0976	-0.9666	-1.1568	-0.2630	-0.0343	-0.1654	-0.6167	-0.8246	-0.9782	-0.0841	-0.3782	-1.7956	0.3949	-0.1549	-0.9999
14	-0.0984	-0.9672	-1.1583	-0.2654	-0.0338	-0.1670	-0.6164	-0.8235	-0.9787	-0.0830	-0.3799	-1.7975	0.3960	-0.1537	-0.9972
15	-0.0991	-0.9677	-1.1596	-0.2675	-0.0332	-0.1684	-0.6160	-0.8225	-0.9792	-0.0822	-0.3814	-1.7992	0.3970	-0.1527	-0.9947
16	-0.0997	-0.9682	-1.1608	-0.2694	-0.0328	-0.1696	-0.6158	-0.8217	-0.9795	-0.0814	-0.3827	-1.8008	0.3978	-0.1517	-0.9926
17	-0.1002	-0.9687	-1.1618	-0.2711	-0.0323	-0.1706	-0.6155	-0.8209	-0.9798	-0.0808	-0.3838	-1.8021	0.3986	-0.1508	-0.9906
18	-0.1006	-0.9692	-1.1627	-0.2726	-0.0318	-0.1715	-0.6153	-0.8201	-0.9801	-0.0802	-0.3848	-1.8034	0.3993	-0.1500	-0.9888
19	-0.1010	-0.9697	-1.1636	-0.2739	-0.0314	-0.1724	-0.6151	-0.8195	-0.9803	-0.0797	-0.3857	-1.8045	0.3999	-0.1492	-0.9871
20	-0.1014	-0.9701	-1.1643	-0.2751	-0.0310	-0.1731	-0.6149	-0.8188	-0.9805	-0.0793	-0.3865	-1.8055	0.4004	-0.1485	-0.9856

d	KEX	KNOP	0QMW.IL	MATX	9104.T	NVGS	NM	NMM	601018.SS	9101.T	NAT	OSG	PANL	PBFX	PXS
2	-0.8968	-0.3180	-0.2867	-0.6232	-0.4708	-0.3577	-0.4931	-0.1950	-0.7546	-0.4587	-0.1042	-0.2364	-1.8282	-0.6702	-0.9108
3	-0.9257	-0.2267	-0.3022	-0.6237	-0.4865	-0.3494	-0.4769	-0.1786	-0.7596	-0.4377	-0.1207	-0.2067	-1.8379	-0.6561	-0.9382
4	-0.9383	-0.1675	-0.3093	-0.6217	-0.4916	-0.3447	-0.4689	-0.1689	-0.7597	-0.4215	-0.1270	-0.1914	-1.8353	-0.6485	-0.9482
5	-0.9446	-0.1285	-0.3137	-0.6196	-0.4932	-0.3416	-0.4645	-0.1623	-0.7586	-0.4095	-0.1297	-0.1833	-1.8307	-0.6433	-0.9522
6	-0.9482	-0.1018	-0.3171	-0.6175	-0.4934	-0.3393	-0.4617	-0.1574	-0.7571	-0.4003	-0.1309	-0.1789	-1.8264	-0.6394	-0.9536
7	-0.9503	-0.0829	-0.3198	-0.6156	-0.4931	-0.3374	-0.4599	-0.1536	-0.7556	-0.3930	-0.1314	-0.1766	-1.8226	-0.6362	-0.9538
8	-0.9516	-0.0690	-0.3220	-0.6138	-0.4926	-0.3359	-0.4585	-0.1507	-0.7541	-0.3871	-0.1316	-0.1753	-1.8193	-0.6337	-0.9536
9	-0.9526	-0.0584	-0.3239	-0.6122	-0.4922	-0.3345	-0.4574	-0.1483	-0.7528	-0.3823	-0.1317	-0.1746	-1.8165	-0.6316	-0.9531
10	-0.9532	-0.0501	-0.3255	-0.6107	-0.4917	-0.3334	-0.4566	-0.1464	-0.7515	-0.3782	-0.1317	-0.1742	-1.8141	-0.6299	-0.9526
11	-0.9536	-0.0435	-0.3269	-0.6094	-0.4914	-0.3324	-0.4559	-0.1448	-0.7504	-0.3747	-0.1318	-0.1739	-1.8120	-0.6284	-0.9520
12	-0.9539	-0.0381	-0.3281	-0.6081	-0.4911	-0.3314	-0.4553	-0.1435	-0.7493	-0.3717	-0.1319	-0.1738	-1.8102	-0.6271	-0.9514
13	-0.9541	-0.0336	-0.3291	-0.6071	-0.4909	-0.3306	-0.4548	-0.1425	-0.7483	-0.3691	-0.1319	-0.1737	-1.8086	-0.6259	-0.9509
14	-0.9542	-0.0298	-0.3300	-0.6061	-0.4907	-0.3299	-0.4544	-0.1415	-0.7473	-0.3669	-0.1320	-0.1737	-1.8072	-0.6249	-0.9504
15	-0.9542	-0.0266	-0.3308	-0.6052	-0.4905	-0.3292	-0.4540	-0.1408	-0.7464	-0.3648	-0.1322	-0.1736	-1.8059	-0.6241	-0.9499
16	-0.9543	-0.0238	-0.3316	-0.6044	-0.4904	-0.3286	-0.4537	-0.1401	-0.7456	-0.3630	-0.1323	-0.1736	-1.8047	-0.6233	-0.9495
17	-0.9543	-0.0213	-0.3322	-0.6038	-0.4903	-0.3281	-0.4534	-0.1395	-0.7448	-0.3614	-0.1324	-0.1736	-1.8037	-0.6226	-0.9491
18	-0.9542	-0.0192	-0.3328	-0.6031	-0.4902	-0.3276	-0.4531	-0.1390	-0.7441	-0.3600	-0.1325	-0.1736	-1.8028	-0.6220	-0.9488
19	-0.9542	-0.0173	-0.3333	-0.6026	-0.4901	-0.3271	-0.4529	-0.1385	-0.7434	-0.3587	-0.1327	-0.1736	-1.8019	-0.6214	-0.9485
20	-0.9542	-0.0156	-0.3338	-0.6021	-0.4900	-0.3267	-0.4527	-0.1382	-0.7427	-0.3575	-0.1328	-0.1736	-1.8012	-0.6209	-0.9482

d	QGTS.QA	QNNS.QA	RCL.BK	SB	SMHI	SHIP	SFL	600018.SS	SINO	STNG	SBLK	GASS	TK	TGP	4030.SR
2	-0.8535	-0.2035	-1.0008	-0.7749	-0.2061	-1.2914	-0.3213	0.3290	-0.8943	-0.6042	-0.6108	-0.8985	-0.7367	-1.1938	0.1466
3	-0.8763	-0.1821	-1.0301	-0.8002	-0.1862	-1.2813	-0.3017	0.3488	-0.8868	-0.6078	-0.6245	-0.8829	-0.7395	-1.2281	0.1994
4	-0.8864	-0.1704	-1.0495	-0.8121	-0.1764	-1.2751	-0.2919	0.3624	-0.8784	-0.6082	-0.6277	-0.8754	-0.7373	-1.2459	0.2295
5	-0.8903	-0.1630	-1.0637	-0.8192	-0.1712	-1.2718	-0.2863	0.3722	-0.8709	-0.6074	-0.6274	-0.8717	-0.7347	-1.2571	0.2489
6	-0.8913	-0.1578	-1.0745	-0.8241	-0.1682	-1.2700	-0.2829	0.3797	-0.8644	-0.6062	-0.6257	-0.8699	-0.7323	-1.2648	0.2624
7	-0.8911	-0.1537	-1.0829	-0.8277	-0.1663	-1.2692	-0.2807	0.3857	-0.8588	-0.6049	-0.6235	-0.8692	-0.7302	-1.2703	0.2722
8	-0.8905	-0.1503	-1.0896	-0.8303	-0.1648	-1.2689	-0.2792	0.3906	-0.8540	-0.6039	-0.6212	-0.8691	-0.7284	-1.2745	0.2796
9	-0.8897	-0.1473	-1.0951	-0.8324	-0.1636	-1.2690	-0.2780	0.3948	-0.8498	-0.6030	-0.6190	-0.8694	-0.7269	-1.2777	0.2854
10	-0.8889	-0.1446	-1.0996	-0.8340	-0.1625	-1.2692	-0.2772	0.3984	-0.8462	-0.6022	-0.6169	-0.8698	-0.7255	-1.2801	0.2899
11	-0.8882	-0.1421	-1.1034	-0.8353	-0.1615	-1.2694	-0.2765	0.4016	-0.8429	-0.6016	-0.6150	-0.8704	-0.7244	-1.2821	0.2936
12	-0.8875	-0.1398	-1.1066	-0.8363	-0.1606	-1.2698	-0.2760	0.4045	-0.8401	-0.6011	-0.6132	-0.8710	-0.7234	-1.2838	0.2966
13	-0.8869	-0.1378	-1.1094	-0.8372	-0.1597	-1.2701	-0.2756	0.4071	-0.8375	-0.6007	-0.6116	-0.8716	-0.7226	-1.2851	0.2991
14	-0.8864	-0.1359	-1.1118	-0.8379	-0.1589	-1.2704	-0.2752	0.4094	-0.8352	-0.6003	-0.6101	-0.8723	-0.7219	-1.2862	0.3012
15	-0.8859	-0.1342	-1.1139	-0.8385	-0.1581	-1.2707	-0.2748	0.4115	-0.8331	-0.6001	-0.6087	-0.8729	-0.7212	-1.2871	0.3030
16	-0.8855	-0.1326	-1.1158	-0.8390	-0.1574	-1.2710	-0.2745	0.4135	-0.8312	-0.5998	-0.6075	-0.8735	-0.7207	-1.2879	0.3046
17	-0.8851	-0.1312	-1.1175	-0.8394	-0.1567	-1.2713	-0.2743	0.4153	-0.8294	-0.5997	-0.6063	-0.8741	-0.7203	-1.2886	0.3059
18	-0.8848	-0.1299	-1.1189	-0.8398	-0.1561	-1.2716	-0.2740	0.4169	-0.8278	-0.5995	-0.6053	-0.8747	-0.7199	-1.2892	0.3071
19	-0.8844	-0.1287	-1.1203	-0.8401	-0.1555	-1.2718	-0.2738	0.4185	-0.8263	-0.5994	-0.6043	-0.8752	-0.7195	-1.2897	0.3082
20	-0.8842	-0.1276	-1.1215	-0.8404	-0.1549	-1.2720	-0.2736	0.4199	-0.8250	-0.5993	-0.6034	-0.8757	-0.7192	-1.2902	0.3091

d	TDW	TLSS	TRE.JO	TNP	TOPS	2606.TW	2615.TW	WTE.TO	XPO
2	0.6381	-1.0532	-1.0342	-0.7370	-0.4566	-0.0280	-0.7126	-0.4532	0.1706
3	0.5966	-1.0509	-1.0426	-0.7396	-0.4728	-0.0375	-0.7313	-0.4639	0.1895
4	0.5614	-1.0505	-1.0447	-0.7474	-0.4772	-0.0472	-0.7408	-0.4659	0.1895
5	0.5347	-1.0500	-1.0461	-0.7539	-0.4779	-0.0528	-0.7464	-0.4655	0.1881
6	0.5147	-1.0494	-1.0474	-0.7585	-0.4776	-0.0559	-0.7500	-0.4645	0.1876
7	0.4995	-1.0488	-1.0487	-0.7615	-0.4770	-0.0575	-0.7525	-0.4634	0.1879
8	0.4877	-1.0483	-1.0498	-0.7635	-0.4764	-0.0584	-0.7542	-0.4624	0.1887
9	0.4784	-1.0479	-1.0507	-0.7648	-0.4759	-0.0588	-0.7555	-0.4616	0.1896
10	0.4708	-1.0475	-1.0515	-0.7657	-0.4755	-0.0590	-0.7564	-0.4610	0.1906
11	0.4647	-1.0472	-1.0522	-0.7663	-0.4752	-0.0590	-0.7572	-0.4605	0.1917
12	0.4595	-1.0470	-1.0527	-0.7668	-0.4750	-0.0590	-0.7577	-0.4601	0.1926
13	0.4551	-1.0468	-1.0531	-0.7671	-0.4748	-0.0588	-0.7582	-0.4599	0.1935
14	0.4514	-1.0467	-1.0535	-0.7673	-0.4747	-0.0587	-0.7586	-0.4597	0.1944
15	0.4482	-1.0466	-1.0538	-0.7675	-0.4746	-0.0586	-0.7590	-0.4597	0.1951
16	0.4454	-1.0465	-1.0541	-0.7676	-0.4745	-0.0584	-0.7592	-0.4597	0.1958
17	0.4429	-1.0464	-1.0543	-0.7677	-0.4745	-0.0583	-0.7595	-0.4597	0.1965
18	0.4407	-1.0463	-1.0545	-0.7678	-0.4744	-0.0581	-0.7597	-0.4598	0.1971
19	0.4388	-1.0462	-1.0547	-0.7678	-0.4744	-0.0580	-0.7599	-0.4599	0.1976
20	0.4370	-1.0462	-1.0549	-0.7679	-0.4744	-0.0578	-0.7601	-0.4601	0.1981

Table 5. Description of different patterns detected in Rényi entropy outputs

Pattern	Description
I	Randomness and disorder has decreased in the post-COVID timeline. The level of information disorder in frequent events has increased during the pandemic, which indicates that investors showed higher level of fear and lower level of future expectations regarding most frequent events.
II	Randomness and disorder has decreased in the post-COVID timeline. The level of information disorder in frequent events has decreased during the pandemic, which indicates that investors showed lower level of fear and higher level of future expectations regarding most frequent events.
III	Randomness and disorder has increased in the post-COVID timeline. The level of information disorder in frequent events has increased during the pandemic, which indicates that investors showed higher level of fear and lower level of future expectations regarding most frequent events.
IV	Randomness and disorder has increased in the post-COVID timeline. The level of information disorder in frequent events has decreased during the pandemic, which indicates that investors showed lower level of fear and higher level of future expectations regarding most frequent events.

For the majority of the equities considered (over 89%), the randomness and disorder have decreased since the pandemic. The investors' expectations and level of fear for this group, however, were evenly distributed. In other words, for the most frequent events in the market, investors showed both lower/higher level of future expectations. Table 6 reports the equities according to their detected pattern. In the most influential stocks (Table 3), the Rényi entropy pattern belonged to group II (Table 4), which indicates that investors had shown a lower level of fear regarding frequent market events in these equities in the post-COVID timeline.

Table 6. The affiliated stocks to each Rényi entropy pattern

Pattern	Affiliated Stocks
I	CMRE; DAC; LPG; DSV.CO; GLNG; INSW; KNOP; MATX; NVGS; NM; NMM; OSG; PXS; QNNS.QA; SMHI; SHIP; SFL; SINO; STNG; GASS; TK; TRE.JO; WTE.TO; 2603.TW; 601018.SS; 601866.SS; 601919.SS; 9101.T; 9107.T.
II	ASC; CPLP; DHT; DSX; EGLE; ESEA; FRO; GLOP; GNK; GSL; GLBS; GOGL; HHFA.DE; HLAG.DE; KEX; NAT; PANL; PBFX; QGTS.QA; TCL.BK; TLSS; SB; SBLK; TGP; TNP; TOPS; 0QMW.IL; 011200.KS; 2606.TW; 2615.TW; 9104.T.
III	DLNG; EURN; HMLP; XPO; 155900.KS; 4030.SR ; 600018.SS.
IV	MAERSK-A.CO; TDW.

5. Conclusion

The entropy analysis of equities in the Oil & Gas Midstream and Marine Shipping sectors reveals changes in their underlying information flow patterns since the emergence of the COVID-19 virus. The post-COVID market action of equities in these two sectors behaves more sensitively to each other, as deducted from the effective transfer entropy results. According to the new (post-COVID) paradigm, the stocks in the Oil & Gas Midstream and Integrated Freight & Logistics industries have gained momentum in occupying six of the ten positions on the list of the most influential equities in the market, in terms of information transmission. The disorder and randomness has generally decreased for the studied equities after the COVID-19 emergence. Investors' fears and future market expectations for the studied equities are found to be mixed. Nevertheless, the Rényi entropy results indicate that investors more likely showed a lower level of fear regarding frequent market events in equities possessing high information transmission status in the market.

6. Declarations

6.1. Author Contributions

All authors have equally contributed towards Conceptualization, methodology, formal analysis, investigation, resources, writing—original draft preparation, writing—review and editing, visualization. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available in article.

6.3. Funding

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6.4. 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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