

Transfer Entropy Analysis of Financial Markets

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Aim & Materials

Q: Can information theory be used to identify and quantify influence between economies and industries?

Hypothesis: Transfer Entropy can be used to identify influential markets and industries.

Market data

Index	Name	Country	n
^GSPC	S&P 500	USA	500
^N100	Euronext 100	Europe	100
^N225	Nikkei 225	Japan	225
^BVSP	Bovespa Index	Brazil	70

ETFs data

Index	Name	Industry
USO	United States Oil Fund	Oil
ICLN	iShares Global Clean Energy ETF	Renewable Energy
JETS	U.S. Global Jets ETF	Airline
IYT	iShares Transportation Average ETF	Transportation
XLP	Consumer Staples Select Sector SPDR Fund	Consumer staples
SMH	VanEck Vectors Semiconductor ETF	Semiconductor
IXP	iShares Global Comm Services ETF	Telecom
VGT	Vanguard Information Technology Index Fund	Technology
XPH	SPDR S&P Pharmaceuticals ETF	Pharmaceutical

Stock data

Index	Name	Industry
XOM	ExxonMobil	Oil
DAL	Delta Airline	Airline

Method

Look at different levels of financial market

- Economy: Stock market index
- Industry: ETF
- Company: Stock price

Transfer entropy

- Kraskov estimator
- $K = 1$
- Nearest neighbors = 4
- Input: Log Daily return

Log daily return at time t :

$$r_t = \ln p_t - \ln p_{t-1} = \ln \left(\frac{p_t}{p_{t-1}} \right)$$

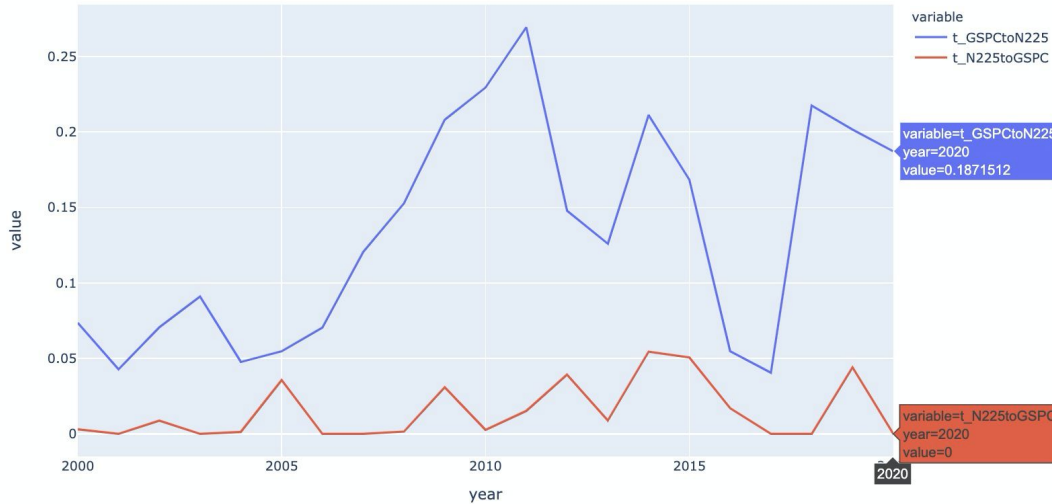


Results - Economy

Net information flow (X → Y):

$$(X \rightarrow Y) = T_{X \rightarrow Y} - T_{Y \rightarrow X}$$

Transfer Entropy between GSPC and N225



year	t_GSPCtoN225	t_N225toGSPC	net_info_flow
2000	0.073134	0.003553	0.069581
2001	0.042647	0.000000	0.042647
2002	0.069011	0.008767	0.060244
2003	0.089585	0.000000	0.089585
2004	0.047205	0.001261	0.045944
2005	0.053783	0.035861	0.017922
2006	0.068499	0.000000	0.068499
2007	0.120493	0.000000	0.120493
2008	0.152692	0.001503	0.151189
2009	0.207931	0.030833	0.177098
2010	0.229401	0.002642	0.226759
2011	0.269289	0.015190	0.254099
2012	0.147744	0.039211	0.108533
2013	0.125985	0.008871	0.117115
2014	0.211213	0.054382	0.156831
2015	0.168373	0.050655	0.117718
2016	0.054729	0.016947	0.037783
2017	0.039777	0.000000	0.039777
2018	0.216686	0.000000	0.216686
2019	0.201544	0.044058	0.157486
2020	0.187151	0.000000	0.187151

Results - Industry (ETFs)

Year	Pharmaceutical	Semiconductor	Renewable Energy	Airline	Consumer Staples	Oil	Telecom	Transportation	Technology
2002	0.000000	0.351504	0.000000	0.000000	0.546312	0.000000	0.102184	0.000000	0.000000
2003	0.000000	0.268880	0.000000	0.000000	0.502318	0.000000	0.228802	0.000000	0.000000
2004	0.000000	0.057117	0.000000	0.000000	0.131527	0.000000	0.255277	0.425826	0.130253
2005	0.000000	0.201834	0.000000	0.000000	0.109531	0.000000	0.087163	0.359444	0.242029
2006	0.000000	0.138424	0.000000	0.000000	0.245103	0.000000	0.227399	0.298876	0.090199
2007	0.023105	0.097225	0.000000	0.000000	0.039366	0.213104	0.068295	0.280837	0.278068
2008	0.206011	0.027874	0.000000	0.000000	0.047243	0.252743	0.199062	0.106525	0.160542
2009	0.025382	0.081523	0.067746	0.000000	0.241051	0.085381	0.103899	0.252535	0.142484
2010	0.074009	0.036683	0.164379	0.000000	0.004832	0.246538	0.268585	0.075735	0.129240
2011	0.153696	0.022067	0.002933	0.000000	0.245540	0.196389	0.127495	0.063833	0.188046
2012	0.106558	0.046596	0.126051	0.000000	0.035346	0.160731	0.157176	0.110552	0.256990
2013	0.157566	0.136117	0.131832	0.000000	0.108710	0.081415	0.163197	0.123647	0.097515
2014	0.156866	0.071775	0.175108	0.000000	0.015930	0.143599	0.145213	0.117638	0.173871
2015	0.134925	0.066612	0.121931	0.000000	0.081826	0.123902	0.240245	0.119352	0.111208
2016	0.030367	0.086001	0.202885	0.169737	0.093977	0.078701	0.168365	0.065023	0.104944
2017	0.044076	0.074593	0.086967	0.092864	0.125465	0.136620	0.105720	0.232160	0.101535
2018	0.086298	0.173048	0.016955	0.082027	0.115597	0.097943	0.194383	0.097919	0.135830
2019	0.106301	0.121157	0.093962	0.223178	0.104455	0.117606	0.083892	0.057465	0.091983
2020	0.137117	0.132593	0.118680	0.019373	0.235498	0.023934	0.156946	0.095072	0.080786

Discussion

Critical evaluation

- Validating / evaluating transfer entropy and net information transfer (i.e. whether optimal parameters were selected for estimators) was done by doing spot checks - looking up news articles

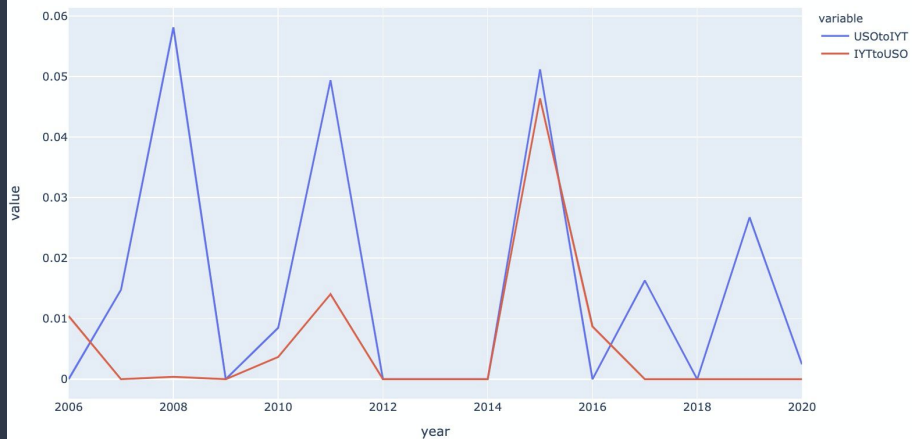
Improvements / Future work

- Select n largest companies by market cap from each industry
 - Selected ETFs not entirely disjoint (semiconductor / technology / telecom) and includes redundancy (Active info. storage)
 - Different degree of diversification
 - Some ETFs are too new (Airline)
- Estimator parameter tuning
 - Difficult to validate how well the computed TE and net info. flow represent the dynamics of the market, aside from Googling articles and conducting spot checks
- Discretization
 - Binary - Positive or negative return, or whether daily return increased or decreased from previous day

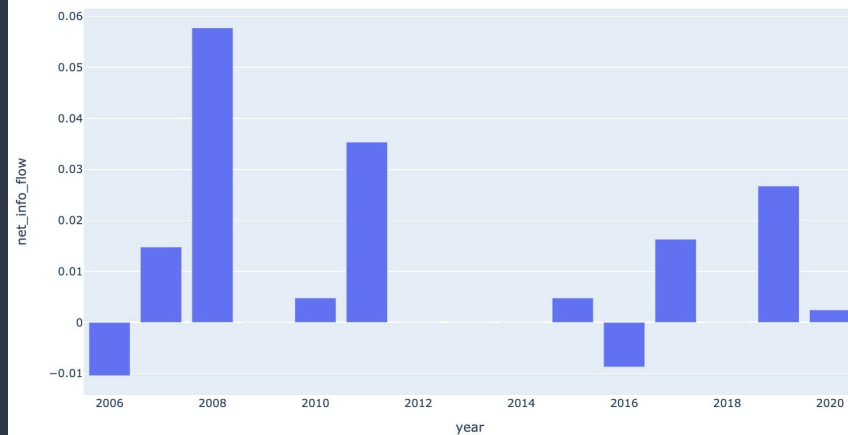
Results - Industry (ETFs)

Oil -> Transportation

Transfer Entropy between Oil (USO) & Transportation (IYT)



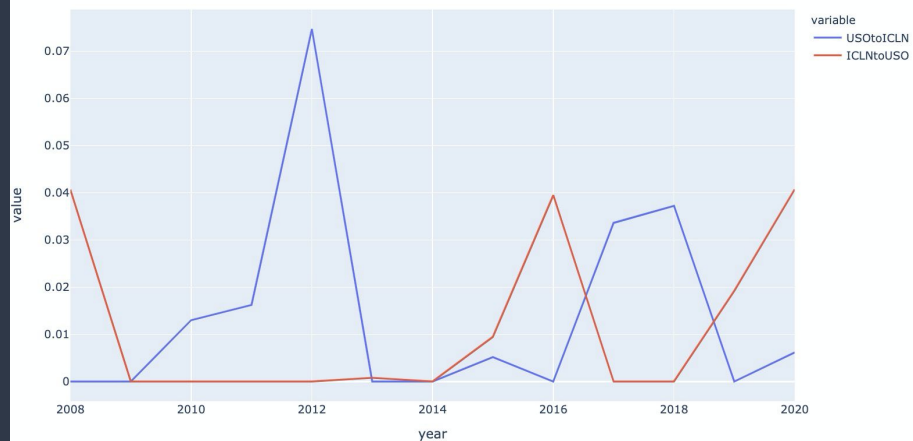
Net Information Flow: Oil (USO) -> Transportation (IYT)



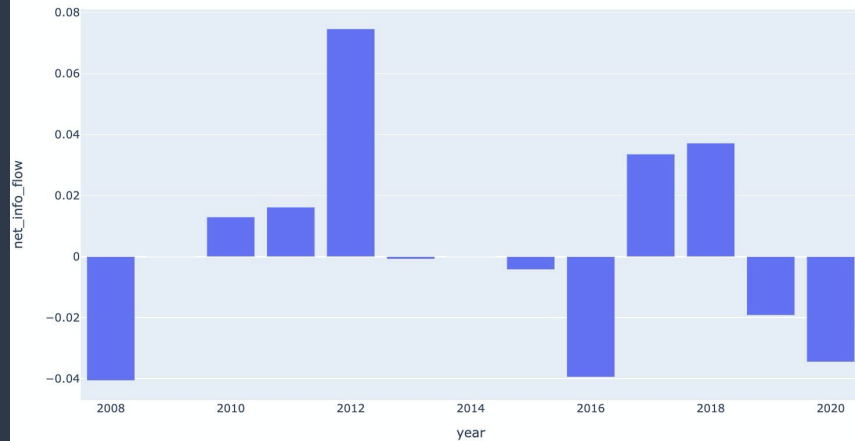
Results - Industry (ETFs)

Oil -> Renewable Energy

Transfer Entropy between Oil (USO) & Renewable Energy (ICLN)



Net Information Flow: Oil (USO) -> Renewable Energy (ICLN)



Not used

Results - Economy

		Target				
		N225		GSPC	N100	BVSP
Source	Japan	N225	0.000000	0.018052	0.022705	0.010250
	USA	GSPC	0.131662	0.000000	0.051715	0.005894
	Europe	N100	0.084533	0.034913	0.000000	0.000000
	Brazil	BVSP	0.036315	0.000000	0.003056	0.000000

Transfer Entropy Contribution:

- Row-wise summation / Sum of TE
- Normalized TE by source variable

ETF	Transfer_entropy_contrib
GSPC	0.47425127919485627
N100	0.2992923005418552
N225	0.1278072338387267
BVSP	0.09864918642456186

Results - Industry (ETFs)

Used the longest contiguous intersection of all ETF (2015-05-02 to 2020-10-31)

	Pharmaceutical	Semiconductor	Renewable Energy	Airline	Consumer Staples	Oil	Telecom	Transportation	Technology
Pharmaceutical	0.000000	0.002002	0.000000	0.026929	0.008916	0.000000	0.005017	0.018801	0.000000
Semiconductor	0.000000	0.000000	0.016593	0.001983	0.005971	0.000000	0.000501	0.013770	0.000000
Renewable Energy	0.042140	0.000000	0.000000	0.012476	0.000000	0.017954	0.000000	0.018155	0.012681
Airline	0.000000	0.000000	0.000000	0.000000	0.021155	0.000000	0.000000	0.000000	0.000000
Consumer Staples	0.001649	0.000000	0.016916	0.013869	0.000000	0.000000	0.000000	0.012087	0.000000
Oil	0.017203	0.000000	0.010774	0.000000	0.000000	0.000000	0.000000	0.005790	0.014790
Telecom	0.003840	0.003950	0.013165	0.001598	0.023812	0.002834	0.000000	0.000000	0.000000
Transportation	0.005510	0.000000	0.000000	0.000000	0.000000	0.000000	0.010406	0.000000	0.000000
Technology	0.000000	0.000000	0.008680	0.000000	0.021081	0.017188	0.004864	0.000000	0.000000

ETF	Transfer_entropy_contrib	industry
ICLN	0.2360911037480295	Renewable Energy
XPH	0.14269329488399313	Pharmaceutical
VGT	0.11813689477084147	Technology
USO	0.11334413284475249	Oil
IXP	0.11265432557711536	Telecom
XLP	0.10046068274679416	Consumer Staples
SMH	0.09084799620798856	Semiconductor
JETS	0.048882765022124075	Airline
IYT	0.03688880419836126	Transportation