A-data: (BDTI TD3: 265,000mt, Middle East Gulf to Japan -- BDTI TD4: 260,000mt, West Africa to US Gulf)

B-data: (BDTI TD4: 260,000mt, West Africa to US Gulf -- BDTI TD5: 130,000mt, West Africa to USAC)

C-data: (BDTI TD3: 265,000mt, Middle East Gulf to Japan -- BDTI TD5: 130,000mt, West Africa to USAC)

Window size: 10—N/4, step 10

DCCA:

|  |  |  |  |
| --- | --- | --- | --- |
| Hurst Exponent | A-data | B-data | C-data |
| Period 1 | 0.629164172724 | 0.582080516556 | 0.584845054399 |
| Period 2 | 0.657615552802 | 0.625168149506 | 0.644580555957 |

DPXA:

|  |  |  |  |
| --- | --- | --- | --- |
| Hurst Exponent | A-data | B-data | C-data |
| Period 1 | 0.64642052322 | 0.605461409439 | 0.605239876561 |
| Period 2 | 0.719606428059 | 0.696333540565 | 0.6917151399 |

Hurst exponent:

1. DCCA, DPXA: 第二段hurst exponent都大于第一段。DPXA的增幅更大一些。说明油价是影响因素，但金融危机前后的核心因素可能综合/复杂无法分析定论。
2. DCCA: A>C>B; DPXA: A>B>C

从经验上来说，A-data有相同船型，B-data航线有相同的起点，C-data表面上没很大关系 -> hurst exponent A>B>C. DCCA得到了一个违背经验的结果。

1. DCCA, DPXA中从Period 1到Period 2，B-data和C-data之间hurst exponent的差异变大，可能是金融危机过后失去了一种共因，有待检验。
2. DCCA, DPXA的general hurst exponent 在同一时段都是极为相似的，说明DPXA是在DCCA基础上一个有效的改进。
3. DCCA, DPXA的图都是非线性的，证明是多分形的。第二段比第一段H\_q跨度更大，分形维度增加。原因是金融危机增强的价格波动。

左：DPXA第一段；右：DCCA第一段

左：DPXA第二段；右：DCCA第二段

τ直接反映分形维度，与上述结论契合。

左：DPXA第一段；右：DCCA第一段

左：DPXA第二段；右：DCCA第二段

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DCCA: | |  | | |  | | |  | |
| A-data delta\_alfa | | origin | | | random | | | surrogated | |
| Period 1 | | 0.464473763 | | | 0.056267675 | | | 0.203790363 | |
| Period 2 | | 0.778346468 | | | 0.086360434 | | | 0.119842361 | |
|  | |  | | |  | | |  | |
| B-data delta\_alfa | | origin | | | random | | | surrogated | |
| Period 1 | | 0.340799995 | | | 0.033431963 | | | 0.153220063 | |
| Period 2 | | 0.826557 | | | 0.082667096 | | | 0.1536731 | |
|  | |  | | |  | | |  | |
| C-data delta\_alfa | | origin | | | random | | | surrogated | |
| Period 1 | | 0.30167057 | | | 0.049644233 | | | 0.134659825 | |
| Period 2 | | 0.636876493 | | | 0.108077358 | | | 0.204101138 | |
|  | |  | | |  | | |  | |
| DPXA: | |  | | |  | | |  | |
| A-data delta\_alfa | | origin | | | random | | | surrogated | |
| Period 1 | | 0.470588203 | | | 0.071429751 | | | 0.195238833 | |
| Period 2 | | 0.734403604 | | | 0.102735036 | | | 0.108792081 | |
|  | |  | | |  | | |  | |
| B-data delta\_alfa | | origin | | | random | | | surrogated | |
| Period 1 | | 0.32204555 | | | 0.08096191 | | | 0.201501728 | |
| Period 2 | | 0.790431184 | | | 0.112843252 | | | 0.172846623 | |
|  | |  | | |  | | |  | |
| C-data delta\_alfa | | origin | | | random | | | surrogated | |
| Period 1 | | 0.303446676 | | | 0.080081168 | | | 0.174042519 | |
| Period 2 | | 0.596614849 | | | 0.122533735 | | | 0.18169771 | |
| DCCA: |  | |  |  | |  |  | |  | |
| A-data | total | | LM | NL | | PDF | eff | | eff percent(%) | |
| Period 1 | 0.4644738 | | 0.1475227 | 0.2606834 | | 0.0562677 | 0.3169511 | | 68.238747 | |
| Period 2 | 0.7783465 | | 0.0334819 | 0.6585041 | | 0.0863604 | 0.7448645 | | 95.698326 | |
|  |  | |  |  | |  |  | |  | |
| B-data | total | | LM | NL | | PDF | eff | | eff percent(%) | |
| Period 1 | 0.3408 | | 0.1197881 | 0.1875799 | | 0.033432 | 0.2210119 | | 64.850909 | |
| Period 2 | 0.826557 | | 0.071006 | 0.6728839 | | 0.0826671 | 0.755551 | | 91.409424 | |
|  |  | |  |  | |  |  | |  | |
| C-data | total | | LM | NL | | PDF | eff | | eff percent(%) | |
| Period 1 | 0.3016706 | | 0.0850156 | 0.1670107 | | 0.0496442 | 0.216655 | | 71.818401 | |
| Period 2 | 0.6368765 | | 0.0960238 | 0.4327754 | | 0.1080774 | 0.5408527 | | 84.9227 | |
|  |  | |  |  | |  |  | |  | |
| DPXA: |  | |  |  | |  |  | |  | |
| A-data | total | | LM | NL | | PDF | eff | | eff percent(%) | |
| Period 1 | 0.4705882 | | 0.1238091 | 0.2753494 | | 0.0714298 | 0.3467791 | | 73.690568 | |
| Period 2 | 0.7344036 | | 0.006057 | 0.6256115 | | 0.102735 | 0.7283466 | | 99.175243 | |
|  |  | |  |  | |  |  | |  | |
| B-data | total | | LM | NL | | PDF | eff | | eff percent(%) | |
| Period 1 | 0.3220456 | | 0.1205398 | 0.1205438 | | 0.0809619 | 0.2015057 | | 62.570569 | |
| Period 2 | 0.7904312 | | 0.0600034 | 0.6175846 | | 0.1128433 | 0.7304278 | | 92.40878 | |
|  |  | |  |  | |  |  | |  | |
| C-data | total | | LM | NL | | PDF | eff | | eff percent(%) | |
| Period 1 | 0.3034467 | | 0.0939614 | 0.1294042 | | 0.0800812 | 0.2094853 | | 69.0353 | |
| Period 2 | 0.5966148 | | 0.059164 | 0.4149171 | | 0.1225337 | 0.5374509 | | 90.083389 | |

1. DCCA, DPXA的有效成分主要是non-linear part（NL），DPXA的non-linear part（NL）更少一些，突出了趋势
2. DPXA的PDF part总是大于DCCA -> 去除油价影响之后更加偏离fat-tailed distribution
3. 从第一段到第二段，effective part的占比都是增加的，说明金融危机之 linear correlation（LM）的占比大幅减小。
4. DPXA里的有效成分占比大体与DCCA相近但都略高出一些，说明DPXA是一个相对更有效的分析方法
5. 如果两个序列的关联越强，则数据越趋向于特定分布-> PDF part 相对固定。根据中心极限定理，随机数据的PDF part= total->波动越随机PDF part越大。外因消除越多越体现市场的随机波动。金融危机之后PDF part总是变大的，随机波动的特点加强。
6. 对于non-linear part（NL）的值，关系较强的序列（A,B），金融危机之后增涨比关系较强的序列（C）大。强相关序列中A的增涨比B小（原因未知）
7. Period 1的时候DCCA/DPXA 中linear correlation part（LM）基本一致Common external force 主要的影响在于non-linear part（NL）和PDF。Period 2的时候LM/PDF/NL三个成分都有比较大的影响。
8. Period 1到Period 2的effective part占比变大符合金融危机后波动更剧烈的现象（non-linear part（NL）显著增加）。

Here we applied two different fluctuation analysis method to calculate generalized Hurst exponents. The Hurst exponents decrease with the order q with a non-linear relation, which indicates the fractal characteristic in the cross-correlation of the three pair of time series. We can also observe that the Hurst exponents of B-data and C-data exchange their relative magnitude at some point, where q-order is smaller(negative) in period 1 and larger(positive) in period 2, meanwhile the Hurst exponents of A-data hold their relative position. We can also observe a stronger non-linear characteristic in period 2 than in period 1, this phenomena can be explained as the expansion of fractal characteristic.

For the two different fluctuation analysis method, we both take multifractality into consideration, so that " Multifractal detrended cross-correlation analysis " will be DCCA in short and " Detrended partial cross-correlation analysis " DPXA in short in the latter sections.

For normal prospect of time series analysis, we consider the Hurst exponent at order q=2, which reveals the long-term cross-correlation of the time series. In both DCCA and DPXA method, we observe an increase of Hurst exponents in three pairs of data from period 1 to period 2. However, Hurst exponents calculated by DPXA has a greater increment.

DCCA, DPXA: 第二段hurst exponent都大于第一段。DPXA的增幅更大一些。说明油价是影响因素，但金融危机前后的核心因素可能综合/复杂无法分析定论。

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DCCA, DPXA的图都是非线性的，证明是多分形的。第二段比第一段H\_q跨度更大，分形维度增加。原因是金融危机增强的价格波动。