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The Cost of SOx Limits to Marine Operators; Results from Exploring Marine Fuel Prices

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ABSTRACT: Marine operators are confronted with the new air emissions regulations that determine the limits of sulfur content in marine fuels. The low-sulfur (LS) marine fuels have a higher price, and their fluctuation is almost similar to the fluctuation of high-sulfur (HS) fuels. The price difference between HS and LS might also determine the decision of operators for alternative technical means, such as scrubbers, in order to comply with the new limits. This paper aims to provide a thorough statistical analysis of the currently available LS and HS marine fuels time series, as well as to present the analysis of the differential of the HS and LS fuel prices. The paper concludes with suggestions for further research.

1 INTRODUCTION

The aim of this paper is to investigate the impact of bunker prices in the compliance decisions related to the MARPOL Annex VI Regulations, and specifically of Regulation 14, which deals with the sulfur emissions (SOx). The set limits apply to all vessels that fly the flag of a country, which has ratified the convention. Additionally, it applies to vessels that fly the flag of a non-signatory state while operating within waters under the jurisdiction of a country adhering to MARPOL's Annex VI Reg. 14. On October 10th 2008 more stringent amendments were adopted to Annex VI, which entered into force on July 1st 2010. Regulation 14 specifies the sulfur limit in marine fuel for global maritime trade. The highest sulfur content allowed in ship fuel will reduce globally as of 1 January 2012 from 4.5% to 3.5% and as of 1 January 2020 to 0.5%, depending on the availability of low sulfur fuel, as this will be discussed and reviewed by the IMO in 2018. Even stricter values apply for the Emission Control Areas (ECA). The ECA includes Baltic Sea, North Sea and the English Channel, as well as the oceanic coastline of the United States and Canada. Within the ECA's the sulfur limit was 1.5% until July 2010. As of July 2010 the allowed sulfur content was reduced to 1.0%. In 2015 the limit will further be decreased to 0.1%.

The issue of compliance with Regulation 14 is well known in the related business and academic literature. The study of EMSA (2010) and the report of Miola et al. (2010), as well as the studies on green house gases (GHG) and air pollution of Buhaug et al. (2009) among others, have paved the way for further research, regulatory action and vivid debates. To this discussion, the authors have also contributed with advanced methodologies estimating the cost of operating in mixed ECA and non-ECA areas (Schinas, et. al. 2012a) as well as with policy support documents, such as in Schinas et al. (2012b). In all the related studies, the focus is either micro-economic, i.e. a focus on the impact from the operation and the related expenses of burning fuels of diverse quality, namely either High-Sulfur (HS) or Low-Sulfur (LS) heavy fuel oil (HFO) or intermediated fuel oil (IFO) marine diesel oil (MDO), or macro-economic, i.e. approaches dealing with the global fleet and total effect of marine fuel consumption to the environment. However, there is no study, to the best of the knowledge of the authors, examining the time series of the prices of the related fuels. Alizadeh et. al. (2004) examined the correlation of Rotterdam, Houston and Singapore bunker prices time-series vis-à-vis the prices of future contracts traded at the New York Mercantile Exchange (NYMEX) and the International Petroleum Exchange (IPE) in London; further work on this subject is not reported. Should the statistical characteristics of the time series be known then better forecasting and explanatory models can be derived. This paper aims to offer some basic analysis of the time series of HS-HFO and LS-HFO in Rotterdam, discuss the results of the analysis and finally discuss some possible steps for further research. It is out of the scope of this paper to analyze the political and economic factors that determine the prices, but scientifically analyze the related time-series.

The following section presents the value of accurate or at least reliable and trustworthy statistical attributes of fuel oil price time series for the support of technical, operational and financial decisions at the micro-level. In the next session, the analyses of the HS- and LS-HFO prices in Rotterdam as well as of the derived time series of the difference between HS- and LS-HFO are presented. In the last section the conclusions are summarized and suggestions for further research are presented.

2 THE IMPACT OF FUEL PRICES

Although different ship types and propulsion plant configurations suggest different cost structures, it is common knowledge that fuel costs determine a large percentage of the overall cost, and therefore the financial performance of this asset. The compliance with reduced sulfur limits can be achieved via various instruments, however two major and most feasible instruments are practically available to operators: a dual fuel system and an exhaust gas cleaning system (EGCS), i.e. a scrubber or similar technology. The dual fuel system implies a switch from regular fuel to LS fuel oil in ECAs. With the installation of scrubbers it is not necessary to operate with more than one fuel: HS fuel oils can be used, the exhausts are then cleaned by the scrubbers in order to reduce the emission of sulfur into the air. Other sulfur abatement instruments are also in discussion, but do not seem to be implementable within the next couple of years, as there are many unsolved questions regarding their usage.

One of those alternatives is the vessel propulsion via liquefied natural gas (LNG). Implementing this technology makes costly retrofitting of the vessel necessary. A further aspect, which has to be taken into account, is the availability of LNG bunkering facilities in ports. Recent policy initiatives, include a proposed European Directive, where the Commission introduces an obligation for all the major European seaports to be equipped by 2020 with publicly accessible LNG refueling points for both maritime and inland waterway transport (EC, 2013). Adding to the policy controversy over air emission issues, ESPO doubts, whether imposing LNG refueling infrastructure in all the major European would be appropriate, since there may not be a market for it in all of those ports, whereas there could be a market in other, non-core ports, as well as alternative solutions to the development of LNG are and will become increasingly available in the near future (ESPO, 2013). Generally speaking, in the short term the availability of LNG bunkering facilities globally cannot be guaranteed and thus this option is intentionally neglected in this analysis. Thus this section will cover two alternatives that seem to be available in short term in detail: the dual fuel system and the exhaust gas scrubber technology.

Assuming the following data for a typical container vessel:

1 Operating Speeds
  - ECO Speed: 16.5 kn
  - Design Speed: 18.5 kn
  - Maximum Speed: 21kn
2 Fuel Types consumed
  - IFO 380
  - MDO
3 Operational Data
  - Steaming @ ECO Speed 16.5 kn (days/year): 50
  - Steaming @ Design Speed 18.5 kn (days/year): 140
  - Steaming @ Maximum Speed 21kn (days/year): 20
  - Port/Idle Time (days/year): 150
  - Time not used for operation (days/year): 5
  - Estimated Annual Operation in ECAs (days/year): 80
4 Main Engine
  - MCR (kW): 16,000
  - Type of Fuel: IFO 380
  - Fuel Consumption (t/yr): 7,939
5 Auxiliary Engine
  - No. of Machinery of this Type: 4
  - MCR (kW): 1,600
  - Total kW Auxiliary Engine: 6,400
  - Specific Fuel Oil Consumption (g/kWh): 180
  - Type of Fuel: MDO
  - Fuel Consumption (t/yr): 1,459
6 Boiler
  - No. of Machinery of this Type: 1
  - Fuel Oil Consumption (t/day): 25
  - Type of Fuel: MDO
  - Fuel Consumption (t/yr): 1,664

Obviously the consumption data can be thoroughly evaluated, and the calculations above yield the product of the daily consumption times the time of operation at various 'expected' levels of load. Given that the consumption data above are accurate enough to support further estimation of the cost, operators face the following dilemma: they should either install a scrubber (generally a EGCS) or to install/use a dual fuel system. The critical parameters that determine the decision are the price of HSHFO and LSHFO, the time (days/year) of expected operation in an ECA and the required investment for EGCS. In few words, operators have the option to install an EGCS and consume the cheaper HSHFO in all operating cases or to use HSHFO and LSHFO wherever permitted or required. The difference of the discounted cost streams will determine, which option is from a financial point of view more appropriate. The method of net present value (NPV) could be considered, although with some cautiousness as many assumptions can jeopardize the validity of the outcome. The NPV analysis pinpoints the economic life of the asset (the age of the ship), the bunker prices and the discount rate as the critical parameters of the decision. This does not contradict with the praxis, and implies that the only parameter not determined by the owner or the fleet status is the price of bunkers, which draws also the attention as the main risk parameter.

Having said that, it is obvious that it is of critical importance to consider rational scenarios of future fuel price values, as the amortization of the investment will be concluded in some future years. In order to deal with these issues, a typical spreadsheet modeler would consider scenarios that are structured as follows:

- Current Fuel Price USD/t: 610
- Price Difference to Sulfur Content of 1% USD/t: 40
- Price Difference to Sulfur Content of 0.5% USD/t: 140
- Price Difference to Sulfur Content of 0.1% USD/t: 225

Considering the above data and an investment horizon of 25 years for the ship, discount rates (for the DCF Analysis) of 1.0% (low), 5.0% (medium) and 10.0% (high), as well as the assumptions of tables X and Y below, the accumulated consumption is depicted in the following graphs:

Table 1. Current Prices and Price Differences (Scenarios)

USD/t	Base	50%	75%
Current Fuel Price	610	610	610
Price Difference 1%	40	60	70
Price Difference 0.5%	140	210	245
Price Difference 0.1%	225	340	390

Table 2. Growth rates (Scenarios)

Scenario	Low	Medium	High
Estimated Fuel Price Increases per Year in %	1%	5%	10%
Estimated Fuel Price Increase as of 2015 (on top of the above increase)	1%	10%	15%
Estimated Fuel Price Increase after 2020/25 (on top of the above increase)	1%	10%	20%

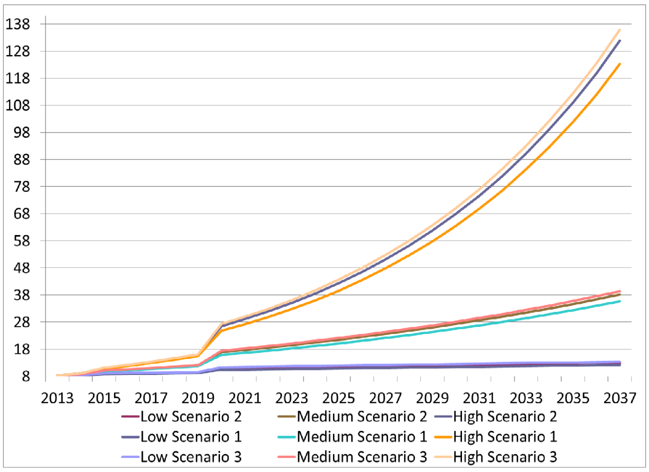

Figure 1. Lifecycle cost of bunkers as per the scenarios

The bunkering hub of Rotterdam is taken as a base case, as prices of all major bunkering hubs follow the same fluctuation pattern, as depicted in Figure 2 (see also section 4 about this issue.)

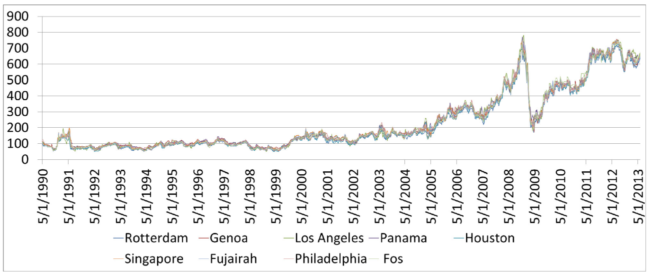

Figure 2. Prices in various bunkering hubs

Obviously the difference of the prices among HS and LS fuels is determining at large the financial exposure for bunkers. Having a closer look at the results of this given and indicative example the difference of 50% from the base scenario implies an annual growth rate of 1.9% vis-à-vis 1.5% for the low cost scenario that suggest an increase of close to 5.8% (ca. 600,000USD) of the annual bunker costs. For the high-scenario, the annual growth rate is 11.9% and the annual increase close to 7% (close to 3.2millions USD). Considering the data of the 75% scenario, then the figures dramatically change for the low and high scenarios, as an annual growth of 2.0% and 12.1% of the expenses is envisaged, an increase of minimum 8.6% and maximum of 9.9% is expected in the average annual bunker cost, implying higher expenses close to minimum 900k USD and maximum 4.7mUSD.

In conclusion, operators can neither ignore the evolution of the HS and LS prices, nor disregard the influence of the difference of the HS and LS prices and it is imperative for them to draft the appropriate scenarios, i.e. to have a better insight of the dynamics of the statistical attributes, in order to support their decisions.

3 PROBABILITY ANALYSIS

The data source used in the present study is the weekly time series of the HS-, LS-HFO (380cSt) in Rotterdam, as published by Shipping Intelligence Network of Clarksons. Although data for the HS-HFO are available since 1990, we decided to use only the subset of data where both values (HS- and LS-HFO) are present. Thus, the analyzed data covers the time period from 2007 till 2012. The total amount of the analyzed data (256 values) is not statistically significant. However, it is the only reliable dataset up to now.

Along with the analysis of basic statistics, probability analysis is also necessary. Probability analysis is a versatile tool for the analysis of historical data. For each dry index, the empirical histogram is calculated as follows (Spanos 2003).

First, a particular partition is defined of the form

$$\left\{\xi_1,\xi_2,\dots,\xi_i,\dots,\xi_{I+1}\right\} \tag{1}$$

in order to appropriately segment the range of possible values of the index. Then, the table of relative frequencies of occurrence (histogram) is calculated as

$$v_i=\frac{k_i}{N},\quad i=1,2,\dots,I, \tag{2}$$

where

$$k_i=\left\{\#of\ X_n's:\xi_i\le X_n<\xi_{i+1},n=1,2,...,N\right\} \tag{3}$$

and N is the total number of observations (measurements).

The selection of the appropriate partition is of paramount importance for the probability analysis and usually is a tantalizing task. It requires much of experimentation before concluding with the right partition that reveals the right form of the underlying probability mass. In the present analysis, the partitions given in Table 3 have used.

Table 3. Partitions used in probability analysis.

Data	Partition
HS-HFO	[0 160:20:820]
LS-HFO	[0 160:20:820]
Difference	[-10:10:100]

3.1 *High Sulfur Heavy Fuel Oil Prices in Rotterdam*

In Table 4, the basic statistics for the time series of HS-HFO are given.

Table 4. Basic Statistics for the HS-HFO

Year	Count	Mean	MIN	MAX	St.Dev.	Skewn.	Kurt.
2007	22	412.95	337.50	495.00	50.15	0.06	1.55
2008	52	474.33	171.50	707.00	145.89	-0.61	2.54
2009	52	352.73	173.50	466.00	84.75	-0.40	1.71
2010	53	451.06	405.00	494.00	22.99	0.08	2.12
2011	52	619.51	511.50	669.50	39.33	-1.55	4.71
2012	25	671.06	553.00	720.00	48.16	-1.24	3.33
all	256	488.24	171.50	720.00	133.74	-0.22	2.40

In Figures 3-9, the histograms of HS-HFO are presented first based on the whole amount of data available and then on each specific year.

In Figure 3, for example, the following areas with concentrated probability mass can be distinguished. There is a 30% of the values falling in the range 420-480 $/ton, a 22% in 600-660, and a 9% in 200-300.

So, these areas of HS-HFO can be considered that they have greater probability to occur in the future.

Working similarly with the annual results, areas of greater probability can be defined.

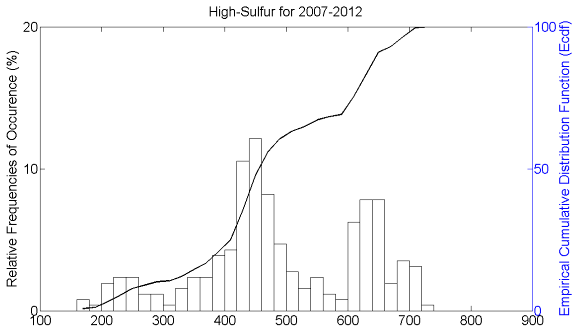

Figure 3. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of HS-HFO for all years.

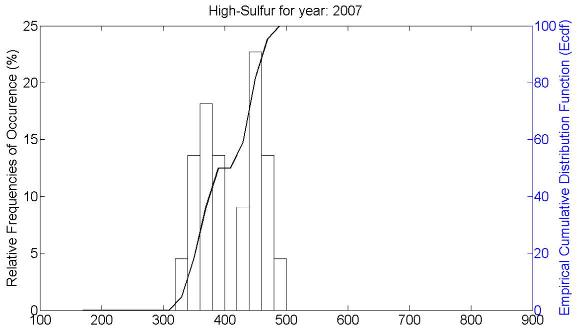

Figure 4. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of HS-HFO for year 2007.

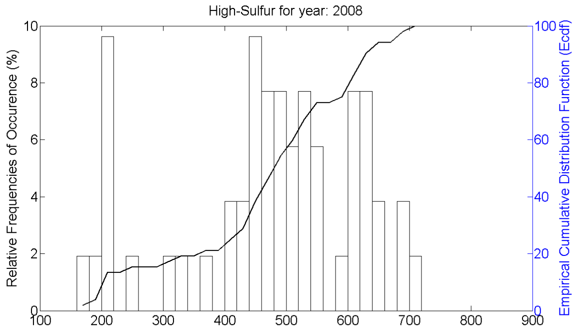

Figure 5. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of HS-HFO for year 2008.

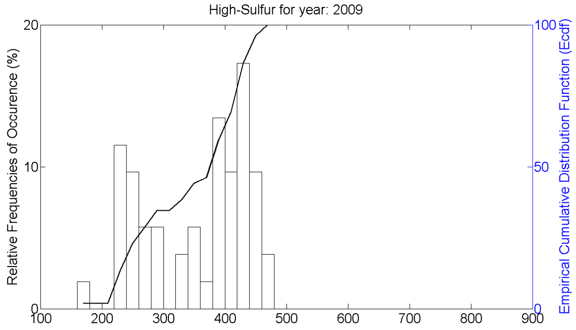

Figure 6. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of HS-HFO for year 2009.

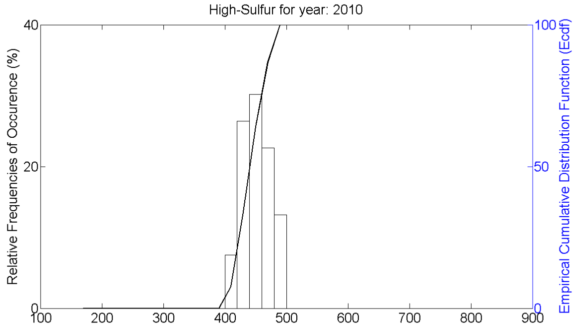

Figure 7. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of HS-HFO for year 2010.

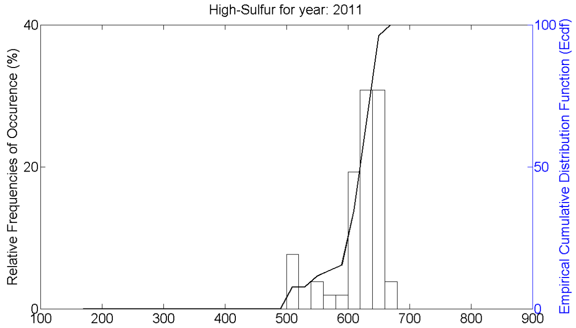

Figure 8. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of HS-HFO for year 2011.

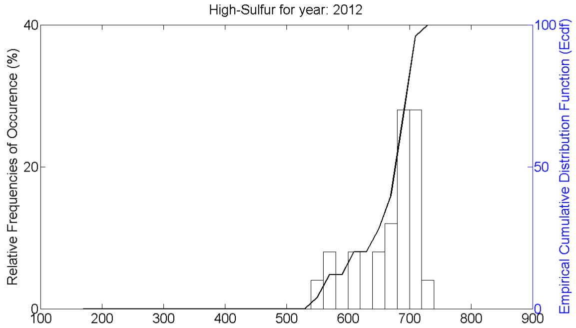

Figure 9. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of HS-HFO for year 2012.

3.2 *Low Sulfur Heavy Fuel Oil Prices in Rotterdam*

In Table 5, the basic statistics for the time series of LS-HFO are given.

Table 5: Basic Statistics for the LS-HFO

Year	Count	Mean	MIN	MAX	St.Dev.	Skewn.	Kurt.
2007	22	436.11	364.00	517.00	50.98	0.06	1.48
2008	52	515.55	212.50	760.00	141.54	-0.48	2.59
2009	52	368.36	197.50	484.50	84.86	-0.35	1.69
2010	53	471.63	415.00	510.50	20.33	-0.16	2.96
2011	52	655.38	516.50	722.00	50.36	-1.50	4.68
2012	25	712.94	593.50	781.50	53.10	-0.70	2.60
all	256	517.41	197.50	781.50	140.30	-0.07	2.26

In Figures 10-16, the histograms of LS-HFO are presented first based on the whole amount of data available and then on each specific year.

Working as in the previous section, areas of greater probability are defined.

In Figure 10, for example, the following areas with concentrated probability mass can be distinguished. There is a 35.5% of the values falling in the range 440-520 $/ton, a 15% in 640-680, and a 9% in 240-320. So, these areas of LS-HFO can be considered that they have greater probability to occur in the future.

By comparing the probabilities of same areas in HS- and LS-HFO interesting results can be extracted: for example, the area 420-480 $/tn has a probability 25% in LS (30% in HS) and similarly the result yield 9% in 600-660 (22% in HS) and 8.5% in 200-300 (9% in HS).

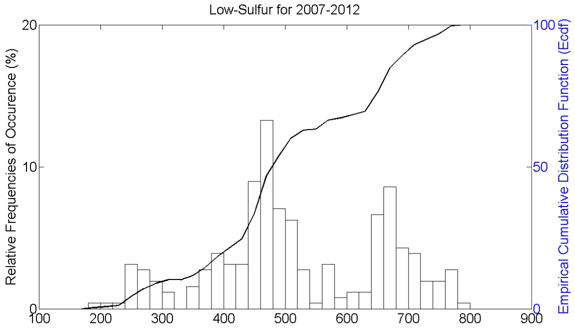

Figure 10. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of LS-HFO for all years.

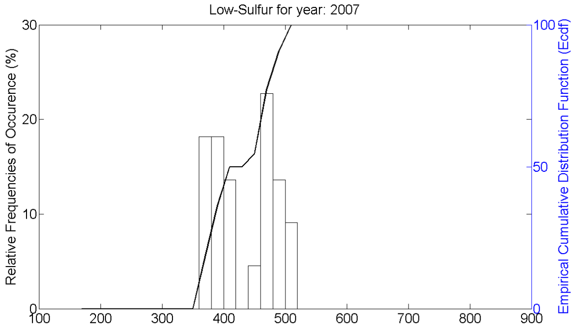

Figure 11. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of LS-HFO for year 2007.

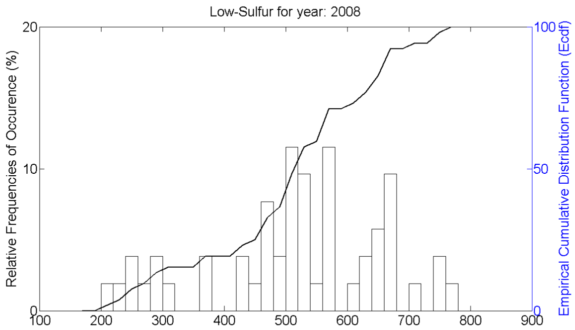

Figure 12. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of LS-HFO for year 2008.

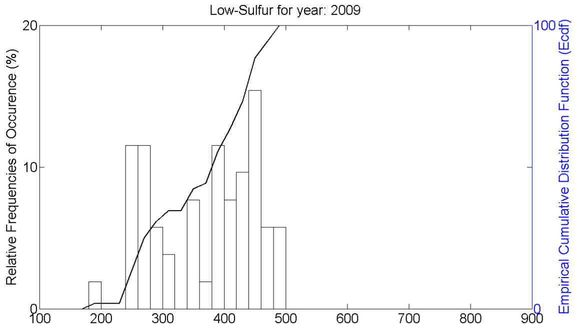

Figure 13. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of LS-HFO for year 2009.

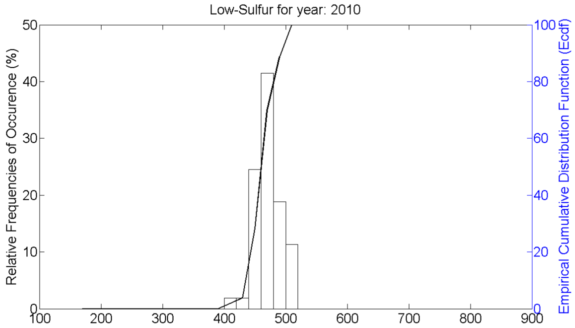

Figure 14. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of LS-HFO for year 2010.

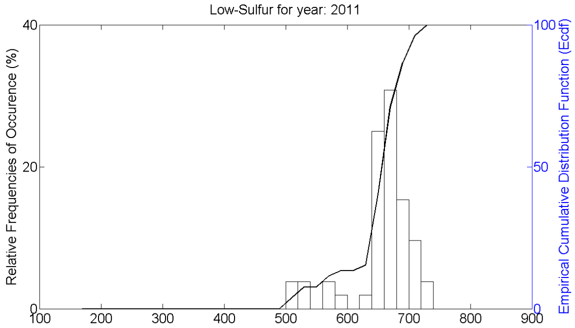

Figure 15. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of LS-HFO for year 2011.

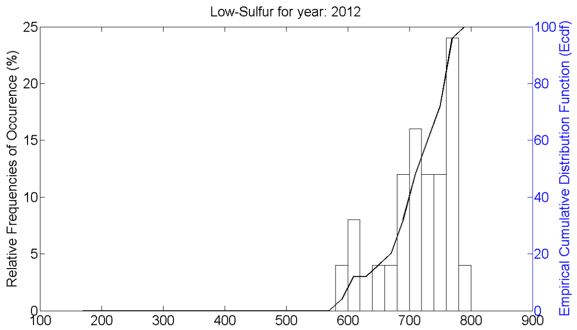

Figure 16. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of LS-HFO for year 2012.

3.3 *The Time Series of the Difference*

The basic statistics of the time series of the difference is summarized in Table 6.

Table 6: Basic Statistics for the Difference (LS-HS)

Year	Count	Mean	Min	Max	St.Dev.	Skewn.	Kurt.
2007	22	23.16	16.00	50.00	8.12	1.82	6.35
2008	52	41.22	16.00	87.50	13.59	1.04	4.64
2009	52	15.63	-7.00	32.00	6.56	-0.75	5.91
2010	53	20.58	10.00	42.50	9.72	0.99	2.85
2011	52	35.87	-1.00	73.00	18.62	0.34	2.13
2012	25	41.88	8.00	71.50	18.29	-0.49	2.30
all	256	29.17	-7.00	87.50	16.78	0.81	3.12

The results yield that it is very difficult and scientifically not justified to extract conclusions over the mean value, which fluctuates substantially year over year. The same result is also extracted for the minimum and maximum values. The overall analysis, i.e. the synthesis of all annual data, suggests that a mean of 30USD should be expected, yet with a standard deviation of almost 17USD, thus setting the range of expected fluctuation close to 35USD. Moreover, it seems that the distribution is not symmetric, 'heavy' tails should be expected as the kurtosis is 3.12, and the positive skew indicates that the tail on the right side is longer than the left side and the bulk of the values lie to the left of the mean.

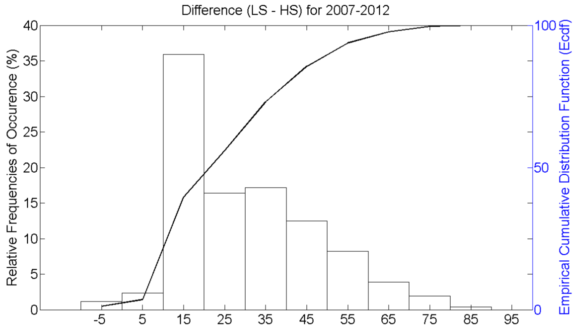

Figure 17. Relative frequencies of occurrence (%) and empirical cumulative distribution function (ecdf) of the Diffrence LS-HS for all years.

Furthermore, in Figure 17, the histogram of the Difference LS-HS is presented based on the whole amount of data available. The histograms based on each specific year are omitted due to space limitation. They are available upon request.

By considering the overall probability analysis, it is obvious that the distributions are not Gaussian or can even be easily approximated. Some of them exhibit more than one crests dictating for a more a sophisticated probability modeling.

4 CONCLUSIONS AND FURTHER RESEARCH

On the basis of the resulted statistics and graphs, it is palpable that operators cannot effortlessly draft scenarios that are based or linked to the statistical attributes of these time series. Although, forecasting or scenario building on the basis of these time series would be desired and meaningful, it seems that conventional statistics do provide solid foundation for further univariate forecasting.

Nonetheless the relatively few observations of the LS time series imply that more advanced models, such as autoregressive ones might not be suitable as well. In the literature there are many works dealing with the issue of small sample properties of estimates of the parameters of autoregressive models. Taking into account the formula:

$$y_t = \alpha + \beta y_t - 1 + \sigma\varepsilon_t,\ t = 1, 2, ..., T,\ \varepsilon_t \sim \text{iid}(0, 1). \qquad (4)$$

The majority of these works concentrates on deriving either exact and/or approximate small sample results for the distribution of the estimated $\boldsymbol{\alpha}_T$ and $\boldsymbol{\beta}_T$ of the Ordinary Least Squares (OLS) estimators of α and β, in the first-order autoregressive (AR(1)) model. The estimation of these parameters is to the direct interest of a forecaster, as bias is hidden if the distributions are not as per theory describes. Such questions have attracted the interest of many researchers, as they melt down to the estimation of the degrees of freedom of σ and [Var], and various methodologies have been developed, that demand not only empirical analysis but also theoretical treatment. In conclusion, researchers should develop new approaches that could be useful to operators and business people.

Taking into account the results of the analysis, further research should be directed towards the relationship (regression analysis) of the prices in Rotterdam with that of the other hubs. Moreover, the analysis of the basic statistics of all these bunkering hubs should be regularly updated and if possible to be linked with time series of wider interest, such as of oil prices and global industrial activity.

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