On stationarity of changes in the trends of selected refining variables

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Abstract

Forecasting time series representing macroeconomic variables becomes increasingly difficult. These variables, often correlated with each other are influenced with political and social decisions, climatic disasters or warfares. The phenomenon of globalization has increased the impact of these factors, the effect of which is temporary or permanent change of correlation between these variables – making it difficult to make management decision based on forecasts. One of solution could be trend's forecasts. The article presents an analysis of selected, important refinery variables in the last 25 years, in particular stationarity related to the trends.

Keywords: *time series, stationarity, unit roots tests*

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1 Introduction

Still the most important global refinery raw material is crude oil. In the last years its price fluctuated – with the maximum value of 124 USD/b in 2012 and minimum value of 31 USD/b in the beginning of January 2016. The crucial question is whether oil prices will decline or rise and what will be the impact on other products. The possibility to support management decisions applying statistical methods can be an important competitive advantage. Dynamic environment – changes in correlation between investigated variables - can make it difficult. Then even forecasting of trend`s changes can be useful. However, it requires choosing proper range of investigated sample to prevent spurious correlation, in particular its stationarity. This study investigates the prices and price changes of refinery raw materials and subproducts, taking into account the interval from November 1992 up to November 2017 (25 years), divided into three subperiods according to variance size and examines their stationarity to determine the possibility of building statistical models. Known literature did not examine neither trend's changes nor stationarity in smaller subperiods.

2 International oil market changes

The domination of crude oil began after World War II, since that time the impact of political decisions is visible as sudden changes of crude oil price – see Fig. 1. First visible crises took

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place in 1973 after embargo of Arab countries (as a reaction on supporting Israel). Next crises happened in 1979 (Iranian Revolution and Iran-Iraq War). Stabilisation in the eighties ended with Gulf War (1990). Very deep price change had place between 1997 and 1998 (Asian financial crisis), extremely high level – occurred in 2010 as a result of "Arab Spring". Together with political decision, the changes in the known oil reserves and production had a visible impact (see Fig. 2) –increase the reserves in North America in 1998, visible decrease in Middle East and very significant (three times) increase in Central and South America in 2008. Therefore the current question is the possibility of further use statistical methods (and statistical models) to forecast price changes in the future.

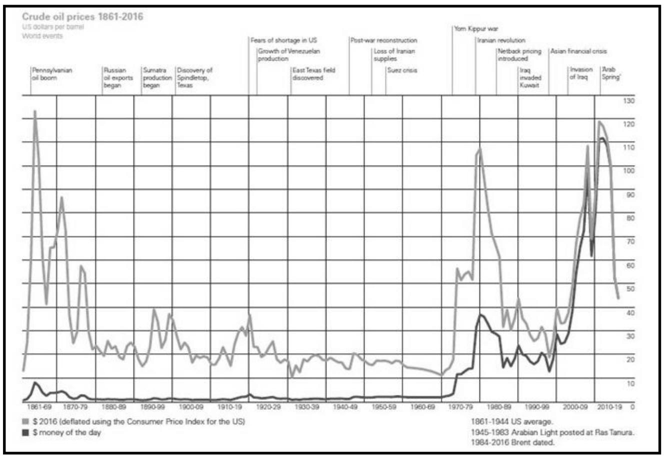

Fig. 1. An impact of political events on crude oil prices (BP Statistical Review of World Energy June 2017).

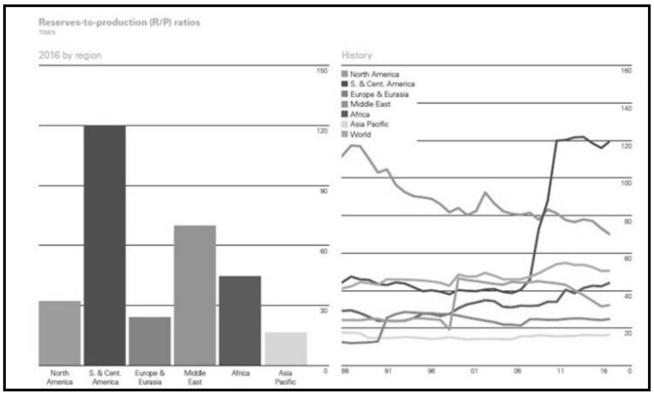

Fig. 2. Reserves to production ratios according to regions in 2016 (left) and historically (right) (BP Statistical Review of World Energy June 2017).

3 Review of econometric models of crude oil price

Known literature let to classify the most popular models in several groups:

- time series models,
- financial models based on the dependencies between spot and future prices,
- structural models, considered as an extension of autoregressive specification.

This paper investigates the possibility of apply time series models with the most popular model as and autoregressive process AR(p):

$$P_i = \varphi_{i-1}P_{i-1} + \cdots + \varphi_{i-p}P_{i-p} + \varepsilon_i \tag{1}$$

where spot price P_i depends on previous values together with uncorrelated error term ε_i.

Mean reverting process with the assumption that a price reverts to the average after a shock can be presented as below:

$$P_{i+1} - P_i = \alpha(P_i^* - P_i) + \varepsilon_i \tag{2}$$

where spot price change depends on long-run equilibrium P_i^* and mean reversion rate α (see Engle and Granger, 1987). Abosedra (2005) proposes another model, observing period January 1991 to December 2001 with monthly unbiased predictor of the future oil price X:

$$P_{i+1} = \alpha + \beta X_{i-1} + \varepsilon_i \, . \tag{3}$$

However, numerous studies (Lalonde at al. 2003; Ye et al., 2005; Pindyck, 1999; Zeng and Swanson, 1998) show rather poor prediction ability. The dynamics of parameters of any model is too significant. Time-series models of other refining variables may behave very similarly. Therefore, both prices and trends of these prices were analysed.

4 The analysis of chosen refinery variables

Taking into consideration that prices of products coming from crude oil depend on crude oil price or on crude oil demand/supply equilibrium – this phenomenon in models should increase the accuracy of forecasts. The analysis covered refinery variables noted monthly in period from November 1992 up to November 2017 (last 25 years), only for variable describing the hydrorefined paraffin, the period is from January 2003 up to November 2017 (www.indexmundi.com, 09.12.2017).

1. Crude oil, dated Brent, monthly price (**CO**) USD/barrel.
2. Australian thermal coal, monthly price (**AC**) USD/metric ton.
3. New York harbour gasoline regular spot FOB (**GA**) USD/gallon.
4. New York harbour heating oil spot FOB (**HO**) USD/gallon.
5. US Gulf Coast Kerosene-type Jet fuel spot FOB (**JF**) USD/gallon.

6. Henry hub natural gas (**NG**) USD/million metric British thermal unit.
7. Mont Belvieu TX propane spot FOB (**PR**) USD/gallon
8. Hydrorefined paraffin ICIS (**HP**) EUR/ton.

However, analysis of such time series indicates a variation of dependencies, see Fig. 3.This phenomenon is better visible analysing an example: a raw material – crude oil (**CO**) and a final product – hydrorefined paraffin (**HP**), see Fig. 4. Up to 2014, there is visible correlation with a shift of 2 months – a time necessary to process raw material into ready product. Last three years, however, due to shutting down number of refineries producing paraffin, the dependence changed. It created new dependencies in which the price of the raw material plays a smaller role. Moreover, analysed time series could be non-stationary, what complicates the prediction. But in such unstable economic world, even a good forecast of changes in trend (like prediction of the sign of the first derivative) can lead to a competitive advantage. Still the stability of model parameters over time and the stationarity of time series should be taken into account as one of the fundamental assumption in modelling econometrics variables.

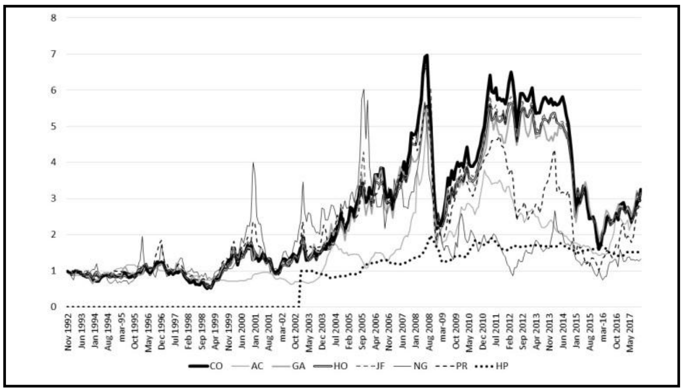

Fig. 3. Plot of analysed time series, values are related to the first observation.

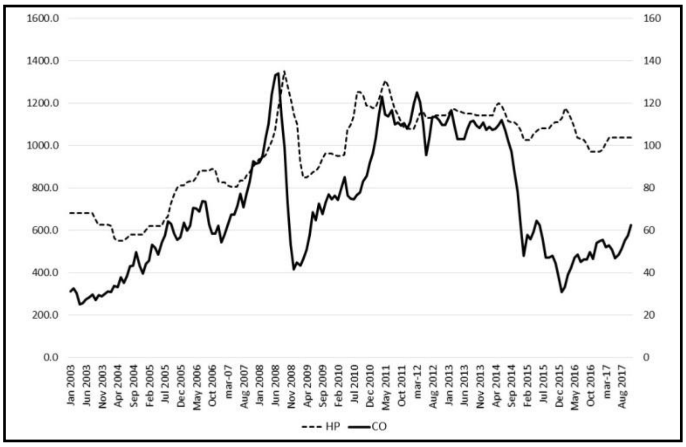

Fig. 4. Plot of crude oil (**CO**) and hydrorefined paraffin (**HP**) time series.

5 The analysis of trends

Trends of investigated variables were estimated decomposing time series with moving average smoothing method with orders: 6, 12, 15 (to check the impact of annual seasonality) and applying Spencer filter (see Brockwell and Davis, 2002).Although the differences between trends estimated by the above methods were small, further investigations were carried for all the moving average methods. The plots of the trends (moving average, order=12) and first derivative (calculated in the form of the first differences) of trends are presented in Fig. 5.

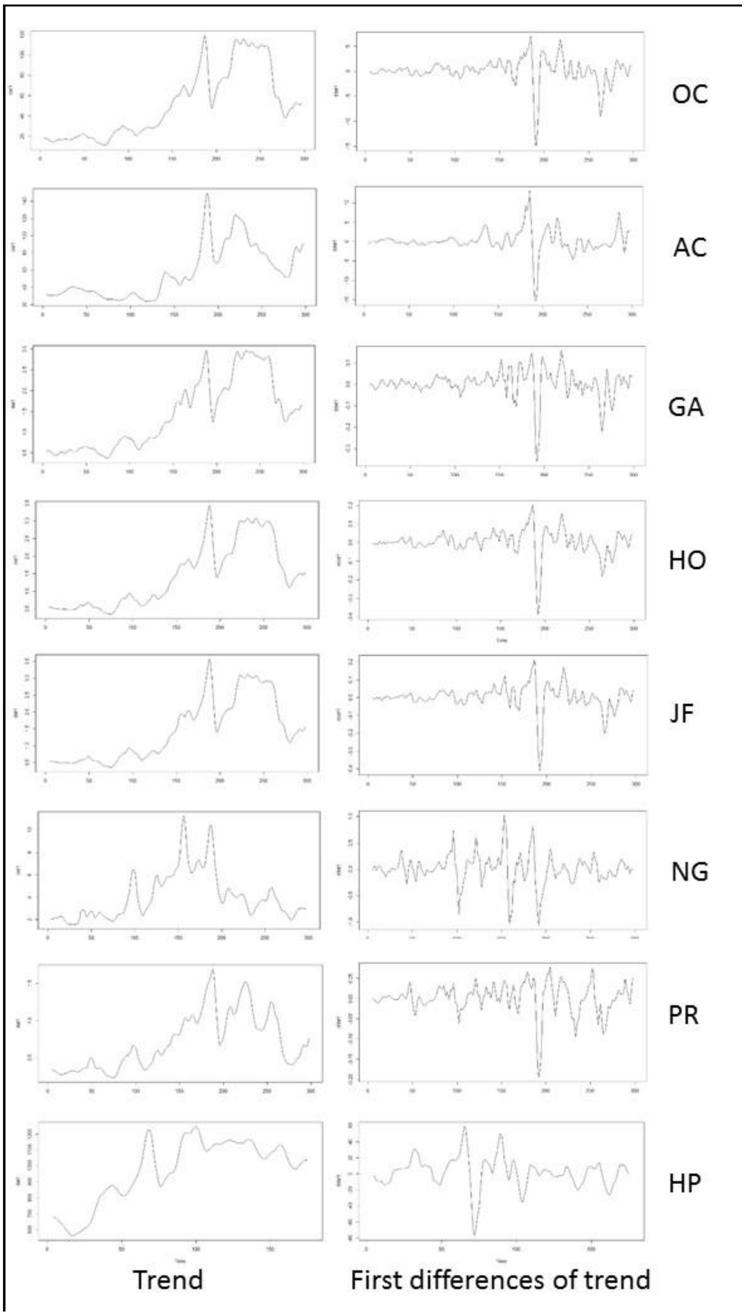

Fig. 5. Plots of trends and their differences of investigated time series.

Analysing these plots, it was decided to divide analysed period into three subperiods:

A. January 1992 – March 2005 (January 2003 – January 2007 for **HP**),
B. April 2005 – January 2011 (February 2007 – January 2011 for **HP**),
C. February 2011 – November 2017,

taking into consideration variation of first differences. First group represents the period before increased variation, second – high changes in unstable environment, third – period of 'stabilisation'. Described studies on stationarity were performed for these three subperiods.

There is a variety of the stationarity tests described in the literature, most commonly used: Dickey-Fuller tests (DF and ADF) (Dickey and Fuller, 1979, 1981), ADF-GLS test (Elliot at al., 1996), Philips-Perron test (Philips and Perron, 1988), KPSS test (Kwiatkowski et al., 1992), and rarely used like: Schmidt-Philips (Schmidt and Philips, 1992) test or Zivot-Andrew test (Zivot and Andrew, 1992). Unfortunately, a power of unit root tests depends on the length of time series. As a result time series can be classified improperly as non-stationary whereas in fact is stationary. Chosen tests are described briefly below. All the tests except KPSS-tests verify a hypothesis of non-stationarity. KPSS-test verifies alternative hypothesis – the stationarity of time series.

5.1 Augmented Dickey-Fuller test

Although probably the most known test is Dickey-Fuller test (Dickey and Fuller, 1979), augmented modification of this test (Dickey and Fuller, 1981) – which was constructed for the cases when non-systematic component is autocorrelated, was chosen. It bases on autoregressive process model (only the limiting distribution of test statistics was tabulated):

$$y_t = \theta_1 y_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-1} + \varepsilon_t \,. \tag{4}$$

5.2 ADF-GLS test

The test is a modification of Augmented Dickey-Fuller test (Elliot at al., 1996).Time series is estimated with GLS (generalised least square) method performing the transformation:

$$\tilde{y}_1 = y_1; \tilde{y}_t = y_t - \rho y_{t-1}; x_1 = 1; x_t = 1 - \rho \tag{5}$$

After that constant and trend are removed:

$$y_t^* = y_t - (\hat{\beta}_0 + \hat{\beta}_1 t) \tag{6}$$

and final model of time series represents following formula:

$$\Delta y_t^* = \beta_0 + \varphi_1 y_{t-1}^* + \sum_{i-1}^{p} \gamma_i \Delta y_{t-1}^* + \varepsilon_t. \tag{7}$$

The critical values were calculated based on simulation (Elliot at al., 1996).

5.3 Philips-Perron test

The test is a modification of standard Dickey-Fuller test with non-parametrically modified test statistics and centred time variable (Philips and Perron, 1988). The test statistics Z can be reduced to Dickey-Fuller tests statistics if ε_t is not autocorrelated.

5.4 KPSS test

This test verifies the opposite hypothesis that the time series is stationary. The idea developed by Kwiatkowski, Philips, Schmidt and Shin (Kwiatkowski et al., 1992) bases on a sum of a deterministic trend, random walk and stationary random error:

$$y_t = d_t + r_t + \varepsilon_t; r_t = r_{t-1} + u_t \tag{8}$$

where: $d_t = \sum_{i=0}^{p} \beta_i t^i$.

The test base on the hypothesis that the random walk has a variance equal to zero. Critical values were calculated with the simulation (Kwiatkowski et al., 1992).

5.5 Schmidt-Philips test

This test bases on an alternative parametrization (Schmidt and Philips, 1992):

$$y_t = \psi + \xi t + x_t; x_t = \beta x_{t-1} + \varepsilon_t \tag{9}$$

extracted from the score of LM principle under the assumptions that random error $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$. The most important advantage of this test is that the meaning of the parameters governing level and trend is independent of whether or not null hypothesis is true. The tabulated critical values were calculate with the simulation (Schmidt and Philips, 1992).

5.6 Zivot-Andrews test

This test is an extension of Philips-Perron test (Zivot and Andrew, 1992) in which it is assumed that breakpoints should be fixed not estimated (like in P-P test). Additionally the new ideas were introduced: the effect on empirical results of fat-tailed and temporally dependent innovations. The tabulated critical values were calculate with the simulation (Zivot and Andrew, 1992).

6 Description of investigations

An experiment was carried out for first differences of trends, estimated as mentioned above with moving average smoothing method with orders: 6, 12, 15 and applying Spencer filter. The investigations were performed with the following tests:

1. Augmented Dickey-Fuller (ADF) test with no trend and drift,
2. Elliott-Rothenberg-Stock DF-GLS test,
3. Elliott-Rothenberg-Stock P-test,
4. KPSS test, no trend,
5. KPSS test, linear trend,
6. Philips-Perron test, Z-alpha statistics,
7. Philips-Perron test, Z-tau statistics,
8. Schmidt-Philips test,
9. Zivot-Andrew test.

The tests were carried out for whole range of samples and three subperiods of chosen time series: A, B and C described below for the same significant level α=0,05

7 Results

The results were coded: for all the tests except KPSS-tests – if the test does not reject the hypothesis, the result was set as "0" (otherwise – "1") and for KPSS-tests – if the test does not reject the hypothesis, the result was set as "1" (otherwise – "0"). Coded values, added up across all the tests and across four method of trend's estimation are presented in Table 1.

Table 1. Aggregated results of the tests.

Variable	Whole period	Subperiod A	Subperiod B	Subperiod C
CO	29	7	25	9
AC	31	27	25	12
GA	30	14	26	11
HO	29	15	25	7
JF	29	10	26	8
NG	32	26	22	17
PR	32	25	24	14
HP	32	7	21	25

The results are rather unexpected. Although the tests mostly rejected hypothesis of non-stationarity, for the two subperiodscovering: January 1992 – March 2005 and February 2011 – November 2017, performed tests did not give a clear result. For majority of variables most of the tests (especially for subperiod: February 2011 – November 2017) did not reject the hypothesis of non-stationarity (or reject stationarity – for KPSS-tests) although this subperiods seems to be rather economically stable. It means that you have to be very careful creating models for forecasting the changes of trends refining variables.

Conclusion

The globalization of today's economy resulting in greater influence of even distant political, social and economic phenomenon interfere seemingly stable economic processes. In contrast to natural phenomena, the dependencies between economic variables constantly change. It makes difficult to build long-term models and limits the accuracy of forecasts. Described study indicates that time series in a seemingly stable environment could be non-stationary. This also applies to changes of trends – on the example of refinery product prices although examined samples coming from rather economically period. Nevertheless, the lower variation of the first differences of trends could allow to set the forecasts useful in making of management decisions taking into account their non-stationarity. This issue will be the subject of further research.

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