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Wojciech LABUDA*

Building an econometric model for african oil production

ABSTRACT: The aim of the paper is to identify which factors influence the production of crude oil in Africa and what it means for the investments in oil production on this continent in the future.

In order to identify these factors it is necessary to create a function of production. A number of variables have been chosen, which are likely to have an influence on the level of exploitation, such as the price of oil, oil consumption in Africa, oil import by the US, etc. The estimation of the function was based on the statistical analysis of empirical data. For the years 1980–2015 the linear regression model was estimated using the method of ordinary least squares (OLS) and econometric software – GRETL. In order to find the best model the academic research on the global oil market has been taken into account and a variety of statistical and econometric tests have been made.

According to the literature on the subject, the production of crude oil in Africa is mostly affected by two players – Europe and the US. The first includes the member states of the OPEC. There are also countries of West Africa which in the past exported most of their production to the US. The model shows that the situation has changed after the "shale revolution", which reduced the level of imported oil and consequently the level of African production. Moreover, an interesting trend has been noticed, namely that when oil prices go up, the oil production in Africa decreases. The reason for this phenomenon is that high oil prices make American shale plays more profitable than West African petroleum basins.

The model aggregating macroeconomic indicators and statistics is a very useful management tool and it reveals the problems of the efficiency of investments in oil production in Africa.

KEYWORDS: crude oil, Africa, US, shale oil, shale revolution

* Student – AGH University of Science and Technology, Faculty of Drilling, Oil and Gas, Kraków, Poland; e-mail: wojciech.labuda@post.com

Introduction

In 2010 production of crude oil in Africa reached more than 10.843 mbbls/d (EIA 2016a). After that time there appeared a downward trend. What was the reason for this situation? Have the crude oil deposits become unattractive for investors? Or maybe the level of domestic consumption has fallen? To answer these questions an in-depth analysis of the whole perspective seems to be essential.

Actually, these occurrences took place more than 4 years before present oil price slide. What is more, the consumption of crude oil in Africa increased by almost 10% between 2010 and 2015 (Fig. 1). Also the emerging economies such as China and India, which are very close to the African East Coast, were boosting their crude oil import by more than 40% (OPEC 2015a–e, 2016). But there is also one important factor which still has not been mentioned – the Shale Revolution.

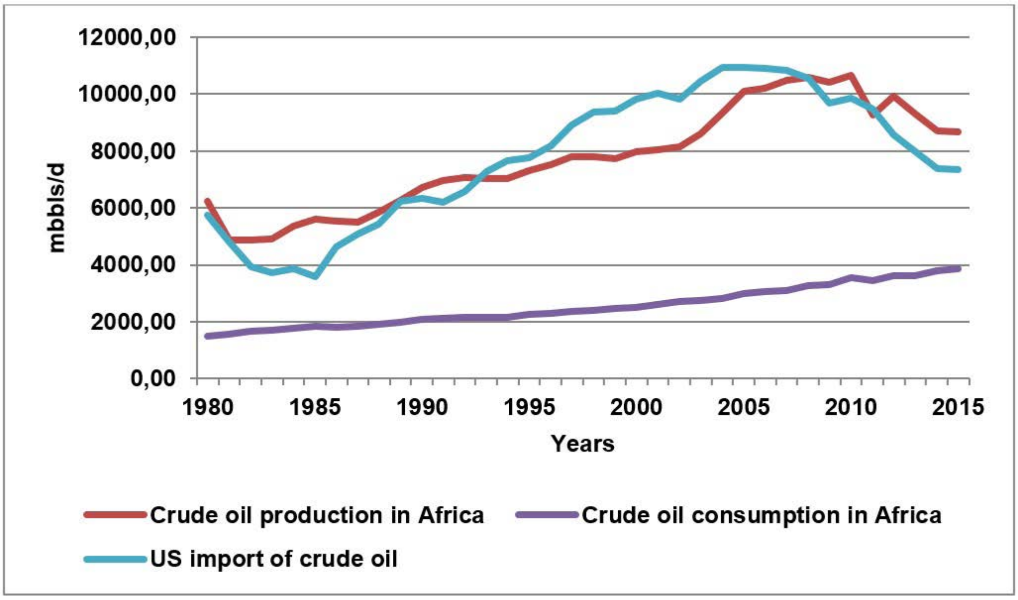

Fig. 1. Crude oil production and consumption in Africa, and crude oil import to the US 1980–2015 (OPEC 2015e; EIA 2016)

Rys. 1. Wydobycie i konsumpcja ropy naftowej w Afryce oraz jej import przez Stany Zjednoczone w latach 1980–2015 (OPEC 2015e; EIA 2016)

In recent decades, till the oil crises the United States of America had been producing less and less crude oil, in 2005 being able to cover only 29% of its demand. Moreover, most of the analysts had been prophesying an imminent 'oil peak' (Watkins 2006; Tsoskounoglou et al. 2008). The US energy strategists had been looking for safe and stable sources of an oil supply.

The African continent was a natural choice – its West Coast, rich in deposits, was relatively close – just across the pond. As a result American refineries have adapted to the types of light oil, like Nigerian Bonny Light, Angolan Cabinda, and Congolese Coco (Chevron 2016). In 2006 more than 20% of the US crude oil and petroleum product import was covered by the African producers (compare Fig. 2), mainly by Nigeria, Angola and Algeria.

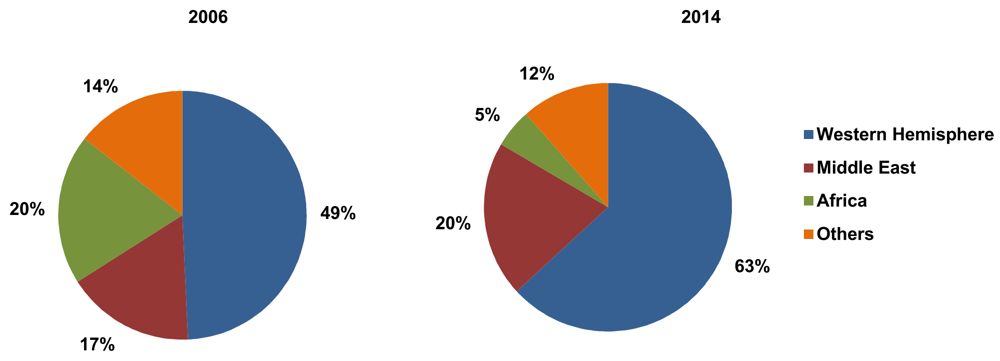

Fig. 2. The major sources of US crude oil import in 2006 and 2014 (BP 2007; BP 2015)

Rys. 2. Główne źródła importu ropy naftowej przez Stany Zjednoczone w roku 2006 i 2014 (BP 2007; BP 2015)

The situation has dramatically changed in 2007. Because the US started to exploit shale oil deposits it began to reduce import. After 8 years, in 2015 it was almost 90% lower (Fig. 1). The growth of production is so huge that at the beginning of 2016 even a ban on export was lifted and the US became an oil exporting country (The Economist 2015; Clayton 2015). According to the situation in Africa, one of the most important aspects is that most of American shale oil grades are light thus they became a direct competitor to the oil from the Guinea Bay. What is more, the high risk (especially political) of investing in Africa and costs of transport across the Atlantic Ocean do not encourage to exploit crude oil (Labuda 2015). Despite finding new clients in Europe, the growth of import by China and India, and also domestic consumption, the total production on the Dark Continent in the last few years has been decreasing (Blas 2014; Klasa 2014). In addition, the huge slide of oil prices stopped new investments (Pembroke 2015).

Information mentioned above can easily be collected from media and statistical yearbooks but one could ask which variables influence the level of production of crude oil in Africa and to what extent. It is also important to identify whether it is possible to predict the future of petroleum branch on this continent. Consequently, the aim of this paper is to answer these questions and presentation of building the function of crude oil production in Africa, basing on statistical and econometric methods. As a result, past, present and, to a certain extent, future perspectives for investing in Africa will be established.

1. Model estimation

One of the possibilities of establishing a statistical relationship between two or more variables is the method of ordinary least squares (OLS), which is commonly used in econometrics (Maddala and Lahiri 2009; Gruszczyński et al. 2014) and it this case it is also applicable (Brigida 2014).

To estimate the model, on the basis of EIA (2015, 2016a, 2016b) and BP (2007, 2015) statistics (Fig. 3), factors which affect to the greatest extent the level of production of crude oil in Africa (*Af_p*) have been identified:

- *US_i** – US net import of crude oil and petroleum products, mbbls/d,
- *Eu_i** – European OECD countries net import of crude oil and petroleum products, mbbls/d,
- *US_irpr* – Real US prices (including inflation) of imported crude oil, US dollars,
- *US_i* – Total US import of crude oil from Africa, mbbls/d,
- *Eu_i* – Total European import of crude oil, mbbls/d,
- *Af_c* – Crude oil consumption in Africa, mbbls/d,
- *In_i* – Total Indian import of crude oil, mbbls/d,
- *Ch_i* – Total Chinese import of crude oil, mbbls/d.

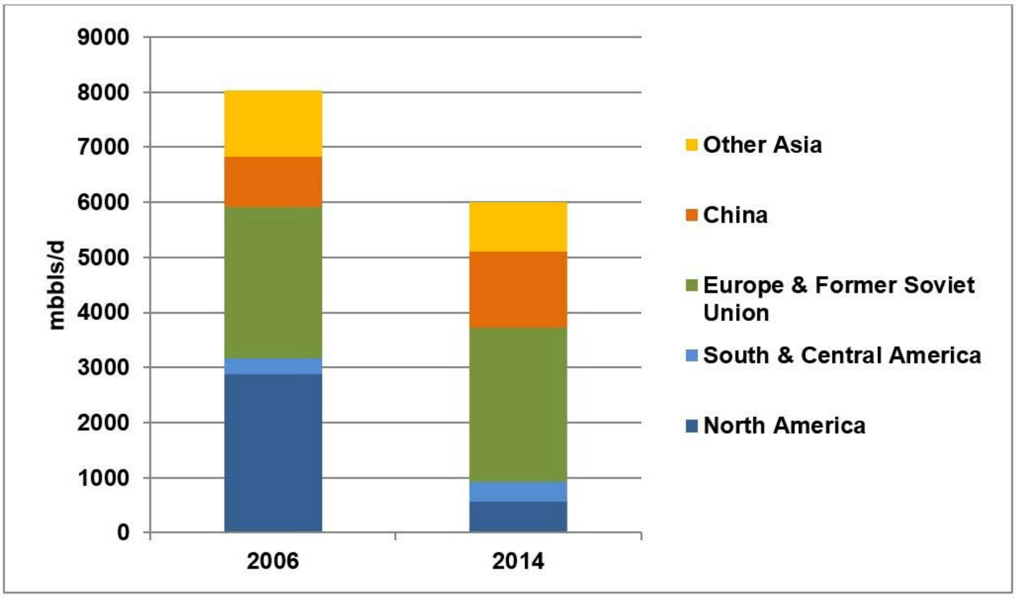

Fig. 3. Crude oil export from Africa in 2007 and 2014 (BP 2007; BP 2015)

Rys. 3. Eksport ropy naftowej z Afryki w roku 2007 i 2014 (BP 2007; BP 2015)

There are accessible data in shorter than annual periods only for the first four variables. What is more, due to the turmoil on the oil market around 2008 financial crisis, this period has to be excluded from analysis. Consequently, by using GRETL 1.9.2cvs software two models have been built – the first for a period before the Shale Revolution and the second one – after that:

- MODEL 1 – for years 1980–2005, annual data, variables: *US_irpr*, *US_i*, *Eu_i*, *Af_c*, *In_i*, *Ch_i*,
- MODEL 2 – for years 2010–2014, quarterly data, variables: *US_irpr*, *US_i**, *Eu_i**.

There was necessary to add some assumptions. Firstly that the Dark Continent is a price taker on the oil market, what means that African producers do not have an influence on the oil price. It is justified by the fact that Africa is responsible only for 9,2% of total world production of crude oil (EIA 2016a). Secondly, that they immediately react on the price changes. In other words, level of crude oil extraction in specific month/quarter/year does not depend on production in previous period. The differences in data source between two models is caused by availability of data in chosen periods.

MODEL 1 – Before the Shale Revolution

To find which variables are statistically significant a number of estimations of the model with different sets of variables have been made.

Table 1 shows the first estimation including all of the available variables.

TABLE 1. Estimation 1: OLS, using observations 1980–2005 (n = 26)

TABELA 1. Estymacja 1: MNK, obserwacje z lat 1980–2005 (n = 26)

Dependent variable: Af_p

Variable	Coefficient	Standard Error	t-ratio	p-value	Significance*
const	–918.776	1351.9	–0.6796	0.50494	
US_irpr	2.39151	5.06371	0.4723	0.64210	
Af_c	2.01919	0.680525	2.9671	0.00792	***
US_i	0.167483	0.0777124	2.1552	0.04419	**
Eu_i	0.215594	0.0623987	3.4551	0.00265	***
In_i	–1.22541	0.39115	–3.1328	0.00548	***
Ch_i	0.815569	0.330672	2.4664	0.02333	**

*Statistical significance on following significance level: * – 10%, ** – 5%, *** – 1%; lack of * means insignificance.

As it is presented in the Table 1 coefficient connected with the *In_i* variable is negative, which is contradictory to the statistics, which indicate that the more crude oil India imports, the more crude oil is exploited in Africa. This relationship is also enhanced by Indian investments in the petroleum industry on the Dark Continent (Business Standard 2016). What is more there appears collinearity problem connected with most of variables (*Variance Inflation Factor (VIF):*

Af_c = 35.898, US_i = 16.421, In_i = 23.027, Ch_i = 30.023). Consequently, the model is not correct. The results of removing *In_i* variable are shown in the following Table 2.

TABLE 2. Estimation 2: OLS, using observations 1980–2005 (n = 26)

TABELA 2. Estymacja 2: MNK, obserwacje z lat 1980–2005 (n = 26)

Dependent variable: Af_p

Variable	Coefficient	Standard Error	t-ratio	p-value	Significance
const	–554.396	1616.68	–0.3429	0.73524	
US_irpr	0.12152	6.01546	0.0202	0.98408	
Af_c	1.64577	0.804212	2.0464	0.05409	*
US_i	0.0865075	0.087968	0.9834	0.33716	
Eu_i	0.253714	0.0734597	3.4538	0.00251	***
Ch_i	0.27757	0.339187	0.8183	0.42281	

The results show that the model still has not been estimated properly. There is still the collinearity problem (*VIF: Af_c = 34.796, US_i = 14.605, Ch_i = 21.926*). Because of that and to avoid autocorrelation, the variables had to be changed to first differences of variables (period-to -period change). Also, due to high p-value the *US_irpr* variable has been removed. The effect of these operations is presented in Table 3.

TABLE 3. Estimation 3: OLS, using observations 1981–2005 (n = 25)

TABELA 3. Estymacja 3: MNK, obserwacje z lat 1981–2005 (n = 25)

Dependent variable: d_Af_p

Variable	Coefficient	Standard Error	t-ratio	p-value	Significance
const	–190.693	149.024	–1.2796	0.21533	
d_Af_c	3.9391	1.97011	1.9994	0.05933	*
d_US_i	0.320666	0.183473	1.7478	0.09584	*
d_Eu_i	0.15318	0.0843395	1.8162	0.08436	*
d_Ch_i	0.327582	0.320215	1.0230	0.31852	

The first difference of *Ch_i* still is not statistically significant. Table 4 shows the model without this variable.

In the estimation shown above *Eu_i* variable is not statistically significant, thus it was omitted in the final model. The result is shown in Table 5.

R^2 coefficient equals 40% which means that 40% of changeability of differences in production of crude oil in Africa is explained by the model.

Table 4. Estimation 4: OLS, using observations 1981–2005 (n = 25)

Tabela 4. Estymacja 4: MNK, obserwacje z lat 1981–2005 (n = 25)

Dependent variable: d_Af_p

Variable	Coefficient	Standard Error	t-ratio	p-value	Significance
const	–210.896	147.874	–1.4262	0.16851	
d_Af_c	4.59169	1.86604	2.4607	0.02262	**
d_US_i	0.387777	0.171533	2.2607	0.03452	**
d_Eu_i	0.141597	0.0836686	1.6924	0.10536	

Table 5. Estimation 5: OLS, using observations 1981–2005 (n = 25).

Tabela 5. Estymacja 5: MNK, obserwacje z lat 1981–2005 (n = 25).

Dependent variable: d_Af_p

Variable	Coefficient	Standard Error	t-ratio	p-value	Significance
const	–287.542	146.61	–1.9613	0.06263	*
d_Af_c	5.39333	1.87983	2.8691	0.00892	***
d_US_i	0.542284	0.151246	3.5855	0.00165	***
RESET test for specification – Null hypothesis: specification is adequate Test statistic: F(2, 20) = 0.114886 with p-value = P(F(2, 20) > 0.114886) = 0.892052					
White's test for heteroskedasticity – Null hypothesis: heteroskedasticity not present Test statistic: LM = 14.6858 with p-value = P(Chi-Square(5) > 14.6858) = 0.0117927					
LM test for autocorrelation up to order 1 – Null hypothesis: no autocorrelation Test statistic: LMF = 0.0112568 with p-value = P(F(1,21) > 0.0112568) = 0.916511					
R-squared = 0.400798					

Because of positive verification, final model for the years 1981–2005 can be written as Eq. 1:

$$d\_Afp = \_287{,}54 + 5{,}39 d\_Afc + 0{,}54 d\_USi \qquad (1)$$

This means that only two factors affect the level of crude oil production in Africa are significant for long-term changes. These are: the changes of levels of consumption of crude oil in Africa and the changes of levels of US imports. The Eq. 1 can be translated into words as the following ones: 'If the change of the consumption of crude oil in Africa grows by 1 mbbls/d (*ceteris paribus*), the change of its production in Africa increases approximately by 5,39 mbbls/d. Also, if the change of the US total import increases by 1 mbbls/d, the change of the crude oil production in Africa grows by 0,54 mbbls/d'. However, the constant factor seems to be very important, but it is not in comparison with huge changes (millions of barrels per day) of the US import. The adjustment of the estimated model and the observed African production is shown in Fig. 4.

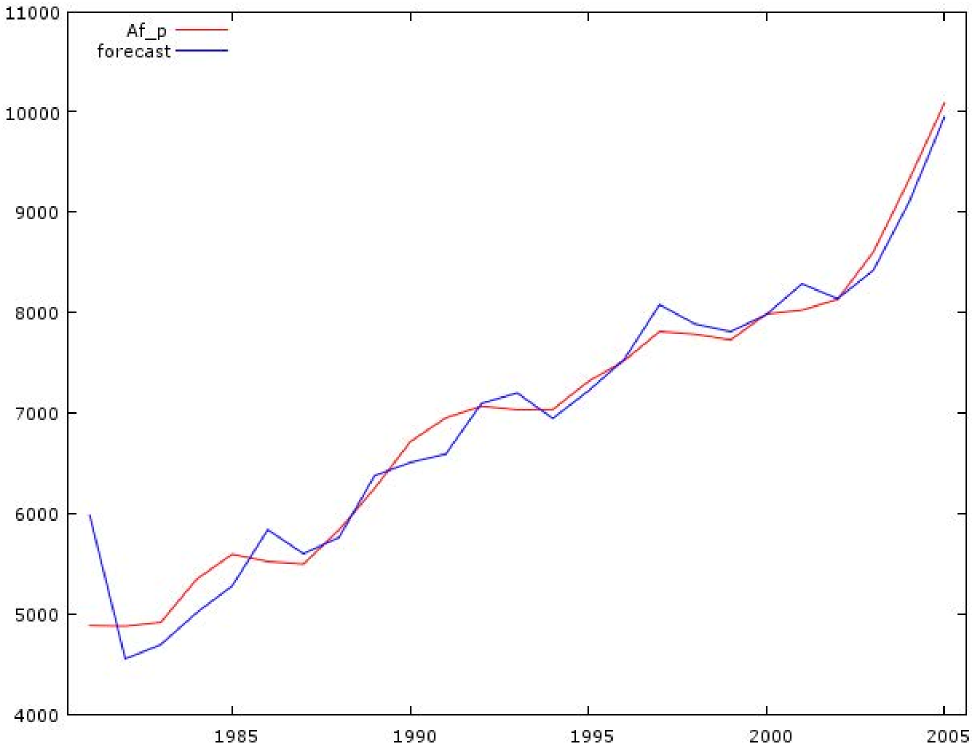

Fig. 4. A graph showing adjustment of the model (forecast) and the observed values (*Af_p*); *Af_p* unit – mbbls/d

Rys. 4. Wykres obrazujący dopasowanie modelu (prognozy) i wartości obserwowanych (*Af_p*, mbbls/d)

MODEL 2 – After the Shale Revolution

After the global financial crisis of 2007–2008 and the Shale Revolution, the situation has changed. The aim of building the second model is to check whether the same factors influence the level of production of crude oil in Africa.

Because of the shorter period, the usage of annual data was impossible (the sample is too small), so for the years 2010–2014 have been chosen quarterly data. Monthly data could also have be used but they are susceptible to politics and seasonal changes.

The first estimation, presented in Table 6, includes *US_i**, *Eu_i** and *US_irpr* variables. Also because of autocorrelation problem natural logarithms of the variables had to be used.

The analysis of the results suggests removing *Eu_i** from the model, which leads to the final estimation of the model, shown in Table 7:

TABLE 6. Estimation 6: OLS, using observations 2010:1–2014:4 (n = 20)

TABELA 6. Estymacja 6: MNK, obserwacje z okresu 2010:1–2014:4 (n = 20)

Dependent variable: l_Af_p

Variable	Coefficient	Standard Error	t-ratio	p-value	Significance
Const	10.4766	3.05117	3.4336	0.00341	***
l_US_i*	0.205021	0.059598	3.4401	0.00336	***
l_US_irpr	–0.286239	0.112873	–2.5359	0.02202	**
l_Eu_i*	–0.197654	0.342464	–0.5772	0.57187	

TABLE 7. Estimation 7: OLS, using observations 2010:1–2014:4 (n = 20)

TABELA 7. Estymacja 7: MNK, obserwacje z okresu 2010:1–2014:4 (n = 20)

Dependent variable: l_Af_p

Variable	Coefficient	Standard Error	t-ratio	p-value	Significance
Const	8.75591	0.635962	13.7680	<0.00001	***
l_US_i*	0.194527	0.0556323	3.4967	0.00276	***
l_US_irpr	–0.286641	0.110635	–2.5909	0.01904	**
RESET test for specification – Null hypothesis: specification is adequate Test statistic: F(2, 15) = 0.440314 with p-value = P(F(2, 15) > 0.440314) = 0.651894					
White's test for heteroskedasticity – Null hypothesis: heteroskedasticity not present Test statistic: LM = 4.30536 with p-value = P(Chi-Square(5) > 4.30536) = 0.50634					
LM test for autocorrelation up to order 4 – Null hypothesis: no autocorrelation Test statistic: LMF = 1.07892 with p-value = P(F(4,13) > 1.07892) = 0.406519					
R-squared 0.486583					

R_2 coefficient equals 49% which means that 49% of changeability of differences in production of crude oil in Africa is explained by the model.

Due to positive verification, the model can also be translated into the following Eq. 2.

$$l\_Afp = 8{,}76 + 0{,}19 l\_USi^* - 0{,}29 l\_USirpr \tag{2}$$

The Eq. 2 means that "the US increase of imports of crude oil and petroleum products by 1% (*ceteris paribus*) results in an increase of production of crude oil in Africa approximately by 0,19%. Simultaneously, if the oil price grows by 1% (*ceteris paribus*), the level of production in Africa declines by circa 0,29%". The comparison between the reality and the model is presented in Fig. 5.

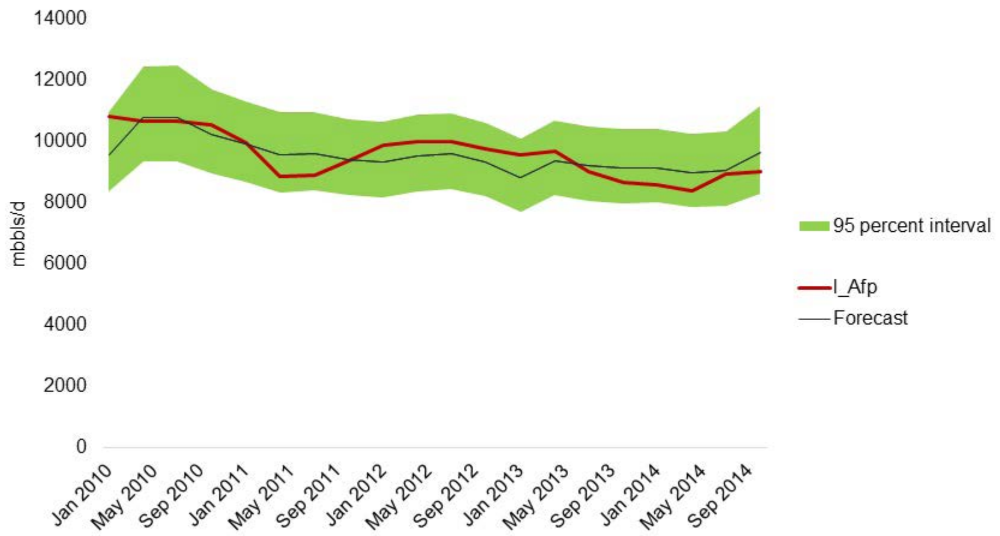

Fig. 5. Graph showing adjustment of the model (forecast) and observed values (*Af_p*) against time

Rys. 5. Wykres obrazujący dopasowanie modelu (prognozy) i wartości obserwowanych (*Af_p*) w czasie

The results of estimations can be surprising, especially according to MODEL 2 and this negative influence of oil price growth.

2. Interpretation and applications

MODEL 1 describes long-term relationships between African oil production and global demand. The level of exploitation of petroleum on the Dark Continent is mostly driven by domestic consumption and the US oil import.

Crude oil consumption in Africa has been a significant factor influencing production with double growth between the 1980s and present. On the other hand, it has been generally a stable increase, thus it is not useful for explaining changes on market after the Shale Revolution.

The European import since the 1900s has been stable with decreasing trend in the last 10 years. After the Shale Revolution even growth of export from Africa to Europe has not been able to stop the decrease of production, especially in the West African Countries. What is more, if Europe imports crude oil from Africa, it is mostly crude oil from North Africa. Thus, this demand, apart from seasonal changes, does not influence changes in the level of total production in Africa.

Although since the 2000s China and India have been reporting a huge growth of petroleum import (Ebner 2015), it has not affected African countries so much. There are two major reasons for this situation – the first is that most of African oil deposits are located on the west coast and the second one – that on the Indian Ocean there is a big competition between oil exporters, mostly from the Persian Bay.

Oil prices in the first analyzed period have not had a significant influence on the level of production in Africa.

MODEL 2 reveals an apparent paradox, that whilst oil prices grow, production in Africa decreases. It has been caused by the emergence of competitors – shale oil producers in the North America, who do not have to cover costs of transportation via the Atlantic Ocean, have good-quality light product and are not politically risky. The higher the price of crude oil is, the more profitable shale oil exploitation becomes and the less petroleum is needed to be imported.

Still the MODEL 2 has many limitations. Firstly, what is very interesting, it seemingly does not work in the opposite direction, while the oil prices decreases. This means that shale oil producers are able to successfully compete even in the more difficult market environment (for example when oil price equals $60 per barrel). The aforementioned ‘seemingly’ means that there is a barrier, when shale oil becomes too costly for exploitation. This turning point is probably about $40 per barrel, basing on data from last quarter of 2015. Presumably, only if the price is lower estimated negative relationship between price and production occurs.

At this point appears one of the most important functions of econometrics as a managerial tool which is not only descriptive instrument but also useful for forecasting.

Basing on EIA’s short term forecasts (2016–2017), connected with oil price (EIA 2016b), and according to previously described relationships between variables, a new model which would determine future production of crude oil in Africa against the US import has been built.

Firstly, basing on monthly data for the period 2014-01–2015-09 (EIA 2016a, 2016b), a model of the production of crude oil in Africa against the US imported oil price has been estimated. There was also estimated a forecast for the years 2015–2017, according to EIA’s short-term predictions (EIA 2016b). Results are shown in the Table 8 and in the Fig. 6.

TABLE 8. Estimation 8: OLS, using observations 2014:01–2015:09 (n = 21)

TABELA 8. Estymacja 8: MNK, obserwacje z okresu 2014:01–2015:09 (n = 21)

Dependent variable: Af_p

Variable	Coefficient	Standard Error	t-ratio	p-value	Significance
const	8671.7	54.7331	158.4360	<0.00001	***
d_US_irpr	–16.7764	8.66552	–1.9360	0.06789	*

The EIA monthly price data based model, shows that if market conditions become constant, crude oil production in Africa probably will not grow a lot in the next 2 years.

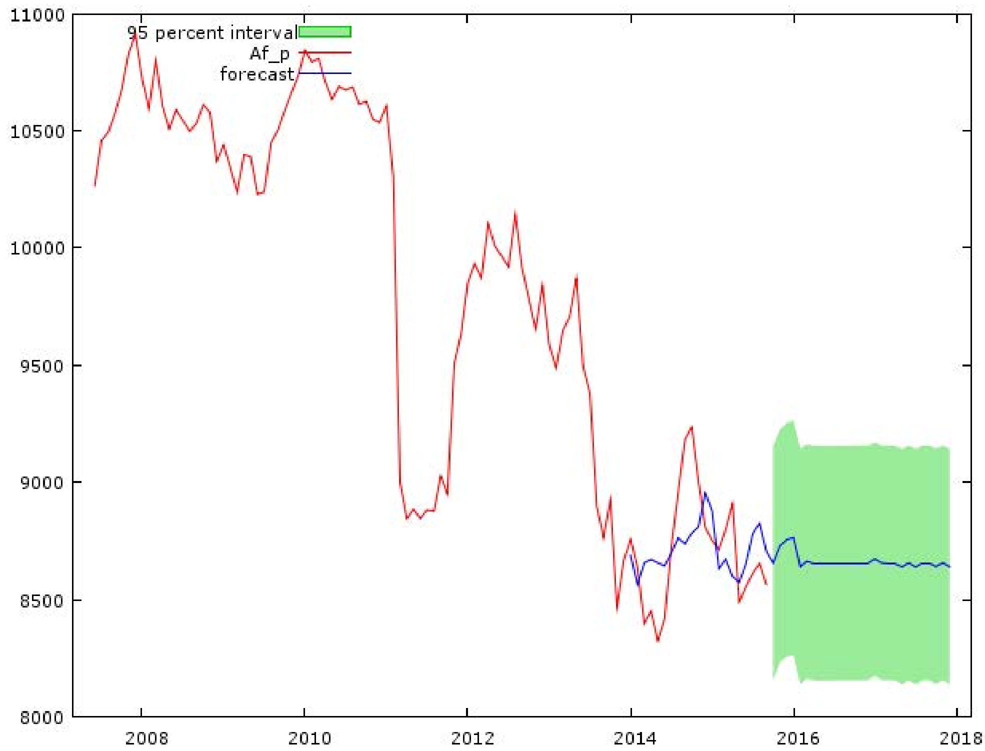

Fig. 6. Graph showing adjustment of the model (forecast) and observed values (*Af_p*, mbbls/d), and also prediction for the years 2016–2017

Rys. 6. Wykres przedstawiający dopasowanie modelu (prognozy) i wartości obserwowanych (*Af_p*, mbbls/d), a także prognozy dla lat 2016–2017

Conclusions

The paper shows the methodology which provides numerical data that are crucial for strategic planners especially in the oil industry. The main conclusion connected with the past situation is that because of the Shale Revolution in the US and reduction of its import most of African exporters lost their main driving force of oil exploitation. What is more, the future of petroleum industry in Africa probably will not be bright – competition with American shale oil producers is possible only when the prices are low, rivalry with Arabian and now also with Iranian exporters is very hard because of price pressure. But there is a possible solution in acting on the basis of growing African domestic consumption, additionally driven by low oil prices, and investing in refinery industry on that continent. On the other hand, low prices of crude oil discourage international oil companies (IOCs) to explore new deposits. As a result only the Chinese and Hindus, who are looking for diversification of energy sources, will probably stay in that field.

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Wojciech Labuda

Budowa modelu ekonometrycznego wydobycia ropy naftowej w Afryce

Streszczenie

Celem niniejszego artykułu jest identyfikacja czynników determinujących poziom wydobycia ropy naftowej w Afryce, a następnie określenie, co to oznacza dla potencjalnych przyszłych inwestycji na tym kontynencie.

Aby rozpoznać wspomniane czynniki, niezbędne jest stworzenie w pierwszej kolejności funkcji wydobycia. Stąd też wybrano szereg zmiennych, mogących mieć wpływ na poziom eksploatacji, m.in. cenę ropy naftowej, poziom jej konsumpcji w Afryce, import ropy do Stanów Zjednoczonych i in. Następnie dokonano estymacji funkcji, posiłkując się statystyczną analizą danych empirycznych. Dla lat 1980–2015 oszacowano za pomocą oprogramowania ekonometrycznego GRETL model liniowej regresji według metody najmniejszych kwadratów (MNK). Aby wybrać model najlepiej odzwierciedlający rzeczywistość, otrzymane wyniki zweryfikowano zarówno danymi pozyskanymi z literatury poświęconej światowemu rynkowi ropy, jak i przy użyciu odpowiednich testów statystycznych oraz ekonometrycznych.

Nawiązując do literatury przedmiotu, na poziom wydobycia ropy naftowej w Afryce mają wpływ przede wszystkim dwaj gracze – Europa i Stany Zjednoczone. Z pierwszym z nich związane są przede wszystkim państwa członkowskie organizacji OPEC. Z drugiej strony kraje Afryki Zachodniej w większym stopniu eksportują ropę do Stanów Zjednoczonych. Oszacowany model pokazuje, że sytuacja ta zmieniła się po tzw. łupkowej rewolucji i spadku ilości importowanej przez Amerykę ropy, a co za tym idzie i wydobycia w Afryce. Co więcej, zaobserwowano interesującą tendencję do zmniejszenia wydobycia w Afryce, kiedy ceny ropy rosną. Przyczyną tego zjawiska może być fakt, że wysokie ceny surowca implikują wzrost opłacalności eksploatacji złóż ropy łupkowej w Stanach Zjednoczonych, będących bezpośrednią konkurencją dla złóż afrykańskich.

Model, który agreguje makroekonomiczne wskaźniki i dane statystyczne jest bardzo użytecznym narzędziem, które wykazuje efektywność inwestycji w wydobycie ropy naftowej w Afryce.

SŁOWA KLUCZOWE: ropa naftowa, Afryka, Stany Zjednoczone, ropa łupkowa, rewolucja łupkowa