MGPB

Development of Tight Oil Resources in the USA: Exploitation Costs and Effect of Macroeconomic Indicators in a Volatile Oil Price Environment

The Mining-Geology-Petroleum Engineering Bulletin
UDC: 622.1:620.9
DOI: 10.17794/rgn.2017.3.3

Original scientific paper

Kristina Strpić[1], Monika Miličević[2], Tomislav Kurevija[3]
[1 2 3] Faculty of Mining, Geology and Petroleum Engineering, Pierottijeva 6, Zagreb, Republic of Croatia

Abstract
Large scale development of tight oil resources in the USA started after 2010 with a following five-year period of favourable steady increase in crude oil price. During this relatively short expansion cycle, operating and capital expenses changed drastically for main tight oil plays due to technological improvements in both well drilling and completion, the expansion of the service sector as well as the loose government monetary policy which allowed favourable financing. This paper analysed trends in costs during the expansion period, as well as the correlation of oil price to a number of operating rigs and production quotas. After 2008/2009, the world financial crisis economy recovery in the USA was somewhat sluggish and it caused an extremely volatile environment in both equity and commodity markets. In such a volatile environment intraday crude oil prices, as well as other commodities and equities, show a significant reaction to monthly published macroeconomic indicator reports, which give better overviews of trends in economic recovery. Prior to the announcement, these reports have always forecasted value determined by a consensus among market analysts. Therefore, any positive or negative surprise in real value tends to influence the price of oil. This paper investigated the influence of such macroeconomic reports to closing intraday oil price, as well as the effect of other important daily market indices. Analysis showed that only the Producer Price Index (PPI), among other indicators, has a statistical significance of affecting intraday closing oil price.

Keywords:
tight oil, breakeven price, macroeconomic indicators, commodity and equity market

1. Introduction

Large scale development of tight oil production in the USA, mainly from low permeable shale, started in the last decade with technological advances and favorable conditions in the commodity market. Technological aspects mainly relate to an improvement in horizontal drilling lengths, as well as well stimulation and completion techniques such as hydraulic fracturing. This allowed for the rapid exploitation of substantial tight oil reserves, whose development was once considered not commercially viable. With the growth of the supporting oil service sector focused solely on tight oil development, production had tremendously increased from a half-million barrels of oil per day in 2008, up to its peak production at the end of the 2014 with 4,6 MMbpd (MMbpd = million barrel of oil per day, 1 bbl = 159 liters) **(EIA 2016)**. At peak, it corresponded to 48% of the total oil produced and almost 24% of the total oil demand in the USA. Such a shift from conventional to unconventional resources significantly lowered the energy dependence on imported oil. This started a kind of global oil supply glut, initiating further contest between the main world oil producers causing a volatile price environment.

Corresponding author: Tomislav Kurevija
tkurevi@rgn.hr

Tight oil in the USA is mainly produced by numerous independent oil companies that are economically very sensitive to any significant fall of crude oil price due to financial debt **(Flores 2011)**. Unlike conventional offshore and onshore projects where the production period is decades long, which major oil companies' favor, tight oil wells' productivity can fall as much as 90% after five years of production. Such intense exploration and production, as well as future expansion of this sector, depends directly on the short-term market oil price and breakeven price for a certain project.

The aftermath of the 2008 financial crisis caused oil prices to plunge to $32/bbl in January 2009 (NYMEX – West Texas Intermediate or WTI), due to low demand and an oversupply of oil. Subsequently, there was a slow but steady increase in prices following a slow economic recovery. Since this recovery was stagnant, especially in the job market, major macroeconomic indicators published on a monthly basis became the leading guideline of a volatile oil and stock market in the last decade. Considering that the USA is a world leading oil consumer, the current tight oil production in the USA has greatly impacted oil prices worldwide since it disrupted some of the previously established global oil trade flows.

Recently, a lot of authors were investigating how the current economical, geopolitical, social and other factors affect oil prices worldwide (WTI, Brent Blend, Dubai/Oman Blend) during the post-recession volatile era.

Datta et all. 2016 investigated how commodities (especially crude oil) and equity returns correlate in a highly volatile environment in a post and pre-recession 2008 era in a so-called zero lower bound environment (constrained monetary policy). Special attention was given to the influence of macroeconomic news in a short period of fluctuations for oil and equity markets. The authors concluded that prior to the recession of 2008/2009, weekly and monthly-published macroeconomic news surprises had little effect on the price movement of equity and commodities, while after this period, the correlation was more distinct.

Domanski et all. 2015 analyzed how an increasing debt in the oil sector and low prices in the period after 2014 influenced the decline in the value of assets backing this debt, which introduces a new element to price developments. They concluded that "There is evidence that higher leverage has affected the response of oil producers to lower prices and oil price dynamics".

Kleinberg et all. 2016 researched tight oil development economics, especially breakeven points, and inelasticity for major tight oil plays in the USA. They stated that "breakeven data which is often presented by analysts or corporations to investors is without adequate disclosure of what exactly is meant by breakeven price". They also concluded that "economics of a long-lived tight oil plays requires understanding how breakeven points change over time, and how they might be affected by future changes in commodity prices".

Kallemets 2016 investigated the sustainability of the shale oil industry on the Estonian example, in terms of the full cycle of breakeven cost of tight oil. He also concluded that the "full-cycle cost is rapidly increasing due to the increasing necessary capital expenditure, increased national taxation and the carbon emissions abatement policies". The author also questioned the sustainability of the tight oil industry in the USA in the case of multiyear global oil prices set below $90/bbl.

2. Overview of tight oil production in the USA

2.1. Main locations of tight oil resources development

Bakken and the underlying Three Forks Formation, subsurface of the Williston Basin, are located in North Dakota and Montana where the exploration and production of tight oil in the USA started at the beginning of the millennium. The Bakken Formation is made out of three members; the Upper and Lower Shale Member and the Middle Bakken Member (sandstone, dolomite, shale), while the Three Forks Group is constituted of dolomite, mudstone and bituminous shale. Current estimates from the **EIA 2016** about the future potential of the Williston Basin, suggests that production peaked in Q1/2015 with 1.2 MMbpd and will follow with a further steady decline up to 2040. Unproven technically recoverable tight oil reserves presently are at 8.5 Bbbl for Bakken, and an additional 14.2 Bbbl for Three Forks. Nevertheless, the production scenarios of a "Realistic Case" indicate that the ultimate recovery by 2040 would be in the range of 6.8-7.6 Bbbl.

Eagle Ford in south Texas is also a relatively new oil field developed in 2007 and with negligible production before 2010. It is a sedimentary formation composed of marine shales and marls with interbedded thin limestones. How rapid expansion was in this tight oil play could be displayed with the fact that almost 11000 wells were drilled in just a decade of exploitation. Production of tight oil peaked in Q1/2015 with production of 1.7 MMbpd and with a steady decline up-to-date. Eagle Ford produces both oil and gas, which divides a field into three plays; a shallow oil formation and a deeper part of the formation with wet gas and dry gas. Currently, 60% of the entire play production is tight oil, while 40% is wet and dry gas expressed in oil equivalent. Oil recovery forecasts are set at 6.2 Bbbl until 2040 as part of the "Realistic Case" scenario, while the EIA estimates that the total technically recoverable resources for oil are 10.1 Bboe for all three plays **(EIA 2016).**

Permian is a third major location and by far the largest source for tight oil development today in the USA. Unlike Bakken and Eagle Ford, the Permian Basin is a very old producing field of conventional oil, with hundreds of thousands of vertical wells drilled in the last century. Most of the USA onshore conventional oil is still produced from this field with the involvement of secondary and tertiary production regimes. Peak production of conventional oil was achieved back in 1973 with 2.1 MMbpd, with a decline to 0.85 MMbpd in 2005, prior to the application of horizontal drilling and fracturing old reservoirs. Due to the fact that oil in the Permian Basin is produced from both horizontal and vertical fractured wells, it is difficult to distinguish the real production of tight oil from conventional oil. The most common approach is that wells drilled before 2006 produce conventional oil, and wells drilled afterwards are tight oil wells. The field is divided into three basins; Delaware, Midland and the Central Basin. Three geological units are significant for tight oil exploration and exploitation; Spraberry sandstone interbedded with shales in the Midland Basin; BoneSpring/Avalon limestone in the Delaware Basin and the underlying Wolfcamp shale formation in both the Midland and Delaware Basins. The Central Basin only has a modest production, primary on

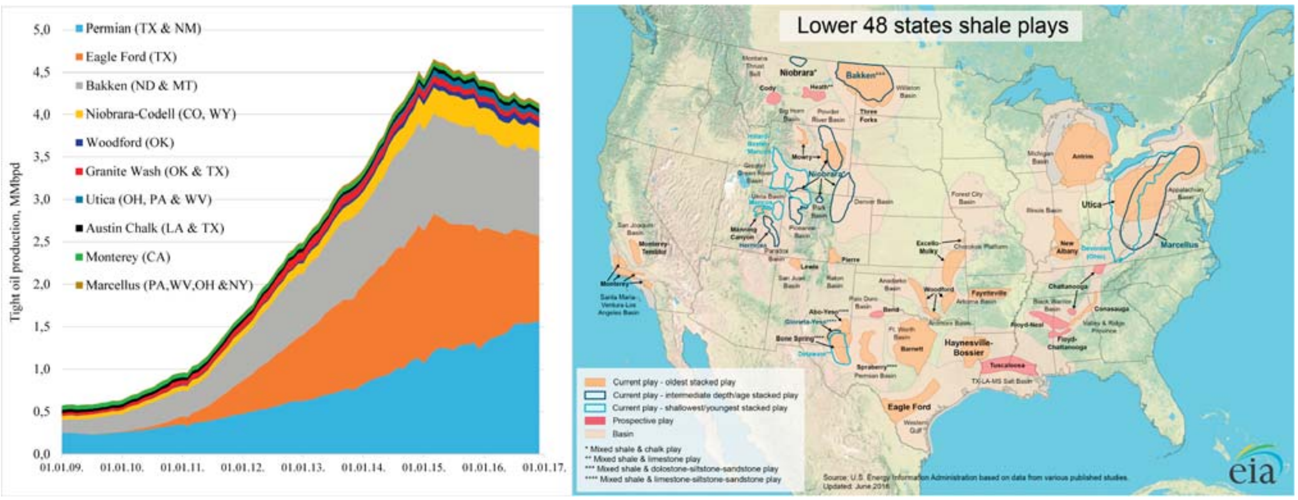

Figure 1: Production from main tight oil plays in the USA since 2009. The chart is made from publicly available data at eia.gov

Yeso and Glorieta sandstone formations. Due to its use of the developed existing oil infrastructure and the proximity of major pipelines and low breakeven prices, the Permian is the most resilient to low oil prices among all the tight oil plays. Furthermore, monthly production is still increasing in spite of the oil price range $40-50/bbl in the period of 2015-2016. Unproven technically recoverable resources of tight oil are 10.6 Bbbl for the Spraberry formation; 2.9 Bbbl for Bonespring/Avalon and 6.1 Bbbl for the Wolfcamp formation. The current estimated cumulative production of tight oil until 2040 for Spraberry is 6.5 Bbbl; 0.7 Bbbl for Bonespring/Avalon and 2.6 Bbbl for Wolfcamp **(EIA 2016).**

2.2. Production of tight oil under the volatile oil price environment

The period of high prices of oil between 2010 and mid-2014 was not the only catalyst that led to a massive increase in the USA tight oil production from 0.5 up to 4.5 MMbpd, as seen in Fig. 1. Though tight oil reserves are uneconomical to exploit without the support of a high market price, there is also a significant importance of the technological advancement in horizontal drilling and hydraulic fracturing. The latter factors lowered breakeven prices during the last decade. Conventional oil production, mainly from the Permian Basin and the Gulf of Mexico, was somewhat unchanged in the last decade with production roughly around 5.0 MMbpd.

Despite tremendous growth in domestic light sweet crude production from tight resource formations, in Q1/2015 peak production of 9.5 Mbpd was still only 48% of the total domestic consumed oil, which stood at approximately 19.5 MMbpd. Although technically recoverable tight oil resources are set at 59 Bbbl (Bbbl = billion of oil barrels) with an estimated recovery of approximately 23 Bbbl until 2040 **(EIA 2016)**, the question arises what would the peak oil production from both conventional and tight oil resources be? Such an estimate is solely linked to the global price of oil.

In an "optimistic scenario" with a considered high oil price, $149/bbl until 2020 and $169/bbl until 2025, the USA peak production would reach 12.8 MMbpd in 2022 with a steady decline afterwards. However, a more realistic scenario considers a low oil price of $64/bbl in 2025 with peak production of 9.9 MMbpd achieved in 2019. A subsequent production estimate is very near to the current level and it only allows for a modest rise in the following years.

This could also be explained through the unique characteristics of tight oil resource development. After an initially high rate of production during the first month, there is a steep and constant drop in the following period. **Maugeri 2013** indexes this production rate during the first month with a so-called IP30 factor. Field research shows that after the first year of well productivity, the IP30 factor declines by 40-50% of its original value, with an additional 30-40% decline after the second year. After the fifth year of production, most of the tight oil wells produce only 10% of their original IP30 **(Curtis 2015)**. Companies make up for such a sudden drop in production rates with constant new drilling to maintain production rates. For example, during 2012 on the Bakken-Three Forks Basin, there were 90 new wells drilled each month, just to maintain the sustainable production at 770Mbpd.

In June of 2014, there was a drop in the market oil price which can be explained with a global supply glut and flat demand. For a few years before the oil market correction there was a continuous increase in production quotas not just in the USA, but also from OPEC member states and non-OPEC states, especially Russia. The slow growth of the Chinese economy, as well as modest growth of the EU and the USA, caused an almost 70% drop in oil prices in the following 18 months with the bottom appearing in Q1/2016. This trend can be clearly seen in Figure 2.

The number of active oil rigs was at its peak in Q1/2014, along with the period of the highest occurred

Figure 2: Overview of interdependent variables of the USA conventional crude and tight oil production, active rig count and Cushing oil stockpiles, chart made from publicly available data at Investing.com

price of oil. The rig count number can be interpreted as a lagging indicator of oil price. With a drop in oil price, there is also a delayed responding drop in the active rig number. The reason for the delay is the time necessary to evaluate a well as non-cost-effective, plus an additional period for abandoning the well, which includes overhead expenses. Those expenses and contract obligations are sometimes the reason to continue drilling in spite of lower oil prices.

In Fig. 2, such a trend can be seen when oil prices are presented with a moving average value of 180 days (MA180) and compared with the oil rig count (rig count number is divided by a magnitude of 15 to better fit correlation). These two variables show very good alignment for this period and therefore it can be interpreted as a good technical indicator for a rig count prediction. Furthermore, after a steep drop in oil price in 2014 and 2015, followed by a drop in active rig counts as well, in the second half of 2016 both MA180 oil price and rig count changed their trend. As seen in Fig.2, this correlated to a MA180 of approximately $40. This could be interpreted as a cost-effective boundary in the process of developing tight oil in the USA.

Another indicator that often affects oil price is the inventory report from a storage facility at Cushing, Oklahoma. Although oil storage at Cushing is only 10% of the total USA inventory capacity (it can hold up to 73 MMbbl of crude oil), it is considered the most important trading hub for crude oil (especially sweet light crude from tight resources), as well as a settlement point for West Texas Intermediate on the New York Mercantile Exchange. In Fig 2. it can be seen that for the last two years, inventories at Cushing are very near its maximum working capacity, which point to a supply glut and flat demand for crude oil.

3. Tight oil upstream costs

The change in total upstream costs during the last decade is analyzed for the three biggest shale oil plays: Bakken, Eagle Ford and Permian. For unconventional plays in Fig.3, 77% of a typical modern well's total cost is comprised of just five key cost categories: Pumping, Drilling, Proppant and Fluid used for hydraulic fracturing. As the service sector expanded to meet demand, their costs decreased significantly since 2012 for all plays. In particular, pumping costs in 2015 have been reduced for all plays despite longer lateral lengths and an increased number of fracturing stages. In addition, fluid costs were the highest in 2012, and since then the rates have come down by approximately 60% despite an increase in the amounts of used fluid. **(EIA 2016)**

Bakken. Since the first exploratory wells, the Bakken play has been known for deep and long lateral wells with high pressure gradients which explain the higher drilling cost. Before the development of horizontal drilling in 2011, well costs in the Bakken play were under $5 million and today total costs reached $7.5 to $8.1 million as shown in Fig 3. Optimal casing completion for the Bakken geological environment was determined with the drilling of initial wells, so casing costs show no variations in future development. Long lateral wells in combination with a high-pressure gradient require the implementation of an artificial proppant and more power for pumping, which leads to a higher total cost. Also, the amount of proppant per well has grown steadily year af-

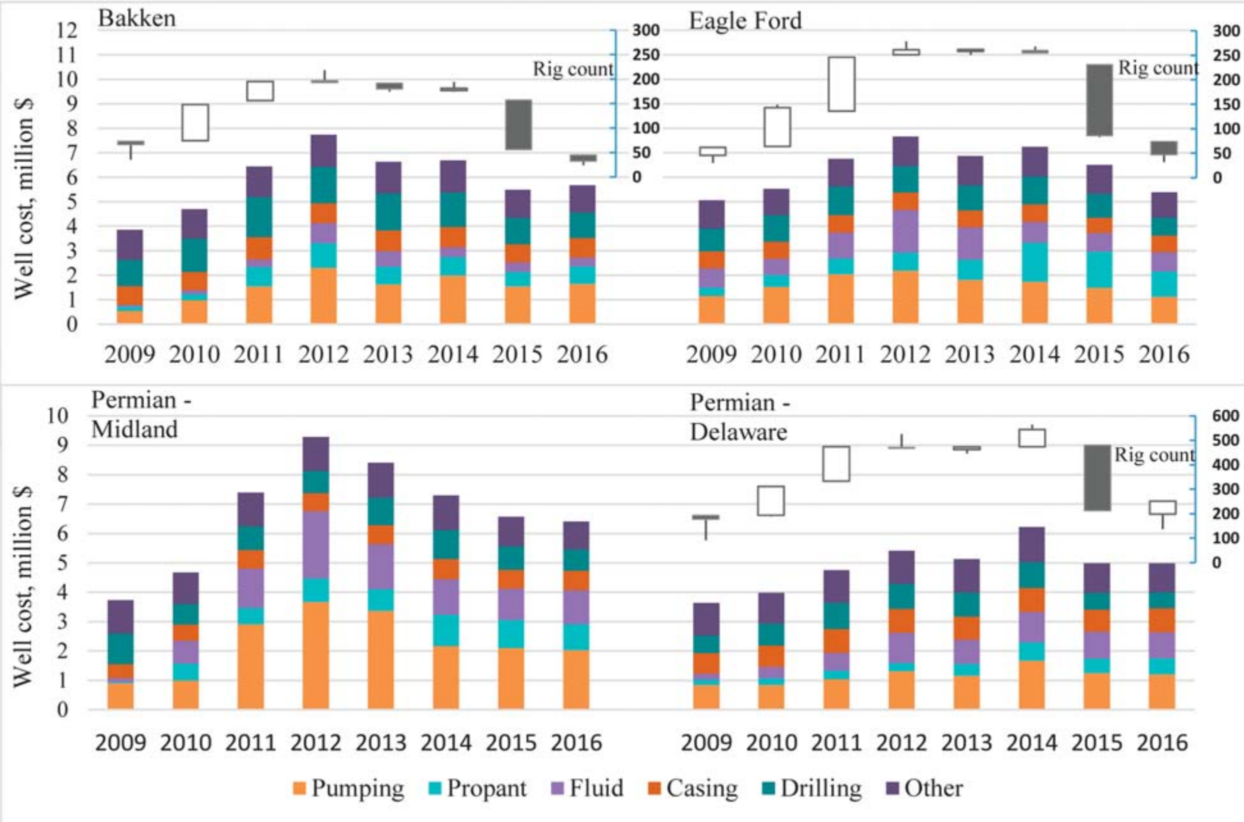

Figure 3: Average well cost for various tight oil plays and active rig count presented in candlestick pattern form (*the Permian rig count is expressed for both the Midland and the Delaware), chart made from publically available data at www.eia.gov

ter year. However, this may not be as effective as planned, as the Estimated Ultimate Recovery (EUR) per unit of proppant is decreasing. That means that the amount of proppant used is increasing faster than performance improvement. Initially, with more horizontal wells completed, costs began to increase despite improvements in drilling technologies and efficiency. It was the result of greater demand for the service industry, but as the service sector expanded to meet demand, costs were lower after 2012.

Eagle Ford is both an oil and gas play and well costs in this play range from $6.9 to $7,6 million. Unlike Bakken, lateral lengths are much shorter but proppant costs are high due to the use of artificial proppant because of the high pressure environment. Casing and drilling expenses have been fairly constant in recent years, with a slight decrease as a result of drilling efficiency improvements. Pumping costs are the most expensive well component due to the high formation break-pressure with a range of 5900 psi to 10600 psi. Among all tight oil basins, Eagle Ford is the most responsive to changes in oil price. Like the Bakken play, about ten producers are making the most of oil production, about 75%.

Permian. Most unconventional wells are horizontal with expensive completions. The number of wells is growing rapidly since 2012, along with upstream well costs. In comparison to other major tight oil plays, the Permian is the most resilient one to lower oil prices. The resilience could be explained trough favorable geological conditions for each basin, the stage of development and a complementary transport infrastructure. The Permian is the only tight oil basin where there was no decline in production despite the period of low oil prices.

In the Delaware Basin, initial wells were with short lateral lengths and drilling and casing make up most of the well costs as shown in Fig.3. With longer horizontal drilling, pumping and fracturing fluids costs rising during the years, this also increased nominal well costs. That lasted until 2013 when the completion costs decreased due to improved service markets. The increase in total cost from 2013 to 2014 can be explained with a longer lateral length and increased formation pressure which led to the need for higher power pumping. The reason for the growth of drilling costs in 2014 is the expanding drilling to riskier areas.

The situation with the Midland Basin is similar, only with more fracturing intensity and longer lateral lengths since the beginning of its completion which explains higher pumping and proppant costs. But, since 2012, the lateral lengths have decreased and improvements in pumping cost are the result of a greater supply of fracturing equipment and crews.

Figure 3 also shows rig count for each of the three major fields since 2009, where the Permian rig count is a cumulative number for both the Midland and Delaware Basins. Rig count data is present in the form of candlesticks patterns, which is a common method for the technical analysis of the stock market. Such an approach gives more distinct movement of the rig count in periods of expansion until 2014, and contraction since then. The candlestick chart is created by knowing four different sets of data for a certain period of time; open, high, low and close value. A hollow or filled portion of candlestick is called the "body", while thin lines above and below the body represent a high and low range during the analyzed period, a so-called "shadow". If the rig count in the beginning of the year is higher than the rig count at the end of the year, the body of the candlestick will be black, and white if the opposite is true. This approach can clearly depict the reversal trend in 2015, when long black bodies for every field occurred, meaning there was a sharp falling trend in drilling due to low oil prices.

4. Operating expenses and breakeven price for major tight oil plays

Operational costs are influenced by location, well performance and operator efficiency. They can be divided into three categories:

Lease operating expenses. These costs are present during the whole life of the well. For example, that includes artificial lift or water disposal costs, highly variable between the plays. Lease operating expenses range between \$2.00 and \$14.50 per bbl, depending on production and lateral lengths. Gathering, processing and transport. High variability of these costs is a result of individual contracts between producers and midstream providers. Every product has its own specific costs and requirements. For example, oil can be transported to the nearest gathering system at a cost ranging between \$0.25 and \$1.50 per bbl, while trucking is much more expensive with costs ranging between \$2.00 and \$3.50 per bbl. Operators will also need to transport oil on variable distances to refineries, either by pipeline or by the rail which creates a price ranging from \$2.20 to \$13.00 per bbl.

Water disposal. These costs are very specific because most of the water ecological disposal expenses from fracturing operations are included in capital costs. According to EIA 2016, after 30 to 45 days of operation, these expenses would then be classified as OPEX and would include residual disposed water and formation water. Costs include reinjecting water back into the reservoir, transportation and recycling programs. Thus, costs are highly variable, ranging from \$1.00 to \$8.00 per bbl of produced water.

General and Administrative costs (G&A) are included as operating expenses and can range from \$1.00 to \$4.00 per bbl.

Bakken. Operating costs are highly variable ranging from \$15 to \$37.50 per bbl with safe water disposal, rail transport and artificial lift making up most of the cost. On average, about 40% of Bakken tight oil is transported by rail and additional pipelines could save \$5-\$10 per barrel.

Eagle Ford. Operating costs for the Eagle Ford play are ranging from \$15.50 to \$24.50 per bbl. These are about \$5 to \$8 lower than in the Bakken because of the closer position of the market, transport infrastructure and refineries. Like Bakken, safe water disposal and artificial lift make up most of the operating costs.

Permian. Operating costs are highly variable ranging from \$13.50 to \$33.50 per bbl. There is no significant difference between the costs in the Delaware and the Midland Basins, but for the Delaware, transportation costs are higher due to its further distance from markets. In general, most of the costs are related to artificial lift and water disposal, but they are still lower than in other plays. The Permian produces oil with a watercut of just 0.2, but because of conventional oil production at this basin, this water is then used as part of waterflooding projects. Therefore, water disposal costs are significantly lower comparing to other plays.

There is a large discrepancy in breakeven prices which could be found in published papers and studies in the last decade. For tight oil resources, it could be argued that a uniform breakeven price actually does not exist.

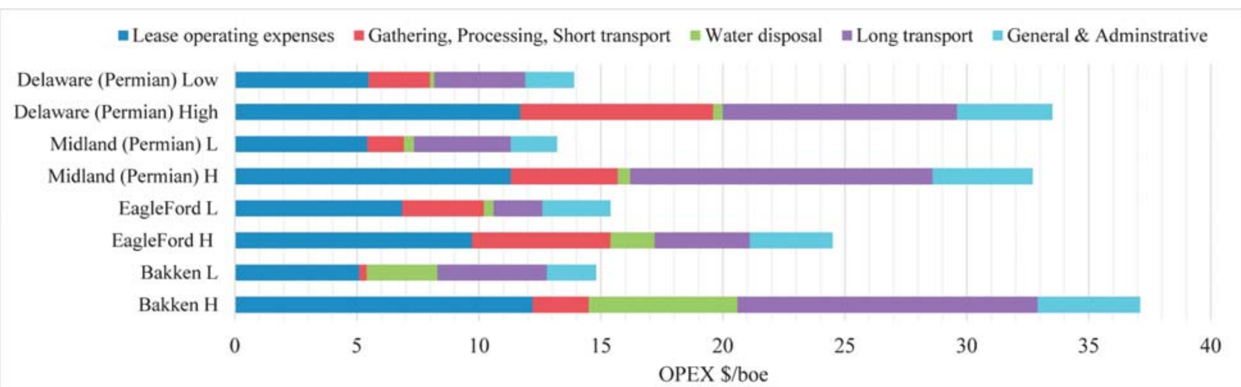

Figure 4: OPEX (High/Low) for major tight oil plays in the USA for 2016, chart made from publically available data at www.eia.gov

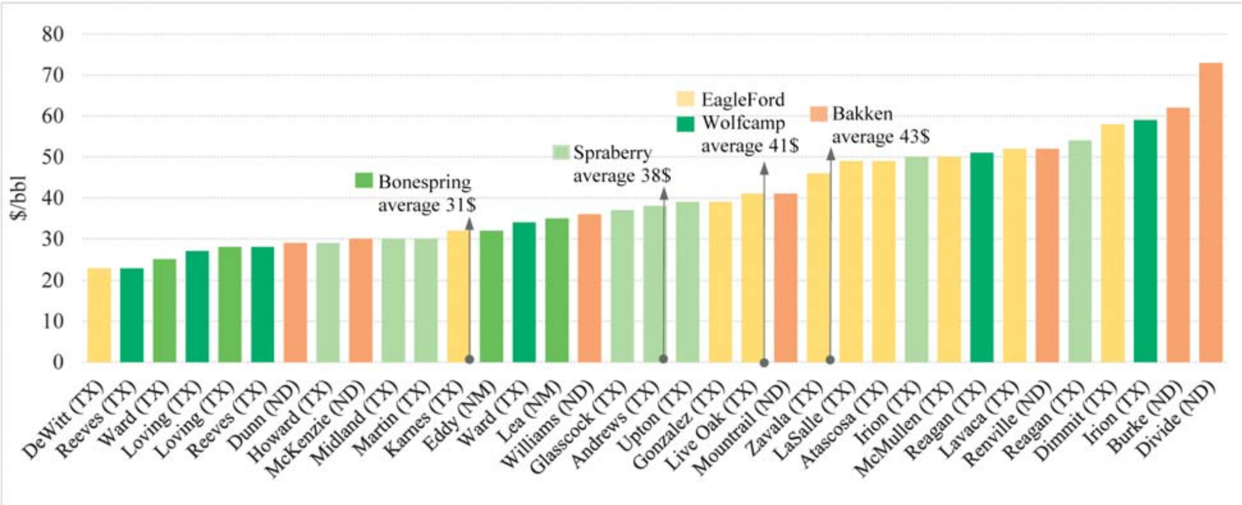

Figure 5: Half-cycle breakeven price for major tight oil plays in 2016 (Bloomberg Intelligence report 2016.)

Moreover, the breakeven point for certain fields can significantly vary depending on: a favourable geological environment (so-called sweet spots), the drilling efficiency of the rig operator, completion and other technical costs, financial costs and the proximity of the transport infrastructure. Kleinberg (2016) gave a good overview of distinction in the full-cycle and half-cycle breakeven prices in the tight oil production segment. In his study, Kleinberg states that the half-cycle breakeven point is the cost of oil production, including lifting cost, the expense of existing well workovers, and of drilling, completing, and stimulating additional wells in a developed field, with the goal of maintaining level production. The cost of financing these activities is included in the half cycle breakeven point.

The Bakken Basin is a good example of very spread out breakeven prices due to transportation issues. The current transport capacity by pipelines in 2016 was 763 Mbpd, as reported by the North Dakota Pipeline Authority. Therefore, overproduced oil outside this pipeline capacity must be transported by rail to Midwestern and Texas refineries. In fact, rail capacity is currently at 60% of the total produced oil at Bakken, although only around 30% of the capacity was actually moved by rail in Q4/2016. These expenses could be as high as $10 per barrel, which makes certain producers at Bakken very vulnerable to low prices of oil, especially below $50/bbl. This was the main reason for reducing production at the Bakken Basin, from its peak at 1.2 MMbpd in Q4/2014 to 0.98 MMbpd at the Q4/2016. To improve the future overall economy of tight oil production at Bakken, the new Dakota Access Pipeline (DAPL) was planned in 2016 with a capacity of 450 Mbpd, but its current construction status is doubtful because of the environmental and cultural protest from local municipalities. There is also a plan for the Sandpiper Enbridge pipeline in 2019 (225 Mbpd) and TransCanada Upland in 2020 (300Mbpd). As seen in Figure 5 the Bakken half-cycle breakeven price average is currently around $43/bbl with the lowest prices recorded at Dunn County ($29/bbl) and McKenzie ($36/bbl), which are considered to be premium sweet spots. At the basin periphery in Burke and Divide County, the half-cycle breakeven price is as high as $62/bbl and $73/bbl, respectively.

The lowest overall half-cycle breakeven prices could be seen at the Permian Bonespring formation, with an average price of $31/bbl. Other Permian formations such as Spraberry average at $38/bbl, while the deepest formation Wolfcamp averages at $41/bbl. Eagle Ford Basin in eastern Texas has half-cycle breakeven prices around $41/bbl. The effect of these half-cycle breakeven prices, presented in Fig 5., can be clearly seen from an increase in the number of active rigs in Fig. 2, as well as from production growth in Q4/2016, when the oil price presented as MA180 reached a trend above $40-45/bbl.

5. The influence of macroeconomic indicators on daily movements of WTI price

Supply and demand for oil depend on macroeconomic factors, as well as on government fiscal policies in view of interest rates. It is also widely considered that oil price responds instantaneously to any kind of shock news in global demand and supply, but responds to macroeconomic aggregates only with a time lag. Statistical research from Kilian&Vega 2011, Anderson et all. 2003 have all shown that this approach was valid for the period before the world financial crisis in 2008. However, later investigations by Datta 2016 have shown that all commodity prices after 2008 react more like assets, instantly responding to periodically published macroeconomic indicators. For oil, this could be explained from two different points of view; with an increasing share of tight oil in cumulative USA crude production and growing oil service sector financing.

Before the 2008 crisis, the share of unconventional tight oil was no more than 10%, which can be seen in Fig 1. Conventional onshore and offshore oil projects are related to long term production of oil, often a decade or longer, and therefore are less sensitive to short-term changes in the macroeconomic environment. Furthermore, oil companies engaged in such projects are mostly high market capitalization companies, with a long tradition in oil production and therefore with a lower risk of financing.

Unlike conventional oil production, the exploitation of tight oil resources is often related to small and medium sized oil companies, which are much more vulnerable in servicing its debts and obtaining favourable financing (Karasalihović-Sedlar et all. 2017). After 2009, the economic recovery of the USA was fragile with interest rates at historically the lowest level, meaning that any negative set of macroeconomic news was interpreted as a possibility of financial crisis returning. In such a dynamic business environment during the last decade, with an increase of tight oil share in the total USA production, it could be argued that crude oil prices therefore react much more like assets to any positive or negative shocks in macroeconomic news announcements.

To evaluate the effect of positive and negative shocks of a macroeconomic news announcement to daily WTI price fluctuation, economic data and streaming quotes were collected from Investing.com, one of leading global financial portals. According to methodology presented in research from Beechey & Wright 2009, news shocks were interpreted as the discrepancy between ex-ante analysts survey anticipations and real announced data. The analysis is performed on data from 01/2009 until 12/2016, which corresponds to the period of the USA economic recovery process, as well as the period of significant growth in tight oil production. As shown in Table 1, the observed data was divided into four major categories; A) Crude related data, B) Main market indexes, C) Financials, D) Macroeconomic indicators. Section D was further divided into four sub-indicators; D1) Industrial, D2) Real estate, D3) Jobs market, D4) Inflation, Retail, GDP.

Discussed data all across indexes differs significantly in measurement units. Therefore, the method presented by Anderson 2007, and later by Datta 2016, was used to standardize indexes and news announcements. Each news shock sample data was divided by its sample standard deviation with the indicator i at published time t as follows:

$$S_{it} = \frac{P_{it} - F_{it}}{\sigma_i} \tag{1}$$

Where:

- S_{it} – the shock component (either positive or negative);
- P_{it} – official published indicator data from various government institutions;
- F_{it} – forecasted value of indicator data prior to official announcement based on market analysts expectation survey;
- σ_i – sample standard deviation of shock component (P_{it} -F_{it}).

WTI oil price was modelled in the same way, as a difference between the closing price of WTI on the day of an indicator announcement and a closing price of a day before an announcement, divided with a standard deviation of a sample. The influence of each indicator on a daily closing price of WTI was carried out with regression statistics between those two sets of data, for a given day of each news announcement. Analysis outputs presented in Table 1. and in Fig 6. were Pearson's product moment correlation coefficient, as a measure of linear dependency between two sets of data, and p-values obtained using robust standard errors. The confidence level of statistical analysis was set at 95%, therefore indicators with obtained p-values of less than 0,05 would show statistical significance of affecting the daily closing price of WTI.

Positive macroeconomic indicators news surprises, and indexes in general, should be related to positive movements in WTI price due to economic growth (a positive value of Pearson correlation coefficient). However, among 30 analysed indicators, there are some exceptions where negative values in announcements should correspond to positive values in the closing daily price of WTI. In Table 1, section A, this is the case for crude oil inventories where a negative change in value suggests a stronger demand for oil and causally a higher oil price.

In section B, which relates to main market indexes, negative values of volatility index (VIX) should be positive for oil prices, as VIX is often referred to as a fear index in markets and represents the measure of the market's expectation of stocks volatility over the next 30-day period.

The entire section C, financial instruments, should be interpreted in a way that negative values are favourable for positive price movements in WTI. Since the US dollar is the benchmark for most of the commodity prices on NYMEX, foreign buyers purchasing power grows when the US dollar value falls against their domestic currencies, which is positive for the WTI price. Like the US dollar, the value of bonds is closely related to the government fiscal policies and overall strength of the economy and stock market. Generally, rising energy and oil prices affect interest rates, even with little change in the inflation rate, which causes bond prices to fall (higher rates).

Among the macroeconomic indicators presented in section D, the reversed interaction with the WTI price is for: business inventories, unemployment rate and initial jobless claims. Figure 6 shows the results of analysis with three examples of correlation chartered inside the

Table 1: Statistical analysis of macroeconomic indicators news and indexes samples (2009-2016)

Indicator	Time frame	Sample	Mean	Standard Deviation	Min.	Max.	Confidence Level (95%)	Sample Variance
Section A: Crude oil data								
WTI futures contract	D	2012	0.000030	0.02330	-0.1225	0.1404	0.001020	0.00054
Brent futures contract	D	2012	0.000260	0.02075	-0.0924	0.1098	0.001192	0.00043
Oil rig count change - BakerHughes	W	406	0.212	16.14	-94	35	1.574	260.40
EIA Crude oil inventories change	W	311	-0.037	3.61	-14.7	9.55	0.403	13.07
Section B: Market indexes								
Standard&Poors 500	D	1960	0.000482	0.01108	-0.0667	0.0708	0.000645	0.000122
Dow Jones Industrial Index	D	1960	0.000405	0.01015	-0.0555	0.0684	0.000591	0.00010
Nasdaq	D	1960	0.000664	0.01215	-0.0690	0.0707	0.000707	0.000157
VIX – Volatility Index	D	1302	0.002346	0.07765	-0.2138	0.4933	0.004222	0.00603
Section C: Financials								
T-Bond 30yr	D	2014	0.000114	0.00730	-0.0271	0.1039	0.000419	0.00005
T-Note 10yr	D	1989	0.000029	0.00378	-0.0216	0.0360	0.000218	0.00001
US Dollar Index	D	1985	0.000099	0.00524	-0.0270	0.0239	0.000231	0.00003
Section D: Macroeconomic News								
D1:Industrial indicators								
Business Inventories	M	94	-5.5E-20	0.00228	-0.006	0.006	0.0006175	5.2E-06
Core Durable Goods Orders	M	93	-0.00255	0.01423	-0.043	0.059	0.0029300	0.000200
Durable Goods Orders	M	94	-0.00017	0.02681	-0.082	0.151	0.0055220	0.00072
Factory orders	M	94	0.000202	0.00628	-0.018	0.016	0.0012872	3.9E-05
Industrial Production	M	94	-0.0007	1.6E-05	-0.014	0.008	0.00082	1.6E-05
Manufacturing PMI	M	94	0.2968	1.8055	-5.1	3.8	0.3698	3.259
Non-Manufacturing PMI	M	94	0.1925	1.7678	-4.6	4.1	0.3621	3.125
D2: Real estate indicators								
Existing Home Sales	M	93	11.613	223.76	-920	480	46.08	50070
New Home Sales	M	93	-1.624	40.84	-150	96	8.41	1668
Pending Home Sales	M	94	0.00107	0.04394	-0.175	0.113	0.0090	0.00193
D3: Jobs market indicators								
Initial Jobless Claims	W	406	0.224	17.11	-73	74	1.669	293
Non-Farm Payrolls	M	94	-2.287	64.1	-126	176	13.12	4104
Unemployment rate	M	94	-0.00045	0.00155	-0.006	0.003	0.00032	2.4E-06
D4: Inflation, Retail, GDP indicators								
Core Consumer Price Index	M	93	-8.6E-05	0.00085	-0.003	0.002	0.00018	7.3E-07
Consumer Confidence	M	93	0.303	5.294	-10.5	13	1.084	28.03
Consumer Price Index	M	93	-0.00021	0.00118	-0.003	0.0030	0.00024	1.39E-06
Core Retail Sales	M	94	-0.00048	0.00449	-0.018	0.0014	0.00092	2.1E-05
Gross Domestic Product QoQ	M	93	-0.00026	0.00488	-0.014	0.024	0.00100	2.4E-05
Producer Price Index	M	93	-1.1E-05	0.00378	-0.011	0.010	0.00078	1.4E-05
Retail Sales	M	93	-0.00050	0.00437	-0.015	0.009	0.00090	1.9E-05

figure. The largest Pearson coefficient is between Brent oil and WTI which is expected as historically, those two oil benchmarks closely follow each other on world markets. The second correlation result is for the Producer Price Index, as the only macroeconomic index with statistical significance to impact oil on a daily basis (p-value below 0,05). The third correlation is between GDP (Quarter to Quarter) and WTI. As found in numerous studies, especially ones made by Datta (2016), the GDP index is considered to be a postponed indicator of econ-

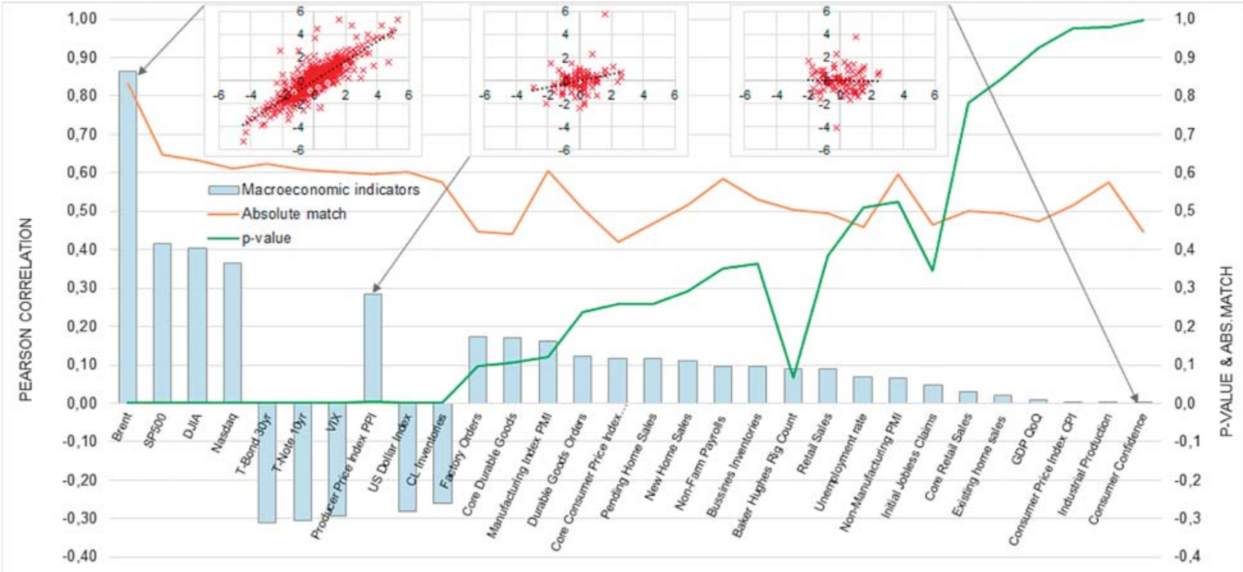

Figure 6: Pearson correlation and p-value for analysed indicators linked to daily changes in crude oil

omy status, and therefore it is to be expected to have the lowest statistical impact on the daily changes of oil.

5. Conclusion

In a volatile economy environment, which was the case for almost a decade after the world crisis of 2008/2009, oil prices were more correlated to the overall stock market movement and economic indicators than in the pre-crisis era. This is especially the case since the development growth of domestic tight oil resources started in the last ten years. From analysis presented in Fig. 6, it can be clearly seen that the WTI oil price is highly dependent upon major stock market indexes in the USA. All three main indexes; Dow Jones Industrial (DJIA), technology index NASDAQ and Standard& Poor's 500 largest companies index, show good correlation between the WTI price with the Pearson correlation coefficient of ~0,40 and with a p-value close to zero. When looking at the coefficient R-squared as a statistical measure of the percentage of the response variable variation that is explained by a linear model, it could be perceived that around 15% of the daily oil price movement could be solely explained by movement in major market indexes. When looking into 20 chosen macroeconomic indicators, the only indicator that could satisfy the statistical significance of the p-value <0,05 condition is the Producer Price Index (PPI) on month-to-month data. The official definition of PPI is that it measures the change in the price of goods sold by manufacturers and it is the leading indicator of consumer price inflation, which accounts for the majority of overall inflation. On scheduled days when this indicator is released, it could be argued that 8% of oil price daily movement is closely tied to the news surprise factor of the PPI value. The entire analysis shows that the daily oil price movement is dependent on many factors, including supply and demand news, economy indicators, fiscal policy decisions and geopolitical news. As investigated by many authors before, on a long-term regression, oil price is closely linked to the USA and overall world economy conditions.

6. References

Andersen, T.G., Bollerslev, T., Diebold, F.X., Vega, C. Micro effects of macro announcements: Real-time price discovery in foreign exchange. American Economic Review, Vol.93, No.1, p.38-62, 2003.

Andersen, T. G., Bollerslev, T., Diebold, F. X., Vega C. Real-Time Price Discovery in Stock, Bond, and Foreign Exchange Markets. Journal of International Economics, Vol.73, No.2, p.251-277, 2007

Beechey, M.J., Wright, J.H. The high-frequency impact of news on long-term yields and forward rates: Is it real?. Journal of Monetary Economics, Vol.56, No.4, p.535-544, 2009.

Data, D., Johannsen, B. K., Kwon, H., Vigfusson, R. J. The correlation of Oil and Equity Prices: The role of Zero Lower Bound. Closing conference of the Bank for international settlement CCA Research Network, The commodity cycle: macroeconomic and financial stability implications, Mexico City, 18-19 August 2016, pp.51

Curtis T. US shale oil dynamics in a low price environment. The Oxford institute for energy studies, OIES paper: WPM 62, ISBN: 978-1-78467-043-6, 2015, pp.51

Domanski, D., Kearns, J., Lombardi, M., Shin, H. S. Oil and debt. Bank for international settlements - BIS Quarterly Review, March 2015, pp.11

Flores C.P., Holditch S.A., Ayers W.B. Economics and technology drive development of unconventional oil and gas reservoirs: lessons learned in the United States. Society of

Petroleum Engineers, Annual Technical Conference and Exhibition, Denver, USA, 2011, pp.16

Kallemets, K. Economic Sustainability of Estonian Shale Oil Industry until 2030, Oil shale, Vol.33, No.3, p.272-289, 2016

Karasalihović-Sedlar, D., Barbir, G., Brkić, V. Types of fiscal regime in hydrocarbon exploration and production, Rudarsko-Geološko-Naftni Zbornik, ISSN 0353-452, Vol.32, No.1, 2016. pp.45-53

Kilian, L., Vega, C. Do energy prices respond to us macroeconomic news? A test of the hypothesis of predetermined energy prices. The Review of Economics and Statistics, Vol93, No.2, MIT Press, p.660-671, 2011.

Kleinberg, R. L., Paltsev, S., Ebinger, C. K., Hobbs D., Boersma, T. Tight Oil Development Economics: Benchmarks, Breakeven Points and Inelasticities. MIT Center for Energy and Environmental Research, August 2016,

Maugeri, L. The shale oil boom: A U.S. phenomenon. Discussion Paper 2013-05, Harvard Kennedy school: Belfer center for science and international affairs, pp.66, 2013.

U.S. Energy Information Administration. Drilling productivity reports. Washington: U.S. Department of Energy, 2016, http://www.eia.gov/petroleum/drilling/

U.S. Energy Information Administration. Trends in U.S. oil and natural gas upstream costs. U.S. Department of Energy, DT007965, CO Task Assignment Definitization Letter FY2015 #4, 2016, pp.141

Bloomberg Intelligence Report 2016: https://www.bloomberg.com/professional/blog/break-even-model-cracking-the-shale-enigma/

SAŽETAK

Razvoj nekonvencionalnih naftnih resursa u SAD-u s aspekta eksploatacijskih troškova i utjecaja makroekonomskih indikatora u volatilnom cjenovnom razdoblju

Ubrzani razvoj nekonvencionalnih ležišta nafte u SAD-u započeo je 2010. godine, uz naredno petogodišnje razdoblje sa stabilnim i relativno visokim cijenama nafte na tržištu. Tijekom toga relativno kratkoga perioda ekspanzije došlo je do znatnijih promjena u kapitalnim i operativnim troškovima zbog neprestanoga tehnološkog napretka u bušenju i opremanju, rastu pratećega naftno-servisnog sektora te povoljnijega financiranja projekata uz državnu politiku monetarnoga popuštanja. U radu su analizirani trendovi u troškovima razvoja nekonvencionalnih ležišta te ovisnost kretanja cijene nafte (WTI – West Texas Intermediate) o intenzitetu broja aktivnih bušotina i ukupnim proizvodnim kvotama s najvećih ležišta nekonvencionalne nafte. Nakon svjetske financijske krize iz 2008./2009. ekonomski oporavak u SAD-u bio je donekle usporen, što je uzrokovalo ekstremnu volatilnost na dioničkim i robnim tržištima. U takvim nesigurnim uvjetima dnevna kretanja cijena nafte te vrijednosti dionica i roba pokazuju znatno reagiranje na periodične izvještaje o promjenama glavnih makroekonomskih indikatora kao glavnih pokazatelja trenda ekonomskoga oporavka. Prije nego što državne institucije objave takve izvještaje, postoje i predviđanja vrijednosti indikatora temeljem anketa među ekonomskim analitičarima i očekivanim trendovima. Stoga, bilo kakvo pozitivno ili negativno iznenađenje prilikom objave stvarnih podataka u odnosu na predviđeno utječe na dnevno kretanje cijene nafte. U ovome radu statistički su analizirani utjecaji takvih promjena u makroekonomskim indikatorima na dnevnu završnu cijenu nafte te utjecaj ostalih važnijih burzovnih indeksa u SAD-u. Analiza je pokazala da od makroekonomskih indikatora najveći utjecaj na dnevne pomake u cijeni nafte ima indeks industrijskih proizvođačkih cijena (PPI – Producer Price Index) kao temeljni indeks pokazatelja inflacije.

Ključne riječi
nekonvencionalni naftni izvori, makroekonomski indikatori, burzovni indeksi