DEVELOPMENT OF UNCONVENTIONAL OIL RESOURCES IN A LOW PRICE ENVIRONMENT : WHAT STRATEGY ?

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ABSTRACT

The shale revolution has reduced the US oil dependency by 2.This influx caused a collapse of prices with a significant impact on development activities. Yet, shale production has proved to be resilient with a slow and delayed decline compared to the dramatic reduction in drilling and fracturing.

Using an in-house model, Total inferred that shale oil resilience relies on : (1) large portfolio of wells (2) improvement in operational efficiency (3) increase in reserves per well boosted by completion technology and identification of sweet spots. Maintaining a production plateau requires a "critical activity" that declines with the number of wells and technology improvements. Consequently, the critical activity at the end of a development can be 5 to 10 times less than during the ramp-up phase.

The model was used to assess the resilience of two major American oil plays: Bakken and Eagle Ford. Using the past well schedule, the actual production history has been matched by calculating the best decline curve per well. The economic resilience of the plays has then been assessed by extending the production period over 5 years (2015-2020) in a durable weak oil price environment and using three different strategies.

The model highlights that when oil prices are high, the resources need to be developed at a fast pace to feed a well portfolio paid by a fast return on investment. In case of decrease in prices, the portfolio will rest on a declining or a moderate development strategy to maintain profits. Thanks to the flexibility of the means (rapid mobilization and demobilization of rigs), the development can be resumed as soon as prices recover.

However, a systematic "stop and go" strategy can be damaging to human resources and loss of skills. Consequently, reducing breakeven prices through technology remains the best guarantee to perpetuate the economic efficiency.

INTRODUCTION

Between 2008 and 2015 the US liquid (oil+NGL) production has almost doubled, from 6.8 Mbopd to 12.8 Mbopd. In less than ten years, the US has reduced its oil dependency by half. This dramatic ramp-up has been dubbed "***the shale revolution***". In late 2015, shale crude & NGL (4.5 Mbopd + 1.5 Mbopd) accounted for nearly half of US liquid production (**Figure 1**).

The three "*champion*" formations are Bakken (North Dakota), Eagle Ford (Texas) and Permian (Texas/New Mexico).

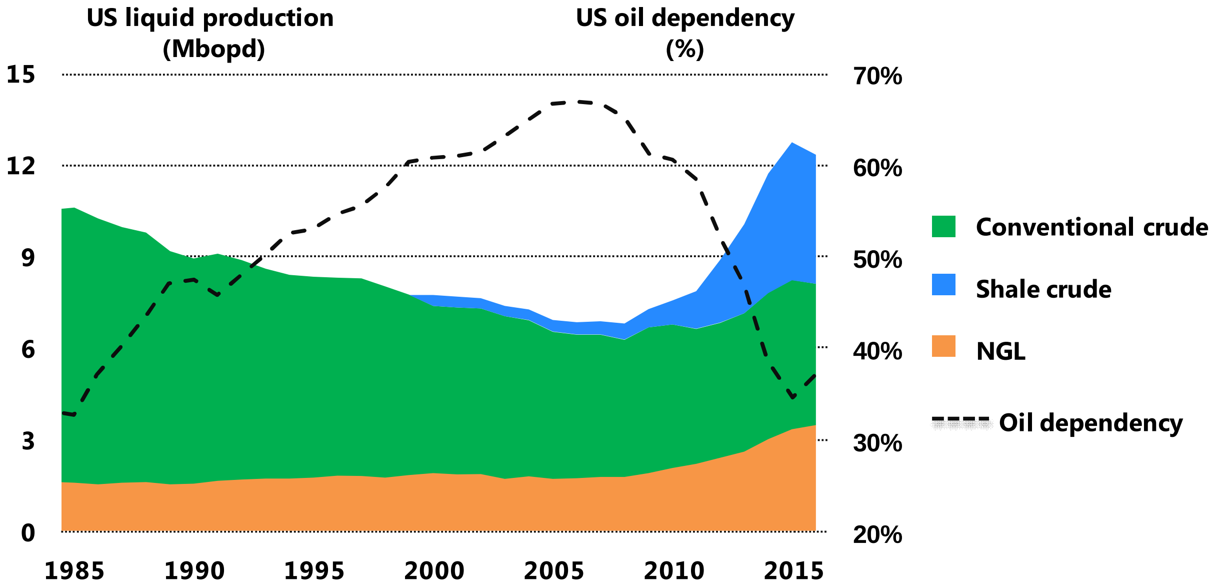


Figure 1 – The dramatic shale oil ramp-up US oil dependency
Data source: BP energy outlook 2016 and EIA

A major consequence of this unexpected supply was its impact on oil prices, which started to decrease at the end of 2014 after nearly 15 years of continuous growth.

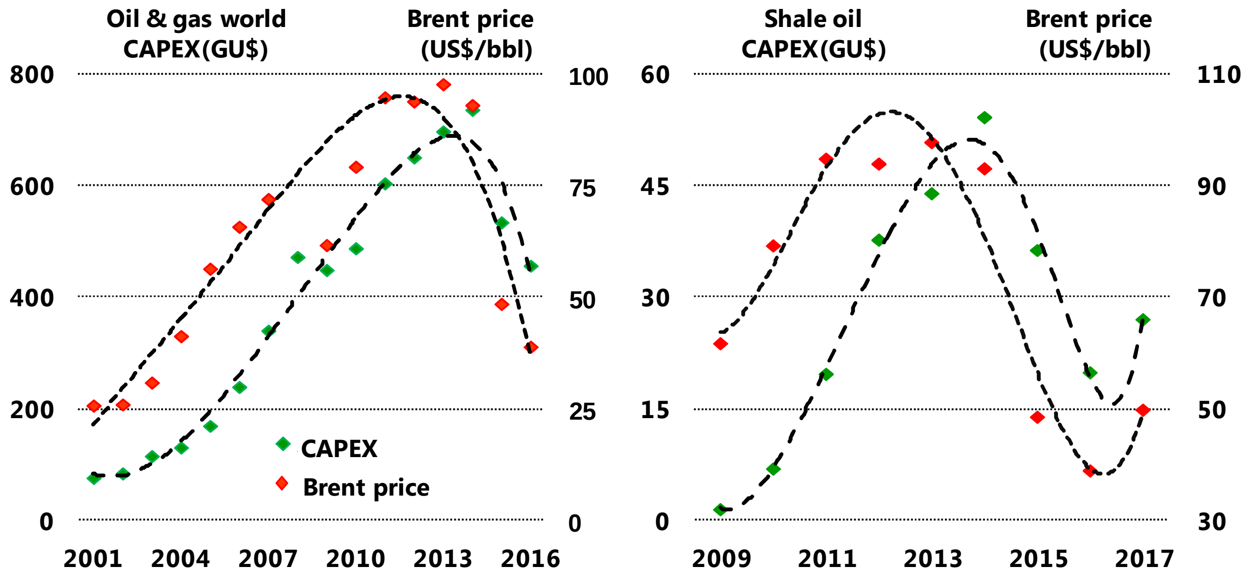


Figure 2 - Oil price and reduction in oil & gas world CAPEX
Oil price and reduction in shale oil CAPEX
(Data source: BP energy outlook 2016, Wood Mac Kenzie)

Following the OPEC's decision not to reduce its quotas, they reached a low point at less than 30 US$/bbl in January 2016. As a result, world oil & gas CAPEX that had been constantly growing since 2000, were dramatically reduced by 46% from 738 GUS$ in 2014 to 458 GUS$ in 2016 (**Figure 2** - left). According to Wood Mackenzie[1], 380 GUS$ of green projects (average 62 US$ breakeven) have been deferred.

Even though deep water activity suffered the greatest blow, shale oil activities did not escape the large cut in investments[2]. After a peak in 2014, shale CAPEX were reduced by more than 50% in 2015 and 2016 (**Figure 2** – right).

Many analysts then forecast a shale oil speculative bubble, and predicted that the dramatic decrease in development activities would induce a rapid and significant drop in production. This argument was based essentially on the fact that shale wells decline fast and produce roughly 80% of their ultimate reserves over a three to four-year period. In spite of the fact that US production has slightly decreased over the last two years, it has managed to withstand the reduction in activity, and remains at a level of around 12 Mbopd (**Figure 3**). This high production level relies mainly on two drivers: resilience and flexibility.

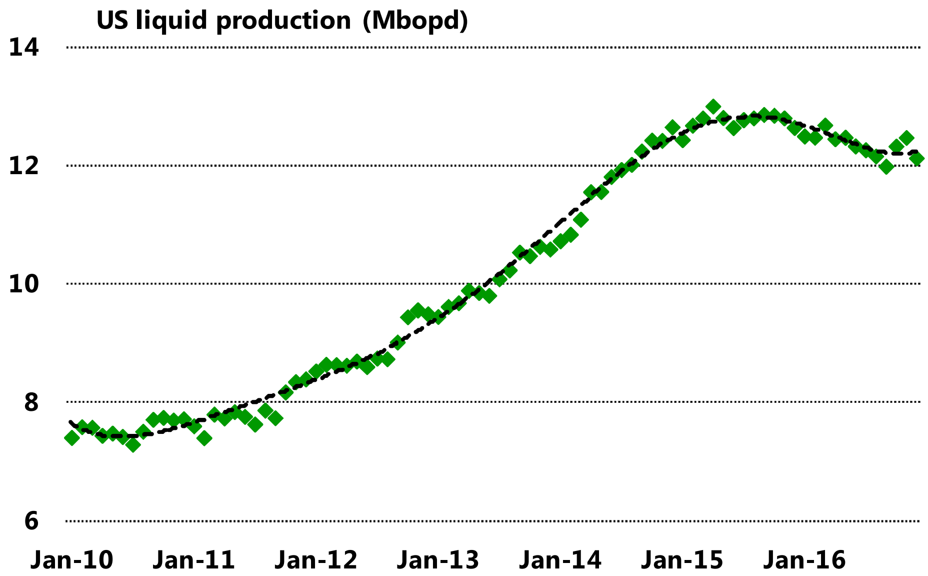


Figure 3 – US liquid production 2010 - 2016
(*Data source: EIA and BP energy outlook 2016*)

A previous paper[3] investigated the technical aspects of resilience of shale gas production in three major US plays (Barnett, Marcellus, and Haynesville). The present paper focuses on shale oil production in the Bakken, Eagle Ford and Permian plays and includes economic and human resources factors in the analysis. The flexibility of shale oil development is also discussed in light of the inventory of drilled but uncompleted wells. Concluding remarks outline expected consequences on oil prices.

[1] A. Andlauer (2016) "*Shale oil & Saudi to drive oil market until 2019*" Alpha Value Report, September 2016
[2] The Shale CAPEX presented in Figure 2 are those from Bakken + Eagle Ford + Permian.
[3] P.A. Charlez & P. Delfiner (2016) "*Resilience of the US shale production to the collapse of Oil & Gas Prices*» URTeC 2439429 San Antonio Texas, USA, 1-3 August 2016

SHALE OIL RESILIENCE

In physics, resilience is the ability of a body to suffer impacts or change and yet resume its initial structure. In psychology, it refers to the ability of an individual to bounce back after negative or traumatic experiences, and adapt to continue developing despite adversity. Resilience must be understood here as the ability of shale oil production levels to remain stable or just slightly decrease when confronted with a dramatic reduction in drilling and fracturing activities (which for shale represent between 80% and 90% of the CAPEX).

Shale oil resilience is clearly demonstrated in **Figure 4**. After the 2014 collapse in oil prices, drilling activity was reduced dramatically, from a peak of 1,550 rigs in August 2014 to just 300 rigs in May 2016. During the same period however, shale oil production dropped by just 11%, from a peak of 4.6 Mbopd in May 2015 to 4.1 Mbopd in January 2017. The decline is however not homogeneous across the three major plays, with a 28% increase in the Permian compared with a 26% decline in the Bakken and a 41% decline in the Eagle Ford. Below is an analysis of the main factors that could explain the resilience of a shale play from technical, economical and human standpoints.

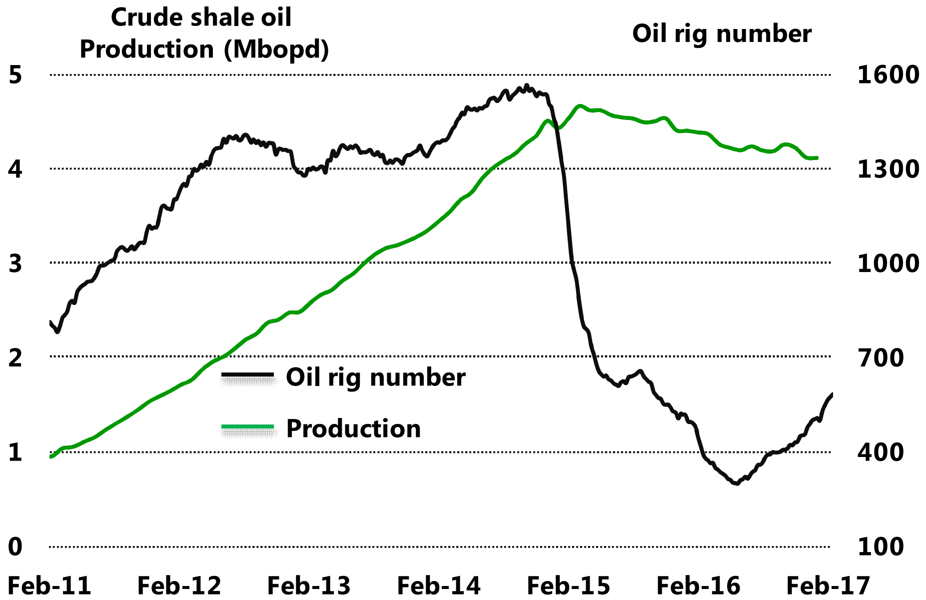


Figure 4 – Resilience of shale oil production faced with the dramatic reduction in development activities.
(Data source: EIA and Baker Hughes)

Technical resilience factors – The concept of critical rig count

In order to highlight and better understand the technical resilience factors of an unconventional play, Total developed a specific model called UFD^{sim} (**U**nconventional **F**actory **D**evelopment **sim**ulator), which has already been presented in other papers[4]. It calculates the development of a shale core area by assessing the required development schedule (i.e.

[4] P.A. Charlez and P. Delfiner (2016) "A Model for Evaluating the Commerciality of an Unconventional Factory Development Outside North America" SPE 179735 in SPE Economics & Management

number of wells to be drilled, fractured and connected) in order to reach and maintain a production plateau.

A hypothetical case is presented in **Figure 5**. It aims to produce a 1000 km^2 core area over a 30-year period, from a portfolio of 1,000 wells, each draining 1 km^2. The ultimate goal is to achieve and maintain a plateau of 75 kbbls/day for 17 years, and then let it decline until the end of the 30-year production license. Each well produces according to a similar decline curve (average "*iso-Bakken*" with 85% decline over the 3 first years and an EUR of 664 kbbls). The study highlights three main factors that explain the resilience of the well portfolio.

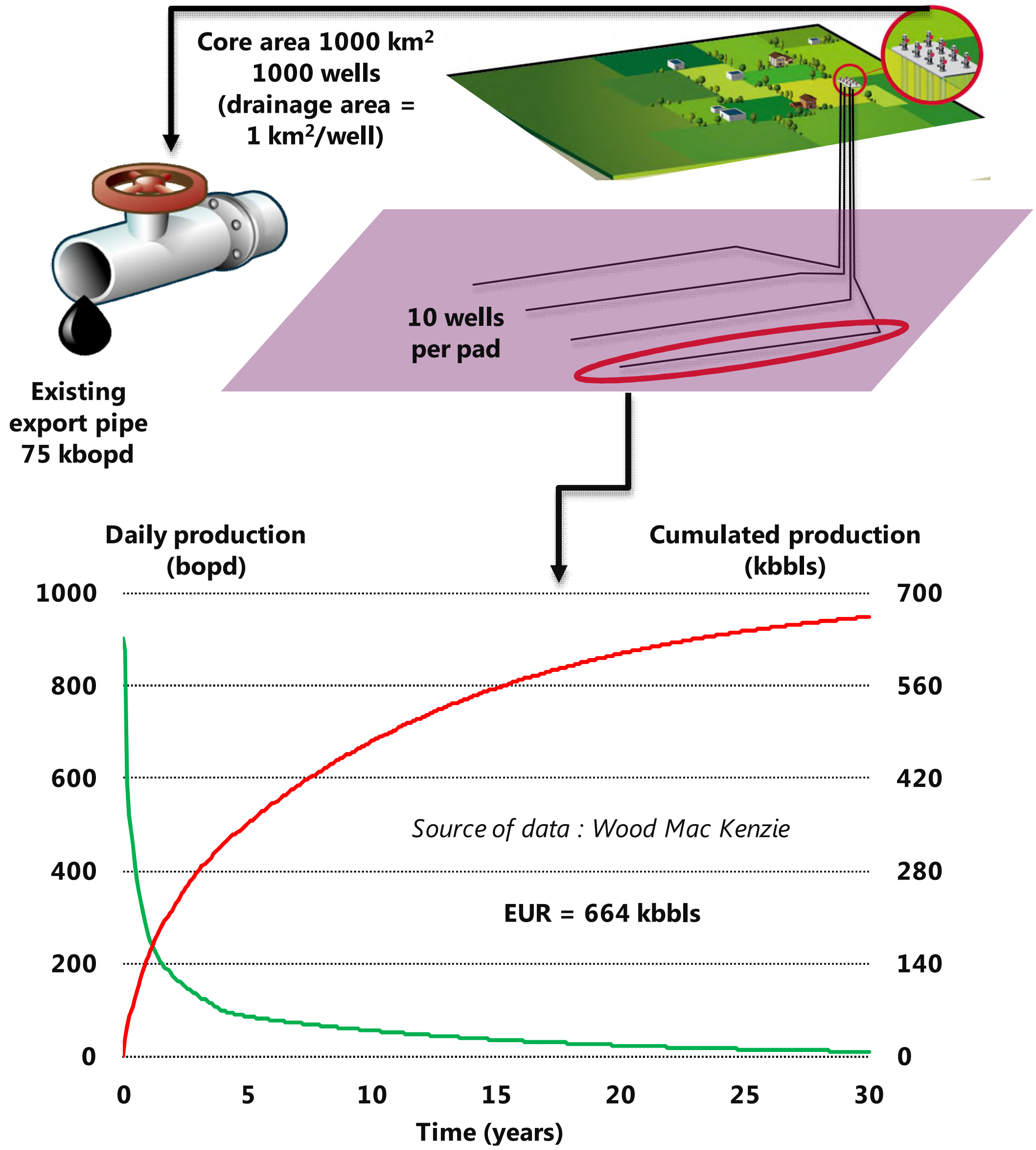


Figure 5 – Simulation of a notional development of 1000 wells to keep a production plateau of 75 kbbls/day
(Data source: Wood Mackenzie)

Resilience factor 1: well portfolio
As shown in **Figure 6,** the 75 kbopd plateau is reached after 3 years using 12 rigs. However, the number of rigs required to maintain the plateau (called the "***critical rig count***") significantly decreases with the number of wells already put on stream. At the end of the development phase, 4 rigs are sufficient to maintain the plateau. When the 1,000 wells have been drilled and completed, production declines. Over the 10-year decline period, it drops to a third of its initial value. The production of a large portfolio of wells drilled at different maturities is therefore highly resilient when compared to that of an individual well, and therefore acts like a '*shock absorber*'.

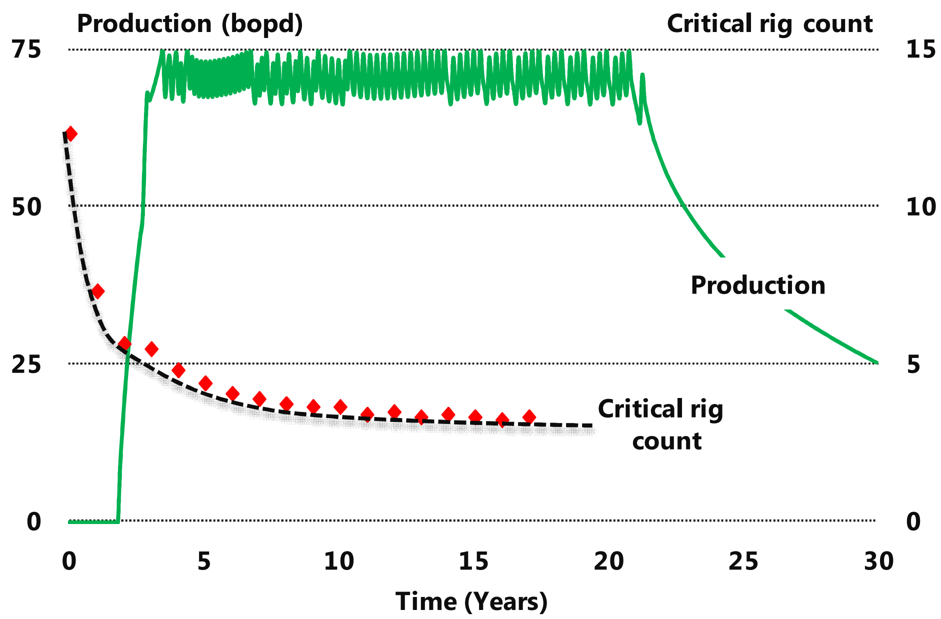


Figure 6 – Simulation of a hypothetical development of 1,000 wells with a 75 bopd plateau (*Data source: UFD^{sim}*)

Resilience factor 2: operational performance
Apart from the number of wells, the drilling and completion times (i.e. operational efficiency) appear as a second resilience factor.

Improving operational performance feeds the well portfolio more quickly and reduces the critical rig count at a faster rate. Two simulations using 30 days and 10 days of drilling time are presented in **Figure 7**. The results show that for the 30-day period, 12 rigs are initially required to maintain the 75 kbopd plateau (case in **Figure 6**), and at the end of the development, three rigs are still needed. For the 10-day period, the initial critical rig count drops to six rigs and the final one to two rigs.

Resilience factor 3: production performance and EUR
Unlike conventional reservoirs, unconventional plays are very large heterogeneous objects that can extend over tens of thousands of km^2. Being able to identify high-potential areas (called "*sweet areas*"), reduces the number of out-of-target wells, mechanically increases the reserves per well, and therefore the resilience. Improving production performance and ultimate recovery also relies on completion design. It includes length of the horizontal

section, the number and size of fracturing stages, the fracturing fluid and proppant optimization.

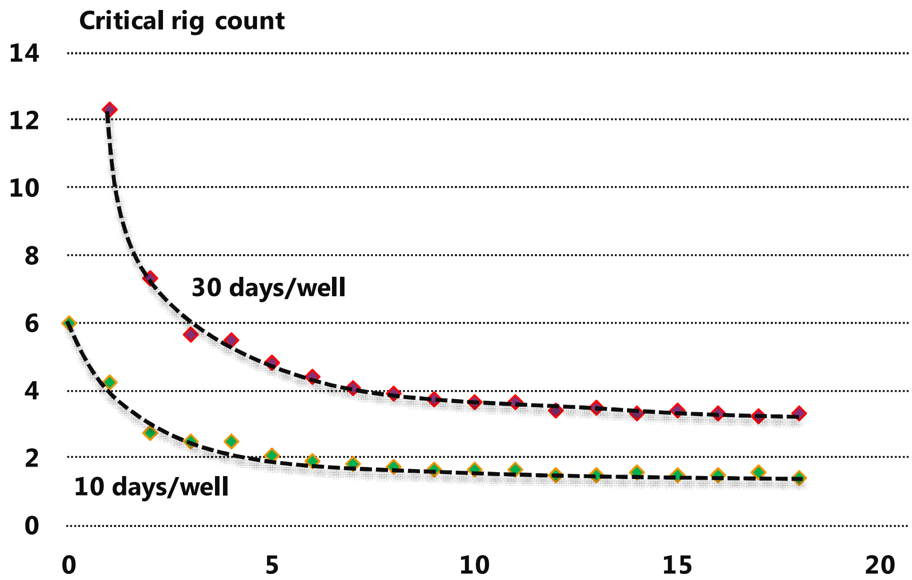
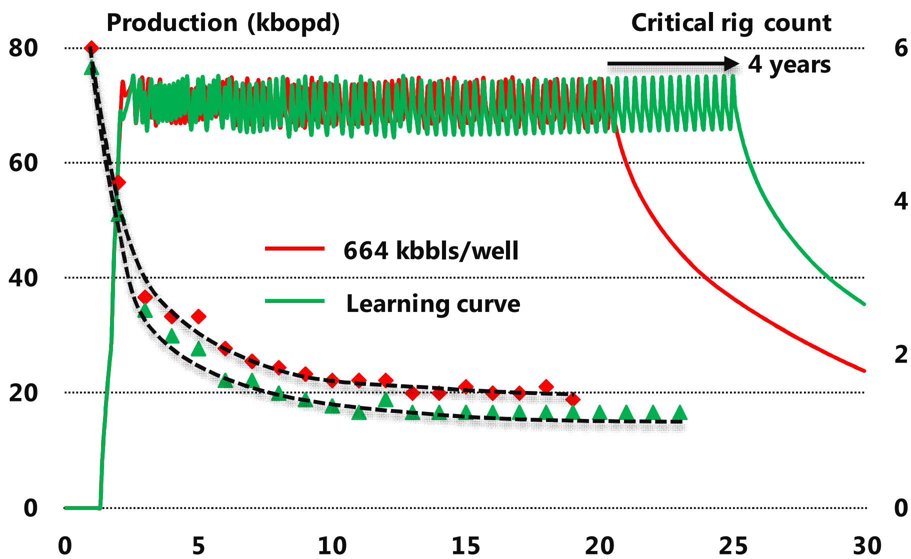


Figure 7 – Comparison of critical activity for two different drilling periods
(Data source: UFD^{sim})

In the UFD^{sim} model, this dual objective is achieved by introducing a “production learning curve”, switching from the initial well decline curve to a more productive one, after completing a certain number of wells.



From	to	EUR (kbbl)
1	10	664
11	40	741
41	100	808

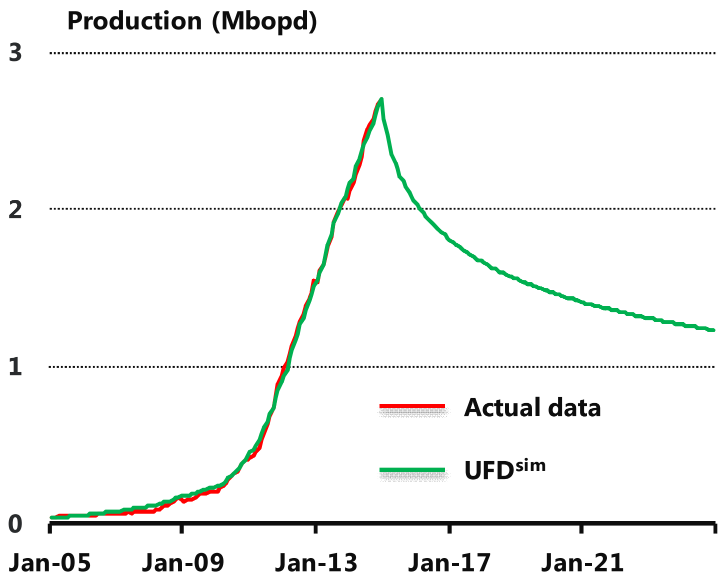
Figure 8 - Simulating a notional development of 1,000 wells using a production learning curve *(Data source: UFD^{sim})*

The simulation in **Figure 8** was achieved by considering that the first 100 wells produce 664 kbbls, the next 300, 741 kbbls and the remaining 600, 808 kbbls. Despite limited progress (ultimate reserves per well are improved by only 20% over the entire development period), the production plateau is extended over four years with a moderate impact on the critical rig count. Identification of sweet areas and improvement of the completion design is therefore a third factor of resilience.

Of the three (size of well portfolio, operational performance and production performance), production performance is the most effective.

Resilience of US oil shale plays

The resilience of the two mature shale oil plays (Bakken and Eagle Ford) was simulated using the UFD^{sim} model. The production and development history (number of wells put on stream every month) were recovered from the ITG database. Production was then history matched until the end of 2014 using a least squares algorithm and wells were put on stream according to the development history. Each well is supposed to produce according to an average decline curve of the power-law type. Both parameters of the decline curve were used to history match production.



Date	Decline
2015	27%
2016	12%
2017	9%
2018	7%
2019	5%
2020	5%
2021	4%
2022	4%
2023	3%
2024	3%

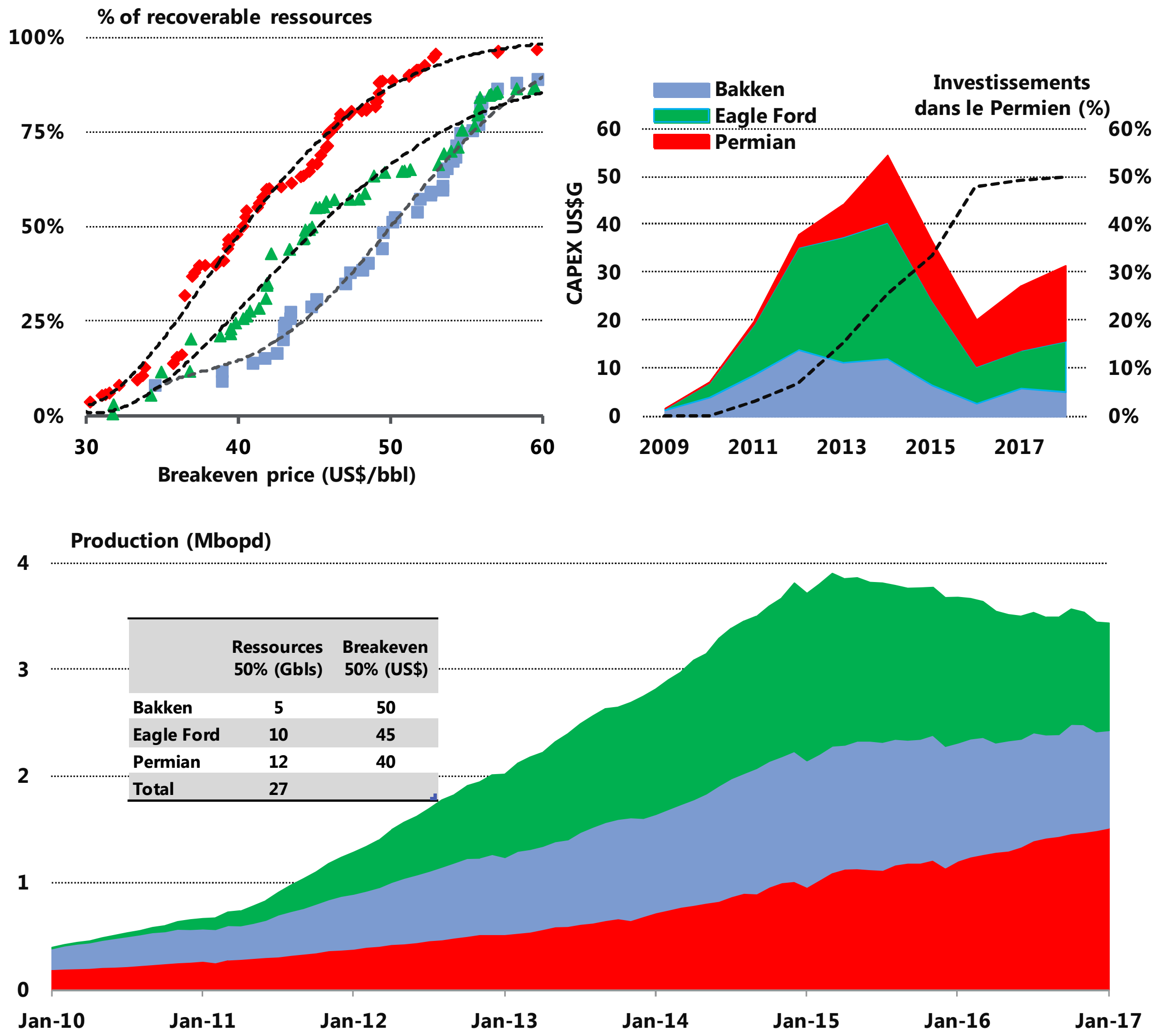
Figure 9 - Aggregate production Bakken + Eagle Ford 2005-2014. Decline curve "no activity"
Data source: ITG and UFD^{sim}

Comparisons between actual and simulated production from aggregate shale plays show a remarkable history match (**Figure 9**). Quality control between calculated and actual EUR is also excellent for both plays, indicating that the calibration method is extremely robust. To test the resilience of the existing portfolio, a production decline over the period 2015 to 2025, assuming "*no development activity*" (i.e. no new wells brought into the portfolio) has been simulated.

As shown in **Figure 9**, although the initial decline (27% the first year) with "no wells added" is high, the production becomes fairly resilient after several years. Globally, the model highlights that without any development, the aggregate production would be halved over the period 2015 to 2025. As observed experimentally, the Bakken play is more resilient than Eagle Ford.

Economic resilience factors

In addition to operational efficiency, the massive improvement in shale economics is also a strong resilience factor.



	Ressources 50% (Gbls)	Breakeven 50% (US$)
Bakken	5	50
Eagle Ford	10	45
Permian	12	40
Total	27	

Figure 10 – Breakeven price, investments and production history for the three main oil plays.
(Data source: Wood Mackenzie)

In 2013, the breakeven oil price in the Bakken was US$70, dropping to US$50 in 2016. Close to US$80 in the Eagle Ford play in 2013, it now hovers around the US$45 mark. In the Permian, the 50% breakeven corresponding to 50% of the recoverable resources in 2016 was around US$40 (**Figure 10**) making the Texan/New Mexico play a new shale oil Eldorado. So the three "shale oil champions" have the potential to produce 27 Gbbls for less than US$50. "*While North Dakota still has a low activity, development in Permian is crazy, like when oil prices were at US$100/bbl*"[5]. At the end of 2016, investments in the Permian represented 50% of the CAPEX for the three big shale plays (**Figure 10**), more than 50 fracking crews were operational on the different sites, salaries and service costs have increased by 30% since mid-2016 and all housing is 100% full.

This explains why the Permian should be the main source of US shale production resilience over the next three years. The impressive ramp-up (**Figure 10**) should easily compensate the decline in Bakken and Eagle Ford where investments will remain moderate. However, although efficiency and technology will still lower the breakeven price by 5% per year for the next three years, more stringent environmental regulations (non-flaring policy, recycling water) could also increase the breakeven.

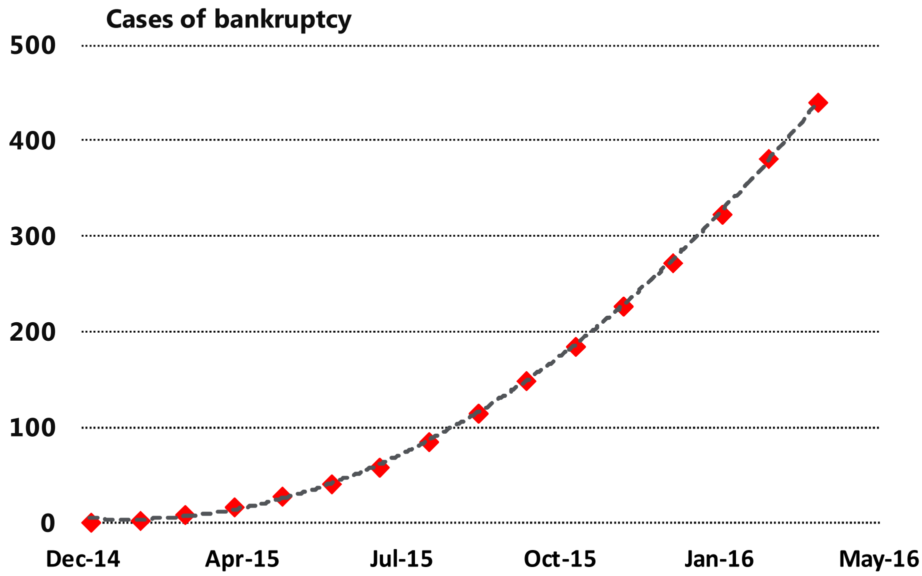


Figure 11 – Cases of bankruptcy
(Source: Haynes & Boon)

Could however the access to capital be a 'counter resilience factor' to further development? Will the money flow back in easily after the exponential increase in cases of bankruptcy in 2015 and 2016, leading to a US$200G 'debt at risk' (**Figure 11**)? Will the banks start to finance the projects again, thereby restarting the activity? Even if the debt emitted[6] on the market was reduced from nearly US$10G during the first quarter of 2015 to less than US$1G during the last quarter, in 2016 the emitted debt rose again, boosted by activity in the Permian play. Instead of direct loans, the banks were pushing companies to hedge with private funds by using bonds. Given the potential of the Permian play, the lower breakeven prices and current oil prices, there should be no shortage of capital and shale resilience should not be affected. The capital invested in the basin should be enough for US shale oil production to grow by 2 Mbopd by the end of 2018.

[5] A. Andlauer (2017) "Permian to challenge OPEC by H2 2017" AlphaValue publication
[6] Source Haynes & Boone

Human resilience factors

Compared with other sectors, the Oil & Gas workforce suffers from the cyclic activity that varies with the barrel price, resulting either in mass recruitment (activity increases with barrel price) or in sudden, drastic cuts, wiping out thousands of jobs (activity decreases with barrel price) particularly in service companies (drilling, well activities, engineering companies). The 1986 crisis (half of the jobs were axed over a ten-year period) was perceived in a particularly negative light (**Figure 12** – left). The sharp increase in the barrel and the strong regain in activity after 2000 was not enough to motivate people, as was the case in the second half of the seventies. This phenomenon is now considered as the main cause of the "peak old" in the oil industry[7]. Will the same phenomenon occur in the US? The shale revolution created 60,000 jobs between 2007 and 2014, but 25,000 of these positions have already been axed since the beginning of 2015 in the wake of the oil price collapse (**Figure 12** – right). It would seem however, that the boom in the Permian did not curb the trend completely, as was the case in the mid-1980s. But what is valid in the US, where the labor market is extremely responsive, is not necessarily applicable to conventional activities outside the US, where massive job cuts were also made. Conventional non-US activity could suffer a much greater impact owing to the lack of human resources in the event of a barrel price rebound.

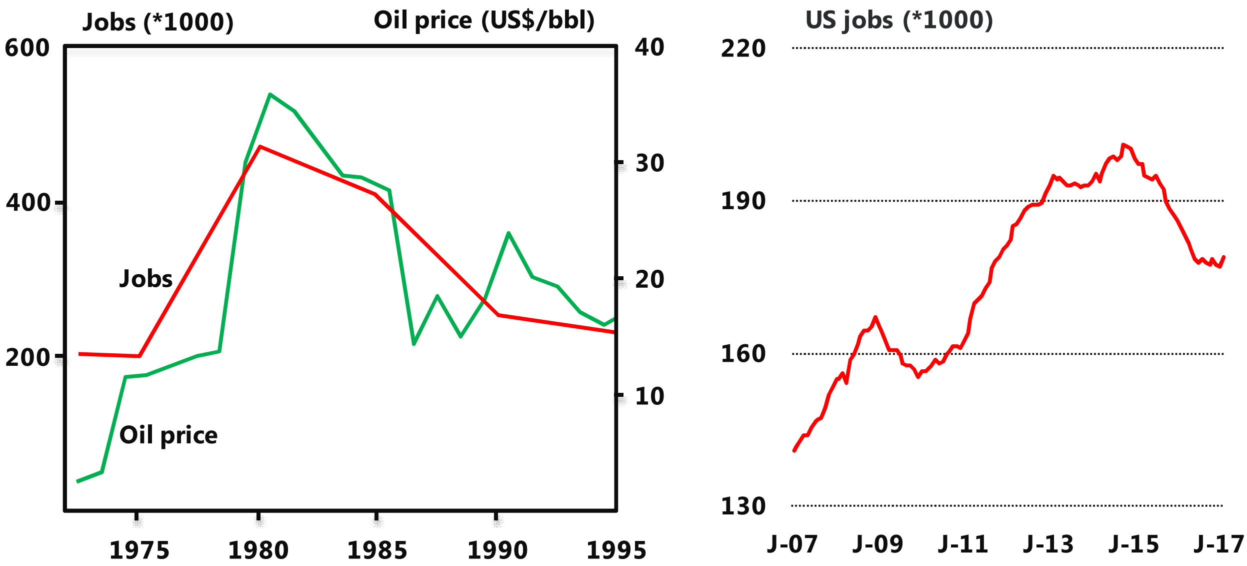


Figure 12 – Consequences of counter oil shock on oil & gas jobs[8]
Oil & gas jobs in the US in 2007[9]

FLEXIBILITY OF SHALE OIL DEVELOPMENT

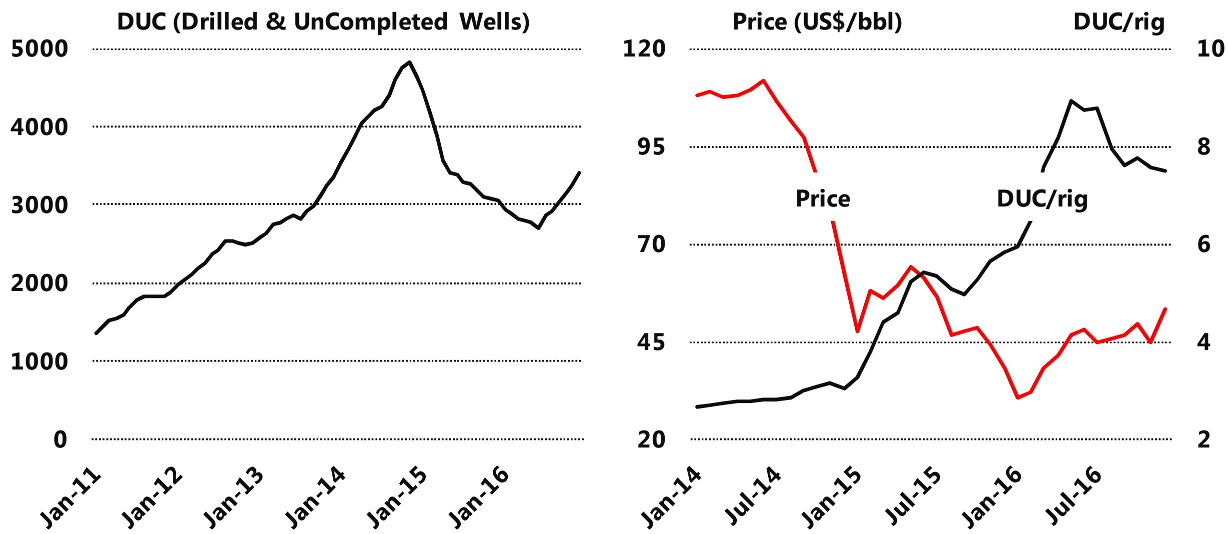
In addition to resilience, another characteristic of shale oil is its great flexibility. Shale development requires few material resources (drilling rigs and fracturing fleets) which are widely available in the US as 80% of the world drilling fleet operates in North America. They

[7] Ph.A. Charlez (2014) "Our Energy Future Is Not Set In Stone" Ed. Technip Chap VI
[8] C. Sbiti (2004) "*Developing human Resources for the Future Oil & Gas Industry*" SPE-10162
[9] https://data.bls.gov/timeseries/CES1021100001?data_tool=XGtable

can be put on stand-by and restarted almost instantaneously, thereby affording a rapid response to variations in oil prices.

As clearly highlighted in **Figure 4**, when oil prices collapsed at the end of 2014, activity was reduced by more than 50% in just a few months (from 1,500 rigs in mid-December 2014 to 750 rigs at the beginning of April 2015) and, at the end of 2016 when prices began to rise again, activity rapidly resumed (300 rigs at the end of May 2016 to 600 rigs at the end of February 2017[10]).

The flexibility of shale development has also been demonstrated by the possible separation between drilling and fracturing with the possibility of putting drilled wells on stand-by before fracturing (DUC – Drilled but UnCompleted wells). As fracturing accounts for half of the DRILLEX (**Figure 13**), DUC therefore represent an extra degree of freedom.



Activity	Bakken		Eagle Ford	
	GUS$		GUS$	
Drilling	25	39%	44	0
Completion	31	48%	57	0
Other CAPEX	9	14%	14	0
Total	64	100%	0	0

Figure 13 – History of Drilled but UnCompleted wells (DUC)
Data source: Rystad Energy

The DUC history shown in **Figure 13** (left) could however prove misleading insofar as it increased when the oil prices were high (2011 to 2014), decreased after the price collapsed (2015 to mid-2016), and started to increase again once the barrel price had partially recovered at the end of 2016.

The absolute curve of DUCs actually includes two different problems. When oil prices are high, drilling activity is very intensive and the DUCs are the result of a stressed rig availability. On the other hand, when prices are low, both drilling and fracturing activities are

10 Data source: Baker Hughes

reduced. The relevant indicator is therefore the number of DUCs with respect to the number of active rigs. **Figure 13** (right-hand graph) clearly highlights that relative DUCs were low before the end of 2014 and sharply increased after the 2014 price collapse. At the end of 2016, when oil prices recovered, the relative DUCs again gradually began to decrease. DUC can therefore be considered as a second flexibility factor.

Finally, unlike most countries, in the USA, the subsurface belongs to the landowners. This totally private market, in which activity starts and stops according to purely economic considerations without any state intervention, further accentuates the flexibility of the business.

IS SHALE OIL THE NEW SWING PRODUCER?

Before the first oil crisis in 1973, nobody really talked about oil prices. Historically, prices were set by consumer countries and despite an increase in demand of 6% per year the price remained constant at US$2. During the golden sixties, major OECD countries experienced an annual economic growth of 5% owing to an almost free energy source (
Figure 14).

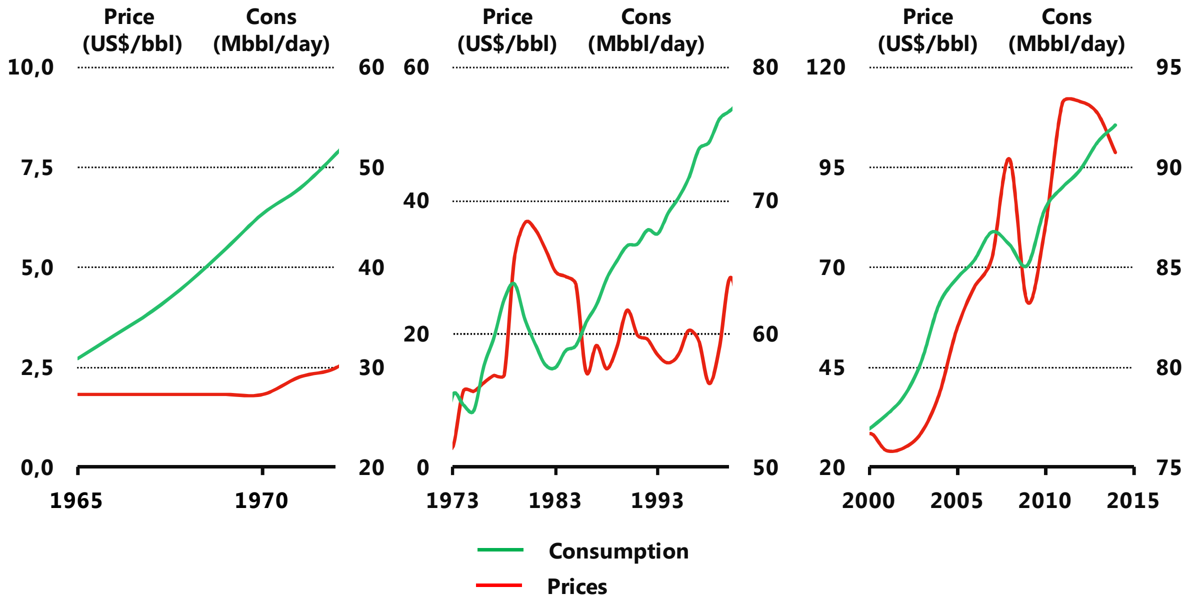


Figure 14 – The three major oil periods
Consumer dominated, Producer dominated, Market dominated
Data source: BP energy outlook 2015

However, as from 1974, producers began to impose higher prices using quotas regulated by the OPEC. In the blink of an eye, growth in OECD countries was eroded, leading to significant public debt and mass unemployment.

Yet producer-dominated period was relatively short-lived. In the early 2000s, owing to the growing demand from emerging countries, the market imposed itself, thereby facilitating a consensus between producers and consumers. Oil therefore became a commodity like any other, and is now subject to the law of supply and demand.

Owing to the resilience and flexibility of shale oil, its massive arrival on the market, shale oil has greatly reinforced this paradigm shift. But will US shale oil take of the role of "swing producer" from the OPEC? Is OPEC really no longer the swing producer? Do we now have two swing producers? What about the impact of the decisions taken by the Organization at its Ministerial Conference on November 30, 2016 after more than two years of inaction despite falling oil prices?[11]

The return of Iran and Libya to the markets could in fact accentuate excess supply and prevent prices from increasing. However, as highlighted before, a further decline in investment could also bring down conventional production in the longer term, to the point of breaking the supply-demand balance and inducing price increases. But given the production rise in the Permian in 2017, most experts consider that oil prices are set to rise slowly[12]. After that, a new decline related to the abundance of supply may then occur.

CONCLUSION

Although the collapse of gas and oil prices had an immediate and dramatic effect on activity levels, production proved to be quite resilient. This resilience can be explained by three main factors: the portfolio effect, improvements in operational performance and progress in sweet area identification and completion design. Regarding the portfolio effect, it is important to realize that the decline of a single well does not represent the decline of a large portfolio of wells that are put on stream at different maturities. As time passes, a growing part of the global production comes from “tail production” and tends to cushion the overall decline. This assumes, of course, that wells are not shut-in before the end of the license, which happens with shale gas but less frequently so with shale oil.

In addition to resilience due to the soft equipment required, the possibility of separating the drilling and fracturing activities (Drilled but Uncompleted wells) and the favorable mining law for landowners in the US the development of unconventional resources in the US is extremely flexible.

The resilience crash test (no new activity over the 2015-2025 period) indicates that the aggregate Bakken & Eagle Ford production strongly declines over the first two years but then rapidly becomes resilient with decline rates of less than 10% per year.

Given its breakeven at US$40, the Permian should however concentrate most of the future activity and allow US oil production to pick up speed over the next three years. This is the reason why shale oil is earmarked as the new swing producer.

[11] F. Perrin (2017) ”Is shale oil the new oil swing producer?” 79th EAGE Conference & Exhibition Paris 12-15 June 2017
[12] A. Andlauer (2017) ”Shale Growth, Trump Are Biggest Oil Wildcards in 2017” Bloomberg brief 27 January 2017