Forecasting new well supply of oil and natural gas

By

Elmira Kalhor, University of New Mexico
Katie Zemlick, University of New Mexico
Janie M Chermak, University of New Mexico

Corresponding author: Elmira Kalhor
University of New Mexico
Albuquerque, NM 87131
MSC 05 3060

Phone: 1-505-277-5304

Email: ekalhor@unm.edu

Abstract

The Oil and Gas Supply Module (OGSM) of the National Energy Modeling System (NEMS) is a forecasting tool that utilizes type curves to estimate the supply of oil and natural gas, disaggregated at the conventional and unconventional levels, by geographic region. The objective of this study is to expand on the OGSM's type curve parameters' estimation model to disaggregate supply of oil from horizontal and vertical new wells by formation. In addition, the production of new wells is disaggregated by the year of completion, which allows mapping production trends over time. This study focuses on New Mexico's Permian and San Juan basins but the estimation framework can be expanded to all onshore plays. Monthly production data for wells drilled between 2001 and 2017 in Permian and San Juan basins are used for this study. On average, natural gas production data from 1,055 wells per year and oil production from 785 wells per year are analyzed. The analysis includes refining and disaggregating production data, and finding optimal type curve parameters using a nonlinear least squares method. In addition to providing a more detailed forecast system, this supply model informs a statewide system dynamics energy water nexus model in New Mexico.

1. Introduction

Production of oil and natural gas is shown to be less elastic to prices than the new well drilling activity . Instead, production varies more closely by physcical attributes of the reserves as well as the production technology (Newell et al. 2016). Estimation of the supply of oil and natural gas is important for energy accounting and long term planning. National Energy Modeling System (NEMS) (EIA 2017) has an Oil and Gas Supply Module (OGSM) that is designed to estimate the supply of oil and natural gas in the United States. OGSM disaggregates production based on the product type (crude oil, and natural gas), type of deposition, method of extraction, or producing formation. Based on the disaggregated production data, Arp's (1945) decline curve analysis is used to estimate monthly production rates for both oil and natural gas.

Building on the OGSM's concept, this study proposes a more detailed disaggregation process. Production data are disaggregated based on the trajectory of the producing wells (i.e. horizontal vs vertical). In addition production data are disaggregated based on the producing wells' completion year. The benefits of this kind of disaggregation are: 1) it enables tracking of production patterns over time; essentially, generating a panel dataset of production decline curves, and 2) it allows understanding of differences between horizontal and vertical extraction technologies specifically in formations that allow both.

2. Data

Data for this study come from multiple sources. Monthly production data are collected from New Mexico Oil Conservation District (NM OCD 2018). Production data attributes include but are not limited to the producing wells' identifying numbers (APIs), producing pools' IDs, year and month of production, production kind (natural gas vs. crude oil), and production amounts (in thousand cubic feet (MCF) for natural gas and barrels (BBL) for oil). Relations between Pools' IDs and formations are made based on USGS' assessment units (Ridgley et al. 2002; Schenk et al. 2008). Wells' trajectory attribute and the wells' completion date (year and month) come from joining API's from the production data and the wells dataset combined by the OCD.

There are about 26 formation in the New Mexico part of the Permian and San Juan basin namely Abo, Artesia, Barnett, Bone spring, Dakota Greenhorn, Delaware, Devonian, Ellenberger, Entrada, Fruitland, Gallup, Grayburg, Leonardian, Lewis, Mancos, Menefee, Mesaverde, Morrow Atoka, Pictured Cliffs, Pennsylvanian, Queen, San Andres, Simpson, Tertiary, Wolfcamp, Woodford (Ridgley et al. 2002; Schenk et al. 2008). Artesia, Barnett, Leonardian, Lewis, and Woodford are not producing according to this datset. Wells completed after 2000 are considered in this study since data collection system by NMOCD was improved after 2000[1].

3. Methodology

Monthly production data recorded during and after 2001 are first dissaggreaged by product type (oil and natural gas), formation, completion year, and well direction (horizontal and vertical), resulting in 854 production timeseries. Decline curve analysis is done similar to OGSM on groups of data. A general hyperbolic function is assumed for the decline curve as shown in Equation 1:

$$Q_t = \frac{Q_i}{(1 + b.D_i.t)^{\frac{1}{b}}} \quad (1)$$

Where

Q_t =production rate in month t,
Q_i =production rate in the initial month t,
b =curvature of the decline curve,

[1] According to conversation with the public records staff at the New Mexico Oil Conservation Division

D_i =initial decline rate,
The production timeline of wells in the same group are adjusted so that the start time is the same. Since these wells are completed in the same year, this means a few months shifting of the production timeline on average. Estimation of the curve parameters are based on non-linear least squares model. For more accuracy, a combinatorial optimization model is used to render the initial decline rate and the curvature at the thousandth decimal place resolution. The optimization model is coded in Matlab. For 854 analysis groups, computation can take up to 40 hours in an average personal computer; computation time was shortened significantly using high performance computing.

4. Results

As mentioned before, there are 854 timeseries for decline curve anlaysis, which means the results are 854 arrays of initial production rate(Q_i), initial decline rate(D_i), and decline curve curvature(b). In order to simplify presentation of the results, the results are discussed in three subsections including dynamic changes in type curves, differences between horizontal and vertical production, and aggregated results. For each section one formation is selected for visualization of the results.

4.1. Dynamic changes in type curves

Figures 1 and 2 show the progress of the horizontal gas production from the Queen formation over time. Figure 1 shows the progression of type curves until 2007. Wells completed to produce from the Queen formation in 2007 had higher production rate throughout their lifetime, compared to wells completed in 2001, and 2006. In fact, the productivity of wells completed in 2007 are above productivity of wells completed prior to 2014, except for those completed in 2010; not all type curves are presented to keep visual simplicity of the results.

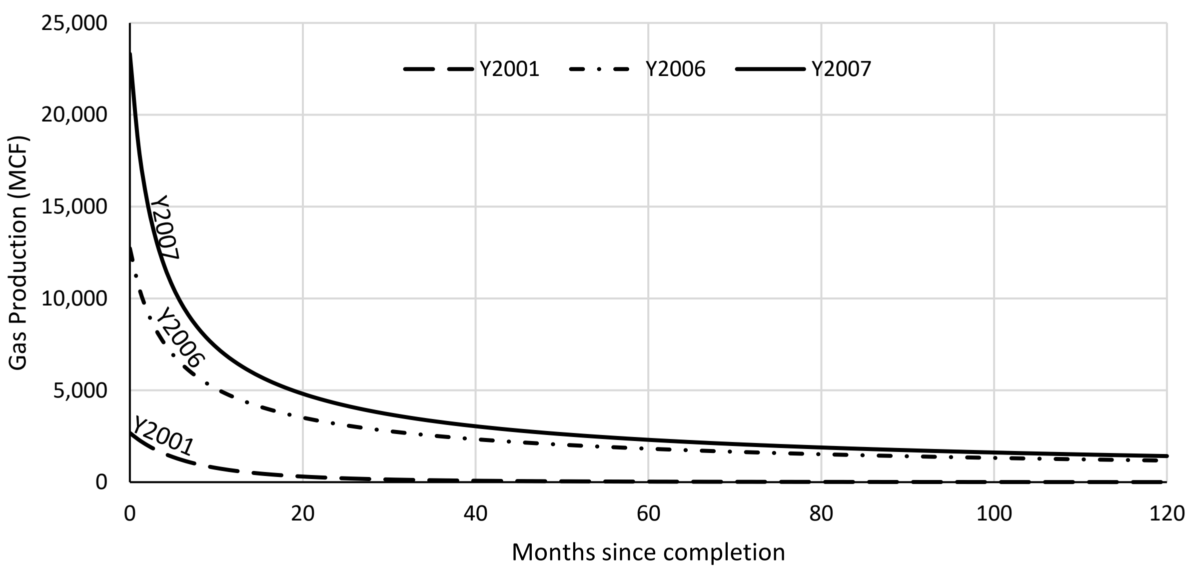

Figure 1: Production decline curves of horizontal gas production for wells completed in years 2001, 2006, and 2007 in Queen formation

As shown in Figure 2, between 2014 and 2017, production rates vary within a certain range around the production rate of wells completed in 2007.

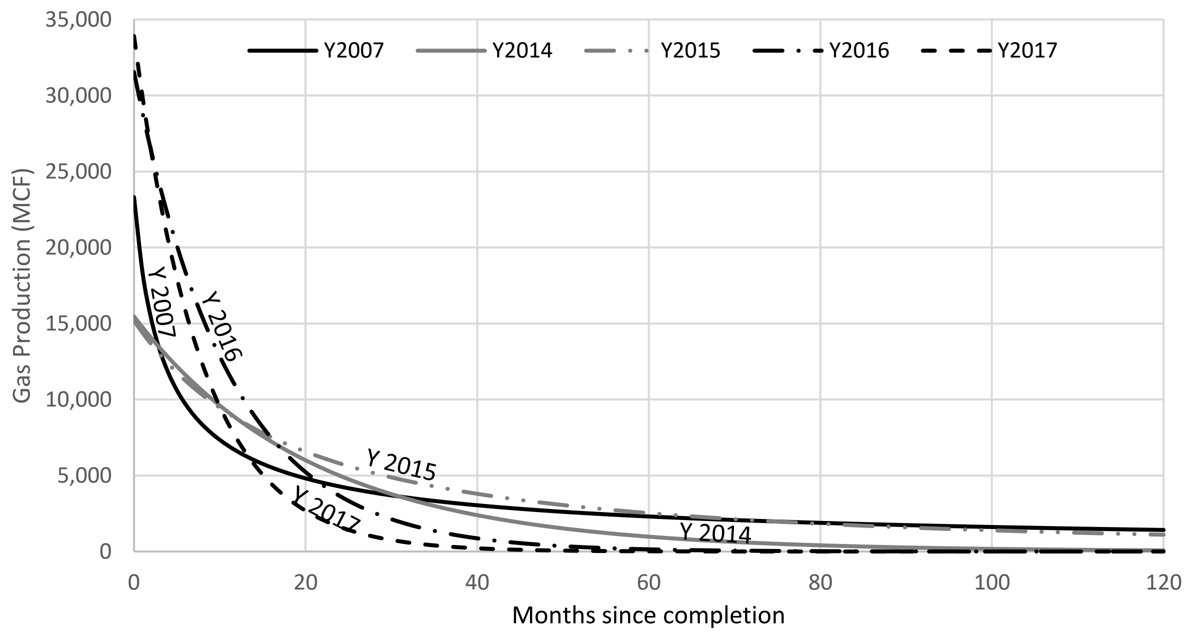

Figure 2: Production decline curves of horizontal gas production for wells completed in years 2007, 2014, 2015, 2016, and 2017 in the Queen formation

4.2. Differences in horizontal and vertical production from formations

Disaggregating wells by completion and direction serves as a basis for monitoring how and when horizontal well drilling was adopted for production from certain formations. For example there was only one horizontal well drilled in the Queen formation in 2007 but all wells since then have been vertical.

Another comparison can be made between production from vertical and horizontal wells producing from the same formation. The results of this analysis show that for wells producing from the same formation in NM, initial production rate is not necessarily lower for vertical wells than horizontal wells.

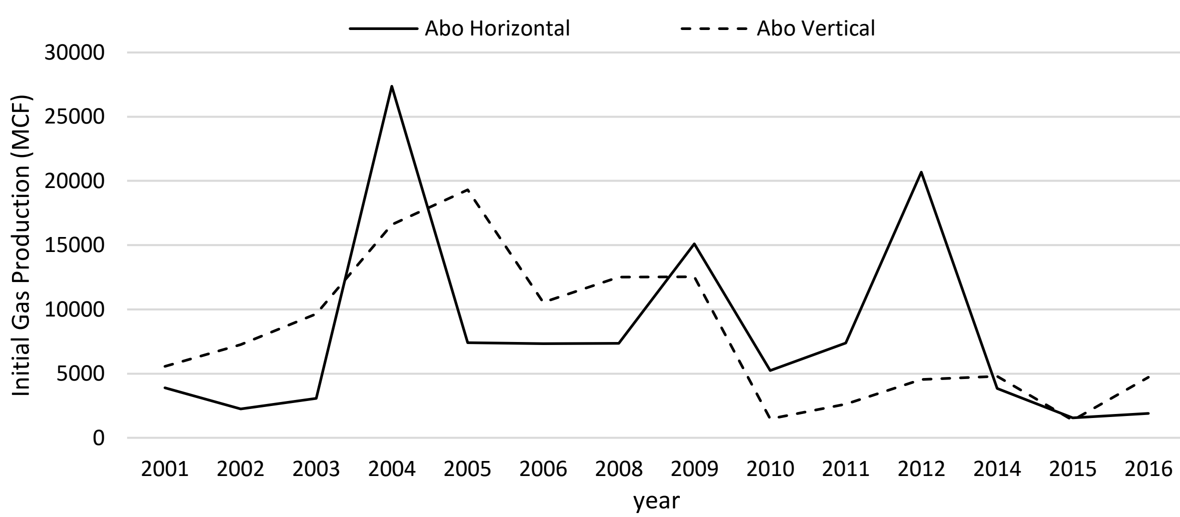

Figure 3: comparison between initial gas production rate between horizonal and vertical wells producing from Abo formation

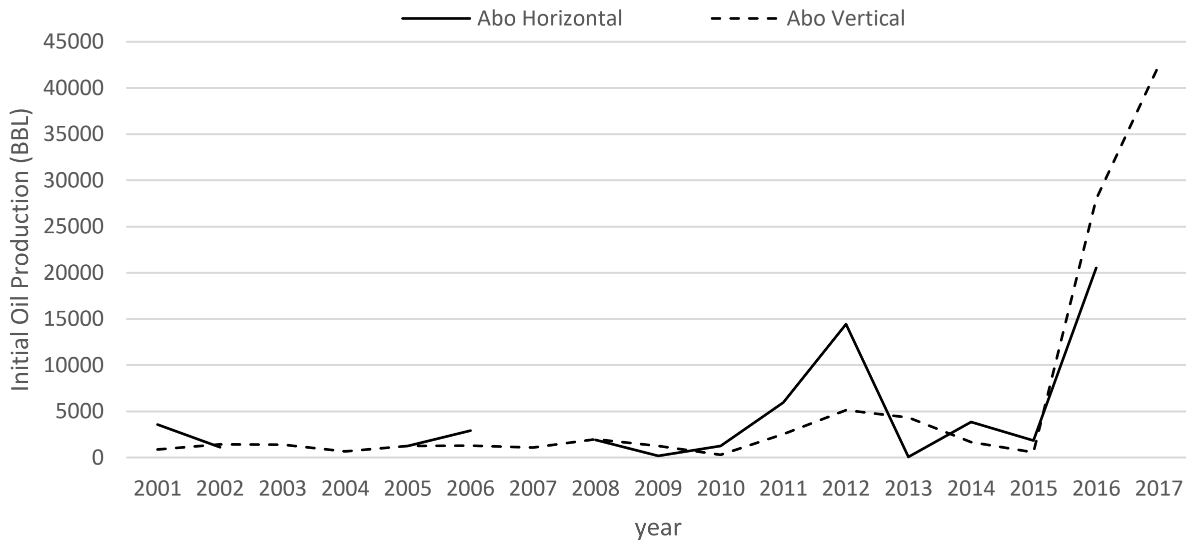

Figure 4: comparison between initial gas production rate between horizonal and vertical wells producing from Abo formation

4.3. Aggregated Supply

The aggregated supply of natural gas and oil from new wells are shown in Figures 5 and 6, respectively, along with the actual aggregated production volumes. In order to estimate supply of oil and natural gas, the initial time needs to be determined. Wells producing prior to the initial time are considered existing wells. There is a spike in production of oil and gas between 2014 and 2015, which are subject to further investigation.

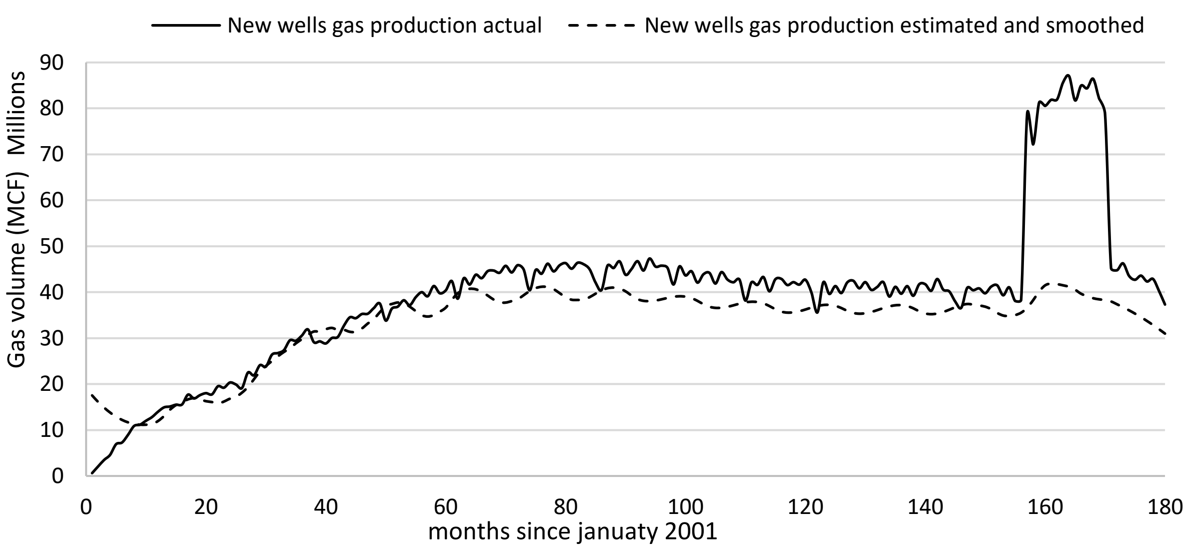

Figure 5: aggregate gas supply based on supply curve parameters' estimates

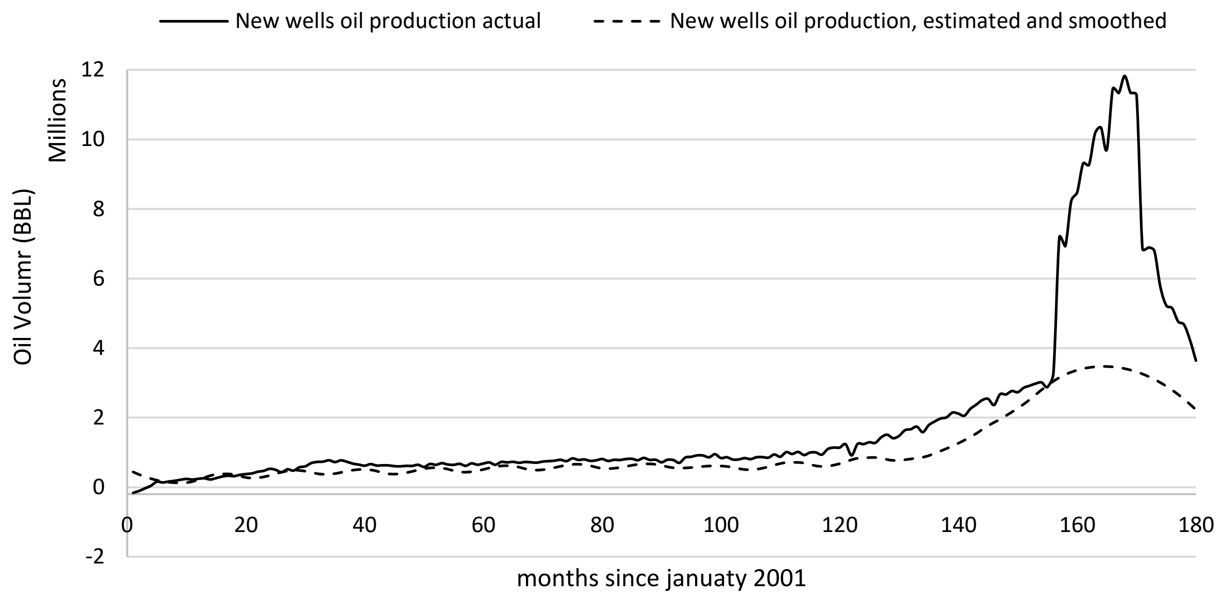

Figure 6: aggregate oil supply based on supply curve parameters' estimates

In order to extend production forecasts to years after 2017, the number of new wells and production decline curve parameters are required. The number of new wells can be determined using the price elasticity concept (Newell 2016; Ringlund et al. 2008; Farzin 2001).

Decline curve parameters for future wells can be sampled from the data generated in this study or similar studies. Suppose $N_{ct}^{f,d}$ is the number of wells completed at time ct, have direction d, and produce from formation f. Also, suppose that the decline curve parameters associated with those wells are $Q_i^{f,d}(cf), D^{f,d}(cf)$,and $b^{f,d}(cf)$. To estimate production at time t, one can use the following formula:

$$\sum_{cf=0}^{t} \sum_{f\in\{formations\}} \sum_{d\in directions} \frac{Q_i^{f,d}(cf)}{(1+b^{f,d}(cf).D^{f,d}(cf).(t-cf))^{\frac{1}{bb^{f,d}(cf)}}} \quad (1)$$

5. Conclusion

This new wells oil and natural gas supply model builds upon the Oil and Gas Supply Module (OGSM) of the National Energy Modeling System (NEMS). The difference is in the disaggregation of the production data prior to the decline curve analysis. In this study, production data are dissagregated based on the trajectory of the producing wells (i.e. horizontal vs vertical). In addition, production data are disaggregated based on the producing wells' completion year. This dissagregation allows for analyzing the dynamics of type curves between wells completed in different years. In addition, this disaggregation procedure makes possible to compare of the productivity of horizontal and vertical wells. The resulting dataset can improve prediction of the decline curve parameters of future wells hence enhancing oil and gas supply forecasts. In addition to providing a more detailed forecast system, this supply model informs a statewide system dynamics energy water nexus model in New Mexico.

6. References

Arps, J.J., 1945. Analysis of decline curves. Transactions of the AIME, 160(01), pp.228-247.

Energy Information Administration (EIA), 2017. Oil and gas supply module of the national energy modeling system: Model documentation 2017. Office of Integrated Analysis and Forecasting, U.S. Department of Energy, Washington, DC.

Farzin, Y.H., 2001. The impact of oil price on additions to US proven reserves. Resource and Energy Economics, 23(3), pp.271-292.

Newell, R.G., Prest, B.C. and Vissing, A., 2016. Trophy hunting vs. manufacturing energy: The price-responsiveness of shale gas (No. w22532). National Bureau of Economic Research.

Oil Conservation District (OCD), 2018, Production by well, http://www.emnrd.state.nm.us/OCD/statistics.html <last access July 2018>

Ridgley, J.L., Condon, S.M., Dubiel, R.F., Charpentier, R.R., Cook, T.A., Crovelli, R.A., Klett, T.R., Pollastro, R.M., & Schenk, C.J. (2002). Assessment of undiscovered oil and gas resources of the San Juan Basin Province of New Mexico and Colorado, 2002, U.S. Geological Survey Fact Sheet 147-02, 2 p.

Ringlund, G.B., Rosendahl, K.E. and Skjerpen, T., 2008. Does oilrig activity react to oil price changes? An empirical investigation. Energy Economics, 30(2), pp.371-396.

Schenk, C.J., Pollastro, R.M., Cook, T.A., Pawlewicz, M.J., Klett, T.R., Charpentier, R.R., and Cook, H.E. (2008). Assessment of undiscovered oil and gas resources of the Permian Basin Province of west Texas and southeast New Mexico, 2007, U.S. Geological Survey Fact Sheet 2007–3115, 4 p.