Variability of Oil and Gas Well Productivities for Continuous (Unconventional) Petroleum Accumulations

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Abstract

Over the last decade, oil and gas well productivities were estimated using decline-curve analysis for thousands of wells as part of U.S. Geological Survey (USGS) studies of continuous (unconventional) oil and gas resources in the United States. The estimated ultimate recoveries (EURs) of these wells show great variability that was analyzed at three scales: within an assessment unit (AU), among AUs of similar reservoir type, and among groups of AUs with different reservoir types.

Within a particular oil or gas AU (such as the Barnett Shale), EURs vary by about two orders of magnitude between the most productive wells and the least productive ones (excluding those that are dry and abandoned). The distributions of EURs are highly skewed, with most of the wells in the lower part of the range.

Continuous AUs were divided into four categories based on reservoir type and major commodity (oil or gas): coalbed gas, shale gas, other low-permeability gas AUs (such as tight sands), and low-permeability oil AUs. Within each of these categories, there is great variability from AU to AU, as shown by plots of multiple EUR distributions. Comparing the means of each distribution within a category shows that the means themselves have a skewed distribution, with a range of approximately one to two orders of magnitude.

A comparison of the three gas categories (coalbed gas, shale gas, and other low-permeability gas AUs) shows large overlap in the ranges of EUR distributions. Generally, coalbed gas AUs have lower EUR distributions, shale gas AUs have intermediate sizes, and the other low-permeability gas AUs have higher EUR distributions.

The plot of EUR distributions for each category shows the range of variation among developed AUs in an appropriate context for viewing the historical development within a particular AU. The Barnett Shale is used as an example to demonstrate that dividing wells into groups by time allows one to see the changes in EUR distribution. Subdivision into groups can also be done by vertical versus horizontal wells, by length of horizontal completion, by distance to closest previously drilled well, by thickness of reservoir interval, or by any other variable for which one
has or can calculate values for each well. The resulting plots show how one can subdivide the total range of productivity in shale-gas wells into smaller subsets that are more appropriate for use as analogs.

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Over the last decade, oil and gas well productivities were estimated using decline-curve analysis for thousands of wells as part of U.S. Geological Survey (USGS) studies of continuous (unconventional) oil and gas resources in the United States. The estimated ultimate recoveries (EURs) of these wells show great variability from well to well as well as among groups of wells with similar characteristics, even within the same assessment unit (AU). Estimation of EURs is a necessary input for geologic assessments of continuous oil and gas resources in the United States. The estimated ultimate recoveries (EURs) of these wells show great variability from well to well as well as among groups of wells with similar characteristics, even within the same assessment unit (AU). Estimation of EURs is a necessary input for geologic assessments of continuous oil and gas resources in the United States. The EURs vary by length of horizontal completion, by distance to closest previously drilled well, by thickness of reservoir type, and among groups of AUs with different reservoir types. Within a particular oil or gas AU (such as the Barnett Shale), EURs vary by about two orders of magnitude between the most productive wells and the least productive ones (excluding those that are dry and abandoned). The distributions of EURs are highly skewed, with most of the wells in the lower part of the range. Continuous AUs were divided into four categories based on reservoir type and major commodity (oil or gas); coalbed gas, shale gas, other low-permeability gas AUs (such as tight sands), and low-permeability oil AUs. Within each of these categories, there is great variability from AU to AU, as shown by plots of multiple EUR distributions. Comparing the means of each distribution within a category shows that the means themselves have a skewed distribution, with a range of approximately one to two orders of magnitude. A comparison of the three gas categories (coalbed gas, shale gas, and other low-permeability gas AU) shows large overlap in the ranges of EUR distributions. Generally, coalbed gas AUs have lower EUR distributions, shale gas AUs have intermediate sizes, and the other low-permeability gas AUs have higher EUR distributions. The plot of EUR distributions for each category shows the range of variation among developed AUs in an appropriate context for viewing the historical development within a particular AU. The Barnett Shale is used as an example to demonstrate that dividing wells into groups by time allows one to see the changes in EUR distribution. Subdivision into groups can also be done by vertical versus horizontal wells, by length of horizontal completion, by distance to closest previously drilled well, by thickness of reservoir interval, or by any other variable for which one has or can calculate values for each well. The use of automation and probabilistic expression to create probabilistic type curves may allow similar well-level results for more wells with a smaller time investment (Charpentier and Cook, 2010).

Estimated Ultimate Recovery (EUR)

For each AU, tens to thousands of hand-fit decline curves to individual wells were used to create a distribution of EURs (Cook and Charpentier, 2010). The use of automation and probabilistic expression to create probabilistic type curves may allow similar well-level results for more wells with a smaller time investment (Cook and Charpentier, 2010).

Clouds: Distribution of Distributions

Either process delivers a single distribution of EURs for use in USGS continuous assessments. Are clouds built from different data sources comparable?

Defining the cloud by using USGS estimates of EUR distributions of undrilled cells gives a good approximation of the range of distributions. Assumptions have been made over the last decade for a wide variety of reservoirs, using a variety of estimation practices, and thus the present sample probably captures much of the range of distributions based on current technology. EUR distributions from decline-curve calculations for previously drilled wells show a consistent cloud pattern, as shown in figures 4 and 7.
Comparing Clouds

Figures 9–11. The USGS AUs were divided into four categories based on reservoir type and major commodity (oil or gas): coalbed gas, tight gas, and continuous oil AUs. These graphs show the variation among the four groups. Note the large variations between the highest EUR distributions and the lowest, and between the highest and lowest EUR means. Note also the considerable overlap among the clouds. Especially note the very high outlier distribution for coalbed gas (the Fruitland Fairway Coalbed Gas AU in the San Juan Basin). The black diamonds are the means for each distribution. Data for these graphs are given in U.S. Geological Survey Oil and Gas Assessment Team (2012).

Drilling Down Into Assessment Unit Variability

Top-Level Variability

Figure 14. This box-whisker plot presents the EURs for all Barnett Shale wells drilled through October of 2009.

Figure 15. This cloud plot presents the EURs for all Barnett Shale wells drilled through October of 2009 (the same data used for figure 14). The fractiles indicate what percent of the wells have an EUR of at least the indicated amount. Note that the range of EURs is approximately two orders of magnitude.

2nd Order Variability

Figure 16. A comparison of EUR between horizontal and vertical Barnett Shale wells.

Figure 17. All Barnett Shale wells drilled through November 2001.

Figure 18. A comparison of Barnett Shale vertical wells drilled before and after January, 2002, to all horizontal wells. Of note is the major change in distribution of EUR when a majority of vertical wells were drilled outside of the original sweet spot.
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Variability Comes from Several Factors

Spatial Changes in EUR

Changes in EUR with Time

Changes in EUR with Horizontal Well Design

Conclusions

A compilation of oil and gas well productivities in continuous AUs shows a complex interaction of factors such as geologic variability and differences in well design. Analysis of the data lead to better estimation of productivity for drilled sites.

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