HOW SPOT PRICES SHAPE FUTURE DRILLING ACTIVITY: AN EMPIRICAL ANALYSIS IN NEW MEXICO

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Abstract

This study investigates the drivers of well drilling activity in New Mexico. Spot prices, price volatility and rig availability are specifically considered as potential factors that shape operators' decision to drill new wells. Two major basins in New Mexico, the San Juan basin and the Permian basin, are considered in this study. Due to their petro-physical and location differences, the two basins are considered separately. Furthermore, to investgate potential trade-offs between gas and oil opeartions, two models are developed for drilling activities in each basin: 1) oil well drilling, and 2) gas well drilling activities. Our results suggest that an increase in the price of natural gas and oil will increase the number of natural gas and oil wells drilled in upcoming months, respectivitly. Our results also show that an increase in the spot price of oil results in lowering natural gas well drilling operations in future months, suggesting that a trade-off between the two operations exists. Although no strong evidence was found about the effect of natural gas spot price change on oil well drilling activity, our results indicate that as oil prices show more volatility, natural gas well drilling in San Juan basin increased (0.35 units per dollar increase in oil price volatility). Whereas natural gas well drilling activitiy was positively impacted by the number of available rigs in the neighbour states (i.e. Texas for Permian basin and Colorado for San Juan basin), our results did not suggest a significant relationship between rig availability and oil well drilling.

1. Introduction

Forecasting new drilling activity is often based on forecast oil and natural gas (O&G) prices. For example, the Petroleum Services Association of Canada increased its forecast of new well drilling in 2017 by 23%, due to recovering oil prices seen earlier this year (Reuters 2017). While this provides a forecast at an aggregate level, drilling at a more localized scale may be impacted by additional factors. For example, the number of rigs in a region at any given time may be limited. Futher, there may be competition across basins, as well as competition between O&G operations (Ringlund et al.2008). For states dependent upon O&G tax revenues, understanding factors that impact not only production, which has been found to be less price responsive than new well drilling (Ringlund et al. 2008), but also new well drilling is imperative. This research foucses on factors that influence new O&G well drilling. We focus on the San Juan basin, located in the Northwest part of the state, and NM portion of the Permian basin, located in the southeast part of the state. Whereas San Juan basin's natural gas proved reserves is among top five natural gas producing basins in the US, Permian basin is one of the most productive oilfields nationwide (EIA 2017). Although this research investigates the new well drilling at the state level, the importance of this subject goes beyond the state of NM.

2. Problem Statement and hypotheses

The O&G operators in the United States, are considered price takers (Berkmen et al. 2005). As a result, for a profit optimizing operator, when the market signals higher prices, higher production is expected. However, that the production of an exisiting well declines over time is a well established theory (Arps 1945). Hence, operators tend to seek more production through drilling new wells. As a result, drilling

activity could be perceived as more price responsive than the production operations of an exiting well. In addition to prices, availability of drilling rigs in the basin poses a physical constraint on the operators' ability to drill a new well. In other words, existence of more rigs in a basin facilitates more drilling activity and vice versa. The hypotheses to be tested in this study are as follow: 1) O&G drilling activitities increase due to own-price increase, 2) O&G drilling activities decrease due to cross-price increase, 3) volatility of prices has a negative impact on drilling activity, and 4) O&G drilling activities increases as the number of available rigs increases.

3. Study Area

This study focuses on the two major basins in New Mexico, the San Juan basin and the ermian basin. Figure 1 shows the locations of these two basins.

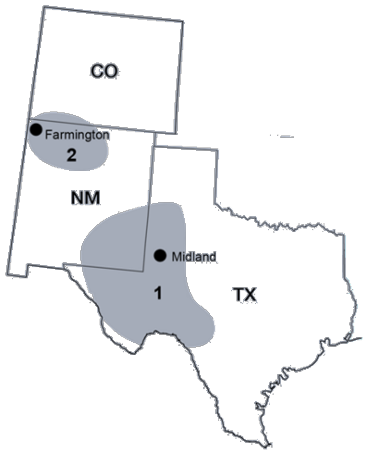

Figure 1: Permian basin (1), and San Juan basin (2)

Between January 2000, and May 2015, there has been an average of 36 wells per month drilled in the San Juan basin, with gas wells making up 81% of the total monthly well drillings. In contrast, during the same time interval, the average number of new wells, on a monthly basis, was 71 in the Permian basin, with only 22% planned to be gas wells. These figures support the volume of oil versus gas operations in the two basins: New Mexico's Permian basin, contains two of the top 100 US oilfields, whereas San Juan basin has one of the largest natural gas proved reserves in the nation (EIA 2017).

4. Data Collection and description

Data for this study comes from three sources, namely, Energy Information Agency (EIA), Baker Hughes: Oil Field Services (BH), and New Mexico Oil Conservation District (NM-OCD). The dependent variable of this study is the number of O&G wells drilled in each basin during each month between January 2000 and May 2015. NM-OCD records the information about the wells including the drilling date, location of the well (latitude and longitude), and the operator-specified well type (oil vs. gas); these data are stored in a well log dataset. Using the well log dataset, four vectors are derived namely number of oil wells drilled in the San Juan basin, number of gas wells drilled in the San Juan basin, number of oil wells in the Permian basin and number of gas wells in the Permian basin. These four vectors are associated with independent variables of the four regression models that will be explained in the methodology section.

There are different data that can be collected regarding prices of crude oil and natural gas that could be used in describing the changes in the number of wells drilled in each basin. These price data sets include Henry Hub spot prices for natural gas and West Texas Intermediate (WTI) spot price for crude oil, Futures prices (1-4 months contracts) set at NYMEX, and Short and Long Outlook Prices estimated by the Environmental Information Agency (EIA). Taking into account the amount of time required for the drilling permit process, it is assumed that the operators have to make the drilling decision using an anticipation of the prices afew months ahead. Although it is unknown, however, what price forecast model an operator may use (e.g. the futures prices, the outlook pices, or price forecast models developed specifically for the operantor's needs),

it is assumed that the historical spot prices and the observed volatility is used in most of price forecast models. Hence, instead of using the Futures prices, the past spot prices, price volatility, and the price difference over a given period of time is used as a proxy to the forecast prices. The past price is the x-month lagged spot prices of crude oil (WTI prices) and natural gas (Henry Hub Prices). Price volatility measures is expressed in terms of the standard deviation of prices over a 12-month interval (i.e. $(t - x - 12\ ,\ t - x)$), and the price difference between the first and last months of the same 12-month period. To clarify, $x - months$ lagged prices means the price of oil/natural gas x months prior to when the drilling has taken place. The lag is selected subjectively. For oil prices 3 months lag is selected ($x = 3$) whereas for natural gas prices 5 months lag ($x = 5$) is deemed appropriate.The drilling activity versus lagged prices is graphed in figures 2 to 5 for oil and gas wells in each basin.

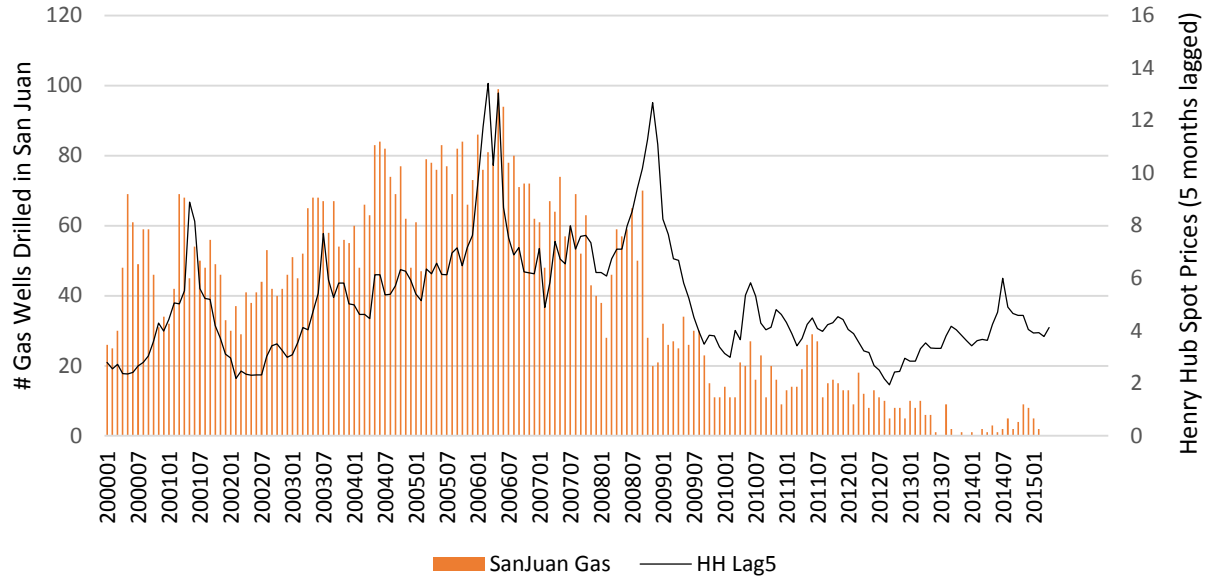

Figure 2: The San Juan basin's gas well drilling activitiy (bar chart) vs. Henry Hub's spot prices, lagged 5 months (line graph)

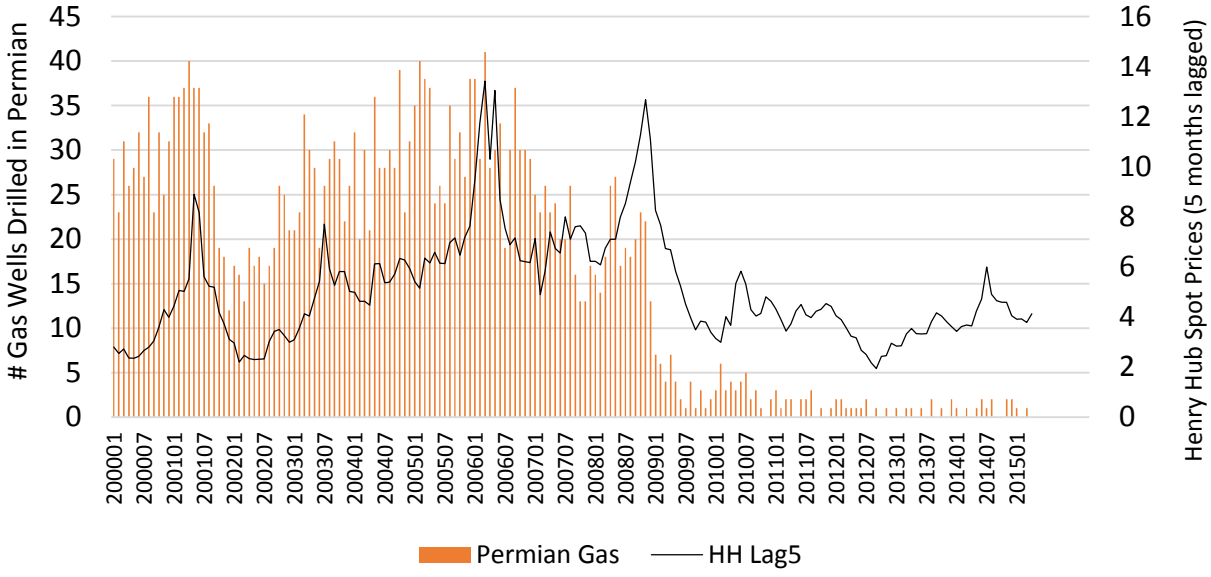

Figure 3: The Permian basin's gas well drilling activitiy (bar chart) vs. Henry Hub's Spot Prices, lagged 5 months (line graph)

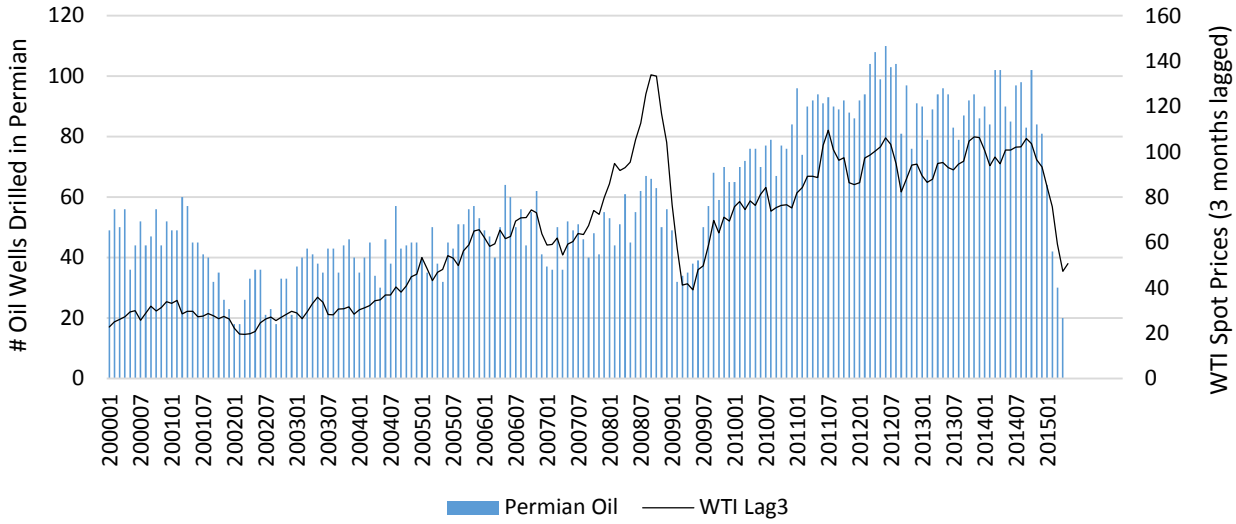

Figure 4: The Permian basin's oil well drilling activitiy (bar chart) vs. Henry Hub's spot prices, lagged 3 months (line graph)

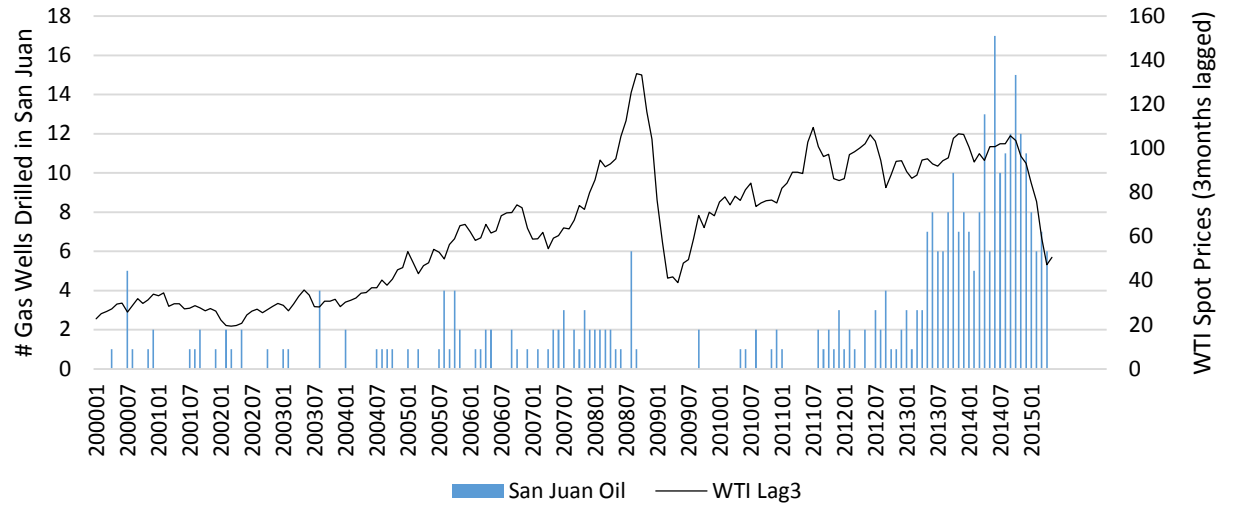

Figure 5: The San Juan basin's oil well drilling activitiy (bar chart) vs. Henry Hub's spot prices, lagged 3 months (line graph)

Number of rigs available in each state at each month is available from BH dataset, rigs in neighboring state (i.e. Texas for Permian basin, and Colorado for San Juan basin) are also taken into considerations since drilling rigs can move between states. The number of wells drilled in the same basin during the month prior to new well drilling month is also taken into account because the rigs have a limited capacity in drilling wells, and we assumed that drilling takes a long-enough time that the production of new wells in a month may be delayed due to prolonged activity of rigs in the previous month.

5. Methods

This empirical study develops an econometrics analysis of the drivers of well drilling at the basin level. The dependent variable is the number of wells drilled in each month, dissagregated to the San Juan and Permian basin and to natural gas and oil, $W_{i,j,t}$ (where i is the basin indicator 1=San Juan and 2= Permian, j is the index for hydrocarbon products, 1= Nat. gas and 2= Oil, and t is the time index in month). Available records

show that, the drilling behaviour varies between the two basins signalling underlying differences between the two basins. Hence, it would be beneficital to differentiate between the two basins. We hypothesize new wells are impacted by the x-month lagged price of the hydrocarbon products ($p_{j,t-x}$), volatility of price (measured by standard deviation of price over the last 12 months, $SD_{j,t}$), and the total change over the 12-months period, $\Delta P_{j,t}$. We consider the potential of competition between drilling for oil and natural gas, by including both prices in each model. In addition, we include the number of active rigs in NM $(R_{NM,t})$, the number of O&G wells drilled throughtout the state in the previous month $(W_{NM,t-1})$, and the active rigs in competing producing state (CO for the San Juan and TX for the Permian; $R_{s,t}$, where $s =$ CO or TX).The basic model is:

$$W_{i,j,t} = \alpha + \sum_{j=1(=NG)}^{2(=O)} \beta P_{j,t-x} + \beta_3 \Delta P_{j,t} + \beta_4 SD_{j,t} + \beta_5 R_{NM,t} + \beta_6 R_{S,t} + \beta_7 \sum_j W_{i,j,t-1} + \varepsilon \quad (1)$$

The time horizon of our inquiry is between January of 2000, and May 2015, with monthly time steps. The descriptive statistics of the variables used in this study are shown in table 1.

Table 1: Descriptive statistics

Variable	Definition	Mean	STD	Min	Max
$W_{1,1,t}$	Number of new gas wells drilled in the San Juan basin	38.67	26.63	0	99
$W_{1,2,t}$	Number of new oil wells drilled in the San Juan basin	1.92	3.13	0	17
$W_{2,1,t}$	Number of new gas wells drilled in the Permian basin	16.09	13.37	0	41
$W_{2,1,t}$	Number of New Oil Wells Drilled in the Permian basin	58.75	23.27	18	110
$\sum_j W_{1,j,t-1}$	Number of wells drilled in previous month in San Juan basin	45.42	28.90	5	117
$\sum_j W_{2,j,t-1}$	Number of wells drilled in previous month in Permian basin	75.66	17.22	34	117
$P_{1,t-5}$	Natural gas spot price, lagged 5 months Prior to well drilling	5.11	2.21	1.95	13.42
$SD_{1,t}$	Natural gas 12-month price volatility (between 17 and 5 months prior to drilling)	1.04	0.71	0.22	3.03
$\Delta P_{1,t}$	Natural gas 12-month price change, between 17 and 5 months prior to drilling)	0.15	2.56	-8.86	7.25
$P_{2,t-3}$	Crude oil spot price, lagged 3 months prior to well drilling	63.95	29.29	19.39	133.88
$SD_{2,t}$	Crude oil 12-month price volatility (between 15 and 3 months prior to drilling)	7.60	7.00	2.27	39.15
$\Delta P_{2,t}$	Crude oil 12-month price change, between 15 and 3 months prior to drilling)	4.29	21.04	-75.75	61.01
$R_{TX,t}$	Number of rigs available in Texas	648.36	213.05	273	949
$R_{CO,t}$	Number of rigs available in Colorado	63.89	27.72	17	125
$R_{NM,t}$	Number of rigs available in New Mexico	74.77	16.08	35	103

As the summary statistics show, There is a substantial variation in the number of wells drilled each month. For example, in the SJ basin, the average number of natural gas wells per month is 39, but ranges from 0 to 99, while the average number of oil wells was two but ranged from 0 to 17. Prices also experienced substantial variations over the time horizon of this study. Average natural gas price was $5.11, with a standard deviation of 2.21. Oil prices, also, experienced a high volatility during this period with an average amount of $63.95 and satandard deviation of $29.29.

6. Results

We model each basin separately and model drilling for both oil and natural gas separately as well. Preliminary results are presented in table 2. Results include a lag of 5 months for natural gas price, and 3 months for oil, as we find thses provide the best statistical fits.

Table 2: EconomistricResults

Variable	$San\ Juan - Nat.Gas$	$San\ Juan - Oil$	$Permian - Nat.Gas$	$Permian - Oil$
$CONSTANT$	1.994 (4.722)	-1.358 (0.995)	7.414 (2.279)***	13.723 (5.273)**
$P_{1,t-5}$	2.821 (1.094)**	0.185 (0.211)	2.400 (0.393)***	-3.977 (0.773)***
$SD_{1,t-5}^{-17}$	-1.663 (1.793)	-0.889 (0.297)**	-0.688 (0.929)	1.037 (1.844)
$\Delta P_{1,t-5}^{-17}$	-1.272 (0.625)	0.074 (0.115)	-0.794 (0.210)***	1.229 (0.442)**
$P_{2,t-3}$	-0.424 (0.893)***	0.085 (0.016)***	-0.416 (0.048)***	0.580 (0.116)***
$SD_{2,t-3}^{-15}$	0.345 (0.187)*	-0.185 (0.039)***	0.168 (0.104)	-0.152 (0.231)
$\Delta P_{2,t-3}^{-15}$	0.189 (0.573)***	-0.085 (0.012)***	0.232 (0.032)***	-0.127 (0.083)
$R_{NM,t}$	0.345 (0.070)	-0.027 (0.014)**	-0.011 (0.006)*	-0.002 (0.015)
$R_{TX,t}$	--	--	0.397 (0.052)***	-0.009 (0.109)
$R_{CO,t}$	0.291 (0.090)***	0.017 (0.018)	--	--
$\sum_j W_{1,j,t-1}$	0.527 (0.063)***	0.002 (0.010)	--	--
$\sum_j W_{2,j,t-1}$	--	--	-0.016 (0.041)	0.407 (5.273)***
$\bar{R}^2$	0.890	0.464	0.867	0.825
N	184	184	184	184

NOTE: Numbers in parenthesis are the standard errors. Significance levels: * 90%, ** 95%, and *** 99%

The price of natural gas has a consistent positive and statistically significant impact on the number of natural gas wells drilled in both basins. A dollar increase in the spot price of natural gas, increases the number of new wells drilled, five months later, in the San Juan basin by 2.82 units, and in the Permian basin by 2.4 units. Similarly, a positive and significant relationship is found between the price of crude oil and oil drilling activity, three month later. However, the impact of oil prices on oil well drilling is considerably different between the two basins, with the impact about seven times higher in the Permian basin (0.58 units) than in the San Juan Basin (0.09 units). An increase in the spot price of crude oil reduces the number of natural gas wells drilled in both basins, with an approximately similar amount of -0.42 unit per unit increase in the crude oil's spot prices. Spot price of natural gas, however, doesn't represent a negative impact on the oil well drilling. Our results show that oil well drilling in the San Juan basin is quite sensitive to the volatility of both natural gas and crude oil prices, with higher volatility resulting in lower drilling acitivity. Another important finding regarding the price volatility is that as oil prices become more volatile, drilling natural

gas wells in San Juan basin is favoured more, increasing the number of gas wells by 0.35 units per dollar increase in the volatility of oil prices. Number of rigs in neighbour states (TX for Permian basin and CO for San Juan basin) also have a positive impact on the number of natural gas wells drilled. An increase in the number of rigs in Texas increases natural gas well drilling activity in Permian basin by 0.39 units and an increase in the number of rigs in Colorado increases natural gas well drilling in San Juan basin by 0.29 units.

7. Conclusions

We undertook an empirical analysis on the number of new wells drilled in two basins in New Mexico, namely the San Juan basin and the Permian basin. Our results showed that the spot prices and price variations have a significant impact on drilling activity in the future months. An Increase in the natural gas and oil price will increase natural gas and oil well drilling activity five and three months later, respectively. Increase in oil prices have a significant negative impact on the natural gas well drilling in both basins; although, similar evidence was not found for the impact of natural gas prices on oil well drilling activity. We also found evidence that the volaitility in oil prices improves the natural gas well drilling in the state. Availability of rigs in the basin's adjacent state was also found to be a positive driver of natural gas drilling activity in New Mexico.

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