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The Relationship Between Oil Price and Costs in the Oil and Gas Industry *

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Abstract:
We propose a simple structural model of the upstream sector in the oil industry to study the determinants of costs with a focus on its relationship with the price of oil. We use the real oil price, data on global drilling activity and costs of drilling to estimate a three-dimensional VAR model. We use short run restrictions to decompose the variation in the data into three structural shocks. We estimate the dynamic effects of these shocks on drilling activity, costs of drilling and the real price of oil. Our main results suggest that (i) a 10% increase (decrease) in the oil price increases (decreases) global drilling activity by 4% and costs of drilling by 2% with a lag of 4 and 6 quarters respectively;(ii) positive shocks to drilling activity affect the oil price negatively; (iii) shocks to costs of drilling do not have a permanent effect on the price of oil.

Keywords: Natural Resource Extraction, Crude Oil Price, Upstream Cost
JEL classification: Q31

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1 Introduction

The economic profession is still struggling to fully understand the crude oil price and the shocks driving it (Hamilton, 2008; Kilian, 2009; Anderson, Kellogg, and Salant, 2014). The goal of this paper is to contribute to understanding the determinants of drilling costs and the relationship between drilling costs and the real price of oil. To do that we use data on individual wells from Wood MacKenzie on drilling activity and costs of drilling. The information provided allows us to construct two quarterly time series capturing (i) the total number of exploration wells drilled in the oil industry and (ii) the average cost of drilling these wells. We use the constructed time series in combination with the real price of oil to estimate a three-dimensional structural VAR model.

The proposed structural model of the **upstream sector** allows us to decompose the variation in the reduced form errors of the estimated VAR into three structural shocks. To identify the shocks we assume a recursive structure. The first structural shock is an *oil price shock* which is defined as an unpredictable innovation to the oil price. Oil price shocks capture *demand shocks* in the upstream sector as an increase in oil prices boosts cash flows of the oil companies and raises the profitability of marginal projects. To identify the shock we assume that the oil price is predetermined to drilling activity and costs of drilling. This assumption is plausible because it takes more than three months, and typically more than a year, following the drilling of an exploration well before the global supply of oil can be affected. Moreover, expectations of the future oil price are unlikely to be formed contemporaneously because it takes often more than a year before reasonable estimates of reserves are available.

The second structural shock is an *activity shock*, which is defined as an unpredictable innovation to the number of wells drilled. Technological advances in the upstream sector (e.g. deep sea offshore drilling) and an expansion of area available for leases allowed oil companies to explore regions of the world which have not been accessible before. On the other hand, the nationalisation of an oil industry or tougher safety regulations may force oil companies to revert to sources of lower quality and higher costs of extraction. We assume that shocks to activity are predetermined to changes in costs. This assumption is plausible because drilling costs depend on geological conditions and the duration of the drilling which may both heavily vary even within a field. As a result drilling costs are rarely known ex ante even by the operating company.

The remaining variation in the errors - after accounting for the variation in the oil price and drilling activity - is referred to as a cost shock. By construction these shocks are orthogonal to the contemporaneous oil price shocks and shocks to drilling activity and, thus, may be used to study the effect of exogenous shocks to costs on the price of oil.

We have three main results. First, following a 10% increase (decrease) in the oil price drilling activity increases (decreases) by 4% and costs of drilling increases (decreases) by 2% with a lag of 4 and 6 quarters respectively. Second, activity shocks affect the oil price negatively but have only a small and insignificant effect on drilling costs. Third, our results suggest that the oil price is not affected by shocks to costs permanently.

Our paper is most closely related in methodology to Kilian (2009) who uses a three-dimensional structural VAR and short-run restrictions to understand the different nature of shocks driving the oil price. As opposed to our approach, he models the world market for crude oil rather than the upstream sector of the oil industry. To do this he uses world oil production to capture supply shocks. To model demand shocks for industrial commodities, he uses dry cargo single voyage ocean freight rates. After accounting for shifts in demand and supply, he argues that the residual variation in the oil price is driven by precautionary demand shocks rather than by supply shocks as has been previously believed. Our work may be thought of as an extension of his work as we take the variation in the oil price (consisting of demand and supply shocks in the crude oil market) as given and use it to decompose the observable variation in the number of wells drilled and costs of drilling.

Our paper is also related to Anderson, Kellogg, and Salant (2014). Using data from Texas on drilling activity and rig rents, they present evidence that drilling activity and drilling costs significantly respond to a change in the oil price. On the other hand, they are not able to find any significant relationship of oil price changes and the contemporaneous extraction of oil. They use these results to motivate a theoretical model in which drilling activity is at the centre of deriving an optimal extraction path. In doing so, they are able to rationalize their empirical findings. Our work differs from their contribution in two main aspects. First, and most importantly, their main contribution is theoretical whereas our focus is on the causal identification of shocks and the estimation of the dynamic responses of the variables in the system to shocks. Second, we use data on drilling and costs of drilling covering the whole world, whereas their data is constraint to activity and rig rents in Texas.

The remainder of this paper is structured as follows. In the next section we provide a discussion on the institutional framework of the upstream sector in the oil industry and drilling costs. In the third section we describe the data. In the fourth section we discuss our identification and estimation strategy. In the subsequent section our results are presented before we conclude.

2 Costs in the upstream sector of the oil industry

Activity in the oil sector can be broadly divided into three sectors: an upstream sector, which involves locating and extracting the product located under the Earth's surface; midstream sector, which mainly involves the transportation and storage of the product; and downstream sector, which involves the processing, distribution and selling of the final product. In what follows we focus on the **upstream sector** as we are interested in the determinants of drilling costs and their interaction with the oil price.

Reserves containing the product are typically buried under many layers of rock and may be located onshore and offshore. Thus, drilling represents the core of activities in the upstream sector as it is essential to access the product. Types of wells drilled differ in their purpose. We broadly differentiate between two types of wells: exploratory wells[1] and production wells. The former have the purpose of identifying new reserves. The latter are mostly drilled in known reservoirs to maintain or increase oil production.

Once the well has been drilled the drilling rig is no longer required and can be moved.

[1] If not explicitly stated otherwise we refer to exploratory and appraisal wells as exploratory wells. Appraisal can be considered to be part of the exploration process (Adelman, 1990).

Drilling activity of any producer fluctuates with outcomes from recently drilled wells and the firm's success in locating new reserves. A successful exploration well drilled attracts subsequent drilling from the own or a competing company, and a dry hole does not. Thus, outsourcing drilling rigs reduces the overall capacity requirements of rigs and greatly reduces transportation and mobilization costs. This explains why companies in the oil industry are not vertically integrated and why drilling is typically outsourced (Kellogg, 2011).

Total cost of developing and operating a successful well consist of capital expenditures and operational expenditures. Costs accrued due to the drilling of a new well are subsumed in capital expenditures and represent an important share of fixed costs of developing a new well (app. 40-50% in recent years according to IHS (2014)). Operational expenditures are required to ensure a day-to day functioning of the well and represent the marginal costs of a productive well. Usually, marginal costs represent only a small part of overall costs which justifies our focus on capital expenditures (Adelman, 1962).

Standard economic theory predicts a strong relationship between the price of crude oil and marginal costs of production. It is easy to see that a productive well should stop producing if the costs of producing an additional unit exceeds the price of oil. On the other hand, wells which are expected to exhibit higher marginal costs may be activated if the oil price is sufficiently high and the profitability of the well appears more likely.

In the intermediate run such a relationship should theoretically also exist between drilling costs and the oil price. The intermediate run may be thought of as the time necessary to treat exploration and development of individual wells as variable in the production process. Ceteris paribus, an increase in drilling costs shifts the average cost curve up such that the break even point (marginal costs equal average costs) of the well can only be reached with a higher price of crude oil.

There are several reasons why this relationship between production costs and the price of oil may be diluted in reality. Most importantly, the existence of barriers to entry and the presence of economic rents. Economic rents can adjust to capture a change in drilling costs or the price of oil and, thus, break the relationship between the two. Moreover, if OPEC is managing global oil supply through spare capacities, the relationship between prices and marginal costs should be diluted. The subsequent empirical approach allows us to test for the existence of such a relationship and quantify the transmission of shocks from oil prices to drilling costs and vice versa.

3 Data

The raw dataset was obtained from Wood Mackenzie, and compiled using a range of methods: (i) meetings with energy companies, annual reports and industry specific publications, (ii) state publications and information from public institutions, (iii) historical data, investor presentations and different types of media sources. Unfortunately, the quality of data is subject to several limitations which are discussed in turn below.

Most importantly, information on production wells is not available. However, due to our focus on growth rates in drilling activity and cost of drillings, the missing information does not appear to be a serious drawback. Global data suggests that the share of exploration drillings in the total number of wells drilled amounts to 20-25% offshore and 7.5-12.5% onshore over the last 10 years (IHS, 2014). The share of total drilling expenditure spent on exploration drillings amounts to 30-35% onshore and offshore. Overall, the numbers suggest that the development of new reserves requires a constant ratio of exploration and production wells to be drilled. If we are willing to assume a constant ratio over time, growth rates in exploration drillings and cost of drillings represent excellent proxies for growth rates in production drillings and costs. [2]

We are also completely missing information on US onshore drillings of exploration wells. Unfortunately, there is little we can do about it. However, as before, we argue that by focusing on growth rates we nearly completely eliminate this drawback. IHS (2014) provides yearly information on the total number of exploration wells drilled onshore and the total amount spent on those drillings for the US and the rest of the world. We use that information to compute correlation coefficients between the growth rates in the US and the rest of the world. The computed correlation coefficient is above 0.95 suggesting that the missing information may be ignored for our purposes.

We limit our data in the time dimension by starting our analysis in 1995 because of two reasons. First, the quality of data appears to decrease significantly over time from 2000 backwards. Moreover, we argue that modelling an integrated global oil

[2] More formally, is is easy to show that the identity $Drilling_{total} = Drilling_{production} + Drilling_{exploration}$ can be transformed into $\frac{\Delta Drilling_{t,total}}{Drilling_{t-1,total}} = \alpha \frac{\Delta Drilling_{t,production}}{Drilling_{t-1,production}} + (1-\alpha)\frac{\Delta Drilling_{t,exploration}}{Drilling_{t-1,exploration}}$, with $\alpha = \frac{Drilling_{t-1,production}}{Drilling_{t-1,total}}$. Thus, if we are willing to assume that α is constant it must be the case that $\frac{\Delta Drilling_{t,production}}{Drilling_{t-1,production}} = \frac{\Delta Drilling_{t,exploration}}{Drilling_{t-1,exploration}}$.

market is much more realistic since the collapse of the Soviet Union in 1991.

Approximately 4% of the reported cost of drilling is missing. To account for the missing observations we proceed as follows. We start with the premiss that the most important predictor of drilling costs is the depth of the well drilled and whether the well is drilled offshore or onshore (henceforth *location* of drilling). The correlation coefficient between the depth of the well drilled (logged) and the cost of drilling (logged) is above 0.5. In Figure IV (see Appendix) we plot the estimated means of the depth of the wells for individual years and locations in case the information on costs is missing and in case it is not. Because most of the data missing is form the period before 1999 we only plot the estimates for the years 1995-1998.[3] Eyeballing the estimated means in Figure IV suggests that for our purposes (calculation of location-quarter specific means) we may treat the missing observations as missing at random. We replace the missing values with the group specific mean of the available information when calculating the location-quarter specific means.

Finally, we exclude successful gas wells from our sample because gas markets are not sufficiently well integrated globally and gas is not a perfect substitute for crude oil. The exclusion of gas wells does not alter our result significantly.

We use the data to construct two variables. First, quarter specific growth rates in *drilling activity*. Drilling activity is captured by the total number of wells drilled in a quarter. [4] Second, quarter specific growth rates in *cost of drilling*. Costs of

[3]The share of cost variables missing in the subsample since 1999 is less than half a percent. Only in 195 cases the information is not available for both variables. This represents less than 1% of our sample.

[4]We have information on the starting day of drilling and on the completion day of drilling. We use the former because we are interested in how quickly companies in the oil sector respond to an increase in the crude oil price.

drilling is the total[5] average cost of drilling one exploration well in $US in a particular quarter.[6] Average costs are transformed into real values using US CPI[7] before calculating the growth rates.

Levels of drilling activity and costs of drilling a well vary considerably across locations (onshore, shelf and deep offshore) as presented in Figure VI and Figure VII. To take this heterogeneity into account we proceed as follows. [8] We construct location-specific time series as presented in Figure VI and VII. The constructed time series are then logged and first differenced to account for the location specific constant heterogeneity. The individual observations in quarter t are then weighted according to the share of wells drilled in a particular location. More formally, $\Delta ln(x) = \sum^{l} \Delta ln(x_{tl})(\frac{x_{tl}}{x_t})$, whereas x either denotes the number of wells drilled or average cost of drilling a well in quarter t and in location l with $l \in$ {onshore, shelf, deep offshore}.[9] Both time series result in 75 observations and are presented in the second and third panel of Figure I.

In the first panel of Figure I the percentage change of the real oil price is presented. The nominal daily price of crude oil[10] is taken from EIA and the arithmetic mean

[5]We could have normalised the variable by the depth of the well drilled. However, that would not capture an important part of the mechanism we have in mind. Ceteris paribus, the necessity to drill deeper to locate new reserves implies that a unit of oil extracted is more expensive.

[6]The calculation of costs per well can vary depending on the region and the company involved. However, there is a great deal of effort from company's employees to construct comparable costs of drilling and exclude "back office" costs.

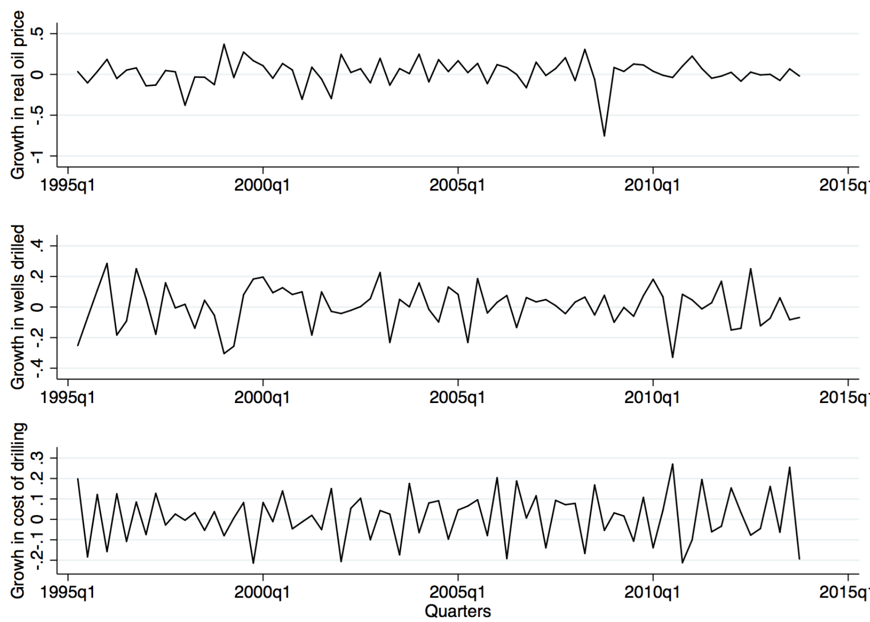
[7]Quarterly CPI for the US is taken from OECD statistics with the base period in 2010.

[8]We initially considered accounting for country fixed effects and company fixed effects. For two reasons we have decided against this approach. First, the increasing sparsity of data points when disaggregating further. This is particularly true if we want to account for company fixed effects. Second, we think of the companies as being globally integrated. Thus, costs of drilling is mainly driven by the location and the depth of the well drilled rather than national borders.

[9]Alternatively, we construct the growth rates by equally weighting the location specific growth rates. The results do not change significantly.

[10]Brent Spot Price FOB (Dollars per Barrel)

Figure I: Time series of the main variables (growth in percent)



is used to calculate quarter specific values. As before the oil price is transformed into real values using US quarterly CPI. Descriptive statistics of our variables are presented in Table I.

Table I: **Descriptive Statistics (growth in percent)**

variable	**mean**	**p50**	**sd**	**max**	**min**
Oil Price	0.02	0.03	0.16	0.37	-0.75
Drilling a well	0.01	0.01	0.12	0.21	-0.28
Costs of drilling	0.00	0.01	0.13	0.31	-0.27

4 Identification and Estimation

We use the growth in the real price of oil, $\Delta ln(p)$, the weighted growth in the number of wells drilled, $\Delta ln(d)$, and the (weighted) growth in costs of drilling a well, $\Delta ln(c)$, to set up a structural model of $Y_t = (\Delta ln(p), \Delta ln(d), \Delta ln(c))'$. We use quarterly data over a sample period of 1995:1- 2013:4. The structural VAR representation is

$$\mathbf{A_0 Y_t} = \alpha + \sum_{\mathbf{i=1}}^{\mathbf{p}} \mathbf{A_i Y_{t-i}} + \varepsilon_{\mathbf{t}} \tag{1}$$

α is a vector of constants capturing the average growth rate. $\mathbf{A_i}$ is a matrix of the respective coefficients in period $t-i$. $\varepsilon_{\mathbf{t}}$ is a three-dimensional vector with serially uncorrelated and mutually uncorrelated errors. We assume that matrix $\mathbf{A_0}$ has a recursive structure such that the reduced form errors $\mathbf{e_t}$ can be decomposed according to $\mathbf{e_t} = \mathbf{A_0}^{\mathbf{-1}} \varepsilon_{\mathbf{t}}$:

$$\begin{pmatrix} e_t^p \\ e_t^d \\ e_t^c \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12}=0 & a_{13}=0 \\ a_{21} & a_{22} & a_{23}=0 \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} \varepsilon_t^p \\ \varepsilon_t^d \\ \varepsilon_t^c \end{pmatrix}$$

We suggest to decompose the variation in the time series into three structural shocks. The first structural shock is an *oil price shock* which is defined by unpredictable innovations to the oil price. Oil price shocks represent *demand shocks* in the upstream sector. An increase in oil prices boosts cash flows and raises the profitability of marginal projects. Both channels trigger a rise in capital expenditure and drilling activity. To identify the shock we assume that the oil price does not respond contemporaneously (within a quarter) to shocks originating in the upstream sector, shocks to drilling activity or cost of drilling. This assumption is justified by the fact that increased activity in drilling does not immediately translate into a change in oil supply. It takes typically longer than a quarter before the drilling of an exploration well translates into an increased production of oil (Jahn, Cook, and Graham, 2008). Alternatively, one could argue that expectations of market participants about new discoveries effect the oil price. But it usually takes more than a quarter before a reasonable estimate of the size of an oil field is formed, and it takes even longer before total drilling costs can be determined (Adelman, 1990; Jahn, Cook, and Graham, 2008). Formally, we assume a_{12} and a_{13} to be zero.

The second structural shock is referred to as a *activity shock* and is defined as an innovation to drilling activity which cannot be explained by oil price shocks. These shocks may be driven by technological progress and a change in regulatory constraints. Technological advances in deep sea offshore drilling and an expansion of area available for leases allowed oil companies to explore regions of the world which have not been accessible before. On the other hand, the nationalisation of an oil industry or tougher safety regulations may decrease drilling activity in certain regions of the world. We assume that shocks to activity are predetermined to changes in costs. This assumption is plausible because it is very difficult to estimate drilling costs accurately and often drilling costs are only known after the drilling has been completed (Jahn, Cook, and Graham, 2008). Formally, we assume a_{23} to be zero.

We refer to the remaining variation in cost of drilling - after accounting for the variation in the oil price and drilling activity - as *cost shocks*. Shocks to drilling costs may represent random variation in drilling costs over time. But they also capture the continues trade-off between technological progress and increasing project complexity of development projects. By construction, cost shocks are orthogonal to oil price shocks and drilling shocks and, thus, may be used to evaluate the impacts of these shocks on drilling activity and the price of oil.

We use the LR sequential test to determine the optimal number of lags (the results are presented in Table II). In our preferred specification we use 8 lags. As a robustness test we also estimate our model with 12 lags and 4 lags which can be found in Figure IX and Figure VIII respectively. Our results are quite robust to the different choices. The reduced-form VAR model is consistently estimated by the least-squares method (Lütkepohl, 2011). Instead of relying on asymptotic theory we use bootstrapping to construct the 90% confidence interval which are used for inference.

5 Results

Historical evolution of structural shocks - In Figure II we plot the structural shocks implied by the model. The presented residuals are smoothed by a local polynomial estimator to ease interpretation. There are several things to note. First, it is apparent that the increase in drilling costs since 2005 was a delayed response to the surge in the price of oil. This is consistent with the general view of the recent increase in drilling costs. Second, our model suggests that the surge in the oil price in the end of 1999 (see Figure V) was the result of an unanticipated drop in drilling activity. Note, that the negative activity shock coincides with several big mergers in the oil industry, e.g. Exon and Mobile, BP and Amoco, Chevron and Texaco. Thus, besides the necessity to decrease capital expenditure since an all time low of the oil price in 1999 the decrease in drilling activity might reflect the purpose of the mergers and acquisitions to reduce costs and increase profitability. We also observe a persistent negative shock to drilling activity since 2010 which might reflect the

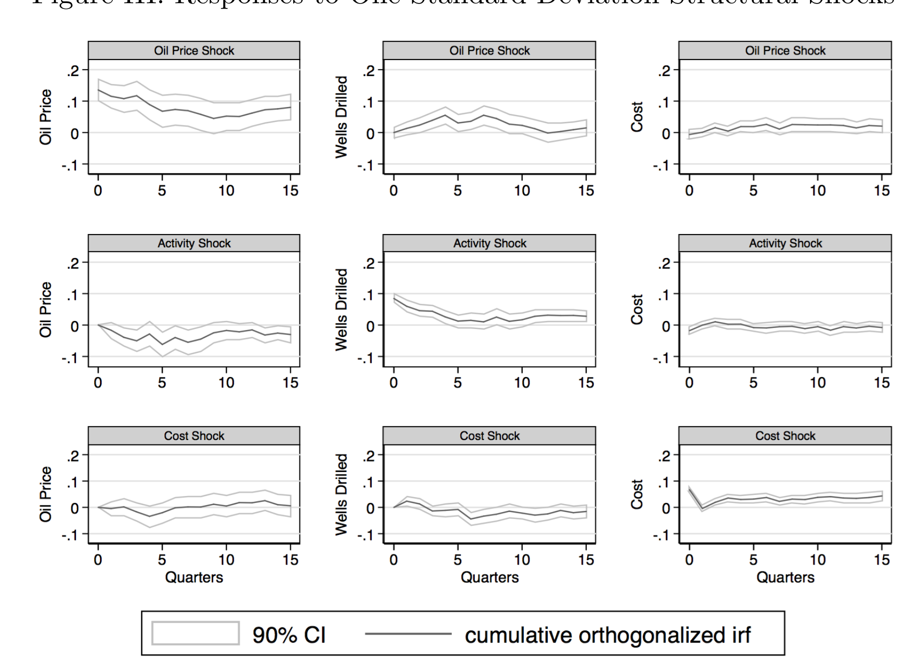
Figure II: Historical Evolution of the Structural Shocks

Notes: Structural residual implied by model one smoothed with a local polynomial estimator.

increased demand for safety regulations following the Deepwater Horizon oil spill in 2010. Finally, our model suggests the occurrence of positive cost shocks in recent years.

Dynamic responses of the variables in the system to structural shocks - In Figure III we present the responses of the real oil price, drilling activity and costs to the structural shocks. We prefer to present the cumulative responses of the variables because we are interested in the new equilibrium reached rather than short run fluctuations. For the interested reader the non-cumulative impulse responses and the results of the mean squared errors decomposition are presented in Figure X and Figure XI (see Appendix).

Figure III: Responses to One-Standard-Deviation Structural Shocks



Notes: Presented are point estimates of the cumulative orthogonal impulse response and 90% confidence intervals.

Following an *oil price shock*, ε_t^p, the oil price increases immediately but then adjusts within the next three years to approximately half of the initial magnitude. The initial 13% increase in the price of oil, increases the number of wells drilled by approximately 5-6% within a year and average cost of drilling by approximately 2-3% within 6 quarters. In the long run (15 quarters) the initial increase int he number of wells drilled returns to the initial level. On the other hand, the increase in costs increases permanently by approximately 2%.

Following a structural *activity shock* , ε_t^d, the number of wells drilled increases by nearly 10% instantaneously but then adjusts to 5% within 6 quarters. Costs of drilling is only affected contemporaneously and does not differ significantly from the initial level in the subsequent periods. On the other hand, the oil price seems to respond within a year to an increased activity in the upstream sector. The negative response in the oil price is consistent with an increase in crude oil supply following an increase in drilling activity. An initial increase in drilling activity by 10% decreases the oil price by approximately 3% permanently.

Following a structural *cost shock*, ε_t^c, we only observe small short run fluctuations in drilling costs an the price of oil but we do not observe any significant cumulative effect on the variables within the first 15 quarters. However, activity decreases temporarily. This is consistent with tight budget constraints enforced by mangers of oil companies which requires a decrease in activity in the presence of unexpected shocks to costs. We should note that the oil price appears to be affected by an activity shock but not by a structural cost shock. This might appear surprising but we can reconcile the results. We argue that the crucial difference between the shocks originating in the upstream sector is the effect on drilling activity. By construction drilling activity increases following a activity shock. The increase in drilling activity, ceteris paribus, affects the supply of crude oil and, thus, the price of oil in the intermediate run (physically or via expectations). Shocks to costs, on the other hand, do not seem to have any lasting impact on drilling activity and, thus, the price of oil.

6 Conclusion

We use micro data from Wood MacKenzie to construct two quarterly time series capturing the total number of exploration wells drilled and (ii) the average cost of drilling. In combination with the real price of oil we estimate a three dimensional structural VAR model. The proposed model allows us to decompose the variation in the reduced form errors from estimating the VAR into three structural shocks by assuming a recursive structure: an *oil price shock*, a *activity shock* and a *cost shock*. We estimate the dynamic effects of these shocks on drilling activity, costs of drilling and the real price of oil.

We have three main results. First, our results suggest an upwards sloping supply curve in the upstream sector of the oil industry. In particular, following an oil price shock of 10% costs of drilling increases permanently by approximately 2%. Second, activity shocks effect oil price negatively. Third, shocks to drilling costs do *not* have any permanent affect on the price of oil. This is particularly interesting because it calls into question the theoretically expected link between extraction costs and the price of oil (Krautkraemer, 1998). We argue that this is mainly due to the existence of economic rents which can adjust in the presence of shocks to costs of drilling and the price of oil and, thus, dilute the theoretically expected relationship between costs of drilling and the price of oil.

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7 Appendix

Figure IV: Estimated means of total depth (metres)

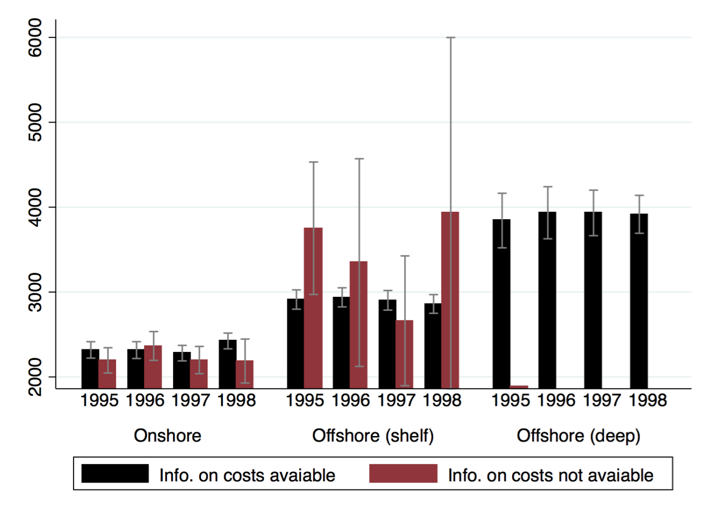

Figure V: Real Oil Price

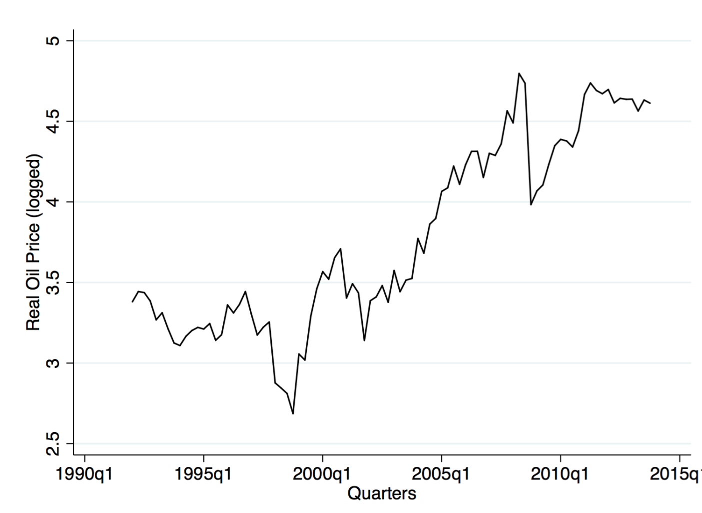

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Figure VI: Number of wells drilled

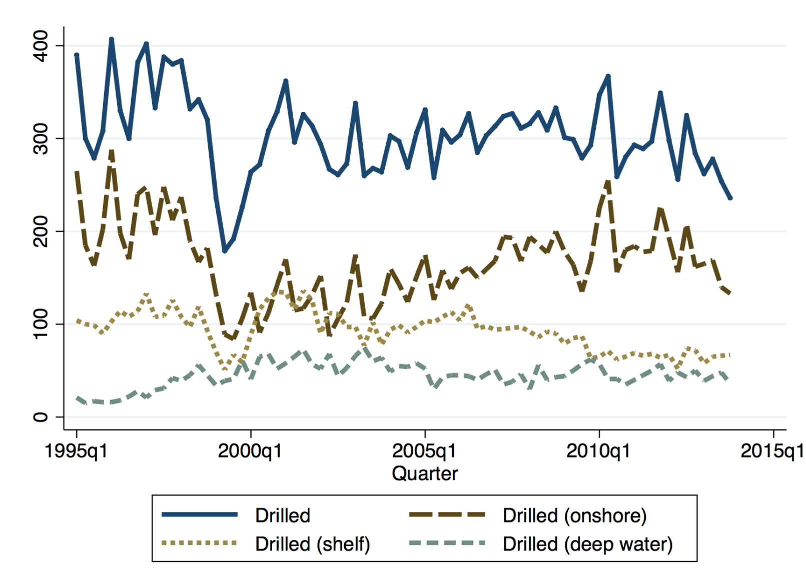

Figure VII: Cost of drilling

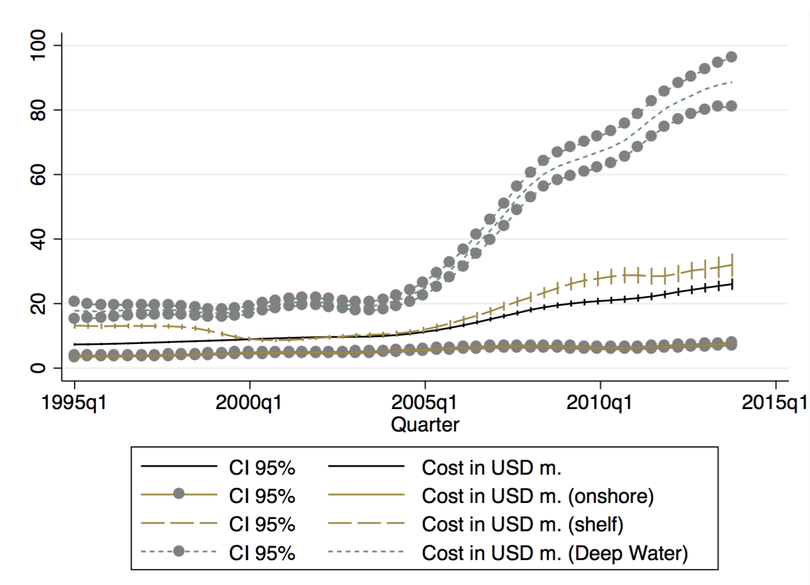

Figure VIII: Responses to One-Standard-Deviation Structural Shocks (4 lags)

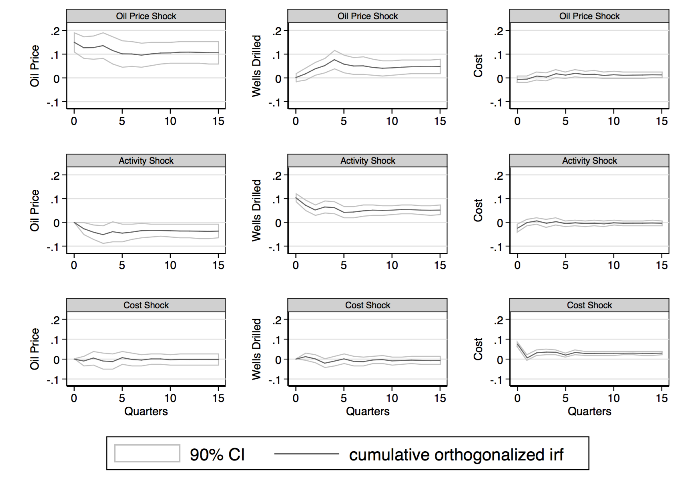

Figure IX: Responses to One-Standard-Deviation Structural Shocks (12 lags)

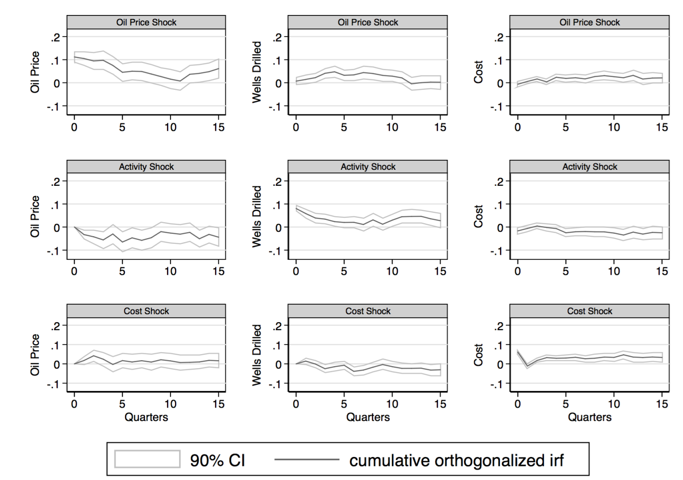

Figure X: Responses to One-Standard-Deviation Structural Shocks

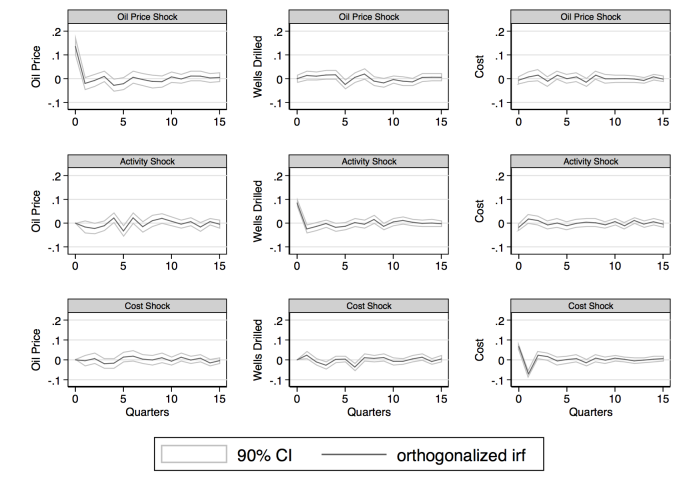

Figure XI: MSE decomposition

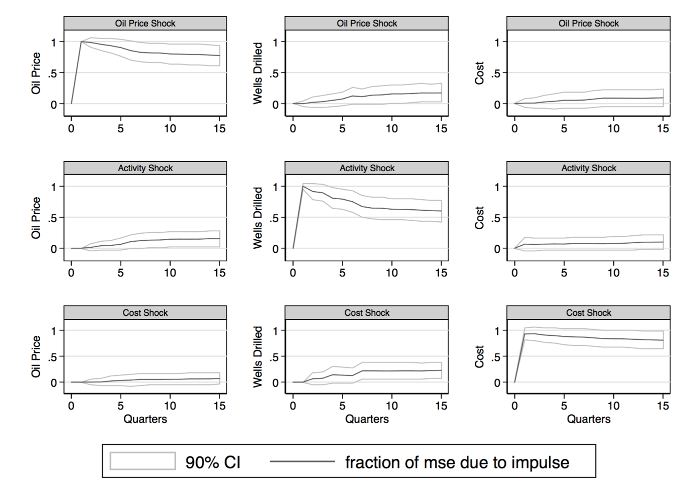

Table II: **Results of the sequential LR tests**

Hypothesis	10 lags	9 lags	8 lags	7 lags	6 lags	5 lags	4 lags
p=1 vs. p=0	32.75	33.134	33.992	35.235	37.131	38.239	39.76
p=2 vs. p=1	25.307	24.245	25.263	25.235	25.551	23.919	24.434
p=3 vs. p=2	9.266	9.4712	9.4168	9.322	10.972	10.084	10.32
p=4 vs. p=3	19.992	20.657	21.227	**20.923**	**21.086**	**21.117**	**21.996**
p=5 vs. p=4	10.066	9.961	11.073	12.225	10.927	11.02	
p=6 vs. p=5	11.766	11.092	11.463	11.773	12.08		
p=7 vs. p=6	**17.495**	17.286	16.377	15.906			
p=8 vs. p=7	16.549	**17.614**	**18.348**				
p=9 vs. p=8	12.102	11.983					
p=10 vs. p=9	4.650						

Table III: **Coefficients of the main specification**

	Oil Price Shock	→ Oil Price	Oil Price Shock	→ Wells Drilled	Oil Price Shock	→ Cost
lag	coef	se	coef	se	coef	se
0	0.135318	0.019549	0.000012	0.00934	-0.006231	0.009875
1	0.115287	0.022502	0.013104	0.012068	0.000851	0.008818
2	0.107767	0.028095	0.023543	0.013899	0.015474	0.007834
3	0.117155	0.030056	0.038829	0.014861	0.004468	0.009831
4	0.08898	0.028896	0.055024	0.016188	0.018863	0.01037
5	0.067632	0.028481	0.030351	0.017506	0.018747	0.011854
6	0.073333	0.028158	0.035618	0.017863	0.026045	0.012372
7	0.069506	0.027214	0.055032	0.017234	0.01091	0.011193
8	0.057675	0.028793	0.044578	0.018763	0.025473	0.01235
9	0.044814	0.028258	0.026687	0.017629	0.024744	0.012486
10	0.052214	0.028559	0.022783	0.016208	0.024016	0.012212
11	0.050871	0.027529	0.012073	0.017473	0.024136	0.013478
12	0.061857	0.026918	-0.001622	0.0176	0.022426	0.013234
13	0.072421	0.028034	0.003156	0.015668	0.014767	0.01269
14	0.075292	0.027544	0.009041	0.015363	0.022272	0.013432
15	0.080055	0.027393	0.01469	0.015468	0.020416	0.013711
	Activity Shock	→ Oil Price	Activity Shock	→ Wells Drilled	Activity Shock	→ Cost
lag	coef	se	coef	se	coef	se
0	0	0	0.084456	0.007402	-0.017661	0.008018
1	-0.016341	0.014399	0.059707	0.01114	-0.000301	0.007171
2	-0.039113	0.01961	0.045649	0.010517	0.010361	0.007457
3	-0.050223	0.022862	0.04383	0.010694	0.002595	0.008248
4	-0.028551	0.026203	0.026015	0.012565	0.002855	0.008691
5	-0.061825	0.024142	0.012557	0.013779	-0.008248	0.008587
6	-0.039611	0.023433	0.014922	0.014575	-0.009237	0.008941
7	-0.054794	0.02316	0.010112	0.014564	-0.005416	0.008459
8	-0.044763	0.022116	0.025383	0.014489	-0.00408	0.009145
9	-0.024781	0.01929	0.011767	0.013552	-0.011419	0.009031
10	-0.017193	0.016096	0.016761	0.013404	-0.005104	0.008828
11	-0.021581	0.01506	0.027923	0.013379	-0.01638	0.00909
12	-0.015403	0.013311	0.031429	0.01197	-0.005131	0.009279
13	-0.031823	0.014708	0.030215	0.010652	-0.009418	0.009128
14	-0.025604	0.015837	0.030516	0.009778	-0.003814	0.008742
15	-0.030133	0.01587	0.027968	0.010025	-0.007888	0.009151
	Cost Shock	→ Oil Price	Cost Shock	→ Wells Drilled	Cost Shock	→ Cost
lag	coef	se	coef	se	coef	se
0	0	0	0	0	0.066665	0.006519
1	-0.004567	0.014629	0.023514	0.009839	-0.004312	0.007557
2	0.001914	0.019182	0.013147	0.01174	0.019075	0.007469
3	-0.017311	0.022932	-0.01387	0.013293	0.03537	0.008536
4	-0.034188	0.025494	-0.011594	0.013318	0.029705	0.007849
5	-0.020324	0.02623	-0.007858	0.013707	0.031386	0.009598
6	-0.001762	0.027169	-0.044201	0.015041	0.037472	0.010078
7	0.001779	0.025659	-0.033437	0.013069	0.022657	0.010102
8	0.001301	0.026948	-0.026068	0.014582	0.031258	0.010971
9	0.01179	0.027113	-0.014424	0.015713	0.029481	0.010132
10	0.004999	0.024895	-0.021867	0.014736	0.037984	0.01041
11	0.018097	0.023784	-0.029611	0.014861	0.040626	0.011361
12	0.017239	0.023832	-0.024883	0.015344	0.035428	0.011105
13	0.025503	0.023242	-0.011632	0.016138	0.034138	0.011374
14	0.010059	0.023553	-0.020198	0.014943	0.03729	0.011834
15	0.005971	0.02337	-0.015706	0.014696	0.043243	0.011302