# Exploration Drilling Productivity at the Norwegian Shelf [1]

by

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**Abstract**

Recently, we have seen falling oil prices combined with sticky costs at a high level in the petroleum industry. This causes project postponements, thus challenging reserve replacement of oil companies and security of supply for consumers. Costs are particularly high for drilling. High rig rates are obviously important. In addition we experience a dramatic fall in drilling productivity. This paper analyses the development in drilling productivity in exploration wells at the Norwegian continental shelf. A unique dataset allows us to apply econometric analyses to ascertain vital explanatory factors for variation in drilling productivity over time and between different wells.

Keywords: Exploration, drilling, productivity, econometrics

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## 1. Introduction

Rig hire and the cost of oil services are the dominant components in drilling expenses, as illustrated in Figure 1 by a representative well. Drilling expenses have increased sharply in recent years. Key causes of this increase include declining drilling productivity and higher rig rates. Oil operations on the Norwegian Continental Shelf (NCS) - as in other petroleum provinces – have recently been characterised by a shortage of rigs and very high rig rates. In new contracts for high-spec semi rigs on the NCS, e.g., the day rate has increased from 147,500 USD per day in July 2004 to 530,820 USD in September 2008, i.e., an increase of 260 per cent over a four-year period, see Figure 2.  This reflects the oil industry boom sparked by the high price of crude, and the fact that few rigs were built over a fairly lengthy period.

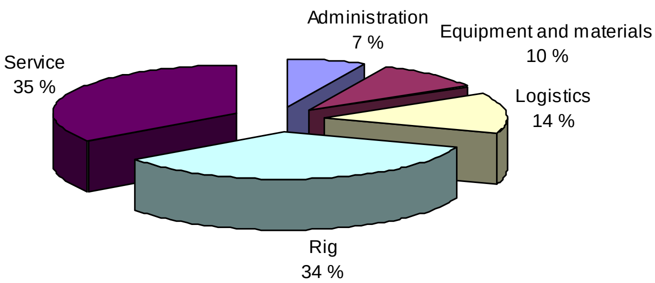


**Figure 1.** Typical composition of drilling costs. Percentage shares.
Source: Data from rig contractors on the NCS.

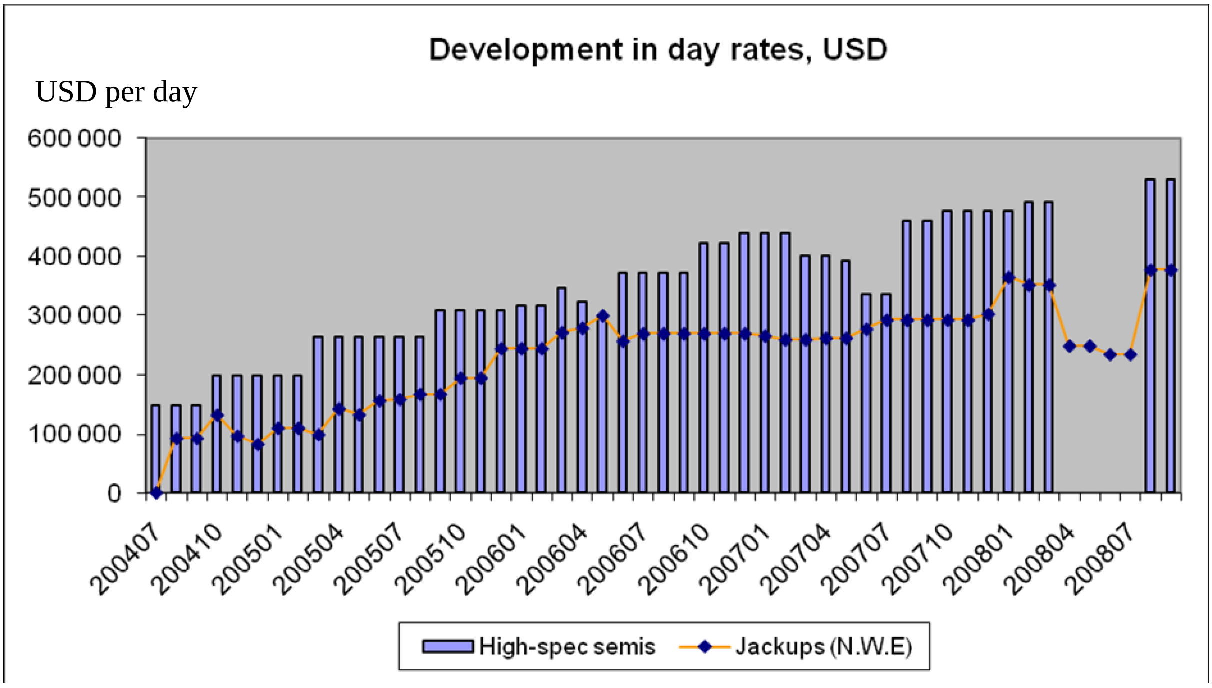


**Figure 2**: Development in day rates for high-spec semi rigs operating on the NCS (new contracts), and high-spec jackups in North West Europe, from 2004 to 2008. Data source: ODS-Petrodata and North Sea Rig Report.

At the same time, a disturbing decline in drilling productivity - measured by the industry standard *drilling meters per day* - can be observed. For instance, as shown by Figure 3, the drilling productivity in the four-year period 2005-2008 was on average 43 meters per day, significantly lower than the average 76 meters per day in the previous four-year period (2001-2004). Although there are not studies on drilling productivity available for many regions, anecdotical evidence suggests that a decrease in drilling productivity is a global tendency. For instance, the Society of Petroleum Engineers (SPE) scheduled a conference in Spain in September 2009 addressing reduced drilling productivity; 'The number of meters drilled per day is falling dangerously and continuously.'

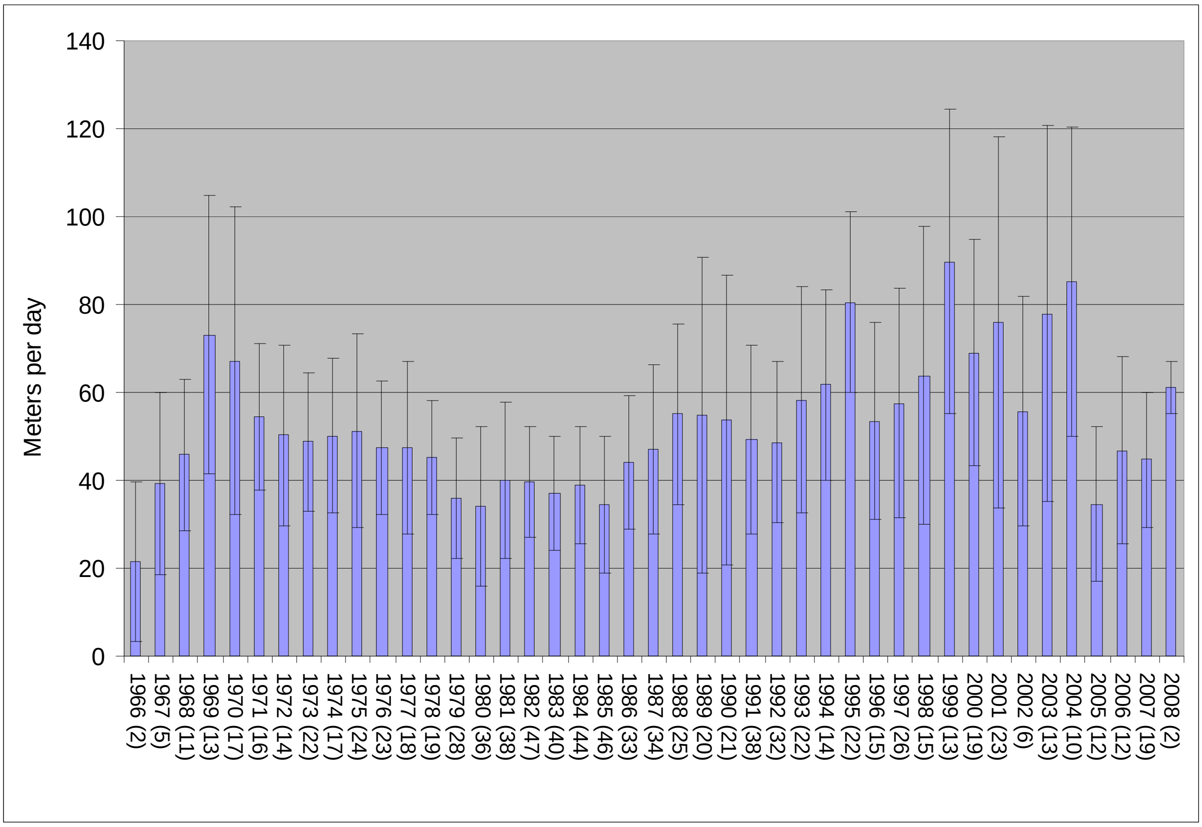


**Figure 3**: Average meters drilled per day. Exploration wells on the NCS, from 1966 to 2008. Annual number of wells in brackets. Black vertical lines indicate standard deviation. Data source: Norwegian Petroleum Directorate.

The combination of falling drilling productivity and increased rig rates have led to a dramatic increase in costs. Helge Lund, CEO of the major player at the NCS – the oil company StatoilHydro -  has referred to this as a 'cost tsunami'. The oil companies could cope with the dramatic cost increase when the oil price was above 100 USD per barrel, but the present cost structure is seriously challenging the development of new reserves at the current downturn of the oil price; see Figure 4.

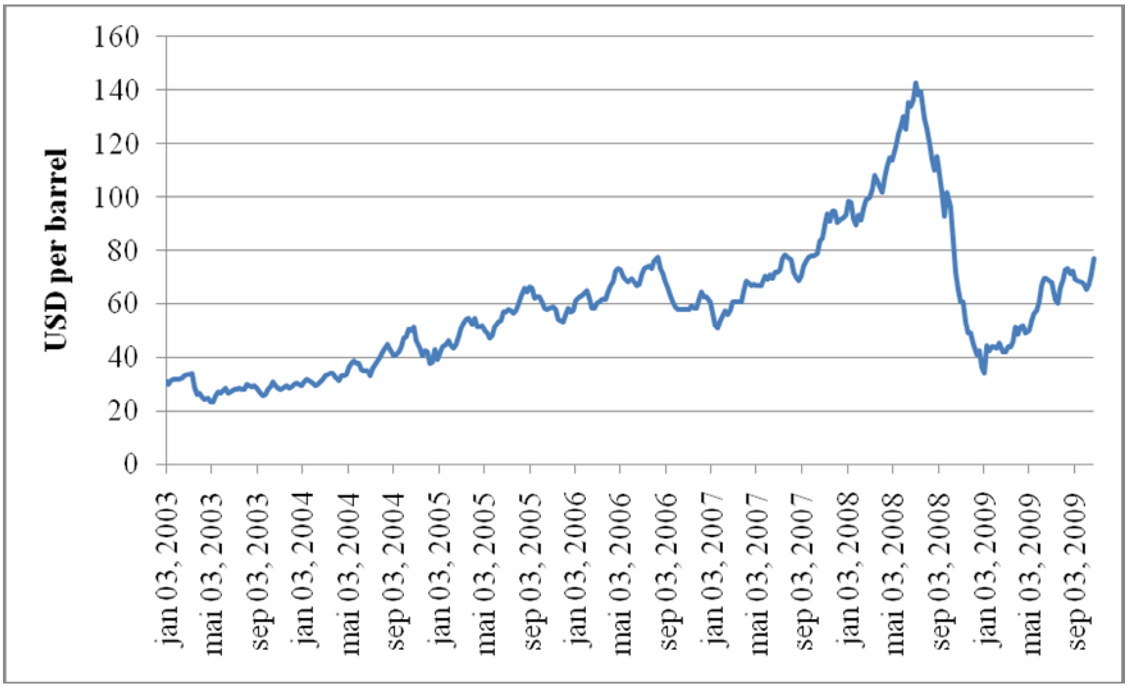


**Figure 4**: Brent Blend Spot Price

As a response to dramatic increasing costs - that seem sticky downward - StatoilHydro has announced cost cuts and postponement of new projects. This is not unique to the NCS. Other oil companies, e.g., Royal Dutch Shell and CococoPhillips, have announced similar strategies on a global basis.[2]

This article analyses one of the major drivers of the recent cost inflation in the Norwegian oil industry - the decrease in drilling productivity. Our case is exploration drilling on the NCS, where we have access to a unique panel data set. The dataset from the Norwegian Petroleum Directorate (NPD) - covering all exploration wells on the NCS - allows us to apply econometric analyses to ascertain the vital explanatory factors for variation in drilling productivity over time and between different wells.

As dependent variable in the econometric analysis we use meter per day, which is the industry standard for measuring drilling productivity, see e.g., drilling statistics generated by

2 Cost cuts in Royal Dutch Shell were reported in April, e.g., before the dramatic fall in the oil price, see TimesOnline, http://business.timesonline.co.uk/tol/business/industry_sectors/natural_resources/article3803252.ece. Falling oil prices will accentuate cost cuts. Recently, ConocoPhillips announced a plan to cut four per cent of the work force; see the report in Houston Cronicle, http://www.chron.com/disp/story.mpl/hofhfhfhtstories/6215681.html

Rushmore Reviews.[3] The measure meter per day is widely used in the oil industry, for benchmarking of drilling performance, for evaluation rig tenders, and as a performance indicator in incentive schemes.[4] If one were merely to evaluate the drilling operation, one might consider only counting the actual drilling time, i.e., to exclude non-productive time. From an economic perspective, however, it is the overall time consumption that counts.[5] The drilling department usually also has influence on non-productive time, as this usually is partly due to them (e.g., due to changes in the drilling plan), and as they have the responsibility to hire in and monitor rig companies and oil service companies.

We do want to emphasize, however, that other measures than drilling speed are necessary to identify value creation in drilling. In addition to drilling speed, which affects the cost side, the amount of oil and gas which can be produced must certainly be taken into account. It is not only a question of drilling fast, but also of drilling correctly. A trade-off may need to be made here, at least in parts of the well path. Drilling speed in exploration must not come at the expense of the primary objective of gathering well information. According to industry source, however, the pure transport phase comprises more than ninety per cent of the drilling time. Moreover, when rigs are scarce, efficient utilization of rig time becomes particularly important. Another trade-off is between drilling speed and matters of health, environment and security (HES). Whereas in some cases such a trade-off certainly exists, it is also the case that some of the success criteria for high drilling speed – like good planning and a tidy working environment – are also crucial to an improvement in the HES-performance.

We analyse an extensive panel data set from the Norwegian Petroleum Directorate (NPD), providing detailed information on all exploration wells drilled on the NCS in the time of operation, i.e., from 1966 to 2008. The article also draws on a number of meetings, presentations and conversations with key specialists in the NPD, oil companies, rig contractors and oil service enterprises.

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3 Www.RushmoreReviews.com

4 See Osmundsen (2009) and Osmundsen et al. (2008, 2009).

5 It is true that a zero rig rate applies in cases where non-productive time is due to the rig company. However, this may be hard to prove. Nevertheless, the rig rate saving to the oil company is normally small compared to consequential losses (payments to other suppliers that are stand-by, and the cost of delay) that are fully borne by the oil company.

## 2. Existing literature

In this section we discuss relevant studies and position our paper in the literature. It seems like the literature analyzing recent developments in exploration drilling productivity and underlying causes is fairly limited, particularly studies published in peer-reviewed journals. However, the literature contains significant contributions on the outcome of exploration drilling, i.e., reserve additions. Petroleum reserve additions per unit of drilling effort have been analysed on US data by Managi et al. (2005), Iledare and Pulsipher (1999) and on British data by Kemp and Kasim (2006). Parts of the dataset on exploration drilling on the NCS that is employed in this paper has been analysed previously in Mohn and Osmundsen (2008), to ascertain the determinants of variations in the overall exploration level. Mohn (2008) also applies the same underlying data set to study reserve additions from NCS oil and gas exploration.

Our approach is complementary to the literature on reserve addition, in that we analyse productivity at a different level. A full economic approach would be to examine the net present value of exploration activity. To do so one would have to account for the quality, cost structure and future value of the volumes of the discovered oil and gas. All this information is of course hard to obtain. The common approach, therefore, is to analyse the volumes of oil and gas that are added. We move farther up the value chain by analysing drilling productivity - defined as the number of meters drilled per day - and ascertain how this measure is affected by economic and technical parameters. Meters drilled per day is the standard key performance parameter in drilling. Our motivation for choosing this approach is that a dramatic drop in meters per day - combined with very high rig rates - is currently perceived by oil companies as one of the main challenges to exploration drilling on the NCS. The maturity of the Norwegian shelf and small discovery sizes is certainly challenging. However, success rates of drilling have been very high on the NCS over the last years, and although discovery sizes are considerably reduced, many of the discoveries are economic to develop by tying in to existing infrastructure. Surging drilling costs, however, are now seriously challenging the economics of exploration drilling. Accordingly, there is much focus in the industry as to the underlying factors that determine drilling speed.

Kellogg (2007) empirically examines the importance of relationship-specific learning using high-frequency data from onshore oil and gas drilling in Texas. He uses the time necessary to drill a well as the measure of drilling productivity, accounting for the depth of the well being drilled. He argues that the measure of drilling speed parallels the way producers and engineers actually view drilling productivity. The analyses show that the joint productivity of a lead firm and its drilling contractor is enhanced significantly as they accumulate experience working together.

Snead (2005) analyses the increased role of deep drilling in Oklahoma. His descriptive analysis of the relationship between well costs and well depth suggests that there is an exponential increase in average well costs per feet as depth increases. In addition to a decline in productivity this also implies that exploration becomes more capital intensive as well depth increases. On the other hand, there is a potential payoff from deep drilling as the average gas production from deep wells has been much higher than for shallow wells.

As drilling operations usually are subject to outsourcing, there is a strand of literature on drilling and oil service contracts that shed light on drilling productivity. Corts (2000) describes the trade-off between turnkey and day-rate contracts. Turnkey contracts give the rig contractor stronger cost incentives and can cut drilling time and costs. The limited utilisation of turnkey contracts for drilling is attributed by Corts in part to the multi-task problem - rewarding one measurable dimension (metres drilled per day) can be at the expense of other important and hard-to-measure quality indicators such as efficient reservoir drainage and information gathering. Corts and Singh (2004) show that repeat contracts between an oil company and a drilling contractor led increasingly to the abandonment of the turnkey model in favour of day rates. They explain this by the build-up of relationships and trust, which reduces the incentive problems and thereby the need for high incentive intensity. Osmundsen et al. (2008) describe and analyse incentives for drilling contractors on the NCS. These are directly represented by the compensation formats utilised in the present and in the consecutive drilling contracts entered into by the drilling contractor, which are analysed. The paper also analyses incentives that are indirectly provided by the evaluation criteria that oil companies use for awarding drilling assignments. Some contracts explicitly link bonus payments to the meter per day measure. For contracts where such incentive schemes are not present, the authors argue that the drilling contractor face indirect drilling speed incentives, as drilling speed is one of the criteria used by the oil companies in the tendering process. An analogous study for oil service contractors on the NCS is provided in Osmundsen et al. (2009). For a discussion of the relationship between health, safety and the environment (HSE) and incentive systems in drilling, see Osmundsen et al (2006).

### 3. Empirical specification and data

We estimate an econometric model of drilling productivity on a log-log form for the continuous variables, which simplifies derivation of elasticities. The model is flexible in the sense that continuous variables are specified as second-order and interacted variables, and will therefore allow for a complete specification of substitution patterns among continues variables, i.e. we have a translog type model. The unit of observation is an exploration well, which is observed from drilling is initiated to the drilling process is finished.

The model is on a general form specified as

$$
\begin{aligned}
(1)\quad \ln Y = {} & \Sigma_i \alpha_i \ln X_i + 0.5 \Sigma_i \Sigma_j \alpha_{ij} \ln X_i \ln X_j \\
& + \alpha_t t + \alpha_{t2} t^2 + \alpha_{t3} t^3 + \Sigma_i \alpha_{it} \ln X_i \cdot t + \alpha_{Pt} \ln OilPrice \cdot t \\
& + \alpha_{OP} \ln OilPrice + \alpha_{OP2} \ln OilPrice^2 + \Sigma_i \alpha_{iP} \ln X_i \cdot \ln OilPrice \\
& + \Sigma_r \mu_r OilCoType_r + \Sigma_s \mu_s FacilityType_s + \Sigma_e \mu_e FacilityExperience_e \\
& + \mu_D Discovery + \mu_W Purpose + \mu_{WBS} WellboreStatusPA + \Sigma_a \mu_a Area_a,
\end{aligned}
$$

where the dependent productivity variable, *Y*, is as previously mentioned, average drilled meters per day and represents drilling productivity. It is measured as total meters drilled from the sea bed to the bottom of the well divided by the number of days from drilling activity is initiated until drilling is terminated, including days with no drilling activity (i.e. downtime). Since the exploration wells may not be vertical, drilling depth may be longer than the vertical distance from the seabed. $X$ is a vector of continuous variables in the model, including well depth in meters, water depth in meters, and well bottom temperature. The terms with the time-trend variable $t$ are included to control for technological change. The “OilPrice” variable is a proxy for the supply and demand conditions in the drilling market, or the scarcity of productive labor, drilling facilities and other specialized inputs. An “OilCoType” dummy describes the type of oil company, with “mid caps am” and “three sisters” as reference category, “rest” as dummy variable 1 and “mid caps euro” as dummy variable 2. The “FacilityExperience” dummy variables control for drilling experience among drilling facilities, where the facilities are separated in three groups based on their drilling experience on NCS.[6] A “FacilityType” dummy variable is included to control for the type of drilling rig. The most common facility type is semisub steel, and this is the default category. Several characteristics of the well are included in the model as dummy variables. The “WellboreStatusPA” variable controls for the wellbore status of the well. Most of the well’s status is plugged and abandoned (P&A). We also control for discovery status of the well through the “Discovery” dummy variable, and the area where the well has been drilled by the “Area” dummy variables. The wells are drilled in the three major offshore regions on the Norwegian Continental Shelf – the North Sea, the Norwegian Sea and the Barents Sea. Finally, we control for the “Purpose”, whether the well is a wildcat or appraisal.

It is difficult to interpret the continuous variables that appear in several terms in equation (1) individually. It is more fruitful to assess the estimated elasticities that can be calculated from these variables. An elasticity is defined as the derivative of the log of the dependent variable with respect to the log of a continuous explanatory variable. The elasticities calculated here are:

(2) $e_i = \partial \ln Y / \partial \ln X_i = 0.5\Sigma_j \alpha_{ij} \ln X_j + \alpha_{it} t + \alpha_{iP} \ln OilPrice$, $i$ = {well depth, water depth, temperature},

[6] If the drilling facility has drilled less than 10 times at NCS over the data period it is classified as ‘less experienced’, between 10-30 times ‘intermediate experienced’, and above 30 times ‘much experienced’.

and

(3) $e_P = \partial \ln Y/\partial \ln OilPrice = + 2\alpha_{OP2}\mathrm{lnOilPrice} + \Sigma_i\alpha_{iP}\ln X_i + \alpha_{Pt}t$.

We also calculate the rate of technical progress, which is captured by the terms involving the time trend variable *t*, given by:

(4) $e_t = \partial \ln Y/\partial t = 2\alpha_{t2}t + 3\alpha_{t3}t^2 + \Sigma_i\alpha_{it}\ln X_i + \alpha_{Pt}\mathrm{lnOilPrice}$.

Our data set is retrieved from the data bases of the Norwegian Petroleum Directorate, which has collected and processed information and statistics on Norwegian oil and gas activities since the early 1970s. We have time series for all variables over the period 1965-2008, split between the three major offshore regions on the Norwegian Continental Shelf – the North Sea, the Norwegian Sea and the Barents Sea. The long time span of our data allows us to account for several oil price cycles, as well as technological development. Summary statistics of the estimating sample is provided in table 1. We had to exclude some of the observations in the original data set due to missing observations on key variables in our econometric model, for example well temperature. Some of the wells are sidestep wells from the original exploration well. Including sidestep wells in the estimating sample leads to biased estimates, since these benefit in terms of reduced drilling time by partly utilizing the original exploration well. Exclusion due to missing variable observations and sidestep wells lead to a reduction in the number of observed wells from 924 to 642. Given the challenging nature of large-scale offshore oil and gas operations on the NCS, the dataset comprises the vital companies in the oil business. The companies participating as operators on the NCS include all super majors, and major oil service companies like Halliburton, Baker Hughes and Schlumberger are present in Norway. For details on NCS resources and participants, see Norwegian Petroleum Directorate (2007) and Ministry of Petroleum and Energy (2008).

**4. Empirical results**

This section presents the empirical results from estimation of the production model (1) together with associated elasticities. First we estimate on all observations in the estimating sample. However, since there may be structural differences in productivity between wildcat and appraisal wells that are not captured by the “Wellbore purpose” dummy variable we also estimate a separate regression model only for the subsample of wildcats, which represent the majority of observations in the sample. Furthermore, to account for possible structural differences in wells with discovery and those with no discovery that is not fully captured by the “Discovery” dummy variable, we estimate a separate regression model on the subsample of wells with no discovery.

*Empirical results for the full estimating sample*

The production model (1) is estimated using OLS with White’s heteroskedasticity-consistent standard errors (White, 1980). Estimated coefficients with heteroskedasticity-consistent standard errors and associated t- and p-values for the full estimating sample are presented in Tables 2, and derived elasticity estimates from the model is presented in Table 3. The elasticities with associated t-values and p-values are calculated for the sample mean values of the variables. Our empirical findings correspond largely with the *a priori* expectations that we have made from conversations with industry specialists. According to the estimated model statistically significant contribution from different factors in explaining drilling productivity are as follows: (1) Well depth: Deeper wells are less productive than shallow wells. (2) Water depth: Water depth has a negative effect on productivity. (3) Well temperature: Drilling productivity declines as temperature increases. (4) Oil price: Drilling productivity slows down when oil prices increase. (5) Technological change over time: We can trace a positive effect on productivity that we can attribute primarily to technological progress over time. (6) Purpose: Wildcats are more productive than appraisal wells. (7) Area: The Barents Sea wells are the least productive, Norwegian Sea wells are most productive, and North Sea wells are in between. (8) Discovery status: Wells with discovery are less productive than dry wells. (9) Drilling facility experience:

The group of drilling facilities with the least experience on the NCS has a lower productivity than the group of most experienced drilling facilities.

We have also tested using F-tests several hypotheses of the joint significance of explanatory variables. A test of the joint insignificance of all parameters except those involving the well characteristics, oil price and time trend, i.e. the parameters associated with the terms ($\Sigma_r\mu_r OilCoType_r + \Sigma_s\mu_s FacilityType_s + \Sigma_e\mu_e FacilityExperience_e + \mu_D Discovery + \mu_W Purpose + \mu_{WBS} WellboreStatusPA + \Sigma_a\mu_a Area_a$) in equation (1), was firmly rejected with an F-test statistic of $F(10, 610) = 10.46$ (p-value $p=0.000$). However, a test of the joint significance of the operator (oil company) type variables (i.e. the terms $\Sigma_r\mu_r OilCoType_r$) rejected joint significance with a test statistic of $F(2, 610) = 1.57$ ($p = 0.2096$). In other words, operator type dummy variables do not contribute to explaining differences in drilling productivity. A joint test of significant differences in productivity between different areas on the NCS (i.e. the terms $\Sigma_a\mu_a Area_a$), is supported with a test statistic of $F(2, 610) = 10.05$ ($p = 0.0001$).

Our findings can be explained as follows. Drilling productivity is lower on average in deeper wells, for several reasons. Higher pressure requires higher mud weight, which implies slower drilling. Moreover, technical problems - like the drill bit going stuck – often takes more time to remedy. High water depth slows down drilling speed. This is not surprising, as our drilling meter measure starts at the sea bed. Thus, a high water depth takes time for the drilling company without contribution to the key performance indicator – drilled meters per day. Industry specialists are not surprised of our finding that temperature is insignificant for drilling speed, as temperatures are not especially high on the NCS. Moreover, high temperatures impose special requirements on equipment, thus affecting costs more than drilling speed. High oil prices are associated with high activity levels and thus a scarcity of qualified labor, drilling facilities and other specialized inputs. Thus, less adequate rigs are being used at the margin, reducing average productivity. Moreover, at the peak of a business cycle for the oil industry there are more likely to be scarcity of trained and experienced personnel and bottle necks at other crucial supply services in drilling, thus driving up the non-productive time.

Over time there have been several technological changes that have contributed positively to drilling speed, e.g., the introductions of the top drive and measurement while drilling. Drilling speed is lower in appraisal wells than for wildcats, due to more testing time. Our time measure includes the testing time. We find that drilling is slower in the Barents Sea than in the other areas on the NCS, even if we account for differences in see deep, water depth, etc. Possible explanation to this is tougher climate conditions and larger logistic challenges due to longer distances from supply clusters. The lower number of wells in the Barents Sea also means that this region has travelled a shorter distance down the learning curve. The oil industry also faces tougher environmental standards in the Barents Sea, negatively affecting drilling speed. Finally, wells with discovery are slower to drill due to time spent on testing. Finally, due to the complex nature of drilling, it is natural that drilling facility experience contributes positively to drilling speed.

*Empirical results for wildcats*

Estimated coefficients with heteroskedasticity-consistent standard errors and associated t- and p-values for the subsample of wildcats are presented in Tables 4, and derived elasticity estimates from the model is presented in Table 5. Our empirical findings are fairly similar to those from the full sample. For the dummy variables in the model there are no changes in sign when we compare tables 2 and 4, or large changes in significance as measured by the p-values. Hence, the findings from the estimation on the full sample discussed above still hold.

The estimated elasticities presented in table 5 are fairly similar to those from the full estimating sample in table 3. The most significant change is the loss of statistical significance for the temperature elasticity. Well depth seems to have a larger negative effect on productivity for wildcats than for wells in the full sample.

*Empirical results for wells with no discovery*

Estimated coefficients with heteroskedasticity-consistent standard errors and associated t- and p-values for the subsample of wells with no discovery are presented in Tables 6, and derived elasticity estimates from the model is presented in Table 7. Most of the empirical findings are similar to those from the full sample. For the dummy variables in the model there are no significant changes in sign when we compare tables 2 and 6.

The values of the estimated elasticities presented in table 7 are fairly similar to those from the full estimating sample in table 3. However, the temperature elasticity and well depth elasticity become statistically insignificant at the 10% level as indicated by their p-values.

## 5. Conclusions

A dramatic increase in drilling costs is a particular challenge in the current situation at the Norwegian continental shelf (NCS), when much effort is put into increased oil recovery from mature fields and development of new deep-water fields, as both these project types are drilling intensive. The increase in drilling costs represents a challenge both to international oil companies (IOCs) and oil consumers. The IOCs are already struggling to maintain production and reserves, and sticky costs at a high level combined with a decrease in oil price make this much harder. Even for projects that are still profitable, the decrease in drilling productivity is problematic as it reinforces the problem posed by scarcity of rigs.

In World Energy Outlook 2008, IEA undertakes a field-by-field analysis of production trends at 800 of the world's largest oilfields. Through a bottom-up analysis of upstream costs and investment, they make an assessment of the potential for finding and developing new reserves. They conclude that the immediate risk to supply is not one of lack of global resources (estimated remaining proven reserves have almost doubled since 1980), but rather a lack of investment. Upstream investments have been rising rapidly in nominal terms, but much of the increase is due to surging costs. In cost-inflation adjusted terms, investments in 2007 were according to IEA 70 per cent higher than in 2000. Worldwide, upstream costs rose on average by an estimated 90 per cent between 2000 and 2007. Most of the increase occurred in the period 2004-2007. IEA warns that there remains a real risk that underinvestment will cause an oil-supply crunch.

This article analyses one of the major drivers of the cost inflation in the oil industry - the decrease in drilling productivity. In our econometric analysis we found empirical evidence that water depth has a strong negative effect on drilling productivity measured as meters per day. Well depth also has a negative effect on productivity. Productivity was also lower in periods of high oil prices, a proxy for high drilling activity levels and increased scarcity of equipment and personnel.

The output of our analyses can be useful, in two ways: 1) By detecting the underlying factors that influence drilling productivity, we provide a basis for making predictions of future drilling productivity levels. For instance, what is the likely effect on drilling productivity if the oil price declines? 2) By indicating the major explanatory factors for variations in drilling productivity over time, we can give advice on where the oil industry has the largest potential for improvement. Is it in a careful management of drilling capacity versus drilling tasks, or is it primarily in better handling of deep-water drilling?

State-of-the-art rig activity monitoring presents an opportunity to revolutionize the way in which contractors are rewarded for above average performance, technically or in safety terms. For many years the few contractual incentives available and utilized have concentrated on very simple metrics, such as rig uptime and on drilling rates. A successful well for most old-time drillers was one that reached total depth quickly and without significant lost time. Whether the well ultimately became an effective producer, drilled and completed with minimum damage to the formation and with high mechanical integrity, was not considered. Rapid drilling is not always compatible with good reservoir utilisation and efficient information gathering, so a trade-off must be made here. Maybe the trade-off has gone too far in the other direction, at the expense of drilling speed, thus making new projects unprofitable. There are positive signs of reorientation, and drilling speed at the NCS improved recently.

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**Table 1. Summary statistics of the estimating sample**

| Variable | Mean | Std.dev. | Min | Max |
|---|---|---|---|---|
| Meters drilled per day | 47.99 | 24.22 | 6.89 | 186.60 |
| Oil company type1 | 0.04 | 0.20 | 0 | 1 |
| Oil company type 2 | 0.51 | 0.50 | 0 | 1 |
| Oil company type 3 | 0.45 | 0.50 | 0 | 1 |
| Facility drilling experience dummy <10 | 0.21 | 0.41 | 0 | 1 |
| Facility drilling experience dummy 10-30 | 0.38 | 0.49 | 0 | 1 |
| Facility drilling experience dummy >30 | 0.38 | 0.49 | 0 | 1 |
| Facility type semisub steel dummy | 0.91 | 0.28 | 0 | 1 |
| Wellbore status P&A dummy | 0.86 | 0.35 | 0 | 1 |
| Wellbore purpose dummy (wildcat) | 0.69 | 0.46 | 0 | 1 |
| Barents sea dummy | 0.08 | 0.28 | 0 | 1 |
| North sea dummy | 0.71 | 0.45 | 0 | 1 |
| Norwegian sea dummy | 0.21 | 0.41 | 0 | 1 |
| Discovery dummy | 0.29 | 0.45 | 0 | 1 |
| Depth in meters | 3044.3 | 1038.6 | 304 | 5470 |
| Temperature | 107.95 | 35.83 | 24 | 200 |
| Water depth | 210.69 | 183.47 | 48 | 1717 |
| Oil price | 44.67 | 24.79 | 9.65 | 93.08 |
| T | 21.20 | 8.77 | 1 | 40 |

N = 642.

**Table 2. Econometric estimates with log of drilled meters per day as dependent variable for all exploration wells***

| Variable | Coef. | Std.Err. | t-value | P-value |
|---|---|---|---|---|
| Oil company type1 | 0.104 | 0.067 | 1.550 | 0.122 |
| Oil company type 2 | -0.011 | 0.032 | -0.340 | 0.735 |
| Facility drilling experience dummy <10 | -0.128 | 0.048 | -2.690 | 0.007 |
| Facility drilling experience dummy 10-30 | -0.053 | 0.033 | -1.600 | 0.110 |
| Facility type semisub steel dummy | -0.009 | 0.067 | -0.140 | 0.889 |
| Wellbore status P&A dummy | 0.061 | 0.047 | 1.310 | 0.192 |
| Wellbore purpose dummy (wildcat) | 0.207 | 0.037 | 5.630 | 0.000 |
| Barents sea dummy | -0.267 | 0.060 | -4.480 | 0.000 |
| North sea dummy | -0.105 | 0.049 | -2.150 | 0.032 |
| Discovery dummy | -0.249 | 0.035 | -7.170 | 0.000 |
| ln(well depth) | -0.263 | 0.323 | -0.820 | 0.415 |
| ln(well depth)^2 | 0.063 | 0.140 | 0.450 | 0.655 |
| ln(well depth)*ln(temperature) | -0.313 | 0.245 | -1.280 | 0.202 |
| ln(well depth)*ln(water depth) | 0.355 | 0.203 | 1.740 | 0.082 |
| ln(temperature) | -0.387 | 0.352 | -1.100 | 0.272 |
| ln(temperature)^2 | -0.384 | 0.246 | -1.560 | 0.119 |
| ln(water depth)*ln(temperature) | -0.125 | 0.204 | -0.610 | 0.541 |
| ln(water depth) | -0.531 | 0.128 | -4.150 | 0.000 |
| ln(water depth)^2 | -0.115 | 0.041 | -2.850 | 0.005 |
| ln(oil price) | -0.300 | 0.126 | -2.390 | 0.017 |
| ln(oil price)^2 | 0.143 | 0.087 | 1.640 | 0.103 |
| ln(oil price)*ln(water depth) | -0.054 | 0.062 | -0.860 | 0.391 |
| ln(oil price)*ln(well depth) | -0.032 | 0.181 | -0.180 | 0.860 |
| ln(oil price)*ln(temperature) | 0.039 | 0.169 | 0.230 | 0.819 |
| t | 0.168 | 0.059 | 2.820 | 0.005 |
| t^2 | -0.007 | 0.003 | -2.470 | 0.014 |
| t^3 | 0.000 | 0.000 | 2.370 | 0.018 |
| t*ln(depth in meters) | 0.003 | 0.015 | 0.200 | 0.838 |
| t*ln(water depth) | 0.010 | 0.005 | 1.910 | 0.056 |
| t*ln(temperature) | 0.003 | 0.016 | 0.200 | 0.842 |
| t*ln(oil price) | 0.000 | 0.006 | -0.060 | 0.952 |
| Constant | 2.360 | 0.460 | 5.130 | 0.000 |

N = 642. R-squared = 0.4867.

* Standard errors are heteroskedasticity adjusted following White (1980).

**Table 3. Elasticity estimates evaluated in mean variable values**

| Variable | Mean | t-value | p-value |
|---|---|---|---|
| Temperature | -0.215 | -1.920 | 0.056 |
| Well depth | -0.277 | -2.360 | 0.019 |
| Water depth | -0.285 | -7.950 | 0.000 |
| Oil price | -0.345 | -4.870 | 0.000 |
| TC | 0.026 | 4.440 | 0.000 |

**Table 4. Econometric estimates with log of drilled meters per day as dependent variable for wildcat wells***

| Variable | Coef. | Std.Err. | t-value | P-value |
|---|---|---|---|---|
| Oil company type1 | 0.061 | 0.071 | 0.870 | 0.387 |
| Oil company type 2 | -0.033 | 0.039 | -0.830 | 0.407 |
| Facility drilling experience dummy <10 | -0.165 | 0.056 | -2.930 | 0.004 |
| Facility drilling experience dummy 10-30 | -0.067 | 0.040 | -1.690 | 0.091 |
| Facility type semisub steel dummy | -0.027 | 0.074 | -0.360 | 0.717 |
| Wellbore status P&A dummy | 0.100 | 0.063 | 1.600 | 0.110 |
| Barents sea dummy | -0.326 | 0.068 | -4.820 | 0.000 |
| North sea dummy | -0.116 | 0.059 | -1.980 | 0.048 |
| Discovery dummy | -0.264 | 0.036 | -7.330 | 0.000 |
| ln(well depth) | -0.937 | 0.384 | -2.440 | 0.015 |
| ln(well depth)^2 | -0.303 | 0.408 | -0.740 | 0.458 |
| ln(well depth)*ln(temperature) | -0.088 | 0.884 | -0.100 | 0.921 |
| ln(well depth)*ln(water depth) | 0.089 | 0.216 | 0.410 | 0.680 |
| ln(temperature) | 0.465 | 0.465 | 1.000 | 0.318 |
| ln(temperature)^2 | -0.287 | 0.546 | -0.530 | 0.599 |
| ln(water depth)*ln(temperature) | 0.099 | 0.218 | 0.450 | 0.650 |
| ln(water depth) | -0.579 | 0.150 | -3.850 | 0.000 |
| ln(water depth)^2 | -0.144 | 0.046 | -3.140 | 0.002 |
| ln(oil price) | -0.089 | 0.171 | -0.520 | 0.603 |
| ln(oil price)^2 | 0.164 | 0.099 | 1.660 | 0.099 |
| ln(oil price)*ln(water depth) | -0.022 | 0.068 | -0.320 | 0.748 |
| ln(oil price)*ln(well depth) | -0.338 | 0.199 | -1.700 | 0.089 |
| ln(oil price)*ln(temperature) | 0.299 | 0.196 | 1.520 | 0.129 |
| t | 0.138 | 0.066 | 2.100 | 0.037 |
| t^2 | -0.006 | 0.003 | -1.910 | 0.057 |
| t^3 | 0.000 | 0.000 | 1.900 | 0.059 |
| t*ln(depth in meters) | 0.022 | 0.017 | 1.330 | 0.185 |
| t*ln(water depth) | 0.012 | 0.006 | 1.980 | 0.048 |
| t*ln(temperature) | -0.029 | 0.020 | -1.440 | 0.150 |
| t*ln(oil price) | -0.010 | 0.008 | -1.320 | 0.188 |
| Constant | 2.871 | 0.510 | 5.620 | 0.000 |

N = 442. R-squared = 0.557.

* Standard errors are heteroskedasticity adjusted following White (1980).

**Table 5. Elasticity estimates wildcat wells evaluated in sample mean variable values**

| Variable | Mean | t-value | p-value |
|---|---|---|---|
| Temperature | -0.149 | -1.04 | 0.298 |
| Well depth | -0.431 | -3.01 | 0.003 |
| Water depth | -0.257 | -6.51 | 0.000 |
| Oil price | -0.359 | -4.17 | 0.000 |
| TC | 0.024 | 3.73 | 0.000 |

**Table 6. Econometric estimates with log of drilled meters per day as dependent variable for wells with no discovery***

| Variable | Coef. | Std.Err. | t-value | P-value |
|---|---|---|---|---|
| Oil company type1 | 0.220 | 0.091 | 2.42 | 0.016 |
| Oil company type 2 | 0.012 | 0.038 | 0.32 | 0.751 |
| Facility drilling experience dummy <10 | -0.098 | 0.056 | -1.74 | 0.082 |
| Facility drilling experience dummy 10-30 | -0.038 | 0.040 | -0.96 | 0.337 |
| Facility type semisub steel dummy | 0.021 | 0.082 | 0.25 | 0.802 |
| Wellbore status P&A dummy | 0.032 | 0.060 | 0.53 | 0.595 |
| Wellbore purpose dummy (wildcat) | 0.218 | 0.039 | 5.60 | 0.000 |
| Barents sea dummy | -0.369 | 0.073 | -5.03 | 0.000 |
| North sea dummy | -0.117 | 0.061 | -1.92 | 0.055 |
| ln(well depth) | 0.307 | 0.402 | 0.76 | 0.445 |
| ln(well depth)^2 | 0.214 | 0.161 | 1.33 | 0.186 |
| ln(well depth)*ln(temperature) | -0.387 | 0.271 | -1.43 | 0.154 |
| ln(well depth)*ln(water depth) | 0.231 | 0.227 | 1.01 | 0.311 |
| ln(temperature) | -0.956 | 0.431 | -2.22 | 0.027 |
| ln(temperature)^2 | -0.472 | 0.267 | -1.77 | 0.078 |
| ln(water depth)*ln(temperature) | -0.011 | 0.235 | -0.05 | 0.963 |
| ln(water depth) | -0.441 | 0.139 | -3.17 | 0.002 |
| ln(water depth)^2 | -0.164 | 0.049 | -3.33 | 0.001 |
| ln(oil price) | -0.488 | 0.147 | -3.31 | 0.001 |
| ln(oil price)^2 | 0.152 | 0.103 | 1.47 | 0.143 |
| ln(oil price)*ln(water depth) | -0.107 | 0.070 | -1.53 | 0.126 |
| ln(oil price)*ln(well depth) | 0.153 | 0.214 | 0.72 | 0.474 |
| ln(oil price)*ln(temperature) | -0.191 | 0.208 | -0.92 | 0.360 |
| t | 0.183 | 0.063 | 2.90 | 0.004 |
| t^2 | -0.007 | 0.003 | -2.49 | 0.013 |
| t^3 | 0.000 | 0.000 | 2.30 | 0.022 |
| t*ln(depth in meters) | -0.021 | 0.019 | -1.14 | 0.255 |
| t*ln(water depth) | 0.006 | 0.006 | 1.12 | 0.265 |
| t*ln(temperature) | 0.032 | 0.020 | 1.62 | 0.107 |
| t*ln(oil price) | 0.008 | 0.008 | 1.04 | 0.301 |
| Constant | 2.244 | 0.530 | 4.23 | 0.000 |

N = 459. R-squared = 0.4845.

* Standard errors are heteroskedasticity adjusted following White (1980).

**Table 7. Elasticity estimates for wells with no discovery evaluated in sample mean variable values**

| Variable | Mean | t-value | p-value |
|---|---|---|---|
| Temperature | -0.206 | -1.44 | 0.149 |
| Well depth | -0.191 | -1.30 | 0.193 |
| Water depth | -0.251 | -5.36 | 0.000 |
| Oil price | -0.352 | -4.18 | 0.000 |
| TC | 0.027 | 3.65 | 0.000 |