Cash Flow and Investment Project Outcomes: Evidence from Bidding on Oil and Gas Leases

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Abstract

How does firm investment change with cash flow? We examine this question for auctions of oil and gas leases because detailed data on specific investment projects are publicly available in this context. All bids, including losing ones, as well as the eventual outcome of the leases can be measured. We find that as cash flow rises firms do spend more on purchasing leases. Interestingly, though, they do not buy more or bigger leases; instead, they simply pay more for each lease. This effect is strongest as firms approach the end of their fiscal year. Leases bought when cash flow is high are not more productive; in fact, they are often *less* productive. In short, when cash flow is high, bidders appear to over-pay for less productive leases without expanding the scale of operations. These results are most consistent with a free cash-flow view of investment in which managers use cash flow to simplify their job (or live a "quiet life") rather than empire build. We also find that the productivity effects are strongest earlier in our sample, consistent with the view that governance in this industry has improved over time.

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1 Introduction

Numerous studies of investment show that cash flow very strongly predicts investment. In fact, as a first pass, cash flow often is a better predictor than measures of investment opportunities or other measures of user cost of capital (Caballero 1999, Stein 2003). Three interpretations have been proposed for this finding. First, managers choose investments to maximize profits and capital markets are perfect but cash flow predicts investment because it proxies for future investment opportunities much better than other measures (Poterba, 1988). Second, managers would like to choose investments to maximize profits but are financially constrained and cash flow eases these constraints allowing them to undertake good projects they otherwise would not be able to (Fazarri, Hubbard and Petersen, 1988). Third, managers do not choose investment to maximize profits but rather for private benefits. In this view, they dissipate free cash on wasteful investment projects because cash on hand is more prone to mis-spending. This last free cash flow view sharply contrasts with the two others in emphasizing that high cash flow induces unprofitable investments.

Despite numerous attempts to empirically test these explanations, there is no consensus to date on which dominates. For example, while Fazzari, Hubbard and Petersen (1988) show that firm investment-cash flow sensitivities are positively related to some a priori measures of financial constraints, Kaplan and Zingales (1997) argue that such relationship does not hold when one uses more precise measures of funds' availability and demand. A deeper issue is seen in Lamont (1997) and Shin and Stultz (1998) who show that plausibly exogenous increases in cash flow raise investment. But they have no way of knowing whether the new investments are profitable or unprofitable. This is key since the cash flow view differs from the other views exactly because it argues that marginal projects are wasteful.

Lack of detailed investment data has been one of the major difficulties. Research typically relies on balance-sheet measures of corporate investment, e.g. total capital expenditures, which mix together numerous, disparate investment projects. Most importantly, with balance sheet data, it is hard or impossible to measure the eventual profitability of projects. To circumvent these concerns, we use project-level data to paint a richer picture of the relationship between investment and cash flow.

We focus on federal auctions of mineral rights to offshore tracts. Firms bid on these leases in order to explore them and hopefully find oil, gas or some other minerals. For each auction, we know the amount bid by all bidding firms (both winners and losers), the identity of the bidding firms, the exact timing of the auction (month and year), and numerous tract-level characteristics that may be predictive of profitability. Importantly, we also know whether any minerals were actually found on the tract and, for a subset of the leases, how much was extracted.

We find that when cash flow rises, firms bid more on observationally equivalent tracts of land. Interestingly, neither the number of tracts nor the characteristics of these tracts (such as size) changes with cash flow. The aggregate investment to cash-flow sensitivity in this industry is almost exclusively driven by the price margin, not by the quantity margin. We also find that this price-cash flow effect is especially strong towards the end of a firm's fiscal year, suggesting that firms may be allocating a fixed annual budget for these investment projects.

While these results shed some new light on the investment-cash flow relationship, knowing the eventual productivity of these tracts is crucial to interpreting the results. As noted earlier, both mismeasurement and credit constraints suggest that higher cash flow induces bidders to bid on profitable tracts, while free cash flow suggests that tracts bought when cash flow is high would be less profitable. To test this, we examine whether minerals are found on the the tracts firms buy. First, we replicate an earlier finding showing that, as a whole, bids are predictive of future productivity (Hendricks and Porter, 1996). Tracts with higher bid price are much more likely to be successful, suggesting that bids have some predictive power. But we also find that cash flow driven increases in bid price do not positively predict productivity. In fact, we often find that such cash flow driven increases in bids predict lower productivity.

We also examine how the total number of successes for all the tracts bought in a given year vary with cash flow. We find that tracts bought in high cash flow years yield less successes than tracts bought in low cash flow years.[1] Thus, while the bidders are paying more for these tracts, they are not getting more revenues. These results are quite stark. Because high cash flow firms are bidding more, they suggest that a firm with low cash flow earns higher *total* profits from its investments than a firm with high cash flow.[2]

Finally, we examine how these results vary over time. Many perceive that the oil industry experienced large improvements in governance in the 1980s. Takeovers and increases in the threat of takeover is thought to have reduced the managerial misbehavior posited by the free cash flow view. In our sample, we find that bids are sensitive to cash flow throughout the period we study (mid 1960s to late 1990s). But consistent with the idea that governance improved, we find that the negative productivity effects are concentrated in the earlier years of our sample (pre-1985).

[1] Note that we find that there are fewer successes in total, not just a lower success rate. So diminishing returns would not explain these results.

[2] Since we control for year dummies, time varying oil prices would not affect this conclusion.

We conclude that our results are most consistent with a free cash flow model of bidder behavior with one important caveat. Free cash flow models often also assume that managers enjoy empire building (Jensen, 1986). In our data, however, bidders do not appear to build empires with their cash flow: they are not bidding on more tracts or bigger tracts of land. Instead, they simply appear to be making worse decisions and dissipating cash through high bid prices. In this sense, our results appear to be most consistent with "quiet life" models of free cash flow in which managers use cash on hand to make their job easier (Hicks 1935, Bertrand and Mullainathan 2003).

2 Industry Overview and Data

2.1 Industry

Since 1954, the U.S. Department of Interior has been auctioning off leases that give mineral exploration rights to tracts of federal land. These lands are located in Alaska, offshore in the Pacific and offshore in the Gulf of Mexico. For data reasons we will focus on the Gulf of Mexico where most of the sales occur. Each sale is a simultaneous auction of many tracts and there are typically several auctions per year. The auction format is a first-price, sealed bid. The highest bidder for each tract is awarded the lease in exchange for the amount bid, assuming that the government does not reject the bid as insufficient which rarely happens. Leases are fairly large investment projects. The average lease in our sample is sold for $12.5 million dollars (in 2000 dollars).

Firms who bid on tracts vary dramatically in size. At the large end are subdivisions of diversified firms who may or may not have other petroleum interests. In the middle are public firms that have some other petroleum interests. At the small end are firms that are partnerships and bid on a tract or two every few years. In order to inform their bidding decisions, firm often hire geologists to collect seismic data. In addition, tracts located within the same area are likely to share common geological features, so firms can also rely on the publicly observed successes of previously auctioned nearby tracts. They may also have some private data if they own some nearby successful tracts and have not yet had to make public those successes.

When a firms wins a tract, it can explore the tract for the length of the lease (typically 5 years). Exploration typically involves drilling bore holes and testing for presence of gas, oil, or other minerals. The exploration process is fairly uniform with a fixed set of exploration technologies. Some firms may even contract out this stage. The only significant cost variation is distance from the shore or depth of the tract, both of which we can measure or proxy for. If the lease expires without the discovery of any major oil and/or gas reserves, the government regains ownership of the tract.

If minerals are discovered before the expiration date, the lease is automatically renewed for as long as the tract is producing minerals. So exploration leases effectively give monopoly rights to extraction as well. Once production begins, the government receives a fixed fraction of production revenues (typically 16.7 percent) as a royalty payment. Royalty rates as well as lease length are known prior to bidding. Production is often contracted out and in any case is done with one of a few uniform technologies. The cost data that is available and anecdotal evidence in the industry suggests that extraction costs are relatively uniform, with only a few sources of variation: distance to other productive tracts, distance to shore and depth.

2.2 Data

The Minerals Management Service (MMS) keeps detailed information on all leases auctioned off in the Gulf of Mexico since 1954. For each lease, the data contain, among other things: complete bidding information (all recorded bids with name of the bidding companies), tract characteristics (size, maximum and minimum depth, location), contract characteristics, and whether the lease ended up being productive or not at the end of the exploration period. The average size of a tract is about 5000 acres. The average bid price is \$2,500 per acre (all dollar figures are expressed in 2000 dollars); the average real bid price has been trending down over time. About 25 percent of the tracts are qualified as productive at the end of the exploration period.

To operationalize our study, we merge this lease-level information to firm-year balance sheet information from COMPUSTAT. Because the MMS and COMPUSTAT do not share the same company identifiers, we merge the two data sets by hand based on company names. One difficulty is the treatment of subsidiaries. Indeed, large publicly traded oil companies often appear in the MMS data through fully or partly owned subsidiaries that specialize in exploration activities. We use various company directories (such as One Source) to match a given subsidiary to its parent company. About 40 percent of all bids belong to privately held stand-alone firms. Such firms are not covered in COMPUSTAT and therefore not included in our final sample. While the MMS data is available from 1954 on, COMPUSTAT data only starts in 1963. Our final dataset covers about 120 firms over the 1963-1999 period.

Because we exclude the smaller bidding firms for lack of cash-flow data, the firms included in our final sample are very large.[3] Total assets for the median firm is $2 billion. Firms bid on average for 9 different tracts every year and win on average 7. Capital expenditures on these tracts represent about 5 percent of total capital expenditures for the firms included in the sample.

We use COMPUSTAT to measure cash flow and investment opportunities for the firms in the sample. We define cash flow as the sum of earnings before extraordinary items (COMPUSTAT item 18) and depreciation (item 14); we deflate this measure by capital, which is measure as net property, plant and equipment (item 8) at the beginning of the fiscal year. We measure average Tobin's Q as the market value of assets divided by the book value of assets (item 6). The market value of assets is defined as the book value of assets plus the market value of common equity less the sum of the book value of common equity (item 60) and balance sheet deferred taxes (item 74). We calculate average Tobin's Q at the beginning of the fiscal year. We also define total investment for these firms as capital expenditures (item 128), which we deflate by net property, plant and equipment at the beginning of the fiscal year.

2.3 Bidding and Investment

Since we are focusing on a specific industry and specific kind of investment, two questions come to mind. First, do the firms in this industry display the usual positive correlation between cash flow and balance sheet capital expenditures? In Panel A of Table 2, we replicate the standard balance sheet cash flow to investment regression for this sample. In column 1, we regress the logarithm of capital expenditures on logarithm of cash flow for the panel of all firms ever present in our sample,

[3]In calculating means, such as average county productivity, we use data on all leases including those sold to private firms.

whether this is a bidding year for these firms or not. We further control for firm and year fixed effects. In this table, and all following tables, we allow for clustering of the standard errors at the firm level. We find a positive and statistically significant relationship. A 1 percent increase in cash-flow leads to .4 percent increase in capital expenditures. In column 2, we further control for Tobin's Q. We find a positive relationship between capital expenditures and Tobin's Q. The inclusion of this additional control for investment opportunities however barely alters the investment-cash flow sensitivity. In the remaining columns, we replicate the specification of column 2 but only include those firm-year observations that correspond to bidding years (column 3) or winning years (column 4) for a firm. Similar results hold in these two sub-samples.

Second, how does spending on off-shore leases, which will be the focus of our detailed project data, relate to overall investment? In Panel B of Table 2, we examine this question. In column 1, the dependent variable is a dummy variable that equals 1 if a firm places at least one bid in that year. We regress this dummy variable on the logarithm of total capital expenditures, further controlling for firm and year fixed effects. We find a positive and statistically significant relationship. The same holds in column 2 where the dependent variable is now a dummy variable that equals 1 if a firm wins at least one auction in that year. In the rest of Panel B, we relate total amount bid (column 3) and total amount spent on winning bids to total capital expenditures.[4] A 1 percent increase in total capital expenditures is associated with about a .5 percent increase in the amount bid and spent on oil and gas leases.

Whether the results we find below generalize to other industries or other types of investments

[4]Note that these two data come from two different sources—balance sheets and the MMS, making it unlikely that mechanical relationships would drive the positive correlation.

is of course an empirical question. But the two panels in Table 2 suggests that we are not focusing on a particularly atypical case. Panel A suggests that, like the rest of the economy, this industry displays a capital expenditures to cash flow sensitivity. Panel B suggests that the particular type of investment we are focusing on comoves with the other types of investment the firms undertake.

3 Analytical Framework

In order to guide the empirical work below, we present a simple model of investment. The goal of this framework is not to elucidate optimal auction bidding but instead to clarify what the different theories would imply for the project data we study. Whenever a firm wins a lease, the profits generated by this single lease is defined to be:

$$p(R - C) - I - E \tag{1}$$

where p is the probability of finding minerals, R is the revenue generated by the lease (conditional on finding minerals), C are production/extraction costs (conditional on finding minerals), I is the price paid for lease and E are exploration costs. In principle, each of these may potentially depend on cash flow, but we make several assumptions in the empirical work below. First, we assume that production/extraction costs for a given lease are not related to cash flow. This assumption seems, at least anecdotally, validated by the fact that extraction technologies are fairly uniform across tracts sharing the same geological features. Obviously, extraction costs may be higher for larger tracts or tracts that are deeper. However, in the empirical work we account for these characteristics.[5] By the same token, we assume that exploration costs do not vary with cash flow.

[5]In fact we find that these geological characteristics do not correlate with cash flow.

We also assume for now that that the revenues generated by a given lease, *conditional* on the lease being productive, are not related to cash flow. Of course this need not be the case. For example, bidders with high cash flow may bid on riskier projects. In practice, we explicitly test this simplifying our assumption later in the paper (for a subset of the leases) and find that it holds.[6]

The remaining two elements, bid price (I) and probability of success (p) are the only dimensions that vary with cash flow. Finally, denote N to be the number of leases bought.[7] Because of diminishing returns, we also assume that the probability of finding minerals on any one lease may change with the number of leases bought. Given the assumptions above, we can express per lease and total profits as:

$$\begin{aligned} \pi(CF) &= p(CF, N)(R - C) - I(CF) - E \\ \Pi(CF) &= N(CF)[p(CF)(R - C) - I(CF) - E] \end{aligned}$$

Differentiating with respect to cash flow shows how average and total lease profits vary with cash flow:

$$\begin{aligned} \pi_{CF} &= p_{CF}(R - C) + p_N N_{CF}(R - C) - I_{CF} && (2) \\ \Pi_{CF} &= \frac{\partial(p * N)}{\partial CF}(R - C) - \frac{\partial(I * N)}{\partial CF} && (3) \\ & && (4) \end{aligned}$$

Under all views, $I_{CF} \geq 0$ because they all predict the basic cash flow to investment sensitivity.

[6] Additionally, as has been shown in earlier work, while bid price is a strong predictor of whether a given tract will be productive, it is not very predictive predictor of how much output is found, conditional on positive output. In other words, while bidders seem able to somewhat predict whether a given lease will be productive or not, they find it much harder to predict actual output.

[7] In this simplified framework, we assume tracts are homogenous and firms increase quantity by increasing number of leases. In practice, of course, other dimensions such as size may vary and we will investigate this in the empirical work.

Also $p_N \leq 0$ because of diminishing returns. This makes the equations easy to interpret. Change in average profits depend on three things: positively on the change in average probability of success, negatively on change in number of tracts bought because of diminishing returns and negatively on the change in bid price. Change in total profits depends on two things. First, it depends negatively on how total dollars ($N * I$) spent changes with cash flow. Second, it depends on how $p * N$ changes with cash flow.

What do the different theories say about how these different variables respond to cash flow? Table 1 provides a summary of these predictions. Under the mismeasurement view, cash flow proxies for investment opportunities and firms may buy more tracts because they are more profitable, or $p_{CF} > 0$. Putting these together means that average profits could rise or fall with cash flow depending on whether $p_C F$ is large enough. This happens if the increased probability of successful tracts outweighs the diminishing returns (the $p_N N_{CF}$ term) and the increased bids. But because of profit maximization total profits should rise: $\Pi_{CF} \geq 0$. For this to happen $N * p$ must rise with cash flow. This is intuitive: if profit maximizing bidders are spending more on tracts, the total revenues produced by these tracts must increase.

Under the liquidity constraints view, cash flow allows firms to buy profitable leases that they otherwise could not have bought. For simplicity, suppose further that $p_{CF} = 0$ so that there's no direct effect of cash flow on profitability. Because firms are buying more leases $N_{CF} \geq 0$. Therefore, average profits will decline with cash flow because of diminishing returns. But again profit maximization means that total profits should rise $\Pi_{CF} \geq 0$. As before, for this to happen $N * p$ must rise with cash flow.

Finally, under the free cash flow view, higher cash flow means managers can undertake more wasteful projects. So $p_{CF} \leq 0$ since leases will be getting worse. The effect on quantity is unclear since managers may buy more or less leases depending on their preferences for empire building or living the quiet life. Putting this together means that average profits are declining in cash flow. But unlike in the other two models, total profits are also declining in cash flow, hence $N * p$ may decline with cash flow.

We empirically analyze each of these terms. First, we will study the relationship between total spending on leases ($N * I$) and cash flow (CF). This first step is equivalent to the type of investment-cash flow regressions estimated with more standard capital expenditures data. We then decompose this total spending effect into a quantity effect (N) and a price effect (I).[8] The quantity effect is important for evaluating whether diminishing returns is important. It is also important in understanding managerial objectives in the free cash flow model since the empire building and quiet life views differ in their predictions for quantity.

Second, we study how cash flow affects the likelihood of success for the average tract. This will tell us about how average profits vary with cash flow CF. As noted earlier, average profits and probability of successes can fall in all three models, because of diminishing returns in the first two models and also because of bad project choice and mismanagement in the free cash flow model.

To differentiate between the models, therefore, we study total probability of success $N * p$. As noted, in the first two models, this must increase with cash flow. Otherwise total revenues would be decreasing and hence total profits would be decreasing with cash flow, contradicting the idea of profit maximization. Only in the free cash flow model where agency problems loom large could

[8]In practice, we will consider two alternative quantity measures: number of leases and number of acres.

total revenues decrease with cash flow.

4 Results

4.1 Total Bids and Cash Flow

In Table 3, we study the relationship between total lease expenditures and cash flow. Panel A focuses on total amount bid, whether the firm eventually wins the contract or not. Panel B focuses on total amount won. Total amount bid and total amount won are deflated by net property, plant and equipment at the beginning of the fiscal year.[9] Each regression in the table controls for Tobin's Q, as well as firm and year fixed effects. The year fixed effects account for any aggregate shocks that might be correlated with firm cash flow, such as oil price changes. Controlling for this is especially important since oil price changes likely affect both cash flow and perceived profitability of leases. The firm fixed effects account for any between firm differences in profitability. For example, some firms may simply be better than others and have both higher cash flow and access to better leases.

We find a positive and statistically significant relationship between expenditures on oil and gas leases and cash flow. The relationship is very similar in magnitude to that observed for overall capital expenditures in Table 2. A 1 percent increase in cash flow increases amount bid and amount won by about .4 percent.

In columns 2 of Panels A and B, we study this relationship in a little more details. More specifically, we ask whether this relationship is linear or instead varies with cash flow level. In

[9] In case of joint bidding, total amount bid and total amount won are based on the fraction of ownership of the firm.

practice, we spline the cash flow variable and allow for different investment-cash flow sensitivities for low cash flow levels (below the 33rd percentile of the cash flow distribution), medium cash flow levels (between 33rd and 66th percentile of the cash flow distribution) and high cash flow levels (above 66th percentile of the cash flow distribution). Interestingly, we find the strongest sensitivity of capital expenditures in the medium cash flow range. In fact, there is no sensitivity of investment to cash flow in the low cash flow range. Investment is positively related to cash flow in the high cash flow range but the relationship is less precisely estimated.

In the remaining columns, we ask whether the investment cash flow sensitivity varies over time. We breakdown our sample into two time periods: pre 1985 and post 1985. This break is interesting since many observers feel the oil industry experienced a fundamental change in governance in the mid 1980s. Despite this, we find a positive relationship between investment and cash flow in both time periods. The point estimates are slightly larger in the earlier period, but one cannot reject the null hypothesis of equal sensitivity across both periods.

4.2 Quantity and Cash Flow

What drives the observed positive relationship between cash flow and total dollars spent? Do cash-rich firms bid on and win more leases or do they spend more per lease? In Table 4, we propose to decompose the results of Table 3 into such quantity and price effects. In Panel A, we use as a dependent variable the average price per lease bid on (columns 1 and 2) and the average price per lease won (columns 3 and 4). In Panel B, we use as a dependent variable the number of leases bid on (columns 1 and 2) and number of leases won (columns 3 and 4). The dependent variables included in all regressions, in addition to cash flow, are Tobin's Q, firm fixed effects and year fixed effects. Interestingly, we find no statistically significant relationship between cash flow and number of leases bid on or number of leases won. The estimated coefficients, while positive, are small and statistically insignificant. Only in the low cash flow range does it appear to be a positive, albeit weak, positive relationship relationship between cash flow and number of tracts bid on or won.

The investment to cash flow sensitivity observed in Table 3 is solely driven by the increased price per lease as cash flow goes up (Panel A). When we allow this price-cash flow sensitivity to vary with cash flow level, we find that it is especially strong in the medium and high cash ranges. In fact, in the low cash flow range, increases in cash flow are not associated with higher price per lease.

In regressions not reported here, we performed an alternative decomposition of total spending into quantity and price effects. Rather than using number of leases as a quantity measure, we use number of acres (either bid on or won). We use average price per acre as a price measure in that alternative decomposition. We found comparable results. In other words, there is no apparent relationship between numbers of acres bid on or won and cash flow. Instead, the positive relationship between investment and cash flow appears solely driven by an increase in bid price per acre as cash flow goes up.

In summary, the results in Tables 3 and 4 indicate that oil firms bid and spent more on oil and gas leases when their cash flow increases. In fact, the investment-cash flow sensitivity we observe for these specific projects is quantitatively very similar to the overall investment-cash flow sensitivity for these firms. Interestingly, though, we find no evidence that this investment-cash flow sensitivity reflects an increase in the number of projects undertaken when cash flow rises, except maybe in the lowest cash flow range. This higher spending however is not matched by an increase in the number of tracts bid on or won. This apparent lack of a quantity response appears at odds with a simple financing constraint interpretation of the investment-cash flow sensitivity. It also appears at odds with a simple empire building interpretation.

That average price (per lease or per acre) increases with cash flow is an intriguing fact. We see two likely interpretations for this fact. First, it is possible that firms experiencing increases in cash flow decide to bid on less risky leases, i.e. leases that have a higher likelihood of being productive. Alternatively, rich firms may simply dissipate cash by paying more (too much) for leases of equal quality. Separating these two explanations is an essential next step. In the next section, we turn to the tract-level data in order to provide some more further insight about these two respective interpretations.

4.3 Bid Per Acre and Cash Flow

In Table 5, we re-examine the relationship between bid price per acre and cash flow. However, instead of studying average price per acre across all recorded bids, we now study this relationship in the micro data. This allows us to control for lease-specific characteristics that could not be included in the aggregate regressions described above. Controlling for such lease-specific characteristics is important in order to separate the two alternative interpretations of the price-cash flow sensitivity. If this sensitivity mostly reflects the fact that cash-rich firms tend to bid on higher quality tracts, one would expect the price-cash flow sensitivity to be much weaker as one controls for lease-specific characteristics that are correlated with productivity. Panel A considers on all bids; Panel B focuses on winning bids only. All regressions in Table 5 include, in addition of cash flow, Tobin's Q, firm fixed effects and year fixed effects. Also, in all regressions, we allow for clustering of the error term at the firm level.

As a benchmark, column 1 shows that, absent any tract-level controls, a 1 percent increase in cash flow increase bid price per acre by .1 to .15 percent. In column 2, we add three types of tract-level controls that capture information that is available to the bidders at the time of the bid and is likely to be correlated with the expected lease productivity. First, we control for the size of the lease, which we measure in number of acres. It is well-known from previous work that larger tracts are on average less likely to be productive and tend to sell at a lower price (see for example Hendricks and Porter, 1996). Second, we control for the minimum and maximum depth of the tract. Everything else equal, tract depth is likely to be negatively correlated with expected profits as exploration and extraction costs increases with depth. Finally, also available to the bidders at the time of a bid is the observed productivity on previously auctioned tracts that are located in the same geographic area. From the MMS data, we construct the fraction of productive tracts at the county-year level.[10]

As expected, we find that larger tracts sell at a lower per acre price. A 1 percent increase in tract size leads to about a .25 percent drop in price. We also find (not reported in the table) that lower bids are recorded for deeper tracts. Also, there is a strong positive correlation between bid price and observed past productivity in a given county. Most important for our purpose, though, the

[10]We prefer this measure to county-specific effects as it is backward looking while county effects would be both backward and forward looking.

inclusions of these three sets of controls has no effect on the estimated price-cash flow sensitivity.

In column 3, we further add controls for lease-specific contract characteristics. These include dummies for royalty rate and dummies for length of lease. The inclusion of these additional controls somewhat lowers the point estimate on cash flow. However, the point estimate stays positive and statistically significant.

Column 4 replicates column 3 but splines the cash flow variable into three groups. In other words, we allow the price-cash flow sensitivity to differ in the low, medium and high cash flow ranges. As before, we find that the positive association between price and cash flow is concentrated in the medium cash-flow range. Columns 5 and 6 replicate column 4 but break down the sample into pre 1985 data and post 1985 data. The estimated price-cash flow relationship is qualitatively similar across both periods. Only in the medium cash flow range do we find a positive association between price and cash flow. The point estimate is larger in the pre-85 period than in the post-85 period; however, standard errors are too large to reject the null hypothesis of identical effects across both periods.

One final tract characteristic is even more informative than these physical characteristics: the bid of the next highest bidder. In column 7 of Panel B, we control for the second highest bid, when the second highest bid exists. If no bid exists, we assume the second highest bid is zero and include a dummy for the existence of a second highest bid. As might be expected, the second highest bid is very predictive of the winning bid. But its inclusion does not affect the price to cash flow sensitivity. In other words, when cash flow rises, bidders are not only bidding more, they are bidding more relative the next highest bidder.

Controlling for tract characteristics does not eliminate the cash flow to price relationship But one could ask the question differently: are firms bidding on different kinds of tracts? Table 6 complements Table 5 by directly relating tract-level characteristics to firm-level cash flow. The dependent variable in column 1 is tract size (in log(acres)). We see that cash-rich firms do not systematically bid on smaller tracts. In column 2, we ask whether cash-rich firms are more likely to bid on tracts located in counties where they have a stronger presence. If this were true, one might argue that these firms may have lower exploration and/or extraction costs, which may justify the higher bids. For each firm-year, we construct the number of tracts previously won by that firm in prior years. We also control for the total number of tracts auctioned off in that county in prior years. Positive shock to cash flows do not appear to lead firms to more systematically bid in areas where they have already engaged in more exploration. This last finding seems inconsistent with the idea that cash-rich firms may bid more because they are able to save on exploration and production costs. In column 3, we ask whether cash-rich firms systematically bid on tracts located in areas where higher success rates have been recorded in the past. We find no evidence for this. In fact, positive shocks to cash flow appear to induce more bidding in areas that have recorded lower prior success rates.

In summary, the positive relationship between bid price per acre and cash flow does not appear to be driven by changes in tract characteristics that are associated with productivity of a given tract. This appears inconsistent with the view that cash rich firms simply bid on higher quality tracts but of course it is possible that unobservable tract characteristics are changing even though the observable ones are not. We return to this question more directly when we study actual productivity of tracts.

In Table 7, we study how the price-cash flow relationship vary over the course of the calendar year. The MMS data reports the exact date at which a given auction occurs. We can therefore ask whether the price-cash flow systematically differs over the course of the year. More precisely, we interact cash flow with the number of months between the auction date and the end of the company's fiscal year and study the relationship between that interaction term and bid price. Columns 1 and 2 focus on all bids; columns 3 and 4 focus on winning bids only. In columns 1 and 3, we control for Tobin's Q, firm and year fixed effects; in columns 2 and 4, we add controls for lease-specific characteristics (tract size and depth, contract characteristics, prior success rate in county). We find that the price-cash flow sensitivity systematically vary over the course of the fiscal year. Everything else equal, higher cash flow seems to lead to higher prices especially for auctions taking place towards the end of the fiscal year. This is an interesting finding. One possible interpretation is that companies are allocated some fixed annual budget (determined based on cash flow) for spending on these investment projects.

In summary, our results above suggest that cash-rich firms pay a higher price for leases that appear observationally equivalent in terms of their expected productivity. In other words, what appears to solely drive the investment-cash flow sensitivity observed in Table 3 is that cash-rich firms are wastefully spending resources by paying more for tracts of a given expected productivity. However, it is still possible that cash-rich firms may have some *private* information about the quality of certain tracts and simply bid more based on this private information. The most direct way to address this remaining possibility is to study how cash flow at the time of bidding relates to the eventual productivity of a given tract. We now turn to these productivity results.

4.4 Tract-Level Productivity and Cash Flow

As we discussed above, included in the MMS data is a dummy variable for whether or not a given tract ended up being productive. In Table 8, we relate this productivity variable to bid price and cash flow. All regressions in this table include Tobin's Q, firm fixed effects and year fixed effects. Column 1 shows a higher bid price per acre is predictive of the eventual productivity of a tract. This is a well-known finding in this literature. A 1 percent increase in bid price acre increases the likelihood that the lease will be productive by about .08 percent. Interestingly, bid price per acre is still a strong positive predictor of productivity even after one controls for tract-level characteristics (column 3). This indicates that there might be more residual information in the price data that is not captured by the tract-specific controls and further reinforces the need to look at how cash flow shocks relate to tract productivity. If cash flow in the year of the auction were to be positively correlated to eventual productivity, this might indicate that the positive price-cash flow sensitivity we have observed before in part reflects some private information cash rich firms may have about tract quality.

Column 2 of Table 8 presents the IV equivalent of the OLS regressions in column 1. More precisely, we instrument bid price per acre with cash flow at the time of the bid, using the splined specification described above. These IV regressions allow us to ask whether cash flow driven increases in bid price per acre are positively related to tract productivity. We find no evidence for this. The point estimate on bid price in columns 2 and 4 are negative and marginally significant!

For example, in column 2, we find that a 1 percent increase in bid price per acre due to a positive cash flow shock *reduces* the likelihood that the tract will be productive by about .13 percent. The same negative correlation holds when we further control for tract-level characteristics (column 4).

In column 5, we present the reduced form equivalent to the IV regression in column 4. This reduced form regression shows that it is in the medium cash flow range that positive shocks to cash flow are associated with lower productivity. There is no relationship between cash flow and productivity in the bottom and top cash flow ranges.

Columns 6 to 9 break down the full sample into the pre 1985 period and post 1985 period. While the IV estimates are much less precise in this case, the point estimates seem to suggest different patterns in the two periods. The point estimates is negative in the pre-period but positive in the post period and not statistically different from the OLS point estimate. While standard errors are too large to draw any conclusion, it is possible that the positive price-cash relationship reflects more wasteful behavior in the early period than in the later period. Such an interpretation would be consistent with the fact that corporate governance improved over time in this industry.

These findings suggest that average probability of finding a tract diminish with cash flow. Recall from Section 3 that this could in principle happen under all three models. To see this, note that:

$$\frac{dp}{dCF} = p_{CF} + p_N N_{CF}$$

Under the mis-measurement and the credit constraints models, this can be negative because diminishing returns makes the second term negative. However, we have seen in Table 4, that quantity does not change at all or $N_{CF} = 0$. Consequently, there is no room for diminishing returns and it appears that $\frac{dp}{dCF} = p_{CF}$ which should not be negative under credit constraints or mismeasurement.

In other words, it is very hard for the first two models to justify why the average probability of finding minerals should diminish with cash flow.

4.5 Total Probability and Cash Flow

A more direct way of seeing this is to simply examine how $p * N$ changes with cash flow. So far we have analyzed how p (Table 8) and N (4) individually change. In Table 9 we investigate $p * N$ by regressing the total number of productive projects on cash flow in the year these leases were undertaken. In the first 4 columns of Table 9, we simply sum all productive leases. In the last 4 columns, we weight each lease by the firm's fraction of ownership. Each regression includes Tobin's Q, firm fixed effects and year fixed effects.

While we know from Table 3 that total spending increases with cash flow, we find no evidence that total revenues increase with cash flow. In fact, the point estimate on cash flow is negative, but not statistically significant. When we replace the linear cash-flow variable with a spline specification, we find that the negative correlation is again concentrated in the middle cash flow range. Interestingly, this negative correlation appears driven by the pre-85 data, where the negative relationship is extremely significant. In this sense, we find support for the idea that governance improved in the mid 1980s in this industry. While firms still increase their bids with cash flow, they do not appear to mismanage as much.[11]

[11] Of course, the firms are still paying more for leases that do not appear to be more likely to find oil. So there is likely still some dissipation in the later period, just not as much.

4.6 Total Resources Found

In both the empirical work and the framework, we have assumed that the quantity of minerals found does not change with cash flow. Is this realistic? One could imagine that cash flow rich firms bid on leases that are riskier: less likely to find oil or gas, but bigger amounts found when the tract is productive. To analyze this question, we turn to production data.

We could only obtain such production data for leases auctioned from 1978 on. For each of these productive leases, we construct the average monthly production of oil and the average monthly production of gas. In Table 10, we regress for the logarithm of these monthly production figures on bid price and cash flow, controlling for year and fixed effects as before. Since we have different time frames of data for each lease, we must also control for the number of months the tract has been under production. We implement this by including dummies for the number of months a tract has been under production.

Two interesting results emerge from Table 10. First, for both gas and oil outputs, bid price itself is small and insignificant predictor of output. In other words, unlike in the regressions above where we study likelihood of productivity, bid price does not predict the amount of minerals found. This is consistent with previous findings and suggests that bidders are not able to accurately predict the amount of resources under the ground.[12]

Second, cash flow does not predict amount of gas found. The coefficient is small and insignificant. For oil resources, the estimated coefficient on cash flow is negative and marginally significant. This is quite the opposite of the risk-return view. In fact, it appears that if anything, high cash flow

[12] Geologically, total amount is hard to predict because it depends on the depth of the well below the ground as well as its topology well below the earth, both of which are hard to measure.

bidders find less oil when they find any. In short, it does not appear that changes in quantity of mineral resources can explain away our results.

5 Conclusion

Our results as a whole support a free cash flow model in which increased cash flow causes managers to make worse decisions but not to expand their "empires", what we refer to as "quiet life" models. We have also reported two other suggestive findings. First, we found evidence that the cash flow to bid relationship occurs more strongly in the later quarters of a firm's fiscal year. Capital budgeting may be playing an important role in our results. It underlines the need for future work on investment using more detailed budgeting or organizational data. Second, our results suggest some change over time. Numerous observers have suggested that corporate governance has improved in the oil industry. We find no evidence of this in bidding since both before and after 1985 bids are sensitive to cash flow. But we do find evidence of a governance change when we examine productivity. As cash flow increases, the probability of finding minerals decreases only in the pre-1985 period.

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Table I: Effect of Cash Flow on Different Variables

	VARIABLE						
	Bid Price		Quantity	Success Probability		Profits	
	Average	Total		Average	Total	Average	Total
	I	$N * I$	N	p	$N * p$	π	Π
THEORY							
Credit Constraints	?	+	+	- Diminishing Returns	+ π-Max.	- DR	+ π-Max.
Mis-Measurement	?	+	+	? DR + Quality $\uparrow$	+ π-Max.	? DR + Quality $\uparrow$	+ π-Max.
Free Cash Flow	?	+	?	- DR + Agency	- Agency	- DR+ Agency	- Agency
Results	+	+	0	-	-		

Table II: Total Capital Expenditures

Panel A: Correlation with Cash-Flow

	All Years	All Years	Bidding Years	Winning Years
Cash Flow	.448	.421	.369	.366
	(.046)	(.046)	(.069)	(.070)
Q		.141	.070	.072
		(.048)	(.032)	(.035)
Year Dummies	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Sample Size	2298	2298	1017	960
Adjusted R^2	.51	.51	.59	.58

Panel B: Correlation with Bidding

	Proba Bidding	Proba Winning	Amount Bid	Amount Won
Capital Expenditures	.047	.044	.515	.458
	(.017)	(.016)	(.118)	(.112)
Year Dummies	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Sample Size	2418	2418	1041	980
Adjusted R^2	.51	.53	.70	.64

Table III: Firm Level Bidding and Cash Flow

Panel A: Total Amount Bid

	All Years	All Years	Pre-85	Post-85	Pre-85	Post-85
Cash Flow	.383		.567	.316		
	(.129)		(.246)	(.172)		
Spline 1		.084			.203	.013
		(.159)			(.322)	(.191)
Spline 2		.898			1.01	.970
		(.346)			(.489)	(.427)
Spline 3		.579			.689	.362
		(.379)			(.435)	(.852)
Q	.029	-.01	.137	-.041	.115	-.101
	(.089)	(.102)	(.101)	(.369)	(.111)	(.385)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	1031	1031	571	460	571	460
Adjusted R^2	.69	.69	.605	.700	.605	.703

Panel B: Total Amount Won

	All Years	All Years	Pre-85	Post-85	Pre-85	Post-85
Cash Flow	.381		.436	.315		
	(.132)		(.306)	(.171)		
Spline 1		.007			-.115	-.011
		(.155)			(.354)	(.203)
Spline 2		1.04			1.128	1.04
		(.370)			(.629)	(.473)
Spline 3		.634			.579	.589
		(.393)			(.414)	(.820)
Q	.060	.006	.180	.034	.147	-.021
	(.072)	.093	(.068)	(.044)	(.081)	(.419)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	973	973	528	445	528	445
Adjusted R^2	.636	.639	.534	.642	.535	.645

Table IV: Decomposing Total Amount into Price and Quantity

Panel A: Price

	Total Amount Bid/ Number of Tracts Bid On			Total Amount Won/ Number of Tracts Won
Cash Flow	.300		.336	
	(.045)		(.087)	
Spline 1		-.129	-.136	
		(.104)	(.114)	
Spline 2		.901	.993	
		(.229)	(.246)	
Spline 3		.810	.985	
		(.226)	(.253)	
Q	.069	-.008	.053	-.048
	(.055)	(.059)	(.051)	(.0549)
Year Dummies	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Sample Size	1031	1031	973	973
Adjusted R^2	.858	.862	.856	.836

Panel A: Quantity

	Number of Tracts Bid On			Number of Tracts Won
Cash Flow	.083		.044	
	(.122)		(.115)	
Spline 1		.213		.143
		(.139)		(.128)
Spline 2		-.003		.049
		(.297)		(.287)
Spline 3		-.231		-.351
		(.273)		(.274)
Q	-.039	.002	.007	.054
	(.060)	(.067)	(.048)	(.058)
Year Dummies	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Sample Size	1031	1031	973	973
Adjusted R^2	.608	.608	.576	.576

Table V: Bid Per Acre and Cash Flow
Tract-Level Data

Panel A: All Bids

	All Years				Pre-85	Post-85
Cash Flow	.108	.113	.069			
	(.049)	(.049)	(.045)			
Spline 1				.027	-.126	.040
‘				(.053)	(.109)	(.061)
Spline 2				.540	.654	.669
				(.201)	(.386)	(.357)
Spline 3				-.115	-.031	-.324
				(.184)	(.223)	(232)
Q	-.095	-.096	-.087	-.079	.009	-.053
	(.044)	(.046)	(.044)	(.053)	(.051)	(.133)
County success		.486	.491	.489	-.502	.725
		(.108)	(.093)	(.093)	(.183)	(.507)
Tract Size		-.254	-.243	-.243	-.456	-.134
		(.040)	(.037)	(.037)	(.051)	(.045)
Tract Depth	No	Yes	Yes	Yes	Yes	Yes
Contract Traits	No	No	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	21240	20556	19552	19552	9255	10631
Adjusted R^2	.700	.708	.715	.716	.401	.1660

Table V(cont.): Bid Per Acre and Cash Flow
Tract-Level Data

Panel B: Winning Bids

	All Years				Pre-85	Post-85	All Years
Cash Flow	.159	.166	.120				
	(.061)	(.058)	(.047)				
Spline 1				.078	-.105	.059	.040
‘				(.056)	(.193)	(.068)	(.046)
Spline 2				.593	.844	.858	.513
				(.216)	(.495)	(.377)	(.208)
Spline 3				-.095	.071	-.296	-.089
				(.193)	(.312)	(.244)	(.161)
Q	-.124	-.129	-.127	-.115	-.032	-.073	-.108
	(.046)	(.046)	(.046)	(.055)	(.057)	(.155)	(.044)
2^{nd} highest bid							.414
							(.012)
County success		.623	.577	.575	-.330	.936	.544
		(.163)	(.129)	(.130)	(.285)	(.667)	(.089)
Tract Size		-.220	-.213	-.213	-.416	-.130	-.263
		(.041)	(.039)	(.039)	(.057)	(.046)	(.041)
Tract Depth	No	Yes	Yes	Yes	Yes	Yes	Yes
Contract Traits	No	No	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	14032	13468	13129	13129	5430	8002	13129
Adjusted R^2	.715	.720	.726	.726	.460	.179	.790

Table VI: Characteristics of Tracts Bid On and Cash Flow

	Tract Size	Firm Presence in County	County Success Rate
Cash Flow	.007	-.202	-.102
	(.016)	(1.11)	(.013)
Q	.008	4.48	-.019
	(.007)	(1.90)	(.009)
County Explored		.025	
		(.004)	
Year Dummies	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Sample Size	21374	20798	20589
Adj. R^2	.048	.536	.287

Table VII: Month to End of Fiscal Year and Price-Cash Flow Relationship

	All Bids		Winning Bids	
Cash Flow	.252	.176	.256	.196
	(.077)	(.060)	(.093)	(.068)
Months to End of Fiscal Year	-.046	-.024	-.018	-.005
	(.018)	(.016)	(.020)	(.017)
Cash Flow*	-.032	-.024	-.022	-.017
Mont to End of Fiscal Year	(.011)	(.010)	(.012)	(.010)
Q	-.088	-.085	-.120	-.126
	(.044)	(.043)	(.046)	(.045)
Tract Controls	No	Yes	No	Yes
Year Dummies	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Sample Size	21340	19552	14032	13129
Adj. R^2	.700	.716	.715	.730

Table VIII: Probability of Finding Oil

	All Years					Pre-85		Post-85	
	OLS	IV	OLS	IV	Red. Form	OLS	IV	OLS	IV
Bid Price	.088	-.137	.064	-.211	–	.105	-.197	.059	.103
	(.004)	(.082)	(.004)	(.127)		(.004)	(.172)	(.005)	(.077)
Spline 1					.013				
					(.015)				
Spline 2					-.118				
					(.053)				
Spline 3					.018				
					(.049)				
Tract Controls	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	21340	21340	20314	20314	21340	9534	9534	10780	10780
Adj. R^2	.298		.334		.268	.189		.129	

Table IX: Total Number of Productive Leases

	Total Number				Ownership Weighted			
	All Years		Pre-85	Post-85	All Years		Pre-85	Post-85
Cash Flow	-.243				-.219			
	(.681)				(.331)			
Spline 1		.342	1.21	.548		-.128	.337	.374
		(.867)	(1.28)	(.292)		(.451)	(.713)	(.222)
Spline 2		-5.96	-14.97	-.187		-1.99	-9.67	.136
		(4.99)	(7.69)	(2.65)		(2.80)	(5.43)	(2.35)
Spline 3		.776	3.81	-.675		.415	2.73	-.337
		(1.50)	(2.79)	(1.04)		(.952)	(1.94)	(.922)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	1033	1033	573	460	1033	1033	573	460
Adj. R^2	.510	.520	.510	.437	.463	.462	.509	.538

Table X: Amount of Resources Found in Productive Tracts

	Gas			Oil
Bid price	-.005		-.185	
	(.044)		(.233)	
Cash Flow		.023		-5.92
		(.159)		(2.28)
Months Producing Dummies	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Sample Size	1845	1262	493	316
Adj. R^2	.367	.372	.428	.454