Do Public Firms Invest Differently than Private Firms? Taking Cues from the Natural Gas Industry*

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Abstract

We exploit a unique dataset of onshore North American natural gas producers to study how private and public firms differ in their investment behavior. We employ two distinct empirical strategies. First, in firm-level regressions we find that investments by private firms respond less to changes in natural gas prices, an exogenous measure that captures marginal q in this industry. Second, we use county-specific shale gas discoveries as a natural experiment and find that private firms react significantly less to a positive investment opportunity shock. These results are not driven by heterogeneity in firm size, product markets, pricing, location, or costs. Financing constraints are a plausible explanation for our results.

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1 Introduction

Do public and private firms invest differently given the same opportunities? If so, why? There are costs and benefits of being privately-held relative to being a publicly-traded firm. These costs and benefits are driven in part by potential differences in agency costs and the ability to obtain external financing, both of which could have an influence on a firm's investment decisions. In this study we show that, relative to public firms' investment behavior, private firms' investment policies are less sensitive to changes in investment opportunities. Given our empirical design, this result suggests that financing frictions can matter for real investments.

Documenting differences in investment behavior between public and private firms is difficult in most empirical settings because detailed data on the investment activity of private firms is typically unavailable.[1] Furthermore, measuring investment opportunities for firms is a well-documented source of contention in the literature (see for example Erickson and Whited (2000), and Alti (2003)). This study seeks to overcome both issues by comparing the investment behavior of private and public firms in a setting where detailed data on investments is available and investment opportunities are measured by an observable and exogenously priced commodity: Natural gas.

We use a unique dataset of *all* public and private drilling activity between 1997 and 2010 of onshore U.S. natural gas producers to identify differences in investment behavior between public and private firms. This drilling database allows us to observe 66,972 new natural gas wells across 369 private firms and 88 public firms in the industry. For any given firm, each new well represents an incremental investment decision. The profitability of each new well is directly tied to the price of natural gas. Hence, changes in marginal q will be proportional to changes in natural gas prices.[2]

As illustrated in Figure 1, the time-series of aggregate drilling of new wells is very responsive to changes in natural gas prices. The detailed project-level information in our dataset

[1] Two notable exceptions are Sheen (2009) and Asker et al. (2011), which are described in more detail in the literature review section.

[2] The incremental production added by a new well comes online in a matter of a few weeks. Among publicly traded firms, we further confirm that operating profitability is highly correlated with natural gas prices.

allows us to undertake two distinct empirical strategies to identify potential differences in investment behavior between private and public firms; one based on firm-level investment to q regressions, and one based on county-specific investment responses to significant new natural gas discoveries (shale) in a natural experiment framework.

First, using standard investment intensity to q regressions, we find that private firms are significantly less sensitive to the price of natural gas than public firms. Specifically, private firms are two thirds less responsive to changes in natural gas prices than their publicly-traded counterparts. While differences in firm size exist across public and private firms, we obtain very similar results when we match public and private firms on size, as well as when we add size controls to our specifications.

Second, we use a natural experiment to identify investment responses to positive exogenous shocks to investment opportunities caused by natural gas shale discoveries. Natural gas shale became economically profitable to develop due to an unexpected technological breakthrough that occurred in 2003 that combined horizontal drilling with hydraulic fracturing ("fracking") (Yergin (2011)). Subsequent prospecting has led to new natural gas shale discoveries in different counties ("boom" counties) every year since 2003. We apply a difference-in-differences approach to shale discoveries in 70 "boom" counties to analyze county-level investment decisions made by private and public firms both before and after the discovery. Consistent with our firm-level panel regression results, we find that public firms respond significantly more than private firms to the changes in their investment opportunity set caused by shale discoveries. Moreover, we find that private firms do not show any statistically significant response in county-level capital expenditures when a shale boom occurs.

Several competing hypotheses could explain the observed differences in investment behavior documented above. First, in a traditional agency cost framework, managerial actions induced by the separation of ownership and control (e.g. Jensen (1986), Stulz (1990)) could cause public firms to overinvest or "empire build." Alternatively, private firms may be under-investing due to greater costs and barriers in accessing external capital (Pagano et al. (1998), Brav (2009), Schenone (2010)). Lastly, the differences in investment patterns could be explained by differences in firm characteristics between private and public firms along any of the following dimensions: Firm size, investment opportunities, costs, location, or technology. We evaluate each of these plausible explanations in turn below.

The unique empirical setting in this study allows us to rule out several of these potential explanations. In particular, our results cannot easily be explained by differences in marginal q, or investment opportunities, between public and private firms. First, on the revenue side, both public and private firms sell the same good and are price takers for this product. Furthermore, as a new well generates most of its output early on in its productive life (Considine et al. (2011)), the current price of natural gas serves as a strong indicator of the profitability of a new project for both public and private firms. Second, on the cost side, natural gas producers contract drilling equipment from third party contractors, which results in similar costs across firms to drill a given well. With no significant returns to scale, cost differences across different types or sizes of firms are unlikely to be driving our results.[3]

Using a natural experiment based on shale discoveries provides for a distinct test from our initial firm-level regression results, and rules out several other possible explanations for our regression-based results. The finding of natural gas rich shale rock under existing acreage is a positive shock to a firm's investment opportunity set, given that shale drilling carries virtually no exploration risk.[4] Furthermore, the technology to develop shale is well known, and supplied by a set of third party contractors, such as Halliburton and Schlumberger, suggesting that differences in access to technology are not driving our results. Additionally, because we require that firms be active in an area *prior* to a shale discovery, we can rule out that our results are due to public firms being better positioned geographically or better at seeking out and exploring for new natural gas finds. Hence our empirical design allows us to rule out many potential reasons for our results related to differences in firm characteristics between public and private firms.

Our results could be driven by public firms overinvesting or "empire building," however,

[3]Consistent with this hypothesis we find that within the subset of publicly-traded firms, large producers (those with above median total assets) have an average cost per well that is neither statistically nor economically different from their much smaller counterparts (below median firms) despite being on average six times larger.

[4]For example, according to the Arkansas Oil and Gas Commission there has been a 100% success rate for Fayetteville shale wells.

when we compare how public and private firms invest in bad states of the world (low natural gas prices), we find similar levels of investment across the two groups. This suggests that public firms do not irrationally overinvest or "empire build" regardless of the price of natural gas. Furthermore, the significant front-loading of a well's revenue stream provides an economic rationale for firms in this industry to respond to higher prices by increasing their capital expenditures.

One other explanation for our results is that differences in access to financing are driving differences in investment behavior between public and private firms. The extent to which external financing constraints matter for investment is an important question in the existing literature (e.g. Fazzari et al. (1988), Whited (1992), Kaplan and Zingales (1997)). Firms in the natural gas industry frequently raise external financing. Using the measure developed by Rajan and Zingales (1998), we find that the median public natural gas producer finances 42% of its annual capital expenditures with debt and equity issuances, putting this industry in the top 20% of all industries based on external financing need. If a private firm cannot generate enough capital internally to fund investments and faces constraints in its access to external capital, it may reduce its investments. If these investments are critical for the future profitability of the firm, then the lack of access to funding can be viewed as costly.

A close comparison of the results from our two empirical strategies suggests that the investment responses we observe from private firms may be caused by more restrictive access to external capital. Specifically, at the firm level, we find that private firms do respond to changes in gas prices, just less than public firms; while in our natural experiment setting, we find that private firms do not respond to new natural gas shale discoveries underneath their existing acreage. This difference in investment responses suggests that a characteristic of shale drilling may make investing in these types of projects more difficult for private firms. One key difference between shale wells and non-shale wells is their cost. Shale wells can cost between $2.5M and $5M, while a non-shale well can cost around $800,000.[5] So while private

[5]Cost estimates are based on a report from the National Energy Technology Laboratory titled "Impact of the Marcellus Shale Gas Play on Current and Future CCS Activities" as well as company reports from Southwestern Energy Company, Range Resources Corporation, and EOG Resources Inc. Note that while shale wells may cost more, the volumes of natural gas extracted are far greater.

firms may be able to respond to overall changes in the price of natural gas, the higher capital expenditures for shale wells and the lack of response to shale discoveries, despite lower project risk and limited technological barriers, point again to access to capital being an important factor behind the observed differences in investment behavior between public and private firms.

The paper proceeds as follows. In Section 2 we survey the related literature. In section 3, we provide motivation as to why the natural gas industry is a desirable empirical setting to analyze investment decisions. In Section 4 we provide more details on our unique dataset. In Section 5 we discuss our results and Section 6 concludes.

2 Related Literature

Sheen (2009) and Asker et al. (2011) also compare the investment behavior of public and private firms, albeit in different empirical settings to ours. Sheen (2009) compares private and public firms in the chemical industry. Looking at multi-year plant expansion decisions, he shows that private firms anticipate future demand better than their public counterparts by expanding their capacity ahead of future positive demand shocks. Asker et al. (2011) make use of a novel dataset on private firms to show that public firms are less responsive to changes in their investment opportunities than private firms. Both papers rely on agency-based theories to explain their results (e.g. Stein (1989)). Asker et al. argue that publicly-traded firms with stock prices that are more sensitive to earnings news might be more prone to "short-termism" and distort investment behavior accordingly. In particular, they find that their results are driven by industries where publicly-traded firms exhibit higher stock price sensitivity to earnings shortfalls. Their results highlight significant heterogeneity in exposure to agency costs across different industries. Bharath et al. (2010) analyze plant-level productivity both before and after the decision to go private. They find no evidence of efficiency gains after going private and that myopic markets do not lead public firms to underinvest. Overall, the nascent literature comparing private firms to public firms offers mixed evidence in terms of the efficiency of private firms' investment policies relative to their publicly-traded counterparts.

The growing literature on private firms shows that they are generally more financially constrained than their publicly-traded counterparts.[6] Saunders and Steffen (2011) find that private firms face greater costs of external financing in the United Kingdom. They show further that greater asymmetry of information between outsiders and insiders among private firms is a key factor in explaining their results.[7] Brav (2009) finds that private firms access external markets less frequently. As a consequence, private firms have higher leverage and their capital structure is more sensitive to profitability. Lastly, Schenone (2010) finds evidence consistent with firms being able to reduce their borrowing costs after going public in the U.S., while Pagano et al. (1998) document a reduction in the cost of bank credit after an IPO using a large sample of Italian firms. Our study extends this literature by providing evidence that access to external capital matters for real investment decisions.

3 Motivation and Natural Gas Industry Background

> "*The Company can adjust quickly to the changes in commodity prices if necessary. Equal has an extensive multiple year drilling inventory so it can increase capital spending in a higher commodity price environment.* "
>
> - Equal Energy, publicly-traded natural gas producer

As the quote suggests, the onshore North American natural gas industry has several characteristics which make it an attractive setting to test how public and private firms respond to changes in investment opportunities. First, changes in investment opportunities for both public and private firms can be measured using commodity prices. Second, we can precisely measure capital expenditures for each public and private firm in this industry. Capital expenditures correspond to the number of new wells being drilled, furthermore, all new wells drilled are directly observable in our dataset for both public and private firms. Lastly, the

[6] Private firms have been shown to differ on other dimensions, including payout policy (Michaely and Roberts (2011)), acquisition premiums (Bargeron et al. (2008)), and agency costs (Edgerton (2011)).

[7] Many theoretical models provide a rationale for a lack of access to external financing. They typically rely on information asymmetry and agency-based models (e.g. Myers and Majluf (1984)).

importance of external financing for natural gas producers allows us to highlight the potential effects of financing frictions on investment decisions.

3.1 Measures of Investments, Capital Stock and Marginal q

Obtaining precise investment opportunity measures and capital expenditure data are among the main challenges faced by empirical researchers when studying the investment behavior of public and private firms. Private firms are rarely required to disclose their accounting statements. In terms of investment activity, net Property, Plant, and Equipment (PP&E) is typically used as a proxy for the capital stock of a firm in large panel studies. In the natural gas industry, net PP&E predominantly consists of proven reserves, i.e. reserves that are meant to be recoverable with reasonable certainty under the current geopolitical, economic and technological conditions (FASB 19). Hence, in order to increase its productive capital, a natural gas producer must drill additional wells thereby increasing the amount of natural gas it can book as reserves. Drilling activity corresponds to the vast majority of a firm's capital expenditures (CAPEX) in this industry. Hand-collected data from 10-Ks of natural gas producers in SIC 1311 (Crude Oil & Natural Gas) reveals that between 2006 and 2009 spending on drilling comprised 78% of all capital expenditures made by natural gas firms.[8]

We make use of a unique dataset of all drilling activity conducted by onshore U.S. natural gas producers to proxy for capital expenditures and net PP&E for each firm in this industry. Capital expenditures for a given year are proxied by the number of wells drilled during that year. As proven reserves correspond to the principal long-term asset of any natural gas producer, a valid proxy for net PP&E can be computed by summing up the wells brought to production in the most recent years. We define net PP&E as the rolling sum of the past three years of drilled wells, which allows for the fact that capital has a relatively high rate of depletion in this industry.

Our empirical setting has several advantages. First, in the North American natural gas industry, governmental regulations require that natural gas wells be permitted and approved

[8] The remaining capital expenditures are comprised of the acreage for drilling or infrastructure investments.

by a regulatory authority. Consequently, a significant amount of information is publicly disclosed as to the precise time and place of natural gas well drilling operations, for both private and public firms. Specifically, in our dataset from the Smith International Rig Count, we can identify the firm that drills a natural gas well, when it drills it, and in which county in the U.S. it drills the well.

With regards to measuring investments, our setting has one other significant advantage: Each capital expenditure project corresponds to one well being drilled, a process which takes only three weeks on average. Although an individual well is subject to irreversibility considerations as it is usually finished once it is started; each well corresponds to an incremental project in a firm's overall drilling program, thus aggregate drilling expenditures at the firm level, measured by the number of wells a firm starts drilling at any point in time, can be scaled up or down depending on the price of natural gas. This situation is significantly different from observing only large multi-year, irreversible expansion-only projects as in Sheen (2009).

In addition to having precise measures of capital expenditures for public and private firms, another key advantage of the natural gas industry is the high degree of commonality between public and private firms in terms of the marginal returns to one extra unit of capital invested. For both types of firms profitability is directly linked to the price of natural gas. The unit of capital investment in the natural gas industry is the natural gas well, which produces natural gas, a commodity quoted and sold per million British thermal units (mmbtu). The average wellhead price obtained across the United States is measured daily and captures the gross profit generated from a firm's main output. Because natural gas is a commodity, all firms are price takers and thus obtain similar prices for their product. Figure 2 confirms that aggregate profitability and operating margins of publicly traded firms in our sample are highly correlated with natural gas prices on a quarterly basis. Furthermore, this price is readily observable to all firms and the econometrician throughout the sample period.

While Figure 2 documents that operating margins and profitability expand when natural gas prices increase, drilling costs could vary in the cross-section; in particular, there may be returns to scale on the cost side. It is often the case in other industries that large companies can extract discounts from suppliers and contractors on investments due to their scale. To test whether scale is a factor in per well costs, we hand-collect data on capital expenditures and wells drilled from 10-K filings of publicly-traded firms in SIC 1311 from 2006 to 2009. We then compute the average per well cost and analyze how it varies within the universe of publicly traded gas producers in our sample. The results from this analysis are displayed in Appendix A and indicate that there is almost no discernible difference between the median per well cost of large and small publicly-traded firms in our sample, even though the large firms are on average five to six times the size of small firms. Additionally, we compute the average drilling days per well, a key indicator of well cost, for both private firms and public firms using our unique dataset. The average drilling days per well over the sample period is equal to 27.6 for private firms and 28.2 for public firms; this difference is economically negligible. These results serve to alleviate concerns that cost heterogeneity in the cross-section is driving our results.[9] Overall, the economics of this industry are such that all firms produce an exogenously priced commodity and have a relatively homogeneous cost structure. Hence the net benefits of one extra unit of capital are similar across private and public firms. This fact creates an attractive setting to compare and contrast the investment decisions made by private and public firms.

3.2 External Financing Needs

One of the key benefits of being public is improved access to financing and capital markets. Therefore in studying public and private firms in a given setting it is important to assess external financing needs. Some industries are less dependent on external financing (e.g. tobacco), while others are very reliant on external financing (e.g. biotechnology). One measure of an industry's dependence on external financing that is often used in the literature is pro-

[9]These results can be explained by the fact that drilling equipment is most often owned by third parties and is rented to natural gas producers on a very competitive basis based on the number of days it takes to drill a well, known in the industry as the day-rate. Patterson-UTI Energy Inc., a firm that leases drilling equipment to natural gas producers, states in its 10-K report: "Our contract drilling and pressure pumping businesses are highly competitive. Historically, available equipment used in these businesses has frequently exceeded demand in our markets. The price for our services is a key competitive factor in our markets, in part because equipment used in our businesses can be moved from one area to another in response to market conditions."

posed by Rajan and Zingales (1998). Their measure is equal to firm i's capital expenditures minus operating cash flow divided by capital expenditures, where each variable is summed over a multi-year period to smooth out business cycle fluctuations:

$$\text{External Financial Dependence} = \frac{\sum_{t=1997}^{2010} \text{Cape}x_{i,t} - \sum_{t=1997}^{2010} \text{Operating C}F_{i,t}}{\sum_{t=1997}^{2010} \text{Cape}x_{i,t}}$$

This measure is equal to 42% for the median public natural gas producer in our sample, placing this industry in the top 20% in terms of external finance dependence relative to all four digit SIC industries within Compustat. The economic interpretation of this measure is that firms must fund on average 42% of their annual capital expenditures from external sources, such as through debt or equity issuances.

To assess whether the ability to issue external capital enables public natural gas producers to fund projects as the price of natural gas changes, we compute net debt and net equity issuances relative to the price of natural gas. With higher natural gas prices over the 2005 to 2008 period, the average public natural gas producer issued net debt ranging from 8% to 16% of assets on an annual basis. Having access to public equity markets also appears to be very important in funding projects; over the 2005 to 2008 time frame the average publicly traded natural gas company issued net equity ranging from 4% to 8% of assets on an annual basis. These results highlight the importance of public equity and debt markets for a firm's ability to react to improvements in investment opportunities.

4 Data

Data on investment activity for private and public firms is obtained from Schlumberger Corporation's Smith International Rig Count, henceforth referred to as our "drilling" dataset. Schlumberger reports information on every rig in the United States that is actively drilling a natural gas well. This dataset provides detailed information on where a natural gas well is being drilled, who is drilling it, and when it is being drilled, at a weekly frequency over the period 1997 to 2010. We conduct lexis nexis and internet searches to determine whether natural gas producers in the drilling database are publicly-traded, a subsidiary of a publicly-traded firm or a private firm. We only include firms in this study that could be conclusively validated as public or private. Drilling activity of a subsidiary is combined with the drilling activity of the parent. All publicly-traded firms not within SIC 1311 (Crude Oil & Natural Gas) are excluded from our sample for firm level regressions. In particular, this restriction eliminates all the vertically integrated oil and gas companies, such as ExxonMobil, whose investment opportunity set is not well captured by changes in the price of natural gas due to their diversified lines of business (i.e. refining).

We aggregate the Smith International weekly Rig Count data into firm-year observations to construct our panel which makes our estimations comparable to the existing literature. We compute measures from the drilling dataset that proxy for investment and capital stock, which we then compare to the PP&E and CAPEX numbers from Compustat for firms that are in both datasets.

Having measures which are reasonable proxies of accounting-based capital stock and investment for both private and public firms is one of the main advantages of our empirical framework. Because drilling is the primary investment activity of natural gas producers, we use the number of wells for which drilling operations have been initiated as our proxy for the amount of investment (I) a firm makes in any given year. The second metric we proxy for is a firm's capital stock (K). Recall from the previous section that a firm's capital stock in this industry is defined as its proven reserves. Hence, we compute a proxy for the capital stock from the drilling data as the number of wells for which drilling operations have been completed in the prior three years. By combining the two measures, we derive a measure of the ratio of investment relative to capital stock (I/K) that is often used in the literature as the main dependent variable of interest for investment sensitivity regressions. Of importance, using the prior three years for our estimate of capital stock requires that the sample for our main regressions starts in the year 2000 rather than 1997, which means we have 11 years of data for our main firm-level regressions.

To reduce the effect of outliers and ensure we have reasonable estimates of a firm's investment and capital stock we apply a number of screens to the raw drilling data. Specifically, we require that a firm must drill at least one well to have a firm-year observation in the sample. This restriction ensures that only firms with active investment programs are included. We also require that a firm have a minimum capital stock of at least 10 wells in the prior three years and we exclude observations with I/K ratio above the 99th percentile. Additionally, we exclude the six firms which switch from private to public or public to private during our sample period. Table 1 outlines the main sample used for the firm level panel regressions. Our sample contains 369 unique private firms and 88 unique public firms, which have 1,668 and 489 firm-year observations, respectively, over the 2000-2010 time period.

We compute an annual measure of natural gas prices by computing the annual average of the daily wellhead gas prices obtained by natural gas producers, as reported by the U.S. Energy Information Administration. One significant advantage of this measure is that we smooth out some transient jumps in the daily wellhead prices linked to two "January cold snaps" in 2001 and 2003 and Hurricane Katrina in 2005. It is interesting to note from Figure 1 that drilling activity does not respond to these temporary shocks. Given that it takes on average three weeks to drill a well, it is not surprising that producers do not react to such short-lived jumps in prices. Our annual measure is nonetheless fairly volatile with a standard deviation of \$1.65 relative to a mean of \$5.16/MMbtu over the sample period.

One of our primary identifying assumptions is that we can accurately proxy for accounting measures of private firms, despite not having access to their financial statements. In order to test this assumption, we assess how well the measures derived from our drilling dataset correlate to accounting measures for the subset of Compustat firms in our sample for which we have both drilling and accounting-based data. As Appendix B documents, the correlation between the measures from the two datasets is high. Specifically the correlation between the number of wells drilled and accounting-based capital expenditures is equal to 71%. Moreover, the correlation between net property, plant, and equipment (PP&E) and the drilling capital stock proxy is 72% when defining the capital stock proxy based on the wells drilled in the previous three years. While the capital stock correlation increases with the number of prior years used to build the drilling data capital stock proxy, it also reduces the number of years in our panel regressions. For our empirical tests, we proxy capital stock using the number of wells completed over the prior three years to achieve a balance between having a reasonably sized sample and having a reasonably good proxy based on the correlations in Appendix B.

To provide further evidence as to whether our capital stock and investment proxies reflect accounting-based measures, we plot the annual levels of the median I/K ratios. In particular we plot the I/K ratio based on Compustat data relative to our drilling data proxies in Figure 3. In this figure we only include firms with both Compustat data and drilling data. Figure 3 documents not only how closely the two measures of I/K compare for the median firm, but also how closely these firm-level measures respond to the price of natural gas over time. This provides firm-level evidence at the annual frequency that is consistent with the evidence from Figure 1 based on the aggregate weekly drilling activity.

As Table 1 highlights, there are significant differences between public and private firms for each of our variables of interest: Investments (I), capital stock (K), and investment/capital stock (I/K). Specifically, private firms are on average significantly smaller than their publicly-traded counterparts. In order to address these differences, we undertake several robustness exercises in our econometric specifications which are described below.

One concern highlighted in Table 1 is that private firms are on average smaller than their publicly traded counterparts. To check whether differences in size between public and private firms are responsible for how firms respond to natural gas prices we undertake several exercises. First we increase the minimum size requirement for inclusion in the sample. Specifically, we require that firms have capital stock levels above different minimum levels, which means we can compare larger private firms to public firms. Table 2 documents how the firm-size distribution changes for both public and private firms when different size cutoffs are used. Our main results are very similar across these different size cutoffs.

While size differences are reduced when we increase the size cutoffs, there remain significant disparities across the two types of firms. To further address this size issue, we create a matched sample on size. We follow the same panel matching methodology as in Asker et al. (2011). In particular, as soon as a private firm enters our sample we match it to a public firm based on its capital stock value in the year it enters the sample. We keep the same match every year until the private firm drops out of the sample or the matched public firm drops out of the sample. If the matched public firm drops from the sample, then we find a new match for the private firm in that year which is kept going forward. Similar to Asker et al., we match with replacement to ensure that we get the best match possible. After conducting this procedure, we end up with a public-private sample matched on size, with 67 unique public firms and 370 unique private firms, and a total of 3,348 firm-years. As Panel B of Table 2 documents, our size matching generates remarkably comparable firm-sizes across public and private firms in the year of the match, with mean capital stock of public firms of 23.0 wells compared to mean capital stock of private firms of 23.5 wells.

Lastly, we control for size explicitly in our regressions of investment levels (I) and logarithm of investments (log(I)), by including the logarithm of capital stock (log(K)) to control for size. Furthermore, we include an interaction term between size and our investment opportunity measures, the price of natural gas and shale booms, to ensure that being private does not proxy for a size effect.

5 Results

5.1 Sensitivity of Investment to Q and Natural Gas Prices

In this section, we set out to empirically measure the sensitivity of capital expenditures to two proxies of marginal q for the publicly-traded natural gas producers in our sample. The goal is to further assess the validity of using natural gas prices as a proxy for marginal q and to compare it to the traditional proxy used in this literature: Tobin's Q. Tobin's Q is defined for each firm as the market-to-book ratio and is computed as Total Liabilities - Deferred Taxes + Preferred Stock + Market Value of Equity in the numerator and Total Assets in the denominator (see for example Jung et al. (1996)). To be consistent with the extant literature, we compute our dependent variable as capital expenditures divided by net property, plant, and equipment (I/K).

Table 3 shows that when we regress I/K on Tobin's Q we find a positive and statistically significant coefficient of 0.133. This suggests that firms with higher Q values invest more, and in economic terms implies that for a one standard deviation increase in Q, I/K increases by 40.1% relative to its median value of 0.30. Given the mismeasurement and endogeneity concerns generally associated with Tobin's Q, we define our second proxy for marginal q as the annual average of daily wellhead natural gas prices. By construction, this proxy takes the same value for all firms in any given year. When we regress the investment rate on natural gas prices (NG_t), the coefficient on natural gas prices is positive and statistically significant. In economic terms, the sensitivity is significant as well. A one standard deviation increase in the price of natural gas results in the investment to capital ratio increasing by 20.3% relative to its median value. In the last specification, we include both Q and natural gas prices in the regression. Both variables remain statistically significant. Overall, these results confirm that natural gas prices are a significant driver of annual capital expenditures for the public firms in our sample. It has the added advantage of being an exogenous proxy for a firm's investment opportunity set both for the public firms as well as the private firms in our sample.

5.2 Sensitivity of Investment to Natural Gas Prices: Public vs. Private Firms

In this section, we compare the sensitivity of investment for both public and private firms to changes in natural gas prices, our proxy for marginal q. Figure 4 plots aggregate drilling activity for public and private firms relative to the price of natural gas. As documented in the figure, in the aggregate, public firms appear to be more sensitive to changes in natural gas prices than private firms. The difference is particularly visible during the 2003-2008 run-up in natural gas prices whereby the drilling activity of public firms follows the upward trend in natural gas prices while the drilling activity of private firms remains flat over that time period.

Table 4 presents the results of univariate tests which compare investment intensity levels of public and private firms at different natural gas price levels. Observations are placed in terciles based on the price of natural gas in a given year, with the bottom third of years being designated as “Low Prices”, the middle third as “Average Prices”, and the top third as “High Prices.” The results of the univariate tests suggest that both public and private firms invest lower amounts at low prices, and that the level of investment intensity between public and private firms is similar when comparing both means and medians when prices in the low price bracket. For example, when using a capital stock/size cutoff of K$\geq$10 public firms have a mean I/K of 0.36 (median 0.24) versus 0.31 (median 0.22) for private firms when prices are low, a difference that is not statistically significant. The evidence across the different size cutoffs provide little support that public firms invest more in general, or “empire build”, in bad states of the world (low natural gas prices)

A second observation can be made from Table 4 regarding investment sensitivity to natural gas prices when we compare investment intensity in different terciles. For example, when comparing the investment mean values from the lowest price tercile to the highest for K $\geq$10, public firms increase I/K from 0.36 to 0.58, while private firms increase I/K from 0.31 to 0.40. These initial univariate tests provide evidence that public firm investment is more sensitive than private firm investment to natural gas prices. Specifically, public firm investment increases 61% from the low tercile to the high tercile compared to only a 29% increase from low to high price terciles for private firms.

We formally test the univariate results in Table 4 in a regression framework in Table 5. Using the proxies for investment and capital stock constructed from our drilling database and natural gas prices as our proxy for marginal q, we are able to test whether public and private firms respond differently to changes in the price of natural gas over our sample period. In Table 5 we regress measures of investment (both I/K in Panel A and log(I) in Panel B) on natural gas prices (NG_t) and natural gas prices interacted with a private dummy ($NG_t * Private_{i,t}$). The key coefficient of interest in determining whether private firms respond differently to a given price of natural gas is the coefficient on the interaction term $NG_t * Private_{i,t}$. The magnitude and sign on the coefficient of this term is an indication of how private firms respond relative to public firms for a given change in natural gas prices.

One of the primary concerns in comparing investment policies of public and private firms is whether size is driving investment decisions, as opposed to being public or private. To address concerns regarding the potentially large differences in sizes between public and private firms, we implement several different minimum size cutoffs in specifications (1)-(6). Secondly, we also run our tests on a size matched sample in specifications (7)-(8).

We find that the coefficient on the interaction term $NG_t * Private_{i,t}$ is negative and statistically significant in all our specifications, including the matched sample. These results suggest that private firm investment responds less to a given change in natural gas prices than public firm investment. The coefficient on the interaction term $NG_t * Private_{i,t}$ is roughly two thirds the coefficient on NG_t, which suggests that private firms are two thirds less responsive to changes in natural gas prices than their publicly-traded counterparts. Relating the coefficients in specification (2) of Panel A to the median investment intensity of each firm type implies that a one standard deviation increase in natural gas prices leads public firms to increase their investment intensity ratio by 21.7% while the investment intensity ratio of private firms only increases by 10.4%. Similarly, in specification (2) of Panel B, with log of investments as the dependent variable, we find that a one standard deviation increase in the price of natural gas leads public firms to increase investment by 29.3% while private firms increase investments by only 13.3%.

Do private firms respond at all to the price of natural gas? To assess the effect of the price of natural gas on private firms we need to test whether the combination of the coefficients on NG_t and $NG_t * Private_{i,t}$ is significantly greater than zero (H_0: $\beta_1 + \beta_2 = 0$ vs. H_a: $\beta_1 + \beta_2 > 0$). The results for this test are shown below the main regressions in both Panel A and Panel B of Table 5. For example, in specification (2) of Panel A we find that the sum of the two coefficients is equal to 0.019 (=.054 - .035), a figure that is both positive and statistically significant. This difference is positive in all specifications found in Panel A and Panel B.

Not only does the sign and significance of our result remain unchanged in most specifications, but the magnitude of our coefficient remains nearly the same throughout. When firms are matched on size in specifications (7)-(8), we find very similar and statistically significant results confirming our initial inferences, this suggests that differences in size does not account for the differences we observe in investment.

An alternative test for whether size is driving investment decisions is shown in Panel C, where we control for size explicitly in the regressions. We interact size with the price of natural gas and find a positive and statistically significant relationship in some specifications when we exclude the interaction of the private dummy with the price of natural gas. However, when we add both the interaction of price with the private dummy and price with size, we observe that only the interaction with the private dummy remains statistically significant throughout all specifications. This result provides further evidence that differences in size between private and public firms are not driving our results.

5.3 Natural Gas Shale Boom Natural Experiment

As recently as the year 2000, natural gas produced from shale comprised only 1% of natural gas production in the United States. The technological breakthrough, which combines "fracking" and horizontal drilling, has enabled the economically profitable development of shale. One consequence of this new technology, is that natural gas produced from shale comprised 25% of 2011 U.S. natural gas production, furthermore, new natural gas reserves from shale are now equivalent to a 100 year supply of U.S. natural gas consumption (Yergin (2011)). These advancements have resulted in unprecedented investment opportunities for the development and production of natural gas in the major natural gas shale fields that have been discovered to date.[10]

We use the unexpected and unprecedented investment opportunities associated with shale gas development as a natural experiment. The detailed location specific investment information in our dataset enables us to undertake a unique separate test, distinct from our firm level investment intensity regressions, of how public and private firm investments respond to growth opportunities. Specifically, we use data on firm investment activity at the county level in a difference-in-differences framework to see how public and private firms respond to a shale gas discovery in the boom counties where they have existing operations. The first

[10]For our study we focus on shale booms in the six states with major natural gas shale discoveries: Arkansas, Louisiana, Oklahoma, Pennsylvania, Texas, and West Virginia.

difference can be viewed as comparing investment pre-discovery versus post-discovery, while the second difference can be thought of as the difference in how public and private firms respond to the shale gas finding.

We focus only on firms that were active in a county prior to a shale boom, so we know that they have leased the right to drill a new well in a shale boom county. Specifically, if a firm was in a county *prior* to the discovery of shale, it now has very valuable acreage that can be further developed to extract the new shale resource. Additionally, we require that a firm has some investment activity after the discovery of shale in a boom county, which insures that they did not exit an area prior to the shale boom or sell their acreage.

Another important feature of the development of shale is that it uses a well-known technology, which third party contractors (e.g. Halliburton) are often hired to help develop. This fact should serve to mitigate concerns regarding differences in technological know-how and patents that could plague similar technological breakthrough tests in other industries or settings. Shale wells also have a low risk of being unproductive ("dry holes"), which means that our shale boom empirical tests would be less likely to be affected by differences in investment risk aversion across firms.

Our data set contains specific information on the location of wells and well characteristics. This data enables us to determine when a boom occurs, economically the objective is to find the point in time when development activity shifts from being prospective, to a boom. To define when a boom occurs, we use a similar definition as Gilje (2011), which relies on the number of horizontal wells[11] drilled in a given county. Specifically, we define a county to be in a "boom" time period once there have been more than 20 horizontal wells drilled. The "boom" threshold is set such that counties in the top quartile of county-years with horizontal drilling activity are boom county-years. Using this definition means that more than 90% of all horizontal wells in our sample are drilled in county-years which we define as "boom" county-years.

The dependent variable in our shale boom regressions is investments made by firm i in county j at time t. For example, it could be the case that a single firm is active in several

[11] Horizontal wells are the primary type of well used to develop shale gas.

counties where shale is discovered. We include firm-county fixed effects to account for time invariant heterogeneity of firm investment policies in different counties. To ensure that we have consistent standard errors in our estimation we follow the approach recommended by Bertrand et al. (2004) and collapse time periods for each boom into two periods one pre-period and one post-period. Specifically, in a given county for a given firm, investment activity is averaged across the three years prior to the boom and the three years after the boom. Thus, for each firm in each boom county we have two observations: One pre-boom and one post-boom.

When we test how private and public firms respond to shale booms in Panel A of Table 6, we find that the interaction coefficient $PostBoom_{j,t} * Private_i$ is negative and statistically significant, which suggests that private firm investment responds less than public firm investment to a shale boom. The economic interpretation of the interaction coefficient is that when there is a shale boom, private firms drill 25.2% fewer wells than public firms. Furthermore, when testing whether private firms respond to a shale boom with any increased investment, we cannot reject the null that the increase in investment is not statistically different from zero, meaning that private firms do not show any statistically significant increases in their investment in boom counties in the three years following a boom.[12]

By testing how private and public firms respond to shale booms, we can rule out several possible alternative explanations for our earlier results. Specifically, it could be the case that the results of our main firm-level specifications in Table 5 are driven by some unobserved heterogeneity between public and private firms such as geographic differences in natural gas development opportunities, which could then lead to transportation cost differences. Alternatively, it could be the case that one set of firms is better at searching for new areas to drill. Our shale boom natural experiment design helps alleviate many of these concerns. For example, because we require all firms to be drilling in a shale boom county prior to the discovery, the difference in investment of public versus private firms cannot be explained by one set of firms always having superior abilities to search and seek out new discoveries.

[12] To formally test this hypothesis, we test whether the linear combination of the coefficient on the post-boom dummy and the coefficient on the interaction term of private and post-boom dummy is significantly greater from zero or not (H_0:$\beta_2 + \beta_3 = 0$ vs. H_a: $\beta_2 + \beta_3 > 0$).

Additionally, because we are comparing the opportunity to invest in a given type of well, a shale well, in the same location, the cost of drilling the well is going to be similar for any given firm. More specifically, the investment opportunity set is comprised of investments in the same time, place, location, and with similar costs; providing for a comparison of similar investments across different types of firms.

To conduct a further test for whether size is driving the observed differences in the responsiveness to shale discoveries, we include additional terms in Table 6 Panel B, namely size ($Size_{i,t}$) and size interacted with the post-boom dummy ($PostBoom_{j,t} * Size_{i,t}$). We use our proxy for capital stock from the drilling data as our estimate of size in this specification. The key coefficient of interest when testing whether larger firms (as opposed to public firms) are able to respond better to shale booms is the coefficient on the interaction term: $PostBoom_{j,t} * Size_{i,t}$. If it is the case that larger firms are able to respond better to shale booms, then we would expect this interaction term to be positive, yet it is neither positive nor statistically significant. Given that the coefficient on $PostBoom_{j,t} * Private_i$ remains negative and significant even after the inclusion of these size controls, we infer that size differences are not driving the observed disparities in investment responsiveness between public and private firms.

Beyond providing evidence directionally consistent with our firm level regressions, the results from the shale boom tests provide evidence of a plausible explanation for the differences in investment behavior we observe between public and private firms. A key distinguishing feature of shale wells, is that they are at least three times more capital intensive than a non-shale well, due to the horizontal drilling and hydraulic fracturing ("fracking") associated with their development.[13] Thus, while in our firm level regressions we observe some responsiveness of investment to the price of natural gas, for wells that are presumably less expensive than shale wells on average, we find no evidence that private firms increase investment in more expensive shale wells when there is a shale boom. This difference in capital requirements suggests that differences in barriers to accessing external financing are a plausible cause for

[13] However, shale wells do produce several times the amount of gas conventional wells produce on average, so they are still economically profitable to drill.

the differences in investment behavior that we observe between public and private firms.

Table 7 provides further robustness for our shale boom tests in the form of a falsification test. There may be some concerns as to whether a shale boom could be anticipated, whether there is an overall time-trend in investment in these specific counties, or whether a spurious correlation is driving the results of our natural experiment. To alleviate these concerns, we artificially move the time of the shale boom to be three years earlier for every boom county in our sample. The results on the interaction term $FalseBoom_{j,t} * Private_i$, as well as the direct effect, $FalseBoom_{j,t}$, are not statistically significant, which suggests that our test of booms is reflecting the proper timing of the shale boom and is not due to a spurious correlation or an overall time-trend in investment activity.

6 Conclusions

In this paper, we exploit a unique dataset of onshore North American natural gas producers to study how private and public firms differ in their investment behavior. We find that private firms are less sensitive to changes in investment opportunities. We reach this conclusion by analyzing the investment sensitivity of private and public firms to two different exogenous measures of investment opportunities: 1) changes in natural gas prices and 2) shale gas discoveries.

Our empirical setting offers several advantages beyond detailing the investment activity of a large sample of both public and private firms. First, due to the economics of this industry, the price of natural gas serves as a valid and exogenously given proxy for marginal q for both private and public firms. We are also able to make use of significant shale gas discoveries in specific counties to design a natural experiment that rules out potential alternative explanations for our findings. As such, our results are not driven by heterogeneity in product markets, pricing, firm size, location, or drilling costs. Due to the high external financing needs of this industry, our findings are consistent with the view that private firms face higher financing costs than their publicly-traded counterparts and that this friction influences their real investment decisions.

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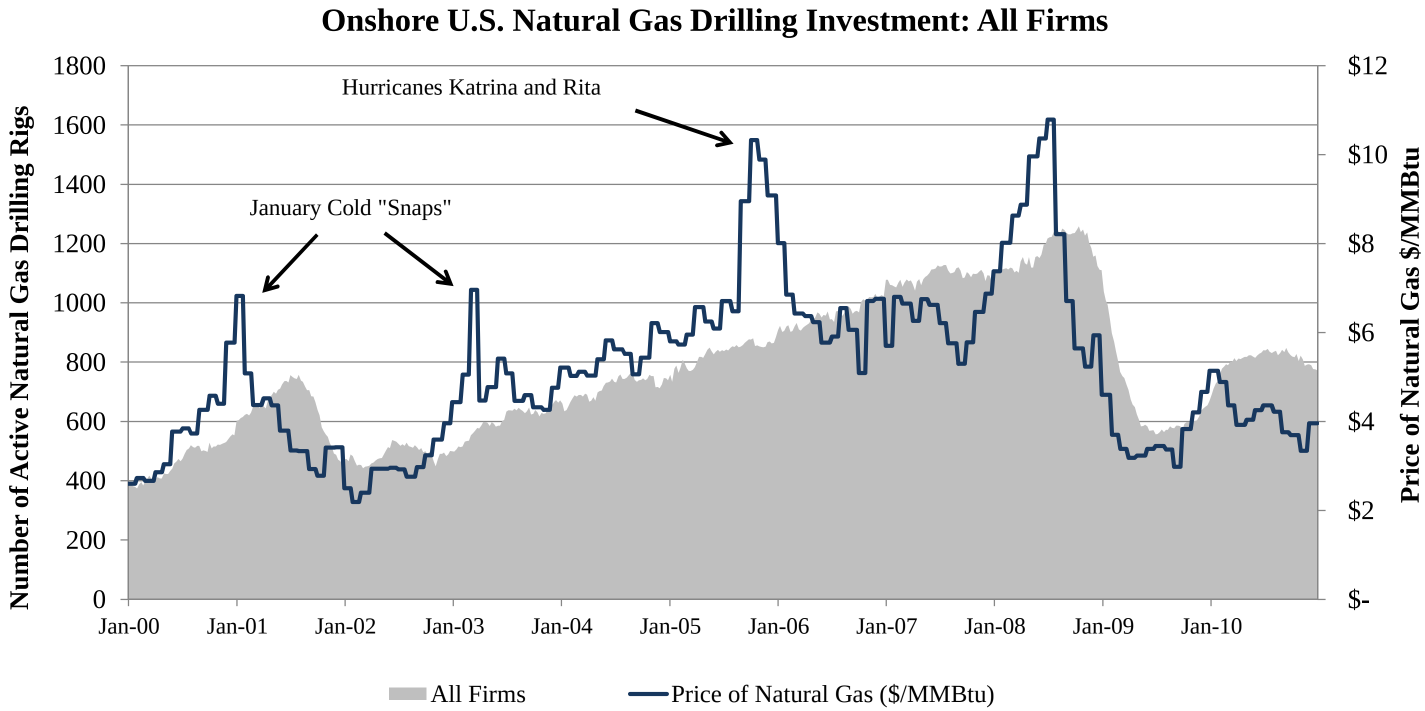
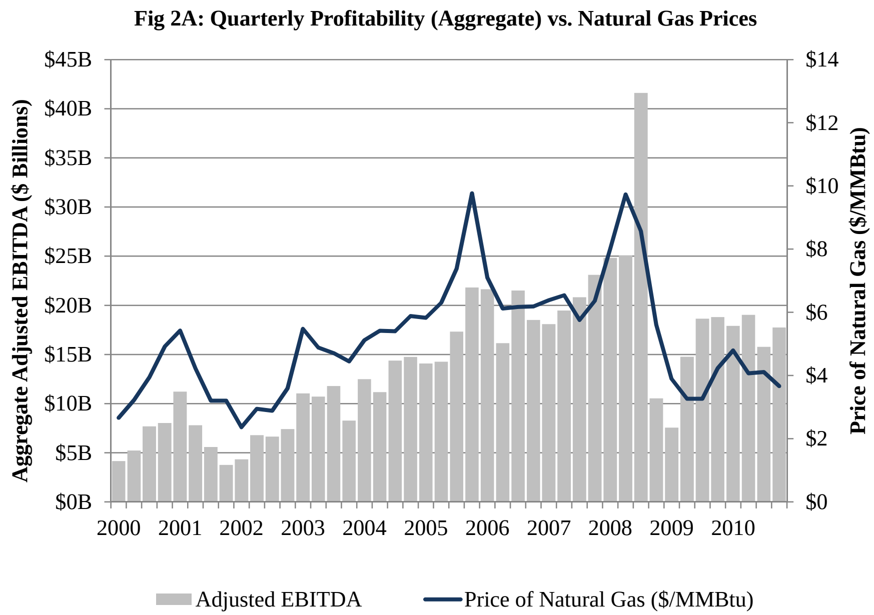


Figure 1: Onshore U.S. Natural Gas Drilling Investment: All Firms
This figure plots investment activity, as proxied by active drilling rigs, relative to the wellhead price of gas for the time period 1997 through 2010.



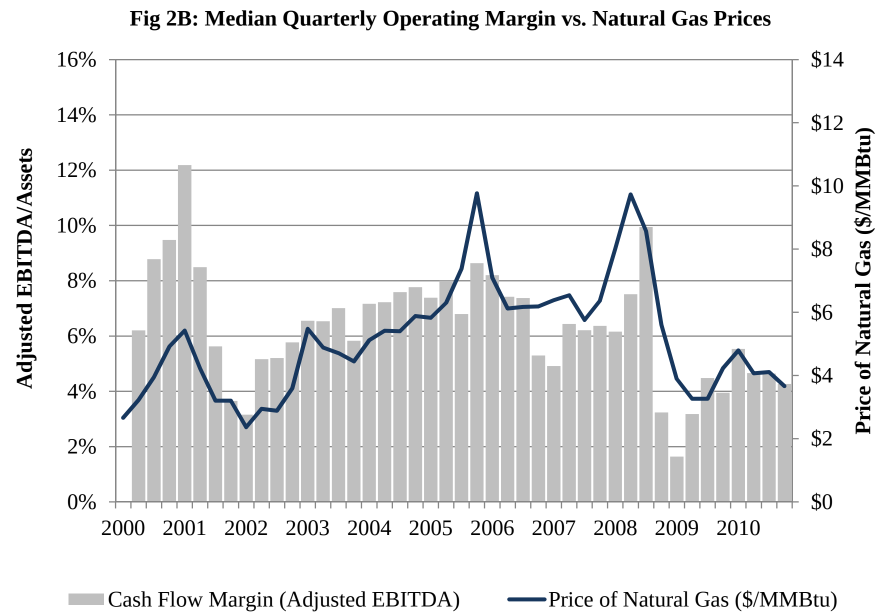


Figure 2A: Quarterly Profitability vs. Natural Gas Prices

This figure plots the quarterly aggregate adjusted EBITDA of all public SIC 1311 firms (Crude Petroleum and Natural Gas) relative to the wellhead price of natural gas. The aggregate adjusted EBITDA is the sum of adjusted EBITDA across all firms that appear in both Compustat accounting data and the drilling data. Our measure of Adjusted EBITDA is equal to operating cash flow (code: oancf) + taxes (code: txt) + interest payments (code: xint). We calculate Adjusted EBITDA in this manner so that we exclude any mark-to-market effects of hedges.

Figure 2B: Median Quarterly Operating Margin vs. Natural Gas Prices

This figure plots the median operating margin for SIC 1311 firms (Crude Petroleum and Natural Gas) for each quarter in our sample relative to the wellhead price of natural gas. Quarterly operating margin is defined as adjusted EBITDA divided by the assets at the beginning of the period. The median calculation is based on firms in both Compustat and the drilling data in a given fiscal year. Our measure of Adjusted EBITDA is equal to operating cash flow (code: oancf) + taxes (code: txt) + interest payments (code: xint). We calculate Adjusted EBITDA in this manner so that we exclude any mark-to-market effects of hedges.

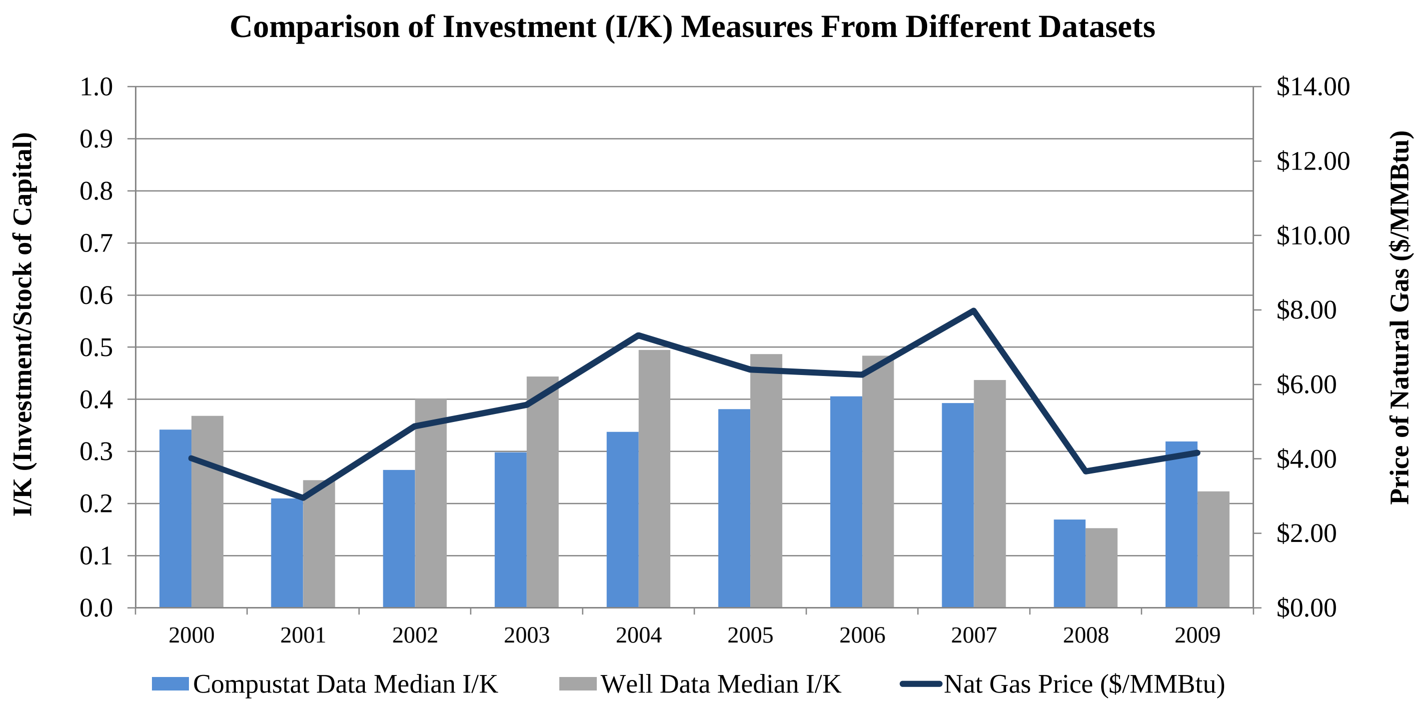


Figure 3: Comparison of Investment (I/K) Measures based on Accounting Data versus Drilling Data

This figure compares the medians of two different measures of Investment/Capital Stock (I/K), one from Compustat accounting data and one from drilling data, plotted with the wellhead price of natural gas. The comparison is done on the same set of sample firms, meaning that a firm must have both Compustat accounting data and drilling activity data in a given year, and be classified in SIC 1311 (Crude Petroleum and Natural Gas). The Compustat measure of I/K is calculated as investment (code: capx) divided by beginning of period net property, plant, and equipment (code: ppent). The drilling data measure of I/K is calculated as investment (proxied by the number wells drilled) divided by capital stock (proxied by the number of wells completed in the previous three years).

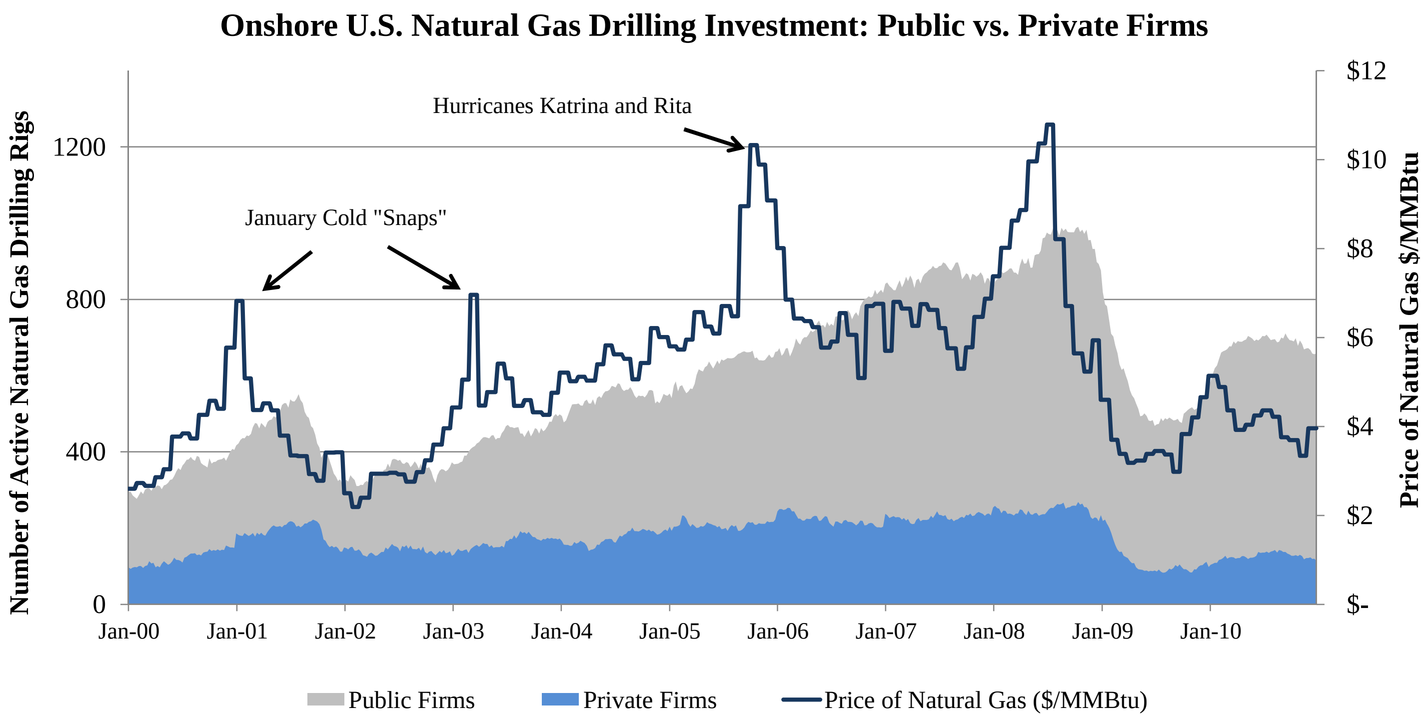


Figure 4: Onshore U.S. Natural Gas Drilling Investment: Public vs. Private Firms
This figure plots investment activity, as proxied by drilling rigs, for public and private firms separately relative to the wellhead price of gas for the time period 1997 through 2010. The aggregate drilling activity of public firms (lighter shade) is always superior to the aggregate drilling activity of private firms (darker shade) over the sample period.

Table 1: Drilling Data Summary Statistics: Public versus Private Natural Gas Producers

This table contains summary statistics for the drilling activity data used in firm-level panel regressions of public and private firms. The capital stock measure is defined as the total number of wells drilled in the previous three years for a given company. The investment measure is defined as the total number of wells drilled in a given year for a company. In order to be included in our sample a firm-year must have 1) non-missing capital stock; 2) drilled at least one well in a year and 3) have capital stock greater than or equal to 10 wells. To mitigate outliers we exclude observations above the 99th percentile for I/K. Based on the above screens we have valid firm-years spanning from 2000 through 2010.

Descriptive Statistics

Sample Size	Public	Private	Total	
Unique Firms	88	369	457	
Firm-Year Observations	489	1668	2157	
Capital Stock (K)				
Well Based Capital Stock Measure	Public	Private	Difference	p-value
Mean	244.6	35.6	209.0***	0.000
Median	96	21	75***	0.000
Standard Deviation	430.8	58.8		
Investment (I)				
New Wells Drilled	Public	Private	Difference	p-value
Mean	97.1	11.7	85.4***	0.000
Median	36	6	30***	0.000
Standard Deviation	175.9	21.8		
Investment/Capital Stock (I/K)				
Wells/Capital Stock	Public	Private	Difference	p-value
Mean	0.47	0.36	0.11***	0.000
Median	0.40	0.29	0.11***	0.000
Standard Deviation	0.37	0.32		
Proxy for Marginal Q				
Natural Gas Price $/MMBtu	$/MMBtu			
Mean	5.16			
Median	4.88			
Standard Deviation	1.65			
Number of Years in Sample	11			

Table 2: Sample Size Comparison: Private Firms vs. Public Firms

Panel A Minimum Capital Stock Requirements: This panel reports how the firm size distribution and number of observations in our sample changes when different capital stock cutoffs are used. The proxy for capital stock that is used is based on the number of wells completed in the previous three years.

Panel B Matched Sample: This panel reports the summary statistics of the matched public-private sample for the year of the sample match. Following Asker et al. (2011), the matching is done based on a nearest neighbor approach, with matching conducted on the drilling data proxy of capital stock in the year that a private firm enters the sample. The match persists until either the private firm is no longer in the sample or the matched public firm is no longer in the sample. If a public firm which has been matched leaves the sample a new public firm is matched to the private firm based on the capital stock in that firm-year. The capital stock measure is defined as the total number of wells drilled in the previous three years for a given company. The investment measure is defined as the total number of wells drilled in a given year for a company.

Panel A: Sample Comparison based on Different Capital Stock Cutoffs

		N	Mean	P25	P50	P75
$K \geq 10$	Private	1,668	35.6	14	21	35
	Public	489	244.6	32	96	241
$K \geq 30$	Private	529	75.5	36	48	75
	Public	372	315.1	69	141	336
$K \geq 50$	Private	253	116.7	58	78	114
	Public	311	368.8	102	178	398

Panel B: Sample Comparison Matched Sample - Year of Match

Sample Size	Public	Private		
Unique Firms	67	370		
Capital Stock (K)				
Well Based Capital Stock Measure	Public	Private	Difference	p-value
Mean	23.0	23.5	-0.59	0.731
Median	14	15	-1	0.191
Standard Deviation	26.8	33.4		
Investment (I)				
New Wells Drilled	Public	Private	Difference	p-value
Mean	13.2	9.7	3.47***	0.000
Median	8	5	3***	0.000
Standard Deviation	15.1	17.5		
Investment/Capital Stock (I/K)				
Wells/Capital Stock	Public	Private	Difference	p-value
Mean	0.70	0.42	0.28***	0.000
Median	0.47	0.31	0.16***	0.000
Standard Deviation	0.79	0.39		

Table 3: Sensitivity of Investment to Tobin's Q and Natural Gas Prices: Public Firms Only

This table reports the regression results of investment to capital ratio (I/K) regressed on Tobin's Q and natural gas prices (NG). The sample is based on all public firms in SIC 1311 (Crude Petroleum and Natural Gas) which also appear in our drilling data sample over the time period 2000 to 2010. Investment is measured as Capital Expenditures (code: capx) divided by beginning of period Net Property, Plant, and Equipment (code: ppent). Tobin's Q is measured as the market value of assets divided by book value of assets (code: at). Market value of assets is defined as Total Liabilities (code: lt) - Deferred Taxes (code: txditc) + Preferred Stock (code: pstkl) + Market Value of Equity (code: csho multiplied by code: prcc_f). The price of natural gas used is the average wellhead price of natural gas in a given year. All regressions include firm fixed effects. Standard errors are clustered by firm, with t-statistics reported in brackets below the coefficient estimates. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

$$(1)\ I/K_{i,t} = \alpha + \beta_1 Q_{i,t-1} + FirmFE_i + \varepsilon_{i,t}$$

$$(2)\ I/K_{i,t} = \alpha + \beta_1 Q_{i,t-1} + FirmFE_i + TimeFE_t + \varepsilon_{i,t}$$

$$(3)\ I/K_{i,t} = \alpha + \beta_1 NG_t + FirmFE_i + \varepsilon_{i,t}$$

$$(4)\ I/K_{i,t} = \alpha + \beta_1 Q_{i,t-1} + \beta_2 NG_t + FirmFE_i + \varepsilon_{i,t}$$

	I/K = Capex/NetPPE			
	(1)	(2)	(3)	(4)
Tobin's $Q_{i,t-1}$	0.133***	0.096***		0.115***
	[3.67]	[2.85]		[3.35]
NG_t			0.039***	0.026***
			[5.36]	[3.76]
$FirmFE_i$	Yes	Yes	Yes	Yes
$TimeFE_t$	No	Yes	No	No
R^2 Within	0.187	0.266	0.100	0.229
N	396	396	397	396

Table 4: Investment Intensity Level for Public and Private Firms at Levels of Natural Gas Prices

This table reports univariate tests which compare whether the mean and median investment intensity (I/K) differ for public and private firms at different price terciles of natural gas. The natural gas price terciles are based on whether the price of natural gas in a given year is in the lowest third, middle third, or highest third of the years in our sample time period. The univariate tests are done across different size cutoffs based on capital stock, as well as for the matched sample. The proxy for capital stock that is used is based on the number of wells completed in the previous three years.

Capital Stock Cutoffs	Natural Gas Price Tercile	Investment/Capital Stock (I/K)				
		Comparison	Public	Private	Difference	p-value
$K \geq 10$	Low Prices	Mean	0.36	0.31	0.05	0.149
		Median	0.24	0.22	0.02	0.216
	Average Prices	Mean	0.44	0.35	0.08***	0.005
		Median	0.37	0.27	0.09***	0.000
	High Prices	Mean	0.58	0.40	0.18***	0.000
		Median	0.49	0.33	0.15***	0.000
$K \geq 30$	Low Prices	Mean	0.28	0.30	-0.02	0.589
		Median	0.23	0.21	0.02	0.481
	Average Prices	Mean	0.39	0.30	0.09***	0.002
		Median	0.34	0.27	0.08***	0.002
	High Prices	Mean	0.55	0.35	0.19***	0.000
		Median	0.48	0.31	0.17***	0.000
$K \geq 50$	Low Prices	Mean	0.29	0.25	0.04	0.262
		Median	0.23	0.18	0.05	0.223
	Average Prices	Mean	0.38	0.30	0.09**	0.011
		Median	0.34	0.25	0.09***	0.006
	High Prices	Mean	0.52	0.33	0.19***	0.000
		Median	0.49	0.29	0.20***	0.000
Matched	Low Prices	Mean	0.40	0.32	0.09*	0.100
		Median	0.25	0.22	0.02	0.552
	Average Prices	Mean	0.47	0.36	0.11**	0.021
		Median	0.37	0.27	0.09***	0.007
	High Prices	Mean	0.64	0.41	0.23***	0.000
		Median	0.48	0.33	0.15***	0.000

Table 5: Sensitivity of Investment to Natural Gas Prices: Private vs. Public Firms

This table reports firm-level regressions of investment sensitivity to natural gas prices for public and private firms. The dependent variables in these regressions are different measures of investment activity. Investment levels are measured as the number of wells a firm drills in a given year, while capital stock is measured as the number of wells completed in the prior three years by the firm. Panel A reports results for investments divided by the beginning of year capital stock measure (I/K), while Panel B reports results for the logarithm of investment levels (Log(I)). Lastly, Panel C adds firm size as a control in all specifications where log(I) is the dependent variable. The columns report different adjustments made to the sample based on size requirements, specifically columns (1) to (6) require different minimum levels of capital stock, while columns (7) and (8) report results for a matched public-private sample, with matching based on capital stock. All regressions include firm level fixed effects. Standard errors are clustered by firm, with t-statistics reported in brackets below the coefficient estimates. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level. Note: The coefficient for $Private_{i,t}$ is not reported because it is not identified with $FirmFE_i$ fixed effects.

Panel A: $I/K_{i,t} = \alpha + \beta_1 NG_t + \beta_2 NG_t * Private_{i,t} + \beta_3 Private_{i,t} + FirmFE_i + \varepsilon_{i,t}$

Panel B: $log(I_{i,t}) = \alpha + \beta_1 NG_t + \beta_2 NG_t * Private_{i,t} + \beta_3 Private_{i,t} + FirmFE_i + \varepsilon_{i,t}$

Panel A: Dependent Variable = I/K = (New Wells)/(Proxy for capital stock based on wells put online in the past)

	K ≥ 10		K ≥ 30		K ≥ 50		Matched on K	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(β_1) NG_t	0.027***	0.054***	0.035***	0.059***	0.040***	0.054***	0.052***	0.080***
	[5.22]	[4.34]	[4.81]	[5.08]	[5.26]	[5.63]	[3.87]	[3.08]
(β_2) NG_t * $Private_{i,t}$		-0.035**		-0.043***		-0.035**		-0.055**
		[-2.58]		[-3.01]		[-2.25]		[-2.07]
$FirmFE_i$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2 Within	0.018	0.018	0.040	0.040	0.069	0.069	0.027	0.034
N - Total Firm Years	2157	2157	901	901	564	564	3348	3348
Private Firm Years	1668	1668	529	529	253	253	1674	1674
Public Firm Years	489	489	372	372	311	311	1674	1674
Effect of NG_t on Private Firms								
$\beta_1 + \beta_2$ =		0.019**		0.016*		0.019		0.024***
		[3.44]		[1.84]		[1.52]		[3.73]

Panel B: Dependent Variable = Log(I) = Log(New Wells Drilled)

	K ≥ 10		K ≥ 30		K ≥ 50		Matched on K	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(β_1) NG_t	0.100***	0.183***	0.136***	0.198***	0.181***	0.221***	0.133***	0.175***
	[7.70]	[8.50]	[6.92]	[9.66]	[7.93]	[10.31]	[5.96]	[4.42]
(β_2) NG_t * $Private_{i,t}$		-0.108***		-0.112***		-0.102*		-0.083*
		[-4.13]		[-3.07]		[-1.93]		[-1.90]
$FirmFE_i$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2 Within	0.055	0.066	0.092	0.108	0.157	0.169	0.079	0.087
N - Total Firm Years	2157	2157	901	901	564	564	3348	3348
Private Firm Years	1668	1668	529	529	253	253	1674	1674
Public Firm Years	489	489	372	372	311	311	1674	1674
Effect of NG_t on Private Firms								
$\beta_1 + \beta_2$ =		0.074***		0.086**		0.118**		0.092***
		[4.94]		[2.86]		[2.43]		[5.03]

Table 5: Continued

Panel C: $log(I_{i,t}) = \alpha + \beta_1 NG_t + \beta_2 NG_t * Private_{i,t} + \beta_3 Private_{i,t} + \beta_4 Size_{i,t} + \beta_5 NG_t * Size_{i,t} + FirmFE_i + \varepsilon_{i,t}$

Panel C: Size Control Dependent Variable = Log(I) = Log(New Wells Drilled)

	K ≥ 10		K ≥ 30		K ≥ 50		Matched on K	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NG_t	-0.009	0.139*	0.007	0.213*	0.188*	0.403***	-0.043	0.019
	[-0.29]	[1.70]	[0.10]	[1.75]	[1.83]	[2.69]	[-1.12]	[0.35]
$NG_t * Private_{i,t}$		-0.094**		-0.115**		-0.132**		-0.055**
		[-2.24]		[-2.26]		[-2.00]		[-2.05]
$Size_{i,t}$	0.070	0.181	0.090	0.258*	0.304**	0.468***	0.002	0.052
	[0.83]	[1.61]	[0.81]	[1.84]	[2.54]	[3.18]	[0.02]	[0.59]
$NG_t * Size_{i,t}$	0.029***	0.008	0.027*	-0.004	-0.003	-0.035	0.046***	0.037***
	[3.19]	[0.51]	[1.88]	[-0.17]	[-0.17]	[-1.37]	[4.39]	[2.88]
$FirmFE_i$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2 Within	0.088	0.093	0.118	0.130	0.187	0.203	0.136	0.138
N - Total Firm Years	2157	2157	901	901	564	564	3348	3348
Private Firm Years	1668	1668	529	529	253	253	1674	1674
Public Firm Years	489	489	372	372	311	311	1674	1674

Table 6: Shale-based Natural Experiment

This table reports firm county level regressions which test the responsiveness of investments from public and private firms to positive shocks to their investment opportunity set generated by shale gas booms. The dependent variable is a measure of investment by firm (i) in county (j) at time (t). Firm level investments in a given county are aggregated into two separate time periods, one for the average number of wells three years prior to a boom and one for the average number of wells three years after a boom. In order to be in our sample, a firm is required to have drilling activity in both the time period before and after the boom. The resulting dataset has two time periods for a firm active in a given boom county, one for the time period before the boom and one for the time period after a boom. The price of natural gas is the average wellhead price over the three year period being aggregated. Investment is measured as either the logarithm of wells drilled or the number of new wells drilled by a firm in a county over the three year period being aggregated. Panel B includes size controls to the specifications. Standard errors are clustered by county, with t-statistics reported in brackets below the coefficient estimates, where * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Panel A: Firm Investment at the County Level and Shale Booms (Firm i, County j, Time t)

$$Investment_{i,j,t} = \alpha + \beta_1 NG_t + \beta_2 PostBoom_{j,t} + \beta_3 PostBoom_{j,t} * Private_i + + \beta_4 Private_i + FirmCountyFE_{i,j} + \varepsilon_{i,j,t}$$

	Investment = Log New Wells			Investment = Number of New Wells		
	(1)	(2)	(3)	(4)	(5)	(6)
(β_1) NG_t	0.140***	0.143***	0.150***	1.277**	1.327**	1.446**
	[3.12]	[3.02]	[3.20]	[2.21]	[2.17]	[2.40]
(β_2) $PostBoom_{j,t}$		0.157**	0.268**		2.270**	4.124**
		[2.18]	[2.46]		[2.39]	[2.56]
(β_3) $PostBoom_{j,t}$ * $Private_i$			-0.252**			-4.181**
			[-2.41]			[-2.60]
Firm-CountyFE$_{i,j}$	Yes	Yes	Yes	Yes	Yes	Yes
R^2 Within	0.042	0.083	0.083	0.016	0.060	0.016
N	796	796	796	796	796	796
Public Firm-County-Years	444	444	444	444	444	444
Private Firm-County-Years	352	352	352	352	352	352
Effect of $PostBoom_{j,t}$ on Private Firms						
$\beta_2 + \beta_3 =$			0.017			-0.057
			[0.32]			[-0.14]

Table 6 continued
Panel B: Shale-based Natural Experiment, Controlling for Size

$$Investment_{i,j,t} = \alpha + \beta_1 NG_t + \beta_2 PostBoom_{j,t} + \beta_3 Size_{i,t} + \beta_4 PostBoom_{j,t} * Private_i$$
$$+ \beta_5 PostBoom_{j,t} * Size_{i,t} + \beta_6 NG_t * Private_i + \beta_7 Private_i + FirmCountyFE_{i,j} + \varepsilon_{i,j,t}$$

	Investment = Log New Wells			Investment = Number of New Wells		
	(1)	(2)	(3)	(4)	(5)	(6)
(β_1) NG_t	0.157***	0.154***	0.161**	1.496**	1.475**	2.135*
	[3.38]	[3.43]	[2.23]	[2.48]	[2.50]	[1.98]
(β_2) $PostBoom_{j,t}$	0.181	0.366*	0.371*	3.525**	4.576	5.031*
	[1.56]	[1.83]	[1.81]	[2.24]	[1.60]	[1.67]
(β_3) $Size_{i,t}$	0.114**	0.121**	0.123**	0.789	0.824	1.005*
	[2.50]	[2.60]	[2.54]	[1.63]	[1.62]	[1.87]
(β_4) $PostBoom_{j,t}$ * $Private_i$	-0.222**	-0.303**	-0.305**	-3.978**	-4.438**	-4.641**
	[-2.16]	[-2.41]	[-2.41]	[-2.53]	[-2.56]	[-2.61]
(β_5) $PostBoom_{j,t}$ * $Size_{i,t}$		-0.032	-0.033		-0.180	-0.262
		[-0.91]	[-0.91]		[-0.34]	[-0.47]
(β_6) NG_t * $Private_i$			-0.015			-1.398
			[-0.21]			[-1.24]
$Firm\text{-}CountyFE_{i,j}$	Yes	Yes	Yes	Yes	Yes	Yes
R^2 Within	0.094	0.096	0.096	0.063	0.063	0.067
N	796	796	796	796	796	796
Public Firm-County-Years	444	444	444	444	444	444
Private Firm-County-Years	352	352	352	352	352	352
Effect of $PostBoom_{j,t}$ on Private Firms						
$\beta_2 + \beta_4 =$	-0.041	0.063	0.066	-0.454	0.138	0.391
	[-0.70]	[0.58]	[0.59]	[-0.96]	[0.08]	[0.23]

Table 7: Falsification Test for Natural Experiment

This table reports falsification regressions of the prior county level firm investment regressions. The dependent variable is the logarithm of wells or number of wells drilled by firm (i) in county (j) at time (t). The falsification tests in this table are based on moving a boom in a given county three years forward to create a $FalseBoom_{j,t}$ variable. Firm level investments in a given county are aggregated into two separate time periods, one for the average number of wells three years prior to a fake boom and one for the average number of wells three years after a fake boom. In order to be in our sample, a firm is required to have drilling activity in both the time period before and after the fake boom. The resulting dataset has two time periods for a firm active in a given boom county, one for the time period before the boom and one for the time period after a boom. The price of natural gas is the average wellhead price over the three year period being aggregated. All regressions include firm-county fixed effects (fixed effect for each firm in each county). Standard errors are clustered by county, with t-statistics reported in brackets below the coefficient estimates, where * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level. Note: The coefficient for $Private_i$ is not reported because it is not identified with $FirmType\text{-}County_{i,j}$ fixed effects.

$$Investment_{i,j,t} = \alpha + \beta_1 NG_t + \beta_2 FalseBoom_{j,t} + \beta_3 Private_i + \beta_4 Log\ Capital\ Stock_{i,t} + \beta_5 FalseBoom_{j,t} * Private_i + \beta_6 FalseBoom_{j,t} * Log\ Capital\ Stock_{i,t} + \beta_7 NG_t * Private_i + FirmCountyFE_{i,j} + \varepsilon_{i,j,t}$$

	Investment = Log New Wells			Investment = Number of New Wells		
	(1)	(2)	(3)	(4)	(5)	(6)
NG_t	0.111***	0.086	0.080	0.950***	0.543	0.552
	[4.41]	[1.29]	[1.15]	[3.95]	[0.83]	[0.83]
$FalseBoom_{j,t}$		0.119	0.258		1.714	1.251
		[0.91]	[1.16]		[1.39]	[0.70]
Log Capital $Stock_{i,t}$			-0.077			-0.229
			[-1.50]			[-0.42]
$FalseBoom_{j,t}$ * $Private_i$		-0.002	-0.057		-0.965	-0.747
		[-0.01]	[-0.32]		[-0.77]	[-0.56]
$FalseBoom_{j,t}$ * Log Capital $Stock_{i,t}$			-0.016			0.101
			[-0.58]			[0.43]
NG_t * $Private_i$		-0.060	-0.048		-0.329	-0.313
		[-0.79]	[-0.61]		[-0.49]	[-0.48]
Firm-$CountyFE_{i,j}$	Yes	Yes	Yes	Yes	Yes	Yes
R^2 Within	0.073	0.083	0.093	0.058	0.075	0.076
N	906	906	906	906	906	906
Public Firm-County-Years	472	472	472	472	472	472
Private Firm-County-Years	434	434	434	434	434	434

Appendix A: Well Cost Comparison Large Firms vs. Small Firms

This table reports the median drilling cost per well for publicly traded firms within the industry code SIC 1311 (Crude Petroleum and Natural Gas) that are also in the drilling data sample. Firms are divided into two groups: 1) Large firms, defined as firms with total assets above the median asset size in a given year and 2) Small firms, defined as firms with total assets below the median asset size in a given year. The well cost for a firm is based on capital expenditures divided by the total number of all wells drilled by that firm in a given year, which is hand collected from firms' 10-K.

	Large Natural Gas Producers (Above Median total assets)			Small Natural Gas Producers (Below Median total assets)			Difference (p-Values)	
Year	Obs	Median Well Cost ($ Millions)	Median Assets ($ Millions)	Obs	Median Well Cost ($ Millions)	Median Assets ($ Millions)	Well Cost (p-Value)	Assets (p-Value)
2006	19	2.3	4829.8	19	2.8	893.0	0.330	0.000
2007	22	2.8	5529.2	23	2.2	861.0	0.460	0.000
2008	22	3.1	6234.9	22	3.7	1055.0	0.370	0.000
2009	18	4.5	6994.4	19	4.3	1435.0	0.870	0.000

Appendix B: Correlation Computations Between Drilling Data-based Measures and Compustat Data-based Measures

This table reports correlations between accounting measures from Compustat with proxies for accounting measures derived from the drilling data. The correlations are computed on the sample of firms that have both Compustat accounting data and drilling data in a given year, and are classified as SIC 1311 (Crude Petroleum and Natural Gas). Additionally, we require that the firm drilling data for a given year must have 1) non-missing capital stock; 2) drilled at least one well in a year and 3) have capital stock greater than or equal to 10 wells. The Compustat investment measure used is Capital Expenditures (code: capx), while the capital stock measure used is Net Property, Plant, and Equipment (code: ppent). The drilling data capital stock measure is defined as the total number of wells completed in the previous x years for a given company, where x runs from one year to eight years. The drilling data investment measure is defined as the total number of wells drilled in a given year for a company.

Investment Measure Correlation

	Drilling Data: Number of Wells Drilled
Compustat Accounting Measure: Capital Expenditures	71%

Capital Stock Measure Correlation

	Drilling Data: Time Period Used for Capital Stock Calculation (Number of wells drilled in past "x" years)							
	1	2	3	4	5	6	7	8
Compustat Accounting Measure: Net Property, Plant, and Equipment	63%	71%	72%	72%	73%	73%	75%	75%