Do Firms Engage in Risk-Shifting? Empirical Evidence*

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Abstract

I empirically test whether firms engage in risk-shifting. Contrary to what risk-shifting theory predicts, I find that firms reduce investment risk when they approach distress. To identify the effect of distress on risk-taking, I use a natural experiment with exogenous changes to leverage. Risk reduction is most prevalent among firms that have shorter maturity debt and bank debt. I also find that risk reduction occurs in firms with tighter bank loan financial covenants. These findings suggest that debt composition and financial covenants serve as important mechanisms to mitigate debt-equity agency conflicts, such as risk-shifting, that are not explicitly contracted on.

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1 Introduction

How does corporate investment risk taking change when a firm has high leverage or approaches distress? In high leverage states of the world equity holders benefit from successful outcomes of high risk projects, while losses from unsuccessful outcomes are borne by debtholders. This asymmetry between who receives the gains and losses from a project could make it optimal for equity holders to maximize the amount of risk a firm undertakes when leverage is high. This hypothesized increased risk taking in a firm's investments, referred to as risk-shifting or asset substitution, could result in an overall cost to the firm (Jensen and Meckling (1976)).

Concerns about the size, prevalence, and mitigation of these costs have been the focus of substantial theoretical work.[1] However, there is little empirical evidence on the size or pervasiveness of changes in investment risk taking when leverage is high or when a firm is in financial distress. The empirical challenges are two-fold. First obtaining a measure of the riskiness of a firm's overall capital expenditures is challenging in most settings. Second, distress and high leverage are not randomly assigned to firms. To the extent a corporate investment plan and high leverage/distress are jointly determined, or are caused by an omitted variable, obtaining clean identification of the effect of distress or leverage on risk taking is problematic. The contribution of this paper is to provide empirical advancements on both these fronts. First, I focus on a setting where a firm's investment risk taking is clearly defined by measures of investment risk from SEC disclosures. Second, I use quasi-random shocks to leverage to identify the effect of an increase in leverage and distress on investment risk taking.

I use a setting in which investments can be categorized into two different types of activities, one that is high risk and one that is low risk. To do this, I focus on the oil and gas industry, where exploratory projects (high risk) are nearly six times more likely to result in an unproductive project than development projects (low risk).[2] Moreover, these categories

[1] Existing theoretical work related to the size and mitigation of risk-shifting includes: Smith and Warner (1979) (covenants), Green (1984) (convertible debt), Barnea et al. (1980) (debt maturity), John and John (1993) (managerial compensation).

[2] The firms in my sample drilled a total of 12,574 exploratory wells of which 3,326 were unsuccessful

have clear definitions outlined by the Financial Accounting Standards Board (FASB) and are disclosed in SEC filings, so there is a standardization in these measures across firms and over time, which is typically unavailable in other settings. I construct a dataset from hand collected data on investment risks from the 10-Ks of 184 firms in the oil and gas industry. Using these risk disclosures, I test how the proportion of high risk investment to total investment changes as leverage increases as well as when firms approach distress.

Contrary to what risk-shifting theory would predict, in firm-level panel regressions I find that high leverage reduces the riskiness of a firm's investments. A one standard deviation increase in leverage reduces the proportion of a firm's high risk investments to total investment by 8.5% relative to the mean level of firm risk taking. I also find that the proportion of high risk investment to total investment is reduced by 21.6% for firm-years in which leverage is in the top quartile of the sample. Furthermore, this risk-reducing behavior also occurs in the years prior to declaring bankruptcy.

One concern with firm-level panel regression results could be reverse causality. For example, it could be that a firm increases its leverage because it is planning to reduce its investment risk in the future. Specifically, a firm, or its lender, may feel more comfortable with higher leverage if the firm has less cash flow uncertainty from its future investments. Such an argument would suggest that firms are not reducing the riskiness of their investments because they have high leverage, but that they increase their leverage because they are planning to reduce investment risk in the future.

To address simultaneity and omitted variable endogeneity concerns and rule out other alternative explanations I use a natural experiment to test how risk taking changes with leverage during two significant commodity based negative leverage shocks in 1998 and 2008. I focus on firms with similar pre-event book leverage, but whose existing assets are differentially affected by the commodity price shocks due to different mixes of oil and gas assets. Despite similar pre-event book-leverage, the differential effect of the commodity price shocks result in

(26.4%), and drilled 88,277 development wells of which 3,809 were unsuccessful (4.3%). Additionally, in comparing reserve additions from discoveries relative to exploration capital expenditures, in 27% of all firm years, firms failed to add reserves through discoveries that exceeded their exploration spending.

the Merton (1974) distance to default (DD) default probability increasing from 0.03 to 0.44 for treatment firms, but only from 0.04 to 0.18 for control firms. I use oil and gas reserve changes due to commodity prices to isolate the component of the leverage changes which are due to exogenous commodity price shocks. I designate treatment firms as firms with shocked book leverage in the top quartile of all firms, control firms are firms matched on pre-event book leverage to the treatment firms. I show that treatment and control firms have a number of similar observable characteristics. Using a difference-in-differences approach, I find that treatment firms reduce investment risk taking relative to control firms.

Why might firms reduce risk-taking in distress? There are a number of risk mitigating incentives a firm may have, which outweigh risk-shifting incentives. For example, managers may have career reputation concerns which result in a reduction in investment risk taking (Hirshleifer and Thakor (1992)). Firms too, likely have incentives to ensure that they have a good reputation to ensure access to debt markets (Diamond (1989)), which can affect their ability to pursue future positive NPV projects (Almeida et al. (2011)). In the natural experiment setting, I find that risk reduction is most prevalent in firms with shorter maturity debt and bank debt. This suggests that debt composition is important for firm risk-taking in distress, and provides support for risk-reducing incentives and monitoring linked to banking relationships.

To further explore the role of banks in risk-reduction I assess the role of bank financial covenants. Banks in my sample do not place explicit covenants on exploration activity, however, financial covenants may allow the bank to exert some indirect control on firm risk-taking activity. To test for this, I hand collect covenant data from credit agreements of firms in my quasi-natural experiment. I find that risk reduction behavior is most prevalent among firms that have stricter financial covenants and more financial covenants prior to the shock. This result provides new empirical evidence that financial covenants may allow banks to exert indirect influence to reduce debt-equity agency conflicts that have not or cannot be explicitly contracted on, such as risk-shifting.

A key potential concern related to using commodity price shocks as part of an identification strategy is whether firms whose existing assets are adversely affected by a commodity price shock, may choose to undertake a different investment program for a reason other than the effect of the commodity price shock on leverage. To mitigate this concern I test whether there is a direct effect of changes in prior period reserves on firms' investment programs. Thereby measuring how changes in reserves due to commodity prices affects investment, but without conditioning on ex ante leverage as in the natural experiment. I find in both the full sample and a limited sample (excluding the years of the natural experiment) that prior period changes in existing reserves due to commodity prices does not affect a firm's mix of exploratory versus development drilling. This is consistent with the view that the new projects a firm undertakes is likely going to be based on where the best new opportunities are, versus where its existing assets are.

Testing risk-taking policies in sub-samples of firms (e.g. firms with shorter maturity debt or bank debt), also helps rule out alternative non-debt related interpretations. Specifically, an alternative interpretation linked to different investment opportunities or other differences would need to relate risk-taking not just to firms whose leverage was adversely affected by a commodity price shock, but relate risk-taking to firms that received these leverage shocks and also had short maturity debt or bank debt. This raises the bar for alternative interpretations of my results.

Existing empirical literature has studied the risk-shifting incentives of equity holders in a variety of ways. Initial work by Andrade and Kaplan (1998) studies 31 firms in financial distress and finds no evidence that distressed firms made large or unusually risky investments or acquisitions. Rauh (2009) studies how risk taking in pension funds change in relation to the financial condition of a firm. Consistent with the findings in this paper Rauh (2009) finds that risk taking in pension funds is reduced as the financial conditions of a firm deteriorate. Parrino and Weisbach (1999) utilize simulation and find that risk-shifting is not a primary driver of capital structure decisions. Gormley and Matsa (2011) find that firms respond to exogenous increases in liabilities by undertaking diversifying acquisitions. Furthermore, survey evidence from Graham and Harvey (2001) suggests that risk-shifting concerns are the least important factor for CFOs in determining the maturity of debt a firm issues as well as whether a firm issues convertible bonds. Gormley and Matsa (2014) show that managers have an incentive to "Play it safe" in order to avoid distress. In an experimental setting Hernandez et al. (2014) demonstrate that risk-shifting is mitigated when reputation and audience effects are present. Alternatively, Eisdorfer (2008) studies risk-shifting within the context of a real options framework, and finds that, consistent with risk-shifting theory, volatility increases investment by distressed firms.[3] However, to my knowledge, my study is the first to use exogenous variation in leverage and ex-ante investment risk measures from SEC disclosures to directly test whether firms engage in risk-shifting behavior.

Because direct measures of risk are difficult to obtain, prior literature has often used different proxies for firm risk taking activities. For example, standard deviation of changes in quarterly ROA and equity price volatility have been used in the past. I document that the standard deviation of changes in ROA and equity price volatility have a low, but positive correlation with my measure of investment risk, suggesting that existing proxies do not capture the investment risk captured by my measure. Additionally, these measures likely capture many effects other than just the operating policies and risk-taking decisions that are made by management. For example, product market competition, financial market volatility, changes in government regulatory regimes as well as other factors could be affecting these measures.

Research & Development (R&D) spending has also been used as a proxy for risk taking, however, due to the multi-year life cycle of typical R&D projects it is difficult to envision that an increase in R&D in a year of financial distress would result in an outcome the following year which could save the firm from further distress or bankruptcy. Alternatively, the primary project type for oil and gas companies, the drilling of a well, typically has a very short project length, ranging from a month to a few months depending on where the well is

[3] Additional work has focused on risk-shifting incentives of banks during the S&L crises and more recently in the sub-prime crisis (Landier et al. (2011)), however, the government role in financial institutions and the mortgage market makes it unclear whether these findings would be applicable to industrial firms (Almeida et al. (2011)).

being drilled. Thus, it is plausible that a successful major exploratory well could alter the fortunes of a company in a short period of time. There is a strong empirical relationship between exploration capital expenditures and reserve additions from discoveries in a given year.[4] This short project time-line also would suggest that if risk-shifting were to occur, it would be more likely to occur in this setting than in others. Furthermore, the higher than average capital intensity of this industry suggests that current period investment can have a large effect on the overall riskiness of the firm, whereas year to year changes in R&D may be less likely to influence the overall risk level of a firm.

This paper proceeds in the following order, Section 2 discusses motivation and related literature. Section 3 outlines the data that is used. Section 4 discusses identification and the empirical design. Section 5 reports the results of the empirical tests, and Section 6 concludes.

2 Motivation and Related Literature

Why might risk-shifting not be observed in empirical tests? A potential explanation that prior theoretical literature has focused on is the reliance of the Jensen and Meckling (1976) risk-shifting result on a single period framework; in other words, agents make decisions as if there is no tomorrow. Jensen and Meckling (1976) directly acknowledge that when their framework is applied to a multi-period setting different outcomes may occur:

> "*It seems clear for instance that the expectation of future sales of outside equity and debt will change the costs and benefits facing the manager in making decisions which benefit himself at the (short-run) expense of the current bondholders and stockholders. If he develops a reputation for such dealings he can expect this to unfavorably influence the terms at which he can obtain future capital from outside sources. This will tend to increase the benefits associated with "sainthood" and will tend to reduce the size of the agency costs.* "
>
> - Jensen and Meckling (1976)

[4] Evidence documenting this relationship is in Appendix A.

Existing theoretical literature using multi-period settings has suggested several possible explanations for why a firm may choose to not undertake risk-shifting. Diamond (1989) suggests that firms may avoid risk-shifting due to borrower reputational concerns, while Hirshleifer and Thakor (1992) suggest that manager reputational concerns leads managers to reduce risky investment. Almeida et al. (2011), suggest that concerns for the ability to fund future projects may cause firms to reduce risk, so that positive NPV projects can be funded in the future.

Covenants on loans and bonds may also play an important role in a firm's investment policies. While the clear accounting based definitions of investment risk used in this study enable tests on risk-shifting, they also would enable a financial covenant to be designed to limit the amount of capital being invested in high risk projects. However, in this setting, as with pension funds in Rauh (2009), I do not find any limitations on risk taking for investments in loan or bond covenants. However, this does not rule out the possibility of financial covenants indirectly effecting a firm's risk taking. I test explicitly whether financial covenants are an important mechanism by which banks mitigate risk-shifting and other debt-equity agency conflicts that are not explicitly contracted on.

3 Data Industry Background

I use hand collected data on investment risk from the 10-K disclosures of all publicly traded U.S. domiciled oil and gas firms (SIC 1311 Crude Oil & Natural Gas) from 1997 to 2010 for this study. The resulting data set is composed of 184 firms and 1,208 firm years. Standard accounting variables were obtained from Compustat, while the detailed hand collected 10-K data was used to develop investment risk measures.

3.1 Investment Risk Variable Definition

Each firm in the study provides disclosures for the "Costs Incurred in Natural Gas and Oil Exploration and Development, Acquisitions and Divestitures." These disclosures provide information on expenditures for high risk (exploratory) capital and low risk (development) capital. The Financial Accounting Standards Board (FASB) provides clear guidance for the definitions of exploratory and development activities which I outline below:

Exploratory well - An exploratory well is a well drilled to find a new field **or** to find a new reservoir in a field previously found to be productive of oil or gas in another reservoir.

Development well - A development well is a well drilled within the proved area of an oil or gas reservoir to the depth of a stratigraphic horizon known to be productive.

I categorize all activities associated with exploratory drilling as high risk, this includes both the capital to drill and the capital to acquire the unproved acreage to drill. All activities associated with development drilling, which include the drilling of development wells and the acquisition of proved/producing acreage for development drilling, I classify as low risk. Moreover, the total capital across all these categories is comparable to the figure reported in Compustat, although there are some slight differences due to the expensing of some types of capital expenditures for oil and gas companies. The unit of observation used in this study is firm-year, firm i in year t, so my primary measure of risk is calculated as the proportion of high risk projects to total costs incurred as shown below:

$$HighRiskCapex_{i,t} = ExploratoryDrilling_{i,t} + AcquisitionOfUnprovedAcreage_{i,t}$$

$$LowRiskCapex_{i,t} = DevelopmentDrilling_{i,t} + AcquisitionoOfProvedAcreage_{i,t}$$

$$RiskRatio_{i,t} = \frac{HighRiskCapex_{i,t}}{HighRiskCapex_{i,t} + LowRiskCapex_{i,t}}$$

The difference in risk between high risk and low risk activities is also documented in the success rate of each activity type. In additional disclosures, firms disclose the number of successful wells and number of unsuccessful wells for both exploratory and development wells. The firms in my sample drilled a total of 12,574 exploratory wells of which 3,326 were unsuccessful (26.4%), and drilled 88,277 development wells of which 3,809 were unsuccessful (4.3%). Thus on average an exploratory well was nearly six times more likely to be unsuccessful than a development well.

In order to assess how exploratory capital expenditures affect a firm's reserve additions (e.g. project profitability), I plot the distribution of reserve additions divided by exploratory capital expenditures. A ratio above one indicates that a firm added more proved reserves from discoveries than it spent on exploration. As can be seen in Figure 1, there is significant variability in the payoff of exploratory drilling in a given year. For example, in 27% of firm years, companies do not recover drilling costs. Alternatively, in 13% of firm years, companies gain 10x their investment in exploratory wells in the form of proved reserves.

3.2 Leverage and Distress Definitions

Existing literature has used different definitions of leverage. In this study I use a market and book based definition of leverage from Welch (2004). The book leverage and market leverage definitions are outlined below:

$$MarketLeverage_{i,t} = \frac{D_{i,t}}{E_{i,t} + D_{i,t}}$$

$$BookLeverage_{i,t} = \frac{L_{i,t}}{A_{i,t}}$$

Where $E_{i,t}$ is the equity market capitalization for firm i in year t, and $D_{i,t}$ is the book value of total debt for firm i in year t. Similarly, $L_{i,t}$ is the total liabilities for firm i in year t, and $A_{i,t}$ is the book value of assets for firm i in year t. While the market leverage of a firm is bounded between 0 and 1 by construction, a firm could have a book leverage of greater than 1 if its liabilities exceed its assets. To ensure that coefficients retain an economically meaningful interpretation and minimize the amount of data that is excluded from the study I winsorize any values of book leverage greater than 1 to 1. Additionally, in all of my tests I use dummy variables for different leverage levels based on market leverage quartiles for the sample, this enables the measurement of any non-linear effects of leverage on investment risk taking. Several other controls are included in the main regressions, these include log of assets, market to book, and profitability.

I follow the method of Bharath and Shumway (2008) in calculating the Merton (1974) distance to default (DD) model probability of default. The Merton DD model uses an option framework to calculate the probability of default. It does so by viewing the equity as a call option on the value of a firm, and using the strike price for the option as the value of a firm's debt. By using the equity and debt values of the firm and the volatility of a firm's equity, the overall value of the firm and volatility of firm value can be calculated, using the iterative procedure outlined in Bharath and Shumway (2008). The model provides a z-score which can be used to calculate a probability of default based on the normal cumulative density function.

3.3 Summary Statistics

Table 1 reports summary statistics for the firm-years of the sample used in this study. The key dependent variable of interest is the risk ratio (previously defined), the higher the risk ratio the more risky a firm's capital investment is in a given year. Across all firm-years the average value for the risk ratio is 32%, which can be interpreted as a firm spending 32% of its capital expenditures on high risk projects. The average market leverage for firm-years in the sample is 0.28, while the average book leverage is 0.52. The average Merton DD default probability is 0.08.

Panel B of Table 1 reports the correlation of the risk ratio constructed for this study with other proxies that other studies have used for risk taking. The correlation with my risk measure is low but positive. This suggests that the investment risk measure I use from SEC disclosures captures important risk taking activity not captured by the other measures.

4 Identification and Empirical Design

4.1 Firm-Level Panel Regressions

The first set of firm level panel regressions estimated in this study are designed to test whether there is a correlation between different measures of leverage and distress with the risk ratio (investment risk) of a firm. By including a number of controls, I can rule out some potential explanations. The main firm-level panel regressions estimated in this study are of a form similar to what is outlined below:

$$RiskRatio_{i,t} = \alpha + \beta_1 Leverage_{i,t-1} + Controls_{i,t-1} + FirmFE_i + YearFE_t + \varepsilon_{i,i}$$

$$RiskRatio_{i,t} = \alpha + \beta_1 Distress_{i,t-1} + Controls_{i,t-1} + FirmFE_i + YearFE_t + \varepsilon_{i,i}$$

The primary definitions of leverage used are the market leverage and book leverage variables defined in the data section. The main measure of distress used is Merton DD default probability, which takes a value between 0 and 1. Additionally, leverage dummy variables are used to allow for non-linearity in the relationship between leverage and investment risk. The timing convention of this specification tests the effect of the beginning of year leverage or distress (leverage and distress is measured at the end of year $t-1$) on the investment risks taken in year t. For example, the impact of December 31, 2009 leverage is being measured on the investment risks taken during the year in 2010. Thus, all leverage measures, distress measures, and controls are measured prior to when investment dollars are spent.

The $Controls_{i,t-1}$ are comprised of size, profitability, and market to book. Size is proxied by the log of assets at time $t-1$, while profitability is measured as operating income before depreciation divided by assets at time $t-1$. Market to book is included as a proxy for investment opportunities, this is measured as the market value of assets divided by book value of assets at time $t-1$. As with the leverage variable, by using time $t-1$ for the control variables, the impact of variables measured at year-end are being compared to investment risks taken in the following year. For example, the influence of profitability during 2009 or market to book at December 31, 2009 is compared to investment risks in 2010.

Additional controls for firm fixed effects $FirmFE_{i,t}$ and time fixed effects $TimeFE_{i,t}$ are included. The inclusion of firm fixed effects controls for any time invariant heterogeneity (for example time invariant lending relationships, CEO characteristics etc.). Time fixed effects are included to control for any time period specific shocks, this is particularly important given that the firms in the sample all produce commodities. By including time fixed effects in the specification changes in investment opportunities due to changes in commodity prices are controlled for, to the extent these shocks affect all firms the same.

4.2 Natural Experiment: Commodity Based Leverage Shocks

While the firm-level regressions outlined above could allow me to establish a basic relationship between leverage and investment risk, with some observables and time invariant heterogeneity controlled for, better inference can be achieved by using a natural experiment framework. The natural experiment I use is two commodity driven leverage shocks. The commodity shocks I use in 1998 and 2008 were driven by unexpected economic collapses, which make them an attractive setting for a natural experiment. Specifically, the price collapse in 1998 was due to the Russian default and Asian financial crisis, these events were not anticipated. In January 1998 futures contracts indicated natural gas prices of $2.46/mmbtu and oil prices of $18.56/barrel for December 1998, while actual realized prices were $1.95/mmbtu and $11.35/barrel respectively. The price collapse in 2008 was due to the financial crisis in the fall of 2008, and also was not anticipated. In January 2008 futures contracts indicated natural gas prices of $9.00/mmbtu and oil prices of $94.05/barrel for December 2008, while actual realized prices were $5.94/mmbtu and $41.12/barrel respectively.

Commodity prices are exogenous, as no single firm can control prices for oil or natural gas. The price collapses experienced by commodities in 1998 and 2008 influenced the leverage levels of firms differently based on 1) the amount of leverage a firm had prior to the shock and 2) the precise exposure a firm's existing assets had to the commodity shock based on its mix of oil and natural gas reserves.

The initial difference-in-differences framework can be thought of as 1) the difference between pre-shock and post-shock behavior 2) the difference in behavior of firms more affected by the shock (treatment) and firms less affected by the shock (control). As mentioned above whether a firm is considered treatment or control is a function of commodity prices on its leverage via the revaluation of its existing assets. Book leverage prior to the shock, can be calculated directly from Compustat data. To calculate the effect of the commodity price shock on a firm's leverage I can take advantage of additional unique disclosures in the oil and natural gas industry. Specifically, in every 10-K a firm has to report the different components of changes to the dollar value of its reserves (acquisitions, discoveries, commodity prices etc.), with this data I can isolate the precise effect of commodity prices on a firm's reserves, distinct from any management action to alter or improve dollar reserves. This enables me to calculate what a firm's book leverage would be if the only event that occurred was the commodity shock, the calculation is as follows:

$$BookLev\tilde{e}rage_{i,Post} = \frac{TotalLiabilities_{i,Pre}}{TotalAssets_{i,Pre} + \$ChangeReservesPrices_{i,Post}}$$

For example, in the case of the shock that occurred in 2008, the total liabilities as of December 31, 2007 are used in conjunction with the change in reserves due to commodity prices during 2008 to calculate leverage as of December 31, 2008. The firms in the top quartile of leverage using the above calculation are used as treatment firms, while the control firms are obtained by matching on December 31, 2007 book leverage. To mitigate any issues with concurrent changes in investment policies, I exclude the year of a shock. So in the case of 2008, I compare investment risks taken in 2007 to investment risks taken in 2009. For the natural experiment

I focus on book leverage as this is what is most closely related to the reserve changes a firm has on its balance sheet.

I use a regression form of difference-in-differences to test the effect of leverage on investment risk in a natural experiment framework. The specific regression I estimate is below:

$$RiskRatio_{i,t} = \alpha + \beta_1 Treatment_{i,t} + \beta_2 Post_{i,t} + \beta_3 Treatment_{i,t} * Post_{i,t}$$

$$+Controls_{i,t-1} + FirmFE_i + YearFE_t + \varepsilon_{i,i}$$

Where the $Treatment_{i,t}$ is a 0 or 1 dummy variable constructed from the reserve based book leverage calculation outlined above and $Controls_{i,t-1}$ are similar to the panel regression. The key coefficient of interest in this specification is β_3, which measures how the treatment group is differentially affected by the shock. For example, if firms whose leverage is more affected by a commodity shock reduce investment risk after the shock, then β_3 would be negative.

5 Results

5.1 Firm Level Panel Regressions

Table 2 reports results from firm-level panel regressions of different measures of investment risk on measures of leverage and distress. Every measure of leverage and distress has a negative and statistically significant effect on the investment risk taken by a firm. The coefficient on market leverage in specification (1) can be interpreted as a one standard deviation increase in leverage reducing the investment risk ratio by 8.5% relative to the mean firm-year investment risk ratio. Alternatively specification (5) can be interpreted as a firm reducing its risk taking by 21.6% relative to the mean firm-year, when it is in the top quartile of sample leverage. The coefficient on the Merton DD default probability can be interpreted as a one standard deviation increase in default probability reducing a firm's risk-taking by

6.8% relative to the mean firm-year investment risk-ratio.

A concern in the interpretation of the firm-level regression results reported in Table 2 is how reverse causality might explain the observed coefficient estimates. It could be the case that firms are increasing leverage because they are planning to reduce investment risk, and are more comfortable with a higher debt load as they reduce their investment risk. One test of the plausibility of the reverse causality argument is in Table 3, which reports how firms change their risk taking prior to bankruptcy. There are only 16 bankruptcies in the sample, yet the reduction in risk in the years prior to bankruptcy is large enough that there is statistical power even for this small number of observations. The economic interpretation of the coefficient in specification (1) is that in the year prior to bankruptcy firms reduce investment risk taking 23.8% relative to the investment risk taking of the mean firm. A result inconsistent with the reverse causality explanation above, as firms that are in distress and about to declare bankruptcy are less likely to be increasing their leverage deliberately.

5.2 Natural Experiment

A key assumption when using a natural experiment framework is the conditionally random assignment of treatment. Treatment in the setting of my natural experiment is based on the effect of a change in existing assets caused by commodity price shocks on leverage. Because leverage is a firm decision, pre-shock differences in leverage may be a cause for concern regarding the conditionally random assignment assumption. As Table 4 Panel A shows, there are economically significant and statistically significant differences in leverage between all firms and the treatment firms. This is not surprising given that pre-existing book leverage affects a firm's probability of being treated. Interestingly, treatment firms are very similar across other observable dimensions, when compared to the other firms in the sample.

To mitigate concerns regarding pre-shock differences in leverage I undertake two matching procedures in Panel B and Panel C. Specifically I match firms on pre-shock book leverage (book leverage as of Dec 31, 1997 or Dec 31, 2007), both with replacement (Panel B) and without replacement (Panel C). In both panels the matching procedure results in firms with similar pre-shock book leverage. Additionally, with the exception of log assets in Panel C, firms in the treatment and control groups match well across market to book, profitability, and market leverage. I hand collect information on executive compensation to calculate CEO delta and vega for the matched samples.[5] I also calculate the percentage of production hedged across treatment and control groups. As Table 4 shows, firms are ex ante similar across these risk and incentive measures.

Table 5 reports the effect of the commodity price shock on treatment and control firms. Specifically, the shocked book leverage reported is based on the book leverage prior to the shock (book leverage as of Dec 31, 1997 or Dec 31, 2007), adjusted only for the effect of the change in commodity prices on a firm's existing assets. This variable is unaffected by any management actions that occur during the period of the negative commodity price shock. Because shocked book leverage is the variable that determines treatment, it is not surprising to see large economically significant and statistically significant differences between the treatment firms and other firms. Additionally, there are also economically significant and statistically significant differences between treatment firms and control firms in Merton DD default probability and market leverage. Panel B and Panel C of Table 5 indicate that despite treatment and control firms having similar observable characteristics and similar pre-shock book leverage, the effect of the negative commodity shock on treatment firms, results in treatment firms being closer to distress than control firms. In essence, this framework relies on negative commodity shocks having quasi-random effects on firms with similar characteristics. Given that the differential effect of commodity price shocks on oil versus gas was unpredictable, this framework yields quasi-random assignment of treatment and control.

Table 6 reports the results of a regression form of difference-in-differences. This specification uses exogenous variation in leverage caused by negative commodity shocks in 1998 and 2008 to identify the influence of leverage on investment risk taking. The key coefficient of

[5]The method used to calculate delta and vega is the same as Coles et al. (2006). Delta is the dollar change in an executive's wealth for a 1% change in stock price. Vega is the dollar change in an executive's wealth for a 0.01 change in standard deviation of returns.

interest is the coefficient for the interaction term $Treatment_{i,t} * Post_t$ which measures how firms with leverage that is more affected by the commodity shock change their investment risk relative to firms less affected by the commodity shock. This coefficient in specification (1) is negative and statistically significant across all specifications, and matching group methodologies. The economic interpretation of the interaction coefficient in (2) is that treatment firms reduce risk taking by 75.3% relative to the mean firm risk level in response to the leverage shock relative to the investment risk taking of control firms.[6] The control variables used in Table 6 are based on t-1 variables, or variables prior to the commodity price shock, as many of the controls themselves are affected by the commodity price shock they could be considered bad controls. Specifically, investment risk taking in 2007 uses control variables from 2006, while investment risk taking in 2009 uses year end 2007 (pre-shock) control variables, as these are unaffected by the shock. The results in Table 6 further mitigate some of the reverse-causality and omitted variable endogeneity concerns in the panel regressions, as the leverage changes in the natural experiment are driven by the effect of commodity prices on a firm's existing assets, which is outside of a firm's control.

5.3 Natural Experiment: Potential Explanations

A number of risk mitigation incentives may exist, which could relate to possible explanations of the results that are observed. To evaluate potential drivers of risk-reducing behavior, I undertake several tests across different sub-samples in the natural experiment. It should be noted that these sub-samples are not randomly assigned. However, analysis of these sub-samples may help provide some support for potential channels that could be affecting risk-taking.

Debt maturity may mitigate risk-shifting incentives (Barnea et al. (1980)). To assess support for this, I subdivide my sample into firms that have above median debt maturity and below median debt maturity. As can be seen in Table 7, firms with below median debt

[6] Though the exploration and development allocations are different, both treatment and control firms have similar total investment levels in the post period

maturity reduce risk-taking. This result suggests that debt composition is an important input in risk-taking decisions of firms close to distress.

Whether a firm has bank debt or not, could also be important. For example, banks may monitor debt-holders more relative to other lenders. Additionally, borrowers may be particularly concerned with their reputation with a given bank, particularly if they are locked in to a banking relationship and have limited other debt financing options (Rajan (1992) and Sharpe (1990)). I subdivide the sample based on firms that have high bank debt, relative to firms that have low bank debt. Table 8 reports these results, and shows that firms with above median bank debt reduce risk taking. This suggests that that borrower-bank relationships (Diamond (1989) and Almeida et al. (2011)) may be important for risk-taking during times of distress.

To understand particular mechanisms that may be important for bank debt and risk-shifting, I test whether bank financial covenants may have an indirect effect on risk-taking activity. While banks do not explicitly contract on exploration activities, they typically have financial covenants that firms must comply with. To test whether these financial covenants are an important mechanism for mitigating risk-shifting, I subdivide my sample firms into sub-samples based on how strict financial covenants for a firm is ex-ante. As Table 9 documents, firms that have tighter covenants prior to the shock ((2) and (4)) and more covenants prior to the shock ((6) and (8)) reduce risk-taking.[7] This result provides evidence that financial covenants may indirectly mitigate a number of debt-equity agency conflicts that are not explicitly contracted on.

5.4 Internal Validity

An important assumption when using a difference-in-differences approach in a natural experiment framework is the parallel trends assumption. That is, in the absence of treatment,

[7] Covenant strictness is calculated using the method of Ertan et al. (2013), and is based on the financial covenant that a firm is closest to violating, given the historical volatility of the financial ratio or figure used for the covenant. This measure satisfies the requirements laid out by Murfin (2012) for measuring covenant strictness. Covenant information was hand collected and calculated from firm 10-Ks and credit agreements.

would the treatment and control groups have behaved similarly. Table 4 provides evidence that the treatment and control groups used are similar across a number of observable dimensions, however, Table 10 takes an additional step in testing whether the treatment and control groups behave similarly in time periods that did not experience negative leverage shocks. In Table 10 I create placebo events in 2001 (three years after 1998) and in 2005 (three years before 2008), to see whether treatment and control firms behave similarly in these other time periods. I find that the interaction coefficient $Treatment_{i,t} * PlaceboPost_t$ is not statistically significant in any of the specifications. This suggests that in other time periods the investment risk trends across these firms was similar or "parallel."

One concern with using a difference-in-differences framework in a natural experiment setting is that many factors that influence investment decisions, in addition to leverage, could be changing. In particular if changes in the value of a firm's existing assets has an impact on its risk taking for a reason other than changes to leverage (e.g. worse investment opportunities), it could be a concern for my identification. To test whether this is the case I report results in Table 11 which measure the effect of prior period changes in reserves due to commodity prices on investment risk taking. The coefficients for this variable are not statistically significant and are close to zero, suggesting that prior period changes in commodity prices are not of first order concern in making decisions regarding investment risk taking. I report results for both the full sample as well as for the sub-sample where the years used in the natural experiment are excluded.

The specifications I report in Table 7 and Table 8 also support the internal validity of my empirical tests. Specifically, for an alternative non-distress related explanation to be consistent with my results, it would not only need to relate to risk taking and firms that had large commodity based leverage shocks, but also to risk taking and firms that had shorter term maturity or more bank debt and large commodity based leverage shocks. This raises the bar significantly for alternative explanations.

6 Conclusion

Whether firms engage in risk-shifting has been an open empirical question. Lack of data and adequate measures of risk, and the endogeneity of leverage and risk taking have meant this question has not been able to be addressed directly. I use a setting which has quasi-random shocks to leverage and objective measures of investment risk, from SEC disclosures, to test whether firms engage in risk-shifting. I find that firms reduce risk, rather than increase risk, when leverage is high and when they get close to distress.

Prior theoretical literature outlines several reasons for why firms may have incentives to reduce risk taking in distress. Firms likely have incentives to ensure that they have a good reputation to ensure access to debt markets (Diamond (1989)), which can affect their ability to pursue future positive NPV projects Almeida et al. (2011). I am able to highlight channels linked to debt maturity and borrower-bank relationships as being important for risk reduction in times of distress. I show that financial covenants are an important mechanism for mitigating risk-shifting, and that these covenants serve to mitigate debt-equity agency conflicts that may not be explicitly contracted on. The evidence in this paper suggests that risk-mitigation incentives and monitoring by banks outweigh risk-shifting incentives in investment decision making for the average firm.

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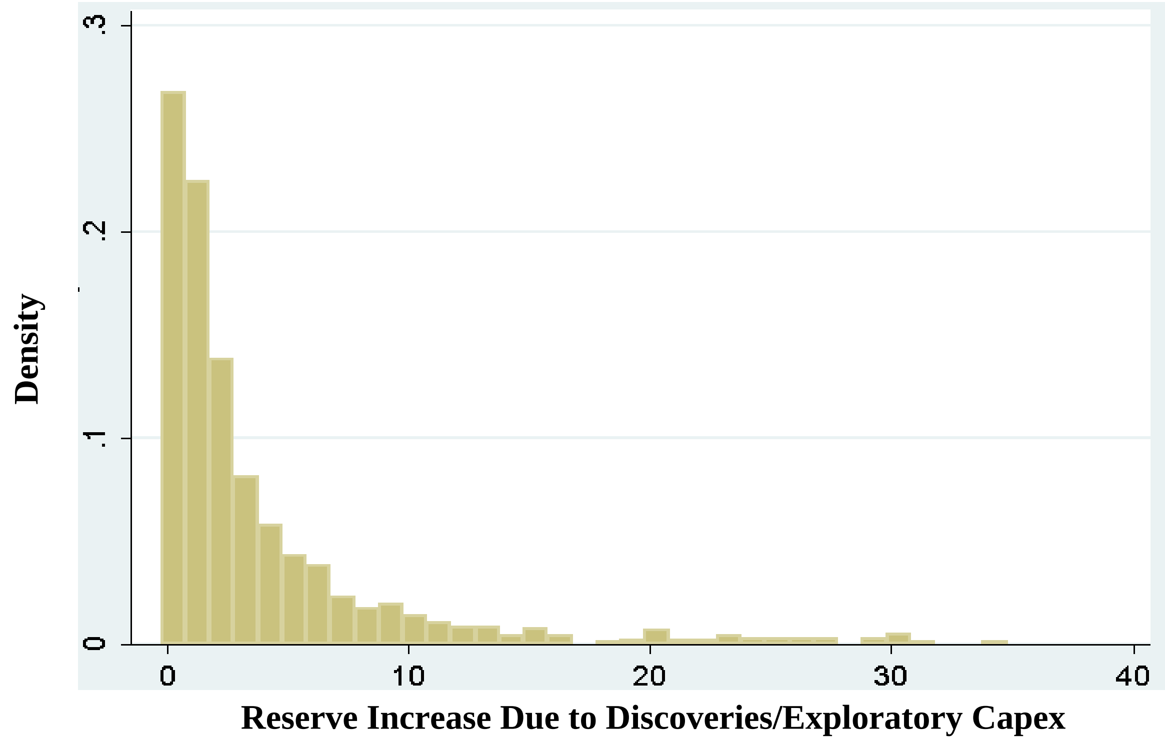

Figure 1: This figure plots the density function of proved reserve additions from discoveries, divided by Exploratory (High Risk Capex). The figure shows the distribution of potential payoffs from exploratory capital expenditures for firms in the sample years. A number of 10 on the horizontal access can be interpreted as $10 of proved reserves being added in a year in which $1 of Exploratory Capital Expenditures was made.

Table 1: Summary Statistics and Correlations

This table contains summary statistics for the variables used in the firm level panel regressions used in this study. The risk ratio is defined as the proportion of capital invested in high risk projects (exploratory activities) to total capital expenditures. Market leverage is defined as the market value of equity divided by the market value of equity plus the book value of debt (Welch 2004). Book leverage is defined as total liabilities divided by total assets. In order to be included in the sample a firm-year must 1) be in SIC 1311 (Crude Oil and Natural Gas) 2) be U.S. domiciled and file a 10-K. To mitigate outliers book leverage values are winsorized at 1, and profitability and market to book variables are winsorized at 1% and 99%. The distance to default is based on the Merton (1974) bond pricing model, as implemented by Bharath and Shumway (2008). Firm-year observations span from 1997 through 2010.

Panel A: Summary Statistics

	N	Mean	Std Dev	p25	p50	p75
Dependent Variable						
Risk Ratio	1208	0.32	0.26	0.12	0.26	0.46
Control Variables						
Market Leverage	1208	0.28	0.23	0.10	0.23	0.41
Book Leverage	1208	0.52	0.23	0.36	0.52	0.66
Size (Assets in $Millions)	1208	2,102.46	5,875.16	52.55	283.10	1,185.76
Profitability	1208	0.17	0.24	0.08	0.19	0.30
Market to Book	1208	1.49	1.07	0.93	1.22	1.68
Merton DD Default Probability	1073	0.08	0.21	0.000	0.000	0.008

Panel B: Correlations With Other Risk Proxies

	Risk Ratio	Std Dev of Quarterly Chg in ROA	Volatility of Monthly Equity Ret
Risk Ratio	1.00		
Std Dev of Quarterly Change in ROA	0.13	1.00	
Volatility of Monthly Equity Ret	0.10	0.24	1.00

Table 2: Investment Risk and Measures of Distress and Leverage - Panel Regression

This table reports firm-level regressions which document the effect of different leverage and financial distress measures on the riskiness of a firm's investments. The dependent variable in these regressions is the risk ratio for firm *i* in year *t*. A firm's risk ratio is calculated as the proportion of capital expenditures invested in high risk projects relative to all capital expenditures. All regressions include firm level fixed effects and time 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.

$$RiskRatio_{i,t} = \alpha + \beta_1 Distress_{i,t-1} + Controls_{i,t-1} + TimeFE_t + FirmFE_i + \varepsilon_{i,t}$$

$$RiskRatio_{i,t} = \alpha + \beta_1 LeverageD_{i,t-1} + Controls_{i,t-1} + TimeFE_t + FirmFE_i + \varepsilon_{i,t}$$

	Risk Ratio = High Risk Capex/Total Capex				
	(1)	(2)	(3)	(4)	(5)
Market Leverage$_{i,t-1}$	-0.118**				
	[-2.32]				
Book Leverage$_{i,t-1}$		-0.122***			
		[-2.65]			
Merton DD Default Probability$_{i,t-1}$			-0.103***		
			[-2.87]		
Q4 Mkt Lev Dummy$_{i,t-1}$				-0.045**	-0.069**
				[-2.26]	[-2.40]
Q3 Mkt Lev Dummy $_{i,t-1}$					-0.025
					[-1.06]
Q2 Mkt Lev Dummy$_{i,t-1}$					-0.025
					[-1.12]
Size$_{i,t-1}$	0.045**	0.042**	0.048**	0.041*	0.044**
	[2.10]	[2.03]	[2.06]	[1.96]	[2.15]
Market to Book$_{i,t-1}$	0.002	0.009	0.008	0.006	0.003
	[0.15]	[0.76]	[0.52]	[0.51]	[0.25]
Profitability$_{i,t-1}$	-0.120***	-0.119***	-0.149***	-0.115***	-0.118***
	[-3.11]	[-3.07]	[-2.99]	[-3.01]	[-3.08]
FirmFE$_i$	Yes	Yes	Yes	Yes	Yes
TimeFE$_t$	Yes	Yes	Yes	Yes	Yes
R^2	0.067	0.068	0.078	0.066	0.067
N	1208	1208	1073	1208	1208

Table 3: Investment Risk Prior to Bankruptcy (16 Bankruptcies in Sample)

This table reports firm-level regressions that document how investment risk changes for a firm in the years prior to bankruptcy. The dependent variable in these regressions is the risk ratio for firm i in year t. A firm's risk ratio is calculated as the proportion of capital expenditures spent on high risk projects relative to all capital expenditures. Dummy variables are inserted based on the number of years prior to bankruptcy, for example in the year immediately prior to declaring bankruptcy the variable "One Year Prior to Bankruptcy Dummy" is equal to 1, and equal to 0 for all other firm-years. All regressions include firm level fixed effects and time 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.

$$RiskRatio_{i,t} = \alpha + \beta_1 OneYearPriortoBankruptcyD_{i,t} + \beta_2 TwoYearsPriortoBankruptcyD_{i,t} + \beta_3 ThreeYearsPriortoBankruptcyD_{i,t} + Controls_{i,t-1} + TimeFE_t + FirmFE_i + \varepsilon_{i,t}$$

	Risk Ratio = High Risk Capex/Total Capex	
	(1)	(2)
One Year Prior to Bankruptcy $Dummy_{i,t}$	-0.076*	-0.118**
	[-1.92]	[-2.08]
Two Years Prior to Bankruptcy $Dummy_{i,t}$		-0.105
		[-1.51]
Three Years Prior to Bankruptcy $Dummy_{i,t}$		-0.034
		[-0.41]
$Size_{i,t-1}$	0.040*	0.042**
	[1.90]	[2.00]
Market to $Book_{i,t-1}$	0.010	0.010
	[0.82]	[0.81]
$Profitability_{i,t-1}$	-0.113***	-0.113***
	[-3.00]	[-2.99]
$FirmFE_i$	Yes	Yes
$TimeFE_t$	Yes	Yes
R^2	0.061	0.064
N	1208	1208

Table 4: Natural Experiment, Pre-Event: Treatment vs. Control Comparison

This table reports univariate t-tests which compare observable variables of the treatment and control groups used in the natural experiment in the pre-event year. The event years are linked to years in which negative commodity price shocks occur, in this case 1998 and 2008. The set of panels below compare pre-event characteristics of the firms used (characteristics as of year end 1997 and 2007). Panel A is comprised of all firms in the pre-event years, while Panels B and C rely on different matching methodologies. Panel B and C are based on obtaining matching firms based on pre-event book leverage. Panel B is comprised of control firms that are matched with replacement while Panel C is comprised of control firms which are matched without replacement. Delta is the dollar change in executive's wealth for a 1% change in stock price. Vega is the dollar change in the executive's wealth for a 0.01 change in standard deviation of returns. Hedge percentage is the percent of total production a firm has hedged. Differences in group means are reported along with p-values, * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Panel A: Full Sample

	Pre-Shock Comparison			
Total	All Firms	Treatment Firms	Difference	p value
Book Leverage	0.46	0.62	-0.16***	0.00
Log Assets	19.93	20.22	-0.29	0.48
Market to Book	1.58	1.61	-0.03	0.83
Profitability	0.14	0.15	-0.01	0.67
Market Leverage	0.22	0.30	-0.08**	0.04
Merton DD Default Probability	0.01	0.03	-0.02*	0.06
Number of Event Firms	105	36		

Table 4 Panel B: Matching Sample With Replacement

	Pre-Shock Comparison			
Total	Control Firms	Treatment Firms	Difference	p value
Book Leverage	0.60	0.62	-0.02	0.76
Log Assets	20.96	20.22	0.74	0.11
Market to Book	1.48	1.61	-0.13	0.57
Profitability	0.11	0.15	-0.04	0.11
Market Leverage	0.34	0.30	0.04	0.43
Merton DD Default Probability	0.04	0.03	0.01	0.52
Hedge Percentage	0.38	0.41	-0.03	0.71
Delta	612.06	1625.76	-1013.70	0.26
Vega	74.34	46.82	27.52	0.32
Number of Event Firms	36	36		
Number of Unique Event Firms	22	36		

Table 4 Panel C: Matching Sample Without Replacement

	Pre-Shock Comparison			
Total	Control Firms	Treatment Firms	Difference	p value
Book Leverage	0.56	0.62	-0.06	0.15
Log Assets	21.01	20.22	0.79*	0.08
Market to Book	1.48	1.61	-0.13	0.53
Profitability	0.13	0.15	-0.02	0.47
Market Leverage	0.28	0.30	-0.02	0.64
Merton DD Default Probability	0.01	0.03	-0.02	0.40
Hedge Percentage	0.39	0.41	-0.02	0.83
Delta	1078.52	1625.76	-547.24	0.57
Vega	48.62	46.82	1.80	0.95
Number of Firms	36	36		
Number of Unique Event Firms	36	36		

Table 5: Natural Experiment, Post-Event: Treatment vs. Control Comparison

This table reports univariate t-tests which compare observable variables of the treatment and control groups used in the natural experiment in the event year. The event years are linked to years in which negative commodity price shocks occur, in this case 1998 and 2008. The set of panels below compare event characteristics of the firms used (characteristics as of year end 1998 and 2008). The composition and matching procedures of Panel A, Panel B, and Panel C are the same as Table 4. Differences in group means are reported along with p-values, * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Panel A: Full Sample

	Post-Shock Comparison			
Total	All Firms	Treatment Firms	Difference	p value
Shocked Book Leverage	0.54	0.98	-0.44***	0.00
Merton DD Default Probability	0.24	0.44	-0.20***	0.00
Market to Leverage	0.40	0.54	-0.14***	0.01

Panel B: Matching Sample With Replacement

	Post-Shock Comparison			
Total	Control Firms	Treatment Firms	Difference	p value
Shocked Book Leverage	0.68	0.98	-0.30***	0.00
Merton DD Default Probability	0.18	0.44	-0.26***	0.00
Market to Leverage	0.37	0.54	-0.17***	0.00

Panel C: Matching Sample Without Replacement

	Post-Shock Comparison			
Total	Control Firms	Treatment Firms	Difference	p value
Shocked Book Leverage	0.62	0.98	-0.36***	0.00
Merton DD Default Probability	0.22	0.44	-0.22***	0.00
Market to Leverage	0.40	0.54	-0.14**	0.02

Table 6: Natural Experiment: Investment Risk and Leverage Shocks

(Pre-Shock vs Post-Shock, Treatment = High Leverage Shock Firms vs. Control = Low Leverage Shock Firms)

This table reports results from a regression form of difference-in-differences. The first difference is pre-shock vs. post-shock, while the second difference is high leverage shock vs. low leverage shock. The dependent variable in these regressions is the risk ratio of firm *i* at time *t*. Firms are divided into treatment and control groups based on the effect of the commodity shock on leverage. For the firms that have implied book leverage in the top quartile due to the commodity shock, the variable Treatment is equal to 1 and 0 otherwise. The two leverage shocks used in this regression are in 1998 and 2008, the years of the shocks are excluded from the sample, therefore the pre-post comparisons compare 1997 (post = 0) to 1999 (post = 1) and 2007 (post = 0) to 2009 (post = 1). (1) and (2) report regression estimates for the matched sample with replacement, (3) and (4) report estimates for the matched sample without replacement, (5) and (6) report estimates for all firms in the sample during the event years. Control variables have been previously defined, after the shock occurs these variables are fixed at their last pre-event values, as they are affected by the shock (for example the size control used for the 1999 post period is based on year end 1997 size). The dependent variable in these regressions is the risk ratio for firm *i* in year *t*. All regressions include firm-event fixed effects and time 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.

$$RiskRatio_{i,t} = \alpha + \beta_1 Post_{i,t} + \beta_2 Treatment_{i,t} + \beta_3 Treatment_{i,t} * Post_{i,t} + Controls_{i,t-1} + TimeFE_t + FirmFE_i + \varepsilon_{i,t}$$

	Differences-in-Differences					
	Matched With Replacement		Matched Without Replacement		All Firms	
	(1)	(2)	(3)	(4)	(5)	(6)
$Post_{i,t}$	Absorbed by $TimeFE_t$		Absorbed by $TimeFE_t$		Absorbed by $TimeFE_t$	
$Treatment_{i,t}$	Absorbed by $FirmEventFE_i$		Absorbed by $FirmEventFE_i$		Absorbed by $FirmEventFE_i$	
$Treatment_{i,t}$*$Post_{i,t}$	-0.241*	-0.237**	-0.172***	-0.186***	-0.094*	-0.112**
	[-1.83]	[-2.25]	[-2.93]	[-3.08]	[-1.95]	[-2.34]
$Size_{i,t-1}$		-0.035		0.054		0.089
		[-0.38]		[0.78]		[1.36]
$Profitability_{i,t-1}$		-1.498**		-0.688		-0.277
		[-2.04]		[-1.66]		[-0.80]
Market to $Book_{i,t-1}$		0.053		0.035		-0.002
		[0.64]		[0.53]		[-0.06]
$FirmEventFE_i$	Yes	Yes	Yes	Yes	Yes	Yes
$TimeFE_t$	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.188	0.320	0.119	0.187	0.031	0.061
N	144	144	144	144	282	282

Table 7: Natural Experiment: Debt Maturity and Risk Taking

(Pre-Shock vs Post-Shock, Treatment vs. Control, Short Maturity Debt vs. Long Maturity Debt)

This table reports results from a regression which alters the prior difference-in-differences regression (Table 6) to test for the effect of debt maturity on risk taking. The specifications subdivide the data by firms that have below median weighted average debt maturity, and above median weighted average maturity. The dependent variable in these regressions is the risk ratio of firm i at time t. These regressions are estimated on the matched sample, without replacement. All regressions include firm-event fixed effects, time fixed effects, and firm type-year 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.

	Short Mat = Yes	Short Mat = No	Short Mat = Yes	Short Mat = No
	(1)	(2)	(3)	(4)
$Post_{i,t}$	Absorbed by $TimeFE_t$		Absorbed by $TimeFE_t$	
$Treatment_{i,t}$	Absorbed by $FirmEventFE_i$		Absorbed by $FirmEventFE_i$	
$Treatment_{i,t}*Post_{i,t}$	-0.312***	-0.087	-0.325***	-0.112
	[-3.21]	[-1.03]	[-3.30]	[-1.49]
$Size_{i,t-1}$			-0.060	0.156*
			[-0.84]	[1.97]
$Profitability_{i,t-1}$			-0.849*	-1.511**
			[-1.89]	[-2.04]
$Market\ to\ Book_{i,t-1}$			-0.069	0.218***
			[-1.25]	[3.36]
$FirmEventFE_i$	Yes	Yes	Yes	Yes
$TimeFE_t$	Yes	Yes	Yes	Yes
R^2	0.289	0.035	0.396	0.432
N	72	72	72	72

Table 8: Natural Experiment: Bank Debt and Risk Taking

(Pre-Shock vs Post-Shock, Treatment vs. Control, High Bank Debt vs. Low Bank Debt)

This table reports results from a regression which alters the prior difference-in-differences regression (Table 6) to test for the effect of bank debt on risk taking. The specifications subdivide the data by firms that have below median bank debt, and above median bank debt. The dependent variable in these regressions is the risk ratio of firm i at time t. These regressions are estimated on the matched sample, without replacement. All regressions include firm-event fixed effects, time fixed effects, and firm type-year 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.

	Bank Debt = High	Bank Debt = Low	Bank Debt = High	Bank Debt = Low
	(1)	(2)	(3)	(4)
$Post_{i,t}$	Absorbed by $TimeFE_t$		Absorbed by $TimeFE_t$	
$Treatment_{i,t}$	Absorbed by $FirmEventFE_i$		Absorbed by $FirmEventFE_i$	
$Treatment_{i,t}$*$Post_{i,t}$	-0.265***	-0.122	-0.259***	-0.146*
	[-2.93]	[-1.44]	[-2.90]	[-1.96]
$Size_{i,t-1}$			-0.022	0.198***
			[-0.19]	[3.58]
$Profitability_{i,t-1}$			-0.931**	0.256
			[-2.28]	[0.47]
Market to $Book_{i,t-1}$			-0.014	0.175***
			[-0.23]	[3.24]
$FirmEventFE_i$	Yes	Yes	Yes	Yes
$TimeFE_t$	Yes	Yes	Yes	Yes
R^2	0.302	0.102	0.378	0.473
N	72	72	72	72

Table 9: Natural Experiment: Bank Loan Covenants and Risk-Taking

(Pre-Shock vs Post-Shock, Treatment vs. Control, Low Covenant Strictness vs. High Covenant Strictness)

This table reports results from a regression which alters the prior difference-in-differences regression (Table 6) to test for the effect of credit agreement financial covenants on risk taking. Specifications (1) through (4) subdivide the data by firms that have below median credit agreement covenant strictness and above median covenants strictness in the years prior to the leverage shocks (1997 and 2007). Covenant strictness is calculated using the method of Ertan, Karolyi, and Ostromogolsky (2013), and is based on the financial covenant that a firm is closest to violating, given the historical volatility of the financial ratio or figure used for the covenant. This measure satisfies the requirements laid out by Murfin (2012) for measuring covenant strictness. Covenant information was hand collected and calculated from firm 10-Ks and credit agreements. Specifications (5) through (8) proxy covenant strictness by the number of covenants. There are a number of firms that have median covenant strictness of 2, therefore the subsamples do not have an even number of firms. The dependent variable in these regressions is the risk ratio of firm i at time t. These regressions are estimated on the matched sample, without replacement. All regressions include firm-event fixed effects, time fixed effects, and firm type-year 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.

	Covenant Tightness				Covenant Count			
	Low Cov Tightness	High Cov Tightness	Low Cov Tightness	High Cov Tightness	Low Cov Count	High Cov Count	Low Cov Count	High Cov Count
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Post_{i,t}$	Absorbed by $TimeFE_t$		Absorbed by $TimeFE_t$		Absorbed by $TimeFE_t$		Absorbed by $TimeFE_t$	
$Treatment_{i,t}$	Absorbed by $FirmEventFE_i$		Absorbed by $FirmEventFE_i$		Absorbed by $FirmEventFE_i$		Absorbed by $FirmEventFE_i$	
$Treatment_{i,t}*Post_{i,t}$	-0.133*	-0.197**	-0.105	-0.211**	-0.111	-0.292**	-0.111	-0.349***
	[-1.71]	[-2.08]	[-1.40]	[-2.26]	[-1.66]	[-2.51]	[-2.26]	[-1.40]
$Size_{i,t-1}$			0.132	0.167			0.104	0.014
			[1.29]	[1.15]			[-0.00]	[1.29]
$Profitability_{i,t-1}$			0.283	-0.225			-0.430	-1.105
			[0.45]	[-0.34]			[-2.03]	[0.45]
Market to $Book_{i,t-1}$			0.067	0.050			0.057	0.033
			[1.00]	[0.77]			[-0.16]	[1.00]
$FirmEventFE_i$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$TimeFE_t$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.072	0.170	0.205	0.268	0.049	0.325	0.139	0.445
N	70	72	70	72	94	48	94	48

Table 10: Placebo Shock: Difference-in-Differences

(Pre-Placebo Shock vs Post-Placebo Shock, Treatment Firms vs. Control Firms)

This table reports estimations from a regression form of differences-in-differences. The first difference is the pre-placebo shock vs. post-placebo shock, while the second difference is the treatment firms used in Table 6 vs. the control firms used in Table 6. Placebo shocks are based on moving the 1998 shock three years forward to 2001 and the 2008 shock three years backward to 2005 (Note: data is not available for having a placebo shock in 1995, so I move the placebo event three years forward instead). The dependent variable in these regressions is the risk ratio of firm *i* at time *t*. The matching and sample composition for (1) to (6) is the same as what is described in Table 6. All regressions include firm-event fixed effects and time 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.

$$RiskRatio_{i,t} = \alpha + \beta_1 PostPlacebo_{i,t} + \beta_2 Treatment_{i,t} + \beta_3 Treatment_{i,t} * PostPlacebo_{i,t} + Controls_{i,t-1} + TimeFE_t + FirmFE_i + \varepsilon_{i,t}$$

	Differences-in-Differences					
	Matched With Replacement		Matched Without Replacement		All Firms	
	(1)	(2)	(3)	(4)	(5)	(6)
$PostPlacebo_{i,t}$	Absorbed by $TimeFE_t$		Absorbed by $TimeFE_t$		Absorbed by $TimeFE_t$	
$Treatment_{i,t}$	Absorbed by $FirmEventFE_i$		Absorbed by $FirmEventFE_i$		Absorbed by $FirmEventFE_i$	
$Treatment_{i,t}*PostPlacebo_{i,t}$	0.088	0.082	0.092	0.024	0.011	-0.034
	[0.82]	[0.79]	[1.37]	[0.37]	[0.21]	[-0.55]
$Size_{i,t-1}$		0.115		-0.126		0.142
		[0.74]		[-1.12]		[1.57]
$Profitability_{i,t-1}$		-0.476		-1.006**		-0.776*
		[-0.73]		[-2.69]		[-1.99]
Market to $Book_{i,t-1}$		-0.051		-0.006		0.012
		[-0.58]		[-0.18]		[0.30]
$FirmEventFE_i$	Yes	Yes	Yes	Yes	Yes	Yes
$TimeFE_t$	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.043	0.119	0.078	0.278	0.084	0.169
N	92	92	84	84	206	206

Table 11: Impact of Reserve Changes on Investment Risk - Panel Regression

This table reports firm-level regressions which document the effect of reserve changes on the riskiness of a firm's investments. Reserve changes are based on a firm's prior year change in reserves due to commodity prices scaled by assets. The dependent variable in these regressions is the risk ratio for firm i in year t. A firm's risk ratio is calculated as the proportion of capital expenditures invested in high risk projects relative to all capital expenditures. Specification (1) reports results for the full sample period, 1997 to 2010, while specification (2) excludes the sample years used in the natural experiment, 1997-1999 and 2007-2009. All regressions include firm level fixed effects and time 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.

$$RiskRatio_{i,t} = \alpha + \beta_1 ReserveChange_{i,t-1} + Controls_{i,t-1} + TimeFE_t + FirmFE_i + \varepsilon_{i,t}$$

	Risk Ratio = High Risk Capex/Total Capex	
	Full Sample	Excluding Natural Experiment Years
	(1)	(2)
Reserve Change/Assets$_{i,t-1}$	0.009	-0.002
	[0.42]	[-0.11]
Size$_{i,t-1}$	0.061***	0.079***
	[2.86]	[3.33]
Market to Book$_{i,t-1}$	0.008	-0.004
	[0.51]	[-0.20]
Profitability$_{i,t-1}$	-0.172***	-0.271***
	[-3.35]	[-3.71]
ShortTermDebt/TotalDebt$_{i,t-1}$	-0.065	-0.055
	[-1.44]	[-0.80]
FirmFE$_i$	Yes	Yes
TimeFE$_t$	Yes	Yes
R^2	0.082	0.107
N	1070	638

Table Appendix A: Effect of Exploratory Capex on Reserves Additions from Discoveries

This table reports firm-level regressions which document the effect of high risk capital expenditures of different lags on reserves added from discoveries. The objective is to measure which lag of capex is most important for proved reserves added in a given year. For example, in specification (1) reserves added in a given year are regressed on the high risk capital expenditures (exploratory capital expenditures) spent in that year. All regressions include firm level fixed effects and time 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.

$$\textit{Reserves Added From Discoveries}_{i,t} = \alpha + \beta_1 \textit{High Risk Capex}_{i,t} + \textit{TimeFE}_t + \textit{FirmFE}_i + \varepsilon_{i,t}$$

	Dependent Variable = Reserves Added From Discoveries/Assets				
	(1)	(2)	(3)	(4)	(5)
High Risk Capex/Assets$_{i,t}$	0.428***	0.489***	0.535***	0.544***	0.465***
	[4.02]	[3.70]	[3.54]	[3.57]	[2.79]
High Risk Capex/Assets$_{i,t-1}$		0.057	0.170*	0.199*	0.093
		[0.73]	[1.67]	[1.73]	[0.83]
High Risk Capex/Assets$_{i,t-2}$			0.167	0.181	-0.013
			[1.58]	[1.13]	[-0.11]
High Risk Capex/Assets$_{i,t-3}$				0.150	-0.023
				[1.08]	[-0.19]
High Risk Capex/Assets$_{i,t-4}$					0.014
					[0.15]
FirmFE$_i$	Yes	Yes	Yes	Yes	Yes
TimeFE$_t$	Yes	Yes	Yes	Yes	Yes
R^2	0.198	0.238	0.236	0.237	0.211
N	1127	999	837	696	573