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Do Firms Engage in Risk Shifting? Empirical Evidence

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Abstract

I mpirically t st wh th r firms ngag in risk-shifting in a s tting wh r corporat inv stm nt risk m asur s ar availabl in SEC disclosur s. Contrary to what risk-shifting th ory pr dicts, I find that firms r duc inv stm nt risk wh n l v rag incr as s. In firm-l v l pan l r gr ssions I find that firms r duc th riskin ss of capital xp nditur s by 23.4% wh n l v rag is high. This r duction in risk taking is mor pr val nt among small firms. In a s cond t st, I us a natural xp rim nt with xog nous shocks to l v rag . Consist nt with th first t st, I find no vid nc that firms incr as risk, and that small firms r duc risk. Conc rn r garding th financing of futur inv stm nts is a plausibl xplanation for th s r sults.

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1 Introduction

How does corporate investment risk taking change when a firm has high leverage? 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 debt-holders. 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 a firm is in financial distress. The primary empirical challenge is obtaining a measure of the riskiness of a firm's overall capital expenditures. The contribution of this paper is to provide empirical evidence on how a firm's investment risk taking is affected by changes in leverage in a setting with clearly defined measures of investment risk from SEC disclosures.

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 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.

[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 (26.4%), and drilled 88,277 development wells of which 3,809 were unsuccessful (4.3%).

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 8.8% relative to the median level of risk. I also find that the proportion of high risk investment to total investment is reduced by 23.4% for firm-years in which leverage is in the top quartile of the sample. Furthermore, this risk-reducing behavior is most prevalent for small firms and 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 the reverse-causality endogeneity concern 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. During these years market leverage for the median firm increased from 0.27 to 0.47 and 0.25 to 0.43 respectively. 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 whose leverage is above median based on the commodity component of the leverage shock, while control firms are those firms with below median leverage based on the commodity component of the shock. Using this framework, I find that firms do not increase the amount of investment risk they undertake after exogenous leverage increases. Furthermore, consistent with the panel regression results, small firms actually reduce the risk level of the investments that they make when their leverage exogenously increases.

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 changes 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. Rampini et al. (2012) provide evidence that reduced hedging activity by airlines entering distress is driven by collateral constraints and not risk-shifting incentives. 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. 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 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. Furthermore, when I replace my measure of risk with the proxies which have been historically used, I find different relationships with leverage, in both sign and statistical significance, than what I obtain with my risk measure.

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 imagine 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

[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)).

length, ranging from a month to a few months depending on where the well is 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. 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 provides evidence on how firms change their risk taking behavior as leverage changes. In particular, the results highlight that small firms reduce risk taking more than large firms when leverage increases. This result could point towards a potential explanation as to why risk-shifting is not observed empirically. For example, if more information asymmetry exists between small firms and lenders/investors (Vermaelen (1981), Diamond and Verrecchia (1991)), then small firms may be more likely to be concerned about future financing frictions. These concerns about financing frictions could directly impact their ability to fund future projects. Almeida, Campello, and Weisbach (2011) suggest that these concerns about future financing constraints could be large enough to lead a firm to reduce its overall investment risk. Hadlock and Pierce (2010) provide empirical support for size as a significant indicator of financing constraints, and argue that size is plausibly more exogenous than other potential measures. However, this does not rule out that other cross-sectional differences between small firms and large firms, unrelated to financing constraints, could explain why small firms reduce investment risk more than large firms. Nonetheless, neither the panel regression results, nor the natural experiment results presented in this study indicate that firms, small or large, increase risk taking in time periods when leverage is high.

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)

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 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. However, this does not rule out the possibility of other covenants indirectly effecting a firm's risk taking. For example, conditional on being limited to a certain investment amount, a firm may elect to invest in lower risk projects, while if it were unconstrained in the amount

it could invest it may have elected to pursue higher risk projects. It could very well be the case that the need for explicit limits on risk taking for a given level of investment are not needed as other covenants may make investing in low risk projects in high leverage states of the world the most attractive choice for a firm's managers/equity-holders.

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 1,210 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 In estment 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 for 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.

3.2 Le erage Definition and Other Controls

Existing literature has used different definitions of leverage. In this study I use a market 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, profitability, and proportion of short term debt.

3.3 Summary Statistics

Table 1 reports summary statistics for the firm-years of the sample used in this study. The key dependent variable for 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 key independent variable of interest in this study is leverage. The average market leverage for firm-years in the sample is 0.28, while the average book leverage is 0.52.

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]

[4] Appendix B provides regression results using the standard deviation in changes in ROA and volatility

4 Identification and Empirical Design

4.1 Firm-Le el 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 with the risk ratio (investment risk) of a firm. By including a number of controls, and some interactions 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:

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

The primary definitions of leverage used are the market leverage and book leverage variables defined in the data section. Additionally, leverage dummy variables are used to allow for non-linearities in the relationship between leverage and investment risk. The timing convention of this specification tests the effect of the beginning of year leverage (leverage 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 and controls are measured prior to when investment dollars are spent.

The $Controls_{i,t-1}$ are comprised of size, profitability, market to book, and proportion of short term debt. 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 $t-1$. Debt maturity could also have implications for investment risk, this is controlled for as the proportion of debt due in the next year divided by total debt 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

of monthly equity price return as alternative proxies for risk. The coefficient estimates suggest that both of these alternative proxies have very different relationships with leverage than accounting based proxy that I use.

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.

In addition to the basic specification outlined above, an additional interaction specification is used to test different hypotheses related to how the influence of leverage on investment risk may vary across firms. This specification takes the form of:

$$RiskRatio_{i,t} = \alpha + \beta_1 Leverage_{i,t-1} + \beta_2 Size_{i,t-1} + \beta_3 Leverage_{i,t-1} * Size_{i,t-1}$$

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

In the above specification, the variable size is used to test whether the influence of leverage on investment risk is different for different size groups. In the specifications reported in the results section the $Size_{i,t-1}$ is a dummy variable, which is 1 if a firm is in the bottom (smallest) size quartile for a given year and zero otherwise. In this specification the key variable of interest is β_3, whose sign and significance will indicate whether firms in a given size group are affected differently by leverage than other firms. For example if the coefficient β_3 is negative and statistically significant, it would indicate that small firms reduce risk more in response to leverage changes than larger firms. In addition to size there are results reported for interactions with short term debt variables.

4.2 Natural Experiment: Commodity Based Le erage 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 had to the commodity shock based on its mix of oil and natural gas reserves. I use these two components to determine a treatment and control group for a given shock, then measure how investment risk is affected.

The initial differences-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 two components. The first, leverage prior to the shock, can be calculated directly from Compustat data. For the second component, the influence of commodities prices 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 leverage would be if the only event that occurred was the commodity shock, the calculation is as follows:

$$MarketLe\tilde{v}erage_{i,Post} = \frac{TotalDebt_{i,Pre}}{MarketCap_{i,Pre} + \$ChangeReservesPrices_{i,Post} + TotalDebt_{i,Pre}}$$

For example, in the case of the shock that occurred in 2008, the equity market cap and debt as of December 31, 2007 are used in conjunction with the change in reserves due to commodity prices during 2008 to calculate the market leverage as of December 31, 2008. The firms with an above median leverage using the above calculation are used as treatment firms, while the firms with below median leverage are control firms. 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. Figure 1 outlines the timing of the different pre-post periods, as well as the excluded shock years. The figure also documents relatively minor leverage changes in the years before and after a shock, which could alleviate some concerns as to whether investment policies are being influences by other contemporaneous shocks.

I use a regression form of differences-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 market 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.

One concern with natural experiments is that several factors that influence the dependent variable, in this case investment risk, could be changing at the same time. In particular, while a firm's leverage is affected by a negative commodity price shock, its investment opportunities may also be affected. Furthermore, if the impacts of changes in investment opportunities affect firms differently, then the time fixed effects will not properly control for investment opportunities. To directly control for changes in investment opportunities I include a control which proxies for a firm's investment opportunities. Specifically, I calculate the dollar change in reserves of a firm due to commodity prices scaled by assets. The more negative this figure is the more a firm is affected by the commodity shock, while the less negative this figure is the less a firm is affected by the commodity shock. I introduce a dummy variable ($BetterReserveD_{i,t-1}$) in the above specification which is equal to 1 if a firm's reserves were less affected by the commodity shock and 0 otherwise. The resulting specification is outlined below:

$$RiskRatio_{i,t} = \alpha + \beta_1 Treatment_{i,t} + \beta_2 Post_{i,t} + \beta_3 Treatment_{i,t} * Post_{i,t} + \beta_4 BetterReserveD_{i,t}$$

$$\beta_5 BetterReserveD_{i,t} * Post_{i,t} + Controls_{i,t-1} + FirmFE_i + YearFE_t + \varepsilon_{i,i}$$

If the estimation of β_3 is not affected by the inclusion of the investment opportunity control, then it is less likely that the estimation of the coefficients are being confounded by changes in investment opportunities that are changing concurrently with leverage.

5 Results

5.1 Uni ariate Tests

Table 2 documents how the riskiness of a firm's investment, as measured by the risk ratio, changes at different levels of leverage. Specifically, firms with leverage in the lowest quartile invest 40% of their capital expenditures in high risk projects, while firms with the highest leverage invest only 25% of their capital expenditures in high risk projects. This difference of 15% is both statistically and economically significant, as it represents nearly a 58% reduction in the risk ratio measure relative to the median firm.

However, the responsiveness of investment risk to leverage is not constant across different types of firms. As Table 2 documents, there are large differences in how investment risks respond to leverage for firms of different sizes. Specifically, for the largest firm-years in the sample, there is neither a statistical nor economical effect on investment risk, while for the smallest firms the risk ratio falls from 46% to 20% when we compare the firm-years with the lowest leverage to firm years with the highest leverage. While there are additional factors that could influence the relationships outlined in these initial univariate tests, they serve as a useful framework when interpreting regression results which control for additional omitted factors.

5.2 Firm Le el Panel Regressions

Table 3 reports results from firm-level panel regressions of different measures of investment risk on leverage. Every measure of leverage 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 8.8% relative to the median firm-year investment risk ratio. Alternatively specification (4) can be interpreted as entering the highest quartile of firm-year leverage results in a 23.4% reduction in risk taking relative to the median firm-year.[5]

[5] Appendix A provides coefficient estimates using an alternate definition of risk, one based on the amount of high risk or low risk investment made relative to a firm's net property, plant, and equipment. The results

A concern in the interpretation of the firm-level regression results reported in Table 3 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. Testing how investment risk responds to leverage across different types of firms may provide evidence for the plausibility of this argument. Table 4 reports a regression specification similar to Table 3, but with a small firm dummy variable interacted with the leverage variables. Confirming the initial univariate results, the interaction terms of size and leverage are negative and statistically significant. This result suggests that smaller firms scale back risk more than larger firms as their leverage goes up. In particular for the reverse causality argument to be a plausible explanation of the results observed, it would need to explain why there is a differential effect in how small firms and large firms react to leverage changes. If firms are levering up to reduce risk it seems unlikely that only small firms would do this and not large firms. However, this differential impact on risk taking at small firms is consistent with small firms being more concerned about future financing of projects and reducing risk accordingly.

An additional test of the plausibility of the reverse causality argument is in Table 5, 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. Specifically, I find that there is a significant reduction in investment risk taking in the two years prior to bankruptcy, this again is 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.

Table 6 reports regression results which test whether the amount of short term debt influences investment risk. Short term debt is defined as debt that is due in the next year, and the interaction term tests whether firms with high leverage that have short term debt reduce investment risk more than firms with high leverage. Based on the coefficients I cannot conclude that there is any differential result for firms with more short term debt, which

document an overall reduction in investment as leverage increases.

suggests that this is not of first order importance in determining investment risk for highly levered firms. This evidence is consistent with the survey results reported by Graham and Harvey (2001).

controls are included in specification (6), the reduction in investment risk of small firms remains statistically significant while the magnitude of reduction increases slightly.

To formalize the differential response of small firms, I use a regression form differences-in-differences-differences in Table 8, and find that the triple interaction term $Small_{i,t} * Treatment_{i,t} * Post_t$ is negative and statistically significant. This suggests that small firms affected by the leverage shock reduce investment risk. An explanation of these results would need to explain why small firms reduce investment risk more than large firms when they experience a leverage shock. Furthermore, these results document that firms do not engage in risk-shifting and that small firms are likely to reduce investment risk when their leverage increases exogenously. Concerns about financing constraints for future projects Almeida et al. (2011) are a plausible explanation of these results.

Table 9 provides a robustness test in the form of a falsification of the natural experiment. One concern in using a natural experiment is that spurious correlations could be driving results or causing problems with coefficient estimates. Table 9 provides a falsification in the form of moving the negative commodity shocks to points in time in which they did not actually occur (to 2001 and 2004). The key coefficient of interest, the interaction term of $Treatment_{i,t} * Post_t$, is not statistically significant, which is what one would expect if the natural experiment is not being driven by spurious correlations.

6 Conclusion

Whether firms engage in risk-shifting has been an open empirical question. Lack of data and adequate measures of risk have meant this question has not been able to be addressed directly. I use a setting which has objective measures of investment risk, from SEC disclosures, to test whether firms engage in risk-shifting. I find that firms do not increase investment risk when leverage increases and that small firms decrease the riskiness of their investments when leverage is high.

To rule out reverse-causality and other endogeneity concerns I use a natural experiment framework using commodity based shocks to leverage. Consistent with firm level panel

regression results I find that firms do not increase investment risk in response to the leverage shock and small firms reduce investment risk. These results are consistent with small firms being more concerned about future financial constraints and reducing investment risk when their leverage increases.

References

Almeida, H., Campello, M., Weisbach, M. S., 2011. Corporate financial and investment policies when future financing is not frictionless. Journal of Corporate Finance 17, 675–693.

Andrade, G., Kaplan, S. N., 1998. How costly is financial (not economic) distress? evidence from highly leveraged transactions that became distressed. Journal of Finance 53, 1443–1493.

Barnea, A., Haugen, R. A., Senbet, L. W., 1980. A rationale for debt maturity structure and cal73(F9Tdfdte3nistions)-te3in73(F9the73(F9ragncys)-te3theoretic73(F9frcamw)-27(ok.73(F9(Journal)-

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Jensen, M. C., Meckling, W. H., 1976. Theory of the firm: Managerial behavior, agency costs, and ownership structure. Journal of Financial Economics 3, 305–360.

John, T. A., John, K., 1993. Top-management compensation and capital structure. Journal of Finance 48, 949–974.

Landier, A., Sraer, D., Thesmar, D., 2011. The risk-shifting hypothesis: Evidence from subprime originations. Working Paper.

Parrino, R., Weisbach, M. S., 1999. Measuring investment distortions arising from stockholder-bondholder conflicts. Journal of Financial Economics 53, 3–42.

Rampini, A. A., Sufi, A., Viswanathan, S., 2012. Dynamic risk management. Working Paper.

Rauh, J., 2009. Risk shifting versus risk management: Investment policy in corporate pension plans. Review of Financial Studies 22, 2687–2733.

Smith, C. W., Warner, J. B., 1979. On financial contracting an analysis of bond covenants. Journal of Financial Economics 7, 117–161.

Vermaelen, T., 1981. Common stock repurchases and market signalling. Journal of Financial Economics 9, 139–183.

Welch, I., 2004. Capital structure and stock returns. Journal of Political Economy 114, 106–131.

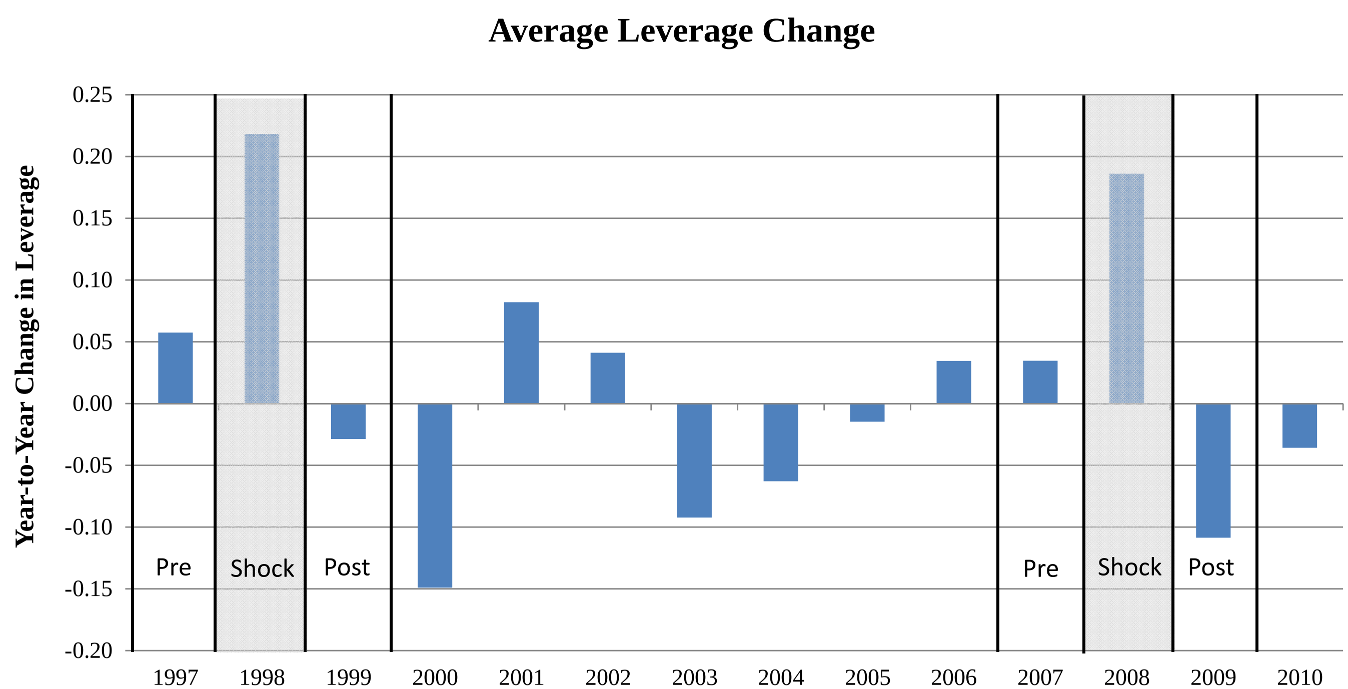

Figure 1: Year-to-Year Leverage Changes

This figure documents the average year-to-year leverage changes for firms in the sample. The two commodity based leverage shocks in 1998 and 2008 are shaded gray to identify the shocks and pre/post time periods used for the natural experiment

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 0.5% and 99.5%. Firm-year observations span from 1997 through 2010.

Panel A: Summary Statistics

	N	Mean	Std Dev	p25	p50	p75
Dependent Variable						
Risk Ratio	1210	0.32	0.26	0.12	0.26	0.46
Control Variables						
Market Leverage	1210	0.28	0.23	0.10	0.23	0.41
Book Leverage	1210	0.52	0.23	0.36	0.52	0.66
Size (Assets in $Millions)	1210	2,101.55	5,870.35	52.55	284.29	1,196.29
Profitability	1210	0.17	0.28	0.08	0.19	0.30
Short Term Debt/Total Debt	1210	0.10	0.24	0.00	0.00	0.05
Market to Book	1210	1.52	1.25	0.93	1.22	1.68

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: Leverage vs. Risk Ratio - Univariate Tests

This table reports univariate tests which compare whether the risk ratio (proportion of capital invested on high risk projects) changes with the level of a firm's leverage. Leverage quartiles are based on the quartile cutoffs of market leverage pooled across firms and years. Based on this methodology leverage quartiles are bounded as follows Q1: (0,0.10), Q2: (0.10,0.23), Q3: (0.23,0.41), Q4 (0.41,1.00). Additional univariate tests compare how a firm's risk ratio vs. leverage relationship changes based on firm size. Size quartiles are based on a firm's size in a given year, relative to other firms in that year.

	Market Leverage				
	Leverage Quartile (Low Leverage to High Leverage)				Difference
Total	Q1 (Low)	Q2	Q3	Q4 (High)	Q1 - Q4
Risk Ratio (All)	0.40	0.31	0.32	0.25	0.15***
By Firm Size Quartiles					
Risk Ratio Q4 (Largest Size)	0.27	0.29	0.30	0.26	0.01
Risk Ratio Q3	0.35	0.29	0.31	0.28	0.07*
Risk Ratio Q2	0.36	0.36	0.40	0.24	0.11***
Risk Ratio Q1 (Smallest Size)	0.46	0.33	0.25	0.20	0.26***

Table 3: Impact of Leverage on Investment Risk - Panel Regression

This table reports firm-level regressions which document the effect of leverage 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.

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

	Risk Ratio = High Risk Capex/Total Capex			
	(1)	(2)	(3)	(4)
Market Leverage$_{i,t-1}$	-0.100**			
	[-2.05]			
Book Leverage$_{i,t-1}$		-0.111**		
		[-2.42]		
Q4 Mkt Lev Dummy$_{i,t-1}$			-0.042**	-0.061**
			[-2.14]	[-2.22]
Q3 Mkt Lev Dummy $_{i,t-1}$				-0.021
				[-0.90]
Q2 Mkt Lev Dummy$_{i,t-1}$				-0.022
				[-1.02]
Size$_{i,t-1}$	0.042**	0.040*	0.039*	0.042**
	[1.98]	[1.94]	[1.87]	[2.03]
Market to Book$_{i,t-1}$	0.005	0.010	0.008	0.006
	[0.49]	[1.00]	[0.79]	[0.59]
Profitability$_{i,t-1}$	-0.097***	-0.096***	-0.095***	-0.096***
	[-2.93]	[-2.85]	[-2.87]	[-2.88]
ShortTermDebt/TotalDebt$_{i,t-1}$	-0.053	-0.054	-0.056	-0.057
	[-1.22]	[-1.23]	[-1.30]	[-1.32]
FirmFE$_i$	Yes	Yes	Yes	Yes
TimeFE$_t$	Yes	Yes	Yes	Yes
R^2	0.042	0.073	0.070	0.072
N	1210	1210	1210	1210

Table 4: Effect of Size on the Relationship between Leverage and Investment Risk - Panel Regression

This table reports firm-level regressions that document the effect of size on the relationship between leverage and 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. Definitions for leverage and leverage dummies have been previously. The size variable in these regressions is a dummy variable equal to 1 if a firm is in the lowest quartile (smallest) in size in a given year, and 0 otherwise. 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.

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

$$RiskRatio_{i,t} = \alpha + \beta_1 Q2LevD_{i,t-1} + \beta_2 Q3LevD_{i,t-1} + \beta_3 Q4LevD_{i,t-1} + \beta_5 Q2LevD_{i,t-1}{*}Size_{i,t-1} + \beta_6 Q3LevD_{i,t-1}{*}Size_{i,t-1} + \beta_7 Q4LevD_{i,t-1}{*}Size_{i,t-1} + \beta_8 Size_{i,t-1} + Controls_{i,t-1} + TimeFE_t + FirmFE_i + \varepsilon_{i,t}$$

	Risk Ratio = High Risk Capex/Total Capex			
	(1)	(2)	(3)	(4)
Market Leverage$_{i,t-1}$	-0.047			
	[-0.89]			
Book Leverage$_{i,t-1}$		-0.047		
		[-0.78]		
Q4 Mkt Lev Dummy$_{i,t-1}$			-0.029	-0.005
			[-1.37]	[-0.17]
Q3 Mkt Lev Dummy $_{i,t-1}$				0.032
				[1.29]
Q2 Mkt Lev Dummy$_{i,t-1}$				0.025
				[1.09]
Smallest Quartile Size$_{i,t-1}$	-0.021	-0.003	-0.041	0.007
	[-0.39]	[-0.05]	[-0.89]	[0.13]
Market Leverage$_{i,t-1}$ * Smallest Quartile Size$_{i,t-1}$	-0.143*			
	[-1.75]			
Book Leverage$_{i,t-1}$ * Smallest Quartile Size$_{i,t-1}$		-0.110		
		[-1.21]		
Q4 Mkt Lev Dummy$_{i,t-1}$ * Smallest Quartile Size$_{i,t-1}$			-0.061*	-0.113***
			[-1.66]	[-2.63]
Q3 Mkt Lev Dummy$_{i,t-1}$ * Smallest Quartile Size$_{i,t-1}$				-0.093*
				[-1.70]
Q2 Mkt Lev Dummy$_{i,t-1}$ * Smallest Quartile Size$_{i,t-1}$				-0.088**
				[-2.01]
Market to Book$_{i,t-1}$	-0.001	0.007	0.003	0.001
	[-0.06]	[0.71]	[0.29]	[0.12]
Profitability$_{i,t-1}$	-0.091***	-0.090***	-0.094***	-0.087***
	[-2.89]	[-2.76]	[-2.88]	[-2.71]
ShortTermDebt/TotalDebt$_{i,t-1}$	-0.058	-0.058	-0.060	-0.058
	[-1.33]	[-1.31]	[-1.37]	[-1.35]
FirmFE$_i$	Yes	Yes	Yes	Yes
TimeFE$_t$	Yes	Yes	Yes	Yes
R^2	0.064	0.066	0.063	0.070
N	1210	1210	1210	1210

Table 5: 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.

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

	Risk Ratio = High Risk Capex/Total Capex				
	(1)	(2)	(3)	(4)	(5)
One Year Prior to Bankruptcy Dummy$_{i,t}$	-0.127**	-0.108*	-0.120**	-0.109*	-0.107*
	[-2.31]	[-1.94]	[-2.24]	[-1.93]	[-1.89]
Two Years Prior to Bankruptcy Dummy$_{i,t}$	-0.117*	-0.121*	-0.123*	-0.113*	-0.114*
	[-1.72]	[-1.77]	[-1.87]	[-1.67]	[-1.69]
Three Years Prior to Bankruptcy Dummy$_{i,t}$	-0.033	-0.030	-0.036	-0.030	-0.026
	[-0.38]	[-0.35]	[-0.44]	[-0.34]	[-0.31]
Market Leverage$_{i,t-1}$		-0.096**			
		[-2.02]			
Book Leverage$_{i,t-1}$			-0.110**		
			[-2.44]		
Q4 Mkt Lev Dummy$_{i,t-1}$				-0.038*	-0.057**
				[-1.97]	[-2.08]
Q3 Mkt Lev Dummy $_{i,t-1}$					-0.018
					[-0.80]
Q2 Mkt Lev Dummy$_{i,t-1}$					-0.022
					[-1.02]
Size$_{i,t-1}$	0.040*	0.045**	0.043**	0.042**	0.044**
	[1.93]	[2.13]	[2.11]	[2.01]	[2.16]
Market to Book$_{i,t-1}$	0.011	0.005	0.010	0.008	0.006
	[1.03]	[0.47]	[0.94]	[0.75]	[0.57]
Profitability$_{i,t-1}$	-0.093***	-0.096***	-0.096***	-0.095***	-0.095***
	[-2.81]	[-2.88]	[-2.80]	[-2.82]	[-2.83]
ShortTermDebt/TotalDebt$_{i,t-1}$	-0.068	-0.061	-0.062	-0.064	-0.064
	[-1.56]	[-1.41]	[-1.43]	[-1.49]	[-1.51]
FirmFE$_i$	Yes	Yes	Yes	Yes	Yes
TimeFE$_t$	Yes	Yes	Yes	Yes	Yes
R^2	0.070	0.075	0.078	0.075	0.076
N	1210	1210	1210	1210	1210

Table 6: Effect of Short Term Debt on the Relationship between Leverage and Investment Risk - Panel Regression

This table reports firm-level regressions that document the effect of short term debt on the relationship between leverage and 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. Definitions for leverage and leverage dummies have been outlined previously. The short term debt dummy variable in these regressions is a dummy variable equal to 1 if a firm has more than 50% of its debt due in the following year. The short term debt ratio variable is the proportion of debt due in the following year divided by total debt. 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.

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

$$RiskRatio_{i,t} = \alpha + \beta_1 Q2LevD_{i,t-1} + \beta_2 Q3LevD_{i,t-1} + \beta_3 Q4LevD_{i,t-1} + \beta_5 Q2LevD_{i,t-1}*ShortTermDebt_{i,t-1} + \beta_6 Q3LevD_{i,t-1}*ShortTermDebt_{i,t-1} + \beta_7 Q4LevD_{i,t-1}*ShortTermDebt_{i,t-1} + \beta_8 ShortTermDebt_{i,t-1} + Controls_{i,t-1} + TimeFE_t + FirmFE_i + \varepsilon_{i,t}$$

	Risk Ratio = High Risk Capex/Total Capex							
	Short Debt = Dummy				Short Debt = Short Term Debt/Total Debt			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Market Leverage$_{i,t-1}$	-0.106**				-0.114**			
	[-2.01]				[-2.13]			
Book Leverage$_{i,t-1}$		-0.132***				-0.144***		
		[-2.90]				[-3.08]		
Q4 Mkt Lev Dummy$_{i,t-1}$			-0.040**	-0.062**			-0.042**	-0.065**
			[-2.06]	[-2.19]			[-2.12]	[-2.31]
Q3 Mkt Lev Dummy $_{i,t-1}$				-0.023				-0.028
				[-0.93]				[-1.11]
Q2 Mkt Lev Dummy$_{i,t-1}$				-0.024				-0.021
				[-1.12]				[-0.98]
Short Term Debt$_{i,t-1}$	-0.030	-0.070	-0.023	-0.039	-0.073	-0.127**	-0.057	-0.068
	[-0.65]	[-1.31]	[-0.53]	[-0.89]	[-1.45]	[-2.24]	[-1.30]	[-1.33]
Market Leverage$_{i,t-1}$ * Short Term Debt$_{i,t-1}$	0.011				0.068			
	[0.13]				[0.71]			
Book Leverage$_{i,t-1}$ * Short Term Debt$_{i,t-1}$		0.093				0.157		
		[0.92]				[1.53]		
Q4 Mkt Lev Dummy$_{i,t-1}$ * Short Term Debt$_{i,t-1}$			-0.027	-0.007			0.004	0.021
			[-0.54]	[-0.12]			[0.07]	[0.30]
Q3 Mkt Lev Dummy$_{i,t-1}$ * Short Term Debt$_{i,t-1}$				0.050				0.089
				[0.46]				[0.74]
Q2 Mkt Lev Dummy$_{i,t-1}$ * Short Term Debt$_{i,t-1}$				0.027				-0.034
				[0.35]				[-0.41]
Market to Book$_{i,t-1}$	0.005	0.009	0.007	0.006	0.006	0.010	0.008	0.007
	[0.42]	[0.92]	[0.70]	[0.62]	[0.53]	[1.01]	[0.79]	[0.72]
Profitability$_{i,t-1}$	-0.097***	-0.097***	-0.095***	-0.097***	-0.097***	-0.098***	-0.095***	-0.096***
	[-2.93]	[-2.91]	[-2.86]	[-2.91]	[-2.95]	[-2.98]	[-2.87]	[-2.85]
Size$_{i,t-1}$	0.043**	0.042**	0.040*	0.043**	0.042**	0.041*	0.039*	0.042**
	[2.02]	[2.01]	[1.91]	[2.07]	[1.97]	[1.97]	[1.87]	[2.03]
FirmFE$_i$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
TimeFE$_t$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
R^2	0.069	0.072	0.069	0.070	0.071	0.076	0.071	0.073
N	1210	1210	1210	1210	1210	1210	1210	1210

Table 7: Effect of Commodity Based Leverage Shock on Investment Risk: Difference-in-Differences

(Pre-Shock vs Post-Shock, High Leverage vs. Low Leverage)

This table reports results from a regression form of differences-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 above median leverage 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). Small firms are firms with below median assets in the pre-periods, while large firms have above median assets in the pre-periods. To control for changes in investment opportunities based on the value of reserve changes, firms are divided into two groups one whose reserves were less affected by the shock reserves (BetterOpportunityD = 1) and one whose reserves were more affected by the shock (BetterOpportunityD = 0). The dependent variable in these regressions is the risk ratio for firm i in year t. 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.

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

$$RiskRatio_{i,t} = \alpha + \beta_1 Post_{i,t} + \beta_2 Treatment_{i,t} + \beta_3 Treatment_{i,t} * Post_{i,t} + \beta_4 BetterOpportunityD_{i,t} + \beta_5 BetterOpportunityD_{i,t} * Post_{i,t} + Controls_{i,t-1} + TimeFE_t + FirmFE_i + \varepsilon_{i,t}$$

	Differences-in-Differences					
	Basic			Controlling for Investment Opportunities		
	All Firms	Large Firms	Small Firms	All Firms	Large Firms	Small Firms
	(1)	(2)	(3)	(4)	(5)	(6)
$Post_{i,t}$	-0.147*	0.016	-0.174	-0.205**	-0.219***	-0.246*
	[-1.95]	[0.45]	[-1.50]	[-2.30]	[-2.78]	[-1.81]
$TreatmentLev_{i,t}$	0.031	-0.086	0.194*	0.033	-0.117**	0.175
	[0.53]	[-1.44]	[1.73]	[0.56]	[-2.04]	[1.52]
$TreatmentLev_{i,t}*Post_{i,t}$	-0.056	0.064	-0.187**	-0.055	0.072	-0.194**
	[-1.21]	[1.26]	[-2.59]	[-1.18]	[1.37]	[-2.64]
$BetterOpportunityD_{i,t}$				-0.053	0.029	-0.126
				[-1.15]	[0.50]	[-1.38]
$BetterOpportunityD_{i,t}*Post_{i,t}$				0.080*	0.072	0.123
				[1.79]	[1.65]	[1.42]
$Size_{i,t-1}$	0.093***	0.088***	0.098***	0.100***	0.084***	0.114***
	[3.40]	[3.26]	[3.05]	[3.62]	[3.31]	[3.26]
$Profitability_{i,t-1}$	-0.088	-0.062	-0.093	-0.117	-0.076	-0.161*
	[-1.25]	[-0.50]	[-1.14]	[-1.57]	[-0.62]	[-1.74]
Market to $Book_{i,t-1}$	0.018	0.025	0.010	0.020	0.025	0.013
	[0.77]	[0.62]	[0.40]	[0.89]	[0.65]	[0.54]
$ShortTermDebt/TotalDebt_{i,t-1}$	-0.093	-0.126	-0.045	-0.071	-0.109	-0.011
	[-1.07]	[-1.39]	[-0.38]	[-0.79]	[-1.26]	[-0.09]
$FirmFE_i$	Yes	Yes	Yes	Yes	Yes	Yes
$TimeFE_t$	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.126	0.200	0.216	0.143	0.238	0.242
N	280	145	135	280	145	135

Table 8: Effect of Commodity Based Leverage Shock on Investment Risk: Difference-in-Differences-in-Differences
(Pre-Shock vs Post-Shock, High Leverage vs. Low Leverage, Small Firm vs. Large Firm)

This table reports results for a regression form of differences-in-differences-in-differences, where the coefficient of interest is the triple interaction term. The dependent variable in these regressions is the risk ratio for firm i in year t. The treatment and post variables have previously been defined. The definition of a small firm is a firm with below median assets in the time period prior to the shock. A set of fully saturated interactions between Post, Treatment, and Small variables are included. The key coefficient of interest for the differences-in-differences-in-differences regression is the triple interaction term β_7. Time fixed effects and firm fixed effects are included in all specifications. Standard errors are clustered by firm, with t-statistics reported in parentheses below coefficient estimates, where * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

$$RiskRatio_{i,t} = \alpha + \beta_1 Post_{i,t} + \beta_2 Treatment_{i,t} + \beta_3 Small_{i,t} + \beta_4 Treatment_{i,t} * Post_{i,t} + \beta_5 Treatment_{i,t} * Small_{i,t} + \beta_6 Small_{i,t} * Post_{i,t}$$
$$+ \beta_7 Treatment_{i,t} * Small_{i,t} * Post_{i,t} + FirmFE_i + \varepsilon_{i,t}$$

	Basic	Controlling for Investment Opportunities
	(1)	(2)
$Post_{i,t}$	-0.226***	-0.289***
	[-3.20]	[-3.50]
$Treatment_{i,t}$	-0.094*	-0.106*
	[-1.81]	[-1.82]
$Small_{i,t}$	-0.098	-0.087
	[-1.08]	[-0.74]
$BetterOpportunityD_{i,t}$		-0.004
		[-0.06]
$Treatment_{i,t}*Post_{i,t}$	0.053	0.057
	[1.09]	[1.12]
$Treatment_{i,t}*Small_{i,t}$	0.284**	0.296**
	[2.58]	[2.55]
$Small_{i,t}*Post_{i,t}$	0.092	0.091
	[1.34]	[1.02]
$Treatment_{i,t}*Small_{i,t}*Post_{i,t}$	-0.242***	-0.249***
	[-2.74]	[-2.80]
$BetterOpportunityD_{i,t}*Small_{i,t}$		-0.060
		[-0.59]
$BetterOpportunityD_{i,t}*Post_{i,t}$		0.077*
		[1.72]
$BetterOpportunityD_{i,t}*Small_{i,t}*Post_{i,t}$		0.020
		[0.22]
Log $Assets_{i,t-1}$	0.097***	0.104***
	[3.99]	[4.08]
$Profitability_{i,t-1}$	-0.095	-0.128*
	[-1.40]	[-1.75]
Market to $Book_{i,t-1}$	0.016	0.020
	[0.79]	[0.98]
$ShortTermDebt/TotalDebt_{i,t-1}$	-0.072	-0.051
	[-0.86]	[-0.59]
$FirmFE_i$	Yes	Yes
$TimeFE_t$	Yes	Yes
R^2	0.186	0.207
N	280	280

Table 9: Falsification: Effect of Commodity Based Leverage Shock on Investment Risk: Difference-in-Differences (False Pre-Shock vs False Post Shock, High Leverage vs. Low Leverage)

	All Firms	Large Firms	Small Firms	All Firms	Large Firms	Small Firms
	(1)	(2)	(3)	(4)	(5)	(6)
$Post_{i,t}$	0.014	-0.002	0.015	0.052	0.004	0.066
	[0.32]	[-0.06]	[0.19]	[1.27]	[0.10]	[0.85]
$Treatment_{i,t}$	-0.022	-0.029	-0.045	-0.026	-0.028	-0.071
	[-0.58]	[-1.17]	[-0.72]	[-0.61]	[-0.95]	[-1.00]
$Treatment_{i,t}$*$Post_{i,t}$	0.006	-0.025	0.019	-0.010	-0.026	-0.008
	[0.13]	[-0.72]	[0.22]	[-0.23]	[-0.72]	[-0.10]
$BetterOpportunityD_{i,t}$				-0.003	-0.034	-0.030
				[-0.08]	[-0.88]	[-0.48]
$BetterOpportunityD_{i,t}$*$Post_{i,t}$				-0.058*	-0.011	-0.071
				[-1.68]	[-0.27]	[-1.04]
Log $Assets_{i,t-1}$	0.126**	0.106*	0.122*	0.114**	0.106*	0.103
	[2.21]	[1.78]	[1.71]	[2.00]	[1.76]	[1.30]
$Profitability_{i,t-1}$	-0.214	-0.043	-0.190	-0.234	-0.028	-0.227
	[-1.47]	[-0.26]	[-1.22]	[-1.57]	[-0.15]	[-1.34]
Market to $Book_{i,t-1}$	-0.007	0.113	-0.024	-0.012	0.104	-0.033
	[-0.25]	[1.30]	[-0.76]	[-0.44]	[1.08]	[-1.09]
ShortTermDebt/$TotalDebt_{i,t-1}$	-0.035	0.131	-0.133*	-0.032	0.126	-0.127*
	[-0.46]	[1.42]	[-1.75]	[-0.42]	[1.30]	[-1.69]
$FirmFE_i$	Yes	Yes	Yes	Yes	Yes	Yes
$TimeFE_t$	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.122	0.161	0.187	0.134	0.172	0.2.2 L6nc 0 0 Tc4 369TJN 0 T-0.673172

Appendix A: Regression of Investment Intensity Risk on Leverage + Controls

This table reports firm-level regressions which document the effect of leverage on the riskiness of a firm's investments relative to the net property plant and equipment a firm has. The dependent variables in these regressions is the capital expenditures spent for firm i in year t in a given risk category (high or low) scaled by lag net property plant and equipment. 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.

$$I/K_{i,t} = \alpha + \beta_1 Leverage_{i,t-1} + Controls_{i,t-1} + TimeFE_t + FirmFE_i + \varepsilon_{i,t}$$

$$I/K_{i,t} = \alpha + \beta_1 Q2LevD_{i,t-1} + \beta_2 Q3LevD_{i,t-1} + \beta_3 Q4LevD_{i,t-1} + Controls_{i,t-1} + TimeFE_t + FirmFE_i + \varepsilon_{i,t}$$

	Dependent = High Risk Inv/Net PPE				Dependent = Low Risk Inv/Net PPE			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Market\ Leverage_{i,t-1}$	-0.146***				-0.158***			
	[-3.98]				[-3.79]			
$Book\ Leverage_{i,t-1}$		-0.152***				-0.055		
		[-3.27]				[-1.18]		
$Q4\ Lev\ Dummy_{i,t-1}$			-0.040***	-0.081***			-0.044**	-0.076**
			[-3.32]	[-3.63]			[-2.54]	[-2.58]
$Q3\ Lev\ Dummy_{i,t-1}$				-0.048**				-0.048*
				[-2.22]				[-1.75]
$Q2\ Lev\ Dummy_{i,t-1}$				-0.032*				-0.007
				[-1.84]				[-0.31]
$Log\ Assets_{i,t-1}$	0.009	0.006	0.003	0.010	-0.034*	-0.041**	-0.040**	-0.033
	[0.52]	[0.34]	[0.19]	[0.53]	[-1.73]	[-2.10]	[-2.15]	[-1.65]
$Market\ to\ Book_{i,t-1}$	0.017*	0.027***	0.024**	0.018*	0.027*	0.036**	0.033**	0.027*
	[1.75]	[2.81]	[2.51]	[1.85]	[1.80]	[2.31]	[2.17]	[1.88]
$Profitability_{i,t-1}$	-0.052*	-0.052*	-0.046	-0.048	0.031	0.035	0.036	0.034
	[-1.79]	[-1.72]	[-1.63]	[-1.65]	[0.78]	[0.89]	[0.89]	[0.84]
$ShortTermDebt/TotalDebt_{i,t-1}$	-0.056**	-0.059***	-0.064***	-0.065***	-0.052	-0.061*	-0.059*	-0.061*
	[-2.47]	[-2.69]	[-2.69]	[-2.88]	[-1.56]	[-1.81]	[-1.77]	[-1.83]
$FirmFE_i$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$TimeFE_t$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.168	0.170	0.157	0.165	0.172	0.161	0.165	0.171
N	1170	1170	1170	1170	1107	1107	1107	1107