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Abstract

Our paper sheds new light on the theoretically ambiguous effect of stock options on managerial incentives for risk-taking by analyzing how equity-based incentives affect firms' responses to an unanticipated and exogenous increase in risk. The particular risk we study is an increase in liability and regulatory risk arising from workers' exposure to newly identified carcinogens. We find that compensation contracts with high sensitivity to stock prices, low sensitivity to volatility, and options that are deep in-the-money reduce managers' risk-taking incentives after risk increases. While options increase compensation's sensitivity to both stock prices and volatility, on net, they encourage risk taking in our setting. We find that variation in managerial stock and option holdings causes meaningful differences in corporate decisions. Our findings underline the importance of corporate boards structuring and maintaining compensation plans properly in order to achieve their desired corporate strategy.

JEL Codes: D21, G32, G34, K13
Keywords: legal liability, tail risk, stock options, compensation, managerial agency

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Abstract

Our paper sheds new light on the theoretically ambiguous effect of stock options on managerial incentives for risk-taking by analyzing how equity-based incentives affect firms' responses to an unanticipated and exogenous increase in risk. The particular risk we study is an increase in liability and regulatory risk arising from workers' exposure to newly identified carcinogens. We find that compensation contracts with high sensitivity to stock prices, low sensitivity to volatility, and options that are deep in-the-money reduce managers' risk-taking incentives after risk increases. While options increase compensation's sensitivity to both stock prices and volatility, on net, they encourage risk taking in our setting. We find that variation in managerial stock and option holdings causes meaningful differences in corporate decisions. Our findings underline the importance of corporate boards structuring and maintaining compensation plans properly in order to achieve their desired corporate strategy.

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1. Introduction

Options-based compensation for corporate executives has grown significantly over the past 30 years. Options on company stock rose to account for almost half of all CEO pay before corporations began expensing option grants in 2004 and continues to account for about a quarter of CEO compensation (Frydman and Jenter 2010). The theoretical effect of these options on managerial risk-taking incentives is unclear. The convex payoffs provided by options can give managers a greater incentive to take on risky projects because the manager shares the gains with shareholders but not all of the losses (Jensen and Meckling 1976; Myers 1977; Smith and Stulz 1985; Haugen and Senbet 1981; Smith and Watts 1992; Gaver and Gaver 1993; Bizjak et al. 1993; Guay 1999; and Core and Guay 1999). But because options contain a leveraged position in the firm's equity, they have the potential to magnify a risk-averse manager's exposure to the firm's risk and thus reduce risk-taking incentives (Lambert, Larcker, and Verrecchia 1991; Carpenter 2000; Ross 2004). Option compensation may also increase or decrease the firm's risk as a byproduct of increasing managerial effort (Kadan and Swinkels 2008).

Uncovering the causal effect of option-based incentives on corporate risk-taking is difficult. The direction of causality underlying positive correlations between the usage of options and various measures of risk, such as stock-return volatility, is unclear.[1] Do option-based incentives lead managers to take more risk, or are firms more likely to use option-based incentives when facing risky environments?[2] Because managers' compensation is chosen endogenously in anticipation of future business risk, the possibility of reverse causality is hard to exclude. This identification challenge is compounded by a lack of plausibly exogenous shocks to managers' option-based incentives.

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[1] Papers documenting a positive association between options and firm risk include Agrawal and Mandelker (1987), DeFusco et al. (1990), Saunders, Strock, and Travlos (1990), Mehran (1992, 1995), May (1995), Tufano (1996), Berger et al. (1997), Denis, Denis, and Sarin (1997), Esty (1997a,b), Jolls (1998), Schrand and Unal (1998), Aggarwal and Samwick (1999), Guay (1999), Knopf et al. (2002), Rajgopal and Shevlin (2002), Rogers (2002), and Armstrong and Vashishtha (2010).

[2] For example, to overcome agency conflicts arising from managerial risk aversion, shareholders may wish to give managers more convex incentives when firms face greater risk (Guay 1999). Firms operating in noisier business environments may also give managers larger ownership stakes because of the greater difficulty in assessing managerial performance (Demsetz and Lehn 1985).

Our paper addresses this identification challenge by exploiting unexpected changes in the firms' business environment that increase left-tail risk (also known as material risk). Left-tail risks are prevalent in practice and can take the form of technological irrelevance, adverse regulatory changes, asset expropriation, and so on. The specific tail risk we study is the risk of large legal liabilities and costly regulation. We exploit exogenous increases in this risk and examine how managers' responses to this new business environment are shaped by their preexisting equity-based incentives. Because the increase in risk is unanticipated, the managers' equity portfolio of stocks and options is predetermined, allowing us to better assess the causal impact of option-based incentives on managerial risk-taking and to exclude the possibility of reverse causality.

In particular, we analyze firms' responses to increased tail risk that is created when a chemical to which a firm's workers have already been exposed is newly identified as a carcinogen. Despite the presence of the workers' compensation system, these exposures can carry significant corporate legal liability (Ringleb and Wiggins 1990). Discovery of a chemical's carcinogenicity increases the likelihood that a firm will need to spend large sums on legal fees, damage payments, and insurance premiums in the future – if and when workers eventually fall ill as a consequence of their exposure to the chemical. It also raises the risk of future workplace safety regulations that may be costly to implement. This increased potential for large cash outflows increases the likelihood of future poor corporate performance and distress, allowing us to cleanly identify an increase in firms' business risks. The most salient risk for these firms is that a chemical they use will become the next asbestos. Litigation related to asbestos exposure, whose medical dangers were known before the sample period of this study, has targeted more than 8,400 corporate defendants, bankrupted at least 85 firms, and is projected to cost defendants $200 to $265 billion in total (Carroll et al. 2005; White 2004). Although the expected liability costs of a newly identified carcinogen are unlikely to approach those of asbestos, there is a chance that a firm that has exposed its workers to a carcinogen will be liable for a substantial payout.

We find that, after left-tail risk increases, firms tend to reduce their cash flow volatility by diversifying their businesses into new industries. An increase in tail risk is associated with a five percent increase in diversifying acquisitions and nearly a third of a standard deviation decline in cash flow volatility. The increase in tail risk appears to be unanticipated in that the firms begin diversifying only after risk increases; there is also no evidence that firms that would become exposed to the risk made different choices with respect to leverage, cash flow volatility, or option-based compensation before the risk increases.[3] Firms' response to the increase in tail risk is consistent with their attempting to reduce the probability of future distress and matches responses, reported elsewhere, to business risks in this and other settings (Jensen and Meckling 1976; Amihud and Lev 1981; and Maksimovic and Phillips 2002; Gormley and Matsa, forthcoming). These risk-reducing investments may create value for shareholders by avoiding costly distress and may also help managers to avoid private costs of distress.

We then analyze how equity-based compensation, particularly options, affects managers' risk-taking incentives following the increase in left-tail risk. The value of a managers' portfolio of options is sensitive both to stock price movements and to stock price volatility. In theory, higher sensitivity to stock price movements provides a greater incentive to reduce left-tail risk, while higher sensitivity to stock price volatility, which is caused by the options' convexity, weakens that incentive. The net incentive impact of options on risk taking is ambiguous.

We find that the manager's equity-based incentives in place prior to the increase in tail risk are related to the firm's observed response in the way theory predicts. Managers with incentives that provide a high sensitivity to stock price movements respond to the increased tail risk with greater risk-reducing activities. Exposed firms' managers with an above median stock price sensitivity in their incentives reduce cash flow volatility after tail risk increases by half of a standard deviation, on average, relative to managers with similarly high stock price sensitivity in unexposed firms. In contrast, managers of exposed firms with a below median stock price sensitivity only decrease cash flow volatility by about a fifth of a

[3] Evidence confirming that this particular increase in risk is unanticipated by firms is not surprising. While a firm always faces the risk that a chemical it uses will be discovered as carcinogenic (thus increasing the risk of legal liability and adverse regulatory changes), the incidence *and* exact timing of a future, new scientific study that identifies the potential hazard -- the increase in risk we study -- is inherently unpredictable.

standard deviation, on average, relative to similarly compensated managers at unexposed firms. Sensitivity to volatility, on the other hand, has the opposite effect. Managers with an above median sensitivity to stock price volatility do not reduce their cash flow volatility after an increase in tail risk, while managers with a below median sensitivity to volatility reduce cash flow volatility, on average, by about half of a standard deviation.

On net, we find that options discourage risk-reducing activities in our setting. Firms that grant a larger share of compensation as options are less likely to respond to greater tail risk by reducing the volatility of cash flows. Consistent with the idea of the convexity of options driving these effects, the extent of "in-the-moneyness" (or moneyness, for short) of a manager's options also matters. Firms whose managers have options that are deeper in-the-money and thereby provide a more linear payoff with respect to stock price movements are more likely to reduce cash flow volatility after risk increases.

While our identification strategy addresses concerns about reverse causality, the interpretation of our findings could be subject to another, more subtle identification challenge. Omitted variables could be a problem if factors that are correlated with the initial choice of compensation structure also affect how a firm responds to the increase in tail risk for reasons unrelated to compensation. For example, firms with greater ex-ante bankruptcy risk or leverage might respond more aggressively to reduce risk following the increase in tail risk. If firms with greater bankruptcy risk or leverage are also less likely to use option-based incentives, this might explain the observed correlation between incentives and changes in cash flow volatility. Our findings, however, do not appear driven by such omitted variables. Observed correlations between bankruptcy risk, leverage, and equity-based incentives are not consistent with this alternative explanation. Likewise, we find that potential differences in firm size, investment opportunities, and external governance also do not explain our findings.

Taken together, these results suggest that the structure of managers' compensation has important effects on corporate responses to tail risk, and that on average, option-based incentives reduce managers' incentives to undertake risk-reducing investments when faced with such risk. The risk-taking incentives provided by options' convexity appear to outweigh the countervailing incentives arising from managers' increased exposure to stock price movements. Coles, Daniel, and Naveen (2006) provide additional evidence regarding the importance of convexity. Using a system of simultaneous equations and the identifying restriction that the riskiness of the firm's business environment only affects project choice through its effect on managerial compensation, they find that pay convexity is associated with increases in R&D and firm leverage. Our work takes this further by exploiting a natural experiment that breaks the endogeneity of managerial compensation to the firm's risk and uncovers the causal effect of convexity on choices related to acquisitions and cash flow volatility. We find that the net effect of options on risk-taking incentives is positive and that observed differences in equity-based incentives can have large effects on corporate responses to changes in business risk.

In recent work, Hayes, Lemmon and Qiu (2010) study the relationship between incentives and corporate outcomes by analyzing the adoption of FAS 123R, which required firms to expense stock option grants. They find that firms cut back on stock option grants after FAS 123R with no observable change in R&D, capital expenditures, leverage, or cash, suggesting that other factors, besides risk-taking incentives, affect compensation choices and that these incremental option grants may have little impact on firms' financial and investment policies. Our analysis differs in that we analyze an exogenous shock to the firm's business environment rather than a shock to compensation and examine different measures of corporate risk taking. We also analyze a particular type of risk, left-tail risk, and find that equity-based incentives affect managers' incentives to reduce this risk by diversifying and decreasing the volatility of cash flows. Put together, these findings suggest that option contracts affect risk-taking incentives in ways that are potentially unintended by the corporate boards that choose them.

Our results have broad implications beyond the effects of liability and regulatory risk. The increases in risk we study have characteristics similar to many other business risks that firms face in that they reduce firms' expected future cash flows and the expected returns on investments but have a limited effect on current cash flows. Parallels can be drawn to any number of other business risks that involve a decrease in expected future cash flows — for example, the risks that a competing technology will be developed or that tariffs will be eliminated. If equity-based incentives affect how firms respond to an increase in liability and regulatory risk, then it may also affect how firms respond to many other types of business risks that firms commonly face. It is also in this spirit that our work contributes to the debate on whether CEOs and their incentives matter.[4]

Our results provide tangible evidence that variation in compensation contracts can cause meaningful differences in corporate decisions. These findings confirm the importance of boards both structuring and maintaining executives' compensation properly in order to achieve their desired corporate strategy, particularly when firms face sizeable left-tail risks. Our results, however, do not imply that a particular compensation structure is best for all firms facing significant tail risk. The optimal compensation structure will likely depend on a firm's specific circumstances (such as the potential costs of distress), and boards can structure managers' equity compensation to encourage or discourage diversification and risk-taking, according to the board's objectives.

These findings complement conclusions from case studies of industries facing a risk of decline. In industries such as defense contracting near the end of the cold war, consolidating and retiring capacity is often thought to maximize shareholder value, but most firms instead diversified into other industries (Anand and Singh 1997). Such diversification is relatively less risky then consolidating a firm's operations in an industry with uncertain prospects. In the same period, General Dynamics (GD) stood out in implementing a strategy of downsizing, restructuring, and exiting. Dial and Murphy (1995) and GD's management team credit the firm's incentive compensation plan for motivating the risky strategy of downsizing, which generated a 550% return for shareholders over two years. Consistent with our results, the most prominent features of executive compensation at GD were stock options and option-like cash bonuses pegged to improvements in the stock price.

The remainder of the paper is organized as follows. Section 2 discusses firms' legal liability for

[4] For example, Bennedsen, Perez-Gonzalez, and Wolfenzon (2010) find that CEOs greatly affect firm performance in Denmark by relying on a unique experiment that examines firm performance in the face of deaths to either the CEO or his/her immediate family members, but using a similar experiment among U.S. firms, Fee, Hadlock, and Pierce (2010) find little evidence that CEO deaths affect corporate outcomes. Regarding CEO incentives, Demsetz and Lehn (1985), Himmelberg, Hubbard and Palia (1999), and Palia (2001) suggest that there is no causal effect of incentives on firm value since both are jointly determined in equilibrium. Our evidence suggests, however, that while compensation may initially be co-determined with firm value, when a shock to firm value (such as the tail risk we study) perturbs the equilibrium, variation in incentives leads to meaningful differences in firm outcomes.

occupational carcinogens and how it is likely to affect the firms' risk of large adverse cash flow shocks. Section 3 describes our empirical strategy and the data sources. Section 4 presents our results on how equity-based incentives affect firms' responses, and Section 5 interprets our findings and presents additional robustness tests. Section 6 presents findings on whether managers attempt to reduce their financial exposure when tail risk increases, and Section 7 concludes.

2. Risk of occupational carcinogens

In the United States, diseases – including cancers – that are contracted by workers in the course of employment are covered by a legal institution known as the workers' compensation system. Under this system, employers are required to compensate workers for all job-related injuries irrespective of fault. Upon establishing that employment was at least a contributing factor in causing a disease, workers typically qualify for payment of their complete medical expenses as well as some compensation for lost wages (Peirce and Dworkin 1988). Because these payments accrue irrespective of employer negligence, the firm bears liability even if it had no knowledge of the danger (Schwartz 1985).

Damages related to carcinogenic exposures in the workplace can be significant. Treating cancer is expensive, and if a worker dies from the disease, surviving family members often qualify for death benefits. Furthermore, sick workers and their family members are entitled to sue employers directly for negligence, pain and suffering, and punitive damages if they can prove that their employer had "dual capacity" (for example, if the employer was also the producer of the substance causing the carcinogenic exposure) or committed "willful misconduct" (for example, if the employer took too few precautions despite knowing the risks of exposure). Even a few such suits can lead to significant damage awards, and numerous suits can tax the financial assets of even large corporations (Ringleb and Wiggins 1990). Managers also cite occupational exposures as a significant risk to their firm's operations.[5]

[5] For example, in their 2008 10-K, Novelis Inc., a producer of aluminum rolled products, noted that the company's use of hazardous materials and chemicals could lead to future litigation pertaining to occupational exposures, and that it "is not possible to predict the ultimate outcome of these claims and lawsuits due to the unpredictable nature of personal injury litigation. If these claims and lawsuits, individually or in the aggregate, were finally resolved against us, our financial position, results of operations and cash flows could be adversely affected."

Using a calibration, Gormley and Matsa (forthcoming) confirm that such workplace exposures to carcinogens can significantly increase a firm's risk of future financial distress and bankruptcy. Using historical data on damage awards (Pontiff 2007) and workplace exposures to known carcinogens, Gormley and Matsa find that a typical potential legal liability faced by firms in our sample (described later) appears to be around 5% of assets. Given firms' historical cash flows, an adverse cash flow shock of this magnitude would increase the median probability of distress among these firms 30-fold (from 0.09% to 3.35%), representing a substantial increase in risk.

Large firms often self-insure against these risks, thereby retaining the primary liability (LeRoy et al. 1989), and general liability and workers' compensation insurance are likely to provide firms with only limited protection from these claims. Third-party policies are often limited in scope and do not provide the firm with any protection against future premium increases due to changes in the firm's risk exposure, and the premiums can become a significant cost of doing business (Williams 1986; Cummins and Olson 1974).[6] For example, a half-dozen surgeries for carpal tunnel problems and other injuries at a factory of 220 workers can lead to costs representing 2.5 percent of revenue ($4,900 per worker per year, or $2.50 for every hour that an employee works; Greenhouse 2009).[7]

Using subsidiary corporate structures is also unlikely to shield firms from any major liability emerging from these claims because courts can "pierce the corporate veil" and hold a parent corporation responsible for its subsidiaries' liabilities. While there is no set rule or formula, it is generally understood that liability will be imposed on the parent "when it is necessary to promote justice or to obviate

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[6] Because of concerns about strong adverse selection, surplus liability insurance policies covering large risks were often unavailable during the period of this study, and insurance policies that were issued typically excluded many risks including "tail coverage" (i.e., the policies covered only damages from lawsuits actually filed during the policy period, excluding losses that would not manifest until much later; Winter 1991).

[7] Firms also warn about this risk in their financial reporting: "Our manufacturing operations are subject to…environmental hazards such as chemical spills, discharges or releases of toxic or hazardous substances or gases into the environment or workplace.… Furthermore, we could be subject to present and future claims with respect to workplace exposure, workers' compensation and other matters. Although we maintain property and casualty insurance of the types and in the amounts that we believe are customary for our industries, we cannot assure you that our insurance coverage will be adequate for liability that may be ultimately incurred or that such coverage will continue to be available to us on commercially reasonable terms. Any claims that result in liability exceeding our insurance coverage could have an adverse effect on our business, financial condition and results of operations." (Northwest Pipe Company 10-Q, September 2006, p. 18)

inequitable results" (Lattin 1971, p. 72), or when a subsidiary is set up to avoid paying foreseeable damages (because it is undercapitalized; Thompson 1991). Furthermore, using a subsidiary structure in the occupational injury context may actually increase the firm's total liability, because legal limitations on employees' ability to sue their employer under the workers' compensation system do not usually transfer to the parent corporation (Treece and Zuckerman 1983). Firms also cannot shield themselves from existing liability by spinning off the troubled assets. Although selling the assets can prevent additional liability expenses, the firms would still be liable to workers for damages already incurred.

Future regulatory changes pose yet another risk for firms where workers have been exposed to potentially carcinogenic materials. In response to evidence that exposure to particular chemicals cause adverse health effects, regulators may limit the future use of these chemicals in the workplace. Such regulation can significantly increase a firm's cost of doing business, and firms report this to be a serious risk when new chemicals are discovered to be carcinogenic.[8] Firms also cannot easily insure or protect themselves against such regulatory changes.

Although the increase in liability or regulatory risk is bad news about the firm's future, it is unlikely to have much of an effect on its *current* cash flows. Damage awards are unlikely to affect cash flows right away because claims for past exposure to carcinogens typically take years to litigate. Moreover, damage payments to workers typically only accrue after worker injuries manifest themselves, because damages are usually assessed only for actual – not speculative – damages (Ringleb and Wiggins 1990). Although premiums for third-party workers' compensation insurance are likely to eventually reflect the increased risk of a payout, they are unlikely to adjust right away (Williams 1986).[9] Any changes in occupational regulations also tend to occur with a lag.

[8] For example, in their 1996 10-K filing, Unifrax Corporation, a company that produces insulation, stated concerns that recent evidence of carcinogenicity in ceramic fibers might lead to new regulatory limits on occupational exposures: "If the U.S. were to adopt legislative or regulatory standards severely restricting the use of ceramic fiber or severely limiting fiber exposure, a material adverse effect on the Company's business could result."

[9] After learning about the increased risk, workers might demand higher wages as a sort of insurance against potential noneconomic harm, such as from pain and suffering. (Economic damages and lost wages would be covered by workers' compensation.) However, Gormley and Matsa (forthcoming) found no evidence of wages increasing after the increase in risk. Similar tests found no immediate change in the ratio of cash flow to assets.

The discovery that a chemical currently being used in a firm's production process – and to which the firm's workers are exposed – is a carcinogen thus has a distinctive feature: it represents a substantial increase in the risk of future distress but has minimal concomitant effect on cash flows. Because the increase in liability and regulatory risk has little effect on current cash flows, which might directly influence investment (Fazzari, Hubbard, and Petersen 1988), we are able to isolate an exogenous increase in managers' exposure to left-tail risk. We exploit this unique feature in the analysis that follows to analyze how a manager's equity-based incentives affect their response to an increase in tail risk.

3. Empirical approach

Identifying workers' exposure to newly identified carcinogens requires the combination of information on (1) scientific discoveries related to chemical carcinogenicity and (2) which firms use these chemicals. For information about the timing of discoveries, we use the National Toxicology Program's (NTP) *Report on Carcinogens* (*RoC*). This report, which is published regularly by the U.S. Department of Health and Human Services under a 1978 congressional mandate, contains a list of all substances (1) that are known or may reasonably be anticipated to be human carcinogens, and (2) to which a significant number of persons residing in the United States are exposed. Nominations for listing in the report are evaluated by scientists from the NTP, other federal health research and regulatory agencies, and non-government institutions. The first two reports were published in 1980 and 1981, and the report has been updated approximately biannually since.

The addition of an agent to the *RoC* indicates an accumulation of new scientific evidence that the agent may be a carcinogen.[10] In our empirical work, we focus on additions to the *RoC* after 1983 for two reasons. First, our data source (described below) for identifying firms' chemical exposures is based on information collected between 1981 and 1983. To avoid the possibility that firms may have already eliminated exposures to carcinogens identified in the two reports prior to the survey, we rely on additions

[10] While it is possible that firms might follow the scientific literature and partially anticipate the timing of a new *RoC* listing, we do not find any evidence of this. As shown in our later analysis, there are no observable ex-ante differences between firms with and without exposures to a new *RoC* listing. There is also no evidence that firms begin undertaking risk-reducing activities until *after* a chemical is added to the *RoC*.

to the *RoC* after 1983. Second, our earliest compensation data begins in 1984, and our subsequent identification strategy requires compensation data in the year before risk increases.

While there are a number of potential sources for scientific developments related to possible carcinogens, we use the *RoC* because federal regulations specifically require U.S. firms to monitor the report and treat any substances listed as carcinogens. For example, firms are required to warn employees about their exposure to substances that are included in the *RoC* [U.S. Government Regulation 29 CFR, parts 1910.1200(b)(1) and (d)(4)]. Because of such regulations, it is likely that firms, and presumably employees, are aware of agents listed in the report, and while it is not required, some firms note relevant changes in the *RoC* in their financial reporting.[11] Nevertheless the listing of a substance in the *RoC* is not in itself a regulatory action that requires firms to limit exposures or uses of the substance in question, although it may prompt regulatory agencies to consider adopting such rules.

To identify firms in which workers were likely to have been exposed to the newly identified carcinogens, we use the National Occupational Exposure Survey (NOES). This survey was conducted by the National Institute for Occupational Safety and Health using on-site visits to 4,490 U.S. business establishments employing approximately 1.8 million workers between 1981 and 1983. In these visits, surveyors recorded all chemical, physical, and biological agents to which workers were observed to be exposed in each firm, the number of workers being exposed to each agent, and the number of these exposures that were uncontrolled. The survey is expansive and lists nearly 13,000 different agents, including agents that were not known or thought to be hazardous at the time of the survey (including water), and because the NOES survey was conducted between 1981 and 1983, it measures worker exposures to possible carcinogens before those chemicals were identified as dangerous by the *RoC*. We obtained a custom extract of this data aggregated by 4-digit SIC code, covering 522 industries.

We determine whether a firm is affected by the listing of a newly classified carcinogen based on

[11] For example, John Manville Corp., a manufacturer of insulation and building products, noted in their June 1994 10-Q filing that fiberglass wool was added to the *RoC* that very month; and Better Minerals & Aggregates noted the *RoC*'s 2000 reclassification of silica from a 'reasonably anticipated' to 'known' carcinogen in its 2000 10-Q.

the firm's SIC code in Compustat in the year prior to each new listing.[12] We consider a firm affected if it operates in a 4-digit SIC code where at least 2.5 percent of workers were observed to be exposed to the carcinogen in the NOES. The cutoff of 2.5 percent captures 52 unique chemical additions to the *RoC* and roughly the top third of observed exposures at the industry level, corresponding to the discoveries that are most likely to result in an increase in legal liability and risk of future distress.

Our financial data on firms are from Compustat, and our data on executive compensation comes from two sources: Yermack (1995) and Execucomp. Yermack (1995) covers approximately 800 large firms for years 1984-1991, and Execucomp covers about 3,000 firms for years 1992-2008. To ensure a consistent sample of observations across specifications, we exclude observations with missing values for cash flow volatility and the inputs necessary to calculate the sensitivity of a manager's wealth to stock price movements and stock price volatility using the manager's portfolio of stocks and options.[13] In all, 69 firms with both financial and compensation data available are affected by a newly identified carcinogen, and these increases in tail risk occur for different firms in 1985, 1989, 1991, 2000, and 2004. These firms operate in 34 different 4-digit SIC industries, and as shown in Appendix Figure 1, these exposed industries are spread across 18 different Fama-French industries.

The use of the NOES likely introduces a degree of measurement error in our ability to identify firms with potential exposures, possibly leading us to underestimate the true effect of tail risk. There are two main measurement issues. First, the NOES only provides data on exposures at the 4-digit industry level; firm level data is not available. Our subsequent analysis implicitly assumes that all firms in the industry are affected and calculates the average effect. If not all firms in the industry are affected, then we are underestimating the true average effect of how compensation affects managers' response to an increase in tail risk. Second, firms may have stopped using a dangerous chemical after the NOES was

[12] To accomplish this, we first convert the NOES data, which are reported using the SIC-1972 coding scheme, to the SIC-1987 coding scheme used by Compustat, by applying an employee-weighted concordance table from the Bureau of Labor Statistics (1989). We then determine which firms were affected by an increase in tail risk based on Compustat's historical measure of a firm's industrial classification.

[13] Because Yermack (1995) does not contain information on a manager's full portfolio of options, we are only able to use information from options granted in the last year to calculate these sensitivities for those observations.

completed in 1983 but before the chemical's listing in the *RoC*. While firms would still be liable for past exposures that occurred while the chemical was still in use, the increase in liability risk would be smaller in such cases.

Despite these measurement concerns, evidence suggests that the NOES indeed captures exposures that later become significant risks. For example, one chemical in our sample is trichloroethylene, which was used in a number of industries including the semiconductor and related devices industry (SIC = 3674). The chemical is often used in semiconductor firms' "clean rooms," and the NOES observed more than 8.5 percent of employees in this industry being exposed.[14] In 2000, trichloroethylene was added to the *RoC* as a probable carcinogen, indicating firms operating in the semiconductor industry were at greater risk of liability and adverse regulatory changes. Other evidence confirms that managers perceived their risk to have increased. Between 1994-1999 and 2000-2005, there was a five-fold increase in the number of semiconductor firms mentioning trichloroethylene in a 10-Q or 10-K filing,[15] and while only a quarter of the 10-K and 10-Q filings in this industry mentioned both the words "exposure" and "liability" between 1994 and 1999, nearly two-thirds of filings mention these words between 2000 and 2005. More directly, trichloroethylene has been the source of recent litigation pertaining to occupational exposures in the semiconductor industry.[16]

For each new chemical's listing in the *RoC*, we construct a comparison group of unaffected firms (firms without observed exposures to any newly listed carcinogens) that were present in both Compustat and our compensation data in the year prior to the *RoC* listing and were in the same Fama and French

[14] Clean rooms are designed to protect semiconductors during their manufacturing by recirculating the air in the room, but in doing so workers can be exposed to high concentrations of trichloroethylene.
[15] For example, MRV Communications Inc. notes in its 2001 10-K filing that trichloroethylene is one of a number of hazardous materials that will be used in a new facility and that "steps will be taken to ensure a high level of safety to protect employees, the facility, surrounding areas, and the environment" from these materials.
[16] Examining equity market returns would be another way to test whether these exposures are salient to managers (and the market), but because *RoC* listings are not associated with exact announcement dates (there is a multi-step review process and information leaks out slowly in the months leading up to a new listing), a standard event study is not feasible. Long-run event studies suggest these exposures are salient, but the results are very noisy. Firms with exposures in our sample experience a two year buy-and-hold return leading up to the announcement that is 5.3 percentage points lower than that of unexposed firms. Although this is consistent with a large effect, the decline is not statistically significant (the standard error is 11 percentage points).

(1997) 48 industry classification as one of the affected firms. (Fama-French industries are collections of 4-digit SIC industries that are meant to represent broader industry categories.) To ensure an adequate control sample in each industry, we drop both affected and unaffected observations in Fama-French industries where there is not at least one unaffected firm for every ten affected firms. (Our findings are robust to using other exclusion thresholds). This yields a comparison sample of 207 unexposed firms in 64 industries.

Firms with exposures to the newly identified carcinogens are very similar to our sample of unexposed firms in the year before the listing of a new carcinogen. The ex-ante characteristics of firms with exposures are reported in column (i) of Table I, and the ex-ante characteristics of firms without exposures are reported in column (ii). Even though we match firms based only on Fama-French industries, the two groups are similar in cash flow volatility, size, recent growth, leverage, and ratios of cash to assets. Compensation and equity-based incentives, as measured by sensitivity to price, sensitivity to volatility, log total pay, and fraction of total pay given as options, are also similar across the two groups of firms. We are unable to reject the null hypothesis that firms whose tail risk increases are similar to other firms in all of these dimensions.

There is also no evidence of any relationship between the increase in tail risk and current cash flows. Average cash flows for exposed and unexposed firms in the year before, the year of, and the year after new carcinogen listings are reported in Table II. In all three years, we are unable to reject the null hypothesis that there is no difference in average cash flows between affected and unaffected firms. This evidence supports the interpretation that the effects of the increase in liability and regulatory risk are caused by changes in tail risk, rather than changes in current cash flows.

To estimate firms' responses to the increase in tail risk, we compare changes in the exposed and unexposed firms' cash flow volatility around the time of each new carcinogen listing in the *RoC*. For each year that new carcinogens are listed in the *RoC*, we construct a cohort of exposed and unexposed firms using firm-year observations for the five years before and the five years after the listing. Firms are not required to be in the sample for the full ten years around the event. We then calculate the pre- and post-tail risk cash flow volatility for each firm using the standard deviation of cash flows / assets. We then pool the data across cohorts (i.e., across all new carcinogen listings) and estimate the average treatment effect. Specifically, we estimate the following firm-panel regression:

$$Volatility_{ijct} = \beta_0 + \beta_1 Exposure_{jct} + \omega_{tc} + \gamma_{ic} + \varepsilon_{ijct}, \quad (1)$$

where *Volatility* is cash flow volatility for firm *i* in period *t*, *Exposure* is an indicator that equals 1 if at least 2.5 percent of employees in cohort *c* and industry *j* were observed to be exposed in the NOES to a known *RoC* carcinogen as of period *t*. For an exposed firm, this indicator changes from 0 to 1 when the chemical is identified in the *RoC* as a carcinogen. We also include firm-cohort fixed effects, γ_{ic}, to ensure that we estimate the impact of exposure after controlling for any fixed differences between firms; and we include period-cohort fixed effects, ω_{tc}, as a nonparametric control for any secular time trends. We allow the firm and period fixed effects to vary by cohort, because this approach is more conservative than including simple fixed effects. We deliberately do not control for any time-varying accounting variables in these regressions because these variables are likely affected by the increase in tail risk and including them would confound estimates of β_1.[17] In any event, including the standard controls does not qualitatively affect the results (see the appendix tables). To account for potential covariance among firm outcomes within the same 4-digit SIC code and over time, we cluster the standard errors at the industry level.

4. Results

4.1 Cash flow volatility and acquisitions

Before analyzing how a manager's compensation scheme influences a firm's response to tail risk, we first show that the average firm responds to an increase in such risk by trying to reduce the likelihood

[17] Because the increase in tail risk is exogenous, β_1 in equation (1) measures the change in cash flow volatility caused by the increased tail risk. If we include endogenous controls, then β_1 would instead measure only the portion of the change in volatility caused by the tail risk that is not driven by causal changes in the other controls. For example, suppose the tail risk leads firms to reduce cash flow volatility by decreasing leverage; then a regression of volatility on the exposure indicator and leverage might yield a coefficient on the exposure indicator that is close to zero – even though exposure caused substantial reduction in cash flow volatility.

of future distress. To do this, we estimate the average effect of tail risk on cash flow volatility. These estimates are reported in Table III. We find that an increase in tail risk is associated with a one percentage point decline in the standard deviation of cash flows normalized by assets. This decline is statistically significant at the ten percent level and corresponds to nearly a third of a standard deviation decline in cash flow volatility in the five years after an increase in tail risk relative to the five years prior to the increase in risk. The estimate is robust to including controls for the market-to-book ratio, book leverage, firm size, and sales growth (see Appendix Table A-I).

This decline in cash flow volatility and risk of distress appears driven by an increase in diversifying acquisitions. To examine the change in total acquisition activity after tail risk increases, we gather data on acquisitions from Securities Data Company's (SDC) U.S. Mergers and Acquisitions Database and run the following industry-panel regression:

$$Ln(deals+1)_{jt} = b_0 + b_1 Exposure_{jt} + \alpha_j + \delta_t + e_{jt}, \tag{2}$$

where *Ln(deals+1)* is the natural log of one plus the total number of deals completed in year t by firms whose primary line of business is industry j. We find similar results if we use the aggregate dollar volume of completed deals rather than the total number. *Exposure* is defined as in equation (1). Industry-level fixed effects, α_j, control for base differences in the level of acquisitions across industries, and year fixed effects, δ_t, control for any secular time trends and changes in the macroeconomy. As in the analysis reported above, we limit the sample to Fama-French industries that experience an exposure during the sample period and measure the impact on exposed industries from the five years before exposure to the five years afterwards. The standard errors are clustered at the industry level.

We find that industries in which workers were exposed to the newly identified carcinogens undertake more diversifying acquisitions after the chemical is listed in the *RoC*. These results are reported in Table IV. Exposed industries complete about five percent more deals on average, relative to industries without an exposure [Column (i)]. Because the specification includes both industry and year fixed effects, the positive coefficient for b_1 indicates the increase in the overall number of acquisitions after tail risk increases, relative to both the typical number of completed deals in these industries before risk increases and the concomitant growth in acquisition activity in unaffected industries. The increase in acquisitions appears driven by diversifying acquisitions. In Columns (ii) and (iii), we separate the acquisitions into related and unrelated acquisitions, where related acquisitions are defined as acquisitions of firms in the acquirer's primary 4-digit SIC industry. We find a significant increase in unrelated acquisitions [Column (iii)] and no significant increase in related acquisitions [Column (ii)].

The timing of the increase in acquisitions largely coincides with the publication of a new carcinogen in the *RoC* and does not seem to reflect a preexisting trend. Figure 1 plots the point estimates from a modified version of equation (2) where the effect of exposure is allowed to vary by year. The annual point estimates show no preexisting trend; in the three years before the increase in tail risk, exposed industries are no more likely to undertake acquisitions than other industries.[18] The point estimates indicate that acquisition activity rises in the year that tail risk increases and remains elevated for the next five years. The precise timing of the growth suggests that it is in fact caused by the increase in tail risk, rather than by any omitted firm or industry characteristic. The timing of the growth also confirms that firms did not anticipate the chemical's being added to the *RoC*.

Overall, firms appear to respond to an increase in tail risk, on average, by trying to reduce the risk of future distress through diversifying acquisitions and less volatile cash flows. This finding builds on the findings of Gormley and Matsa (forthcoming). Analyzing the same increase in tail risk, that paper found firms tend to respond to the increase in tail risk by trying to reduce the probability of future distress by growing and diversifying their cash flows. That paper did not consider the connection between this behavior and executive compensation.

The observed diversifying growth and reduced cash flow volatility may or may not be in shareholders' interests. If distress is costly (Froot, Scharfstein, and Stein 1993; Fluck and Lynch 1999) or

18 The plotted coefficients measure the change in log acquisitions for affected firms relative to other firms. The confidence intervals shown have much less power than estimates from equation (2) because they compare each year separately against the reference period.

causes a loss of organizational capital (Prescott and Visscher 1980; Tomer 1987), reducing the risk for future distress may create value for shareholders. But because the reduced likelihood of distress may also be personally beneficial for managers (Amihud and Lev 1981; Grossman and Hart 1982; Gilson 1989; Holmström 1999; Jensen and Meckling 1976), the observed reductions in firm risk may also reflect an agency conflict between managers and shareholders. Whether or not the observed reduction in firm risk is in shareholders' interests or not, however, is tangential to our subsequent focus on equity-based incentives. We are interested in whether options have a positive or negative effect on managers' motives for risk-taking. Answering this question does not depend on whether or not these motives are in line with that of shareholders following an unexpected increase in tail risk.[19] We next turn to our analysis of compensation and managerial incentives.

4.2 Connection with compensation

In this section, we examine whether firms' attempts to reduce the risk of future distress after tail risk increases are related to the structure of managers' compensation. In theory, more linear contracts, which provide greater exposure to the firm's left-tail risk, such as restricted stock or options that are very much in-the-money, provide a greater incentive to reduce the likelihood of future distress. More convex contracts, such as contracts including more out-of-the money options and fewer shares, provide less exposure to left-tail risk and weaker incentives to reduce risk.

To analyze these predictions, we examine whether the observed decline in cash flow volatility varies depending the manager's compensation structure in the year prior to the increase in tail risk. (Our findings are also robust to instead using the average incentives in the three years prior to the increase in tail risk.) In using a manager's compensation structure prior to an increase in tail risk, we are making a few implicit assumptions. First, we are assuming that a manager's compensation structure does not adjust

[19] Whether more equity-based incentives reduce the likelihood of an agency conflict is also unclear. Agency problems are likely to be particularly severe for risk-averse managers who have much of their wealth tied to the value of the firm's assets (Holmström 1999; Parrino, Poteshman, and Weisbach 2005; Hugonnier and Morellec 2007). Although high managerial ownership may help reduce other agency conflicts by inducing a manager to work hard, it exacerbates the agency problem arising from the manager's risk aversion by increasing a manager's personal exposure to the firm's risk and giving the manager a greater incentive to reduce that risk.

instantaneously to the increase in tail risk. While shareholders certainly adjust CEO incentives at various points in time, much of managers' incentives are given by their existing portfolio of stocks and options, which cannot be easily or quickly changed to reflect the new business environment (Zhou 2001).[20] Second, we are assuming that the increased tail risk was not anticipated by shareholders at the time the compensation was determined. The precise timing of the growth, shown in Figure 1, confirms that firms did not appear to anticipate the increase in tail risk. Firms begin to diversify only after the chemicals are added to the *RoC*. Moreover, we see in Table I that before chemicals are added to the *RoC,* compensation was not observably different between firms with exposures and those without.

4.2.1 Sensitivity to Price and Sensitivity to Volatility

As our first measure of manager's compensation structure, we calculate each manager's sensitivity to stock price movements from their portfolio of stocks and options in the year before tail risk increases. We use the Core and Guay (2002) definition for sensitivity to price – the dollar change in wealth experienced by the manager for a one percent increase in the firm's stock price. This type of sensitivity measure is commonly referred to as the "delta" of a manager's portfolio. A higher sensitivity to price indicates that the manager has greater exposure to the firm's tail risk. As a robustness check, we also use Jensen and Murphy's (1990) estimate of the manager's sensitivity – the dollar change in wealth for a dollar change in firm value – and the Edmans, Gabaix, and Landier (2009) estimate of sensitivity – the percent change in wealth for a one percent increase in the firm's stock price – as two other linear measures of managers' exposure to the firm's risk. To analyze how sensitivity to price is related to firms' responses, we compare the response of exposed firms with above median sensitivity with that of unexposed firms with above median sensitivity. We then perform the same comparison for firms with below median sensitivity. These results are reported in Table V.

We find that managers with a high sensitivity to price tend to respond to the increase in tail risk

[20] If this assumption is violated, however, it would only work against us in finding an effect. That is, if shareholders could quickly adjust the managers' compensation after the tail risk increases, there would be less reason to expect ex-ante compensation to affect CEOs responses to an increase in left-tail risk.

by reducing cash flow volatility sharply, whereas managers with a low sensitivity to price do not. As reported in Table V, column (i), exposed firms where managers have a high sensitivity reduce cash flow volatility by 1.5 percentage points, on average, after the increase in tail risk relative to other high sensitivity firms that are not exposed to the liability. The observed decline in volatility is statistically significant at the five percent level and corresponds to nearly a half of a standard deviation decline. Firms with managers that have a low sensitivity to price, as reported in column (ii), only reduce volatility, on average, by 0.6 percentage points, and it is not statistically significant at conventional levels. The findings are similar when we use other measures of managers' sensitivity to price. Exposed firms with above median Jensen and Murphy (1990) sensitivity reduce volatility by 1.7 percentage points relative to unexposed, above median sensitivity firms [Columns (iii)-(iv)]. Firms with a below median Jensen-Murphy sensitivity do not exhibit any significant decline in volatility in response to the increase in tail risk. We find similar results with the Edmans, Gabaix, and Landier (2009) measure of sensitivity to price [Columns (v)-(vi)], and all findings are robust to controlling for market-to-book ratios, book leverage, firm size, and sales growth (see Appendix Table A-II).

To measure the convexity of managers' incentives, we calculate each manager's sensitivity to stock price volatility from their portfolio of options in the year before tail risk increases. This measure of sensitivity is defined as the dollar change in wealth experienced by the manager for a 0.01 increase in the volatility of a firm's stock price. This measure of sensitivity is commonly referred to as the "vega" of a manager's portfolio and has been used to measure a manager's incentive to take risks (e.g. Guay, 1999; Habib and Ljungqvist, 2005). A low sensitivity to volatility indicates that the manager has a relatively symmetric payoff exposure to movements in the firm's stock, whereas a high sensitivity indicates that manager's payoff function is relatively more convex in the firm's stock price. Because such convexity is driven by options, this would imply that the manager has relatively less exposure to low realizations of firm value (i.e., left-tail risk) then to high realizations of firm value.

We find that managers with a low sensitivity to volatility tend to respond to the increase in left-tail risk by reducing cash flow volatility sharply, whereas managers with a relatively high sensitivity to volatility do not. As reported in Table VI, column (i), exposed firms with high-volatility-sensitive managers reduce volatility by only 0.2 percentage points, on average, relative to unexposed firms with high-volatility-sensitive managers, and this difference is not statistically significant at conventional levels. On the other hand, firms with a low sensitivity to volatility reduce cash flow volatility by 1.9 percentage points (more than a half standard deviation), on average, and this decline is statistically significant at the six percent level [Column (ii)]. The results are robust to additional controls (see Appendix Table A-III).

Combined, the sensitivity to volatility and sensitivity to price findings illustrate options' competing effects on a manager's risk-taking incentives. Options increase managers' sensitivity to both price and volatility, but the greater sensitivity to price reduces risk-taking incentives while greater sensitivity to volatility increases them. These competing effects are further illustrated when we subdivide the sample based on both types of sensitivity and re-estimate the effect of tail risk on volatility. The results are reported in Table VII. Only when managers have both a low sensitivity to volatility and high sensitivity to price do we observe a statistically significant decline in cash flow volatility [second row of Column (ii)]. Because of these competing effects, Dittmann and Yu (2010) propose using the sensitivity of volatility scaled by the sensitivity of price as an alternative measure of options' incentives for risk-taking. As reported in Table VI, columns (iii)-(iv), this ratio is also positively related to reductions in cash flow volatility after tail risk increases.

4.2.2 Moneyness of Options and Total Pay

We next test whether the observed response to an increase in tail risk is related to other compensation features that might affect risk-taking incentives: the moneyness of the manager's options and total pay. Similar to owning shares, options that are in-the-money provide a greater exposure to the firm's left-tail risk, whereas options that are out-of-the-money provide less exposure to this risk. This implies the moneyness of a managers' option portfolio should be negatively related to risk-taking. Risk-taking incentives may also matter less when managers are wealthy and receive a high amount of total pay if this moves managers to a relatively less risk-averse portion of their utility function (Ross 2004).[21]

To measure the moneyness of a manager's portfolio of options, we use the difference between the average exercise price and the current stock price to estimate the likelihood of a manager's options expiring in the money.[22] Because data on a manager's full portfolio of options is not available in the Yermack executive compensation data, we use only the sample of Execucomp firms for this analysis. The estimates of how firms' responses to an increase in tail risk vary based on the moneyness of their managers options are provided in Table VIII, Columns (i)-(ii).

We find that managers with more in-the-money options respond to the increase in tail risk by decreasing cash flow volatility sharply, whereas managers with more out-of-the-money options do not. As reported in Table VIII, Column (i), exposed firms run by a manager with an above median moneyness for his/her options respond to an increase in tail risk by reducing volatility relative to unexposed firms with above average moneyness. For exposed firms with a below median moneyness on the managers' options, there is no evidence of a decline in volatility relative to unexposed firms, and if anything the observed response of these low moneyness firms is positive [Column (ii)]. The findings are also robust to including additional controls (see Appendix Table A-IV).

We also find that managers with less overall pay appear to respond more aggressively when tail risk increases. As reported in Table VIII, Column (iv), relative to unexposed firms run by managers with below median total pay, exposed firms with below median total pay reduce volatility after tail risk increases. Managers with above median pay do not exhibit a statistically significant decline in volatility [Column (iv)]. The findings are robust to including additional controls (see Appendix Table A-IV) and, to the extent that total pay is positively correlated with wealth, suggest that managers with greater wealth

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[21] Lambert, Larcker and Verrechia (1991) make a similar theoretical argument. Empirically, Becker (2006) and Neyland (2010) use Swedish data and CEO divorces, respectively, to confirm that wealth affects a manager's risk tolerance.

[22] More precisely, we first calculate $[\ln(S/K)+rT]/\sigma\sqrt{T}$, where S is the current stock price, K is the average exercise price, r is the risk-free rate, T is the average time to expiration, and σ is the historic volatility of the firm's stock price. This measure captures the average number of standard deviations the existing stock price, adjusted forward by the risk-free rate, is above the average exercise price. We then use the standard normal distribution to convert this number into a likelihood of the average options expiring in the money.

are less sensitive to risk. This might occur if additional pay or wealth tends to move the average manager to a less risk-averse portion of their utility function. To analyze this possibility further, we subdivide the sample based on both total pay and managers' sensitivity to price. These estimates are reported in Table IX. Consistent with managers' sensitivity to risk declining with total pay, a high sensitivity to price is only associated with a decline in volatility among managers with below median total pay.

4.2.3 Net Effect of Options

We also test the net relationship between options and managers' responses to left-tail risk. Because a larger portfolio of options can increase both a manager's sensitivity to price and his/her sensitivity to volatility, the net effect of options on managerial incentives regarding risk is uncertain. A larger sensitivity to price increases managerial incentives to reduce risk, while a larger sensitivity to volatility decreases incentives to reduce risk. Estimates of the net effect of options are reported in Table X.

The net effect of options appears to *decrease* managers' incentives to reduce risk after tail risk increases. Firms with a potential exposure and below median usage of options decrease cash flow volatility, on average, by 2.3 percentage points after tail risk increases relative to other low option firms [Table X, Column (ii)]. Exposed firms with a high usage of options, however, do not respond to an increase in tail risk relative to other high option firms [Column (i)]. These findings are also robust to including time-varying controls for log assets, debt/assets, sales growth, and market-to-book ratio [Columns (iii)-(iv)]. Overall, these findings suggest that, on average, granting managers more options tends to decrease their incentives to undertake risk-reducing activities.

5. Interpretation and Robustness Analysis

Overall, the findings appear to confirm that the structure of a manager's compensation influences risk-taking choices even if this might not be the primary objective of corporate boards as per Hayes, Lemmon, and Qiu (2010). Firms whose managers have compensation structures that provide greater exposure to their firm's left-tail risk appear more likely to act to reduce their firm's exposure to this risk.

Managers with high sensitivity to price, low sensitivity to volatility, a large share of the option-based compensation, and a greater moneyness in their existing options, respond with significant decreases in cash flow volatility to an increase in tail risk. On the other hand, managers with low sensitivity to price, high sensitivity to volatility, a small share of option-based compensation, and less moneyness of their existing options do not reduce volatility, on average, after tail risk increases – consistent with these managers having weaker incentives to reduce their firm's exposure to left-tail risk.

One possible concern with this interpretation is that an omitted variable could be related to both a manager's *ex ante* incentive structure in the year before risk increases and the firm's optimal response afterwards. For example, Gormley and Matsa (forthcoming) find that firms with greater ex-ante bankruptcy risk (as measured by the modified Altman-Z score), smaller firms, and more levered firms, are more likely to engage in diversifying growth after tail risk increases, because these firms experience a much larger increase in the likelihood of distress. If these factors are related to the initial choice of compensation structure, then they, rather than incentives from the compensation, might explain our findings. Likewise, if a manager's initial compensation scheme is related to the firm's external governance or investment opportunities, and if these affect how firms respond to an increase in tail risk, then our findings could reflect these determinants of the initial compensation structure rather the influence of compensation incentives on the manager's risk-taking choices.

Our findings, however, do not appear driven by such factors. When comparing the ex-ante characteristics of low and high price sensitivity firms, as reported in Table XI, we find that there is no difference in cash flow volatility or leverage, and that it is low price sensitivity firms, rather than high price sensitivity firms, that have a higher ex-ante bankruptcy risk (as measured by the modified Altman-Z score).[23] Likewise, there is no ex-ante difference between firms with high and low sensitivity to volatility with respect to cash flow volatility, and it is firms with high sensitivity to volatility rather than firms with low sensitivity to volatility that have greater leverage and higher bankruptcy risk, on average. And while

[23] Following MacKie-Mason (1990), we calculate a modified-Altman z-score as 3.3*(EBIT/assets)+1.0*(sales/assets) +1.4*(retained earnings/assets)+1.2*(working capital/assets). Including the ratio of market equity to book debt decreases our sample size by about 20 percent.

firms with low sensitivity to volatility are smaller, we find that *within* the subsample of small firms, firms with a low sensitivity to volatility are more likely to grow, on average, in response to the increase in tail risk (see Table XII).

The greater growth among firms with high sensitivity to price and low sensitivity to volatility also does not appear driven by differences in investment opportunities or external governance. As reported in Table XI, there is no difference in the external governance, as measured by the Gompers, Ishii, and Metrick (GIM) governance index for firms with high and low sensitivity to volatility.[24] There is also no difference in the market-to-book ratio, a potential proxy for investment opportunities. And while there is evidence that firms with a high sensitivity to price have a higher average market-to-book ratio prior to the increase in tail risk, we find that the increase in growth among firms with high sensitivity to price is driven by those with a low market-to-book ratio rather than firms with a high market-to-book ratio (see Table XIII). This suggests the observed differential growth among firms with high sensitivity to price is not driven by differences in investment opportunities for these firms.

Unobservable differences in managerial risk preferences are also unlikely to explain our findings. While a manager's risk preferences will be directly related to both the initial contract and a manager's desired response to an increase in tail risk, this omitted variable would bias our findings in the opposite direction. Theory suggests that the optimal contract for managers with greater risk aversion will be more convex. If unobservable risk preferences were then driving our observed responses, we would expect to find that more convexity (i.e., sensitivity to volatility) would be associated with more risk-reducing activities following the increase in tail risk. We observe the opposite.

6. Changes in stock and option holdings

In this last section, we examine whether managers attempt to adjust their equity exposure in response to an increase in their firm's tail risk. We might expect managers to reduce their stock and

[24] Because the GIM-index is available only from 1990, we are only able to compare the ex-ante governance characteristics for increases in tail risk that occur after 1990.

option holdings in an attempt to reduce their personal exposure to risk.[25] To test whether managers' equity exposure responds to the increase in tail risk, we re-estimate equation (1) with dependent variables measuring managers' stock and option holdings and the value of options exercised. Like before, we restrict the sample of comparison firms to those located in the same Fama-French industry as firms experiencing increases in tail risk. The results are reported in Table XIV.

There is weak evidence that managers attempt to reduce their equity exposure. The relative number of shares held by managers of exposed firms declines by an average of 0.26 log points, or 30 percent, after tail risk increases. This decline is statistically significant at the ten percent level [Table XIV, Column (i)]. Managers also appear to increase the amount of options they exercise. After tail risk increases, the total value of options exercised normalized by total pay increases [Column (ii)], and while not statistically significant, the average number of vested options held also decreases [Column (iii)].

7. Conclusion

Every firm is exposed to business risks, including the possibilities of large, adverse shocks. Potential sources for such shocks abound – examples include new technologies that reduce barriers to entry, disruptive product innovations, the relaxation of international trade barriers, and changes in government regulations. The results presented in this paper suggest that the structure of managers' compensation significantly affects how managers will guide their firms in reaction to such tail risks.

When a firm learns that it's exposing workers to carcinogens, the risks of a significant corporate legal liability and costly workplace regulations increase. We find that CEOs with compensation that is more like straight equity (e.g., has more restricted stock, a high sensitivity to stock price movements, and deep in-the-money options) tend to reduce cash flow volatility after these risks increase. Firms whose CEOs have compensation heavily weighted on the upside (e.g, more out-of-the money options and a high sensitivity to stock price volatility) tend to roll the dice by not reducing cash flow volatility so as to insulate the firm from the risk.

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[25] We might also expect boards to adjust managers' compensation to reflect the new risk. However, we find little evidence of a change in average total pay, sensitivity to price, or sensitivity to volatility following the increase in tail risk. This might reflect that incentives are difficult for firms to adjust quickly (Zhou 2001).

These effects highlight the importance of boards structuring executives' compensation correctly in order to complement their desired corporate strategy. Holding constant total compensation, boards interested in discouraging excessive risk-taking could use restricted stock; whereas other boards could grant options to provide incentives for greater risk. Granting stock options that are far out of the money encourage the greatest risk-taking, even while they are relatively inexpensive when issued.

Finally, our results may also shed light on debate about whether the structure of employee compensation played a role in the risk-taking practices of financial institutions in the lead up to the recent financial crisis (e.g., Rajan 2008). The financial sector tends to have a high proportion of compensation for senior executives in the form of restricted stock grants (Clementi et al. 2009). Our results indicate that such compensation is unlikely to cause excess risk-taking, potentially supporting the idea that senior management does not have the granular knowledge required to properly manage the company's risk book (Robert Rubin, quoted in Brown and Enrich 2008). Deeper in the organization in areas like sales and trading, securitization, and financial engineering, however, bonus pools were typically allocated based on current-period performance, providing large bonuses for good performance. Although we do not study financial firms directly, our results suggest that this sort of compensation scheme with option-like features and limited clawback provisions will provide strong incentives for corporate risk-taking.

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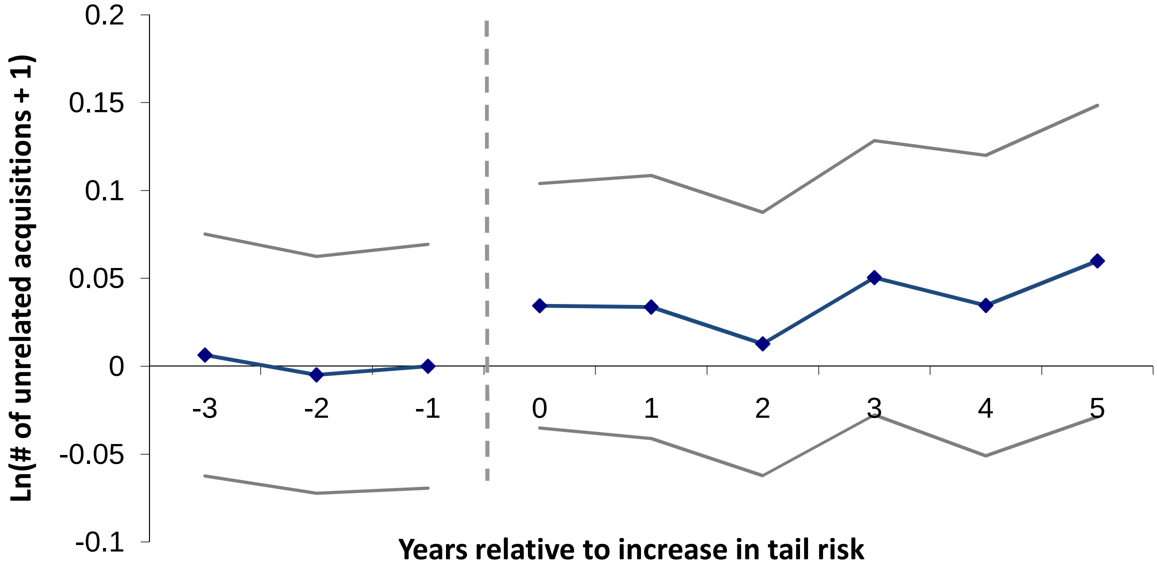


Figure 1 -- Effect of exposure on unrelated acquisitions by year

This figure reports the point estimates from an industry-panel regression of ln(number of acquisitions + 1) onto an indicator for exposure, industry fixed effects, and year fixed effects. The specification is the same as that reported in Table 4, column (iii), except that the effect of exposure is allowed to vary by year for each year from three years before the increase in tail risk through five years after. Ninety-five percent confidence intervals, adjusted for clustering at the industry level, are also plotted.

Table I
Ex-ante firm characteristics

This table reports summary statistics for firm characteristics in the year before a new chemical was added to the *Report on Carcinogens*. The mean and standard deviation (in parentheses) for each variable are reported separately for two samples of firms. Column (i) reports estimates for firms in 4-digit SIC industries for which more than 2.5% of employees were observed to be exposed to the chemical in the 1981-1983 National Occupational Exposure Survey. Column (ii) reports estimates for other firms in the same Fama-French 48 industry classification. Column (iii) reports the p-value from a t-test for the difference between exposed and unexposed firms, where the standard errors are clustered at the 4-digit SIC industry level. The sample is restricted to firms with nonmissing observations for cash flow volatility, sensitivity to price, and sensitivity to volatility.

	Exposed	**Unexposed**	**p-value of difference**
	(i)	(ii)	(iii)
Firm Characteristics			
Volatility(Cash Flows/Assets)	0.053	0.049	0.600
	(0.034)	(0.031)	
Ln(Assets)	7.690	7.450	0.204
	(0.971)	(1.358)	
5-year asset CAGR (%)	-15.26	-12.94	0.827
	(38.23)	(54.58)	
Leverage	0.257	0.249	0.791
	(0.156)	(0.140)	
Cash / Assets	0.044	0.038	0.656
	(0.065)	(0.059)	
Compensation Characteristics			
Sensitivity to Price	580.6	732.6	0.691
	(1971.6)	(3965.1)	
Sensitivity to Volatility	25.15	44.17	0.411
	(97.79)	(231.98)	
Ln(Total Pay)	7.010	7.161	0.352
	(0.712)	(1.113)	
Options/Total Pay	0.221	0.239	0.653
	(0.220)	(0.255)	
Observations	69	207	
# of Industries	34	64	

Table II
Cash flows around time of liability shock

This table reports summary statistics for cash flows/assets in the years around a new chemical being added to the *Report on Carcinogens.* The mean and standard deviation (in parentheses) for cash flows in the years t = -1, t = 0, and t = 1, are reported separately for two samples of firms. Column (i) reports estimates for firms in 4-digit SIC industries for which more than 2.5% of employees were observed to be exposed to the chemical in the 1981-1983 National Occupational Exposure Survey. Column (ii) reports estimates for other firms in the same Fama-French 48 industry classification. Column (iii) reports the p-value from a t-test for the difference between exposed and unexposed firms, where the standard errors are clustered at the 4-digit SIC industry level. The sample is restricted to firms with nonmissing observations for cash flow volatility, sensitivity to price, and sensitivity to volatility.

Year relative to liability shock	Exposed	Unexposed	p-value of difference
	(i)	(ii)	(iii)
t = -1	0.154	0.170	0.236
	(0.073)	(0.084)	
t = 0	0.151	0.162	0.530
	(0.071)	(0.079)	
t = 1	0.151	0.161	0.474
	(0.068)	(0.095)	

Table III
Effect of exposure on cash flow volatility

This table reports coefficients from firm-panel regressions of cash flow volatility on an indicator for exposure, firm-by-cohort fixed effects, and period-by-cohort fixed effects. The exposure indicator equals 1 if more than 2.5% of employees in the firm's 4-digit SIC industry were observed to be exposed in the 1981-1983 National Occupational Exposure Survey to a chemical listed in the most recent edition of the *Report on Carcinogens (RoC)*. For each firm, cash flow volatility is calculated for both the 5 years before and 5 years after the increase in tail risk using the standard deviation of (cash flows/assets). The data includes pre- and post-risk cash flow volatility for all firms with nonmissing observations for cash flow volatility, sensitivity to price, and sensitivity to volatility in the year prior to a new *RoC* listing. Standard errors, clustered at the industry level, are reported in parentheses. * significant at 10% level.

Dep. Variable =	**Volatility (Cash Flows/Assets)**
	(i)
Exposure	-0.010*
	(0.006)
Observations	532
# of Firms	276
R-Squared	0.03
Fixed effects:	
Firm-cohort	X
Period-cohort	X

Table IV
Effect of exposure on acquisition activity

This table reports coefficients from industry-panel regressions of *ln(acquisitions+1)* on an indicator for exposure, industry fixed effects, and year fixed effects. The exposure indicator equals 1 if more than 2.5% of employees in the firm's four-digit SIC industry were observed to be exposed in the 1981-1983 National Occupational Exposure Survey to a chemical listed in the most recent edition of the *Report on Carcinogens* (*RoC*). We further classify acquisitions into two types: "related" if the primary SIC industry for the acquiring firm coincides with the primary SIC code of the target and "unrelated" if the acquirer's primary SIC code does not match the primary SIC code listed for the target. The sample includes all acquisitions announced between 1980 and 2006 that were recorded in SDC's Mergers and Acquisitions Database, but it excludes acquisitions meeting any of the following criteria: (1) the ratio of the deal size to market value of the acquirer's assets is less than 1%; (2) the acquiring firm controlled more than 50% of the target prior to the announcement date or less than 100% after the acquisition was completed; (3) the ultimate parent of the acquirer and the target are the same (i.e., consolidations within holding companies); (4) either the acquirer or the target is a financial firm; or (5) the deal was not completed within 1,000 days of the announcement date. We also exclude Fama-French (1997) industries where none of the included four-digit SIC codes experience an exposure during the sample period. Standard errors, clustered at the industry level, are reported in parentheses. * significant at 10% level, ** significant at 5% level.

Dependent Variable **= Ln(Number of Acquisitions + 1)**
[850 Industries; 22,950 Observations]

	Type of Acquistions		
	All	**Related**	**Unrelated**
	(i)	(ii)	(iii)
Exposure	0.053**	0.017	0.052**
	(0.024)	(0.018)	(0.021)
Observations	16,034	16,034	16,034
# of Industries	850	850	850
R-Squared	0.19	0.12	0.14
Fixed effects:			
Industry	X	X	X
Year	X	X	X

Table V
Sensitivity to stock price movements and the effects of exposure

This table reports coefficients from firm-panel regressions of cash flow volatility on an indicator for exposure, firm-by-cohort fixed effects, and period-by-cohort fixed effects. The specifications are the same as those reported in Table III, Column (i), but estimates are obtained for different subsamples of firms: firms with above and below median sensitivity to stock price movements as measured by Core and Guay (2002) [columns (i)-(ii)], firms with above and below median Jensen-Murphy sensitivity to price [columns (iii)-(iv)], and firms with above and below median Edmans-Gabaix-Landier sensitivity to price [columns (v)-(vi)]. Standard errors, clustered at the industry level, are reported in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Dep. Variable = Volatility(Cash Flows / Assets)

	Sensitivity to Price		**Jensen-Murphy**		**Edmans, et al.**	
	High	**Low**	**High**	**Low**	**High**	**Low**
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Exposure	-0.015**	-0.006	-0.017**	0.001	-0.017*	-0.005
	(0.007)	(0.009)	(0.007)	(0.007)	(0.008)	(0.008)
Observations	268	264	263	267	262	266
# of Firms	138	138	137	138	136	138
R-Squared	0.08	0.11	0.06	0.03	0.07	0.10
Fixed effects:						
Firm-cohort	X	X	X	X	X	X
Period-cohort	X	X	X	X	X	X

Table VI

Sensitivity to volatility and the effects of exposure

This table reports coefficients from firm-panel regressions of cash flow volatility on an indicator for exposure, firm-by-cohort fixed effects, and period-by-cohort fixed effects. The specifications are the same as those reported in Table III, Column (i), but estimates are obtained for different subsamples of firms: firms with above and below median sensitivity to volatility [columns (i)-(ii)] and firms with above and below median sensitivity to volatility/sensitivity to price [columns (iii)-(iv)]. Standard errors, clustered at the industry level, are reported in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Dep. Variable = Volatility(Cash Flows / Assets)

	Sensitivity to Volatility		**Sensitivity to Volatility / Sensitivity to Price**	
	High (i)	**Low** (ii)	**High** (iii)	**Low** (iv)
Exposure	-0.001	-0.022*	0.002	-0.022**
	(0.007)	(0.011)	(0.008)	(0.009)
Observations	262	270	258	268
# of Firms	135	141	133	140
R-Squared	0.02	0.09	0.07	0.11
Fixed effects:				
Firm-cohort	X	X	X	X
Period-cohort	X	X	X	X

Table VII

Heterogeneity based sensitivity to price and sensitivity to volatility

This table reports coefficients from firm-panel regressions of firm size on an indicator for exposure, firm-by-cohort fixed effects, and period-by-cohort fixed effects. The specifications are the same as those reported in Table III, Column (i), but Column (i) restricts the sample to firms with above median sensitivity to volatility while Column (ii) restricts the sample to firms with below median sensitivity to volatility The estimates reported in the first row further restrict the sample to firms with below median sensitivity to price, and the estimates reported in the second row further restrict the sample to firms with above median sensitivity to price. The dependent variable is the volatility of (cash flows/assets). Standard errors, clustered at the industry level, are reported in parentheses. *** significant at 1% level.

Dep. Variable =	**Volatility(Cash Flows / Assets)**			
	(i)	(ii)		
	High Sensitivity to Volatility *[Above median value at t=-1]*	**Low Sensitivity to Volatility** *[Below median value at t=-1]*	**Number of firms** ***Number of observations***	
Low Sensitivity to Price *[Sensitivity below median at t=-1]*	0.003 (0.010)	-0.011 (0.017)	63 *120*	75 *144*
High Sensitivity to Price *[Sensitivity above median at t=-1]*	-0.002 (0.009)	-0.032*** (0.011)	72 *142*	66 *126*

Table VIII

Moneyness, total pay and the effects of exposure

This table reports coefficients from firm-panel regressions of cash flow volatility on an indicator for exposure, firm-by-cohort fixed effects, and period-by-cohort fixed effects. The specifications are the same as those reported in Table III, Column (i), but estimates are obtained for different subsamples of firms: firms with above and below median moneyness of options [columns (i)-(ii)], and firms with above and below median total pay [columns (iii)-(iv)]. Standard errors, clustered at the industry level, are reported in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Dep. Variable = Volatility(Cash Flows / Assets)

	Moneyness of Options		**Total Pay**	
	High (i)	**Low** (ii)	**High** (iii)	**Low** (iv)
Exposure	-0.033***	0.015	-0.003	-0.015*
	(0.005)	(0.015)	(0.008)	(0.009)
Observations	70	72	265	265
# of Firms	37	38	137	138
R-Squared	0.23	0.07	0.03	0.07
Fixed effects:				
Firm-cohort	X	X	X	X
Period-cohort	X	X	X	X

Table IX
Heterogeneity based total pay and sensitivity to price

This table reports coefficients from firm-panel regressions of firm size on an indicator for exposure, firm-by-cohort fixed effects, and period-by-cohort fixed effects. The specifications are the same as those reported in Table III, Column (i), but Column (i) restricts the sample to firms with below median sensitivity to price while Column (ii) restricts the sample to firms with above median sensitivity to price. The estimates reported in the first row further restrict the sample to firms with a below median total pay and the estimates reported in the second row further restrict the sample to firms with an above median total pay. The dependent variable is the volatility of (cash flows/assets). Standard errors, clustered at the industry level, are reported in parentheses. ** significant at 5% level.

Dep. Variable =	**Volatility(Cash Flows / Assets)**			
	(i)	(ii)		
	Low Sensitivity to Price *[Below median value at t=-1]*	**High Sensitivity to Price** *[Above median value at t=-1]*	**Number of firms** ***Number of observations***	
Low Total Pay *[Total pay below median at t=-1]*	-0.008 (0.015)	-0.027*** (0.009)	86 *165*	53 *102*
High Total Pay *[Total pay above median at t=-1]*	-0.002 (0.011)	-0.004 (0.010)	52 *99*	85 *166*

Table X
Options and the effects of exposure

This table reports coefficients from firm-panel regressions of cash flow volatility on an indicator for exposure, firm-by-cohort fixed effects, and period-by-cohort fixed effects. The specifications are the same as those reported in Table III, Column (i), but estimates are obtained for different subsamples of firms: firms with above median options as a share of total pay [Columns (i) and (iii)], and firms with below median options as a share of total pay [Columns (ii) and (iv)]. The specifications in Columns (iii)-(iv) include time-varying controls for Ln(asset), debt/ assets, sales growth, and market-to-book ratio/100. Because there is only one pre- and post-risk observation for each firm, the additional controls are measured as of t-1 and t=0. Standard errors, clustered at the industry level, are reported in parentheses. ** significant at 5% level.

Dep. Variable = Volatility(Cash Flows / Assets)

	Options / Total Pay			
	High (i)	**Low** (ii)	**High** (iii)	**Low** (iv)
Exposure	-0.002	-0.024**	-0.003	-0.024**
	(0.008)	(0.010)	(0.008)	(0.010)
Observations	259	269	256	263
# of Firms	133	141	131	138
R-Squared	0.04	0.11	0.08	0.16
Additional controls			X	X
Fixed effects:				
Firm-cohort	X	X	X	X
Period-cohort	X	X	X	X

Table XI
Ex-ante firm characteristics, by compensation incentives

This table reports summary statistics for firm characteristics in the year before a new chemical was added to the *Report on Carcinogens* similar to what was done in Table I, but the summary statistics are now broken down by firms with above and below median sensitivity to price [Columns (i)-(ii)] and firms with above and below median sensitivity to volatility [Columns (iv)-(v)]. The mean and standard deviation (in parentheses) for each variable are reported separately for two samples of firms. Columns (iii) and (vi) report the p-value from a t-test for the difference between high and low sensitivity to price and sensitivity to volatility firms, where the standard errors are clustered at the 4-digit SIC industry level. The sample is restricted to firms with nonmissing observations for cash flow volatility, sensitivity to price, and sensitivity to volatility.

	Sensitivity to Price		p-value of difference	Sensitivity to Volatility		p-value of difference
	High	Low		High	Low	
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Volatility(Cash Flows / Assets)	0.051	0.048	0.495	0.047	0.052	0.175
	(0.031)	(0.033)		(0.030)	(0.034)	
Ln(Assets)	7.596	7.426	0.418	7.917	7.048	0.000
	(1.377)	(1.159)		(1.177)	(1.224)	
Market-to-book ratio	2.831	1.907	0.005	2.363	2.369	0.985
	(5.451)	(2.448)		(5.355)	(2.396)	
Modified Altman-Z Score	2.435	2.073	0.054	2.134	2.392	0.046
	(1.019)	(1.162)		(0.975)	(1.228)	
Debt / Assets	0.242	0.261	0.403	0.277	0.222	0.001
	(0.155)	(0.132)		(0.140)	(0.143)	
Governance (GIM Index)	9.146	9.278	0.792	9.500	8.841	0.348
	(2.917)	(2.722)		(2.590)	(3.050)	

Table XII
Heterogeneity based firm size and sensitivity to volatility

This table reports coefficients from firm-panel regressions of firm size on an indicator for exposure, firm-by-cohort fixed effects, and period-by-cohort fixed effects. The specifications are the same as those reported in Table III, Column (i), but Column (i) restricts the sample to firms with below median sensitivity to volatility while Column (ii) restricts the sample to firms with above median sensitivity to volatility The estimates reported in the first row further restrict the sample to firms with below median assets, and the estimates reported in the second row further restrict the sample to firms with above median assets. The dependent variable is the volatility of (cash flows/assets). Standard errors, clustered at the industry level, are reported in parentheses. * significant at 10% level.

Dep. Variable =	**Volatility(Cash Flows / Assets)**			
	(i)	(ii)		
	Low Sensitivity to Volatility *[Below median value at t=-1]*	**High Sensitivity to Volatility** *[Above median value at t=-1]*	**Number of firms** ***Number of observations***	
Small Firm	-0.024*	0.004	92	49
[Assets below median at t=-1]	(0.012)	(0.011)	*176*	*96*
Large Firm	-0.027*	-0.004	49	86
[Assets above median at t=-1]	(0.015)	(0.009)	*94*	*166*

Table XIII
Heterogeneity based MTB and sensitivity to price

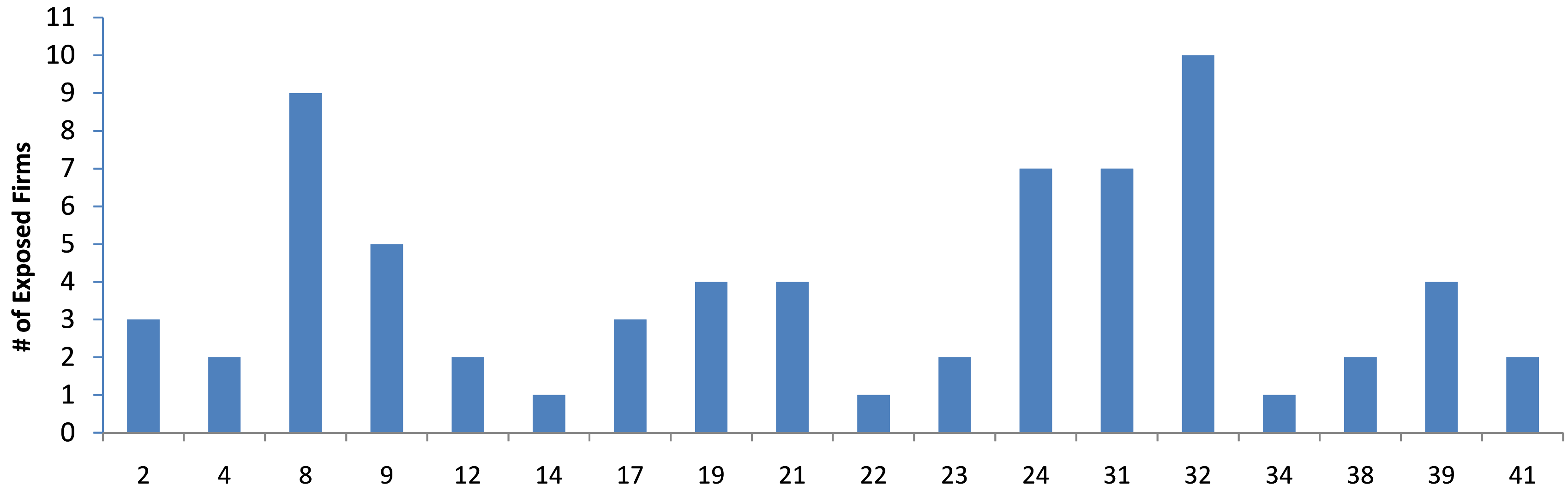
This table reports coefficients from firm-panel regressions of firm size on an indicator for exposure, firm-by-cohort fixed effects, and period-by-cohort fixed effects. The specifications are the same as those reported in Table III, Column (i), but Column (i) restricts the sample to firms with below median sensitivity to price while Column (ii) restricts the sample to firms with above median sensitivity to price. The estimates reported in the first row further restrict the sample to firms with a below median market-to-book ratio and the estimates reported in the second row further restrict the sample to firms with an above median market-to-book ratio. The dependent variable is the volatility of (cash flows/assets). Standard errors, clustered at the industry level, are reported in parentheses. ** significant at 5% level.

Dep. Variable =	**Volatility(Cash Flows / Assets)**			
	(i)	(ii)		
	Low Sensitivity to Price *[Below median value at t=-1]*	**High Sensitivity to Price** *[Above median value at t=-1]*	**Number of firms** ***Number of observations***	
Low Market-to-Book *[MTB below median at t=-1]*	-0.001 (0.007)	-0.028** (0.012)	89 *168*	53 *101*
High Market-to-Book *[MTB above median at t=-1]*	-0.023 (0.032)	-0.013 (0.008)	49 *96*	85 *167*

Table XIV
Effect of exposure on stock and option holdings

This table reports coefficients from firm-panel regressions of managerial stock and option holdings on an indicator for exposure, firm-by-cohort fixed effects, and period-by-cohort fixed effects. The specifications are the same as those reported in Table III, Column (i) but for different dependent variables: ln(# of shares owned) [Column (i)], value of options exercised / total pay [Column (ii)], and ln(# of vested options held) [Column (iii)]. Standard errors, clustered at the industry level, are reported in parentheses. * significant at 10% level.

Dep. Variable =	**Ln(# of shares owned)**	**Value of options exercised / Total pay**	**Ln(# of vested options held)**
	(i)	(ii)	(iii)
Exposure	-0.262*	0.438*	-0.204
	(0.148)	(0.241)	(0.237)
Observations	1,047	823	1,685
# of Firms	163	101	222
R-Squared	0.16	0.18	0.65
Fixed effects:			
Firm-cohort	X	X	X
Period-cohort	X	X	X



Appendix Figure 1-- Number of firms affected by the tail risk by Fama-French 48 industry code

This figure graphs the number of firms newly affected by the tail risk by their Fama-French 48 industry code. A firm is considered affected if at least 2.5 percent of employees in its 4-digit SIC industry were observed in the National Occupational Exposure Survey to be exposed to a chemical listed in the *Report on Carcinogens* in that year, and the firm has compensation data available in the year prior to the *RoC* listing. A total of 34 4-digit SICs and 69 firms are affected by the tail risk.

Appendix Table A-I
Effect of exposure on cash flow volatility, controlling for firm size, leverage, growth, and MTB

This table reports coefficients from firm-panel regressions of firm size on an indicator for exposure, firm-by-cohort fixed effects, period-by-cohort fixed effects, Ln(asset), debt/ assets, sales growth, and market-to-book ratio/100. The liability exposure indicator equals 1 if more than 2.5% of employees in the firm's 4-digit SIC industry were observed to be exposed in the 1981-1983 National Occupational Exposure Survey to a chemical listed in the most recent edition of the *Report on Carcinogens (RoC)* . For each firm, cash flow volatility is calculated for both the 5 years before and 5 years after the increase in liabilitry risk using the standard deviation of (cash flows/assets). The data includes pre- and post-risk cash flow volatility for all firms with nonmissing observations for cash flow volatility, sensitivity to price, and sensitivity to volatility in the year prior to a new *RoC* listing. Because there is only one pre- and post-risk observation for each firm, the additional controls are measured as of t-1 and t=0. Standard errors, clustered at the industry level, are reported in parentheses. * significant at 10% level, ** significant at 5% level.

Dep. Variable =	**Volatility (Cash Flows/Assets)**
	All Firms (i)
Exposure	-0.010*
	(0.006)
Ln(Assets)	-0.014
	(0.014)
Debt/Assets	-0.006
	(0.046)
Sales Growth	0.003
	(0.015)
MTB/100	0.010**
	(0.005)
Observations	523
# of Firms	271
R-Squared	0.037
Fixed effects:	
Firm-cohort	X
Period-cohort	X

Appendix Table A-II

Sensitivity to price and the effects of exposure, controlling for firm size, leverage, sales growth, and MTB

This table reports coefficients from firm-panel regressions of firm size on an indicator for exposure, firm-by-cohort fixed effects, period-by-cohort fixed effects, Ln(asset), debt/ assets, sales growth, and market-to-book ratio/100. The specifications are the same as those reported in Appendix Table A-I, Column (i), but estimates are obtained for different subsamples of firms: firms with above and below median sensitivity to price, as defined by Core and Guay (2002) [columns (i)-(ii)], firms with above and below median Jensen-Murphy sensitivity [columns (iii)-(iv)], and firms with above and below median Edmans-Gabaix-Landier sensitivity [columns (v)-(vi)]. Standard errors, clustered at the industry level, are reported in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Dep. Variable = Volatility(Cash Flows/Assets)

	Sensitivity to Price		**Jensen-Murphy**		**Edmans, et al.**	
	High (i)	**Low** (ii)	**High** (iii)	**Low** (iv)	**High** (v)	**Low** (vi)
Exposure	-0.015**	-0.006	-0.017**	0.001	-0.017**	-0.007
	(0.007)	(0.010)	(0.008)	(0.008)	(0.008)	(0.008)
Ln(Assets)	-0.009	-0.032	-0.011	-0.022	-0.015	0.005
	(0.017)	(0.028)	(0.013)	(0.044)	(0.018)	(0.034)
Debt/Assets	-0.005	-0.010	-0.050	0.031	-0.012	-0.028
	(0.069)	(0.045)	(0.058)	(0.067)	(0.055)	(0.054)
Sales Growth	-0.110	-0.010	-0.007	0.007	-0.018	0.015
	(0.268)	(0.021)	(0.017)	(0.026)	(0.284)	(0.020)
MTB/100	0.015***	-0.019**	-0.093	0.010*	0.014***	-0.012
	(0.002)	(0.009)	(0.336)	(0.006)	(0.002)	(0.009)
Observations	261	262	257	265	258	262
# of Firms	135	136	134	136	134	135
R-Squared	0.09	0.14	0.07	0.04	0.11	0.12
Fixed effects:						
Firm-cohort	X	X	X	X	X	X
Period-cohort	X	X	X	X	X	X

Appendix Table A-III
Sensitivity to volatility and the effects of exposure, controlling for firm size, leverage, sales growth, MTB

This table reports coefficients from firm-panel regressions of firm size on an indicator for exposure, firm-by-cohort fixed effects, period-by-cohort fixed effects, Ln(asset), debt/assets, sales growth, and market-to-book ratio/100. The specifications are the same as those reported in Appendix Table A-I, Column (i), but estimates are obtained for different subsamples of firms: firms with above and below median sensitivity to volatility [columns (i)-(ii)], and firms with above and below median sensitivity to volatility / sensitivity to price [columns (iii)-(iv)]. Standard errors, clustered at the industry level, are reported in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Dep. Variable = Volatility(Cash Flows/Assets)

	Senstivity to Volatility		**Sensitivity to Volatility / Sensitivity to Price**	
	High (i)	**Low** (ii)	**High** (iii)	**Low** (iv)
Exposure	-0.001	-0.022**	-0.000	-0.023**
	(0.007)	(0.011)	(0.009)	(0.009)
Ln(Assets)	0.019	-0.036**	-0.007	-0.005
	(0.026)	(0.016)	(0.036)	(0.013)
Debt/Assets	-0.054	0.102*	-0.020	0.012
	(0.057)	(0.059)	(0.048)	(0.058)
Sales Growth	0.005	-0.013	0.028	-0.035
	(0.023)	(0.022)	(0.027)	(0.022)
MTB/100	0.014***	-0.032***	0.012***	-0.010
	(0.002)	(0.009)	(0.002)	(0.009)
Observations	258	265	254	263
# of Firms	133	138	131	137
R-Squared	0.04	0.15	0.10	0.16
Fixed effects:				
Firm-cohort	X	X	X	X
Period-cohort	X	X	X	X

Appendix Table A-IV

Moneyness, total pay, and the effects of exposure, controlling for firm size, leverage, sales growth, MTB

This table reports coefficients from firm-panel regressions of firm size on an indicator for exposure, firm-by-cohort fixed effects, period-by-cohort fixed effects, Ln(asset), debt/ assets, sales growth, and market-to-book ratio/100. The specifications are the same as those reported in Appendix Table A-I, Column (i), but estimates are obtained for different subsamples of firms: firms with above and below median moneyness of options [columns (i)-(ii)], and firms with above and below median total pay [columns (iii)-(iv)]. Standard errors, clustered at the industry level, are reported in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Dep. Variable = Volatility(Cash Flows/Assets)

	Moneyness of Options		Total Pay	
	High	Low	High	Low
	(i)	(ii)	(iii)	(iv)
Exposure	-0.026*	0.016	-0.002	-0.017*
	(0.013)	(0.016)	(0.008)	(0.009)
Ln(Assets)	0.064	-0.071	0.009	-0.056**
	(0.056)	(0.068)	(0.020)	(0.022)
Debt/Assets	-0.076	-0.101	-0.019	0.033
	(0.098)	(0.067)	(0.057)	(0.067)
Sales Growth	0.036	0.041	0.007	0.005
	(0.045)	(0.029)	(0.023)	(0.020)
MTB/100	0.013***	0.016	0.011***	-0.130
	(0.003)	(0.304)	(0.004)	(0.645)
Observations	69	72	261	260
# of Firms	37	38	135	135
R-Squared	0.33	0.21	0.04	0.13
Fixed effects:				
Firm-cohort	X	X	X	X
Period-cohort	X	X	X	X