

# Does Executive Compensation Depend on Product Market Structure? Evidence from Shocks to Firm Risk

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## Abstract

This paper shows that, depending on product market structure, firms adjust executive compensation differently in response to shocks to firm risk. Using a natural experiment that increases firm risk due to discoveries of carcinogens, I find that treated firms increase CEO risk-taking incentives to mitigate underinvestment. This result is mainly driven by treated firms in less affected industries, which suggests that firms respond to shocks more strongly when fewer rivals face the same shock, and extends existing work on executive compensation adjustments based on industry-level analyses.

**Keywords:** Executive Compensation, Risk-taking Incentives, Firm Risk, Product Markets

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## Introduction

The design of executive compensation receives substantial interest from both practice and academia. The average real value of total CEO pay in S&P 500 firms climbed from \$1.1 million in 1970 to \$10.9 million in 2011. Most of the increase in CEO pay during this period is explained by the growth in stock option compensation (Murphy, 2013). Agency theories suggest that firms use compensation contracts to align managers' and shareholders' interests. A number of studies recognize that risk-averse, under-diversified managers may underinvest in risky and valuable projects (e.g., Jensen and Meckling, 1976; Smith and Stulz, 1985; Guay, 1999). To mitigate this risk-related agency conflict, firms may provide managers risk-taking incentives by using option compensation, the value of which increases with firms' stock return volatility (a measure for firm risk). However, existing evidence on the relationship between firm risk and executive compensation is mixed. In addition, it remains under-explored how firms take into account both their own and other firms' risk profiles when choosing compensation policies. In this paper, I examine how firms adjust executive compensation in response to unexpected shocks to their firm risk, and compare firms in two types of industries: *more affected industries*, in which a larger fraction of firms is affected by a same shock to firm risk, and *less affected industries*, in which a smaller fraction of firms is affected by the shock.

How firms respond to shocks may depend on whether their rival firms face the same shock. Subsequent to an unexpected change in firm risk, affected firms in a more affected industry may not need to adjust executive compensation. Since they account for a majority of firms in the industry, they may be able to increase product prices to reflect any unexpected increase in marginal costs. In other words, product prices may absorb common shocks within an industry. However, affected firms in a less affected industry may need to adjust compensation to remain competitive, because idiosyncratic shocks may not be absorbed in product prices.<sup>1</sup> By taking into account the risk profiles of all firms in an industry, this paper helps to understand within-industry variations in executive compensation policies.

It is also important to examine the relationship between firm risk and executive compensation,

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<sup>1</sup>Despite the fact that firms may mitigate the impact of a domestic shock by trading in foreign markets, to the extent that firms cannot fully diversify away the risk, I expect to find different responses between more affected and less affected industries. In addition, firms with market power may mitigate the impact of the shock by adjusting product prices. Thus, I expect to find a larger difference between more affected and less affected industries when both types of industries are more competitive.

since the relationship between the two is controversial both theoretically and empirically. A group of theoretical studies suggests that convex payoffs like stock option grants induce managers to take risks, because managers share in the gains but not all the losses (e.g., [Jensen and Meckling, 1976](#); [Smith and Stulz, 1985](#); [Edmans and Gabaix, 2011](#)). Another group of studies note that option compensation does not unambiguously lead to more risk-taking, because, apart from increasing convexity, it also increases risk-averse managers' exposure to firm risk (e.g., [Lambert, Larcker, and Verrecchia, 1991](#); [Carpenter, 2000](#); [Ross, 2004](#)). The empirical literature documents a positive effect of convexity given to managers on managerial risk-taking, but mixed evidence on the effect of option grants.<sup>2</sup> Unlike this literature, my paper focuses on a different question: how firms adjust managerial risk-taking incentives when firm risk changes. Existing evidence on this question is also mixed. Based on an industry-level analysis, [Gormley, Matsa, and Milbourn \(2013\)](#) find that firms reduce managerial risk-taking incentives after firm risk increases. They suggest that firms may want to mitigate managers' exposure to firm-specific risk. In contrast, [Panousi and Papanikolaou \(2012\)](#) and [De Angelis, Grullon, and Michenaud \(2015\)](#) show that firms increase managerial risk-taking incentives when firm risk rises. [Panousi and Papanikolaou \(2012\)](#) argue that firms may want to mitigate underinvestment by risk-averse managers.

One challenge to the related empirical research is that risk and compensation may be jointly determined. To identify a causal relationship, I exploit sudden increases in firm risk when the National Institutes of Health (NIH) discovers the carcinogenicity of a chemical produced or used by a firm. Under a congressional act<sup>3</sup>, the NIH formally identifies and issues a list of carcinogens to the public. Between 1980 and 2014, the NIH updated the list 13 times, resulting in a total of 267 carcinogens. Newly discovered carcinogens attract attention from the public, academia, businesses, and policy-makers. Firms producing or using those carcinogens may face increased risk of litigation regarding issues like workplace injuries, consumer product safety, and environmental pollution. The litigation uncertainty may exist for a couple of years before regulatory agencies make specific decisions, which might then lead to sizable firm value losses. For example, formaldehyde was identified in 2011 as a known carcinogen. On February 22, 2016, when the Centers for Disease Control and Prevention confirmed that the formaldehyde-containing products sold by Lumber Liquidators, a

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<sup>2</sup>See, for example, [Agrawal and Mandelker \(1987\)](#), [DeFusco, Johnson, and Zorn \(1990\)](#), [Guay \(1999\)](#), [Rajgopal and Shevlin \(2002\)](#), [Lewellen \(2006\)](#), [Coles, Daniel, and Naveen \(2006\)](#), and [Low \(2009\)](#).

<sup>3</sup>Section 301(b)(4) of the Public Health Service Act, amended in 1978.

flooring retailer, can cause cancer, the company’s stock price plunged by 23 percent.<sup>4</sup>

My sample consists of 7,614 treated and control firm-year observations during the period of 1987–2013 within six-year windows around discoveries of carcinogens in 1989, 1991, 2000, 2004, and 2011.<sup>5</sup> To identify treated and control firms, I first match the NIH’s list of carcinogens with plant-level information on toxic chemical emissions (including carcinogens and non-carcinogenic toxic chemicals) from the Toxic Release Inventory (TRI) database maintained by the U.S. Environmental Protection Agency (EPA). A plant may emit a certain chemical because it produces the chemical for sales, or uses or processes the chemical to produce other products.<sup>6</sup> I then map the parent companies of TRI-reporting plants to firms listed in Compustat. Around one-fifth of the firms in the Compustat database own TRI-reporting plants. Finally, I restrict my sample to firms with available information on executive compensation from Execucomp and [Yermack \(1995\)](#). My final sample includes 370 unique treated firms, or 601 treatment events.

I first verify that the discovery of carcinogens leads to an increase in firm risk. Using a difference-in-difference methodology, I show that treated firms experience a 5% increase in firms’ option-implied volatility within a 12-month window around the discovery, and a 18% increase in stock return variance within a six-year window.<sup>7</sup> I then examine how firms adjust managerial risk-taking incentives, measured mainly by CEO flow vega, the sensitivity of a CEO’s current-year compensation to stock return volatility. Treated firms increase the value of CEOs’ current-year compensation, on average, by \$2,859 per 0.01 increase in the firms’ stock return volatility, which accounts for around 10% of the sample mean of flow vega prior to the discovery of carcinogens. The result is mainly driven by less affected industries, in which treated firms increase flow vega by around 20%. [Figure 1](#) illustrates the different incentive adjustments between more affected and less affected industries. Firms adjust CEO risk-taking incentives more strongly when they are among a smaller fraction of firms in the industry facing the same shock to firm risk. One possible explanation is that product prices may absorb common shocks within an industry, but

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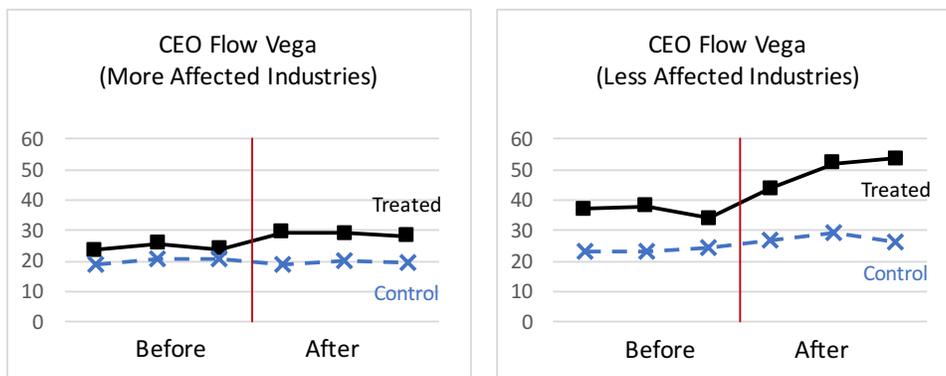
<sup>4</sup>Source: <http://www.cbsnews.com/news/lumber-liquidators-falls-in-premarket-on-revised-cdc-report/>.

<sup>5</sup>I focus on these five discoveries of carcinogens due to data availability.

<sup>6</sup>I exclude from my control sample firms that never own a TRI-reporting plant during my sample period, because those firms may have a much lower probability of emitting carcinogens and have different characteristics from firms with TRI-reporting plants. See [Faulkender and Petersen \(2012\)](#) for a discussion on related empirical strategies.

<sup>7</sup>I find that the average cumulative abnormal returns (CARs) of treated firms is only -0.7% to -0.5% within a three-day or five-day window. One possible reason for the small CARs is a survivorship bias, since the discovery induces some plants to exit. Alternatively, the market reactions could suggest that the discovery mainly affects firm risk rather than expected firm value.

not idiosyncratic shocks. Treated firms in more affected industries may increase product prices to reflect any increase in marginal costs when they need to switch to new inputs or products. Thus, those firms may not need to react strongly. However, treated firms in less affected industries may need to adjust incentive contracts to remain competitive. Consistent with this explanation, I find that the increases in option-implied and stock return volatility are both driven by treated firms in less affected industries.



**Figure 1: CEO Incentive Adjustments: More Affected Industries vs. Less Affected Industries**

This figure presents the annual mean value of CEO incentives (*FlowVega*), defined as the sensitivity of a CEO's current-year compensation (in \$000s) to the firm's stock return volatility, before and after the discovery of carcinogens, by treated and control groups, and by more affected 4-digit SIC industries and less affected 4-digit SIC industries.

The increase in CEO risk-taking incentives is consistent with the argument that firms want to mitigate underinvestment by risk-averse, undiversified executives when idiosyncratic risk rises (Panousi and Papanikolaou, 2012). I provide further evidence that the increase in CEO incentives is accompanied by more R&D expenditures, which is also driven by less affected industries. Also, the increase in CEO incentives is more evident in treated firms that keep producing or using the newly discovered carcinogens than those firms that stop producing or using those carcinogens. In addition, I test several alternative explanations and find no consistent evidence. First, the increase in CEO vega does not seem to be mainly driven by an increase in total pay rather than risk-taking incentives, since treated firms in less affected industries grant more options to their CEOs, but do not significantly change cash or stock compensation, which remains robust after 2005, when the adoption of FAS 123R reduced the accounting advantage of using options. Second, the increase in vega is not driven by firms with greater risk-shifting incentives, measured by ex-ante higher leverage or financial distress. Finally, the results are not driven by firms with weaker governance

strength, measured by ex-ante lower board independence or lower active institutional ownership.

I further explore firm heterogeneity, and show that the increase in CEO incentives is more evident in treated firms producing the newly discovered carcinogens for sales than those firms using the carcinogens to manufacture other products. Furthermore, the increase in incentives is more pronounced in firms with fewer foreign sales or subsidiaries. These results suggest that compensation adjustments depend on how easily a firm can substitute or outsource carcinogen-related production. Consistent with my main findings, less affected industries also drive the subsample results.

I conduct several robustness tests. I find no preexisting trends in CEO incentives prior to the shock to firm risk. In addition, my results are robust to controlling for several firm and CEO characteristics and their interactions with the shock.<sup>8</sup> To further account for ex-ante differences between the treated and control groups, I match treated and control firms based on firm characteristics. Furthermore, I find robust results using the number of option grants to proxy for CEO risk-taking incentives, which suggests that the results are not purely driven by mechanical changes in stock volatility. Also, my findings remain similar when I exclude the 2004 discovery of carcinogens, which affected the most number of firms. Finally, I use alternative specifications such as alternative fixed effects, standard errors, and estimation windows.

This paper contributes to the literature on the linkage between product markets and managerial compensation. My analysis indicates that, in response to shocks to firm risk, firms adjust managerial compensation more strongly when fewer rival firms face the same shock. A group of studies explore the effect of product market competition on managerial incentives (e.g., [Holmstrom, 1982](#); [Hart, 1983](#); [Schmidt, 1997](#); [Raith, 2003](#)). Unlike these studies, I distinguish between product markets in which firms face common shocks to firm risk and those in which few firms face idiosyncratic shocks. Another group of studies investigates how managerial compensation depends on firm performance relative to peers (e.g., [Murphy, 1985](#); [Aggarwal and Samwick, 1999](#)). This paper emphasizes unexpected changes in firm risk rather than relative performance. Also, the evidence in this paper does not seem to suggest that discoveries of carcinogens reveal bad managerial

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<sup>8</sup>Controlling for the interaction terms helps to mitigate the concern of bad controls. Simply including a number of control variables could bias the estimation results if the shock to firm risk affects the value of control variables or the way the dependent variable depends on the control variables. See [Angrist and Pischke \(2009\)](#), pp. 64–66, and [Roberts and Whited \(2012\)](#) for more details on the issue of bad controls.

decisions in less affected industries. Furthermore, a strand of literature shows that firms strategically choose peer companies to justify their own compensation policies (e.g., [Bizjak, Lemmon, and Naveen, 2008](#); [Faulkender and Yang, 2010](#)). Instead of focusing on self-selected peers, I investigate same-industry firms that face a similar exogenous shock. Finally, the industry equilibrium models of investment and financing decisions suggest that a production technology chosen by many firms in the industry becomes a natural hedge (e.g., [Maksimovic and Zechner, 1991](#); [Williams, 1995](#)). Unlike this literature, I examine firms' compensation decisions and exploit shocks to firm risk. My findings suggest that firms' compensation adjustments are determined by not only their own risk, but also by the risk profiles of other firms in an industry.

In addition, this paper contributes to existing work on the effect of firm risk on executive compensation. Building on the industry-level analysis in [Gormley, Matsa, and Milbourn \(2013\)](#), this paper uncovers additional evidence on within-industry variations in compensation adjustments. [Gormley, Matsa, and Milbourn \(2013\)](#) highlight the importance of firm risk in the design of compensation contracts and examine exogenous increases in firm risk due to discoveries of carcinogens. Their study assumes that all firms in more affected industries were treated and all firms in less affected industries were controls due to data availability, and finds that more affected industries reduce CEO flow vega relative to less affected industries after the discovery of carcinogens.<sup>9</sup> I find a similar industry-level result by replicating their empirical strategy based on my sample. In addition, using micro-level data, I show that treated firms increase CEO flow vega, and the increase is driven by treated firms in less affected industries. The results suggest that firms may increase managerial risk-taking incentives in order to mitigate underinvestment by risk-averse, under-diversified managers.

The rest of this paper proceeds as follows. Section 1 reviews the related literature and develops the hypotheses. Section 2 discusses the data. Section 3 presents the results and robustness checks. Section 4 concludes.

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<sup>9</sup>[Gormley, Matsa, and Milbourn \(2013\)](#) use the 1981–1983 industry-level National Occupational Exposure Survey to identify treated and control groups.

# 1 Related Literature and Hypotheses Development

## 1.1 Industry Equilibrium of Corporate Decisions

A body of theoretical literature explores the industry equilibrium of investment and financing choices (e.g., Maksimovic and Zechner, 1991; Williams, 1995; Fulghieri and Suominen, 2012). Maksimovic and Zechner (1991) demonstrate that the risk of a firm's technology choice is endogenously determined and depends on the equilibrium number of firms choosing each type of technology in an industry. In their paper, each firm can invest in either a technology with a known marginal cost or another technology with an uncertain marginal cost. Suppose that a given firm faces an unexpectedly high cost. If most other firms in the industry have chosen the same production technology and therefore experience the same shock in production costs, then the higher production costs will translate into a higher price of the products sold. Thus, that technology becomes a better hedge and will generate less risky cash flows. In contrast, if a firm is one of few firms in the industry facing an unexpected increase in costs, prices will not reflect the higher production costs. Hence, that technology will exhibit riskier cash flows than the other one.

Unlike their study, this paper focuses on compensation decisions rather than investment and financing policies, and investigates unexpected shocks to firm risk rather than endogenous choices of technologies. Nevertheless, the theoretical intuition in their study can be extended to develop my hypothesis. In this paper, I explore how firms adjust executive compensation following shocks that increase firm risk. Specifically, I examine firms' responses to the discovery of carcinogenicity of a chemical produced or used by the firms. Because of potential litigation and reputation concerns, affected firms may switch to non-carcinogenic or less toxic chemicals, which may result in higher marginal costs of production. If most of the rival firms in the industry face the same shock to firm risk, affected firms may be able to increase product prices to reflect any increase in marginal costs. In contrast, if only a small fraction of firms in the industry experiences the shock, these firms may not be able to affect product prices. Hence, I expect that treated firms in less affected industries would experience a larger increase in firm risk, and thus would be more responsive to the shock in adjusting executive compensation. This leads to my first hypothesis:

**Hypothesis 1.** *If a firm is among a small fraction of companies in the industry facing the same*

*shock to their firm risk, the firm would more actively adjust executive compensation, compared to the case in which most of the firms in the industry face a same shock to their firm risk.*

One implicit assumption of this hypothesis is that firms cannot fully diversify away the increased risk through international trade. In my setting, treated firms might be able to mitigate the impact of the discovery of carcinogens by outsourcing their carcinogen-related production to countries with less rigid regulations than the United States. Thus, I expect the above hypothesis to hold to the extent that firms cannot fully diversify away the risk.<sup>10</sup> In addition, treated firms with market power may be able to adjust product prices even if they are in a less affected industry. Hence, the hypothesis is more likely to hold in competitive markets in which firms take product prices as given.

This paper is also related to literature on the relationship between product market competition and corporate outcomes. A strand of studies explores the effect of competition on managerial incentives. For instance, [Holmstrom \(1982\)](#), [Hart \(1983\)](#), and [Hermalin \(1994\)](#) argue that competition reveals additional information about managerial ability if firms in a product market are hit by common productivity shocks. [Hermalin \(1994\)](#) shows that the best response to other firms providing weak (strong) managerial incentives can be to provide strong (weak) incentives. [Schmidt \(1997\)](#) and [Raith \(2003\)](#) suggest that competition drives down firm profits, and thus may discourage managerial efforts but may also discipline managers and boost productivity. Unlike these studies, this paper distinguishes between product markets in which firms face common shocks to firm risk and those in which few firms face idiosyncratic shocks. In another related study, [Hadlock and Sonti \(2012\)](#) examine how revisions to firms' asbestos liabilities affect market reactions to their competitors. Unlike their paper, I exploit exogenous shocks to firm risk rather than self-reported revisions to litigation liabilities and focus on treated firms rather than their competitors.

In addition, this paper is related to the literature on relative performance evaluation and compensation peer benchmarking. A strand of literature explores whether managerial compensation is determined by firm performance relative to peers (e.g., [Murphy, 1985](#); [Aggarwal and Samwick, 1999](#)). This paper examines unexpected changes in firm risk rather than relative performance, and finds no evidence that discoveries of carcinogens reveal bad managerial decisions in less affected industries. Other studies document that firms strategically choose peer companies that pay

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<sup>10</sup>This may occur, for example, due to uncertainties about foreign trade, imperfect foreign product markets, etc.

higher executive compensation to justify their own compensation policies (e.g., [Bizjak, Lemmon, and Naveen, 2008](#); [Faulkender and Yang, 2010](#); [Albuquerque, De Franco, and Verdi, 2013](#)). Instead of focusing on self-selected peers, I investigate same-industry firms that face a similar exogenous shock to their firm risk.

## 1.2 Firm Risk and Executive Compensation

Existing literature provides mixed evidence on the effect of firm risk on compensation decisions. Using industry-level evidence, [Gormley, Matsa, and Milbourn \(2013\)](#) investigate how firms adjust managerial incentives when their liability risk rises due to workplace exposure to newly discovered carcinogens. Their study assumes that all firms in more affected industries were treated, and all firms in less affected industries were controls, and shows that more affected industries reduce CEO flow vega relative to less affected industries after the discovery of carcinogens.<sup>11</sup> This paper extends their work by using micro-level data and exploring within-industry variations in compensation adjustments.

Another strand of studies suggests a positive effect of firm risk on managerial risk-taking incentives. For instance, [De Angelis, Grullon, and Michenaud \(2015\)](#) investigate a sudden increase in downside firm risk following removal of short-selling constraints, and show that treated firms grant relatively more stock options to their executives than restricted stocks. A recent study by [Panousi and Papanikolaou \(2012\)](#) distinguishes between systematic and idiosyncratic components of risk, and argue that top executives can hedge away their exposure to systematic risk but not to idiosyncratic risk, since they are not permitted to buy put options or short their own company's stock. They use a theoretical model to show that risk-averse, undiversified managers may underinvest in projects characterized by idiosyncratic risk, and risk-neutral, well-diversified shareholders may want to increase managerial risk-taking incentives to mitigate the underinvestment.<sup>12</sup> Consistent with their paper, existing studies on option repricing also suggest that the wedge between managers' and shareholders' optimal decisions increases with idiosyncratic risk, managerial risk aversion, and the extent of under-diversification (e.g., [Hall and Murphy, 2000](#); [Chidambaran and Prabhala, 2003](#);

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<sup>11</sup>The treated group in [Gormley, Matsa, and Milbourn \(2013\)](#) consists of a set of SIC industries in which above a threshold fraction of workers is exposed to newly discovered carcinogens.

<sup>12</sup>[Armstrong and Vashishtha \(2012\)](#) also assume that managers can hedge against systematic risk rather than idiosyncratic risk and find that vega encourages managers to increase systematic risk more than idiosyncratic risk. Unlike their paper, I focus on a sudden increase in idiosyncratic risk.

Ingersoll Jr., 2006).<sup>13</sup>

The intuition on the relationship between idiosyncratic risk and managerial incentives can be extended to my paper. Under the assumption that managers are risk-averse and under-diversified and cannot flexibly sell or hedge against idiosyncratic risk, prior studies suggest two competing hypotheses on the effect of idiosyncratic risk on managerial incentives:

**Hypothesis 2a.** *Firms would reduce managerial risk-taking incentives if idiosyncratic risk increases.*

**Hypothesis 2b.** *Firms would increase managerial risk-taking incentives if idiosyncratic risk increases.*

The two competing hypotheses have different implications from an agency theory perspective. Hypothesis 2a implies that firms cut managerial incentives to meet managers' constraints, while Hypothesis 2b suggests that firms increase incentives to maximize shareholders' value. Following the theoretical framework of Holmstrom and Milgrom (1987), I consider a firm that designs incentive compensation contracts to maximize shareholders' value subject to managers' participation constraint. Since the manager is risk-averse, a sudden increase in idiosyncratic risk may raise her marginal costs of exerting efforts. Hypothesis 2a suggests that the firm would cut managerial incentives to mitigate the increase in the costs of efforts and meet managers' constraints. The finding of Gormley, Matsa, and Milbourn (2013) is consistent with this hypothesis. In contrast, Hypothesis 2b, consistent with Panousi and Papanikolaou (2012), argues that the firm would give managers a greater reward of risk-taking in order to maximize shareholders' value.

Another body of literature examines the impact of option compensation on managerial risk-taking activities. In general, this literature suggests that vega (sensitivity of a manager's wealth to firm volatility) induces managerial risk-taking, while the effect of delta (sensitivity of a manager's wealth to changes in stock price; also known as pay-for-performance sensitivity) or option grants depends on managerial risk aversion, ability to hedge, and outside wealth.<sup>14</sup> A number of theoretical studies demonstrate that option compensation increase vega, which encourages managers to take risks, because the expected payoff of an option increases in the volatility of the underlying stock's

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<sup>13</sup>These studies show that repricers tend to be smaller, younger firms that experienced an abrupt decline in growth and profitability. In contrast, my sample consists of larger, older firms.

<sup>14</sup>See also Armstrong and Vashishtha (2012) for a discussion on this body of literature.

return (e.g., Jensen and Meckling, 1976; Myers, 1977; Haugen and Senbet, 1981; Smith and Stulz, 1985; Edmans and Gabaix, 2011). Other studies argue that besides vega, option grants also increase delta, which makes managers' firm-specific wealth more sensitive to changes in stock prices (e.g., Lambert, Larcker, and Verrecchia, 1991; Carpenter, 2000; Ross, 2004). Thus, if managers are risk-averse and cannot sell or hedge against the risk associated with their options, they may be less willing to take risks. Consistent with the theoretical predictions, empirical studies show that higher vega is associated with greater managerial risk-taking activities, measured by higher stock return volatility, more R&D investments, lower capital expenditures, and higher leverage (e.g., Coles, Daniel, and Naveen, 2006; Low, 2009). There is mixed evidence on the effect of delta or option grants on managerial risk-taking (e.g., Agrawal and Mandelker, 1987; DeFusco, Johnson, and Zorn, 1990; Guay, 1999; Rajgopal and Shevlin, 2002), which suggests that the effect may depend on empirical values of managers' risk aversion, wealth, and hedging ability. Unlike this literature, my paper investigates how firms adjust executive compensation in response to changes in firm risk, rather than how firms use compensation contracts to induce managerial risk-taking activities.

## 2 Data

I rely on several data sources to construct my sample. First, I collect the timing of discoveries of carcinogens from the Report on Carcinogens (RoC) prepared by the National Institutes of Health (NIH). Second, to identify treated and control groups in the event of discoveries, I match the RoC data with the plant-level Toxic Release Inventory (TRI) data from the U.S. Environmental Protection Agency (EPA), which differs from existing literature. The TRI data contains plant-level annual information on toxic chemical usage and emissions (including carcinogens and non-carcinogenic toxic chemicals). Third, I use the Compustat database to obtain firm-level financial data. I aggregate the plant-level chemical data to the firm level and match the parent companies of TRI-reporting plants to firms listed in Compustat. Finally, I focus on a sample with available information on executive compensation from the Execucomp database and Yermack (1995).

I focus on the discoveries of carcinogens in 1989, 1991, 2000, 2004, and 2011, due to data availability. Following Gormley, Matsa, and Milbourn (2013), I construct a pooled sample, which consists of five cohorts of treated and control firm-year observations. Each cohort is a six-year

period around the discovery. In robustness tests, I use alternative estimation windows. Next, I discuss the data and sample construction in details, and present summary statistics.

## 2.1 Discoveries of Carcinogens

In this paper, I exploit discoveries of carcinogens by the NIH as exogenous variations in firm risk. Data on the timing of discoveries is available through the RoC, which is a congressionally mandated, science-based, public health document prepared by the National Toxicology Program of the NIH.<sup>15</sup> Section 301(b)(4) of the Public Health Service Act, amended in 1978, requires that the NIH publishes and updates a list of chemicals, either known to be or reasonably anticipated to be human carcinogens. The RoC provides important information that supports decision-making by the public, businesses, and regulatory agencies.<sup>16</sup>

Between 1980 and 2014, the NIH updated the RoC 13 times, resulting in a total of 267 listed carcinogens. Table A.2 in the appendix reports the years of discoveries (column 1). On average, each edition of the RoC includes around 20 newly discovered carcinogens (column 3) and affects 185 Compustat firms (column 5). Among all discoveries, the 2004 discovery affected the most firms (643 firms), followed by the 1989 discovery (312 firms) and the 2000 discovery (245 firms). I obtain the announcement dates of the RoC by searching the news articles published by the National Institute of Environmental Health Sciences (NIEHS) and the National Center for Biotechnology Information (NCBI).<sup>17</sup> The dates are available since 1994 and listed in column 2.<sup>18</sup>

I exclude all delisted chemicals and firms affected by delisting. The number of newly discovered carcinogens presented in Table A.2 already excludes delisted chemicals. Delisting is not common. Between 1980 and 2014, only nine chemicals were once discovered as carcinogens but then delisted later (column 4). Only 54 Compustat firms in 2000 were affected by two delisted chemicals (column 6). The reasons for delisting include a low possibility of human exposure and insufficient evidence

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<sup>15</sup> Available at <http://ntp.niehs.nih.gov/pubhealth/roc/>.

<sup>16</sup> The regulatory agencies that cite the RoC include Centers for Disease Control and Prevention (CDC), EPA, Occupational Safety and Health Administration (OSHA), Consumer Product Safety Commission (CPSC), and the Food and Drug Administration (FDA).

<sup>17</sup> Sources: <http://www.niehs.nih.gov/news/newsroom/releases>; <http://www.ncbi.nlm.nih.gov/pmc>.

<sup>18</sup> The NIH scheduled the 2004 discovery announcement in that year but actually released it to the public in January 2005. My findings could be biased for this particular year if firms adjusted executive compensation prior to the actual announcement based on leaked information. However, in robustness tests, I exclude the 2004 discovery and find similar and even stronger results for other years of discoveries. Thus, the inclusion of the 2004 discovery only works against finding the results in my paper.

of carcinogenicity after reevaluation.

In each edition of the RoC, the NIH indicates whether a chemical is known to be or reasonably anticipated to be a human carcinogen. I identify newly discovered carcinogens via their first appearance on the RoC, whether or not they are known or reasonably anticipated to be carcinogens. For instance, formaldehyde was listed as a reasonably anticipated carcinogen in 1981, and then updated to be a known carcinogen in 2011. I treat formaldehyde as discovered in 1981. For robustness checks, I identify newly discovered carcinogens via their first appearance as known carcinogens, that is, I treat formaldehyde as discovered in 2011. Alternatively, I examine a subsample of chemicals that first appeared on the RoC as known carcinogens, that is, I exclude formaldehyde.

## 2.2 Toxic Chemical Emissions

A key step in my analysis is to identify treated and control firms around discoveries of carcinogens. Unlike existing literature, I use a plant-level panel database on toxic chemical usage and emissions (including carcinogens and non-carcinogenic chemicals). I match the RoC data with the TRI data from the EPA.<sup>19</sup> TRI data provides plant characteristics, including plant name, industry, location, chemical characteristics, such as the name of chemicals emitted by a plant and how a chemical is used, and parent company name. A firm may emit a toxic chemical because it produces the chemical for sales or distribution purpose. Alternatively, the firm may use or process the chemical as an input during its production.

TRI data has been an important resource for regulators, investors, environmentalists, and communities to assess plant-level and firm-level environmental performance. In 1986, Congress passed the Emergency Planning and Community Right-to-Know Act (EPCRA) to inform the public about toxic chemical emissions in the local community. Under the requirements of EPCRA, all U.S. plants that meet the following reporting criteria must submit annual TRI data to the EPA: (i) The plant is in a specific NAICS industry sector, including manufacturing, mining, utility, wholesalers, etc.<sup>20</sup>, or is owned or operated by federal government; (ii) the plant employs 10 or more full-time equivalent employees; and (iii) the plant produces, processes, or otherwise uses one of the TRI-listed toxic

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<sup>19</sup> Available at <https://www.epa.gov/toxics-release-inventory-tri-program/tri-data-and-tools>.

<sup>20</sup> Specifically, TRI-covered plant-level NAICS industries include mining (NAICS 212), utilities (221), manufacturing (31–33), miscellaneous manufacturing (1119, 1131, 2111, 4883, 5417, 8114), merchant wholesalers and non-durable goods (424), wholesale electronic markets and agents brokers (425), publishing (511, 512, 519), and hazardous waste (562).

chemicals in quantities above threshold levels in a given year.

I match the TRI data with the RoC data using chemical CAS registry number and chemical names.<sup>21</sup> Between 1987 and 2014, TRI-reporting plants emitted 610 unique toxic chemicals, including 126 carcinogens and 484 non-carcinogenic toxic chemicals. I aggregate the plant-level chemical data to the firm level, and identify parent companies of TRI-reporting plants listed in Compustat (hereafter referred to as “TRI-Compustat firms”). Specifically, I map the name of a parent company in the TRI data to a firm name in Compustat using a string matching algorithm, then manually check each potential match to improve accuracy. I exclude parent companies with no match from my sample, including potential unmatched Compustat firms and private firms not listed in Compustat.

During the period 1987–2014, there are 58,076 unique TRI-reporting plants (656,592 plant-year observations). Around 80% of these observations have available information on parent companies. There are 11,357 unique parent companies with TRI-reporting plants (160,815 firm-year observations), among which 2,415 are identified as Compustat firms (39,939 firm-year observations). Since 1987, discoveries of carcinogens have affected 3,718 (28.0%) out of the 11,357 TRI firms and 878 (36.4%) out of the 2,415 TRI-Compustat firms. The median TRI-Compustat firm has more TRI-reporting plants than other TRI firms but emits a lower fraction of carcinogens. Specifically, the median TRI-Compustat firm has 15 TRI-reporting plants, among which 10 plants (66.7%) emit carcinogens. The median TRI-reporting plant of a Compustat firm emits eight toxic chemicals, among which one chemical (12.5%) is carcinogenic. In comparison, the median TRI firm has six TRI-reporting plants, among which five plants (83.3%) emit carcinogens. The median TRI-reporting plant emits six toxic chemicals, among which one chemical (16.7%) is carcinogenic.

TRI-Compustat firms account for around one-fifth of the full Compustat database. Compared to other Compustat firms, TRI-Compustat firms are, on average, two times larger and older, grow slower, have better operating performance, and spend less in R&D.<sup>22</sup> My final sample consists of firms with available financial and compensation data, and thus my results mostly apply to large public firms.

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<sup>21</sup>The Chemical Abstracts Service (CAS) has assigned a unique numerical identifier to every chemical described in the open scientific literature since 1957.

<sup>22</sup>In comparison, the Compustat firms in the S&P 1500 with available compensation data from Execucomp are, on average, four times larger in size than other Compustat firms.

Around 90% of the TRI-reporting plants belong to the manufacturing sector (NAICS 31–33). Figure 2 presents the distribution of TRI-reporting plants by the Fama-French 48 industry. The plants are concentrated in a few industries, such as construction materials, chemicals, steel works, rubber and plastic products, and fabricated products. Six Fama-French industries, including real estate, banking, entertainment, insurance, communication, and trading, have no TRI-reporting plant between 1987 and 2014. Figure 2 also distinguishes between plants that emit existing carcinogens (black bars) and plants that emit non-carcinogenic toxic chemicals (white bars). Around 40% of the plants emit carcinogens.

Compared to the plant-level distribution, the industry distribution of TRI-Compustat firms is less concentrated, as shown in Figure 3.<sup>23</sup> Electronic equipment, machinery, chemicals, and construction materials have more TRI firms than other Fama-French industries. However, they are not necessarily the industries with higher proportions of firms releasing carcinogens. Aircraft industry has the highest fraction of firms releasing carcinogens (84.6%). In 21 Fama-French industries, including food products, computer software, rubber and plastic products, and electronic equipment, less than 50% of the TRI firms emit existing carcinogens (blue color). In the remaining 27 industries, including aircraft, utilities, chemicals, and petroleum and natural gas, over 50% of the TRI firms emit carcinogens (black color). Figure 3 indicates that there are within-industry variations in carcinogen emissions. Thus, the TRI data provides an opportunity to examine the difference between treated firms in more affected industries and treated firms in less affected industries.

The use of the TRI data may introduce measurement errors if plants misreport their toxic chemical emissions, but this concern is mitigated in my paper, since I examine exogenous increases in the risk of releasing certain chemicals. Furthermore, the EPA’s enforcement policies give plants an incentive to accurately report toxic chemical emissions. Under EPCRA, the EPA conducts compliance inspections, investigates cases of non-compliance, and can issue a maximum civil penalty of \$25,000 per violation for not reporting or misreporting emissions.<sup>24</sup>

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<sup>23</sup>One reason is that TRI-Compustat firms are more diversified. Compared to the median Compustat firm, the median TRI-Compustat firm has one more segment or unique segment-level 4-digit SIC code.

<sup>24</sup>In 2001, the EPA conducted 321 compliance inspections for TRI reporting. Between 1990 and 1999, the EPA brought 2,309 administrative actions against non-compliance (De Marchi and Hamilton, 2006).

### 2.3 Sample Construction

Following [Gormley, Matsa, and Milbourn \(2013\)](#), I construct a pooled sample, which consists of five cohorts of treated and control firm-year observations. Each cohort is a six-year period (from year T-3 to year T+2) around the discovery of carcinogens (in year T, where T=1989, 1991, 2000, 2004, or 2011). For instance, Air Products & Chemical Inc. (APC) was affected by the 1989 discovery and is included in my sample for the six-year period, between 1986 and 1991.<sup>25</sup> I use alternative windows around the discovery in robustness tests. I include firms affected for the second or more times during my sample period and keep overlapping years across cohorts. For example, APC was affected again in 1991, and is included in my sample for the six-year period of 1988 to 1991 for the 1991 cohort, in which 1998–1991 overlap with the four years in the 1989 cohort. For robustness checks, I exclude overlapping years, and, alternatively, split the sample between firms affected for the first time and for the second or more times.

I focus on the discoveries in 1989, 1991, 2000, 2004, and 2011, because they have available TRI data and because the first four years overlap with the years in [Gormley, Matsa, and Milbourn \(2013\)](#). Restricting my sample to these five years only excludes 7% of treated firms. In robustness tests, I include other years of discoveries. My final sample is restricted to firms with available data on CEO compensation from Execucomp and [Yermack \(1995\)](#). I identify 370 unique treated firms, in total 601 treatment events, since some firms were affected for multiple times. A firm is identified as treated if it owns at least one plant that produces or uses and thus, emits a chemical newly discovered as a carcinogen. Among the 601 events, 231 occurs in less affected 4-digit SIC industries, in which less than or equal to 50% of the TRI firms are simultaneously affected (e.g., cosmetics manufacturing in [Figure 4](#)); the remaining 370 events occur in more affected 4-digit SIC industries, in which over 50% of the TRI firms are simultaneously affected (e.g., plastics manufacturing in [Figure 4](#)). The pooled sample between 1986 and 2013 has 2,838 treated firm-year observations.

My control sample consists of firms with plants that emit non-carcinogenic toxic chemicals. In other words, I exclude firms that never had a plant that emitted any toxic chemical above a threshold value. The rationale is that those firms may have a much lower probability of being affected than TRI firms. In addition, they differ in other firm characteristics from TRI firms. This empirical

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<sup>25</sup>I do not require a firm in my sample to survive for all six years in a given cohort.

strategy follows [Faulkender and Petersen \(2012\)](#), who show that different empirical strategies can lead to different estimation results when there is a third group besides the traditional treated and control groups, and combining the third group with the control group may bias estimation results. I identify 624 unique control TRI firms with available compensation data. The pooled sample between 1986 and 2013 has 4,776 control firm-year observations. For robustness checks, I match treated and control firms based on firm size, firm age, and SIC industry. The matched sample consists of 218 unique treated firms (1,158 firm-year observations) and 411 unique control firms (1,683 firm-year observations).

## 2.4 CEO Compensation

I collect executive compensation data from Execucomp and [Yermack \(1995\)](#). Execucomp covers active and inactive firms in the S&P 1500 index since 1992. Yermack's sample consists of 792 U.S. firms (5,955 firm-year observations) that appeared in the *Forbes* magazine lists of the 500 largest public U.S. corporations between 1984 and 1991.<sup>26</sup>

My main measure for managerial risk-taking incentives is *FlowVega*, the change in a CEO's compensation (effectively the value of option grants) during a given year for a 0.01 increase in a firm's stock return volatility.<sup>27</sup> I use the [Black and Scholes \(1973\)](#) formula to value options following [Core and Guay \(2002\)](#) and account for the 2006 change in reporting format in Execucomp following [Coles, Daniel, and Naveen \(2013\)](#). To proxy for risk-free rates, I use the Treasury rate corresponding to the actual option maturity if the option maturity is less than or equal to 10 years, and use the 10-year Treasury rate if the option maturity exceeds 10 years. Stock return volatility is calculated as the annualized standard deviation of monthly stock returns during the past 60 months.

To examine whether firms adjust other aspects of compensation besides risk-taking incentives, I collect information on individual components of compensation, including the values of option grants (*Options*), restricted stock grants (*StockComp*), salary and bonus (*CashComp*), and total compensation (*TotalComp*, the sum of option, stock, and cash compensation). I use logged values of these measures to mitigate the concern that CEO compensation has a skewed distribution. For

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<sup>26</sup>Yermack's sample provides information on CEO age, tenure, stock ownership, cash compensation, and option grants based on firms' proxy statements, 10-K, and 8-K filings.

<sup>27</sup>*FlowVega* effectively only accounts for the value of option compensation, since the value of stock or cash compensation do not change with stock return volatility.

robustness checks, I adopt alternative measures for managerial incentives, including the number of option grants (*Options\_N*), flow delta (*FlowDelta*, the change in the value of a CEO’s compensation during a given year for a 1% increase in a firm’s stock prices), and vega calculated using current-year plus previous years’ option compensation. I use the number of option grants to test whether there is a real effect rather than a mechanical effect driven by changes in stock prices and volatility. I use vega to account for a total wealth effect.

## 2.5 Other Variables

Before preceding to my main analysis, I test how the discovery of carcinogens affects firm risk, measured by option-implied or stock return variance. I obtain data on implied volatility from OptionMetrics, and focus on at-the-money call options with at least 90 days to expiration (following DeFusco, Johnson, and Zorn, 1990). I take the open-interest-weighted average value of implied volatility for each firm. The tests are based on a reduced sample, because OptionMetrics is available since 1996. Stock return variance is calculated using data from CRSP.

I examine whether weakly governed firms drive the results and use the fraction of independent directors on boards (*Independence*) and potentially active institutional ownership (*ActiveOwnership*, following Almazan, Hartzell, and Starks, 2005) to proxy for governance strength. The first test is based on a reduced sample, because board information from the ISS (formerly RiskMetrics) database is available since 1996. In addition, I examine risk-shifting as an alternative explanation for my results. Risk-shifting incentives are measured by leverage ratio (*Leverage*) and an indicator for distress based on the Altman (1968) Z-score (*Z*).

In robustness tests, I control for firm and CEO characteristics that may affect a firm’s design of CEO compensation. Following Guay (1999), I include firm size (*FirmSize*), CEO tenure (*CEOTenure*), and CEO cash compensation (*CashComp*) as controls. To address the concern of potential bad controls, I interact these controls with the shock to firm risk. In addition, I also control for cash flows, leverage, and CEO age.

Detailed definitions of all variables are included in the appendix (Table A.1).

## 2.6 Summary Statistics

Table 1 reports the mean comparison results between treated and control groups during three years prior to the discovery of carcinogens. Panel A presents the results based on the full sample, which consists of 370 unique treated firms and 624 unique control firms. Compared to an average control firm, an average treated firm has a similar ex-ante market-to-book ratio, leverage, cash flows, and fraction of option grants in total CEO compensation. However, the average treated firm is larger and older, and has a lower stock variance and higher CEO vega (calculated using compensation in current and previous years). These ex-ante differences are statistically significant. For robustness checks, I include firm characteristics as controls and use a matched sample to account for these differences. Specifically, I match treated and control firms by firm size decile, age decile, and 4-digit SIC industry. Panel B reports the comparison results based on the matched sample, which consists of 218 unique treated firms and 411 unique control firms. The ex-ante differences between the two groups become generally insignificant.

Panel C presents the comparison between treated and control groups based on an industry-level measure for the shock to firm risk, similar to the measure in [Gormley, Matsa, and Milbourn \(2013\)](#).<sup>28</sup> The treated group consists of a set of more affected 4-digit SIC industries, in which over 50% of the firms are affected by the discovery of carcinogens in a given cohort. The control group consists of another set of less affected SIC industries. Compared to the original statistics in [Gormley, Matsa, and Milbourn \(2013\)](#) (panel D), the industry-level statistics based on my sample are similar except for the vega. The vega in my sample is around three to four times larger than the vega in their sample. One possible reason is that their sample includes earlier cohorts than my sample, and that the vega is, on average, smaller in earlier years than in later years.<sup>29</sup>

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<sup>28</sup>[Gormley, Matsa, and Milbourn \(2013\)](#) rely on the 1981–1983 industry-level National Occupational Exposure Survey to identify treated and control groups. The survey used to be available from the website of the National Institute for Occupational Safety and Health (NIOSH), but was taken down because of the age of the data and because the data does not represent current exposures in U.S. industries, according to the NIOSH.

<sup>29</sup>[Gormley, Matsa, and Milbourn \(2013\)](#) examine the discoveries in 1985, 1989, 1991, 2000, and 2004. I focus on the discoveries in 1989, 1991, 2000, 2004, and 2011. The average vega for the pre-1992 period, calculated using data from [Yermack \(1995\)](#), is around \$10,000, while the average vega for the post-1992 period, based on the Execucomp data, is over \$100,000. This is partially because only options granted in a given year, but not previous years, are available in Yermack’s sample, and thus option grants in previous years are approximated by options granted in the last year for the pre-1992 period.

### 3 Results and Robustness Analysis

#### 3.1 A Pre-Step: Effect on Firm Risk

Before preceding to my main tests, I first examine the effect of the discovery of carcinogens on firm risk to verify that treated firms face a material increase in their risk.

##### 3.1.1 Option-implied and Stock Return Volatility

I use a difference-in-difference methodology and measure firm risk by option-implied variance as well as realized stock return variance. A firm is included in the analysis if it is listed in Compustat and owns at least one plant that emits toxic chemicals (including carcinogens and non-carcinogens) during the sample period. The sample consists of several cohorts of treated and control observations during a window around the discovery of carcinogens. To analyze implied volatility, I use a 12-month window (from 180 days before to 180 days after the discovery announcement date) of firm-date observations. Around 60% of the firms in my sample have available information on implied volatility. To examine stock variance, I construct a six-year window (from three years before to two years after the year of discovery) of firm-year observations. In addition to an unmatched sample, I construct a matched sample by firm size decile, age decile, and 4-digit SIC industry. I use the following specification:

$$Volatility_{ict} = \beta_0 + \beta_1 Discovery_{ict} + \alpha_{ct} + \omega_{ic} + \epsilon_{ict}, \quad (1)$$

where  $i$  denotes firm,  $c$  denotes cohort, and  $t$  denotes time (date or year).  $Volatility_{ict}$  is one of the measures for firm risk ( $StockVolat$ , annualized sum of squared daily stock returns, or  $ImpliedVolat$ , open-interest-weighted average of annualized daily option-implied volatility based on at-the-money call options with at least 90 days to expiration) for firm  $i$  in cohort  $c$  in time  $t$ .  $Discovery_{ict}$  is an indicator equaling one, if the NIH has discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by firm  $i$  as of time  $t$  in cohort  $c$ . To account for unobserved heterogeneity over time and across firms, and to allow the heterogeneity to vary across cohorts, I include a month- or year-cohort fixed effect and a firm-cohort fixed effect, denoted by

$\alpha_{ct}$  and  $\omega_{ic}$ .<sup>30</sup>

The results from estimating Equation (1) are presented in the appendix (panel A of Table A.3). Subsequent to the discovery of carcinogens, treated firms experience significant increases in option-implied volatility and stock return variance. Based on the matched sample, annualized daily option-implied volatility, on average, rises by 0.019 during the 12 months around the discovery (column 1), which accounts for 5% of the sample mean (0.36) or 12% of the sample standard deviation (0.16) of implied volatility prior to the discovery. Annualized stock variance, on average, increases by 0.033 (column 4), which accounts for 18% of the sample mean (0.18) or 16% of the sample standard deviation (0.21). The results are statistically significant at the 1% level.

The increases in implied volatility and stock variance are driven by treated firms in less affected 4-digit SIC industries, in which less than or equal to 50% of the firms are simultaneously affected. On average, implied volatility increases by 0.042 and stock variance increases by 0.034 for treated firms in less affected industries, both significant at the 5% level (columns 2 and 5). In contrast, there is no statistically significant change in either implied or stock return volatility in more affected industries (columns 3 and 6). One possible explanation is that treated firms in more affected industries may be able to increase product prices to reflect any potential increase in marginal costs due to switching to new inputs or products.<sup>31</sup>

An ideal natural experiment would impose a significant impact on firm risk but zero impact on expected firm value, so that the results can be interpreted as solely driven by changes in risk rather than by changes in expected value. The discovery of carcinogens can negatively affect expected firm value. To examine the effect on firm value, I estimate cumulative abnormal returns (CARs) around the discovery announcement date using an event study methodology.<sup>32</sup> Treated firms only experience an average three-day CAR of -0.52% and an average five-day CAR of -0.75% (panel B of Table A.3). The market reactions could suggest that the discovery of carcinogens mainly affects

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<sup>30</sup>For example, consider a firm affected by the discovery of carcinogens in 1989, then again affected in 1991. The firm-cohort fixed effects treat the firm as two separate entities for the period around 1989 and the period around 1991.

<sup>31</sup>Alternatively, litigation and reputation concerns may induce some treated firms to exit, thus, the remaining treated firms may generate riskier cash flows. In an untabulated table, I find that the average exit rate of treated firms' plants increases by 5% or doubles the sample mean prior to the discovery.

<sup>32</sup>The event study is based on a reduced sample of 1,191 treated observations due to availability of announcement dates and data on stock returns. I use CRSP value-weighted returns to proxy for market returns and estimate CARs using the Fama-French three-factor model.

firm risk rather than expected firm value.<sup>33</sup>

### 3.1.2 Anecdotal Cases and Medical Research

In this section, I provide evidence on the mechanisms of the effect on firm risk. I briefly discuss two anecdotal cases and examine related medical research subsequent to the discovery of carcinogens.

In practice, firms emitting newly discovered carcinogens may face litigation issues related to employee health, product safety, pollution, and investor losses. The following anecdotal cases suggest that the litigation uncertainty may exist for several years until regulatory agencies make decisions for specific industries or firms. For instance, asbestos was first listed in 1980 as a known carcinogen. In 1986, the Occupational Safety and Health Administration (OSHA) reduced the legal standards required in claims for workplace asbestos injuries, making it easier for plaintiffs to recover on these claims, and thus leading to an increase in the number of asbestos claims.<sup>34</sup> General Motors manufactured asbestos-containing brake linings from the 1930s through 1980s. However, the first asbestos claim against the company was in the 1990s, leaving a 10-year gap between the discovery of asbestos as a carcinogen and the actual litigation. By 2009, there were approximately 29,000 pending asbestos worker injury claims against General Motors, accounting for over \$600 million liabilities.<sup>35</sup> In addition to workplace exposure, another example is consumer exposure to carcinogens like formaldehyde. Formaldehyde was first listed in 1981 as a reasonably anticipated carcinogen, then updated to a known carcinogen in 2011. On February 22, 2016, when the Centers for Disease Control and Prevention (CDCP) confirmed that the formaldehyde-containing products sold by Lumber Liquidators, a flooring retailer, can cause cancer, the company's stock price plunged by 23 percent.<sup>36</sup> In this case, there was a gap between the discovery and its material consequence on firm value. The announcement by the regulatory agency (CDCP) made it likely for consumers to sue the firm, which translated into sizable value losses.

The previous section provides evidence for increased firm risk in both a shorter period (three months) and a longer period (two years) following the discovery of carcinogens, which suggests that

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<sup>33</sup>In addition, the small CARs may be partially explained by a survivorship bias, since discoveries of carcinogens induce some plants to exit.

<sup>34</sup>OSHA. 29 CFR Parts 1910 and 1926, Occupational Exposure to Asbestos, Tremolite, Anthophyllite, and Actinolite; Final Rules. 51 FR 22612-22790.

<sup>35</sup>Source: <https://www.crowell.com/Practices/Bankruptcy-Creditors-Rights/History-of-Asbestos-Bankruptcies/>.

<sup>36</sup>Source: <http://www.cbsnews.com/news/lumber-liquidators-falls-in-premarket-on-revised-cdc-report/>.

firm risk may keep increasing for two years. Alternatively, firm risk may jump in the first one or two months and then stop increasing. To distinguish between these two potential patterns, I explore related medical research. I collect a sample of 520 chemicals that were discovered as carcinogens between 1989 and 2011, and search the articles that mention each chemical during a six-year period around the discovery via Google Scholar. In an untabulated table, I find a significant increase in the number of articles about a chemical once discovered as a carcinogen. The average annual increase is around 3%, which accounts for around 20 more articles per year. In addition, the magnitude gradually increases from the year of discovery to two years after the discovery. This evidence suggests that the discovery of carcinogens attracts continuous attention from the academia in two years, and are consistent with the former hypothesis about changes in firm risk.

## 3.2 Main Results: Effect on CEO Risk-taking Incentives

### 3.2.1 Effect on Flow Vega

To test how firms adjust CEO risk-taking incentives subsequent to the discovery of carcinogens, I use a difference-in-difference methodology and estimate the following baseline model:

$$FlowVega_{ict} = \gamma_0 + \gamma_1 Discovery_{ict} + \alpha_{ct} + \omega_{ic} + \epsilon_{ict}, \quad (2)$$

where  $i$  denotes firm,  $c$  denotes cohort, and  $t$  denotes year.  $FlowVega_{ict}$  is the sensitivity of a CEO's current-year compensation to stock return volatility for firm  $i$  in cohort  $c$  in year  $t$ .  $Discovery_{ict}$  is an indicator equaling one, if the NIH has discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by firm  $i$  as of year  $t$  in cohort  $c$ . Following [Gormley, Matsa, and Milbourn \(2013\)](#), I include year-by-cohort fixed effect and firm-by-cohort fixed effect, denoted by  $\alpha_{ct}$  and  $\omega_{ic}$ , to account for unobserved heterogeneity across years and firms, and allow the heterogeneity to vary across cohorts. I use alternative fixed effects in robustness tests.

I do not include time-varying control variables due to potential concern of bad controls. Carcinogenicity discoveries may affect the control variables or the way flow vega depends on the controls, and therefore may bias the estimate of  $\gamma_1$ . In robustness tests, I control for firm size, CEO tenure and CEO cash compensation, and further address the concern by interacting the controls with the discovery indicator. In addition, I exclude firms that replace their CEOs in the year prior to the

discovery of carcinogens, because vega before and after the shock correspond to different CEOs and thus are less informative.

To examine whether firms' executive compensation adjustments depend on both their own and other firms' risk profiles, I split my sample between two types of industries: the more affected 4-digit SIC industries, in which more than 50% of the firms face the same shock to firm risk due to the discovery of carcinogens, and the less affected 4-digit SIC industries, in which less than or equal to 50% of firms face the shock. For example, in 2004, plastics manufacturing (SIC 2821) is classified as a more affected industry, in which 68% of the firms are affected by the discovery in that year; at the same time, cosmetics manufacturing (SIC 2844) is classified as a less affected industry, in which only 6% of the firms are affected (Figure 4). In robustness tests, I adopt alternative threshold fractions to split the sample.

Table 2 presents the main results. As shown in column (3), treated firms in less affected industries significantly increase CEO flow vega subsequent to the discovery of carcinogens. On average, those firms increase incumbent CEOs' value of current-year compensation (effectively the value of option grants) by \$6,018 per 0.01 increase in the firms' stock return volatility, which accounts for approximately 20% of the subsample mean (26,756) or standard deviation (32,529) of flow vega prior to the discovery. The coefficient estimate is statistically significant at the 5% level. In contrast, treated firms in more affected industries make no significant change to flow vega (column 5). Based on the full sample, treated firms significantly increase the value of CEOs' current-year compensation by \$2,859 per 0.01 increase in the firms' stock return volatility, which accounts for approximately 10% of the sample mean or standard deviation (column 1). The results are robust to including industry-by-year fixed effects (columns 2, 4, 6), which further accounts for unobserved heterogeneity across industries that may vary over time.

In addition, I adopt an alternative specification to compare less affected and more affected industries. I regress flow vega on the discovery of carcinogens and the interaction between the discovery indicator and an indicator for more affected industries. Unlike the previous subsample tests, this specification does not allow the year-by-cohort fixed effect to vary between less affected and more affected industries. Thus, I focus on subsample tests in later analyses. Nevertheless, the interaction term is significantly negative after controlling for unobserved heterogeneity across industries (column 8). Furthermore, as shown in a later table, the interaction term remains significant

using a matched sample, which indicates a robust difference between the two types of industries.

The above evidence is consistent with Hypothesis 1, which implies that firms take into account not only their own but also other same-industry firms' risk profiles in designing an executive compensation contract. One possible explanation is that product prices may absorb common shocks within an industry, but not idiosyncratic shocks. Treated firms in more affected industries may increase product prices to reflect any increase in marginal costs if they have to switch to new inputs or products. However, treated firms in less affected industries may not be able to increase product prices, and thus they may need to adjust CEO risk-taking incentives to remain competitive.

The results in Table 2 also explain why I arrive at a seemingly opposite sign to an existing study by Gormley, Matsa, and Milbourn (2013), which suggests a reduction in CEO flow vega when firm risk increases. Based on an industry-level workplace exposure survey, their study assumes that the treated group consists of all firms in more affected SIC industries, in which above a threshold fraction of workers is exposed to newly discovered carcinogens. They assume that the control group consists of all firms in less affected SIC industries. Their study shows that more affected industries reduce CEO flow vega relative to less affected industries. I replicate their empirical strategy using my sample and find similar results (column 9). Specifically, I replace the firm-level indicator for the discovery of carcinogens (*Discovery*) in Equation 2 with an industry-level indicator (*Discovery\_Industry*), which equals one for all firms within 4-digit SIC industries in which over 50% of the firms have been affected by the discovery as of a given year in a given cohort. More affected industries give incumbent CEOs, on average, \$3,319 less current-year compensation per 0.01 increase in the firms' stock return volatility than less affected industries.<sup>37</sup> Building on their industry-level analysis, this paper provides additional evidence on within-industry variations in compensation adjustments. My findings indicate that treated firms increase CEO flow vega, which is driven by less affected industries. I explore the rationale for the increase in CEO incentives in the next section.

The above analysis also notes that identifying treated and control observations at a fine level is important. Figure 5 illustrates the differences between the firm-level and the industry-level

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<sup>37</sup>One minor difference between my industry-level estimates and that of Gormley, Matsa, and Milbourn (2013) is that they find a larger difference between more affected and less affected industries. One reason is that they consider earlier cohorts such as 1985, in which period the chemical data used in my paper is not available. Based on my sample, the difference between more affected and less affected industries is also larger in earlier periods (Table A.4).

identification strategies. Panel A presents the number of Compustat firms affected by the discovery of carcinogens in each cohort (excluding observations without available financial data and CEO compensation data). Panel B illustrates potential measurement errors resulted from identifying treated and control groups at the 4-digit SIC industry level. The number of unidentified treated observations using the industry-level measure (striped bars) accounts for around 40% of the treated observations in panel A. Another type of measurement errors is that the industry-level measure identifies some control firms as treated. Those observations (white bars) are equivalent to 50% of the number of treated observations in panel A.<sup>38</sup> The issue of measurement errors would be more severe if the number of treated firms is closer to the number of control firms within an industry, that is, if there are within-industry variations in the choice of chemicals. In the 1991, 2000, and 2011 cohorts, the total number of incorrectly identified observations (striped bars plus white bars) exceeds correctly identified treated observations (gray bars).

One potential concern with natural experiment studies is sample selection bias. My results might be subject to this concern if few control observations are comparable to treated observations. In previous tests, I use fixed effects and control variables to account for heterogeneity between treated and control groups, but the sample selection bias may still exist if the two groups have different distributions of firm characteristics. I address this concern by matching the two groups by firm size deciles, age deciles, and 4-digit SIC industries. Around 60% of treated firms can be successfully matched based on these criteria. While using additional or more rigid matching criteria may improve matching quality, it would sacrifice power of the tests. Matching by the above three criteria actually generates a comparable treated and control sample in various ex-ante firm characteristics, such as firm size, stock returns, stock variance, delta, and vega (panel B of Table 1). Table 3 shows that my findings are robust to using the matched sample.

### 3.2.2 Effect on Composition of Compensation

I further analyze how firms adjust the composition of CEO compensation. In Table 4, I present the results from regressing CEO total compensation, cash compensation (salary plus bonus), the value of option grants, and the value of restricted stock grants on the discovery of carcinogens. I use the

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<sup>38</sup>This analysis uses 50% as a threshold value to construct the industry-level measure. Lowering the threshold value would lead to a decrease in the number of unidentified treated observations but an increase in false treated observations.

logged values for all dependent variables, since the distribution of CEO compensation is heavily skewed to the right. For each dependent variable, I conduct the test based on the full sample and subsamples of less affected and more affected industries.

Consistent with the increase in flow vega, I find that treated firms significantly increase the value of options grants (column 1 of panel B), which translates into an increase in total compensation (column 1 of panel A). The increases in option compensation and total compensation are mainly driven by less affected industries (columns 2 and 3 of both panels). In contrast, there is no significant change in the value of restricted stocks or cash compensation (columns 4–6 of both panels).<sup>39</sup>

The above results provide further support for the different responses to changes in firm risk between more affected and less affected industries. In addition, the results suggest that the increase in CEO vega does not seem to be mainly driven by an increase in total pay rather than risk-taking incentives. In an untabulated table, I find that treated firms significantly increase option grants, but not cash or stock compensation, in the 2011 cohort, when the adoption of FAS 123R in 2005 reduced the accounting advantage of using options.

### 3.3 Interpretation

In the previous section, I provide evidence that firms give CEOs more risk-taking incentives when they face greater firm risk, which is consistent with Hypothesis 2b. A possible interpretation is that risk-averse, under-diversified managers may underinvest in valuable risky projects, and thus firms want to mitigate the underinvestment and maximize shareholders' value (Panousi and Papanikolaou, 2012). In this section, I further investigate the effect of the discovery of carcinogens on investments, and test alternative explanations.

#### 3.3.1 Effect on Investments

I examine how R&D investments and capital expenditures change following the discovery of carcinogens and present the results in Table 5. If firms increase CEO risk-taking incentives in order to mitigate underinvestment, one would expect that treated firms do not experience a significant decline, or even increase their investments, especially in less affected industries. Consistent with

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<sup>39</sup>Around a quarter of the sample firms report other types of CEO compensation in addition to cash, restricted stock, and option compensation, which, on average, account for around 0.7% of total CEO pay. In an untabulated table, I find that treated firms make no significant adjustment to other CEO compensation.

this hypothesis, I find that treated firms, on average, increase the ratio of R&D investments to total sales by 0.2 percentage point (column 1 of panel A). Similar to previous findings, the effect on R&D is also driven by less affected industries. Treated firms in less affected industries increase R&D investments by 0.5 percentage point (column 2), while their counterparts in more affected industries make no significant change (column 3). In addition, the increase in R&D investments is significantly larger among treated firms that increase CEO flow vega after the discovery of carcinogens. A one standard deviation increase in CEO flow vega is associated with a 0.1 percentage-point larger increase in the ratio of R&D investments to total sales (column 4), which is also more evident in less affected industries, in which the magnitude is 0.7 percentage point (column 5).

The effect on capital expenditures is less evident (panel B). In less affected industries, an increase in CEO flow vega after the discovery of carcinogens is associated with a marginally significant reduction in the ratio of capital expenditures to total assets (column 5), which implies a substitution effect between R&D and capital investments. Relatively more investment in R&D and less investment in capital expenditures are typically viewed as riskier investment choices (e.g., [Coles, Daniel, and Naveen, 2006](#)).<sup>40</sup>

Furthermore, I distinguish between treated firms that keep producing or using newly discovered carcinogens and their counterparts that abandon those carcinogens. Keeping the newly discovered carcinogens may reflect a riskier investment or production decision. Consistent with the hypothesis that firms want to mitigate potential underinvestment, I find that the increase in CEO flow vega is more evident in treated firms that keep the newly discovered carcinogens. These results are unreported for brevity.

The above analysis shows that the increase in CEO risk-taking incentives is accompanied by an increase in risky investments in treated firms, consistent with Hypothesis 2b. Hence, my results indicate that firms give CEOs a greater reward of risk-taking to mitigate underinvestment and maximize shareholders' value when idiosyncratic risk increases, contrary to [Gormley, Matsa, and Milbourn \(2013\)](#), who suggest that firms cut incentives to reduce CEOs' exposure to firm-specific risk and meet participation constraint.

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<sup>40</sup>In contrast, Table 5 shows that capital expenditures rise among treated firms in more affected industries that increase CEO flow vega (column 6 of panel B), which is consistent with the finding in [Gormley and Matsa \(2011\)](#) that more affected industries increase acquisitions relative to less affected industries after the discovery of carcinogens.

### 3.3.2 Alternative Explanations

In this section, I provide evidence that my results do not seem to be driven by weak governance or risk-shifting incentives.

First, I investigate whether the compensation adjustments are dominated by firms with weaker governance strength. An alternative explanation to the increase in flow vega is that boards may be captured by the CEOs and raise CEO compensation at the expense of shareholders' value. However, Table 6 shows that the increase in flow vega is more evident in firms with ex-ante higher board independence, measured by the percentage of independent directors on board in the year prior to the discovery of carcinogens (columns 1 and 2 of panel A). In addition, the increase in flow vega is driven by firms with ex-ante higher potentially active institutional ownership, computed as in [Almazan, Hartzell, and Starks \(2005\)](#) (columns 5 and 6).<sup>41</sup> This evidence suggests that the results do not seem to be driven by weakly governed firms. Within the subsample of firms with more independent boards or higher institutional ownership, the increase in flow vega is more pronounced in less affected industries (columns 3, 4, 7, 8), which implies that the different responses between less affected and more affected product markets cannot be purely explained by board structure or institutional ownership.

Second, I test the alternative explanation that firms may increase CEO risk-taking incentives to shift risk to debtholders, which predicts that firms closer to distress or highly levered prior to the discovery of carcinogens would drive the subsequent increase in CEO risk-taking incentives. Contrary to this prediction, I find that the increase in flow vega is driven by firms with lower leverage ratios in the year prior to the discovery (columns 1 and 2 of panel B). Also, the increase in flow vega is driven by ex-ante non-distressed firms, measured by the [Altman \(1968\)](#) Z-score (columns 5 and 6). These results indicate that risk-shifting does not seem to be a main reason that treated firms increase CEO risk-taking incentives. Within the subsamples of lower-levered or non-distressed firms, treated firms in less affected industries drive the increase in flow vega (columns 3, 4, 7, 8), which suggests that the different responses between product markets cannot be attributed to differences in capital structure or financial health.

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<sup>41</sup>Following [Almazan, Hartzell, and Starks \(2005\)](#), potentially active institutional investors include investment companies and independent investment advisors. They are more likely to use shareholder proposals and other mechanisms to monitor managers than potentially passive institutional investors, such as banks and insurance companies, which are more likely to "vote by feet."

Finally, in previous tests, I exclude firms that replace their CEOs around the discovery of carcinogens, because the vega of different CEOs is less comparable. However, firms might also find it more efficient to replace the CEO and provide a new compensation contract rather than adjust the existing CEO's compensation.<sup>42</sup> I find that the increase in flow vega is robust to extending my sample to include new CEOs. To further analyze whether the increase in flow vega is an efficient decision to retain key executives or is driven by entrenched CEOs, I examine CEO turnover rates. The management entrenchment hypothesis predicts a lower turnover rate in treated firms that increase vega than in treated firms that do not increase vega. However, I find the opposite based on my sample. The average CEO turnover rate is 10.6% for the treated firms that increase vega and 6.7% for the treated firms that do not increase vega. The difference is statistically significant at the 5% level. The average CEO forced turnover rate (if CEOs are replaced before the age of 60) is 3.6% for the treated firms that increase vega and 1.9% for their counterparts. The difference is significant at the 10% level. This evidence suggests that my results are not driven by management entrenchment.

### 3.4 Firm Heterogeneity

The effect of the discovery of carcinogens may vary across firms. First, I distinguish between treated firms that use the newly discovered carcinogens to produce other products and those that produce the carcinogens for sales or distribution. It can be easier for a firm to substitute the carcinogen for a non-toxic chemical or conduct renovations if the carcinogen is a catalyst instead of a final product. Thus, the increase in litigation uncertainty may be greater for carcinogen producers than for carcinogen users. Hence, I expect that the effect on flow vega would be more evident for carcinogen producers. To test this hypothesis, I split the treated sample between carcinogen users and carcinogen producers. Table 7 presents the results. Consistent with the hypothesis, the discovery of carcinogens leads to a significant increase in CEO flow vega in carcinogen producers (column 2) but no significant change in flow vega by carcinogen users (column 1). In addition, the increase in flow vega is also driven by carcinogen producers in less affected industries (columns 3 and 4).

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<sup>42</sup>For example, some firms may be able to find a less risk-averse CEO, and thus do not need to give as many risk-taking incentives as to the incumbent CEO.

Second, I compare domestically focused firms with foreign-focused firms. Similar to the analysis on investments, I expect that the effect on flow vega would be less evident in foreign-focused firms, since they may face lower costs to outsource the carcinogen-related production. Foreign-focused firms may move the affected plant or product line to other countries with less rigid environmental or product safety regulations, which may mitigate the increase in firm risk. Consistent with this hypothesis, I find that more domestically focused treated firms significantly increase flow vega (by \$3,641; column 6), while more foreign-focused treated firms do not significantly adjust flow vega (column 5), where foreign focus is measured by the ratio of foreign sales to total sales in the year prior to the discovery of carcinogens. Similar to previous findings, the increase in flow vega is more pronounced in less affected industries within the domestically focused subsample (columns 7 and 8). The results in Table 7 indicate that the effect on CEO risk-taking incentives is mainly driven by firms with less substitutable carcinogens.

Finally, I test whether the results depend on industry competition. As discussed in previous sections, treated firms in more affected industries may face smaller potential losses, since they may increase product prices to mitigate any increase in marginal costs due to switching to new inputs or products. However, one implicit assumption is that firms take product prices as given. Firms with market power may mitigate the impact of discovery of carcinogens by adjusting product prices. Thus, I expect a larger increase in CEO incentives and a greater divergence in treated firms' responses between more affected and less affected industries when firms operate in more competitive industries. Consistent with these hypotheses, I find that the increase in CEO flow vega is mainly driven by treated firms in industries with a lower Herfindal-Hirschman index and thus more intense competition in the year before the discovery. Treated firms in more competitive industries significantly increase flow vega (by \$5,074; column 4 of Table 8), while treated firms in less competitive industries do not significantly change flow vega (column 1). In addition, the increase in flow vega is more evident in less affected industries within the subsample of more competitive industries (columns 5 and 6).

### **3.5 Robustness Analyses**

I conduct a number of robustness checks. First, I find robust results after controlling for firm size, CEO tenure, and CEO cash compensation (even columns of Table A.5). Although including

time-varying control variables may bias the estimates, I find no significant effect of the discovery of carcinogens on any of these control variables in untabulated tables. To further address the concern of bad controls, I include the interactions between the control variables and the discovery indicator. I find a similar increase in flow vega. All estimates on the interaction terms are insignificant except for the interaction between cash compensation and the discovery indicator. The discovery of carcinogens leads to an average increase in flow vega, but the magnitude diminishes with higher levels of CEO cash compensation.<sup>43</sup> This result is consistent with Guay (1999), who suggests that CEOs with greater cash compensation have a larger capacity to invest outside the firm and diversify their portfolios. Those CEOs may be less likely to underinvest when idiosyncratic risk increases, and thus may not need as much risk-taking incentives as other CEOs. Furthermore, my results are robust to additional controls, including cash flows, leverage, and CEO age, in addition to their interactions with the discovery indicator.

Second, my results are robust to alternative measures for managerial incentives. I regress the number of option grants on the discovery of carcinogens and find robust results (Table A.6), which suggests a real effect on managerial incentives rather than a pure mechanical effect. Since flow vega is a function of stock return volatility, any change in volatility will translate into a change in flow vega by definition. In addition, the discovery of carcinogens also leads to a similar effect on flow delta (Table A.7). Furthermore, I calculate vega using a CEO's complete portfolio of compensation, including compensation in a given year and previous years, to account for a total wealth effect.<sup>44</sup> In an untabulated table, I find that the increase in flow vega translates into a significant increase in vega. Finally, I regress the change in CEO flow vega on the discovery of carcinogens, and find that treated firms in less affected industries significantly increase the change in flow vega.

Third, I estimate the effect of the discovery by year. My results may be subject to the reversal causality concern if, for instance, firms with ex-ante lower CEO risk-taking incentives could lobby to prevent the NIH from establishing the carcinogenicity of a chemical emitted by those firms. To address this concern, I replace *Discovery* in Equation (2) with four indicators: *Discovery*(-1), an indicator equaling one, if the NIH will discover the carcinogenicity of a chemical emitted by a given

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<sup>43</sup>In an untabulated table, I find that for one-standard-deviation higher of the logged value of cash compensation (0.60, based on my sample), the marginal increase in flow vega diminishes by  $0.60 \times 4.197 \times 1,000$ , which is \$2,520.

<sup>44</sup>CEO vega is computed as flow vega plus the vega based on the option grants in previous years, minus the vega based on options exercised by the CEO.

firm in the following year;  $Discovery(0)$ , an indicator for the discovery of carcinogens in the current year;  $Discovery(+1)$ , an indicator for the discovery in the last year; and  $v(+2)$ , an indicator for the discovery occurred two years ago. As shown in Table A.8, the estimate on  $Discovery(-1)$  is statistically insignificant and smaller in magnitude than the estimates on indicators for later years (column 1). In addition, the increase in flow vega two years after the discovery is significant at the 5% level and largest in magnitude compared to other years. The results remain similar when I use the number of option grants as dependent variable, or focus on a subsample of less affected industries. This evidence mitigates the reversal causality concern.

I also use several alternative specifications to Equation (2). In previous analyses, I use firm-cohort and year-cohort fixed effects to allow unobserved heterogeneity to vary across cohorts. I use firm and year fixed effects as a robustness check and obtain similar results. In addition, I cluster standard errors at the firm level instead of the industry level and find robust results. The firm-level clustering accounts for potential covariance among firm outcomes and over time, while the industry-level clustering accounts for covariance among firm outcomes within industry and over time. Furthermore, the different responses between more affected and less affected industries are robust to alternative threshold fractions of treated firms (30% and 40%). I also find similar results using alternative estimation windows, such as a four-year (year T-2 to year T+1) or eight-year period (year T-4 to year T+3) around the discovery of carcinogens (in year T). These results are unreported for brevity.

In addition, my results are robust to several other subsample and extended sample tests. First, I exclude the 2004 cohort. The 2004 discovery of carcinogens affected the most firms (around 40% of total number of treated firms) among all discoveries in my sample, and had a several months' gap between scheduled and actual announcement, which could introduce biases if there was information leakage and firms responded prior to the actual announcement. However, the increase in flow vega is actually more evident once I exclude the 2004 cohort. In other words, the inclusion of the 2004 cohort only works against my main findings. Second, I extend my sample to 1994, 1998, and 2002 cohorts and find similar results. Third, my findings remain robust when I exclude overlapping years across cohorts. Fourth, I distinguish between firms affected for the first time in my sample and firms repeatedly affected, and find robust results in both subsamples. Finally, my results are robust when I identify newly discovered carcinogens via their first appearance as known carcinogens

instead of reasonably anticipated carcinogens, or focus on a subsample in which I exclude chemicals that first appeared on the carcinogen list as reasonably anticipated carcinogens. The above results are untabulated for brevity.

## 4 Conclusion

This paper shows that firms' executive compensation choices depend on both their own and other firms' characteristics. I exploit exogenous increases in firm risk when a chemical produced or used by a firm is discovered as a carcinogen. Using a difference-in-difference methodology, I find that treated firms increase CEO risk-taking incentives. This result is mainly driven by treated firms in less affected industries, in which a smaller fraction of the firms face the shock to firm risk.

The discovery of carcinogens leads to an average 5% to 18% increase in treated firms' option-implied or realized stock volatility, which indicates a material change in firm risk. I show that treated firms significantly increase CEO risk-taking incentives, measured mainly by flow vega. Subsequent to the discovery of carcinogens, treated firms increase CEOs' current-year compensation by a \$2,859 per 0.01 increase in stock return volatility, which accounts for around 10% of the sample mean of flow vega. The increase in flow vega is mainly driven by less affected industries. Treated firms in those industries increase flow vega by 20%, which indicates that affected firms significantly adjust executive compensation when most of their rival firms in the industry do not face the same shock to firm risk. Furthermore, I show that treated firms in less affected industries increase option grants, but do not significantly change other components of compensation. My findings suggest that compensation adjustments depend on the risk profiles of all firms in an industry. When a firm is the only one or among few companies in an industry that face a same shock to firm risk, it significantly adjusts managerial incentives to remain competitive. In contrast, when a firm is among many companies in an industry that face the same shock, it may not react strongly.

By exploring within-industry variations in executive compensation adjustments, this paper provides additional evidence to the existing literature on the effect of firm risk on compensation decisions. I extend the industry-level analysis by [Gormley, Matsa, and Milbourn \(2013\)](#), who find that more affected industries reduce managerial incentives relative to less affected industries following the discovery of carcinogens. I show that firms give managers a greater reward of risk-taking sub-

sequent to the discovery, and the incentive adjustments are driven by less affected industries. My findings are consistent with the prediction of [Panousi and Papanikolaou \(2012\)](#) that firms may give risk-averse, under-diversified managers more risk-taking incentives to mitigate underinvestment when idiosyncratic risk rises. I provide supporting evidence that the increase in CEO incentives is accompanied by an increase in risky investments, measured by R&D expenditures. Consistent with my main results, the effect on R&D is also more evident in less affected industries. In addition, I test several alternative explanations such as risk-shifting and weak governance, and find no consistent evidence.

In addition, I show that the increase in CEO incentives is more evident in carcinogen producers than carcinogen users. Also, the increase in CEO incentives is more pronounced in firms with fewer foreign subsidiaries or sales. The subsample results are also driven by less affected industries.

My results are robust to several alternative specifications. For instance, I find no preexisting trends in CEO incentives prior to the discovery of carcinogens. In addition, my results are robust after controlling for firm and CEO characteristics, in addition to their interactions with the discovery. My results also remain similar, based on a matched sample, which further accounts for ex-ante differences between the treated and control groups. Furthermore, I find robust results using alternative measures for CEO incentives, including the number of option grants. I also find similar results after excluding the 2004 discovery, which affected the most number of firms. Finally, my results are robust to alternative fixed effects, standard errors, and estimation windows.

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**Table 1: Summary Statistics**

This table reports mean comparison results between treated and control groups. The sample includes firm-year observations in the three years prior to the discovery of carcinogens by the National Institutes of Health (NIH) occurred in 1989, 1991, 2000, 2004, or 2011. In panel A, a firm belongs to the treated group if the NIH discovered the carcinogenicity of a chemical produced or used thus, emitted by the firm in the most recent edition of the Report on Carcinogens, as reported in the EPA’s Toxic Release Inventory database. A firm belongs to the control group if it emitted at least one toxic chemical but no recently discovered carcinogen. In panel B, treated and control groups are matched based on firm size decile, firm age decile, and 4-digit SIC industry. In panel C, a firm is assigned to the treated group if it belongs to a 4-digit SIC industry in which more than 50% of the firms emitted a newly discovered carcinogen, and is assigned to the control group otherwise. Panel D reports original summary statistics from [Gormley, Matsa, and Milbourn \(2013\)](#). Variables include: firm size (*FirmSize*) defined as the logged value of total assets; firm age (*FirmAge*) defined as the number of years listed in Compustat; the ratio of market value of equity to book equity (*M/B*); the ratio of total liabilities to total assets (*Leverage*); cash flows scaled by total assets (*CashFlows*); stock returns (*StockReturns*); stock return volatility (*StockVolat*); CEO delta (*Delta*) defined as the sensitivity of a CEO’s total wealth (in \$000s) to stock prices; CEO vega (*Vega*) defined as the sensitivity of a CEO’s total wealth (in \$000s) to stock return volatility; and the value of option grants divided by a CEO’s total pay (*Options/TotalComp*). Detailed definitions of variables are presented in [Table A.1](#). The last row in each panel reports the number of unique firms. Columns 3 and 6 present the *p*-value statistics from a *t*-test of the difference between treated and control groups, where standard errors are clustered at the industry level.

Variables	Panel A: Full Sample			Panel B: Matched Sample		
	(1) Treated	(2) Control	(3) <i>p</i> -value	(4) Treated	(5) Control	(6) <i>p</i> -value
FirmSize	8.09	7.33	0.02	8.08	7.48	0.10
FirmAge	36.77	21.18	0.00	36.94	28.7	0.06
M/B	0.03	0.03	0.26	0.03	0.03	0.42
Leverage	0.57	0.54	0.30	0.58	0.54	0.25
CashFlows	0.13	0.13	0.18	0.13	0.12	0.20
StockReturns	0.09	0.16	0.01	0.08	0.14	0.17
StockVolat	0.22	0.32	0.00	0.21	0.29	0.16
Delta	454.34	631.96	0.09	400.82	517.1	0.23
Vega	141.13	101.22	0.02	129.46	104.86	0.21
Options/TotalComp	0.28	0.28	0.49	0.27	0.32	0.17
Firms	370	624		218	411	
Variables	Panel C: Industry-level Measure			Panel D: Gormley, Matsa, and Milbourn (2013)		
	(1) Treated	(2) Control	(3) <i>p</i> -value	(4) Treated	(5) Control	(6) <i>p</i> -value
FirmSize	7.78	7.43	0.15	7.15	7.44	0.47
FirmAge	35.47	21.33	0.00	N/A	N/A	N/A
M/B	0.02	0.03	0.01	0.03	0.03	0.99
Leverage	0.57	0.54	0.30	N/A	N/A	N/A
CashFlows	0.13	0.13	0.32	0.16	0.15	0.42
StockReturns	0.10	0.15	0.04	N/A	N/A	N/A
StockVolat	0.22	0.33	0.01	0.24	0.18	0.35
Delta	346.21	674.01	0.01	326.20	519.30	0.30
Vega	101.86	114.70	0.25	41.74	27.60	0.59
Options/TotalComp	0.25	0.29	0.10	0.31	0.27	0.56
Firms	370	624		143	341	

**Table 2: Effect of Discoveries of Carcinogens on CEO Flow Vega**

This table reports estimates from regressing CEO flow vega on the discovery of carcinogens (Equation 2). The sample consists of five cohorts of firm-year observations during the six-year period (from year T-3 to year T+2) around the discovery of carcinogens by the National Institutes of Health (NIH) occurred in 1989, 1991, 2000, 2004, or 2011 (year T). A firm is included in the sample if it owned at least one plant that produced or used thus, emitted toxic chemicals (not necessarily carcinogens) during the sample period, as reported in the EPA’s Toxic Release Inventory database. The dependent variable is *FlowVega*, the sensitivity of a CEO’s current-year compensation (in \$000s) to the firm’s stock return volatility. *Discovery* is an indicator equaling one, if the NIH discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens. *Discovery\_Industry* is an indicator for all firms within the 4-digit SIC industries in which over 50% of the firms were affected by the discovery of carcinogens. Detailed definitions of variables are presented in Table A.1. Columns 3 and 4 present subsample results for less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery. Columns 5 and 6 report subsample results for more affected 4-digit SIC industries, in which over 50% of the firms were simultaneously affected by the discovery. In column 9, the sample is restricted to the Fama-French industries in which there is at least one firm in a less affected 4-digit SIC industry for every ten firms in a more affected 4-digit SIC industry, following Gormley, Matsa, and Milbourn (2013). All specifications exclude observations for which firms replace their CEOs in the year prior to the discovery of carcinogens. All specifications include firm-cohort fixed effects and year-cohort fixed effects. The even columns include 4-digit SIC industry-year fixed effects. Standard errors reported in parentheses are clustered at the industry level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

	Dependent Variable = FlowVega								
	Full Sample		Less Affected Industries		More Affected Industries		Full Sample		Full Sample
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Discovery	2.859** (1.408)	4.918** (1.950)	6.018** (2.715)	10.21*** (2.615)	2.252 (1.769)	3.092 (2.421)	5.704** (2.469)	10.19*** (2.598)	
Discovery × Discovery_Industry							-3.364 (2.421)	-7.098** (3.565)	
Discovery_Industry									-3.319** (1.576)
<i>N</i>	5635	4402	2207	1525	3428	2861	5635	4402	5501
Adjusted <i>R</i> <sup>2</sup>	0.638	0.636	0.594	0.567	0.667	0.662	0.638	0.636	0.694
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes	No

**Table 3: Effect of Discoveries of Carcinogens on CEO Flow Vega: Matched Sample**

This table reports variants of Table 2 in which treated and control firms are matched based on firm size decile, firm age decile, and 4-digit SIC industry. The dependent variable is *FlowVega*, the sensitivity of a CEO’s current-year compensation (in \$000s) to the firm’s stock return volatility. *Discovery* is an indicator equaling one, if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens. *Discovery\_Industry* is an indicator for all firms within the 4-digit SIC industries in which over 50% of the firms were affected by the discovery of carcinogens. Detailed definitions of variables are presented in Table A.1. Column 2 presents subsample results for less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery. Column 3 reports subsample results for more affected 4-digit SIC industries, in which over 50% of the firms were simultaneously affected by the discovery. In column 5, the sample is restricted to the Fama-French industries in which there is at least one firm in a less affected 4-digit SIC industry for every ten firms in a more affected 4-digit SIC industry, following Gormley, Matsa, and Milbourn (2013). All specifications exclude observations for which firms replace their CEOs in the year prior to the discovery of carcinogens. All specifications include firm-cohort fixed effects and year-cohort fixed effects. Standard errors reported in parentheses are clustered at the industry level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

	Dependent Variable = FlowVega				
	Matched Sample	Less Affected Industries	More Affected Industries	Matched Sample	Matched Sample
	(1)	(2)	(3)	(4)	(5)
Discovery	3.742* (2.002)	8.699** (3.132)	1.632 (1.959)	7.522** (2.968)	
Discovery × Discovery_Industry				-5.299** (1.954)	
Discovery_Industry					-4.072*** (1.290)
<i>N</i>	2079	965	1114	2079	2067
Adjusted <i>R</i> <sup>2</sup>	0.608	0.518	0.686	0.609	0.640
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes
Firm-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes

**Table 4: Effects of Discoveries of Carcinogens on CEO Cash, Option, and Stock Compensation**

This table reports estimates from regressing individual components of CEO compensation on the discovery of carcinogens. The dependent variables are: Total compensation (*TotalComp*) defined as the logged value of a CEO's total compensation in a given year in columns 1–3 of panel A; cash compensation (*CashComp*) defined as the logged value of a CEO's salary plus bonus in a given year in columns 4–6 of panel A; stock option compensation (*Options*) defined as the logged value of one plus the value of options granted to a CEO in a given year in columns 1–3 of panel B; and stock compensation (*StockComp*) defined as the logged value of one plus the value of restricted stocks granted to a CEO in a given year in columns 4–6 of panel B. All raw values used to calculate dependent variables are in \$000s. *Discovery* is an indicator equaling one, if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens. Detailed definitions of variables are presented in Table A.1. Columns 2 and 5 in both panels present subsample results for less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery. Columns 3 and 6 in both panels report subsample results for more affected 4-digit SIC industries, in which over 50% of the firms were simultaneously affected by the discovery. All specifications include firm-cohort fixed effects and year-cohort fixed effects. Standard errors reported in parentheses are clustered at the industry level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

<b>Panel A: Total Compensation and Cash Compensation</b>						
	Full Sample	Less Affected Industries	More Affected Industries	Full Sample	Less Affected Industries	More Affected Industries
	(1)	(2)	(3)	(4)	(5)	(6)
	TotalComp	TotalComp	TotalComp	CashComp	CashComp	CashComp
Discovery	0.094** (0.043)	0.151** (0.074)	0.079 (0.052)	0.030 (0.023)	0.015 (0.052)	0.040 (0.026)
<i>N</i>	5765	2201	3564	5795	2203	3592
Adjusted <i>R</i> <sup>2</sup>	0.717	0.635	0.774	0.761	0.712	0.792
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
<b>Panel B: Option Compensation and Stock Compensation</b>						
	Full Sample	Less Affected Industries	More Affected Industries	Full Sample	Less Affected Industries	More Affected Industries
	(1)	(2)	(3)	(4)	(5)	(6)
	Options	Options	Options	StockComp	StockComp	StockComp
Discovery	0.324** (0.148)	0.720** (0.344)	0.227 (0.171)	0.045 (0.141)	0.082 (0.299)	0.092 (0.176)
<i>N</i>	5573	1975	3598	5795	2203	3592
Adjusted <i>R</i> <sup>2</sup>	0.541	0.478	0.578	0.642	0.638	0.643
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

**Table 5: Effects of Discoveries of Carcinogens on R&D and Capital Expenditures**

This table reports estimates from regressing R&D and capital expenditures on the discovery of carcinogens and its interaction with the change in CEO flow vega. The dependent variables are: R&D expenditures scaled by total sales ( $R\&D$ , missing values are replaced with zeros) in panel A; and capital expenditures scaled by total assets ( $CapEx$ ) in panel B.  $Discovery$  is an indicator equaling one, if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens.  $\phi(\Delta FlowVega)$  is computed as the average difference in CEO flow vega before and after the discovery scaled by the sample standard deviation of  $FlowVega$ .  $FlowVega$  is defined as the sensitivity of a CEO's current-year compensation (in \$000s) to the firm's stock return volatility. Detailed definitions of variables are presented in Table A.1. Columns 2 and 5 in both panels present subsample results for less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery. Columns 3 and 6 report subsample results for more affected 4-digit SIC industries, in which over 50% of the firms were simultaneously affected by the discovery. All specifications include firm-cohort fixed effects and year-cohort fixed effects. Standard errors reported in parentheses are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

<b>Panel A: R&amp;D Investments</b>						
	Full Sample	Less Affected Industries	More Affected Industries	Full Sample	Less Affected Industries	More Affected Industries
	(1)	(2)	(3)	(4)	(5)	(6)
	R&D	R&D	R&D	R&D	R&D	R&D
Discovery	0.002*** (0.001)	0.005** (0.002)	0.000 (0.000)	0.003** (0.001)	0.009* (0.005)	0.001 (0.000)
Discovery $\times$ $\phi(\Delta FlowVega)$				0.001** (0.001)	0.007*** (0.003)	0.000 (0.000)
$N$	8774	3578	5196	7468	2969	4499
Adjusted $R^2$	0.886	0.873	0.920	0.889	0.877	0.918
Firm-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
<b>Panel B: Capital Expenditures</b>						
	Full Sample	Less Affected Industries	More Affected Industries	Full Sample	Less Affected Industries	More Affected Industries
	(1)	(2)	(3)	(4)	(5)	(6)
	CapEx	CapEx	CapEx	CapEx	CapEx	CapEx
Discovery	-0.000 (0.001)	-0.002 (0.003)	-0.001 (0.001)	0.002 (0.002)	-0.004 (0.003)	0.001 (0.003)
Discovery $\times$ $\phi(\Delta FlowVega)$				0.003 (0.002)	-0.005* (0.003)	0.005** (0.002)
$N$	8691	3530	5161	7398	2931	4467
Adjusted $R^2$	0.683	0.671	0.689	0.679	0.662	0.687
Firm-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

**Table 6: Alternative Explanations: Weak Governance and Risk-Shifting Incentives**

This table reports subsample tests of column 1 in Table 2. The dependent variable is *FlowVega*, the sensitivity of a CEO’s current-year compensation (in \$000s) to stock return volatility. *Discovery* is an indicator equaling one, if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens. Column 1 of panel A presents subsample results for firms in which the fraction of independent directors on board (*Independence*) was less than or equal to median in the year prior to the discovery of carcinogens. Columns 2–4 report subsample results for firms with above-median ex-ante board independence. Column 5 reports subsample results for firms in which the fraction of shares owned by active institutional investors (*ActiveOwnership*), computed as in [Almazan, Hartzell, and Starks \(2005\)](#), was less than or equal to median in the year prior to the discovery. Columns 6–8 present subsample results for firms with above-median ex-ante active institutional ownership. Column 1 of panel B presents subsample results for firms with a higher ratio of total liabilities to total assets (*Leverage*) compared to the 33th percentile in the year prior to the discovery. Columns 2–4 report subsample results for firms with an ex-ante leverage ratio lower or equivalent to the 33th percentile. Column 5 reports subsample results for firms with an [Altman \(1968\)](#) Z-score (*Z*) below 1.81 at the beginning of the year prior to the discovery. Columns 6–8 present subsample results for firms with an ex-ante Z-score above or equal to 1.81. Detailed definitions of variables are presented in Table A.1. Columns 3 and 7 in both panels present subsample results for less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery. Columns 4 and 8 report subsample results for more affected 4-digit SIC industries, in which over 50% of the firms were simultaneously affected by the discovery. All specifications exclude observations for which firms replace their CEOs in the year prior to the discovery. All specifications include firm-cohort fixed effects and year-cohort fixed effects. Standard errors reported in parentheses are clustered at the industry level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

<b>Panel A: Ex-ante Board and Institutional Investor Monitoring</b>								
	Less Independent Boards	More Independent Boards			Lower Institutional Ownership	Higher Institutional Ownership		
		All Firms	Less Affected Industries	More Affected Industries		All Firms	Less Affected Industries	More Affected Industries
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega
Discovery	0.605 (2.382)	4.335** (1.999)	8.943** (3.918)	2.583 (2.363)	1.211 (1.781)	4.033** (1.947)	9.428** (4.170)	1.982 (2.807)
<i>N</i>	1813	2381	869	1512	2304	2228	936	1292
Adjusted <i>R</i> <sup>2</sup>	0.632	0.678	0.646	0.691	0.698	0.615	0.567	0.651
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<b>Panel B: Ex-ante Risk-shifting Incentives</b>								
	Highly Levered	Not Highly Levered			Distressed	Non-distressed		
		All Firms	Less Affected Industries	More Affected Industries		All Firms	Less Affected Industries	More Affected Industries
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega
Discovery	1.967 (3.512)	3.496** (1.541)	6.029** (2.658)	1.716 (2.107)	1.584 (2.213)	3.552** (1.412)	6.409** (2.817)	2.538 (2.078)
<i>N</i>	1921	3628	1572	2056	1248	4387	1783	2604
Adjusted <i>R</i> <sup>2</sup>	0.650	0.628	0.589	0.657	0.683	0.646	0.609	0.671
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

**Table 7: Firm Heterogeneity: Carcinogen Usage and Foreign Diversification**

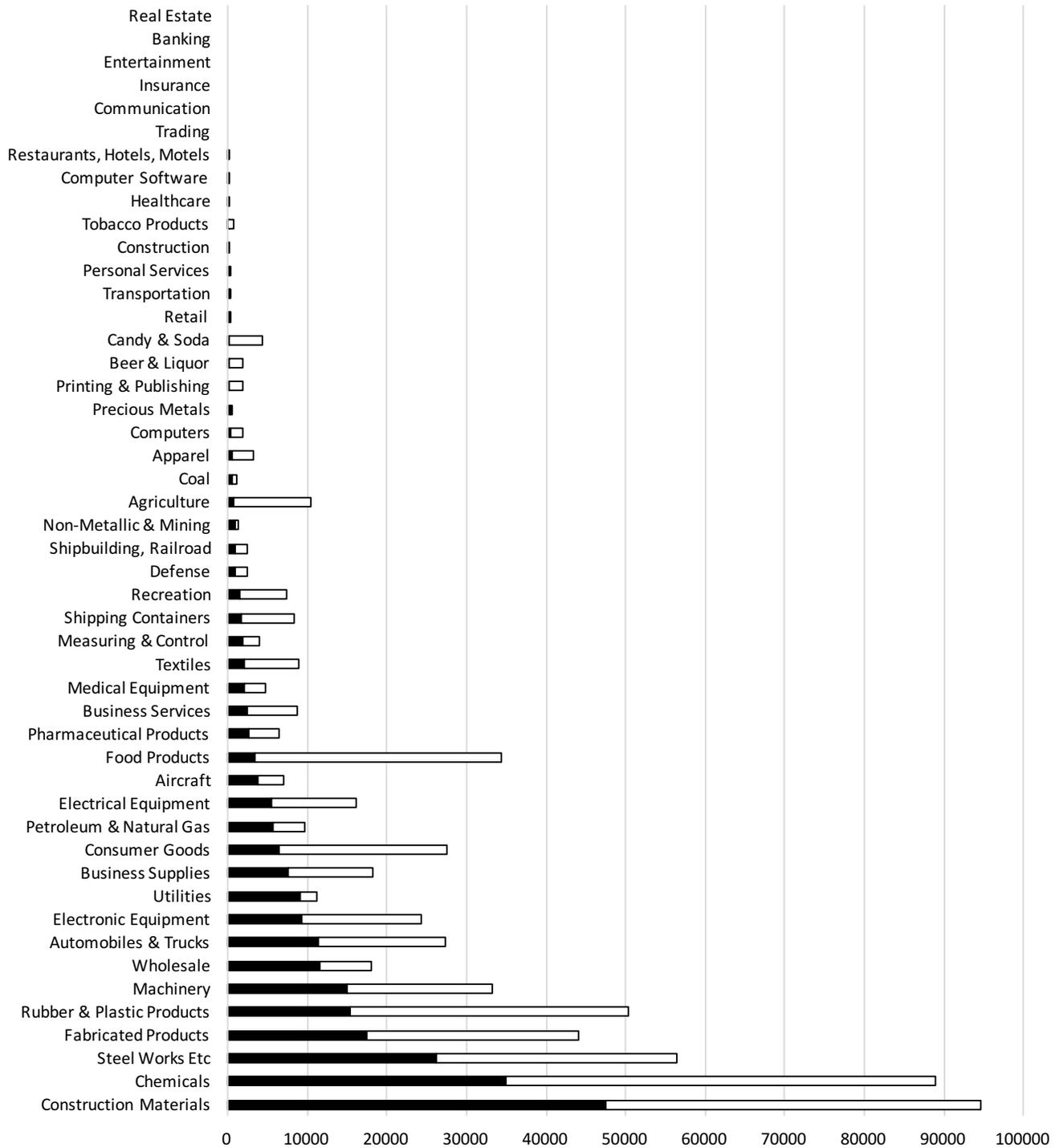
This table reports subsample tests of column 1 in Table 2. The dependent variable is *FlowVega*, the sensitivity of a CEO’s current-year compensation (in \$000s) to the firm’s stock return volatility. *Discovery* is an indicator equaling one, if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens. Column 1 presents subsample results for treated carcinogen users and all control firms. Columns 2–4 report subsample results for treated carcinogen producers and all control firms. A treated firm is classified as a carcinogen user (rather than producer) if a greater fraction of newly discovered carcinogens were used or processed to produce other products rather than produced for sales or distribution purpose. Column 5 reports subsample results for firms with a higher ratio of foreign sales to total sales (*ForeignSales*) compared to the 33th percentile in the year prior to the discovery of carcinogens. Columns 6–8 report subsample results for firms with ex-ante foreign sales lower or equivalent to the 33th percentile. Detailed definitions of variables are in Table A.1. Columns 3 and 7 present further subsample results for less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery. Columns 4 and 8 present further subsample results for more affected 4-digit SIC industries, in which over 50% of the firms were simultaneously affected by the discovery. All specifications exclude observations for which firms replace their CEOs in the year prior to the discovery. All specifications include firm-cohort fixed effects and year-cohort fixed effects. Standard errors reported in parentheses are clustered at the industry level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

	Carcinogen Producers				Domestically Focused			
	Carcinogen Users	All Firms	Less Affected Industries	More Affected Industries	Foreign-focused	All Firms	Less Affected Industries	More Affected Industries
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega
Discovery	2.390 (1.502)	3.304* (1.841)	12.52** (5.900)	1.971 (2.142)	2.423 (2.589)	3.641** (1.733)	10.73** (5.201)	2.564 (1.920)
<i>N</i>	4826	4223	1838	2385	1761	3232	1121	2111
Adjusted <i>R</i> <sup>2</sup>	0.660	0.656	0.632	0.674	0.643	0.629	0.593	0.649
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

**Table 8: Firm Heterogeneity: Industry Competition**

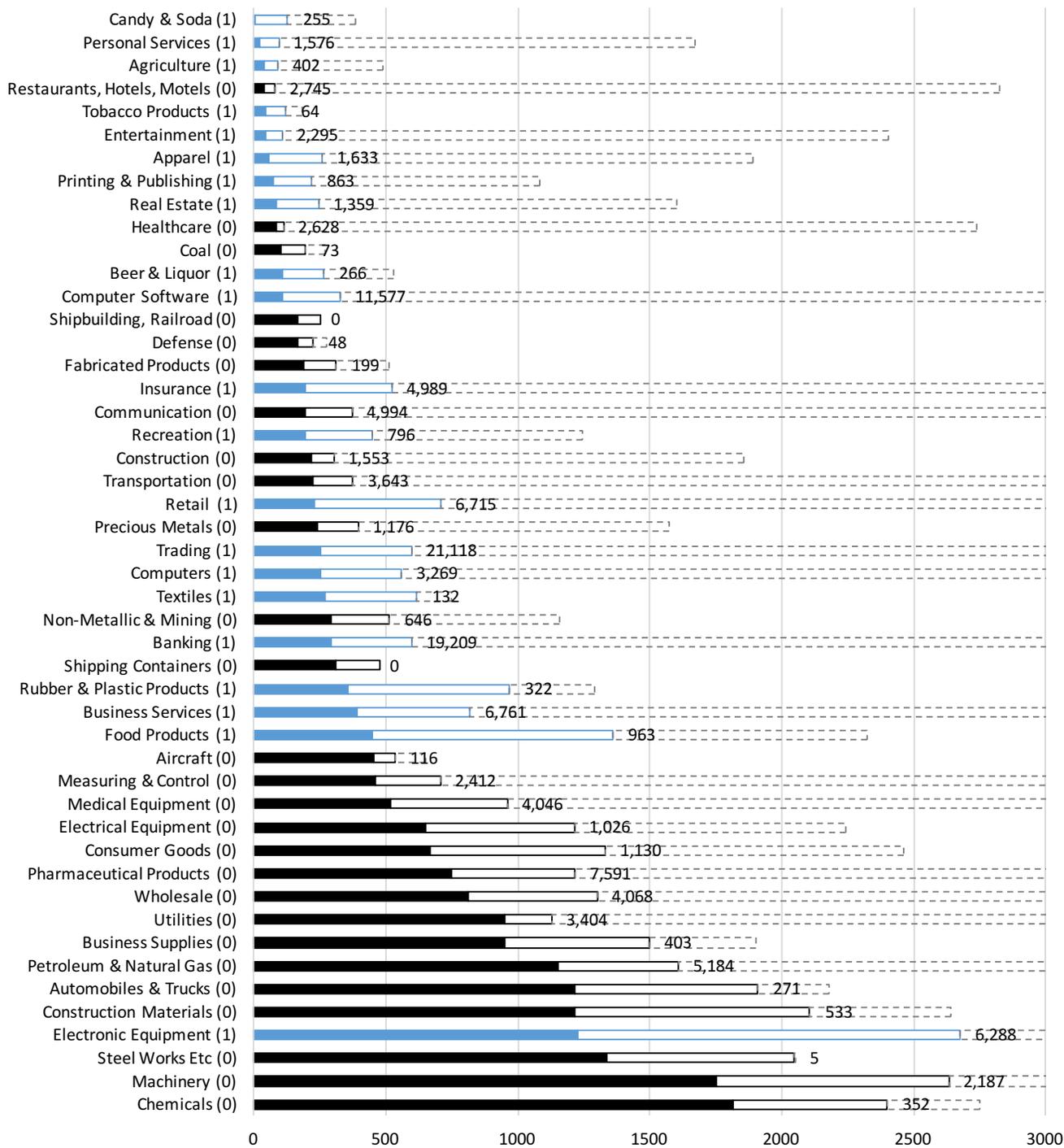
This table reports subsample tests of column 1 in Table 2. The dependent variable is *FlowVega*, the sensitivity of a CEO’s current-year compensation (in \$000s) to the firm’s stock return volatility. *Discovery* is an indicator equaling one, if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens. Columns 1–3 present subsample results for the 4-digit SIC industries with above-median Herfindal-Hirschman index (*HHI*) defined as the sum of squared shares of sales in the year prior to the discovery of carcinogens. Columns 4–6 report subsample results for the 4-digit SIC industries with ex-ante Herfindal-Hirschman indices lower or equivalent to the median. Detailed definitions of variables are presented in Table A.1. Columns 2 and 5 present further subsample results for less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery. Columns 3 and 6 present further subsample results for more affected 4-digit SIC industries, in which over 50% of the firms were simultaneously affected by the discovery. All specifications exclude observations for which firms replace their CEOs in the year prior to the discovery. All specifications include firm-cohort fixed effects and year-cohort fixed effects. Standard errors reported in parentheses are clustered at the industry level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

	Less Competitive Industries			More Competitive Industries		
	All Firms	Less Affected Industries	More Affected Industries	All Firms	Less Affected Industries	More Affected Industries
	(1) FlowVega	(2) FlowVega	(3) FlowVega	(4) FlowVega	(5) FlowVega	(6) FlowVega
Discovery	0.654 (1.926)	-1.567 (5.645)	0.802 (2.300)	5.074*** (1.866)	9.395*** (2.842)	4.173 (2.585)
<i>N</i>	2939	932	2007	2696	1275	1421
Adjusted R. $R^2$	0.658	0.575	0.694	0.614	0.607	0.614
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes



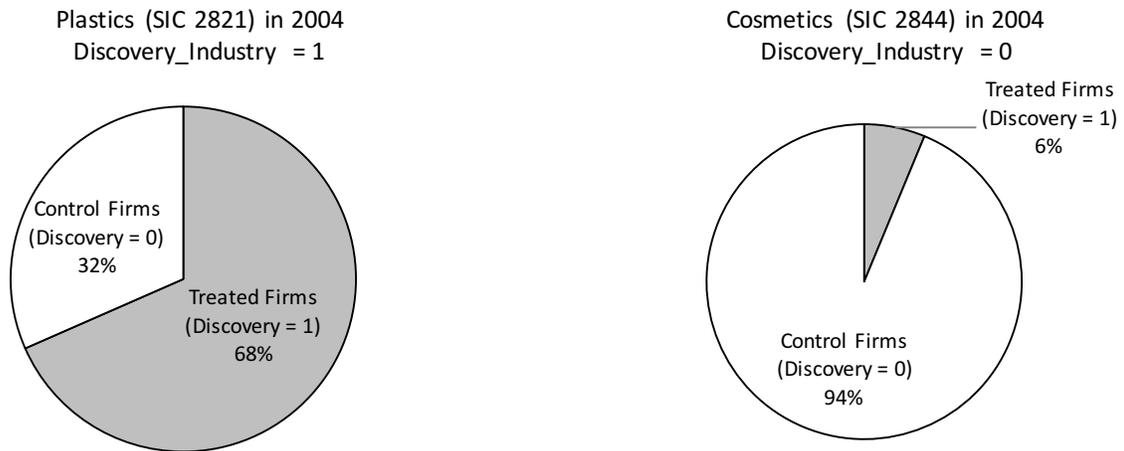
**Figure 2: Plants in the Toxic Release Inventory Database by Industry**

This figure presents the number of plant-year observations during 1987-2014 by the Fama and French (1997) 48 industry. Black bars indicate plants that emitted carcinogens, as reported in the Toxic Release Inventory (TRI) database. White bars indicate plants that emitted non-carcinogenic toxic chemicals.



**Figure 3: Compustat Firms by Industry**

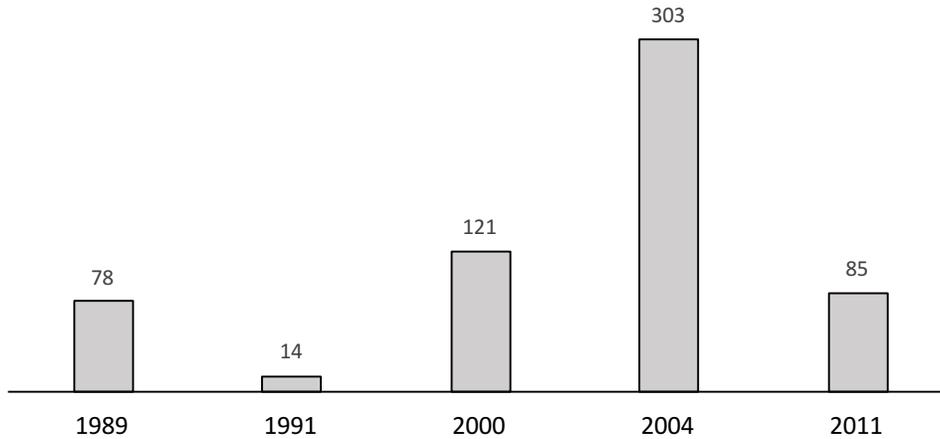
This figure presents the number of firm-year observations during 1987-2013 by the Fama and French (1997) 48 industry. Colored bars indicate firms with plants that emitted carcinogens, as reported in the Toxic Release Inventory (TRI) database. White bars indicate firms with plants that emitted non-carcinogenic toxic chemicals. Black color and zeros in parentheses indicate industries in which over 50% of the firms with TRI-reporting plants emitted carcinogens. Blue color and one in parentheses indicate industries in which less than or equal to 50% of the firms with TRI plants emitted carcinogens. Dashed bars with values indicate firms that emitted no toxic chemical.



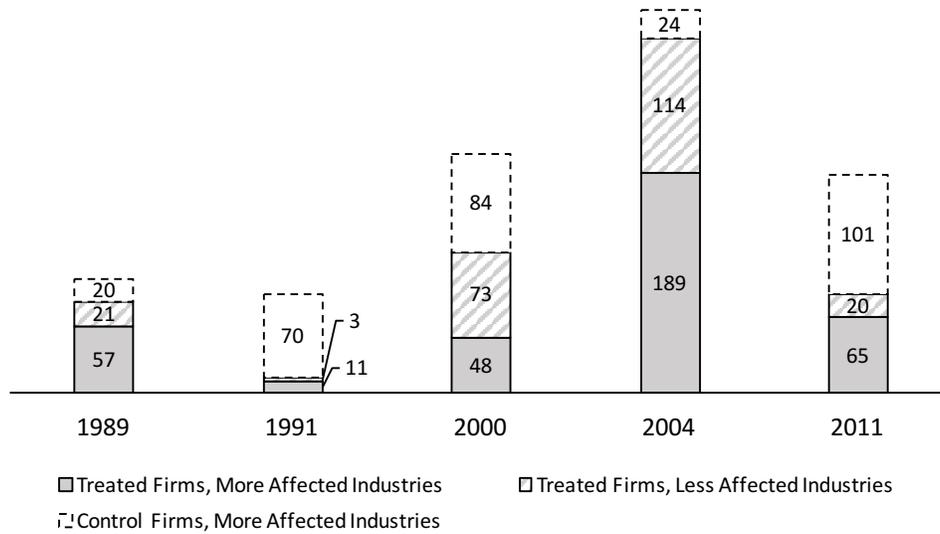
**Figure 4: Example of a More Affected Industry and a Less Affected Industry**

This figure illustrates an example of a more affected 4-digit SIC industry (plastics manufacturing, SIC 2821) and an example of a less affected 4-digit SIC industry (cosmetics manufacturing, SIC 2844) in the event of the 2004 discovery of carcinogens by the National Institutes of Health (NIH). Both industries belong to the chemical manufacturing sector. Grey color indicates the number of treated firms, i.e. firms that emitted carcinogens discovered in 2004. White color indicates the number of control firms, i.e. firms that did not emit any carcinogen discovered in 2004. *Discovery* is an indicator equaling one, if the NIH discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm. *Discovery\_Industry* is an indicator for all firms within the 4-digit SIC industries in which over 50% of the firms were affected by the discovery of carcinogens. Detailed definitions of variables are presented in Table A.1. The sample includes firms listed in Compustat that emitted toxic chemicals (including carcinogens and non-carcinogens) in 2004.

Panel A: Number of Treated Firms



Panel B: Identifying Treated and Control Groups at Industry level



**Figure 5: Identifying Treated and Control Groups at Firm Level vs. Industry Level**

Panel A presents the number of firms affected by discoveries of carcinogens by year. The sample is restricted to firms with available financial and compensation data. A firm is considered treated if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by the firm in a given year. Striped bars and white bars of panel B illustrate potential measurement errors resulted from identifying treated and control groups by 4-digit SIC industry. For each year, panel B reports the following: The number of treated firms in more affected 4-digit SIC industries, in which over 50% of the firms were simultaneously affected by the discovery of carcinogens, i.e. firms identified as treated at both firm and industry levels (gray bars); the number of treated firms in less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery, i.e. firms identified as treated at the firm level but as control using the industry-level measure (striped bars); and the number of control firms in more affected 4-digit SIC industries, i.e. firms identified as treated using the industry-level measure but as control at the firm level (white bars).

## Appendix

**Table A.1: Variable Definitions**

Variables	Definitions
<b>Panel A: Discoveries of Carcinogens (Sources: Report on Carcinogens and Toxic Release Inventory)</b>	
Discovery	Indicator equaling one, if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens, as reported in the Toxic Release Inventory database maintained by the U.S. Environmental Protection Agency (EPA).
Discovery_Industry	Indicator for all firms within a 4-digit SIC industry in which over 50% of the firms were affected by the discovery of carcinogens in the most recent edition of the Report on Carcinogens.
<b>Panel B: CEO Compensation and Characteristics (Sources: Execucomp and Yermack, 1995)</b>	
FlowVega	Change in the value of a CEO's current-year compensation (effectively measured by the value of options granted in a given year; in \$000s) for a 0.01 increase in the firm's stock return volatility (measured by the annualized standard deviation of stock returns). The calculation follows the methodology from <a href="#">Core and Guay (2002)</a> and <a href="#">Coles, Daniel, and Naveen (2013)</a> using compensation data from Execucomp for post-1992 and Yermack's sample for pre-1992.
FlowDelta	Change in the value of a CEO's current-year compensation (effectively measured by the value of stock and options granted in a given year; in \$000s) for a 1% increase in stock prices. See the definition for <i>FlowVega</i> for more details.
TotalComp	Logged value of CEO total compensation (in \$000s), calculated using <i>TDC1</i> from Execucomp and the sum of <i>SALBON</i> , <i>OTHCOMP</i> , and <i>GRANTVAL</i> from Yermack's sample.
CashComp	Logged value of CEO cash compensation (in \$000s), calculated using <i>SALARY</i> plus <i>BONUS</i> from Execucomp and <i>SALBON</i> from Yermack's sample.
Options	Logged value of one plus options granted to the CEO in a given year (in \$000s), calculated using <i>OPTION_AWARDS_BLK_VALUE</i> for pre-2006 and <i>OPTION_AWARDS_FV</i> for post-2006 from Execucomp, and <i>GRANTVAL</i> from Yermack's sample.
Options_N	Number of options granted to the CEO in a given year (in 000s), calculated using <i>OPTION_AWARDS_NUM</i> from Execucomp and <i>OPTGRANT</i> divided by 1000 from Yermack's sample.
StockComp	Logged value of one plus restricted stocks granted to the CEO in a given year (in \$000s), calculated using <i>RSTKGRNT</i> for pre-2006 and <i>STOCK_AWARDS_FV</i> for post-2006 from Execucomp, and <i>OTHCOMP</i> from Yermack's sample.
CEOTenure	Logged value of one plus the number of years being CEO.
<b>Panel C: Firm Characteristics (Sources: Compustat, OptionMetrics, CRSP, ISS, Thomson Reuters)</b>	
FirmSize	Logged value of total assets ( <i>AT</i> from Compustat; same source below).
FirmAge	Number of years listed in Compustat.
M/B	Market-to-book ratio, calculated as $(CSHO \times PRCC\_F)/CEQ$ .

CashFlows	Cash flows divided by total assets ( $AT$ ). Cash flows are calculated by extracting <i>Accruals</i> from <i>OIADP</i> , where $Accruals = (ACT_t - ACT_{t-1}) - (CHE_t - CHE_{t-1}) - (LCT_t - LCT_{t-1}) + (DLC_t - DLC_{t-1}) - dp$ from Compustat.
CapEx	Capital expenditures ( $CAPX$ ) divided by total assets ( $AT$ ).
R&D	R&D expenditures ( $RD$ ) divided by total sales ( $SALE$ ). Missing values are replaced with zeros.
Leverage	Total liabilities ( $LT$ ) divided by total assets ( $AT$ ).
Z	<a href="#">Altman (1968)</a> Z-score at the beginning of the year, calculated as $1.2 \times WCAP/AT + 1.4 \times RE/AT + 3.3 \times EBIT/AT + 0.6 \times CSHO \times PRCC\_F/LT + 0.999 \times SALE/AT$ .
ForeignSales	Sum of the sales from foreign segments ( $SALE$ , where $GEOTOP = 3$ ) plus export sales from domestic segments ( $SALEXG$ , where $GEOTOP = 2$ ) from Compustat Segment data.
ImpliedVolat	Open-interest-weighted average value of annualized daily implied volatility based on at-the-money call options with at least 90 days to expiration, using OptionMetrics data.
StockVolat	Sum of squared daily returns during a given year multiplied by 252 and divided by the number of trading days, calculated using CRSP data.
StockReturns	Annualized holding period stock returns, calculated using CRSP data.
Independence	Fraction of independent directors on board from ISS (formerly RiskMetrics).
ActiveOwnership	Fraction of shares owned by potentially active institutional investors, using data from 13-f filings in Thomson Reuters, which distinguishes among five types of institutional investors: (1) investment companies; (2) independent investment advisors; (3) banks; (4) insurance companies, and (5) other institutions. Following <a href="#">Almazan, Hartzell, and Starks (2005)</a> , potentially active investors refer to (1) and (2).
HHI	Industry Herfindal-Hirschman index, computed as the sum of squared shares of sales within a 4-digit SIC industry.

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**Table A.2: Timing of Discoveries of Carcinogens**

This table presents the timing of discoveries of carcinogens. Column 1 reports the fiscal years in which the National Institutes of Health (NIH) released the Report on Carcinogens (RoC) to the public. Column 2 reports the dates on which the NIH released the RoC, as reported in news releases and articles by the National Institute of Environmental Health Sciences (NIEHS) and the National Center for Biotechnology Information (NCBI) available since 1994. Column 3 presents the number of chemicals newly discovered as carcinogens in a given edition of the RoC, excluding chemicals delisted in a later edition. Column 4 reports the number of chemicals previously discovered as carcinogens but delisted in a given edition of RoC due to a low possibility of human exposure and/or insufficient evidence of carcinogenicity after reevaluation. The last two columns report the number of Compustat firms releasing newly discovered carcinogens (excluding chemicals later delisted) and the number of Compustat firms releasing delisted carcinogens in a given fiscal year, as reported in the Toxic Release Inventory database available since 1987.

(1)	(2)	(3)	(4)	(5)	(6)
Year	Date	Newly Discovered Carcinogens	Delisted Chemicals	Firms Affected by Discoveries	Firms Affected by Delisting
1980	N/A	27	0	N/A	N/A
1981	N/A	65	1	N/A	N/A
1983	N/A	29	0	N/A	N/A
1985	N/A	32	0	N/A	N/A
1989	N/A	18	4	312	0
1991	N/A	13	2	45	0
1994	June 24, 1994	8	0	7	0
1998	May 14, 1998	15	0	4	0
2000	May 15, 2000	16	2	245	54
2002	December 11, 2002	17	0	190	0
2004	January 31, 2005	17	0	643	0
2011	June 10, 2011	6	0	156	0
2014	October 2, 2014	4	0	60	0
Total		267	9	1662	54

**Table A.3: Effects of Discoveries of Carcinogens on Volatility and Returns**

Panel A reports estimates from regressing volatility on the discovery of carcinogens (Equation 1). A firm is included in the analysis if it owned at least one plant that produced or used thus, emitted toxic chemicals (not necessarily carcinogens). In columns 1–3 of panel A, the sample consists of three cohorts of firm-date observations during the twelve-month period (from day D-180 to day D+180) around the discovery of carcinogens by the National Institutes of Health (NIH) occurred in 2000, 2004, or 2011 (on day D). The discovery announcement dates are reported in Table A.2. The dependent variable is option-implied volatility (*ImpliedVolat*), the open-interest-weighted average value of annualized daily implied volatility based on at-the-money call options with at least 90 days to expiration. In columns 4–6 of panel A, the sample consists of five cohorts of firm-year observations during the six-year period (from year T-3 to year T+2) around the discovery occurred in 1989, 1991, 2000, 2004, or 2011 (year T). The dependent variables is stock return volatility (*StockVolat*), the annualized sum of squared daily returns during the year. Treated and control firms in panel A are matched based on firm size decile, firm age decile, and 4-digit SIC industry. *Discovery* is an indicator equaling one, if the NIH discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens. Detailed definitions of variables are presented in Table A.1. All specifications include firm-cohort fixed effects and month-cohort or year-cohort fixed effects. Standard errors reported in parentheses are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. Panel B presents summary statistics on three-day and five-day average cumulative abnormal returns (CARs) around the discovery announcement date, estimated using the Fama-French model, using CRSP value-weighted returns to proxy for market returns. Columns 2 and 5 of panel A and column 4 of panel B present subsample results for less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery. Columns 3 and 6 of panel A and column 5 of panel B report subsample results for more affected 4-digit SIC industries, in which over 50% of the firms were simultaneously affected by the discovery.

<b>Panel A: Volatility</b>						
	Full Matched Sample	Less Affected Industries	More Affected Industries	Full Matched Sample	Less Affected Industries	More Affected Industries
	(1)	(2)	(3)	(4)	(5)	(6)
	ImpliedVolat	ImpliedVolat	ImpliedVolat	StockVolat	StockVolat	StockVolat
Discovery	0.019*** (0.004)	0.042** (0.016)	0.018 (0.011)	0.033*** (0.009)	0.034** (0.017)	-0.006 (0.008)
<i>N</i>	143594	71175	72419	7382	3935	3447
Adjusted <i>R</i> <sup>2</sup>	0.895	0.862	0.920	0.601	0.599	0.585
Firm-cohort FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-cohort FE	Yes	Yes	Yes			
Year-cohort FE				Yes	Yes	Yes

<b>Panel B: Cumulative Abnormal Returns (CARs; in %)</b>						
	Full Sample			Less Affected Industries	More Affected Industries	
	(1)	(2)	(3)	(4)	(5)	(6)
	CAR	<i>p</i> -value ( <i>t</i> -test)	<i>p</i> -value (rank test)	CAR	CAR	<i>p</i> -value (difference)
Days						
(-1,+1)	-0.52	0.01	0.01	-0.61	-0.33	0.02
(-2,+2)	-0.75	0.00	0.00	-1.09	-0.46	0.00
<i>N</i>	1191			756	435	

**Table A.4: Subsample Tests: Earlier vs. Later Discoveries of Carcinogens**

This table reports subsample tests of columns 7 and 9 in Table 2. The dependent variable is *FlowVega*, the sensitivity of a CEO's current-year compensation (in \$000s) to the firm's stock return volatility. *Discovery* is an indicator equaling one, if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens. *Discovery\_Industry* is an indicator for all firms within the 4-digit SIC industries in which over 50% of the firms were affected by the discovery of carcinogens. Detailed definitions of variables are presented in Table A.1. Columns 1 and 3 present subsample results for pre-2004 discoveries. Columns 2 and 4 present subsample results for 2004 and 2011 discoveries. Column 5 reports subsample results for pre-2011 discoveries. Column 6 reports subsample results for the 2011 discovery. All specifications exclude observations for which firms replace their CEOs in the year prior to the discovery of carcinogens. All specifications include firm-cohort fixed effects and year-cohort fixed effects. Standard errors reported in parentheses are clustered at the industry level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

	Pre-2004	Post-2004	Pre-2004	Post-2004	Pre-2011	2011
	(1)	(2)	(3)	(4)	(5)	(6)
	Flowvega	Flowvega	Flowvega	Flowvega	Flowvega	Flowvega
Discovery	11.81** (4.857)	3.241 (2.466)				
Discovery × Discovery_Industry	-10.50** (5.107)	-0.479 (2.410)				
Discovery_Industry			-5.622** (2.766)	-2.230 (1.592)	-4.028** (1.824)	-1.902 (2.071)
<i>N</i>	1865	3770	1853	3648	3744	1757
Adjusted <i>R</i> <sup>2</sup>	0.523	0.704	0.569	0.746	0.643	0.791
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

**Table A.5: New CEOs and Control Variables**

This table presents robustness checks to Table 2. The dependent variable is *FlowVega*, the sensitivity of a CEO’s current-year compensation (in \$000s) to the firm’s stock return volatility. *Discovery* is an indicator equaling one, if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens. *Discovery\_Industry* is an indicator for all firms within the 4-digit SIC industries in which over 50% of the firms were affected by the discovery of carcinogens. Control variables include: firm size (*FirmSize*) defined as the logged value of total assets; CEO tenure (*CEOTenure*) defined as the logged value of one plus the number of years being CEO; and CEO cash compensation (*CashComp*) computed as the logged value of a CEO’s salary and bonus in a given year. Detailed definitions of variables are reported in Table A.1. Columns 1–4 and 5–8 report variants of column 1 and 4 in Table 2, respectively. Columns 3, 4, 7, 8 exclude observations for which firms replace their CEOs in the year prior to the discovery of carcinogens. All specifications include firm-cohort fixed effects and year-cohort fixed effects. Standard errors reported in parentheses are clustered at the industry level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega	FlowVega
Discovery	2.256** (1.045)	2.106** (0.969)	2.859** (1.329)	2.536** (1.186)				
Discovery_Industry					-2.473** (1.117)	-2.326** (1.108)	-3.319** (1.449)	-2.823** (1.396)
FirmSize		4.232*** (1.168)		5.327*** (1.431)		8.258*** (1.473)		9.612*** (1.825)
CEOTenure		-2.825*** (0.477)		-1.681 (1.047)		-4.379*** (0.605)		-3.982*** (1.399)
CashComp		5.148*** (0.780)		4.397*** (0.976)		6.204*** (0.973)		4.536*** (1.227)
<i>N</i>	7468	7417	5635	5635	7297	7249	5501	5501
Adjusted <i>R</i> <sup>2</sup>	0.637	0.642	0.638	0.642	0.694	0.701	0.694	0.698
Exclude New CEOs	No	No	Yes	Yes	No	No	Yes	Yes
Firm-cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

**Table A.6: Effect of Discoveries of Carcinogens on the Number of Option Grants**

This table reports estimates from regressing the number of CEO option grants on the discovery of carcinogens. The dependent variable is *Options\_N*, the number of options granted to a CEO in a given year (in 000s). *Discovery* is an indicator equaling one, if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens. *Discovery\_Industry* is an indicator for all firms within the 4-digit SIC industries in which over 50% of the firms were affected by the discovery of carcinogens. Detailed definitions of variables are reported in Table A.1. Column 2 presents subsample results for less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery. Column 3 reports subsample results for more affected 4-digit SIC industries, in which over 50% of the firms were simultaneously affected by the discovery. All specifications exclude observations for which firms replace their CEOs in the year prior to the discovery of carcinogens. All specifications include firm-cohort fixed effects and year-cohort fixed effects. Standard errors reported in parentheses are clustered at the industry level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

	Full Sample	Less Affected Industries	More Affected Industries	Full Sample	Full Sample
	(1)	(2)	(3)	(4)	(5)
	Options_N	Options_N	Options_N	Options_N	Options_N
Discovery	18.49* (10.55)	69.53** (27.94)	5.666 (10.82)	56.08*** (20.15)	
Discovery × Discovery_Industry				-43.89** (20.05)	
Discovery_Industry					-27.35** (11.02)
<i>N</i>	5599	1975	3624	5599	5286
Adjusted <i>R</i> <sup>2</sup>	0.503	0.420	0.571	0.504	0.470
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes
Firm-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes

**Table A.7: Effect of Discoveries of Carcinogens on CEO Flow Delta**

This table reports robustness checks to Table 2. The dependent variable is *FlowDelta*, the sensitivity of a CEO’s current-year compensation (in \$000s) to the firm’s stock prices. *Discovery* is an indicator equaling one, if the National Institutes of Health (NIH) discovered the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the most recent edition of the Report on Carcinogens. *Discovery\_Industry* is an indicator for all firms within the 4-digit SIC industries in which over 50% of the firms were affected by the discovery of carcinogens. Detailed definitions of variables are reported in Table A.1. Column 2 presents subsample results for less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery. Column 3 reports subsample results for more affected 4-digit SIC industries, in which over 50% of the firms were simultaneously affected by the discovery. All specifications exclude observations for which firms replace their CEOs in the year prior to the discovery of carcinogens. All specifications include firm-cohort fixed effects and year-cohort fixed effects. Standard errors reported in parentheses are clustered at the industry level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

	Full Sample	Less Affected Industries	More Affected Industries	Full Sample	Full Sample
	(1)	(2)	(3)	(4)	(5)
	FlowDelta	FlowDelta	FlowDelta	FlowDelta	FlowDelta
Discovery	4.080** (1.901)	11.03** (4.590)	1.754 (2.098)	9.502*** (3.597)	
Discovery × Discovery_Industry				-6.404* (3.607)	
Discovery_Industry					-5.875* (3.321)
<i>N</i>	5785	2277	3508	5785	5630
Adjusted <i>R</i> <sup>2</sup>	0.536	0.437	0.610	0.536	0.553
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes
Firm-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes

**Table A.8: Effects of Discoveries of Carcinogens on Managerial Incentives by Year**

This table reports robustness checks to Table 2. The dependent variables are: *FlowVega*, the sensitivity of a CEO’s current-year compensation to the firm’s stock return volatility, in columns 1 and 4; *Options\_N*, the number of options granted to a CEO in a given year, in columns 2 and 5; and *FlowDelta*, the sensitivity of a CEO’s current-year compensation to the firm’s stock prices, in columns 3 and 6. All dependent variables are in (\$)000s. *Discovery(-1)* is an indicator equaling one, if the National Institutes of Health (NIH) will discover the carcinogenicity of a chemical produced or used thus, emitted by one of the plants owned by the firm in the following year. *Discovery(0)* is an indicator equaling one, if the NIH discovers the carcinogenicity in the current year. *Discovery(+1)* is an indicator equaling one, if the NIH discovered the carcinogenicity in the previous year. *Discovery(+2)* is an indicator equaling one, if the NIH discovered the carcinogenicity two years ago. Detailed definitions of variables are presented in Table A.1. Columns 4–6 present subsample results for less affected 4-digit SIC industries, in which less than or equal to 50% of the firms were simultaneously affected by the discovery. All specifications exclude observations for which firms replace their CEOs in the year prior to the discovery of carcinogens. All specifications include firm-cohort fixed effects and year-cohort fixed effects. Standard errors reported in parentheses are clustered at the industry level. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively.

	Full Sample			Less Affected Industries		
	(1) FlowVega	(2) Options_N	(3) FlowDelta	(4) FlowVega	(5) Options_N	(6) FlowDelta
Discovery(-1)	0.111 (1.524)	27.20 (18.92)	1.865 (2.467)	-2.934 (3.405)	-23.27 (35.77)	-2.184 (5.855)
Discovery(0)	2.990* (1.644)	25.13 (17.42)	4.845* (2.661)	1.597 (3.635)	4.951 (38.45)	9.042 (6.240)
Discovery(+1)	1.999 (1.769)	28.79** (13.01)	4.689 (2.874)	4.969 (4.113)	78.84* (43.52)	12.09* (7.210)
Discovery(+2)	3.911** (1.936)	31.98** (14.10)	4.640 (3.071)	10.45** (4.508)	139.6*** (45.97)	10.41 (7.728)
<i>N</i>	5635	5599	5785	2118	1975	2277
Adjusted $R^2$	0.654	0.503	0.536	0.631	0.422	0.436
Exclude New CEOs	Yes	Yes	Yes	Yes	Yes	Yes
Firm-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes