Corporate Hedging and the Design of Incentive-Compensation Contracts

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Abstract: We use the introduction of exchange-traded weather derivative contracts as a natural experiment to examine the relation between risk and incentives. Specifically, we examine how executives' ability to hedge weather-related risk that was previously difficult and costly to manage influences the design of executives' incentive-compensation contracts. We find that the CEOs of firms that are relatively more exposed to weather risk—and therefore stand to benefit the most from hedging this source of risk—receive less annual compensation and have fewer equity incentives following the introduction of weather derivatives. We attribute the former finding to a reduction in the risk premium that CEOs demand for exposure to firm risk. The latter finding suggests that uncertainty in firms' operating environments and equity incentives are complements in our sample firms. Collectively, our results highlight how hedging corporate risk influences agency conflicts and the associated incentive mechanisms.

Keywords: executive compensation; contract design; equity incentives; risk-taking incentives; stock options; derivatives; hedging; natural experiment

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1. Introduction

The theoretical agency literature highlights the importance of risk-related agency conflicts—whereby undiversified managers are more averse to firm-specific, idiosyncratic risk than are shareholders—as a potential source of wealth destruction. Although providing managers with incentives tied to stock price can sometimes alleviate these agency conflicts, doing so imposes risk on managers and therefore requires payment of a commensurate risk premium.[1] Consequently, firms trade off the benefits of providing incentives against the costs of compensating managers for bearing the associated risk. While this tradeoff leads to relatively straightforward predictions about the effect of risk on *compensation*, the effect of risk on *incentives* is theoretically ambiguous (Hemmer, 2006, 2012; Prendergast, 2002).

Identifying the effect of risk on the design of executives' incentive-compensation contracts is empirically challenging not only because of the theoretical ambiguity of the relation, but also because of the endogenous relation between risk and compensation contracts (Demsetz and Lehn, 1985; Aggarwal and Samwick, 1999; Core and Guay, 2002). A cross-sectional correlation between risk and various features of incentive-compensation contracts might not reflect the (causal) effect of risk because contract design is likely to be correlated with unobservable factors that also have a direct effect on firms' risk.

Despite these challenges and concerns, we examine the effect of risk on the design of executives' incentive compensation contracts. To address the endogenous nature of risk and incentive-compensation contracts, we examine a natural experiment involving the introduction of exchange-traded weather derivative contracts—or simply "weather derivatives" for short—on a

[1] As we discuss below, in certain instances, it may not even be feasible to further mitigate agency conflicts. In such a setting, providing a manager with additional equity incentives (e.g., stock and stock options) can actually induce *greater* risk aversion and exacerbate the risk-related agency conflict (Lambert, Larcker, and Verrecchia, 1991; Ross, 2004).

sample of firms in the utility industry. Prior to the introduction of weather derivatives, it was difficult (i.e., costly, if at all feasible) for these firms to hedge the risk associated with their exposure to the weather. The introduction of weather derivatives either enabled these firms to hedge weather-related outcomes for the first time or, at a minimum, hedge them more efficiently. Consequently, the introduction of weather derivatives allowed firms to alter their exposure to weather-related risk and, in turn, should have influenced the design of their executives' incentive-compensation contracts in several important ways.

First, the ability to hedge risk should affect the amount of executives' annual compensation. Core, Guay, and Larcker (2003), Core and Guay (2010), Armstrong, Core, and Guay (2016), and others discuss how a portion of an executives' annual compensation consists of a risk-premium to compensate them for bearing risk associated with their performance-based incentives and firm-specific human capital. If hedging allows executives to eliminate some of this risk, they should receive less of a risk-premium in their annual pay.

Second, the ability to hedge risk could also affect executives' incentives in general, and their equity incentives in particular. However unlike its effect on annual pay, the effect of hedging away risk on executives' incentives is theoretically ambiguous (Hemmer, 2006, 2012).[2] A seemingly widespread belief—at least in the *empirical* contracting literature—is that risk (e.g., variance of the performance measure) should be negatively related to the strength of managers' incentives. As Hemmer (2006) observes, many studies appeal to either Holmstrom (1979) or

[2] Note that an influential paper by Prendergast (2002) develops a model that also predicts a positive, rather than a negative relation between risk and incentives. Prendergast's (2002) model highlights the tradeoff between incentives and monitoring and shows how a principal might want to rely more on incentives when there is greater uncertainty in the operating environment (i.e., risk) and monitoring the agent's inputs becomes relatively more costly. Although our results are largely consistent with Prendergast's (2002) predictions, we do not explicitly test for substitution from incentives to monitoring following a decline in risk.

Holmstrom and Milgrom (1987)—or sometimes simply "the standard model," which presumably refers to one or both of these studies—as support for their prediction of a negative relation.

However, as Hemmer (2006) shows analytically, the conventional wisdom that these models predict a negative relation between risk and incentives is demonstrably false. Although the exact reasons are somewhat technical, the intuition for the theoretical ambiguity of the relation between risk and incentives is simple: risk is generally endogenously determined by the agent's actions.[3] In other words, "while it may appear that at least for the case of the linear principal agent model that σ^2 [or risk] is truly an exogenous variable, it isn't." Rather "it is simply one of the moments of the outcome distribution to be determined by the equilibrium effort level which in turn is determined by the properties of the production function and the preferences of the contracting parties." In other words, in all but the most restrictive contracting environments, the moments of the outcome distribution (e.g., stock price) are correlated, so the agent's actions cannot affect the mean of the outcome independent of the variance (or other higher moments). As Hemmer (2006) further discusses, for more general distributions that have a support that is bounded below—which seems descriptive of stock price as a performance measure—increasing the mean of the distribution typically produces a corresponding increase in its variance as the distribution becomes more "stretched out."[4]

[3] The technical reasons largely relate to the validity of the so-called first-order approach (FOA), whereby the first-order condition for the agent's incentive compatibility (IC) constraint replaces this constraint in the principal's objective function. Several authors (e.g., Mirlees, 1974; Rogerson, 1984; Jewitt, 1988) have characterized the (somewhat restrictive) conditions that are necessary for the validity of the FOA. Two of the more well-known conditions are the Convexity of the Distribution Function Condition (CDFC) and the Monotone Likelihood Ratio Condition (MLRC). However, as Hemmer (2006) notes, distributions that satisfy these conditions do not have attractive mathematical distributions that yield trackable solution or mirror the empirical distribution of parameters of interests (e.g stock values) , nor are they easily ranked in terms of riskiness based on simple summary statistics.

[4] This phenomenon seems to capture the spirit of Demsetz and Lehn's (1985) prediction of a positive relation between firms' ownership concentration and uncertainty in their operating environment.

The theoretically ambiguous nature of the relation between risk and the design of incentive-compensation contracts has a close analog in the literature that examines the risk-taking effects of incentive-compensation contracts.[5] In particular, a number of studies, both theoretical (e.g., Lambert, Larcker, and Verrecchia, 1991; Ross, 2004) and empirical (e.g., Armstrong and Vashishtha, 2012), discuss how equity portfolio delta has a theoretically ambiguous effect on a manager's risk-taking incentives because of two countervailing effects. On one hand, if a risky project is expected to produce a sufficient increase in firm value, then delta will encourage a manager to take risk. On the other hand, since delta "amplifies" the variability of a risk-averse manager's equity portfolio value, it also discourages risk-taking. Because these two competing effects operate in different directions, the overall effect of delta on a manager's risk-taking incentives is theoretically ambiguous and it is an empirical question as to which effect dominates. Analogously, in our study of contract design, the direction of the effect of risk on incentives is theoretically ambiguous and is ultimately an empirical question.

A summary of our findings is as follows. First, using a differences-in-differences research design, we find that firms with greater *ex ante* exposure to weather risk are more likely to use weather derivatives to hedge their exposure to this risk following the introduction of weather derivatives. In particular, these firms experienced a statistically significant and economically meaningful reduction in the covariance of their stock returns with weather-related outcomes following the introduction of weather derivatives. This finding suggests that these firms did, in fact, make use of weather derivatives to hedge at least some of their weather risk and experienced a meaningful reduction in their exposure to weather risk as a result. We corroborate this finding

[5] The relation between the contract design literature and the literature that examines the effects of incentive-compensation contracts is that the former models the incentive-compensation contract (e.g., annual pay, equity portfolio delta and vega) as the dependent variable, while the latter models various measures of incentives (e.g., equity portfolio delta and vega) as the independent variables of interest. Our study is a member of the former group.

by searching our sample firms' 10-K filings for references to weather derivative contracts and find that these firms are also significantly more likely to use these contracts.

Second, we find that the CEOs of firms that are more exposed to weather risk prior to the introduction of weather derivatives experienced a significant reduction in their total annual compensation—including both the cash and equity grant components—following the introduction of weather derivatives. We attribute this reduction in annual compensation to a decrease in the risk premium that these CEOs demand for being exposed to weather risk through their equity (i.e., stock and option) holdings and their firm-specific human capital.

Third, we find that the CEOs of firms that are more exposed to weather risk have significantly fewer equity incentives following the introduction of weather derivatives: equity *Portfolio Delta* declines by an average of 8.1% and equity *Portfolio Vega* declines by an average of 34.3%. Coupled with our evidence that firms that were more exposed to weather risk did, in fact, experience a significant reduction in their risk, our finding that their executives' equity incentives also declined indicates a *positive*, rather than a negative relation between risk and incentives. Although this finding is *not inconsistent* with the predictions of the most frequently cited agency models—namely Holmstron, 1979 and Holmstrom and Milgrom, 1987—it is inconsistent with the predictions of several prior empirical studies (e.g., Aggarwal and Samwick, 1999; Gao, 2010).

Our study makes several contributions to the incentive-compensation and corporate hedging literatures. First, our research setting allows us to construct a powerful set of tests that speak to how the magnitude of risk—and the ability to eliminate a portion of this risk through hedging—affects the design of executives' incentive-compensation contracts. Much of the prior empirical research in this area has focused on how the design of executives' incentive-compensation contract influences their risk-taking choices and the risk of the firm (e.g., Agrawal and Mandelker, 1987; DeFusco, Johnson, and Zorn, 1990; Rajgopal and Shevlin, 2002; Coles, Daniel, and Naveen, 2006; Low, 2009; Gormley, Matsa, and Millbourn 2013; Armstrong, 2013). We focus on the converse: how firm risk influences the design of executives' compensation contracts. Unlike the prior empirical studies that examine the effect of incentives on firm risk, studies that examine how risk affects the design of incentive-compensation contracts have produced mixed results (e.g., Demsetz and Lehn, 1985; Lambert and Larcker, 1987; Garen, 1994; Bushman, Indjejikian, Raffi, and Smith, 1996; Aggarwal and Samwick, 1999; Core and Guay, 1999). Some authors attribute these conflicting results to the endogenous relation between firm risk and contract design (Core and Guay, 2002; Aggarwal and Samwick, 1999). We acknowledge this important concern and contribute to this literature by examining the effect of an arguably exogenous shock to firm risk on executives' incentives.

Second, we help bridge the *theoretical* agency literature with the *empirical* contracting literature by examining an important research question guided by an accurate interpretation of the underlying theory. Our study sheds light on how risk contributes to agency conflicts by quantifying the benefits of eliminating such risk through hedging. And, more importantly, we identify the effect of risk of risk on the design of executives' compensation and incentives.

Third, our results contribute to the literature on corporate hedging. Prior studies examine whether hedging affects firm value and, more generally, why hedging is done at the corporate level rather than by shareholders directly (e.g., Modigliani and Miller, 1958; Mayers and Smith, 1982; Perez-Gonzalez and Yun, 2013). Our finding that corporate hedging reduces the risk premium that undiversified executives demand for being exposed to firm risk highlights an important channel through which hedging can mitigate agency conflicts and increase firm value and provides an explanation for the prevalence of corporate hedging and insurance (Stulz, 1984; Smith and Stulz, 1985).

We deliberately focus on a relatively small sample of companies that are expected to be most affected by the introduction of weather derivatives because doing so allows us to construct relatively powerful empirical tests that are less susceptible to hidden bias (e.g., endogeneity concerns) and, in turn, supply more credible inferences. Rosenbaum (2005, 151) explains the importance of reducing sample heterogeneity in an observational study because doing so "reduces both sampling variability and sensitivity to unobserved bias—with less heterogeneity, larger biases would need to be present to explain away the same effect." In this regard, our study complements large-sample studies that examine the design and consequences of incentive-compensation contracts in the cross-section, and in which unobserved heterogeneity is a much more acute validity threat.

The remainder of the paper is organized as follows. We provide background information on weather derivatives and discuss related studies in Section 2. We describe our research design in Section 3 and discuss our sample, data sources, and variable measurement in Section 4. We present our results in Section 5 and describe several supplemental sensitivity analyses in Section 6. We provide concluding remarks in Section 7.

2. Background

2.1. Weather derivatives

Weather derivatives are financial contracts whose payoffs are determined by the realization of weather-related events. Similar to other types of financial derivatives, these contracts can be used to both speculate and to hedge—in the latter case, they can provide protection against adverse weather conditions. A weather derivative's payoff (or value) is determined by realized climatic conditions such as temperature, precipitation (e.g., rainfall and snowfall), or the occurrence of extreme events (e.g., hurricanes). A typical weather derivative contract specifies the following parameters: (1) an underlying weather measure (e.g., temperature or cumulative precipitation); (2) the location at which the weather is measured (e.g., a weather measurement station); (3) the contract period; (4) the exercise or "strike" price; and (5) a function that maps the realized weather measure to the contract's monetary payout (Considine, 2000).

The most common type of weather derivatives are temperature-based futures that come in one of two varieties: Heating Degree Day and Cooling Degree Day contracts (hereafter referred to as HDD and CDD, respectively). HDD and CDD capture—and can therefore be used to hedge—the energy demand for heating and cooling services, respectively.[6] The payoff of these contracts is based on the cumulative difference between the daily temperature and 65 degrees Fahrenheit (18 degrees Celsius) during a certain period of time (e.g., one month). The baseline temperature (i.e., 65 degrees Fahrenheit) is that at which there is relatively little demand for heating and cooling. HDD contracts payoff if the cumulative temperature is relatively *low* and, conversely, CDD contracts payoff if the cumulative temperature is relatively *high*.[7]

The following excerpt from Washington Gas Light Co.'s 2007 Annual Report (Form 10K) provides an example of a weather derivative contract that is used to hedge weather risk.

> *On October 5, 2006, Washington Gas purchased a new HDD derivative designed to provide full protection from warmer-than-normal weather in Virginia during the upcoming 2006-2007 winter heating season. Washington Gas will receive $25,500 for every HDD below 3,735 during the period October 15, 2006 through April 30, 2007. The maximum amount that Washington Gas can receive under this arrangement is $9.4 million.*

[6] According to the Chicago Mercantile Exchange, the trading volume of CME weather futures during 2003 more than quadrupled from the previous year and equaled roughly $1.6 billion in notional value.
[7] $CDD = Max\{0, 1/2*(T_{max}+T_{min})-65\}$ and $HDD = Max\{0, 65-1/2*(T_{max}+T_{min})\}$, where T_{max} and T_{min} are the maximum and minimum temperature, respectively, measured in degrees Fahrenheit over a specific period.

> *The pre-tax expense of this derivative is $2.5 million, which is being amortized over the pattern of normal HDDs during the 6.5-month term of the weather derivative.*

This contract was based on the number of Heating Degree Days (HHD), which is the contractual measure of the underlying weather outcome. The contract covered the period October 15, 2006 through April 30, 2007 (essentially the winter of 2006-07) and had an exercise (or "strike") price of 3,735. If the winter had been warmer than usual, Washington Gas would have received $25,500 for each HDD below the strike price. The winter of 2006-07 turned out to be colder than usual, and the actual HDD was 3,955, which exceed the contract's strike price. Accordingly, Washington Gas was not entitled to any payment from this particular weather derivative, and the contract expired worthless.

Prior to introduction of weather derivatives, firms with significant exposure to the weather had only a limited number of financial instruments with which they could hedge this risk. Moreover, those instruments that were available (e.g., individual contracts with large property and casualty insurers acting as counterparties) often provided an imperfect hedge and were potentially very costly. For examples, firms could potentially use agriculture commodity futures to hedge weather risk because commodity prices and demand are affected by weather conditions. However, agricultural commodity futures yield imperfect hedges and are subject to basis risk. Alternatively, firm could enter into a weather insurance contract with a property and casualty insurer. However, like most other insurance contracts, weather insurance contracts only provide protection against catastrophic damage and would do nothing to protect against the reduced demand that utility businesses experience as a result of weather that is warmer or colder than expected.[8]

[8]Weather insurance contracts suffer from a difficulty in attributing incurred losses to the insured weather event, resulting in high insurance premiums to reduce potential moral hazard problems (Gardener and Rogers, 2003). In practice, weather insurance only tends to be useful for hedging against infrequent (i.e., low probability), but costly events (Meyer, 2008). In contrast, weather derivative contracts can be used to protect against less detrimental, but higher probability events such as droughts or warmer than usual winters.

Weather derivatives also differ from conventional insurance contracts in several other important respects. First, weather derivatives are financial instruments with payoffs that are tied to objective, measurable weather events such as hours of sunshine, amount of precipitation, snow depth, temperature, or wind speed. These realizations are measured at different weather stations around the country, and cannot be influenced by the holder of a weather derivative. Consequently, the contractual payoffs are difficult to manipulate. In contrast, loss payments from conventional insurance contracts can be manipulated by the insured, and therefore present significant moral hazard problems. Second, the loss settlement process for weather derivatives depends on measurements (e.g., temperature or hours of sunshine) that are collected for other purposes and therefore constitute a negligible marginal cost of contract settlement. In contrast, the settlement process for conventional insurance contracts usually entails costly investigation and verification at the loss site, and can even involve litigation before reaching a final settlement of claims. Third, credit risk is present with insurance contracts, although this risk is somewhat limited through monitoring by insurance regulators, external audits, and debt and claims-paying rating agencies. In contrast, some weather derivatives are traded on exchanges, which virtually eliminates any credit risk.[9] Fourth, exchange-traded weather contracts provide the holder the ability to exit the position at a relatively low cost if the market moves in adverse directions. In contrast, insurance contracts cannot be traded and cancellation by the insured during the contract term can involve significant penalties and other transaction costs.

Absent suitable financial instruments with which to hedge, managers can also engage in “real actions” to hedge their risk. For example, a firm could diversify its operations across either product lines or geographic regions to reduce its total exposure to the weather. However, such

[9] Although credit risk remains with over-the-counter weather risk trading, protection is provided by the International Securities and Derivatives Association and external audits of financial records.

diversification strategies are often expensive to implement and their efficacy in managing risks are questioned by prior studies (Berger and Ofek, 1995; Lamont and Polk, 2002). Moreover, these and other types of "real actions" can also introduce additional agency conflicts between managers and shareholders.

Utilities may use regulatory measures to minimize the impact of weather. Specifically, a weather normalization adjustment (WNA) is a method of adjusting customers' bills to reflect normal, rather than actual, weather conditions, WNAs effectively allow utilities to reduce weather risk during unexpected weather seasons. However, WNAs do not cover the unregulated portion of utilities' business and are not available in every state. The cash flow recovery from WNAs may lag weather shocks, particularly in extreme cases, and their use is subject to moral hazard on the part of the consumer, as well as regulatory and political risk.

To summarize, although firms had options to reduce their exposure to weather risk prior to the introduction of weather derivatives, these options were imperfect and costly relative to weather derivatives. Furthermore, the fact that some firms pursued these alternatives is not necessarily a threat to our research design or our inferences. Our differences-in-differences model relies on variation in firms' weather exposure to identify "treated" and "untreated" firms (i.e., those that are relatively more and less exposed to weather, respectively). As a result, firms using WNAs or other methods to control their exposure to weather risk prior to the introduction of weather derivatives, and who were therefore less likely to use the derivatives after their introduction, act as part of our control group.

The first over-the-counter (OTC) weather derivative contract was introduced in 1997, primarily in response to severe and unexpected weather conditions caused by the 1997 to 1998 El Nino-Southern Oscillation (ENSO). Compared to the aforementioned methods for managing weather risk, weather derivatives were more efficient and less costly. According to the Weather Risk Management Association, the total value of weather derivative contracts traded on the Chicago Mercantile Exchange was nearly $8 billion in 2003 and increased to roughly $45.2 billion by 2006.[10] Unsurprisingly, 70% of the end-users of weather derivatives are members of the energy industry (WMRA, 2005). Moreover, fueled by demand for greater control over earnings, hardening insurance markets, and growing interest in weather derivatives by the investment banking and insurance communities, the weather derivative market has expanded beyond the U.S., both in terms of the types of risks being addressed and the nationalities of firms involved in the market.[11]

2.2. Prior literature on corporate hedging

Under a set of restrictive assumptions, Modigliani-Miller (1958) demonstrate that corporate hedging is, at best, a value-neutral activity.[12] However, the prevalence of corporate hedging and insurance is striking (Mayers and Smith, 1982). Motivated by the widespread incidence of hedging and insurance, subsequent authors have relaxed the Modigliani-Miller assumptions and have offered several potential explanations for corporate hedging, including (i) reducing financial distress and bankruptcy costs (Smith and Stulz, 1985; Mayers and Smith, 1990; Bessembinder, 1991; Géczy, Minton, and Schrand, 1997; Haushalter, 2000), (ii) reducing underinvestment (Froot, Scharfstein, and Stein, 1993; Gay and Nam, 1998), (iii) reducing tax expenses (Mayers and Smith, 1982; Smith and Stulz, 1985; Graham and Rogers, 2002), (iv) taking advantage of an existing derivatives operation to speculate (Géczy, Minton, and Schrand, 2007), (v) rent extraction by entrenched managers (Kumar and Rabinovitch, 2013), and (vi) reducing the

[10] http://usatoday30.usatoday.com/weather/forecast/2008-06-09-weather-derivative_N.htm.

[11] Counties in which weather transactions have been completed include the U.S, U.K, Australia, France, Germany, Norway, Sweden, Mexico and Japan. Standardized weather derivative contracts are now listed on the Chicago Mercantile Exchange (CME), The Intercontinental Exchange (ICE), and the London International Financial Futures and Options Exchange (LIFFE).

[12] The Modigliani-Miller assumptions include frictionless markets, no taxes, no information asymmetries, no bankruptcy costs, no agency costs, and equal costs of borrowing for firms and individuals.

risk premium that undiversified employees demand for their exposure to firm–specific idiosyncratic risk (Stulz, 1984; Smith and Stulz, 1985).

Our study adds to this literature by using the arguably exogenous introduction of weather derivatives to examine the link between executive incentive-compensation contracts and firm-specific risk. Our evidence that the availability of hedging instruments reduces executives' flow pay is consistent with hedging leading to a reduction in the risk premium paid to undiversified employees. We also provide novel evidence on how hedging affects executives' equity incentives.

3. Research Design

The introduction of weather derivatives in 1997 provided firms that were exposed to weather-related risks with an efficient way to manage (i.e., hedge) these risks. And, importantly for our research design, the introduction of weather derivatives was arguably exogenous from the perspective of any particular firm and with respect to firm-level expectations of the outcomes that we examine.[13]

Furthermore, we expect weather derivative contracts to disproportionately benefit those firms that were historically more subject to local weather shocks. We combine the temporal variation caused by the introduction of weather derivatives with cross-sectional variation in firms' *ex ante* exposure to weather risk to estimate a differences-in-differences regression.

3.1. Sensitivity of equity market returns to weather

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[13] The distinction between an event being *exogenous* and the event being *exogenous with respect to any particular firm* is crucial for our study. The former use of the word "exogenous" is synonymous with "stochastic" or "random" and carries an unconditional connotation. The latter use of the word "exogenous" is a less stringent notion and acknowledges that many—if not most—events that are used as the basis for so-called "natural experiments" (e.g., regulations) are not exogenous in the literal sense, but are the outcome of some deliberate (in the case of legislation, regulation, or court rulings) or are the result of competitive market forces (e.g., supply and demand), as is the case in our research setting. The efficacy of using events of the latter type as "natural experiment" depends on the event not being in response to a particular firm of interest. If such a condition holds, even though the event is not "exogenous" in the sense of being "random," it can still be "exogenous" from the perspective of any particular firm.

Our first analysis models the likelihood of using weather derivatives to hedge weather risk. Before the introduction of weather derivatives, firms with local weather exposure did not have access to financial contracts with which they could directly hedge their weather risk. After the introduction of weather derivatives, we expect firms with greater historical exposure to weather risk to benefit more from hedging. To gauge the extent of derivative hedging, we hand collect information on whether firms utilize weather derivatives after 1997.[14] We use a web crawling program to search for weather derivative keywords in every quarterly and annual report filed during the 1997 to 2002 period by firms in our sample. We use the following keywords that are unique to weather derivative hedging to locate weather derivative usage: “Weather Derivative”, “Cooling Degree Day”, “Heating Degree Day”, “CDD” and “HDD.” If a firm-year’s reports does not contain these hedging keywords, we treat that firm-year as nonuser. We then use each firm-year’s weather derivative usage as the dependent variable in the following differences-in-differences regression

$$DerivativeUsage_{it} = \beta_{0,\mathrm{it}} + \beta_{1,\mathrm{it}} After_t \times Treated_i + \gamma' X_{it} + FirmFE + YearFE + \varepsilon_{it} \quad (1)$$

We expect $\beta_1 > 0$ because firms with greater historical exposure to weather risk are more likely to use weather derivatives to hedge weather risk.

Next, if the introduction of weather derivatives was in fact an economically important event for these firms, then it should produce an empirically detectible change in the sensitivity of their equity market returns to fluctuations in weather conditions. We conduct this analysis in two steps. First, we regress each exposed firm’s daily stock returns over a one-year period on the three Fama-French factors and our measure of daily weather exposure[15]:

[14] We do not focus on the extent of hedging because of poor accounting environment during the pre-SFAS 133 period and the switch to fair value reporting post-SFAS 133.
[15] We also ensure our results are robust to the inclusion of a Carhart (1997) momentum factor.

$$Ret_{i,t} = \beta_0 + \beta_1 Size_t + \beta_2 Hml_t + \beta_3 Mkt_t + \beta_4 EDD_t + \varepsilon_{i,t} \quad (2)$$

Where *i* indexes firms and *t* indexes time (i.e., each one-year period). *EDD* measures total weather exposure and is defined as the sum of *HDD* and *CDD*, which are calculated as Max{0, 65-½*(T_{max}+T_{min})} and Max{0, ½*(T_{max}+T_{min})-65}, respectively, where T_{max} and T_{min} are the maximum and minimum daily temperature measured in degrees Fahrenheit, respectively. We only estimate Eq. (2) for firm-years with at least 60 daily observations. We refer to the estimated coefficient β_4 as a firm's "weather beta."

It is important to note that utilities can potentially benefit from hedging weather risks irrespective of the sign of their weather beta. For example, some firms may benefit from abnormally cold weather, whereas others may be adversely affected by cold weather conditions. Therefore, the absolute value of the estimated coefficient β_4 captures the sensitivity of the firm's equity returns to weather. We also multiply the absolute value of the estimated weather betas by the annualized volatility of EDD, or $|\beta_4|$**volatility(EDD)*, to obtain an alternative measure of weather risk which captures the proportion of a firm's stock return volatility that is attributable to weather exposure.

In the second step, we use each firm-year's estimated exposure to weather risk (i.e., either $|\beta_4|$ or $|\beta_4|$**volatility(EDD))* as the dependent variable in the following differences-in-differences regression:[16]

$$WeatherRisk_{it} = \beta_{0,it} + \beta_{1,it} After_t \times Treated_i + \gamma' X_{it} + FirmFE + YearFE + \varepsilon_{it} \quad (3)$$

Where *i* and *t* index firms and time, respectively. *After* is an indicator that equals one from 1998 onwards and zero otherwise. *Treated* is a firm-specific indicator that equals one if the firm's

[16] Since the dependent variables in the "second-stage" given by Eq. (3) are estimated rather than observed (i.e., so called "estimated dependent variables"), the residual in the Eq. (3) inherits sampling uncertainty from the "first-stage" regressions. To ensure that our second-stage estimates are consistent and efficient, we weight each observation by the inverse of the estimated variance of dependent variables from the first-stage (Hornstein and Greene, 2012).

historical (i.e., pre-1997) weather exposure is relatively high, which is explained in more detail in Section 4. *X* represents a vector of control variables, which are also discussed in more detail below. *FirmFE* denotes firm fixed effects, which are included to abstract away from (i.e., "control for") cross-sectional variation in weather exposure, so that the resulting empirical specification relies primarily on *within-firm* (i.e., time-series) variation in firms' exposure to weather risk. Similarly, *YearFE* denotes year fixed effects, which are included to abstract away from any systematic temporal effects on firms' exposure to weather risk that are unrelated to the introduction of weather derivatives. Note that we do not include separate indicators (i.e., main effects) for either *Treated* or *After*, since neither would be identified in the presence of firm and year fixed effects. We expect $\beta_1 > 0$ because firms with greater historical exposure to weather risk are more likely to hedge and reduce their exposure to weather risk in the post period.

Although our predictions in these tests appear relatively straightforward, it is important that we first document the link between firms' exposure to weather risk prior to the introduction of weather derivatives and both a subsequent increase in their hedging and a corresponding reduction in their subsequent exposure to weather risk. This is because our following tests exploit the variation in the intensity of subsequent hedging as a source of cross-sectional variation to couple with the time-series variation generated by the introduction of the weather derivatives. Together, these two sources of variation allow us to construct focused and powerful tests that are relatively insulated from threats posed by concurrent time trends, changes firms' in investment opportunities, and other potential confounding variables.

3.2. CEO compensation

Our tests described in the previous section are designed to assess whether the introduction of weather derivatives did, in fact, have an empirically detectable effect on the equity returns of firms that were relatively more exposed to weather risk prior to the introduction of weather derivatives. To the extent that the introduction of weather derivatives allows these firms to alter their exposure to weather risk, their introduction should also have an effect on the design of their executive's incentive-compensation contracts. To determine whether executives' annual pay changed following the introduction of weather derivatives, we estimate the following differences-in-differences specification.

$$Comp_{it} = \beta_{0,\mathrm{it}} + \beta_{1,\mathrm{it}} After_t \times WeatherExp_i + \gamma' X_{it} + FirmFE + YearFE + \varepsilon_{it} \qquad (4)$$

where i and t index firms and time, respectively. *Comp* represents one of several measures of CEOs' annual compensation that we discuss in more detail in Section 4. The remaining variables are as defined in the previous subsection in the context of Eq. (3).

In general, a differences-in-differences research design estimates the difference in an outcome (i.e., the dependent variable) around an event of interest between two groups of firms that differ in the extent to which they are affected by the event. The difference between the changes (or "differences") experienced by the two groups of firms provides an estimate of the causal effect of the event on the outcome. The crucial maintained identifying assumption of a differences-in-differences research design is that the two groups of firms would have continued to exhibit the same time-trend in the outcome, but for the occurrence of the event. This so-called parallel trends assumption facilitates inferences about the causal effect of the event by allowing the relatively less affected group to be used as a counterfactual against which to compare the relatively more affected group. In our research setting, the differences-in-differences specification in Eq. (4) compares one of several annual compensation measures before and after the introduction of weather derivatives (the first difference) between firms that are relatively more and less influenced by the weather (the second difference). The resulting estimate of β_1 indicates the causal effect of the introduction of weather derivatives on the different components of CEOs' annual compensation.

We include the following determinants of CEO compensation identified by prior research (e.g., Core, Holthausen, and Larcker, 1999; Core, Guay, and Larcker, 2008): *CEO Tenure* measured as the natural logarithm of one plus the number of years that the executive has held the CEO title; *Firm Size* measured as the natural logarithm of the firm's total assets; *Firm Age* measured as the natural logarithm of one plus number of years since stock price data for the firm becomes available from CRSP; the *Book-to-Market* ratio is included to capture growth opportunities; and *ROA* and *Stock Return* to measure firms' accounting and stock returns, respectively.

Perez-Gonzalez and Yun (2013) find that firms that are exposed to weather risk increased their debt capacity and investment following the introduction of weather derivatives. To mitigate the concern that changes in executive compensation are driven by changes in these corporate decisions rather than the ability to hedge, we also control for *Leverage*, which is measured as the total of short-term and long-term debt minus cash holding scaled by total assets, and capital expenditure (*CAPEX)*, which is measured as the total capital expenditure scaled by total assets. A more detailed description of the variables is provided in the Appendix.

3.3. CEO equity portfolio incentives

We also estimate a model of CEO equity portfolio incentives (i.e., equity portfolio Delta and Vega) that is similar to Eq. (4). We rely on the same set of control variables as in the compensation specifications, although several are included for different reasons because the theoretical determinants of equity portfolio incentives are somewhat different from those of annual compensation. First, we include a proxy for firm size to capture variation in talent and wealth across CEOs.[17] Prior literature has argued that larger firms require more talented CEOs and that CEOs of larger firms tend to have more wealth (Smith and Watts, 1992; Core and Guay, 1999). Therefore, we predict a positive relationship between firm size and the level of equity incentives. Next, we expect the consequences of managerial risk aversion (i.e., rejecting risky but positive net present value projects) to be more costly to shareholders of firms with more investment opportunities. We also expect that it is more difficult to monitor managers of firms with greater investment opportunities, so equity incentives will be used as a substitute mechanism for mitigating agency costs in these firms (Smith and Watts, 1992). We therefore expect both types of equity incentives to be negatively associated with the book-to-market ratio. Finally, we control for CEO tenure to capture both experience (Gibbons and Murphy, 1992) and the degree to which there might be horizon problems as a result of an anticipated departure (Dechow and Sloan, 1991).

4. Variable Measurement and Sample Selection

4.1. Measurement of firms' weather exposure

We measure our sample firms' pre-1997 weather exposure following the procedure developed by Perez-Gonzalez and Yun (2013), which estimates the portion of firms' revenue volatility that is related to weather fluctuations using the following specification.

$$Rev/Assets_{it} = \beta_{0,i} + \beta_{1,i}\, EDD_{it} + \gamma_i\, ln(Assets_{it}) + \varepsilon_{it} \tag{5}$$

Where $Rev/Assets_{it}$ is quarterly revenue scaled by ending total assets. We also include the natural logarithm of total assets as a measure of firm size that is intended to control for fluctuations in revenue attributable to sources other than the weather. *EDD* is the sum of daily CDD and HDD for

[17] Our results are similar when we include CEO fixed effects to capture heterogeneity in compensation that is due to unobservable, time-invariant CEO characteristics such as skill and risk-tolerance. We describe these results in more detail in Section 6.

each quarter and is measured at the firm's historical corporate headquarter location.[18] We estimate Eq. (4) separately for each firm in our sample using data from 1980 to 1997, and we require each firm to have at least 40 quarterly observations. To isolate the volatility of each firm's revenue that is attributable to weather fluctuations, we multiply the absolute value of the estimated beta ($\widehat{\beta_1}$) by the historical standard deviation of EDD during the 1980-1997 estimation period. A firm is classified as having a relatively high exposure to weather if the resulting value is above the sample median and, conversely, relatively low exposure to weather if the resulting value is below the sample median.[19]

4.2. Measurement of CEO incentive-compensation

We examine various attributes of CEOs' incentive-compensation contracts using data from the Execucomp database. Our first four measures are related to the composition (or "mix") and magnitude (or "level") of CEOs' annual compensation and are (1) *CashComp*, defined as the natural logarithm of the sum of the CEO's annual salary and bonus payments, (2) *EquityComp*, defined as the natural logarithm of an adjusted Black-Scholes value of the CEO's option and restricted stock grants received during the year, (3) *TotalComp*, defined as the natural logarithm of the value of the CEO's total annual compensation (i.e., salary, bonus, restricted stock and option grants, and long-term incentive plan payouts), and (4) *EquityMix*, defined as *EquityComp* divided by *TotalComp*.

In addition to these four measures of CEOs' annual (or "flow") compensation, we also examine two common measures of the incentives provided by CEOs' equity portfolio (i.e., stock

[18] Compustat reports the address of a firm's current principal executive office, which could be different from its historical address if the firm has changed the location of its headquarters. Since most utilities are regional distributors of electricity and/or gas, we rely on company headquarter information to estimate their weather exposure. We extract historical headquarter locations from historical 10-K filings from the SEC's Edgar database. If the historical 10-K is not available for a particular year, we use the 10-K from the closest available year.

[19] We consider alternative definitions of weather exposure based on the sensitivity of firms' stock returns to weather in Section 6.

and option) holdings. The first measure of equity incentives is *Portfolio Delta*, which measures the sensitivity of a CEO's equity portfolio value to changes in stock price. The second measure of equity incentives is *Portfolio Vega*, which measures the sensitivity of a CEO's equity portfolio value to changes in volatility of stock returns. We follow prior literature (e.g., Core and Guay, 1999; Coles, Daniel, and Naveen, 2006; Burns and Kedia, 2006) and measure *Portfolio Delta* as the natural logarithm of the change in the risk-neutral (Black-Scholes) value of the CEO's equity portfolio for a 1% change in the firm's stock price and *Portfolio Vega* as the natural logarithm of the change in the risk-neutral (Black-Scholes) value of the CEO's equity portfolio for a 0.01 change in the risk of the company's stock (measured by standard deviation of the firm's return).[20,21]

4.3. Sample selection

The sample period for our primary tests runs from 1993 to 2002, spanning the five years prior to and the five years following the introduction of weather derivatives. We start with 370 unique utilities that engaged in the generation or distribution of electricity or natural gas (Standard Industrial Classification Codes 4911, 4923, 4924, 4931 and 4932). We then require the following information for each firm: (1) the location of the firm's headquarters (we lose 49 firms), (2) at least

[20] The parameters of the Black-Scholes formula are calculated as follows. Annualized volatility is calculated using continuously compounded monthly returns over the previous 60 months, with a minimum of twelve months of returns, and winsorized at the 5th and 95th percentiles. If the stock has traded for less than one year, we use the imputed average volatility of the firms in the Standard and Poor's (S&P) 1500. The risk-free rate is calculated using the interpolated interest rate on a Treasury Note with the same maturity (to the closest month) as the remaining life of the option, multiplied by 0.70 to account for the prevalence of early exercise. Dividend yield is calculated as the dividends paid during the previous twelve months scaled by the stock price at the beginning of the month. This is essentially the method described by Core and Guay (2002).

[21] An alternative to the dollar-holdings measure of the incentive to increase stock price is the fractional-holdings measure, calculated as the change in the (risk-neutral) value of the executive's equity portfolio for a $1,000 change in firm value (Jensen and Murphy, 1990). Baker and Hall (2004) and Core, Guay, and Larcker (2003) discuss how the suitability of each measure is context-specific and depends on how the CEO's actions affect firm value. When the CEO's actions affect the dollar returns of the firm (e.g., consuming perquisites), fractional holdings is a more appropriate measure of incentives. When the CEO's actions affect the percentage returns of the firm (e.g., strategic decisions), dollar holdings are a more appropriate measure of incentives. Since we are concerned about strategic actions that affect the firm's risk profile, we rely on the dollar-holdings measure of incentives.

ten years of quarterly data prior to 1997 to estimate the firm's historical exposure to weather risk (we lose 68 firms), (3) valid historical temperature measurements in the firm's county from the North America Land Data Assimilation System available from Center for Disease Control and Prevention (CDC),[22] (4) Execucomp data to calculate incentive-compensation measures (we lose 45 firms), and (5) financial information from Compustat and CRSP. We also require that the firm has at least one year of data before and after the introduction of weather derivatives for the differences-in-differences specification (we lose 96 firms). Our final sample consists of 112 unique utility firms and 899 firm-year observations for which we have the required data for all of our analyses.

4.4. Descriptive statistics

Table 1 presents descriptive statistics for our sample. All continuous variables are winsorized at the 0.5% percentile in each tail. Panel A reports the extent of weather derivative usage after 1997. On average, 12% of our sample reports using weather derivatives and their usage increases over time from 4.08% in 1998 to almost 17% in 2002. Panel B reports descriptive statistics for different measures of weather sensitivity. The Fama-French three-factor model and the Carhart (1997) four-factor model both produce similar estimates. In particular, Panel A shows that the average return sensitivity to weather is 0.75 and that weather betas exhibit substantial dispersion (standard deviations of 0.86 and 0.90 when calculated with the three- and four-factor models, respectively). These estimates indicate that the utilities in our sample have relatively large average exposure to the weather and exhibit substantial variation in the extent to which they are exposed to the weather.

[22] http://wonder.cdc.gov/nasa-nldas.html.

Panel C of Table 1 reports descriptive statistics for the various incentive variables. The mean (median) of our sample CEOs' annual cash compensation is $849,000 ($738,000) and the average *Equity Mix* is 22%. The mean (median) sensitivity of their equity holdings to stock price and stock return volatility, *Delta* and *Vega*, are 3.44 (3.45) and 2.27 (2.61), respectively. Because our sample firms are drawn from a relatively unique industry, we also report the average values of the incentive-compensation measures for non-utilities in the Execucomp database. Panel C shows that the CEOs in our sample receive less total compensation and have lower levels of equity incentives relative to CEOs in other industries.

Panel D of Table 1 reports descriptive statistics for select firm and CEO characteristics. The average (i.e., mean) tenure of the CEOs in our sample is 6.4 years and the average firm has total assets of $7,543 million. The average stock market and accounting returns of our sample firms are 10% and 3%, respectively. In addition, our sample firms have an average book-to-market ratio of 0.67 and leverage ratio of 0.37. We also report similar descriptive statistics for the non-utility firms in the Compustat database for comparative purposes.[23] These descriptive statistics indicate that the firms in our sample are, on average, larger, have fewer growth opportunities, and are more levered than their counterparts in other industries. These differences are not surprising because utilities are more heavily regulated and relatively more asset intensive, which explains their larger size and the differences in their capital structure. The differences that we document are also consistent with prior studies that examine utilities (e.g., Rajgopal and Shevlin, 2002; Jin and Jorion, 2006; Perez-Gonzalez and Yun, 2013).

[23] The mean ROA of -0.18 reported in Panel C of Table 2 for the sample of Compustat non-utilities is partially due to the presence of "penny stocks." If we exclude firms that have a share price of $5 or less, the mean (median) ROA for the sample of non-utilities is -0.06 (0.03).

5. Results

5.1. Sensitivity of equity market returns to weather

We present the results of estimation equation (1) in column 1 of Table 2. The results show that treated firms are more likely to use weather derivatives to hedge their exposure to weather-related risk following the introduction of weather derivatives.[24] Specifically, we find that treated firms are 12% more likely to hedge with weather derivatives than their less exposed counterparts[25]. Columns 2 through 5 of Table 2 presents results from estimating the sensitivity of our sample firms' equity returns to weather realizations. The two sets of columns report estimates for weather exposure based on a three Fama-French factor model of returns and a three Fama-French factor plus a momentum factor model of returns, respectively. The results from both specifications indicate that the treated firms in our sample experienced a significant reduction in their relative exposure to (i.e., co-movement with) weather fluctuations following the introduction of weather derivatives. This finding is consistent with treated firms in our sample using weather derivatives to reduce their exposure to weather fluctuations to a greater extent than control firms. Moreover, the economic magnitude of the treated firms' relative reduction in their exposure to weather risk following the introduction of weather derivatives is large: when weather exposure is calculated using the Fama-French three factor model, these firms experienced an average relative reduction in their exposure to weather of roughly 21%.[26]

5.2. CEO compensation

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[24] Column 1 presents estimates from a linear probability model. We obtain similar results when we estimate a logit model. Due to the "incidental parameters problem," the logit specification does not allow us to include firm fixed effects.

[25] We did not use notional value of hedging because SFAS 133 was introduced in late 2000, requiring firms to recognize all derivatives as either assets or liabilities in the statement of financial position and measure those instruments at fair value as opposed to notional value of hedging.

[26] The mean of our sample firm's *Weather Beta* is 0.75. The coefficient on *After*Treated* in column (1) of Table 2 of -0.16 implies a 21% (= -0.16 / 0.75) reduction in *Weather Beta*.

Our next set of tests examines whether several aspects of CEOs' annual compensation changed following the introduction of weather derivatives. The results reported in column (1) of Table 3 indicate that the total annual compensation of the treated CEOs in our sample declined by roughly 22% (*t*-statistic of -3.01) following the introduction of weather derivatives.[27] Columns (2) and (3) indicate that the decline in total annual compensation comes from a reduction in both its cash and equity components.[28] The decline in total annual compensation—as well as its separate components—is consistent with our prediction that weather derivatives allow executives to hedge risk that they would otherwise have to bear and, consequently, they receive less of a risk premium in their annual compensation (Core and Guay, 2010; Conyon, Core, and Guay, 2011).

Column (4) reports estimates for *EquityMix*, which is the proportion of total annual compensation paid in the form of equity, which is thought to be more risky than cash compensation from the perspective of a risk-averse CEO. The coefficient on *After*Treated* shows that the fraction of our sample treated CEOs' compensation paid in the form of stock and options declined by an average of 10% relative to that of our control CEOs following the introduction of weather derivatives. Together with the results in the first three columns, this finding indicates that the treated CEOs in our sample not only receive less total annual compensation following the introduction of weather derivatives, but that they also receive less of their compensation in the form of equity (i.e., restricted stock and options). This finding is also consistent with an intentional substitution away from equity incentives by boards.

5.3. CEO equity portfolio incentives

[27] The coefficient of -0.25 applies to a change in the natural logarithm of annual pay, so the introduction of weather derivatives resulted in a -22% (= exp(-0.25) – 1) change in total annual compensation.

[28] We obtain similar results when we jointly estimate the two equations for cash and equity compensation using seemingly unrelated regression (SUR) (Zellner, 1962), which accommodates correlation between the errors of the two equations. In particular, we estimate the SUR using Stata command SUREG. Since this Stata routine does not allow for clustering of standard errors, we use bootstrapped standard errors.

Table 4 presents the results of estimating our models of CEOs' equity portfolio incentives. The first column examines how the introduction of weather derivatives affected the sensitivity of CEOs' equity portfolio values to changes in stock price, or *Delta*. The coefficient on *After*Treated* is negative and statistically significant (*t*-statistic of -2.36), which indicates that treated CEOs tend to have relatively lower levels of equity incentives following the introduction of weather derivatives. The economic magnitude of this decline is large: on average, treated CEOs have roughly 8.1% less equity portfolio *Delta* following the introduction of weather derivatives, relative to the sample mean.[29] We find similar results for *Vega*: the coefficient on *After*Treated* is negative and significant (*t*-statistic of -3.64) and the magnitude of coefficient indicates that the average treated CEO in our sample holds roughly 34% less equity risk-taking incentives following the introduction of weather derivatives.

An auxiliary prediction is that risk-averse executives should be willing to hold their options longer following the introduction of weather derivatives because of the reduction in their exposure to firm risk (Hemmer, Matsunaga, and Shevlin, 1996). We construct a variable, *Unex/Total*, defined as the ratio of the value of vested (i.e., exercisable) in-the-money options to total vested options, to measure the timeliness of CEOs' option exercise. Consistent with our prediction, we find that treated CEOs hold a larger relative proportion of vested in-the-money options following the introduction of weather derivatives. The economic magnitude of our estimate indicates that, on average, our sample treated CEOs hold 11.4% more intrinsic value of vested in-the-money options following the introduction of weather derivatives. Combined with the change in granting behavior by the board, this result suggests the decrease in treated CEOs' *Vega* is attributable to boards re-optimizing the executives' compensation contracts.

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[29] The mean of *Portfolio Delta* is 3.44. A coefficient of -0.28 implies a -8.1% (= -0.28/3.44) reduction in *Delta* relative to the control group following the introduction of weather derivatives.

Coupled with evidence that firms that were more exposed to weather risk did, in fact, experience a significant reduction in their risk, our finding that their executives' equity incentives also declined indicates a *positive*, rather than a negative relation between risk and incentives.

6. Sensitivity Analysis

We conduct several supplemental analyses to assess the sensitivity our primary inferences to our maintained identifying assumptions.

6.1. Evaluating the parallel trends assumption

Inferences from our differences-in-differences specification rely on the maintained identifying assumption that, absent the treatment, both treated and control firms would have continued to exhibit similar trends. To assess the validity of this assumption, we examine whether firms with relatively high and relatively low exposures to weather risk did, in fact, exhibit parallel trends before the introduction of weather derivatives. In particular, we estimate a specification that is analogous to Eq. (4), except that we replace the *After* indicator with separate indicators for each of the four years surrounding and the year of the introduction of weather derivatives: *After(t=-2), After(t=-1), After(t=0), After(t=1)* and *After(t>=2),* which are indicators that equal one in the two years before, the year before, the year of, the year after, and the second year and thereafter, following the introduction of weather derivatives, respectively. We present the results of this specification in Table 5. None of the pre-event variables are significant at conventional levels, consistent with the maintained assumption that the firms with relatively high and low exposures to the weather had similar—and therefore parallel—trends.

6.2. *State level industry deregulation, changing business prospects and policies*

Electricity in America was traditionally supplied by regional monopolies that owned both the power plants and the transmission lines used to distribute power. Because of the utilities' monopolistic power, states heavily regulated utility companies, setting their rate of return of profit based on the cost of services and planned for future power needs. Deregulation was triggered by a series of federal actions, which were followed by the passage of state laws ordering the separation of power plants from the distributional facilities. The Energy Policy Act of 1992 was the first act to curb utilities monopolies by expanding the Federal Energy Regulation Commission's (FERC) authority. On April 24, 1996 FERC issued a landmark ruling, Order 888, requiring utilities to open their power transmission lines to independent producers. FERC's intent was to introduce competition at the wholesale level and to keep utilities from using their control of the transmission system to limit the entry of lower priced generation. The primary result or Order 888 was to force many states to deregulate, due to concerns that their regulated monopolies would be priced out by interstate competition. By 2000, 24 states and the District of Columbia had passed laws deregulating their utility industries. However, within the next eight years, ten states had repealed or delayed their deregulation laws, mainly as a response to the California Energy Crisis of 2000-2001.[30] Two additional deregulated states (Ohio and Pennsylvania) still retain retail price controls and thus, most households in these two states are not yet exposed to the higher prices found in the deregulated market. There were only 12 U.S states where utility industries were totally deregulated by 2008.

[30] These states are Arizona, Arkansas, California, Connecticut, Delaware, Illinois, New Jersey, New Hampshire, Maine, Maryland, Massachusetts, Michigan, Montana, Nevada, New Mexico, New York, Oklahoma, Ohio, Oregon, Pennsylvania, Rhodes Island, Texas, Virginia, and West Virginia. By 2008, ten states has repealed or delayed their deregulation laws (Arkansas, Arizona, Illinois, New Mexico, Nevada, Michigan, Oklahoma, Oregon, Virginia and West Virginia).

To mitigate the concerns that our results might be confounded by the effects of state level industry deregulation, we re-estimate our main tests after including state of location and year joint fixed effects. After including these additional fixed effects, our tests *only* compare treated and control firms located in the same state, and who were therefore subject to the same state regulations. These additional fixed effects ensure that any observed treatment effect is due solely to differences in treatment and cannot be explained by concurrent regulatory or state economic effects. We present the results of this adjusted analysis in Panel A of Table 6. The coefficient on *After*Treated* remains largely unchanged, demonstrating that our results are robust to this alternative specification and that our primary inferences are unaltered.

A related concern is that change in state policies or rulings might occur at the state of incorporation level, rather than at the state of location level. To address this related concern, we include state of incorporation and year joint fixed effects, in addition to the firm fixed effects and the state of location and year joint fixed effects. Our tests now compare only treated and control firms that are located in the same state and incorporated in the same state. We present the results of these adjusted tests in Panel B of Table 6. Again, the coefficient on *After*Treated* remains largely unchanged. We conclude that our results are not driven by changes in state economics or regulations.

6.4. SFAS133 adoption and shorter event windows

The choice of any particular sample period in a differences-in-differences analysis entails a cost-benefit tradeoff. The benefits of a longer window are twofold. First, expanding the window utilizes more data, which, in turn, produces more powerful statistical tests. Second, a wider window allows more time for both boards' contracting decisions and executives' risk-taking decisions to take effect and manifest in the data. The cost of using a wider window is that doing so introduces a greater chance of capturing differential trends that are unrelated to the event of interest, which, in our setting, is the introduction of weather derivatives. As a result, we explore the sensitivity of our inferences to the choice of event window.

Examining a shorter window also allows us to examine the possibility that our results are confounded by the adoption of accounting standard SFAS 133 (*Accounting for Derivative Instruments and Hedging Activities*). SFAS 133 establishes accounting and reporting standards for derivative instruments and requires an entity to recognize all derivatives as either assets or liabilities in the statement of financial position and to measure derivative instruments at their fair value.[31] The standard became effective for fiscal years beginning after June 15, 2000. Using a three-year event window around 1997 should reduce the risk that our results are due to confounding effects from the adoption of SFAS 133.

We tabulate the results of estimating our main tests when using a three-year event window in Table 7. The coefficient on *After*Treated* is statistically significant at conventional levels for five out of six of our dependent variables. The lone exception is when examining *Delta* as the dependent variable of interest (*t*-statistic of -1.46). We conclude that our inferences are robust to the choice of a shorter event window.

6.5. CEO preferences

The introduction of weather derivatives could change the skills that the boards and shareholders of utility firms desire from CEOs, implying that our results could be driven by the turnover and replacement of existing CEOs. To address concerns that our results are attributable

[31] After SFAS 133 was introduced, the accounting treatment for hedges arguably became more complicated, burdensome, and costly to implement. It requires that an entity recognize all derivatives as either assets or liabilities in the statement of financial position and measure those instruments at fair value as opposed to notional value of hedging. Several studies examine the relevance of SFAS 133 to risk management activities and document mixed evidence. For example, Singh (2004) and Park (2004) find no significant change in earnings volatility after the adoption of SFAS 133, while Zhang (2009) finds that some firms changed their risk management activities after the adoption of SFAS 133.

to differences in CEO ability and styles driven by turnover, we estimate additional tests in Table 8. We first exclude 72 firms associated with 90 CEO turnover events which occurred during our sample period. In untabulated results, we find that our inferences are robust to excluding these firms from the sample (*t*-statistics range from -1.76 to -2.73). Next, we re-estimate our main regressions after including CEO fixed effects, in addition to firm and year fixed effects. CEO fixed effects absorb time-invariant features of CEO ability and preferences and limit our analysis to within-CEO, within-firm variation. Therefore, introducing these fixed effects controls for any changes in the identity of CEOs. We present the results of this adjusted analysis in Table 8, and find that our inferences remain unchanged. We conclude that our results are not driven by CEO turnover or changes in the desired skills of CEOs.

6.6. Alternative measure of weather exposure

Our primary measure of historical weather exposure is based on the sensitivity of a firm's revenue to weather. However, it's also possible that weather can affect the cost structure or risk of a firm. For example, extremely cold weather could increase the maintenance and repair costs of gas distribution pipeline. Therefore, we explore the robustness of our results to an alternative measure of weather risk based on stock price fluctuations, which should aggregate the revenue, cost, and risk implications of abnormal weather. To do so, we re-estimate Eq. (2), as described in section 3.1:

$$Ret_{i,t} = \beta_0 + \beta_1 Size_t + \beta_2 Hml_t + \beta_3 Mkt_t + \beta_4 EDD_t + \varepsilon_{i,t} \quad (2)$$

We classify those firms with an average weather beta ($\beta_{4)}$ greater than the median during the 1993-1996 period as high weather exposure firms. We present the results of re-estimating our main tests after using this alternative definition of high weather exposure in Panel A of Table 9. Our results are largely unchanged.

We also examine this alternative measure of weather risk for violations of the parallel trends assumption. To do so, we replace *After*Treated* with a series of pre- and post-treatment indicators and report the results of estimating this adjusted version of our main tests in Panel B or Table 9. None of the pre-treatment indicators are statistically significant at conventional levels, suggesting that the parallel trends assumption is not violated for our alternative measure of weather risk. Collectively, we conclude that our results are robust to using alternative definitions of ex-ante weather risk to sort firms into treatment and control groups.

6.7 Endogenous Hedging

Our identification strategy relies on the assumption that firms which were exposed to greater ex-ante weather risk were more affected by the introduction of weather derivatives. While we test this assumption explicitly in Table 2, we also explore the strength of our inferences to modelling the link between ex-ante weather exposure and derivative use as part of our differences-in-differences estimation.

We first model the adoption of weather derivatives as a function of ex-ante weather risk in a first stage instrumental variables regression:

$$DerivativeUsage_{it} = \beta_{0,\mathrm{it}} + \beta_{1,\mathrm{it}}After_t \times Treated_i + \gamma' X_{it} + FirmFE + YearFE + \varepsilon_{it} \quad (6)$$

Next, we use the predicted weather derivative usage in the second stage to test for the effect of hedging on the design of incentive contracts. Specifically, we estimate following second-stage regression:

$$Comp_{it} = \beta_{0,\mathrm{it}} + \beta_1 Predicted\ DerivUse + \gamma' X_{it} + FirmFE + YearFE + \varepsilon_{it} \quad (7)$$

We present the results of our combined instrumental variables and differences-in-differences estimation in Table 10. The magnitude of the coefficients on *PredictedDerivUse* is similar to the treatment effects documented in our baseline regressions, and is statistically significant at conventional levels in all specifications. We conclude that our results are robust to explicitly modelling the adoption of weather derivatives.

7. Conclusion

We examine how executives' ability to hedge weather-related firm risk that was previously difficult and costly to manage influences the design of executives' incentive-compensation contracts. Our results suggest that boards respond quickly to changes in their firms' business risk by adjusting the structure of CEOs' incentive-compensation contracts. We find that CEOs receive less total annual compensation—and that this reduction is attributable to a decline in cash and equity compensation alike—following the introduction of weather derivatives. This finding is consistent with the notion that weather derivatives allow executives to hedge risk that they would otherwise have to bear and, consequently, they demand less of a risk premium in their annual compensation. We also document significant decline in CEOs' equity incentives (i.e., *Delta* and *Vega*) following the introduction of weather derivatives, which provides important evidence about the theoretically ambiguous relation between risk and incentives (Hemmer, 2006, 2012). Overall, our results show that firms' risk-profiles and hedging opportunities affect the design and structure of CEOs' incentive-compensation contracts. Our results also highlight the importance of risk in exacerbating agency conflicts.

However, because we examine a relatively small sample of firms in a specific industry, it is important to consider how our results might extrapolate beyond our research setting. On one hand, the economic magnitude of the effects that we document might represent a lower bound on the importance of executives' ability to hedge risk because utilities are a relatively stable industry with relatively low inherent volatility. On the other hand, if more risk-averse executives select into the utility industry (e.g., because of its relative stability), then the economic magnitude of the effects that we document might be large relative to the effects that one would expect in other industries. While it’s somewhat unclear how the magnitude of our results extrapolate beyond our setting, there’s no reason to believe that the sign of the relation between risk and incentives that we document is specific to our setting.

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Appendix

Variables Definitions

Variable	Definition
WeatherDeriv Use	Dummy equal to one if a firm mention following keywords in 10-K or 10-Q: "Weather Derivative", "Cooling Degree Day", "Heating Degree Day", "CDD" and "HDD". If a firm-year's reports has no reference of these hedging keywords, the value is set at zero.
Beta-FF	For each year each firm, we regress daily stock return on Fama-French 3 factors and daily EDD. Beta-FF is the absolute value of the estimated coefficient on EDD.
Risk-FF	Beta-FF multiplied by volatility of EDD.
Beta-FFM	For each year each firm, we regress daily stock return on Fama-French 3 factors plus momentum factor and daily EDD. Beta-FF is the absolute value of the estimated coefficient on EDD.
Risk-FFM	Beta-FFM multiplies by volatility of EDD.
Log Total Comp	Log of total compensation.
Log Cash Comp	Log of Salary and Bonus.
Log Equity Comp	Log of value of the restricted stock plus value of the options
Equity Mix	*Equity Comp/Total Comp*
Portfolio Vega	Log of compensation Vega. Vega measures dollar change in wealth associated with a 0.01 change in the standard deviation of the firm's returns and is obtained from Coles et al (2013).
Portfolio Delta	Log of compensation delta. Delta measures dollar change in wealth associated with a 1% change in the firm's stock price and is obtained from Coles et at (2013).
Unex/Total	Value of in-the-money unexercised exercisable options divided by the total value of unexercised and exercised options
Log Assets	Log of total assets.
Log Firm Age	Log of firm age, where firm age is the year firm first appear in CRSP
Log Stock Return	Log of one plus stock return over fiscal year.
ROA	Net income plus extraordinary items and discontinued operation, all divided by lagged total asset.
Book-to-Market	Book value over market value of equity.
Leverage	Short term debt plus long term debt minus cash, all over total asset.
CAPEX	Capital expenditure/total assets
After	Dummy equal to one for observations from 1998 onwards.
After (t=-2)	Dummy equal to one if it is two year before the introduction of weather derivative.
After(t=-1)	Dummy equal to one if it is one year before the introduction of weather derivative.
After (t=0)	Dummy equal to one if it is the year during which weather derivative is introduced.
After(t=1)	Dummy equal to one if it is one year after the introduction of weather derivative.
After(t>=2)	Dummy equal to one if it is 2 or more years after the introduction of weather derivative.
Treated	Dummy equal to one if a firm has above median pre-event sensitivity of revenue to weather fluctuations. We estimate the sensitivity of revenue to weather conditions before 1997 using quarterly compustat data. Specifically, we estimate following specification: $Rev/Asset_{it}=\alpha_i+\beta_i*EDD+\gamma_i*Firm\ Size+\varepsilon_t$, where Rev/Asset is the quarterly revenue-to-assets ratio. EDD is the sum of Cooling Degree Days (CDD) and Heating Degree Days (HDD) aggregated at quarterly level at county where corporate headquarters are located. CDD is calculated as Max(0, ½*($T_{max}+T_{min}$)-65) and HDD is Max(0, 65 -1/2*($T_{max}+T_{min}$)) . T_{max} and T_{min} are maximum and minimum daily temperature measured in Fahrenheit, respectively.
Treated(StockRet)	Dummy equal to one if a firm has above median average sensitivity of stock return to weather fluctuations during pre-event period (1992-1997). We estimate following regression by year for each stock-year that has at least 60 observations: $\mathrm{Ret}_{it} = \beta_{0,it} + \beta_{1,it} * \mathrm{EDD}_{it} + \gamma' \mathrm{Factors} + \varepsilon_t$,Where Ret_{it} is daily stock returns, EDD_{it} is the sum of CDD and HDD measured at the county where corporate headquarter is located and Factors are risk factors from Fama-French Model.

Table 1
Descriptive Statistics

The sample period is from 1993 to 2002. All variables are defined in the Appendix.

Panel A: Use of Weather Derivatives After 1997

	N	Mean	Std
WeatherDeriv Use	434	0.12	0.33

	Total number of firms	Weather derivative users	% Firms that uses weather derivatives
1998	98	4	4.08%
1999	92	8	8.70%
2000	85	12	14.12%
2001	80	15	18.75%
2002	79	13	16.46%

Panel B: Weather Sensitivity

	N	Mean	Std	Median	25th Pctle	75th Pctle
Beta-FF	899	0.75	0.86	0.49	0.22	0.96
Risk-FF	899	7.37	6.85	5.35	2.57	9.99
Beta-FFM	899	0.75	0.90	0.48	0.22	0.93
Risk-FFM	899	7.34	7.02	5.26	2.39	10.17

Panel C: CEO Incentive-Compensation Measures

Panel C1: Our Sample

	N	Mean	Std	Median	25th Pctle	75th Pctle
Cash Comp	899	849.28	484.31	738.20	512.21	1033.60
Equity Comp	899	592.60	1187.12	152.21	0.00	604.34
Total Comp	899	1841.82	2318.41	1148.66	712.58	2025.74
Equity Mix	899	0.22	0.22	0.15	0.00	0.37
Portfolio Delta	840	3.44	1.42	3.45	2.46	4.42
Portfolio Vega	868	2.27	1.86	2.61	0.00	3.80

Panel C2: Execucomp Ex Utilities

	N	Mean	Std	Median	25th Pctle	75th Pctle
Cash Comp	13674	1148.99	1044.63	837.33	514.18	1385.70
Equity Comp	13748	2190.40	4340.58	669.22	72.49	2139.18
Total Comp	13748	4261.02	12162.88	1880.68	946.59	4132.77
Equity Mix	13725	0.39	0.30	0.39	0.08	0.64
Portfolio Delta	12713	5.37	1.56	5.32	4.38	6.33
Portfolio Vega	13396	3.41	1.64	3.56	2.50	4.55

Table 1 Descriptive Statistics, Continued

Panel D: Firm Characteristics

Panel D1: Our Sample

	N	Mean	Std	Median	25th Pctle	75th Pctle
CEO Tenure	899	6.43	3.78	6.00	4.00	8.00
Total Assets	899	7543.32	8859.48	3865.97	1780.81	9688.06
Firm Age	899	48.63	11.50	48.00	44.00	52.00
Stock Return	899	0.10	0.27	0.09	-0.06	0.25
ROA	899	0.03	0.02	0.04	0.03	0.05
Book-to-Market	899	0.67	0.24	0.62	0.53	0.75
Leverage	899	0.37	0.08	0.36	0.32	0.41
CAPEX	899	0.06	0.04	0.05	0.04	0.07

Panel D2: Compustat Ex Utilities

	N	Mean	Std	Median	25th Pctle	75th Pctle
CEO Tenure	13817	8.32	6.91	7.00	4.00	10.00
Total Assets	98770	1817.53	7249.15	104.33	18.92	548.04
Firm Age	99052	12.85	12.85	8.00	4.00	16.00
Stock Return	68778	0.10	0.67	0.00	-0.30	0.33
ROA	89329	-0.18	0.81	0.01	-0.10	0.07
Book-to-Market	85201	0.55	1.25	0.51	0.24	0.89
Leverage	98254	0.10	0.48	0.09	-0.14	0.33
CAPEX	98770	0.06	0.08	0.03	0.01	0.07

Table 2
Sensitivity of Equity Returns to Weather

This Table presents the results of estimating the two-stage regressions given by Equations (1) and (2). The sample period is from 1993 to 2002. We use Hornstein and Greene's (2012) method to account for the estimated (rather than observed) dependent variable in the second-stage. All variables are defined in the Appendix. Intercepts are included but unreported. *t*-statistics are presented below the coefficients in parentheses. ***, **, and * denote statistical significance (two-sided) at the 1%, 5%, and 10% levels, respectively. Standard errors are corrected for heteroscedasticity and are clustered by firm and period (pre-1997/post-1997) level.

		Fama French 3 Factor Model		Carhart 4 Factor Model	
	(1)	(2)	(3)	(4)	(5)
	WeatherDeriv Use	*Beta-FF*	*Risk-FF*	*Beta-FFM*	*Risk-FFM*
After*Treated	**0.12****	**-0.16*****	**-1.64****	**-0.15****	**-1.48****
	(2.55)	**(-2.63)**	**(-2.56)**	**(-2.44)**	**(-2.40)**
Log CEO Tenure	-0.01	-0.01	-0.08	-0.02	-0.15
	(-0.34)	(-0.26)	(-0.19)	(-0.40)	(-0.34)
Log Assets	0.08	-0.01	0.21	-0.03	-0.07
	(1.55)	(-0.09)	(0.26)	(-0.36)	(-0.09)
Log Firm Age	0.49	-1.08	-12.18	-0.98	-12.35
	(0.52)	(-1.16)	(-1.15)	(-1.04)	(-1.18)
Log Stock Return	0.00	-0.08	-0.85	-0.10	-1.16
	(0.09)	(-0.70)	(-0.59)	(-0.83)	(-0.80)
ROA	0.01	0.10	-1.74	-0.13	-4.09
	(0.02)	(0.08)	(-0.11)	(-0.10)	(-0.26)
Book-to-Market	0.01	0.05	-0.16	0.09	0.33
	(0.11)	(0.34)	(-0.09)	(0.60)	(0.18)
Leverage	-0.70***	0.05	-0.21	0.01	-0.47
	(-2.78)	(0.14)	(-0.05)	(0.04)	(-0.11)
CAPEX	-0.11	0.55	6.11	0.66	7.70
	(-0.28)	(0.94)	(0.95)	(1.14)	(1.20)
Observations	899	899	899	899	899
R-squared	0.48	0.40	0.32	0.39	0.31
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Table 3
CEO Compensation

This Table presents the results of estimating the regressions given by Equations (3). The sample period is from 1993 to 2002. All variables are defined in the Appendix. Intercepts are included but unreported. *t*-statistics are presented below the coefficients in parentheses. ***, **, and * denote statistical significance (two-sided) at the 1%, 5%, and 10% levels, respectively. Standard errors are corrected for heteroscedasticity and are clustered by firm and period (pre-1997/post-1997) level.

	(1) *Total Comp*	(2) *Cash Comp*	(3) *Equity Comp*	(4) *Equity Mix*
After*Treated	**-0.25*** **	**-0.12*** **	**-1.14*** **	**-0.10*** **
	(-3.01)	**(-2.63)**	**(-3.11)**	**(-3.86)**
Log CEO Tenure	0.06	0.07**	-0.61**	-0.06***
	(1.19)	(2.57)	(-2.22)	(-3.12)
Log Assets	0.13	0.13	-0.14	-0.00
	(0.98)	(1.60)	(-0.24)	(-0.10)
Log Firm Age	-2.08**	-0.93**	-7.70**	-0.76**
	(-2.53)	(-2.24)	(-2.34)	(-2.54)
Log Stock Return	0.38**	0.22***	1.67***	0.08*
	(2.50)	(2.62)	(3.23)	(1.67)
ROA	1.47	3.46***	6.84	0.17
	(1.07)	(5.06)	(0.92)	(0.29)
Book-to-Market	0.05	-0.11	0.88	0.05
	(0.24)	(-1.10)	(1.05)	(0.78)
Leverage	0.16	-0.05	-0.53	0.07
	(0.34)	(-0.19)	(-0.26)	(0.43)
CAPEX	1.44*	1.23**	-2.95	-0.12
	(1.69)	(2.48)	(-0.77)	(-0.41)
Observations	899	899	899	899
R-squared	0.77	0.83	0.54	0.50
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 4
CEO Equity Portfolio Incentives

This Table presents the results of estimating the regressions given by Equations (3). The sample period is from 1993 to 2002. All variables are defined in the Appendix. Intercepts are included but unreported. *t*-statistics are presented below the coefficients in parentheses. ***, **, and * denote statistical significance (two-sided) at the 1%, 5%, and 10% levels, respectively. Standard errors are corrected for heteroscedasticity and are clustered by firm and period (pre-1997/post-1997) level.

	(1) *Portfolio Delta*	(2) *Portfolio Vega*	(3) *Unex/Total*
After*Treated	**-0.28****	**-0.77*****	**0.05***
	(-2.36)	**(-3.64)**	**(1.67)**
Log CEO Tenure	0.37***	0.03	-0.03
	(4.32)	(0.26)	(-1.36)
Log Assets	0.54***	0.52	-0.04
	(3.58)	(1.50)	(-1.06)
Log Firm Age	-6.24***	-3.63	0.35
	(-4.95)	(-1.41)	(0.95)
Log Stock Return	0.31*	0.03	0.03
	(1.85)	(0.12)	(0.62)
ROA	1.96	1.18	-0.22
	(1.02)	(0.36)	(-0.31)
Book-to-Market	-1.11***	-0.39	-0.15**
	(-4.33)	(-0.98)	(-2.02)
Leverage	0.34	-0.15	0.12
	(0.54)	(-0.13)	(0.83)
CAPEX	0.61	1.32	-0.20
	(0.67)	(0.61)	(-0.60)
Observations	840	868	899
R-squared	0.87	0.76	0.83
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Table 5
Evaluating the Parallel Trend Assumption

The sample period is from 1993 to 2002. All variables are defined in the Appendix. Intercepts are included but unreported. *t*-statistics are presented below the coefficients in parentheses. ***, **, and * denote statistical significance (two-sided) at the 1%, 5%, and 10% levels, respectively. Standard errors are corrected for heteroscedasticity and are clustered by firm and period (pre-1997/post-1997) level.

	(1) *Total Comp*	(2) *Cash Comp*	(3) *Equity Comp*	(4) *Equity Mix*	(5) *Portfolio Delta*	(6) *Portfolio Vega*	(7) *Unex/Total*
*After (t=-2)*Treated*	0.00	0.02	0.34	-0.00	-0.03	0.12	0.09
	(0.07)	(0.59)	(0.69)	(-0.04)	(-0.27)	(0.89)	(1.55)
*After (t=-1)*Treated*	0.03	0.02	-0.12	-0.00	-0.16	0.11	0.06
	(0.32)	(0.41)	(-0.24)	(-0.11)	(-1.21)	(0.66)	(1.16)
After (t=0)*Treated	**0.01**	**-0.01**	**-0.85**	**-0.03**	**0.01**	**-0.12**	**0.08***
	(0.08)	**(-0.21)**	**(-1.73)***	**(-0.92)**	**(0.08)**	**(-0.51)**	**(1.88)**
After (t=1)*Treated	**-0.16**	**-0.03**	**-0.85**	**-0.06**	**-0.15**	**-0.22**	**0.06**
	(-1.65)	**(-0.49)**	**(-1.37)**	**(-1.28)**	**(-0.89)**	**(-0.77)**	**(1.05)**
After (t>=2)*Treated	**-0.27****	**-0.15****	**-1.45*****	**-0.13*****	**-0.39****	**-0.96*****	**0.11*****
	(-2.53)	**(-2.48)**	**(-2.96)**	**(-3.82)**	**(-2.23)**	**(-3.49)**	**(2.72)**
Log CEO Tenure	0.06	0.07**	-0.61**	-0.06***	0.36***	0.02	-0.02
	(1.16)	(2.50)	(-2.20)	(-3.17)	(4.25)	(0.15)	(-1.25)
Log Assets	0.13	0.12	-0.13	-0.00	0.54***	0.51	-0.04
	(0.96)	(1.58)	(-0.22)	(-0.10)	(3.57)	(1.49)	(-1.09)
Log Firm Age	-2.07**	-0.89**	-6.79**	-0.71**	-6.12***	-3.41	0.23
	(-2.49)	(-2.19)	(-2.06)	(-2.26)	(-4.84)	(-1.39)	(0.61)
Log Stock Return	0.39**	0.23***	1.74***	0.08*	0.35*	0.13	0.03
	(2.49)	(2.72)	(3.26)	(1.77)	(1.97)	(0.51)	(0.59)
ROA	1.49	3.50***	7.74	0.20	2.00	1.42	-0.23
	(1.07)	(5.12)	(1.05)	(0.35)	(1.05)	(0.44)	(-0.32)
Book-to-Market	0.05	-0.10	0.91	0.05	-1.09***	-0.34	-0.15**
	(0.26)	(-1.02)	(1.09)	(0.83)	(-4.19)	(-0.85)	(-2.08)
Leverage	0.16	-0.04	-0.47	0.08	0.35	-0.11	0.13
	(0.35)	(-0.15)	(-0.23)	(0.45)	(0.55)	(-0.10)	(0.89)
CAPEX	1.35	1.14**	-3.05	-0.16	0.48	0.77	-0.21
	(1.64)	(2.34)	(-0.79)	(-0.55)	(0.52)	(0.36)	(-0.61)
Observations	899	899	899	899	840	868	899
R-squared	0.77	0.83	0.55	0.50	0.87	0.77	0.83
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 6
Changes in Business Prospects and Policies

This Table presents the results of estimating the regressions given by Equations (3). The sample period is from 1993 to 2002. All variables are defined in the Appendix. Intercepts are included but unreported. *t*-statistics are presented below the coefficients in parentheses. ***, **, and * denote statistical significance (two-sided) at the 1%, 5%, and 10% levels, respectively. Standard errors are corrected for heteroscedasticity and are clustered by firm and period (pre-1997/post-1997) level.

Panel A: Control for Local Business Conditions

	(1) *Log Total Comp*	(2) *Log Cash Comp*	(3) *Log Equity Comp*	(4) *Equity Mix*	(5) *Portfolio Delta*	(6) *Portfolio Vega*
After*Treated	**-0.25****	**-0.11***	**-1.20****	**-0.13*****	**-0.31****	**-0.53****
	(-2.28)	**(-1.94)**	**(-2.25)**	**(-3.87)**	**(-2.32)**	**(-2.25)**
Log CEO Tenure	-0.08	0.02	-1.17***	-0.11***	0.11	-0.28*
	(-0.86)	(0.43)	(-2.91)	(-3.90)	(1.00)	(-1.78)
Log Assets	0.19	0.14	0.33	0.02	0.57***	0.47
	(0.99)	(1.35)	(0.47)	(0.41)	(2.83)	(1.41)
Log Firm Age	1.61	0.71	7.95	0.38	-7.53***	5.47
	(0.64)	(0.62)	(1.10)	(0.61)	(-3.80)	(1.58)
Log Stock Return	0.47**	0.31***	1.14*	0.06	0.10	-0.19
	(2.30)	(2.76)	(1.65)	(0.92)	(0.38)	(-0.50)
ROA	2.01	3.50***	6.67	0.48	2.75	1.09
	(1.10)	(3.66)	(0.75)	(0.73)	(1.02)	(0.28)
Book-to-Market	0.20	0.09	-0.06	-0.00	-1.33***	-0.79
	(0.78)	(0.71)	(-0.05)	(-0.04)	(-3.57)	(-1.59)
Leverage	-0.37	-0.11	-4.62	-0.20	-0.28	-1.08
	(-0.58)	(-0.36)	(-1.62)	(-0.90)	(-0.41)	(-1.10)
CAPEX	2.82**	1.82***	0.43	0.33	0.65	1.08
	(2.27)	(2.66)	(0.08)	(0.84)	(0.50)	(0.41)
Observations	899	899	899	899	840	868
R-squared	0.87	0.90	0.75	0.74	0.94	0.88
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Location-Year Joint FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 6 Cont'd

Panel B: Control for Changes at State of Incorporation

	(1) *Log Total Comp*	(2) *Log Cash Comp*	(3) *Log Equity Comp*	(4) *Equity Mix*	(5) *Portfolio Delta*	(6) *Portfolio Vega*
After*Treated	**-0.38******	**-0.16****	**-1.87*****	**-0.14*****	**-0.41*****	**-1.04*****
	(-3.09)	**(-2.44)**	**(-2.67)**	**(-3.15)**	**(-2.61)**	**(-3.16)**
Log CEO Tenure	-0.11	-0.03	-1.57***	-0.14***	0.04	-0.52**
	(-0.83)	(-0.35)	(-3.02)	(-3.59)	(0.28)	(-2.20)
Log Assets	0.03	-0.00	-0.16	0.03	0.65**	0.21
	(0.15)	(-0.01)	(-0.20)	(0.48)	(2.56)	(0.63)
Log Firm Age	2.79	1.49	15.59*	0.89	-6.14**	8.96**
	(0.95)	(0.86)	(1.90)	(1.21)	(-2.50)	(2.18)
Log Stock Return	0.63**	0.48***	1.49	0.04	0.22	0.43
	(2.40)	(3.41)	(1.58)	(0.53)	(0.75)	(0.93)
ROA	2.51	3.52**	5.66	0.25	1.33	3.43
	(1.03)	(2.49)	(0.51)	(0.28)	(0.42)	(0.70)
Book-to-Market	0.33	0.18	0.72	0.06	-1.17**	-0.17
	(0.99)	(0.92)	(0.51)	(0.58)	(-2.20)	(-0.31)
Leverage	-0.07	0.13	-5.84	-0.20	-0.32	-0.28
	(-0.08)	(0.31)	(-1.55)	(-0.66)	(-0.37)	(-0.19)
CAPEX	3.84**	2.33**	-0.53	0.24	0.68	-0.15
	(2.24)	(2.23)	(-0.07)	(0.43)	(0.42)	(-0.05)
Observations	899	899	899	899	840	868
R-squared	0.91	0.94	0.83	0.81	0.96	0.93
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Location-Year Joint FE	Yes	Yes	Yes	Yes	Yes	Yes
Incorporation-Year Joint FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 7
SFAS 133 Adoption and Shorter Event Window

This Table presents the results of estimating the regressions given by Equations (3). The sample period is from 1995 to 2000. All variables are defined in the Appendix. Intercepts are included but unreported. *t*-statistics are presented below the coefficients in parentheses. ***, **, and * denote statistical significance (two-sided) at the 1%, 5%, and 10% levels, respectively. Standard errors are corrected for heteroscedasticity and are clustered by firm and period (pre-1997/post-1997) level.

	(1) *Log Total Comp*	(2) *Log Cash Comp*	(3) *Log Equity Comp*	(4) *Equity Mix*	(5) *Portfolio Delta*	(6) *Portfolio Vega*
After*Treated	**-0.21****	**-0.08***	**-0.95****	**-0.08*****	**-0.14**	**-0.49****
	(-2.47)	**(-1.74)**	**(-2.56)**	**(-2.83)**	**(-1.46)**	**(-2.42)**
Log CEO Tenure	0.03	0.06	-0.79**	-0.06**	0.44***	0.04
	(0.45)	(1.45)	(-2.21)	(-2.50)	(4.30)	(0.21)
Log Assets	0.07	0.05	-0.07	0.02	0.49***	0.34
	(0.46)	(0.58)	(-0.10)	(0.30)	(3.41)	(0.88)
Log Firm Age	-1.32	-0.59	-9.14	-0.46	-6.23***	-5.54
	(-0.84)	(-0.74)	(-1.64)	(-0.93)	(-3.07)	(-1.48)
Log Stock Return	0.26	0.08	0.76	0.03	0.22	-0.27
	(1.31)	(0.74)	(1.29)	(0.57)	(1.35)	(-0.87)
ROA	1.46	3.62***	-1.61	-0.62	1.49	1.65
	(0.84)	(3.65)	(-0.23)	(-1.12)	(0.68)	(0.43)
Book-to-Market	-0.10	-0.26**	0.07	-0.02	-1.27***	-0.40
	(-0.39)	(-2.21)	(0.07)	(-0.23)	(-4.99)	(-1.16)
Leverage	0.64	0.08	-2.77	-0.04	-0.40	-1.62
	(1.19)	(0.26)	(-1.26)	(-0.19)	(-0.62)	(-1.27)
CAPEX	0.66	0.96	-3.44	-0.21	0.01	0.55
	(0.54)	(1.55)	(-0.69)	(-0.49)	(0.01)	(0.19)
Observations	569	569	569	569	531	549
R-squared	0.79	0.86	0.62	0.56	0.89	0.78
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 8
CEO Preferences

This Table presents the results of estimating the regressions given by Equations (3). The sample period is from 1993 to 2002. All variables are defined in the Appendix. Intercepts are included but unreported. *t*-statistics are presented below the coefficients in parentheses. ***, **, and * denote statistical significance (two-sided) at the 1%, 5%, and 10% levels, respectively. Standard errors are corrected for heteroscedasticity and are clustered by firm and period (pre-1997/post-1997) level.

	(1) *Log Total Comp*	(2) *Log Cash Comp*	(3) *Log Equity Comp*	(4) *Equity Mix*	(5) *Portfolio Delta*	(6) *Portfolio Vega*
After*Treated	**-0.18****	**-0.08***	**-0.91****	**-0.08****	**-0.23***	**-0.60****
	(-2.14)	**(-1.74)**	**(-2.07)**	**(-2.53)**	**(-1.73)**	**(-2.53)**
Log CEO Tenure	-0.03	0.00	-0.45	-0.08**	0.30	0.04
	(-0.36)	(0.06)	(-0.85)	(-2.17)	(1.63)	(0.14)
Log Assets	0.22*	0.20***	0.43	0.05	0.53***	0.73**
	(1.66)	(2.80)	(0.71)	(1.05)	(3.27)	(2.02)
Log Firm Age	-2.03	-0.22	-8.71	-1.70***	-3.74**	1.13
	(-1.16)	(-0.23)	(-1.51)	(-3.89)	(-2.49)	(0.34)
Log Stock Return	0.30*	0.17**	1.42**	0.05	0.22	-0.18
	(1.86)	(2.15)	(2.54)	(0.93)	(1.47)	(-0.74)
ROA	2.07	3.83***	-1.62	-0.48	2.09	-1.70
	(1.40)	(5.39)	(-0.21)	(-0.81)	(1.11)	(-0.50)
Book-to-Market	-0.10	-0.14	1.11	0.04	-1.12***	-0.66
	(-0.53)	(-1.55)	(1.32)	(0.51)	(-3.85)	(-1.58)
Leverage	-0.02	-0.15	-2.04	-0.01	0.44	0.51
	(-0.04)	(-0.50)	(-0.96)	(-0.03)	(0.61)	(0.40)
CAPEX	1.20	0.98**	1.31	-0.01	1.21	1.16
	(1.55)	(2.19)	(0.34)	(-0.04)	(1.34)	(0.61)
Observations	899	899	899	899	840	868
R-squared	0.86	0.90	0.67	0.62	0.93	0.85
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
CEO FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 9
Alternative Measure of Weather Exposure

This Table presents the results of estimating the regressions given by Equations (3). The sample period is from 1993 to 2002. All variables are defined in the Appendix. Intercepts are included but unreported. *t*-statistics are presented below the coefficients in parentheses. ***, **, and * denote statistical significance (two-sided) at the 1%, 5%, and 10% levels, respectively. Standard errors are corrected for heteroscedasticity and are clustered by firm and period (pre-1997/post-1997) level.

Panel A: Differences-in-Differences

	(1) *Log Total Comp*	(2) *Log Cash Comp*	(3) *Log Equity Comp*	(4) *Equity Mix*	(5) *Portfolio Delta*	(6) *Portfolio Vega*
After*Treated (StockRet)	**-0.22***** **(-2.71)**	**-0.07** **(-1.58)**	**-1.03***** **(-2.94)**	**-0.11***** **(-4.51)**	**-0.44***** **(-3.77)**	**-0.74***** **(-3.39)**
Log CEO Tenure	0.07 (1.29)	0.08*** (2.75)	-0.57** (-2.05)	-0.05*** (-2.95)	0.40*** (4.71)	0.07 (0.58)
Log Assets	0.12 (0.82)	0.11 (1.31)	-0.10 (-0.17)	-0.01 (-0.25)	0.54*** (3.66)	0.43 (1.15)
Log Firm Age	-2.55*** (-2.91)	-1.12*** (-2.63)	-9.82** (-2.59)	-0.95*** (-2.78)	-6.95*** (-5.98)	-5.46** (-2.00)
Log Stock Return	0.36** (2.24)	0.21** (2.31)	1.48*** (2.77)	0.07 (1.46)	0.26 (1.47)	-0.08 (-0.31)
ROA	1.21 (0.83)	3.34*** (4.75)	3.58 (0.47)	-0.04 (-0.06)	1.94 (1.03)	1.44 (0.45)
Book-to-Market	-0.09 (-0.47)	-0.14 (-1.45)	0.02 (0.02)	-0.02 (-0.23)	-1.32*** (-5.06)	-0.73* (-1.81)
Leverage	-0.03 (-0.06)	-0.12 (-0.44)	-1.63 (-0.83)	-0.01 (-0.05)	-0.09 (-0.15)	-0.83 (-0.73)
CAPEX	1.32 (1.54)	1.25** (2.50)	-3.64 (-0.95)	-0.18 (-0.64)	0.27 (0.31)	1.00 (0.46)
Observations	842	842	842	842	792	817
R-squared	0.77	0.83	0.54	0.50	0.87	0.76
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 9 (cont'd)

Panel B: Event-Time Differences-in-Differences

	(1) *Log Total Comp*	(2) *Log Cash Comp*	(3) *Log Equity Comp*	(4) *Equity Mix*	(5) *Portfolio Delta*	(6) *Portfolio Vega*
*After (t=-2)*Treated (StockRet)*	-0.02	0.02	-0.20	0.00	-0.05	-0.01
	(-0.24)	(0.44)	(-0.43)	(0.01)	(-0.51)	(-0.12)
*After (t=-1)*Treated (StockRet)*	0.07	0.00	-0.66	0.01	-0.01	-0.11
	(0.72)	(0.01)	(-1.30)	(0.32)	(-0.07)	(-0.70)
After (t=0)*Treated (StockRet)	**0.08**	**0.02**	**-0.36**	**0.00**	**0.16**	**-0.24**
	(1.00)	**(0.42)**	**(-0.63)**	**(0.03)**	**(0.98)**	**(-1.05)**
After (t=1)*Treated (StockRet)	**-0.17**	**-0.03**	**-1.40****	**-0.07***	**-0.11**	**-0.39**
	(-1.59)	**(-0.60)**	**(-2.46)**	**(-1.65)**	**(-0.71)**	**(-1.38)**
After (t>=2)*Treated (StockRet)	**-0.20***	**-0.08**	**-1.25*****	**-0.12*****	**-0.56*****	**-0.99*****
	(-1.95)	**(-1.28)**	**(-2.61)**	**(-3.77)**	**(-3.31)**	**(-3.57)**
Log CEO Tenure	0.07	0.08***	-0.58**	-0.05***	0.41***	0.08
	(1.32)	(2.77)	(-2.04)	(-2.89)	(4.78)	(0.59)
Log Assets	0.12	0.11	-0.10	-0.01	0.52***	0.41
	(0.81)	(1.29)	(-0.16)	(-0.28)	(3.54)	(1.09)
Log Firm Age	-2.60***	-1.14***	-9.53**	-0.96***	-7.11***	-5.45**
	(-3.00)	(-2.66)	(-2.46)	(-2.72)	(-6.30)	(-2.02)
Log Stock Return	0.36**	0.21**	1.49***	0.07	0.30*	-0.04
	(2.24)	(2.31)	(2.79)	(1.52)	(1.67)	(-0.14)
ROA	1.18	3.35***	3.61	-0.03	1.87	1.39
	(0.80)	(4.74)	(0.47)	(-0.05)	(1.01)	(0.43)
Book-to-Market	-0.09	-0.14	-0.01	-0.02	-1.32***	-0.74*
	(-0.45)	(-1.45)	(-0.01)	(-0.24)	(-5.20)	(-1.86)
Leverage	-0.04	-0.13	-1.56	-0.02	-0.17	-0.95
	(-0.08)	(-0.47)	(-0.80)	(-0.12)	(-0.30)	(-0.87)
CAPEX	1.32	1.25**	-3.67	-0.18	0.17	0.99
	(1.54)	(2.50)	(-0.96)	(-0.64)	(0.19)	(0.46)
Observations	842	842	842	842	792	817
R-squared	0.77	0.83	0.54	0.50	0.87	0.76
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 10
Endogenous Hedging

This Table presents second stage regression results from two-stage least square estimation using Equation (4). *Predicted DerivUse* is the predicted weather derivative usage from the first stage regression. The sample period is from 1993 to 2002. All variables are defined in the Appendix. Intercepts are included but unreported. *t*-statistics are presented below the coefficients in parentheses. ***, **, and * denote statistical significance (two-sided) at the 1%, 5%, and 10% levels, respectively. Standard errors are corrected for heteroscedasticity and are clustered by firm and period (pre-1997/post-1997) level.

	(1) *Log Total Comp*	(2) *Log Cash Comp*	(3) *Log Equity Comp*	(4) *Equity Mix*	(5) *Portfolio Delta*	(6) *Portfolio Vega*
Predicted DerivUse	-0.21***	-0.11***	-0.98***	-0.09***	-0.24**	-0.66***
	(-3.01)	(-2.63)	(-3.11)	(-3.86)	(-2.36)	(-3.64)
Log CEO Tenure	0.05	0.07**	-0.68**	-0.06***	0.35***	-0.02
	(0.85)	(2.23)	(-2.48)	(-3.42)	(4.16)	(-0.14)
Log Assets	0.29**	0.21***	0.60	0.06	0.73***	1.02***
	(2.25)	(2.81)	(0.92)	(1.38)	(4.36)	(3.00)
Log Firm Age	-1.04	-0.40	-2.91	-0.34	-5.04***	-0.38
	(-1.04)	(-0.77)	(-0.75)	(-1.01)	(-3.49)	(-0.13)
Log Stock Return	0.39**	0.22***	1.70***	0.08*	0.32*	0.05
	(2.54)	(2.66)	(3.29)	(1.73)	(1.89)	(0.21)
ROA	1.50	3.47***	6.95	0.18	1.99	1.26
	(1.08)	(5.07)	(0.93)	(0.31)	(1.04)	(0.39)
Book-to-Market	0.06	-0.10	0.93	0.06	-1.10***	-0.35
	(0.30)	(-1.02)	(1.11)	(0.85)	(-4.26)	(-0.88)
Leverage	-1.33**	-0.80**	-7.37**	-0.52**	-1.36	-4.79***
	(-2.40)	(-2.52)	(-2.51)	(-2.56)	(-1.37)	(-2.97)
CAPEX	1.21	1.12**	-3.99	-0.21	0.35	0.62
	(1.47)	(2.29)	(-1.06)	(-0.73)	(0.39)	(0.29)
Observations	899	899	899	899	840	868
R-squared	0.77	0.83	0.54	0.50	0.87	0.76
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes