Risk Management and Firm Value:

Evidence from Weather Derivatives [*]

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June 2011

This paper shows that active risk management policies lead to an increase in firm value. To identify the causal effect of hedging and to overcome endogeneity concerns, we exploit the introduction of weather derivatives as an exogenous shock to firms' ability to hedge weather risks. This innovation disproportionately benefits weather sensitive firms, irrespective of their future investment opportunities. Using this natural experiment and data from energy utilities, we find that derivatives lead to higher valuations, investments and leverage. Overall, our results demonstrate that risk-management has real consequences on firm outcomes.

JEL classification: G30, G32

Keywords: risk management, hedging, derivatives, firm value, capital structure, weather risk

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An important and highly debated topic in corporate finance is whether active risk-management policies affect firm value. Conceptually, the seminal work of Modigliani and Miller (1958) has long shown that in a frictionless setting, hedging is irrelevant for value.[1] This invariance result, however, stands in sharp contrast to the prominence of risk management in practice, and the rapid growth in financial innovation (Miller, 1986; Tufano, 2003).

Despite the relevance of risk management, we know surprisingly little about the causal effect of risk management on value. An important challenge with pre-existing empirical studies examining the impact of hedging on firm value is that they rely on endogenous variation in risk-management policies.[2] Given that firms do not randomize their hedging decisions, it has been difficult to establish whether hedging does in fact lead to an increase in firm value.

The objective of this paper is to estimate the causal effect of risk-management policies on value. To this end, we exploit the introduction of weather derivatives as a natural experiment. Weather derivatives are financial contracts whose payoffs are contingent on weather conditions. Because these derivatives were introduced in 1997, they provide arguably exogenous variation in the cost of hedging weather risks, which we use empirically. To further identify the causal effect of weather derivatives, we exploit the historical weather exposure of firms. Intuitively, we expect that those firms whose cash flows historically fluctuated with changing weather conditions to be more prone to use weather derivatives once these contracts are introduced, irrespective of their

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[1] Subsequent analyses have stressed that hedging can affect value in the presence of market frictions, such as transaction costs, informational asymmetries, taxes, etc. See Mayers and Smith (1982), Stulz (1984), Smith and Stulz (1985), Froot, Scharfstein, and Stein (1993), DeMarzo and Duffie (1995), and Leland (1998), among others.

[2] Allayannis and Weston (2001), Carter, Rogers, and Simkins (2006), MacKay and Moeller (2007), Berrospide, Purnanandam, and Rajan (2007), and Bartram, Brown, and Conrad (2009) among others, show that hedging is correlated with higher valuations. Jin and Jorion (2006) document insignificant risk management effects. Guay and Kothari (2003) question the empirical relevance of hedging for firm value.

investment opportunities. Econometrically, we use the pre-1997 weather exposure rankings as instrumental variables (IVs) for the use of weather derivatives after 1997.

To test for the importance of weather derivatives, we focus on electric and gas utilities. These firms provide a near-ideal laboratory for determining the importance of weather risk exposures because heating and cooling demands are tightly linked to changes in weather conditions. Furthermore, if regulated utilities are able to pass along their costs to consumers, the main exposure they face is quantity risk, which weather variables closely track. Not surprisingly, nearly 70% of the end users of weather derivatives are from the energy industry (Weather Risk Management Association, 2005). We use financial data from COMPUSTAT, weather information from the National Oceanic and Atmospheric Administration (NOAA), and hand-collected information on the use of financial derivatives since 1997. Our sample includes data on 203 U.S. utilities. Using these data, we report four main findings.

First, in the absence of weather derivatives, firms that are highly exposed to weather volatility exhibit significantly lower valuations and pursue more conservative financing policies. Our estimates show value differences of around 4% for firms in the highest weather-exposure quartiles. Also, weather-exposed firms use less debt financing and pay fewer dividends than other firms.

Second, we show that historical (pre-1997) weather exposure is a strong predictor of weather derivative use after 1997. Firms that are historically highly weather-exposed are 2 to 3 times more likely to use weather hedges after 1997 than other utilities. This evidence shows that an important fraction of firms use derivatives for hedging reasons.

Third, we show that weather derivatives lead to an economically large and statistically robust increase in firm value. Using instrumental variables specifications, we show that hedging leads to an increase in M-B ratios of at least 6%. We investigate whether the reported results can alternatively be explained by weather trends, deregulation, or the use of other risk management tools. After controlling for those effects, we find robust evidence for the causal interpretation of the link between hedging and value.

Fourth, we find that hedging leads to more aggressive financing policies and higher investment levels. Such results are consistent with the idea that left-tail cash flow realizations can limit debt capacity due to distress costs or other frictions. Similarly, they provide evidence that smooth cash flows allow firms to relax their borrowing constraints or to pursue valuable investments in low cash flow scenarios.

Overall, our results demonstrate that active risk management policies have real consequences. The estimates of the value of risk management, based on both cross-sectional and time-series tests, are consistent with those reported by Allayannis and Weston (2001) and Carter, Rogers, and Simkins (2006). Our results on hedging and debt capacity are also in line with Smith and Stulz (1985) and Leland (1998). Moreover, the investment effects reported are consistent with Froot, Scharfstein, and Stein (1993).

An attractive feature of our analysis is that it provides unique insights on the value of quantity risk insurance. Quantity risk may, in some cases, be more relevant for value than price risk exposures. Information asymmetries, however, provide an important barrier to the development of quantity-based insurance contracts. A clear advantage of weather derivatives relative to other contracts is that information asymmetry concerns are minor because it is difficult to argue that a given utility has superior weather forecasting abilities relative to other market participants, or that the actions of energy firms affect weather outcomes.

Our focus on financial innovation to identify the value of hedging is, to the best of our knowledge, new in the literature.[3] This approach is promising for a number of reasons. First, it provides exogenous variation in the cost of hedging. Second, it tightens the link between *specific* risk exposures and hedging instruments, allowing researchers to understand which policies are directly affected by risk management. Finally, the results provide rough estimates of the value of financial innovation, which is an important topic in the literature.

The rest of the paper is organized as follows. Section I describes the weather exposure of utilities and the tools used to mitigate those risks. Sections II and III present the empirical strategy and data, respectively. Section IV examines the impact of weather shocks on operating results while Section V tests for the effect of weather exposure on value in the absence of weather derivatives. Section VI presents the main results of the paper, examining the impact of weather derivatives on value. Section VII concludes.

I. Risk Management and Energy Utilities

According to the National Research Council, energy is one of the most weather sensitive sectors in the economy (2003). Heating and cooling demands are tightly linked to changes in weather conditions.[4] Furthermore, utilities are often required to serve such changing demands at fixed prices. As a result, it is unsurprising that weather events have often been reported to affect

[3] Our approach is closest to Conrad (1989), who examines the effect of the introduction of option contracts on the returns of the underlying securities. She, however, does not analyze a market-wide innovation, nor does she examine the consequence of completing a market on capital structure decisions.

[4] We focus on frequent but relatively low impact weather events, rather than on catastrophic insurance.

the profits of energy firms.[5] In lieu of this risk, utilities face the dilemma of determining whether to hedge their weather exposure and, if they choose to do so, deciding which tools to use.

Prior studies have stressed several rationales for risk management. Smith and Stulz (1985), Leland (1998), and Graham and Rogers (2002) emphasize the tax benefits from hedging. Froot, Scharfstein, and Stein (1993) show that risk management can alleviate investment distortions when external financing is costly. Adam, Dasgupta, and Titman (2007) demonstrate the value of hedging as a strategic tool in competitive settings. Stulz (1984), in contrast, shows that risk-averse managers may prefer to hedge firm value.

A challenge in selecting risk management tools is that several standard mechanisms are effective at hedging price or cost, but not quantity risk (Brockett, Wang, and Yang, 2005).[6] On the operational side, firms can diversify weather risks by investing in several geographic regions or by offering several product lines; economies of scale, however, are often higher in nearby communities, which exhibit similar weather conditions. Bundling several product lines is effective when individual product risks exactly offset each other. Other operating strategies to offset risk include using flexible operating technologies, storing or trading energy, and long-term contracts. There are, however, some barriers to such approaches. For example, electricity cannot be efficiently stored. Natural gas can be stored, but risk-sharing opportunities are limited by the lack of integration of regional markets (Energy Information Administration, 2002).

[5] Abnormally high (low) cooling degree days have, for example, been reported to boost (harm) the cash flows of the Florida Power and Light Group (Midwest Resources Inc). Sources: *The Palm Beach Post*, July 16, 1998, and *The Omaha World-Herald*, November 3, 1992, respectively. On the other end, high (low) heating degree days have been reported to strengthen (weaken) the cash flows of Dominion Resources Inc. (Atmos Energy Corp). Sources: *Dow Jones News* Service, April 15, 1994 and *The Dallas Morning News*, May 11, 1989, respectively.

[6] See Petersen and Thiagarajan (2000) for a detailed analysis of the alternative hedging strategies of two firms in the gold industry.

Firms can alternatively use their capital structure or other financial tools. Higher cash or lower debt levels reduce earnings volatility and protects investments. Lower leverage, however, limits the tax or the disciplining benefits of debt, affecting valuation. Firms can also use energy derivatives to sell output forward, potentially alleviating the negative consequences of low energy demand. While natural gas futures are widely used among utilities, electricity futures are, in contrast, virtually nonexistent.[7] These contracts, however, provide imperfect hedges against weather risks. The lack of regional integration of energy markets highlighted above, make it extremely difficult to find counterparties for the entire exposure facing large utilities. An alternative potential hedging strategy relies on agricultural derivatives. While, under some circumstances, commodity prices may correlate with local weather conditions (Roll, 1984), these instruments are likely to exposure utilities to substantial basis risk.

Utilities may use regulatory measures to minimize the impact of the weather. Weather normalization adjustments (WNA) allow utilities to transfer the weather risk to consumers by increasing (decreasing) energy bills in mild (extreme) weather seasons. However, WNA clauses have limitations. First, their coverage is limited: they do not cover the unregulated portion of energy firms' business and they are not available in every state.[8] Second, cash flow recovery may lag weather shocks, particularly in extreme cases (Jenkin and Ives, 2002), which may be important for increasing debt capacity or funding a growing investment program. Third, recovery is subject to regulatory risk.

[7] See Energy Information Administration (2002) for a review of these risk management tools.
[8] See http://www.aga.org/SiteCollectionDocuments/RatesReg/0708WEANORM.PDF for a list of states with natural gas WNA clauses.

Since 1997, energy firms have also used weather derivatives to manage their weather exposures.[9] Since the inception of these derivatives, energy firms have been the biggest end users of these contracts. Over 90% of transactions in this market are set in terms of cooling and heating degree days (CDD and HDD, respectively), which are temperature-based measures that seek to capture the energy demand for cooling and heating services.[10] More specifically, CDD (HDD) values capture deviations in mean temperatures above (below) 65°F, the benchmark at which energy demand is low.[11]

Weather derivatives specify five characteristics: (1) the underlying index, i.e. HDD, etc.; (2) the period of accumulation, i.e., season; (3) the weather station; (4) the dollar value of each tick size, i.e., the amount to be paid per unit of CDD or HDD; and (5) the strike price, which is indexed as the number of degree days in a period of time.

While the Chicago Mercantile Exchange (CME) has offered exchange-traded futures and options since 1999, most transactions in this market are over-the-counter (Golden, Wang, and Yang, 2007).[12] OTC transactions allow firms to tailor the contracts to their individual needs (Considine, 2000). OTC contracts, however, are less likely to be liquid, have higher transaction costs, and are subject to credit risk exposures.

While systematic data on this market do not exist at the firm-level, corporate filings and anecdotal evidence indicate the use of puts, collars, and swaps to hedge weather exposures. Puts allow firms to retain the upside potential of high weather-driven demand at the cost of a

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[9] For the first weather derivative contact, see *Houston Chronicle*, November 7th, 1997.

[10] Weather Risk Management Association (2009).

[11] $CDD = \max\,[0, \frac{T_{max}+T_{min}}{2} - 65°]$ and $HDD = \max\,[0, 65° - \frac{T_{max}+T_{min}}{2}]$. As an example, if the average temperature is 75°F, the corresponding CDD value for the day is 10.

[12] The CME offers CDD and HDD contracts for 42 cities around the world. According to the exchange, weather derivatives are one of the fastest growing derivative sectors (CME, 2005).

premium. Strike values are typically set at or slightly below historical (10-20 year) HDD or CDD values. Collars and swaps are often preferred by firms because they do not require upfront premiums, even though protection comes at the cost of lower profits in high weather scenarios. Finally, these derivatives have maximum payouts associated with them.

We illustrate the type of contracts that energy firms can use in the presence of weather risks with the following example from KeySpan Corp's 2006 annual report:

> "In 2006, we entered into heating-degree day put options to mitigate the effect of fluctuations from normal weather on KEDNE's financial position and cash flows for the 2006/2007 winter heating season - November 2006 through March 2007. These put options will pay KeySpan up to $37,500 per heating degree day when the actual temperature is below 4,159 heating degree days, or approximately 5% warmer than normal, based on the most recent 20-year average for normal weather. The maximum amount KeySpan will receive on these purchased put options is $15 million. The net premium cost for these options is $1.7 million and will be amortized over the heating season. Since weather was warmer than normal during the fourth quarter of 2006, KeySpan recorded a $9.1 million benefit to earnings associated with the weather derivative."

In this contract, the weather variable is HDD, the accumulation period is November 2006 to March 2007, the tick size is $37,500, and the seasonal strike price is 4,159. With this transaction, the firm obtains protection against low heating demand scenarios. Specifically, if winter temperatures are 5% milder than normal (the cumulative HDD values are below 4,159) then the company will receive $37,500 per HDD below this threshold.[13] The realized HDD value for the year was 3,916, which gave the contract a payoff at maturity date of $9.1 million.

Beyond energy companies seeking weather protection, other market participants include dedicated brokers and market makers, investment banks, insurance and re-insurance firms, and hedge funds. As stressed above, the magnitude of utility transactions is unlikely to involve other end users with identical but opposite exposures. As a result, market makers provide the key risk capital in this market.

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[13]The average of 4,159 HDDs corresponds to average daily temperatures of 37.5°F (65-HDD/n days) for the 151 days in the season, and the realized value of 3,916 corresponds to average temperature of 39.1°F.

Based on survey data, the average notional value of this market between 2006 and 2008 was $32.2 billion per year, significantly larger than the average annual level of $4.4 billion between 2001 and 2004 (WRMA, 2009). While small in scale, this market is likely to be extremely important for the most weather-exposed utilities. As we will discuss in subsequent sections, we find that only a fraction of utilities use derivatives, but those firms that use them reduce their weather exposure and improve their valuations.

II. Empirical Strategy and Predictions

A common approach to examining the effect of derivatives on firms' outcomes is to use cross-sectional tests that compare firm value as a function of hedging decisions. For example:

$$y_{it} = \alpha + \beta * hedge_{it} + \psi_\chi X_{it} + \varepsilon_{it} \quad (1)$$

where y_{it} is firm value and $hedge_{it}$ is a dummy equal to one if the firm uses derivatives, zero otherwise. X_{it} consists of control variables. If hedging is valuable, β would be expected to be positive and significant.

In terms of inference, (1) provides an unbiased estimate of the effect of hedging whenever the use of derivatives is uncorrelated with other determinants of firm value. However, a large number of studies, starting with Nance, Smith, and Smithson (1993), have shown that hedging decisions are correlated with size, investment opportunities, and leverage.[14] Whenever hedging is endogenously determined, OLS or propensity score-based estimates are subject to inference concerns: it is difficult to interpret β as an estimate of the causal effect of derivatives.

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[14] See, for example, Geczy et al. (1997), Haushalter (2000), and Geczy et al. (2006).

In this paper, we exploit both time-series and cross-sectional variation in the use of weather derivatives to overcome these inference concerns. Because weather derivatives were introduced in 1997, they provide arguably exogenous time-series variation in the cost of hedging weather risks. Furthermore, weather derivative contracts are expected to disproportionately benefit those firms that, from a historical (pre-1997) perspective, were most subject to weather shocks. This second layer of analysis is important because it provides cross-sectional predictions on the effect of weather risk exposure, both before and after weather derivatives were introduced, and because it allows the econometrician to control for other concurrent aggregate trends.

Using these sources of variation, we test the following two predictions:

1. Weather-exposed firms are more likely to use weather derivatives. While all firms potentially benefit from hedging, we expect that those firms whose cash flows have historically fluctuated with changing weather conditions will be more likely to use weather derivatives after 1997, irrespective of their investment opportunities.

2. The introduction of weather derivatives leads to an increase in firm value. To the extent that left tail weather-driven cash flow realizations limit debt capacity or investments, we expect weather-exposed firms to increase in value as weather derivatives allow them to insure against those negative weather realizations.

Prediction 1, while intuitive, is critical for our empirical tests, as it provides variation in weather derivative use that is likely to be orthogonal to future investment opportunities. Together with the time-series variation that results from the introduction of weather derivatives, they provide the arguably exogenous variation that we use to investigate Prediction 2.

To test Prediction 2, we alternatively rely on (a) fixed effects instrumental variables (FE-2SLS-IV), and (b) lagged dependent variables 2SLS-IV specifications. FE-2SLS-IV models are attractive tests that allow us to overcome unobserved time-invariant firm heterogeneity, but they may exaggerate (underestimate) the effect of risk-management when hedging is negatively (positively) correlated with lagged M-B ratios.[15] Lagged dependent variable 2SLS-IV specifications, in contrast, are attractive in settings where the key omitted variables are time-varying. In the results section, we discuss the robustness of the results to these alternative tests.

Formally, the first-stage FE-2SLS-IV specification is given by:

$$wderiv_{it} = b * weatherexp_i * post + d * post + \eta_i + a_\chi X_{it} + e_{it}. \qquad (2)$$

where $weatherexp_i$ captures historical (pre-1997) sensitivity to weather fluctuations. This variable proxies the potential gains from hedging with weather derivatives after 1997. $post_t$ is an indicator variable that is equal to one after 1997. η_i are firm fixed effects. Note that $wderiv_{it}$ is zero for the pre-1997 period; thereafter, it takes the value of one for weather derivative users.[16]

We then use $\widehat{wderiv}_{it}$ to test for the effect of weather derivatives on value using the following second-stage specification:

$$y_{it} = \alpha + \beta_{wderiv} * \widehat{wderiv}_{it} + \psi_\chi X_{it} + \eta_i + \varepsilon_{it} \qquad (3)$$

[15] See Angrist and Pischke (2009), pp. 243-247 for a discussion on the relative merits of these alternative models, as well as for the challenges of including lagged dependent variables in fixed effects specifications. The use of lagged dependent variable FE-2SLS models, however, does not affect the results of this paper.

[16] Even though $wderiv_{it}$ is a dichotomous variable, we estimate (2) using OLS, since a probit or a logit first stage can harm the consistency of the IV estimates (Angrist and Krueger, 2001). Using a non-linear specification, however, does not affect the results of this paper.

where β_{wderiv} provides the FE-2SLS-IV estimate of the value of hedging. β_{wderiv} captures the causal effect of weather derivatives on value, where the empirical counterfactuals are the same firm without derivatives in a period where these contracts were not available, and other firms without derivatives after 1997. Lagged dependent variable IV specifications are analogously defined, with the exception that lagged M-B ratios are used instead of firm fixed effects. We expect β_{wderiv} to be positive and significant.

Finally, to take specifications (2) and (3) to the data, we require an estimate of $weatherexp_i$. We estimate pre-1997 weather exposures using the following measures:

(a) Volatility (quarterly) of revenue to assets before 1997. Revenue volatility is attractive because it is straightforward to compute, and also because it captures the total hedging potential available to firms. It, however, includes revenue variation that results from other non-weather sources, which may be irrelevant for weather derivative use.

(b) Weather-induced revenue-assets volatility (quarterly) before 1997. To focus on weather volatility, we proceed in two steps. First, we estimate the sensitivity of revenue to changing weather conditions before 1997 using the following specification:

$$revassets_{it} = \alpha_i + \beta_i * DD_{it} + \gamma_i * ln(assets_{it}) + \varepsilon_t \qquad (4)$$

where $revassets_{it}$ is the quarterly revenue to assets ratio. DD_{it} is the relevant "degree day" weather measured at the firm level. We use cooling, heating, and energy degree days (CDD, HDD, and EDD, respectively) as controls. EDD is the sum of CDD plus HDD, and proxies for total energy demand. In (4), we control for the level of assets. To avoid multicollinearity concerns, we estimate separate regressions for each weather-related variable. $\beta_i^{EDD}, \beta_i^{HDD}$, and β_i^{CDD} capture the sensitivity of revenue to variation in EDD, CDD, and HDD, respectively. We refer to those estimates as "weather betas." Utilities can potentially gain from hedging weather risks irrespective of the sign of these betas. As a result, the absolute value of these weather betas is informative about the firms' hedging opportunities as a function of each variable.

Second, to obtain an estimate of the relevant revenue volatility that is attributable to weather fluctuations, we multiply the estimated weather betas by the relevant historical standard deviation of the corresponding weather variable. For hedging purposes, the meaningful weather exposure is the product of the absolute value of weather betas ($|\hat{\beta}_i^{EDD}|$, etc) and the degree of variation in each variable (σ_i^{EDD}, etc.). As such, $|\hat{\beta}_i^{EDD}| * \sigma_i^{EDD}$, for example, captures the historical weather-induced volatility of revenue that results from changing EDD values.

We use these historical weather exposure measures to investigate the importance of weather distortions. Our main empirical tests, however, emphasize the importance of weather-induced volatilities for valuation, both with and without weather derivatives.

III. Data Description

We use data from COMPUSTAT firms engaged in the distribution and generation of electricity and natural gas (Standard Industrial Classification (SIC) codes 4911, 4923 4924, 4931, and 4932). Given our interest in estimating pre-1997 weather exposure measures, we focus on U.S. firms with matching quarterly data for at least 10 years before 1997. We arrive at a sample of 203 firms with up-to 8,161 firm-year observations between 1960 and 2007.[17]

[17] Selected variables such as market capitalization or deferred taxes are not available for all firm-years.

Summary statistics are presented in Table I, Panel A. To facilitate comparisons over time, we report information in constant 2008 dollars. Average (median) total assets are $5.2 (2.7) billion. Mean (median) revenue is $2 ($1.1) billion. The mean (median) market capitalization is $2.3 ($1.1) billion. We follow the pre-existing literature in using market-to-book (M-B) ratios as a measure of value. The average M-B is 1.075, with a standard deviation of 0.21.[18]

Weather data are from the National Oceanic and Atmospheric Administration (NOAA). NOAA reports monthly temperatures and, cooling and heating degree day data from 1895 to the present for 344 climate divisions in the U.S. We compute energy degree days (EDD) as the sum of CDD and HDD values. To match firms with weather sites, we use latitude and longitude information on the firms' main business and each of the weather stations. For each firm, we find the closest climate division and use its weather information.[19] The annual weather information is summarized in Table I, Panel A. The mean (median) annual HDD level is 5,170 (5,577). The annual mean (median) CDD value is 1,040 (809). Similarly, the average (median) annual EDD value is 6,210 (6,386).

The data on the use of financial derivatives in the post-1997 period is hand-collected from the Securities and Exchange Commission (SEC) filings using the *LexisNexis Academic* application. We use a list of related keywords to identify firms that rely on weather derivatives, as well as those that use natural gas and interest rate hedging instruments.[20]

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[18] M-B ratios are calculated as the ratio of the sum of the book value of assets, plus the market value of equity, minus the sum of the book value of equity and deferred taxes over book assets.

[19] NOAA reports the latitude and longitude data of all climate divisions. COMPUSTAT reports the firms' zip codes and we rely on data from the U.S. Census Bureau to approximate the latitude and longitude location of each zip code. See http://www.census.gov/geo/www/gazetteer/places2k.html#counties for zip code location information, and Vincenty (1975) for computing geodesic distances between locations.

[20] For each of the weather, natural gas, and interest-rate contracts, we use the following accompanying keywords: derivatives, forwards, futures, hedging, options, and swaps. For example, for interest-rate derivatives, we used

While we do not have data on actual derivative exposure by firm, we use indicator variables to classify firms as derivative users whenever SEC filings describe such contracts. Table I, Panel B reports information for the post-1997 sample or 1,633 firm-year observations. Weather derivatives are used by one quarter of the sample firms. This ratio contrasts with survey data from the CME that shows that the ratio of firms using weather hedges in this industry is 35% (CME, 2008). The difference between these numbers may indicate that we are underreporting their usage. Both ratios, however, signify that weather derivatives are unlikely to be beneficial for all firms in the sample, reinforcing the importance of focusing on those utilities with significant weather exposures.

In terms of other derivative use in the post-1997 period, natural gas and interest rate derivatives were used by 57% and 87% of the sample firms, respectively. The fact that the latter ratio is the largest is not surprising given the importance of the interest rate swaps markets.

Table II shows the variables that we use to capture the historical weather exposure faced by utilities. These include: (a) revenue volatility (volatility of quarterly sales to assets), (b) CDD, HDD, and EDD weather betas (absolute value of the estimated coefficient of CDD, HDD, and EDD on revenue to assets), and (c) CDD, HDD, and EDD weather-induced volatility (weather betas times the relevant historical standard deviation). All measures are estimated using pre-1997 quarterly data.

Table II, Panel A provides consistent evidence that the reported weather exposure measures tend to vary substantially. The mean of revenue to assets volatility is 0.043, but the 10th and 90th percentiles are 0.01 and 0.11, respectively. Weather betas also exhibit substantial

“interest-rate derivatives,” “interest-rate forwards,” “interest-rate futures,” “interest-rate hedging,” “interest-rate options,” and “interest-rate swaps.”

dispersion. The averages of CDD or EDD betas, for example, are 0.9 and 0.3, respectively. Yet the 10th and 90th ranges are 0.06 and 3 for CDD betas and 0.01 to 0.93 for EDD betas. Similarly, weather-induced volatility measures vary greatly. While these weather exposure numbers are difficult to interpret in isolation, the relative ranks that they generate are intuitive: they are orderings of risk exposure, which is what we use in the paper.

Interestingly, Table II, Panel B shows that revenue and weather-induced volatility measures are highly correlated. The correlation between revenue and weather-induced volatility is 0.921, 0.916, or 0.86 for weather measures CDD, HDD, and EDD, respectively. Moreover, the CDD-HDD (HDD-EDD) volatility correlation is 0.99 (0.98); such correlations corroborate that these volatility measures capture the same underlying weather-induced variation.

IV. Changing Weather Conditions and Cash Flow Effects

To formally test for the effect of changing weather conditions on operating performance, and to assess whether all sample firms are subject to meaningful weather risks, we investigate whether relatively clement weather seasons relative to historical averages, or weather shocks for utilities, affect firm results.

More specifically, we test whether relatively low EDD values affect firm outcomes. To this end, we introduce a firm-specific weather shock variable that is set to one for the lowest quintile of annual EDD values per firm (i.e. each firm has one shock per five observations) and is zero otherwise. We focus on the effect of mild EDD values to provide a single and simple test that captures the importance of weather variation on cash flows independent of a firm’s main seasonal exposures (CDD or HDD). We rely on fixed effects specifications where we control for year effects using indicator variables, firm size using the natural logarithm of lagged assets, and lagged profitability in those specifications where the dependent variable is not profits itself.[21]

The results are presented in Table III. Column I shows that mild weather realizations are correlated with lower revenue. The effect is statistically significant but economically modest; weather shocks lead to average declines of 2% in revenue. Columns II and III confirm that weather shocks lead to lower operating cash flows. Both operating return on assets and the level of operating profits decline with mild weather realizations. The effect on profits is also modest in economic terms. Columns IV and V, in contrast, cast doubt on the notion that moderate weather conditions meaningfully affect dividend or investment decisions. The specifications in Columns I to IV report relatively large R-squared statistics, which are mostly driven by the firm fixed effects controls, and the significant degree of persistence in the relevant outcome variables.

To explore whether the results in Table III, Columns I to V, are evidence of small weather effects across the board or, whether they reflect heterogeneous consequences across firms, we rely on the weather exposure variables described in Table II. For each weather exposure measure, we (a) divide the sample firms into four equally sized groups, which are referred to as "quantity risk" quartiles, (b) interact each quartile with the firm-specific weather shock variable, and (c) test which quartile exhibits the largest sensitivity to weather shocks. By construction, we expect firms with higher weather exposures to be most sensitive to weather shocks. We are, however, interested in testing whether those rankings provide significant economic and statistical differences across groups of firms.

[21] The estimated coefficients on the year dummies, lagged size and profitability are omitted in Table III.

The results are shown in Table III, Columns VI through X. Column VI shows that weather shocks lead to insignificant effects on all but the most volatile quartile of firms; firms in this quartile exhibit a drastic decline in revenue of 9%, significant at the 1% level. Columns VII, VIII, and IX show that alternative weather exposure measures (EDD, CDD, or HDD weather volatilities) generate similar results. In each specification, the interactions of the most weather-exposed quartile indicate large and significant declines in revenue. Lastly, using profitability as an alternative outcome variable, in Column X, we confirm that the negative effects of weather shocks are concentrated on quartile four firms.

Taken together, the results from Table III show that changing weather conditions affect operating profitability. Furthermore, they demonstrate that mild weather events are relevant for a subset of utilities that have the highest weather exposure. In other words, the fact that only a fraction of firms are subject to cash flow volatility provides information on which utilities are likely to be subject to the largest distortions in terms of value, investment, and financing policies. We turn to those tests next.

V. Weather Exposure Without Derivatives: Value, Investment, and Financing Effects

In this section, we investigate the value, investment and financing effects of weather risk exposure before the introduction of weather derivatives.

In Table IV, Columns I and II, we examine the effect of weather risk on M-B ratios prior to 1997. Given that weather exposure variables are time-invariant, we rely on firm and regional controls to account for firm heterogeneity.[22] The results show that firms in the fourth quartile of weather exposure are subject to a discount in terms of value in the range of 3 to 4%, irrespective of the weather exposure measure used (revenue or EDD weather-induced volatility). In contrast, the value difference between firms in quartiles 2 and 3 and those in quartile 1 while negative and increasing in absolute value with weather exposure, are not robustly significant. The effects of profitability and investment growth controls are both positive and significant, as expected.

To assess whether the differences in market values reported above reflect distortions in operating decisions, in Columns III and IV of Table IV, we examine the impact of weather exposure on the ratio of capital expenditures to assets. The results, however, cast doubt on the idea that weather exposure affects firms' investment decisions, at least before 1997.

In Table IV, we also test for the effect of weather exposure on leverage (Columns V and VI) and payout policies (Columns VII and VIII). The evidence shows that firms in the most weather-exposed quartile have 2 to 4 percentage points lower debt ratios than their peers. This is consistent with the idea that creditors care about left-tail cash flow events. Economically, such estimates imply a 6 to 11% difference in leverage ratios. Similarly, we find that highly weather-exposed firms have lower dividend ratios than other firms. The differences are in the 0.003 to 0.004 range, significant at conventional levels. These estimates indicate that firms in the most volatile group pay at least 10% fewer dividends than other firms. In contrast, firms in quartiles 2 and 3 do not exhibit robust differences in their leverage or dividend ratios across specifications.

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[22] We include dummies for each of the U.S. Census divisions (see http://www.census.gov/geo/www/us_regdiv.pdf). Furthermore, the number of observations in Table IV declines relative to Table III because M-B ratios are not available for all firms. The results shown in Table III are unchanged if we focus solely on firms with M-B values. Also, the number of observations in Columns III to VI in Table IV declines because capital expenditures and cash data are available for fewer firm-years than other variables. Lastly, using the natural logarithm of market value as an alternative outcome variable obtains the same results as those in Columns I and II.

These results show that financial distortions may be important to understanding the weather exposure effects on value. The presence of sizeable weather risk esposures leads firms to use conservative financial structures, which may limit tax or incentive debt-based benefits. Similarly, while the average level of investments is not affected, weather-exposed utilities exhibit less aggressive payout policies, consistent with the presence of external financing costs.

Overall, the results provide empirical support for the idea that, absent weather derivatives, weather-exposed firms are less valuable and adopt more conservative financial policies than their peers. We now test whether these distortions were relaxed by financial innovation.

VI. Hedging and Firm Value: Evidence from Weather Derivatives

VI.A Differences-in-differences Specifications

Before implementing the main instrumental variables specifications, we test for the effect of hedging on value using differences-in-differences specifications. Intuitively, the introduction of weather derivatives after 1997 would be expected to disproportionately benefit those firms with substantial ex-ante weather exposures. To implement these tests, we interact the weather exposure groupings based on pre-1997 information with an indicator variable equal to one in the post-1997 period. We expect firms in quartile 4 in terms of weather exposure to gain in value relative to their peers. Given our interest in testing for the effect of weather uncertainty, we present tests based on weather-exposure measures (e.g. EDD weather induced volatility) as the key quantity risk variables, rather than relying on proxies for total revenue volatility.

Table V, Columns I and II show the results using firm fixed effect specifications with and without firm controls, respectively. The results show that quartile 4 firms in terms of EDD weather exposure, which were reported to underperform in the pre-1997 period, increase their valuations following the introduction of weather derivatives.[23] The estimated coefficient is large: M-B ratios increase by 11 to 13 percentage points, significant at the 1% level. As in the pre-1997 period, firms in weather-exposure quartiles 2 and 3 do not exhibit differential value effects; this suggests that moderate weather exposures may be managed using other risk-management tools.

One concern with fixed effects specifications is that they may not adequately control for time-varying omitted variables that can differentially affect firms based on their historical weather exposure. To address this concern and to assess the robustness of the results to alternative specifications, in Column III of Table V, we report results from a lagged dependent variables model. The results again indicate that firms in the most weather sensitive quartile increase in value after 1997. The estimated coefficient is 1.7 percentage points, significant at the 5% level. Also, as expected, lagged M-B ratios are important determinants of M-B values.

Columns IV and V of Table V show that even a noisy proxy variable for historical weather exposure, such as having a statistically significant EDD weather beta before 1997, which holds for 71% of the sample firms, is correlated with meaningful gains in M-B ratios after the introduction of weather derivatives. The value gains are in the 2 to 7% range depending on the specification, and are significant at the 1% level. These results confirm that weather-exposed firms increased in value after 1997, which is consistent with the idea that weather derivatives have a positive effect on firm value.

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[23] The results are robust to using CDD or HDD weather induced volatility measures. Other controls such as firm size and profitability are robustly significant and exhibit the expected signs (results not shown)

An alternative difference-in-differences test for the importance of weather derivatives is to investigate whether the correlations between weather shocks and net income change around 1997 for firms with and without weather derivatives. If firms hedge their weather exposures with derivatives, these contracts would tend to pay in periods of low energy demand, reducing the volatility of profits. As a result, we would expect the interaction of weather derivatives and weather shocks to be positive and significant.

Table V, Column VI presents the results for the top half of the sample firms in terms of weather exposure. Consistent with the evidence presented in Table 3, the profits of highly weather-exposed firms decline in the presence of weather shocks. Weather shocks lead to an average decline of 6% of profits, significant at the 1% level. The estimated coefficient on weather derivatives is negative but insignificant, consistent with the idea that firms are primarily using these contracts to shift cash flows across states of the world. Interestingly, the interaction term between weather derivatives and weather shocks is positive and significant. Furthermore, the estimated coefficient of the interaction term overcomes in magnitude the effect of the weather shock variable. This result implies that weather sensitive firms using derivatives are able to eliminate the negative consequences of weather shocks and that weather hedge ratios are statistically indistinguishable from 100%. More broadly, these results are important in lieu of the Guay and Kothari (2003) observation that derivative positions are typically relatively small and unlikely to significantly affect firm value. Our results show that weather derivatives have a statistically significant and economically meaningful effect on profits for weather sensitive firms.

To further investigate the implicit hedge ratios of weather sensitive firms, we introduce an alternative net income smoothing test based on firm filings and anecdotal evidence that suggest that energy firms seek weather insurance contracts with strike prices that are in the 5 to 10% range of historical (10 to 20 year) weather levels. We incorporate these features by (a) setting the weather shock to be equal to one in years where annual EDD values are 90% or less than historical values, and (b) testing for the impact of the interaction between this alternative weather shock dummy and the weather derivatives variable. The results, presented in Table V, Column VIII, confirm the two findings above; hedging smoothes weather shocks and implicit hedge ratios are consistently large. Table V, Columns VII and IX, in contrast, shows that both weather shocks and their interactions with weather derivatives have insignificant effects on net income for the bottom half of the sample in terms of weather exposure.

Overall, Table V provides evidence consistent with the notion that weather derivatives disproportionately benefit those firms with high ex-ante weather exposure. After 1997, weather-exposed firms increase in value. Furthermore, the profits of weather sensitive firms that relied on weather derivatives after 1997 become isolated from weather shocks. This latter evidence suggests that if abnormally low cash flow realizations limit debt capacity or investments, weather hedging may allow firms to overcome those constraints, and to increase firm value.

VI.B Instrumental Variables Specifications

The difference-in-differences results show that weather-exposed firms disproportionately increase in value after the introduction of weather derivatives. If weather derivatives drive this effect, then weather sensitive firms should be more likely to use weather derivatives after 1997. We test for this formally using an instrumental variables framework.

We proceed with these tests by first investigating whether pre-1997 weather exposure variables predict weather derivative use after these financial contracts were introduced. Columns I and II of Table VI present the results. In both specifications, the dependent variable is an indicator variable that, in the post-1997 period, is equal to one for weather derivative users, and is zero for both non-users and all pre-1997 observations.

The evidence confirms that weather-exposed firms are significantly more likely to use weather derivatives. Using EDD weather-induced volatility as a measure of weather exposure, we show in Column I of Table VI that EDD weather-induced volatility quartiles 3 and 4 are 23.9 and 24.4 percentage points, respectively, more likely to use weather derivatives than quartile 1 firms. Only 12% of firms in quartile 1 use weather derivatives after 1997. These differences are statistically significant at the 10% and 5% levels, respectively. Economically, these results show that firms in the most weather-sensitive quartile are 2.9 times more likely to use weather derivatives than those in quartile 1. Interestingly, this differential variation is likely to capture the insurance, as opposed to the speculative, demand for derivatives.[24]

Table VI, Column II relies on an alternative and simpler measure of weather exposure, i.e., a dummy variable equal to one whenever the firm shows a statistically significant EDD weather beta before 1997. The results show that firms with significant weather betas in the pre-1997 period are 20 percentage points more likely to use weather derivatives than other firms, significant at the 5% level. In economic terms, this difference implies that weather sensitive firms are 2.4 times more likely to use weather derivatives than other firms. Furthermore, the F-

[24] For evidence on speculation with derivatives, see for example, Géczy, Minton, and Schrand (2007) and Adam and Fernando (2006).

test in these specifications is 9.8 (Column I) and 19.2 (Column II), which shows that these variables provide meaningful variation in weather derivatives.

Consistent with prediction 1, the results shown in Table VI, Columns I and II provide empirical support for the notion that pre-1997 weather exposure rankings are important determinants of weather derivative use after 1997. As such, we are able to confirm that those firms that from an ex-ante perspective would be expected to benefit from "completing" the weather exposure market are indeed using these financial instruments more frequently than other firms.

Having shown that weather exposure begets usage of weather derivatives, we now present the main results, which examine the consequences of risk management on firm value. We use market-to-book ratios as a benchmark for firm value. Columns III and IV of Table VI present 2SLS-IV estimates of the effect of weather derivatives on value corresponding to the first-stage specifications reported in Columns I and II. These fixed effects specifications show a positive and arguably causal effect of financial derivatives on value. The point estimates are in the 24 to 25% range, depending on the source of variation used in the first-stage, and are significant at the 1% level. To assess the robustness of the results to time-varying omitted variables, we also examine the effect of weather derivatives on value using an IV-2SLS lagged M-B model. The results, shown in Table VI, Column V, indicate that weather derivatives lead to an increase in firm value of 12%, significant at the 1% level. Overall, these results provide empirical support for prediction 2, which anticipates that weather derivatives lead to economically large and statistically significant effects on value.

In Table VI, Columns VI to IX, we examine the robustness of our results against alternative hypotheses. Our inference may be challenged, for example, by a combination of changing business prospects due to deregulation, variation in climate conditions due to global warming, or a reduction in exposure driven by other hedging technologies. We report 2SLS-IV specifications with fixed effects (Columns VI and VIII) and lagged M-B ratios (Columns VII and IX), respectively. All specifications include year controls.

We use information from the Energy Information Administration (EIA) to test whether state level deregulation of electricity and natural gas markets drives the reported effects on market valuation. We include dummy variables that are equal to one for the observations where the relevant state-year has experienced electricity and natural gas deregulation actions. We also include detailed indicator variables to control for specific electricity (Fabrizio, Rose, and Wolfram, 2007) and natural gas deregulation events. These include having access to retail, industrial, or all electricity consumers, and having pilot, partial, or complete choice in natural gas markets. Each indicator variable is set to one for the observations where, according to the EIA, the relevant state-year experienced deregulation.[25] While we find that (a) access to all consumers in electricity lead to an increase in M-B ratios of 3 to 7%, and (b) access to retail clients had a negative effect on value in the 3 to 10% range (other effects are insignificant or not robust across specifications), we do not find that such detailed deregulation indicator variables affect the key coefficients of interest.

[25] Information on electricity and natural gas deregulation was obtained from the following EIA websites:
http://www.eia.doe.gov/cneaf/electricity/page/restructuring/restructure_elect.html
http://www.eia.doe.gov/natural_gas/restructure/restructure.html.

In Table VI, Columns VIII and IX, we provide results of further tests on whether changing weather conditions and alternative hedging technologies affect the key results of this paper. To this end, we include controls for cooling or heating degree day values. The estimated coefficient of CDD on M-B ratios is positive and significant, showing that higher cooling demand leads to higher firm value. The effect of HDD is, in contrast, insignificant. We also investigate whether the post-1997 effects are related to the use of other financial contracts. We fail to find significant effects on the interaction between the use of interest rate and natural gas derivatives and the post-1997 indicator variable. Interpreting these latter coefficients is, however, challenging given the endogeneity between hedging decisions and firm value, which we cannot overcome in the case of interest rate and natural gas derivatives. Finally, to investigate whether the differential effects of regional diversification have a bearing on the results, we assess the differential post-1997 behavior of those utilities that, as of 1997, operated only within one state, relative to multiple jurisdiction firms. This additional interaction is, however, insignificant. In terms of firm controls, we include proxies for profitability, size and investment opportunities. These controls, whenever they are significant, have the expected effects on M-B ratios: positive for lagged profitability and investments, and negative for size (results not shown).

Overall, the evidence presented in Table VI shows that after controlling for a long array of alternative variables, the effect of weather derivatives on value remains positive and significant, bolstering the case for the causal interpretation of the effect of weather derivatives on value. As is common with instrumental variables estimates, the standard errors are significantly large in some specifications because IV estimates rely on relatively fewer observations. However, the most precisely estimated coefficients are in the 6 to 8% range, which are consistent with prior estimates in the literature (Allayannis and Weston, 2001; Carter, Rogers, and Simkins, 2006).

An alternative potential concern with the preceding results is that they might be capturing differences in performance attributable to particular states, events, or time periods that overlap with the introduction of weather derivatives. As a result, the increases in value reported in Table VI may potentially be unrelated to weather hedging. An illustration of this concern is the deregulation and eventual energy crisis in California (Borenstein, 2002), which may have a bearing on the results. In Column I of Table VII, we address this concern by investigating the robustness of the results to excluding firms located in California. We report results using lagged dependent variables (Panel A) and fixed effects (Panel B) instrumental variables specifications. The results show that the positive effect of weather derivatives on value holds in this subsample. In addition, in untabulated tests, we investigate the sensitivity of the results to excluding firms from one state at a time and confirm that no single state is critical for the results.

In Table VII, Column II, we investigate whether excluding the 1997 to 2002 period, which coincided with the rise and fall of Enron Corporation, affects the estimates. The results show that the effect of weather derivatives on value is unlikely to be driven by those events. Similarly, in Table VII, Column III, we examine the robustness of the results to narrowing the window of analysis and including only the post 1994 period. Yet, focusing on this subsample does not affect the result of the paper. Also, across subsamples, we verify that the fixed effects estimates in Panel B exhibit significantly larger estimated coefficients than those presented in Panel A, which is consistent with the idea that time-varying omitted variables may be important in this setting, and that fixed effects IV models may not be efficient.

In Table VII, Columns IV and V, we examine the robustness of the results to splitting the sample firms into two groups based on whether or not they have a weather normalization adjustment (WNA) provision. As argued in Section I, while available only in relatively few jurisdictions (26% of the firms) and subject to regulatory risks, WNA clauses may serve as a non-market alternative to weather derivatives. Weather normalized rates allow utilities to partially transfer their weather risk to consumers. Consistent with this substitution hypothesis, we show that the positive effect of weather derivatives on value is only obtained for firms that do not possess WNAs, which are the majority in the sample. Weather derivatives, in contrast, do not affect M-B ratios in the subsample of firms with regulatory insurance.

In Table VII, Columns VI and VII, we examine the importance of leverage for the effect of weather derivatives on value. Given that (a) weather-exposed firms used less debt financing before 1997 (Table IV), and that (b) the tax or incentive based benefits of leverage may be important for valuation, the introduction of weather derivatives may have been predominantly beneficial for firms with conservative financial policies in the pre-1997 sample. We test for this hypothesis by splitting the sample firms into two groups based on pre-1997 net debt ratios. Table VII, Columns VI and VII show the results for the bottom and top half of the sample in terms of pre-1997 leverage. Consistent with the idea that unhedged weather shocks limit debt capacity and that leverage enhances firm value, we show that weather derivatives lead to positive and significant effects on value mainly in the subsample of firms with low pre-1997 leverage. Implicit in these results is the idea that weather derivatives allow highly weather sensitive firms to smooth their cash flows and increase their leverage. Having shown that weather derivatives do indeed smooth cash flow volatility, we now test whether weather derivatives lead to significant effects on operating and financing policies.

VI.C Specific Channels

The evidence presented thus far demonstrates that weather-exposed utilities use weather derivatives more frequently than other firms, and that weather derivatives lead to significant gains in firm value. But what exactly changes inside firms with risk management? Previous studies have emphasized the role of hedging for investment and capital structure decisions. Furthermore, as argued above, financing policies were shown to be at least partially distorted by weather exposure before weather derivatives were available. We examine those and other alternative channels in Table VIII.

Table VIII reports both difference-in-differences (Panel A) and fixed effects 2SLS-IV (Panel B) estimates, where the instrumental variables are EDD weather exposure quartiles. We investigate whether revenue, financing, investments, and payout policies reacted differentially for firms in distinct weather quartiles after 1997 in response to weather derivative use.

The impact on revenue is presented in Table VIII, Column I. Using differences-in-differences estimates, we do not find systematic evidence that revenue increased in a differential manner for weather-exposed firms. Not surprisingly, the instrumental variables estimates on the effect of weather derivatives on revenue are also insignificant. Such results are also inconsistent with the hypothesis that global warming or deregulation may be driving the effects on value, as those factors would tend to affect revenue differentially as a function of weather exposure.

The risk management consequences for financing decisions are investigated in Table VIII, Columns II (net debt), III (book leverage), and IV (cash to assets). Irrespective of the measure used, differences-in-differences estimates (Panel A) indicate that after 1997, quartile 4 firms rely more heavily on debt financing. Book leverage increases by 3.3 percentage points while cash ratios decline by 0.7 percentage points. The effect on net-debt is 4 percentage points, significant at the 1% level. Consistent with tradeoff theories of capital structure, we find that weather sensitive firms were able to use more debt and hold less cash whenever they use financial derivatives.

The IV estimates on the effect of weather derivatives shown in Table VIII, Panel B reflect the same signs as the reduced form correlations in Panel A. The instrumental variables estimate of the effect of derivatives on net debt is 7.1 percentage points, significant at the 10% level due to the larger estimated standard errors associated with IV specifications. Such large standard errors make the effect of hedging on book leverage only significant at the 15% level. Lastly, despite the increased noise in the IV estimates, Column IV shows that active risk management policies lead to lower cash holdings. The estimated coefficient is -1.5 percentage points, significant at the 10% level.

Beyond these instrumental variables specifications, an alternative test for the effect of risk management on leverage is to evaluate, in the cross-section, whether weather risk characteristics matter for capital structure after 1997. In unreported results, we find that after 1997, the across group differences in leverage, such as those reported in Table IV, are no longer statistically different from zero at conventional levels.

Having shown that weather risk exposure affects debt financing policies before 1997, and that weather derivatives reduce the volatility of profits and enhance value after 1997, a potential issue is whether the changes in leverage alone can contribute to the reported increases in value. The arguably least controversial method to examine the effect of leverage on value is to estimate the tax related savings from debt financing, a likely lower bound of the contribution of leverage to value.[26] Using cross-sectional and IV-2SLS estimates of Tables IV and VIII, we find that hedging may allow firms to increase their leverage ratio by 2.2 to 7 percentage points of assets. Assuming a perpetual increase in debt and a tax rate of 35%, those estimates suggest a contribution of debt to value in the 0.8 to 2.5% range, which is consistent with the estimates of Graham and Rogers (2002). In other words, while tax shields provide an important contribution to firm value, they do not fully account for the total increase in M-B ratios reported in this paper.

To further explore the effects of hedging inside firms, we investigate the impact of weather derivatives on investment. Table VIII, Column V examines the effect of risk management on the ratio of capital expenditures to assets. The difference-in-differences estimates of Panel A indicate that firms in quartile 4 increased their capital expenditures by one percentage point of assets after 1997, which is significant at the 5% level. The resulting IV estimates, shown in Panel B, indicate that weather derivatives lead to a positive and significant effect on investment; the IV estimate is 0.046, significant at the 5% level.

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[26] Increasing leverage reduces tax obligations (Leland, 1998, and Graham and Rogers, 2002), but may also enhance the incentives of managers to perform (Jensen, 1986), leading them to improve the allocation of resources to both existing and new investments. Higher debt financing also raises asset substitution concerns (Jensen and Meckling, 1976), changes the costs of financial distress (Warner, 1977, and Weiss, 1990), and potentially leads to assets fire sales (Shleifer and Vishny, 1992), among other margins.

The fact that capital expenditures respond to risk management is consistent with the insight of Froot, Scharfstein, and Stein (1993) that risk management can enhance value through the firms' investment policy. Higher investment is, however, also potentially consistent with overinvestment stories due to agency concerns (Jensen, 1986; Tufano, 1998). While this paper does not provide a structural model that concurrently encompasses and quantifies these financing and incentive (among other) frictions, the reduced form correlation between investment and value suggest that the net effect of overcoming financial frictions is positive for firm value.[27]

Lastly, Table VIII, Column VI examines the effect of weather derivatives on dividend ratios. We do not report significant effects on dividend payouts.

VI.D Interpretation

This paper has examined the effect of active risk management on firm value. To test for this effect, we have relied on an empirical strategy that emphasizes a plausibly exogenous source of variation in the use of derivatives. In our tests, we compared the relative valuation of weather-exposed firms with and without weather derivatives, and relied on historical weather exposures to provide arguably causal estimates on the effect of hedging on value.

Our main results demonstrate that hedging leads to a positive and significant effect on firm value. We have also shown that risk management allows firms to increase their debt capacity, invest more, and enjoy smoother earnings. Overall, we interpret the evidence as supportive of the idea that financial derivatives have a positive effect on firm value.

[27] See, for example, Hennesy and Whited (2007) for an illustration of a structural model of optimal financial and investment policy in the presence of a broad set of frictions.

VII. CONCLUDING REMARKS

Financial derivatives lie at the heart of Miller's (1986) "revolution" in financial innovation. Derivatives are powerful tools for shifting or hedging risks. They also reduce the cost of engaging in speculative transactions. Furthermore, as Rajan (2005) anticipated, financial innovation can exacerbate both firm and systemic risks exposures. Not surprisingly, derivatives have played a central role in recent financial crises.

Despite the prominence of financial derivatives, we know surprisingly little about the causal effect of hedging on firm value. In this paper, we exploit the introduction of weather derivatives as an exogenous shock to firms' costs of hedging weather-related risks. Using this natural experiment and data from energy utilities, we find that derivatives lead to higher valuations, investments, and leverage.

Overall, our results demonstrate that financial innovation that is targeted to meaningful economic risks can significantly affect firm decisions. Whether our results extend to other industries and other financial products are fascinating areas for further research.

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TABLE I. SUMMARY STATISTICS

This table shows summary statistics for 203 U.S. electric and gas firms (SIC codes 4911, 4923, 4924, 4931, and 4932) with matching (a) financial information from COMPUSTAT for at least 10 years prior to 1997 and (b) weather data from the National Oceanic and Atmospheric Administration (NOAA). Panel A presents financial and weather variables. Total assets, revenue, and market value of equity are in thousands of constant 2008 dollars (Consumer Price Index, adjusted, 2008=100). *OROA* is the ratio of operating income before depreciation to assets. *Book leverage / assets* is the ratio of the sum of long-term debt plus existing debt in current liabilities to total assets. *Market value of equity* is the price (close) times the number of common shares outstanding. *M-B ratio or market-to-book ratio* is the book value of assets plus market value of common equity minus book value of common equity and deferred taxes divided by total assets. *Net debt / assets* is the ratio of book leverage minus cash and marketable securities to total assets. *CAPEX / assets* is the ratio of capital expenditures to total assets. *Investment rate* is the growth rate of total assets. *Dividends / assets* is the ratio of total dividends over total assets. Weather variables reported are cooling, heating and energy degree days. A heating (cooling) degree day reflects the number of degrees that a daily average temperature is below (above) 65°F, zero otherwise. *Energy degree days* are the sum of heating and cooling degree days. Cooling, heating, and energy degree days seek to capture cooling, heating, and combined cooling and heating energy demand, respectively. *Heating (cooling, energy) degree days, annual* is sum of daily heating (cooling) degree days in a year in the firms' main location. In Panel B, *weather (natural gas, interest) derivative user* is an indicator variable equal to one if a firm used weather, natural gas, or interest rate derivatives in the post-1997 period, zero otherwise.

Panel A. Firm and Weather Information

Variables	Number Obs	Mean	Std Dev.	Min	p10	Median	p90	Max
Total assets	8,161	5,152	6,723	62	500	2,702	13,662	73,370
Revenue	8,161	1,994	2,712	39	265	1,070	4,865	72,339
OROA	8,161	0.117	0.026	0.030	0.084	0.117	0.150	0.199
Book leverage/ assets	8,161	0.411	0.087	0.001	0.306	0.410	0.516	0.888
Market value of equity	5,630	2,290	3,345	0.031	176	1,128	5,750	56,052
M-B ratio	5,532	1.075	0.207	0.733	0.862	1.027	1.370	1.950
Net debt / assets	6,353	0.376	0.084	(0.125)	0.278	0.372	0.478	0.821
CAPEX / assets	6,353	0.074	0.035	0.015	0.035	0.067	0.124	0.212
Investment rate	8,161	0.072	0.082	(0.204)	(0.006)	0.061	0.159	0.716
Dividends / assets	8,161	0.030	0.011	0.000	0.016	0.030	0.041	0.267
Heating degree days, annual	8,161	5,170	1,965	85	2,131	5,577	7,408	10,244
Cooling degree days, annual	8,161	1,040	809	5	295	809	2,246	4,443
Energy degree days, annual	8,161	6,210	1,381	2,056	4,311	6,386	7,842	10,684

Panel B. Use of Derivatives After 1997

Variables	Number Obs	Mean	Std Dev.	Min	p10	Median	p90	Max
Weather derivative user	1,731	0.249	0.433	0	0	0	1	1
Natural gas derivative user	1,731	0.574	0.495	0	0	1	1	1
Interest rate derivative user	1,731	0.866	0.341	0	0	1	1	1

TABLE II. MEASURES OF WEATHER EXPOSURE

This table shows summary statistics (Panel A) and correlations (Panel B) for various measures of weather risk exposure. Risk measures include (a) revenue volatility (standard deviation of quarterly revenue to assets), (b) CDD, HDD, and EDD betas (absolute value of the estimated coefficient of CDD, HDD, and EDD, respectively, on quarterly revenue to assets) or "weather betas," (c) CDD, HDD, and EDD historical standard deviation at the quarterly level, and (d) CDD, HDD, and EDD weather-induced volatility, which is the product of CDD, HDD, and EDD weather betas times their relevant historical standard deviation. All measures are estimated using pre-1997 data.

Panel A. Measures of Pre-1997 Weather Exposure

Variables	N	Mean	Std Dev.	Min	p10	Median	p90	Max
Revenue volatility	203	0.043	0.040	0.006	0.013	0.024	0.111	0.193
CDD beta $(\lvert \beta_i^{CDD} \rvert)$	203	0.908	1.419	0.003	0.059	0.310	2.972	10.508
HDD beta $(\lvert \beta_i^{HDD} \rvert)$	203	0.255	0.360	0.000	0.008	0.099	0.823	2.209
EDD beta $(\lvert \beta_i^{EDD} \rvert)$	203	0.300	0.449	0.000	0.013	0.114	0.930	3.480
CDD standard deviation	203	0.027	0.015	0.005	0.009	0.024	0.048	0.078
HDD standard deviation	203	0.102	0.033	0.009	0.047	0.112	0.135	0.165
EDD standard deviation	203	0.085	0.033	0.020	0.031	0.096	0.121	0.150
CDD weather induced volatility $(\lvert \beta_i^{CDD} \rvert) * \sigma_i^{CDD}$	203	0.019	0.026	0.000	0.001	0.008	0.066	0.123
HDD weather induced volatility $(\lvert \beta_i^{HDD} \rvert) * \sigma_i^{HDD}$	203	0.024	0.033	0.000	0.001	0.009	0.088	0.152
EDD weather induced volatility $(\lvert \beta_i^{EDD} \rvert) * \sigma_i^{EDD}$	203	0.022	0.031	0.000	0.001	0.009	0.086	0.131

Panel B. Correlation Table

	Revenue Volatility	CDD Weather Ind. Volatility	HDD Weather Ind. Volatility	EDD Weather Ind. Volatility
Revenue volatility	1.000			
CDD weather induced volatility	0.921	1.000		
HDD weather induced volatility	0.916	0.991	1.000	
EDD weather induced volatility	0.863	0.957	0.977	1.000

TABLE III. REVENUE CONSEQUENCES OF WEATHER SHOCKS: BY MEASURES OF WEATHER EXPOSURE

This table presents the impact of mild weather conditions (low energy degree days (EDDs)) or weather shocks for utilities, on measures of operating performance both for all sample firms (Columns I through V) and for subsamples sorted into quartiles based on their pre-1997 estimated weather exposure, or quantity risk quartiles (Columns VI through X). The dependent variables are (a) *ln revenue*, the natural logarithm of revenue in constant 2008 dollars (Columns I, VI, VII, VIII, and IX), (b) *OROA*, the operating profitability on assets (Columns II and X), (c) *ln operating income*, the natural logarithm of operating income in constant dollars (Column III), (d) *dividends/assets*, the ratio of dividends to assets (Column IV), and (e) *investment rate*, the growth rate of total assets (Column V). EDDs are defined as the sum of the annual heating and cooling degree day values; a temperature-based measure that seeks to capture the energy demand for heating and cooling services. Heating (cooling) degree days reflect the number of degrees that a daily average temperature is below (above) 65°F. *Weather shock* is an indicator variable equal to one if the annual EDD values are in the lowest quintile for each sample firm, zero otherwise. Measures of weather exposure are (a) *Revenue/Assets* quartiles, equal-sized groupings based on the historical standard deviation of quarterly revenue divided by assets (Column VI), (b) *weather-induced volatility* quartiles, equal-sized groupings based on the product of EDD (Columns VII and X), CDD (Column VIII), and HDD (Column IX) weather betas in the pre-1997 period, and the relevant historical standard deviation. EDD, HDD, and CDD weather betas correspond to the absolute value of the sensitivity of revenue to EDD, CDD, and HDD values, at the quarterly level. Each column shows the results of a fixed effects (firm) regression that also includes the following controls: the natural logarithm of lagged total assets, lagged OROA (except Columns II, III, and X, where it is omitted), and year dummies (estimated coefficients are not reported). Standard errors are clustered at the firm level and are shown in parentheses.

	Dependent Variables									
	Ln Rev.	***OROA***	***Ln. Op. Inc***	***Div. / Assets***	***Inv. Rate***	***Ln Rev.***	***Ln Rev.***	***Ln Rev.***	***Ln Rev.***	***OROA***
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
Weather shock	***-0.0161*** **	***-0.0023*** **	***-0.0196*** ***	***0.00004***	***0.0029***	**0.0092**	**0.0003**	**0.0172**	**0.0144**	**-0.0001**
	(0.007)	*(0.001)*	*(0.008)*	*(0.0014)*	*(0.003)*	*(0.012)*	*(0.015)*	*(0.016)*	*(0.016)*	*(0.001)*
Quantity risk quartile 2						-0.0048	0.0243	-0.0092	-0.0016	-0.0009
** weather shock*						*(0.019)*	*(0.018)*	*(0.020)*	*(0.019)*	*(0.002)*
Quantity risk quartile 3						-0.0048	-0.0117	-0.0128	-0.0269	-0.0031
** weather shock*						*(0.019)*	*(0.027)*	*(0.024)*	*(0.027)*	*(0.002)*
Quantity risk quartile 4						**-0.0872** ***	**-0.0775** ***	**-0.1041** ***	**-0.0906** ***	**-0.0050** **
**** weather shock***						***(0.024)***	***(0.022)***	***(0.024)***	***(0.023)***	***(0.002)***
Weather-based quantity risk quartiles						*Vol. of Rev / Assets*	*EDD Weather Ind. Vol.*	*CDD Weather Ind. Vol.*	*HDD Weather Ind. Vol.*	*EDD Weather Ind. Vol.*
Year controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,743	7,743	7,743	7,743	7,743	7,743	7,743	7,743	7,743	7,743
R-squared	0.970	0.400	0.977	0.370	0.175	0.970	0.970	0.970	0.970	0.401

***, ** and * denote significance at the 1, 5 and 10 percent level, respectively.

TABLE IV. WEATHER RISK EXPOSURE WITHOUT WEATHER DERIVATIVES: PRE-1997 EVIDENCE

This table examines the impact of weather risk exposure on firm value, investment, financing, and dividend policies before weather derivatives were introduced in 1997. The dependent variables are: (a) the market-to-book ratio: the value of total assets plus the market value of common equity (stock price times the number of common shares outstanding) minus book value of common equity and deferred taxes divided by total assets (Columns I-II), (b) *CAPEX/Assets*: the ratio of capital expenditures to total assets (Columns III and IV), (c) *Net Debt/Assets*: the ratio of the book value of debt minus cash and marketable securities over total assets (Columns V and VI), and (d) *Dividend/Assets*: the ratio of total dividends over total assets (Columns VII and VIII). Weather exposure is measured using, alternatively, (i) *Revenue/Assets* quartiles (Columns I, III, V, and VII), equal-sized groupings based on the historical standard deviation of quarterly revenue divided by assets, and (ii) *EDD weather-induced volatility* quartiles (Columns II, IV, VI, VIII), equal-sized groupings based on the product of energy degree days (EDD) *weather beta* times the historical standard deviation of EDD values. The EDD weather beta measures the sensitivity of revenue to EDD variation. EDDs are defined as the sum of the annual heating and cooling degree day values, temperature-based indexes that seek to capture the energy demand for heating and cooling services. *Ln assets* is the natural logarithm of the lagged value of total assets. *OROA* is the lagged value of the ratio of operating income to total assets. *Investment rate* is the growth rate of total assets. Each regression also includes regional indicator variables for each of the U.S. Census divisions, and year dummies as controls (estimated coefficients are omitted). Standard errors are clustered at the firm level and are shown in parentheses.

Dependent variables	***Market to Book Ratio***		***CAPEX / Assets***		***Net Debt / Assets***		***Dividends / Assets***	
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
Quantity risk quartile 4	**-0.0415 *****	**-0.0330 ****	**-0.0001**	**0.0019**	**-0.0430 *****	**-0.0240 ****	**-0.0044 *****	**-0.0030 *****
	(0.014)	*(0.013)*	*(0.003)*	*(0.003)*	*(0.012)*	*(0.012)*	*(0.001)*	*(0.001)*
Quantity risk quartile 3	-0.0206 *	-0.0177	0.0006	-0.0008	-0.0222 **	-0.0065	-0.0018 **	0.0002
	(0.012)	*(0.012)*	*(0.003)*	*(0.003)*	*(0.010)*	*(0.009)*	*(0.001)*	*(0.001)*
Quantity risk quartile 2	-0.0098	-0.0129	-0.0001	0.0031	-0.0186 **	0.0032	-0.0004	0.0008
	(0.011)	*(0.011)*	*(0.003)*	*(0.002)*	*(0.009)*	*(0.009)*	*(0.001)*	*(0.001)*
Ln assets	-0.0078 *	-0.0056	-0.0001	0.0001	-0.0032	-0.0009	0.0003	0.0005 *
	(0.004)	*(0.004)*	*(0.001)*	*(0.001)*	*(0.003)*	*(0.003)*	*(0.0003)*	*(0.0003)*
OROA	1.5851 ***	1.5446 ***	-0.0648	-0.0624	-0.9376 ***	-0.9980 ***	0.0613 ***	0.0556 ***
	(0.155)	*(0.152)*	*(0.043)*	*(0.043)*	*(0.129)*	*(0.127)*	*(0.010)*	*(0.010)*
Investment rate	0.2380 ***	0.2393 ***						
	(0.041)	*(0.042)*						
Market to book ratio			0.0902 ***	0.0898 ***	-0.0298	-0.0212	0.0152 ***	0.0158 ***
			(0.015)	*(0.015)*	*(0.044)*	*(0.042)*	*(0.004)*	*(0.004)*
Weather-based quantity risk quartiles	*Vol. of Rev / Assets*	*EDD Weather Ind. Vol.*	*Vol. of Rev / Assets*	*EDD Weather Ind. Vol.*	*Vol. of Rev / Assets*	*EDD Weather Ind. Vol.*	*Vol. of Rev / Assets*	*EDD Weather Ind. Vol.*
Year controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,490	4,490	3,080	3,080	3,080	3,080	4,490	4,490
R-squared	0.729	0.728	0.302	0.303	0.488	0.478	0.332	0.329

***, ** and * denote significance at the 1, 5 and 10 percent level, respectively.

TABLE V. WEATHER EXPOSURE EFFECTS ON VALUE AND PROFITABILITY AROUND 1997

This table reports changes in market to book ratios as a function of weather risk exposure variables (Columns I to V), and net income weather sensitivity (Columns VI to IX), around 1997. *Market-to-book* is defined as the value of total assets plus the market value of common equity (stock price times the number of common shares outstanding) minus book value of common equity and deferred taxes divided by total assets. *Market value of equity* is the price (close) times the number of common shares outstanding. *Ln Net Income* is the natural logarithm of net income. Measures of weather risk exposure are: (a) *Quantity risk quartiles*: EDD weather-induced volatility quartiles, equal-sized groupings based on the product of the EDD weather beta and the standard deviation of EDD before 1997, and (b) *Weather based quantity risk indicator*: an indicator variable equal to one if the EDD weather beta in the pre-1997 period is statistically significant at the 5% level, zero otherwise. *Post* is an indicator variable equal to one in the post-1997 period, zero otherwise. *Weather shock* is an indicator variable equal to one if (a) the annual EDD values are in the lowest quintile for each sample firm, zero otherwise (Columns VI and VI), or (b) the annual EDD values are below 90% of the average in the 1977-1997 period per firm (Columns VIII and IX). *Weather derivatives* is an indicator variable equal to one if a firm used weather derivatives after 1997, and zero otherwise. Results from fixed effects (firm) specifications are shown in Columns I, II, and IV and Columns VI-IX. Estimates from lagged dependent variables (M-B) specifications are shown in Columns III and V. All specifications include a post-1997 dummy variable, year dummies, and controls for lagged firm size and lagged OROA (results not shown). Columns II and IV include controls for lagged investment rates, and Columns III and IV include controls for each of the quantity risk quartiles (results not shown). Columns I-V report results for all sample firms with relevant data, and Columns VI-IX split the sample into two groups based on quantity risk quartiles. Results for Quartiles 3-4 (Quartiles 1-2) are shown in Columns VI and VIII (Columns VII and IX). Standard errors are clustered at the firm level and are shown in parentheses.

	Market to Book Ratio					*Ln Net Income*			
Variables	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)
Quantity risk quartile 4 * post	**0.1153** ***	**0.1305** ***	**0.0172** **						
	(0.032)	*(0.030)*	*(0.008)*						
*Quantity risk quartile 3 * post*	-0.0023	0.0145	0.0157 *						
	(0.028)	*(0.030)*	*(0.008)*						
*Quantity risk quartile 2 * post*	0.0163	0.0178	0.0080						
	(0.034)	*(0.032)*	*(0.011)*						
Weather-based quantity risk indicator				***0.0693*** ***	***0.0196*** ***				
**** Post***				*(0.024)*	*(0.007)*				
Lagged M-B ratio			0.8464 ***		0.8464 ***				
			(0.011)		*(0.010)*				
Weather shock						-0.0624 ***	0.0076	-0.0808 **	-0.0082
						(0.019)	*(0.023)*	*(0.036)*	*(0.038)*
Weather derivatives						-0.0178	-0.0017	0.0086	0.0122
						(0.079)	*(0.078)*	*(0.075)*	*(0.069)*
Weather derivatives * weather shock						***0.1481*** **	***0.0029***	***0.1329*** **	***-0.0547***
						(0.073)	*(0.084)*	*(0.067)*	*(0.118)*
Sample	All firms	All firms	All firms	All firms	All firms	Quantity Risk Quartiles 3-4	Quantity Risk Quartiles 1-2	Quantity Risk Quartiles 3-4	Quantity Risk Quartiles 1-2
Year controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Observations	5,226	5,226	5,226	5,226	5,226	3,779	3,837	3,779	3,837
R-squared	0.721	0.762	0.904	0.756	0.904	0.928	0.911	0.928	0.911

***, ** and * denote significance at the 1, 5 and 10 percent level, respectively.

TABLE VI. WEATHER DERIVATIVES AND FIRM VALUE

This table presents 2SLS-IV estimates on the impact of weather derivatives on firm value (Market to Book Ratios). Columns I and II report first-stage estimates of the effect of pre-1997 weather exposure measures and a post-1997 indicator variable on weather derivative use. Columns III-IX report 2SLS-IV estimates on the impact of weather derivatives on market-to-book ratios. *Weather Derivatives* is an indicator variable equal to one if a firm used weather derivatives in the post-1997 period, zero otherwise. Weather derivatives were introduced in 1997. The instrumental variables for weather derivatives are based on measures of pre-1997 weather exposure defined as (a) *Quantity risk quartiles* (Columns I, III, and V-IX): EDD weather-induced volatility quartiles, equal-sized groupings based on the product of the EDD weather beta and the standard deviation of EDD before 1997, and (b) *Weather based quantity risk indicator* (Columns II and IV): an indicator variable equal to one if the EDD weather beta in the pre-1997 period is statistically significant at the 5% level, zero otherwise. *Post* is an indicator variable equal to one in the post-1997 period, zero otherwise. *Deregulation electricity (natural gas)* is an indicator variable equal to one for the observations where the relevant state-year has experienced deregulation in electricity (natural gas) markets, zero otherwise. *Deregulation access to retail, industry, and all electricity consumers* are indicator variables equal to one for the observations where the relevant state-year has experienced deregulation to access retail, industry, and all electricity consumers, respectively, and zero otherwise. *Deregulation NG pilot, partial, and all consumers* are indicator variables equal to one for the observations where the relevant state-year has experienced natural gas deregulation for pilot, partial, and all consumers, respectively, and zero otherwise. *Interest rate (natural gas) derivatives* is an indicator variable equal to one if a firm used interest rate (natural gas) derivatives in the post-1997 period, zero otherwise. *Ln CDD* (*Ln HDD*) is the natural logarithm of annual cooling (heating) degree day values. *Single state utility* is an indicator variable equal to one for utilities that operated in a single U.S. state as of 1997. Results from fixed effects (firm) specifications are shown in Columns I-IV, VI, and VIII. Estimates from lagged dependent variables (M-B) specifications are shown in Columns V, VII, and IX. Specifications in Columns VI-IX include year dummies and controls for lagged firm size, lagged OROA, and lagged investment rates; those in Columns V, VII, and IX also control for lagged M-B ratios, and for each of the quantity risk quartiles (estimated coefficients are omitted). Standard errors are clustered at the firm level and are shown in parentheses.

	Weather Derivatives		*Market to Book Ratio*						
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)
Weather derivatives			**0.2442** ***	**0.2452** ***	**0.1177** ***	**0.3124** **	**0.0635** **	**0.2959** *	**0.0834** *
			(0.055)	*(0.055)*	*(0.024)*	*(0.154)*	*(0.030)*	*(0.172)*	*(0.044)*
Quantity risk quartile 4 * post	**0.2437** **								
	(0.110)								
*Quantity risk quartile 3 * post*	0.2387 *								
	(0.123)								
*Quantity risk quartile 2 * post*	0.1464								
	(0.123)								
Weather-based quantity risk indicator * post		**0.1989** **							
		(0.088)							
Post	0.1242 *	0.1441 **							
	(0.064)	*(0.065)*							
Deregulation electricity						-0.0459	0.0204	-0.0585 *	0.0176
						(0.033)	*(0.012)*	*(0.031)*	*(0.013)*
Dereg. Elect. Retail consumers						-0.0845 *	-0.0347	-0.0950 *	-0.0441 *
						(0.049)	*(0.024)*	*(0.051)*	*(0.026)*
Dereg. Elect. Industrial consumers						0.0561	0.0060	0.0646	0.0182
						(0.049)	*(0.018)*	*(0.054)*	*(0.019)*
Dereg. Elect. All consumers						0.0628 **	0.0356 *	0.0600 *	0.0294
						(0.032)	*(0.020)*	*(0.035)*	*(0.022)*
Deregulation natural gas						-0.0094	-0.0133	-0.0052	-0.0213
						(0.049)	*(0.022)*	*(0.050)*	*(0.024)*
Deregulation NG pilot program						-0.0246	-0.0051	-0.0211	0.0013
						(0.048)	*(0.022)*	*(0.045)*	*(0.023)*
Deregulation NG partial program						0.0687	0.0258	0.0727	0.0295
						(0.054)	*(0.021)*	*(0.053)*	*(0.024)*
Deregulation NG all consumers						-0.0074	-0.0181	-0.0120	-0.0188
						(0.068)	*(0.022)*	*(0.065)*	*(0.025)*
Ln CDD								0.0346 ***	0.0003
								(0.010)	*(0.001)*
Ln HDD								0.0084	-0.0008
								(0.023)	*(0.002)*
Interest rate derivatives								-0.0510	-0.0270
								(0.050)	*(0.017)*
Natural gas derivatives								0.0018	0.0021
								(0.037)	*(0.012)*
*Single state utility * post*								0.0266	0.0175
								(0.048)	*(0.013)*
Firm fixed effects	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
Year controls	No	No	No	No	No	Yes	Yes	Yes	Yes
Observations	5,226	5,226	5,226	5,226	5,226	5,226	5,226	5,226	5,226

***, ** and * denote significance at the 1, 5 and 10 percent level, respectively.

TABLE VII. WEATHER DERIVATIVES AND FIRM VALUE: SUB-SAMPLES

This table presents 2SLS-IV estimates on the impact of weather derivatives on firm value for sub-samples of firms based on geography, time, and firm characteristics. The dependent variable is the market-to-book (M-B) ratio. M-B ratios are defined as the value of total assets plus the market value of common equity (stock price times the number of common shares outstanding) minus book value of common equity and deferred taxes divided by total assets. *Weather Derivatives* is an indicator variable equal to one if a firm used weather derivatives in the post-1997 period, zero otherwise. Weather derivatives were introduced in 1997. The instrumental variables for weather derivatives are *Quantity risk quartiles*Post*. *Quantity risk quartiles* are based on EDD weather-induced volatility quartiles, equal-sized groupings based on the product of the EDD weather beta and the standard deviation of EDD before 1997. *Post* is an indicator variable equal to one in the post-1997 period, zero otherwise. Column I shows results for all sample firms except those whose primary business is located in the state of California. Column II presents results for all sample firms and years except for the 1997-2002 sample period. Column III shows results for the post-1994 sample period only. Columns IV and V show results for firms that are sorted as a function of whether they do (Column IV) or do not (Column V) have, respectively, a Weather Normalization Adjustment (WNA) in their rate structures. WNAs allow utilities to partially transfer weather risk to consumers by increasing (decreasing) energy bills in mild (extreme) weather seasons. Column VI presents results for those firms that before 1997 had below median levels of net debt ratios (the ratio of the book value of debt minus cash and marketable securities over total assets). Column VII shows results for those firms that before 1997 had above median levels of net debt ratios. Panel A presents results from lagged dependent variables (M-B) specifications that include the following controls: lagged M-B ratios, lagged firm size, lagged OROA, and lagged investment rates (estimated coefficients are omitted). Panel B presents results from fixed effects (firm) specifications. All specifications include year controls. Standard errors are clustered at the firm level and are shown in parentheses.

	Dependent Variable: Market to Book Ratio						
	Sub-Samples						
	Firms Outside California	Before 1997 & After 2002	Post-1994 Only	WNA=1	WNA=0	"Low" Pre-1997 Leverage	"High" Pre-1997 Leverage
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
Panel A. Lagged Dependent Variable Specifications							
Weather derivatives	***0.0617*** **	***0.0680*** **	***0.0774*** **	***0.0748*** *	***0.0184***	***0.0621*** *	***0.0374***
	(0.028)	*(0.035)*	*(0.033)*	*(0.041)*	*(0.042)*	*(0.032)*	*(0.040)*
Year controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,080	4,785	1,069	3,614	1,612	2,722	2,504
Panel B. Fixed Effects Specifications							
Weather derivatives	***0.2881*** ***	***0.2494*** ***	***0.2523*** ***	***0.4404*** **	***-0.0413***	***0.2356*** *	***0.1853***
	(0.103)	*(0.093)*	*(0.095)*	*(0.197)*	*(0.054)*	*(0.123)*	*(0.161)*
Year controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,080	4,785	1,069	3,614	1,612	2,722	2,504

***, ** and * denote significance at the 1, 5 and 10 percent level, respectively.

TABLE VIII. WEATHER DERIVATIVES: REVENUE, FINANCING, INVESTMENT, AND DIVIDEND EFFECTS

This table examines the effect of weather derivatives on (a) revenue (natural logarithm of revenue) (Column I), (b) financing (net debt/assets (Column II), book leverage/assets (Column III) and cash/assets (Column IV)), (c) investment (CAPEX/assets) (Column V), and (d) dividends (dividend/assets) (Column VI). Panel A presents estimates on the effect of EDD weather-induced volatility quartiles on each of the outcome variables in the post-1997 period. Panel B presents 2SLS-IV estimates on the effect of weather derivatives on revenue, financing, investment, and dividend policies. The instrumental variables for weather derivatives use in the post-1997 period are based on pre-1997 weather exposure or *Quantity risk quartiles*Post*. *Quantity risk quartiles* are based on EDD weather-induced volatility quartiles, equal-sized groupings based on the product of the EDD weather beta and the standard deviation of EDD before 1997. *Post* is an indicator variable equal to one in the post-1997 period, zero otherwise. The EDD weather beta measures the sensitivity of revenue to EDD variation. EDDs are defined as the sum of the annual heating and cooling degree day values, temperature indexes that seek to capture the energy demand for heating and cooling services. Quartile 1 is the omitted category. *Quantity risk quartiles*Post* captures the differential evolution of each outcome variable for each quartile of firms after 1997. Weather derivatives were introduced in 1997. Weather derivatives is an indicator variable equal to one if the firm used weather derivatives after 1997, zero otherwise. Each specification also includes year dummies as controls (estimated coefficients are omitted). Standard errors are clustered at the firm level and are shown in parentheses.

	Dependent Variables:					
	Ln Revenue	**Net Debt / Assets**	**Book leverage / Assets**	**Cash / Assets**	**CAPEX / Assets**	**Dividends / Assets**
	(I)	(II)	(III)	(IV)	(V)	(VI)
Panel A. Differences-in-Differences Specifications						
Quantity risk quartile 4 * post	**0.0091**	**0.0402 *****	**0.033 ****	**-0.0072 ****	**0.0113 *****	**0.0020**
	(0.093)	*(0.014)*	*(0.014)*	*(0.003)*	*(0.004)*	*(0.002)*
*Quantity risk quartile 3 * post*	0.0932	0.0014	-0.00004	-0.0015	0.0034	0.0018
	(0.086)	*(0.015)*	*(0.014)*	*(0.003)*	*(0.004)*	*(0.002)*
*Quantity risk quartile 2 * post*	0.0809	-0.0145	-0.0130	0.0015	0.0025	-0.0005
	(0.074)	*(0.014)*	*(0.014)*	*(0.003)*	*(0.004)*	*(0.002)*
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,343	6,343	6,343	6,343	6,343	6,343
Panel B. Instrumental Variables (IV) Specifications. Instruments: EDD Weather-Induced Volatility Quartiles*Post						
Weather derivatives	**0.4044**	**0.0712 ***	**0.0560**	**-0.0152 ***	**0.0461 *****	**-0.0056**
	(0.249)	*(0.040)*	*(0.038)*	*(0.009)*	*(0.014)*	*(0.006)*
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,343	6,343	6,343	6,343	6,343	6,343

***, ** and * denote significance at the 1, 5 and 10 percent level, respectively.