Corporate Hedging, Investment, and Higher Moments of Stock Returns*

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Abstract

We develop a dynamic production-based model with real options to examine the implications of changes in output, investment and financial policies on firms' future stock return distributions. We introduce novel, competing channels showing that cash-flow hedging and capital investment by firms endogenously impact not only future variance, but also future skewness and kurtosis. Empirically, using option prices and hand-collected data on firms' risk management policies, we find that hedging exhibits a *pull-to-normality* effect on firms' returns, reducing future variance, excess negative skewness and excess kurtosis, while this effect is offset with increasing levels of investments.

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1 Introduction

Do risk-management policies affect firms' risk? While the answer to this question may seem obvious, the seminal work of Modigliani and Miller (1958) demonstrates that hedging is irrelevant within a frictionless setting. Even with the inclusion of frictions in the economy, the impact of hedging on firms' performance can be modest at best (Ghoddusi, Titman and Tompaidis (2023)). Empirically, previous literature document no differential effect in firms' value from implementing hedging policies and no link between firms' risk-management policies and their future return volatility (see, for example, Hentschel and Kothari (2001) and Jin and Jorion (2006)). Taken together, these studies suggest that the relevance of hedging for firms' performance is not a settled debate and several questions remain open. Under what circumstances it is optimal for firms to hedge and what is the impact of hedging decisions on firms' risk beyond return volatility?

In this paper, we attempt to answer these questions from a combined theoretical and empirical perspective. We address this task with a dynamic framework relating firms' production, investment and risk management (hedging) policies with their future return distributions, beyond the second moment. We then contrast the predictions of our model with firms in the energy sector, for which reliable data on hedging is available, and study whether hedging can, in fact, reshape firms' future return distribution.

Modern finance theory indicates that the higher moments of stock returns will be substantially affected by firms' real (production and investment) and financial (leverage and hedging) policies. To fix ideas, consider a levered commodity producing firm that manages default risk by hedging through (commodity price) swap contracts, which effectively eliminate the firm's price risk exposure over some time interval. Risk management of this form clearly affects not just volatility but also the higher moments—in particular, skewness and kurtosis—of prices, cash flows and, hence, equity returns.

Extending this example further, suppose that the firm also has a real option (project) to reduce production costs based on capital investment in a new technology; and this investment is financed through additional debt. The literature documents the significant effects of price uncertainty on capital investment and risk management of commodity producing firms (Doshi, Kumar and Yerramili (2018); Gilje and Taillard (2017)). Conversely, however, capital investment should affect higher moments of future stock returns. Intuitively, in the example at hand, capital investment will increase—relative to the pre-investment phase—the firm's profits in high price states (where the reduced cost effect dominates), and reduce profits in low price states (where the higher debt repayment effect dominates). Consequently, the variance and kurtosis of returns should rise, other things being equal, while the effect on skewness may depend on whether the firm faced negative or positive skewness prior to investment.

But while there is an extensive existing literature that examines the relation of investment and hedging with (price, cash flows or return) uncertainty (or variance), the links between firms' real and financial policies with skewness and kurtosis are relatively unexplored.[1] Therefore, some fundamental questions remain open. In particular, with concavity of the value function, hedging is optimal in the sense of restricting uncertainty. But firms' preferences towards higher moments are generally ambiguous because it is well known that shareholder risk aversion does not restrict preferences over skewness or kurtosis (e.g., Brockett and Kahane (1992)). Hence, the effects of firms' hedging choices on higher moments require empirical resolution. In particular, the influence of firm characteristics, such as size and leverage, on the relation of firms' hedging and return moments requires attention. Turning to the role of real options and risk management, Doshi, Kumar and Yerramili (2018) document the negative effects of uncertainty on capital investment for small firms, but find that larger firms increase hedging to moderate its impact of greater uncertainty on capital investment. To our knowledge, the endogenous effects of capital investment and hedging on

[1] This literature includes Rolfo (1980), Stulz (1984), Froot et al. (1993), Graham and Smith (1999), Campello et al. (2011), Kumar and Rabinovitch (2013) and Kellogg (2014).

higher moments are not examined in the literature.

To develop empirical implications that relate firms' real and financial policies to higher moments of stock returns, we construct a dynamic production-based model of levered firms subject to default risk in the presence of financial covenants (Leland (1994); Toft and Prucyck (1997)). We derive the endogenous risk-neutral distribution of stock returns along the optimal production path. This distribution is generally asymmetric with excess negative skewness and excess positive kurtosis (relative to the normal distribution). That is, we show that asymmetric risk-neutral return distributions arise for firms in rather general product market settings and facing realistic default risk boundaries.

The presence of default risk endogenously generates a demand for managing cash flow risk by hedging commodity or product price risk. We characterize the optimal hedging policy to generate empirical predictions on the demand for hedging. Consistent with intuition, hedging demand is, ceteris paribus, positively related to leverage and the economic costs of bankruptcy, while it is negatively related to profits. We then show that hedging using fixed price contracts affects higher moments of future risk-neutral return distributions by reducing not only variance but also excess skewness and kurtosis. Hence, firms optimally hedge to avoid endogenous default risk (along the optimal production path) and thereby reduce higher moments of their future risk-neutral stock distribution and lower its deviation from a normally distributed variable. We label this novel set of theoretical results as the *pull-to-normality* effect of corporate hedging on firms' return distributions. Based on the predictions on the demand for hedging, the theoretical analysis generates the empirical hypotheses that the *pull-to-normality* effect will be stronger among firms with high leverage, small size and high rollover-risk, as well as low net sales and low market-to-book. The first three covariates proxy for bankruptcy risk and costs of distress, while the last two covariates reflect lower profitability.

We then consider the implications of real options on higher moments by extending our model to allow capital investment in a cost saving technology, financed with additional debt. We characterize the optimal exercise policy: The firm optimally invests when the product prices crosses a threshold level. Following investment, the spread in profits between high and low price states expands, increasing volatility and kurtosis, while the effect on skewness depends on the direction of the skew prior to investment. Therefore, capital investment has an opposing effect to *pull-to-normality*, by amplifying higher moments; firms can moderate this effect by hedging, however.

Our empirical tests are guided by the availability of hedging and equity options data. We therefore focus on firms in the oil and gas (O&G) sector, where product price hedging is prevalent among non-vertically integrated firms. We rely on entities from this sector, as information provided by these firms allows us to compute a direct, quantifiable measure of hedging intensity instead of implied hedging measures based on textual analytics techniques applied to firms in other industries. Hedging intensity is the firm-level percentage of hedged oil and gas production. In addition, firms in this sector have access to one of the most liquid derivatives markets in order to hedge output price risk. Our hand-collected hedging data, complemented by data on equity options and the underlying stock prices from OptionMetrics, covers the period 1996-2014. The main outcome variables are end-of-month higher moments computed using equity options data. We compute the option-implied variance, skewness and kurtosis using the methodology in Bakshi, Kapadia and Madan (2003). We utilize monthly predictive panel regressions where the dependent variable is the firm's distributional moment (estimated using option prices) and the main covariate is hedging intensity. We control for firm-level variables that can potentially impact return distributions, including latent time-trends.

We find strong support for the hypothesis that hedging has a *pull-to-normality* effect on firms' future stock return distribution. Raising hedging intensity significantly reduces future variance, negative excess skewness and excess kurtosis of firms' returns. These effects are both statistically and economically significant. A one-standard-deviation shock to hedging intensity reduces firm-level return variance by more than 3.2% of the mean variance in the following month, and this result is robust to the inclusion of lagged option implied volatility. Meanwhile, a change in the hedging intensity coefficient from the 25th to the 75th percentile generates a reduction in excess negative skewness next month of about 8.3% of average skewness. In a similar vein, a change in the hedging intensity coefficient from the 25th to the 75th percentile generates a reduction in excess kurtosis next month of about 2.5% of the mean kurtosis.

In line with our priors (based on intuition and results in the literature), firms' variance increases with higher levels of leverage and rollover risk, while it decreases with higher levels of profitability. We also find that leverage and market-to-book significantly impact on future skewness and carry the expected sign. However, their effect pales when compared to the impact of hedging. And the effects of leverage, roll-over risk, size and book-to-market on the kurtosis of firms' return distribution are also significant and of expected sign. In sum, our basic test specification is consistent with the received literature.

Having established the significant *pull-to-normality* effect of hedging, a natural question is: Who benefits most from a reduction in variance, excess negative skewness and excess kurtosis due to hedging? Based on our theoretical framework, we expect that hedging is a more effective tool for firms that face a relatively more challenging environment for their financial management. Thus, our hypothesis is that firms that exhibit the strongest effects of hedging on their higher moments will be smaller in size, carry larger levels of leverage, have higher rollover risk, and exhibit lower levels of market-to-book and profitability. To test this hypothesis, we estimate predictive regressions by splitting the sample into firms with below- and above-median levels of these characteristics.

We find that the reduction in return variance from hedging is significant for small firms, but not for large firms. Furthermore, while hedging significantly lowers excess negative skewness and excess kurtosis for small firms, it (hedging) has opposing effects on these higher moments of large firms' return distributions. These results have general implications for risk management by small firms. The literature finds that small size firms lower capital expenditures and debt issuance instead of increasing hedging to mitigate uncertainty. Our findings suggest that hedging could be a more effective tool at reducing firms' return variance, excess negative skewness and excess kurtosis. Hedging has significant negative effects on return variance for both high and low levered firms, but only highly levered firms benefit from the reduction in excess negative skewness and excess kurtosis due to hedging. Furthermore, hedging has significant reduction effects on return variance, excess negative skewness and excess kurtosis only for high (but not low) rollover risk firms as well as high (but not low) book-to-market firms. Hedging also significantly reduces return variance of low (but not high) profitability firms.

We also find that firms' volatility, skewness and kurtosis are significantly and positively affected by capital investment. While the effects on volatility and kurtosis are unambiguously predicted by our model, the positive relation of skewness and investment provides empirical resolution. To our knowledge, this paper is the first to document the impact of investment on higher moments of firms' stock distribution. In addition, and consistent with the predicted effects of commodity price hedging, we find that hedging ameliorates or weakens the effect of capital investment on firms' higher moments.

We organize the paper as follows. Section 2 discusses the literature related to our paper. Section 3 develops the dynamic model and derives the empirical hypotheses. Section 4 describes the data and the empirical test design. Section 5 discusses the empirical results and Section 6 concludes.

2 Related Literature

Our study contributes to both corporate finance and asset pricing literatures. Several important studies document the implications of corporate hedging on firms' value (e.g., see Almeida, Hankins and Williams (2017), Brown and Toft (2002), Corgnaggia (2013), Kumar and Rabinovitch (2013), MacKay and Moeller (2007) and Purnanandam (2008)). Second, a prominent line of work finds significant predictability of higher moments of firms' returns on the firms' future stock performance (e.g., see Ang, Hodrick, Xing, and Zhang (2006), Bali, Cakici and Whitelaw (2011), Bali, Hu and Murray (2019), Conrad, Dittmar and Ghysels (2013), Kim and White (2004) and Xing, Zhang and Zhao (2010)). We introduce a novel channel connecting both fields of research.

The literature on the links between firms' investment and future return distributions is rather succinct. Schneider and Spalt (2015) empirically find a positive relationship between investment and skewness in conglomerates, with segment-level investment in conglomerates increasing with the expected skewness of the segment. Our paper support this finding. In our theoretical framework, investment endogenously impact on future return distributions, and our regression analysis documents a positive link between investments and future variance, skewness and kurtosis.

Our paper has important implications for the literature on corporate risk management. We provide economic foundations for the impact of firms' hedging policies on their access to and use of external financing. For example, Campello, Lin, Ma and Zou (2011) document that firms that hedge have access to lower borrowing costs, while Doshi, Kumar and Yerramili (2018) find that investment of firms with hedging policies in place is less sensitive to output price uncertainty.[2] Our dynamic model introduces the channel through which

[2]Studies using hedging intensity from energy related firms (for different purposes than ours) include Bakke, Mahmudi, Fernando and Salas (2016), Chen, Lu, and Vij (2021), Gilje (2016), Gilje and Taillard (2017) and Jin and Jorion (2006).

these effects manifest in the data. Specifically, we show that hedging reduces firms' future risks (i.e., variance, skewness and kurtosis) and we empirically confirm these results using forward looking option implied moments. Additionally, while recent studies document conflicting arguments as to whether firms in worse financial conditions hedge less (Rampini and Viswanathan (2013)) or more (Bolton, Chen and Wang (2011)), we demonstrate that financially constrained firms are the ones benefiting the most (by reducing returns variance, excess negative skewness and excess kurtosis) from hedging. Lin and Paravisini (2011) document that firms' distribution of cash-flows becomes more volatile and skewed as they experience financial constraints. We find that the *pull-to-normality* effect of hedging on firms' returns is stronger among these type of firms.

To our knowledge, this is the first paper to theoretically and empirically link firms' hedging to the higher moments of their stock returns distributions. While there is a vast body of work on the motivations for and implications of hedging and risk management, the effects of hedging on higher moments of stock return distributions that we theoretically motivate and empirically document are novel to this literature. Protection against default risk and avoidance of bankruptcy costs are emphasized in the literature to be major motivations for hedging (Bessembinder (1991); Froot, Scharfstein and Stein (1993)). However, the impact on future return distributions of changes in risk-management and investment policies (the competing channels in our framework) are not highlighted in the existing literature. In addition, we show that firm-level investment has a counter effect to that of hedging, mitigating the initial effect of stricter risk-management policies.

We also add to an incipient literature that explores micro-level foundations of higher moments. For instance, Morellec and Zhadnov (2019) relate product market competition to the generation of the well known negative volatility skew in option prices. However, as we mentioned at the outset, the analysis of firm-level determinants of higher moments is still quite unexplored.

3 The Model

This section introduces the dynamic production-based model for a representative firm, links corporate hedging policies to the risk-neutral distribution of the firm's stock returns and then expands the framework as firms have a real option to invest.

3.1 Firms and Profits

We consider a competitive industry in a partial equilibrium setting. The typical firm has non-depreciable capital stock K that allows it choose output $\{Y_t : 0 \leq t < \infty\}$ with the variable cost function $\Phi(Y_t) = \frac{\phi Y_t^2}{2}, \phi > 0$.[3] The industry price $\{P_t : 0 \leq t < \infty\}$ follows a geometric Brownian motion with constant drift and volatility, that is,

$$dP_t = \mu P_t dt + \sigma P_t dW_t, \tag{1}$$

where W_t is a standard Brownian motion. With the competitive industry market structure, the firm is a price-taker and and hence its operational profits, as a function of output, are given pointwise by

$$\pi_t = P_t Y_t - \frac{\phi Y_t^2}{2}. \tag{2}$$

The optimal production policy of the firm will be derived below following the specification of the firm's objective function. Note that operational profits will be strictly decreasing with the cost parameter ϕ. Hence, variations in ϕ will be a convenient way to model cross-sectional differences across firms in terms of profit opportunities.

The firm faces a constant marginal corporate tax rate τ. We will refer to the expected present value of after tax operational profits, that is, the asset—or the unlevered—value of

[3] The results are qualitatively unchanged as long as $C(Y_t)$ is strictly increasing, strictly convex and twice continuously differentiable.

the firm as V^u.

3.2 Financial Structure and Equity Cash Flows

The firm is widely-held and levered. Security markets are frictionless, and there exists a traded riskless asset that pays a continuous interest rate r. Similar to Leland (1994) and Toft and Prucyck (1997), it is convenient to derive the basic results under the assumption that the firm has non-callable consol debt with face value F that promises continuous coupon payments of C to perpetuity, unless there is bankruptcy. In that event, and consistent with absolute priority rule (APR), the firm's production processes and capital stock are transferred to the bondholders as an unlevered firm with equity claims based on existing bond ownership.[4] The asset value at bankruptcy will be denoted by V_B^u. But because of bankruptcy costs, debt holders receive only $(1-\gamma)V_B^u$. The bankruptcy "trigger" is given by a financial covenant that forces the firm to declare bankruptcy when the recoverable asset value (i.e., $(1-\gamma)V_B^u$)) falls below the present value of promised coupon payments, that is, C/r.[5]

Coupon payments are tax deductible. Therefore, the net equity cash flows or dividends in solvent states are given by

$$\eta_t dt \equiv (1-\tau)(\pi_t - C)dt. \tag{3}$$

Positive dividends are paid out to equity holders pointwise, while negative dividend values imply equity issuance to finance the coupon payments.

[4] This is consistent with APR. There is a literature that examines deviations from APR (see, e.g., Allanis, Chava and Kumar (2018) and the references cited therein). However, these considerations are extraneous to the objectives of our study.

[5] This bankruptcy trigger is also considered in Toft and Prucyck (1997).

3.3 Equity Value

We now derive the firm's equity value, denoted V. It is apparent from (2) that as long as it is solvent at t, the firm's operational profits and, hence, its dividends depend on P_t. Because $\{P_t : 0 \leq t < \infty\}$ is a Markov process, in the standard fashion it represents the state variable for the firm's optimization problem. Namely, at each instant, conditional on P, equity holders optimally decide the optimal production level Y if the firm is solvent.

Using Ito's Lemma along the solvency path, the pointwise Bellman representation of optimal production is given by

$$rV\,dt = \max_{Y} \left[\eta dt + \left(V_P \mu P + \frac{1}{2} V_{PP} \sigma^2 P^2 \right) dt \right]. \tag{4}$$

In addition, there are two boundary conditions imposed by the financial covenant that triggers bankruptcy, namely,

$$V(P_B) = 0, \tag{5}$$

$$V_B^u \equiv V^u(P_B) = \frac{C}{r(1-\gamma)}. \tag{6}$$

where P_B is the default threshold for the price process. The first boundary condition sets the equity value to zero at the default boundary while the second sets the underlying asset value at default, as required by the financial covenant.

Using (2) and (4), it is straightforward to derive the firm's optimal production policy and the attendant indirect (or maximized) operating profits as $Y^* = \frac{P}{\phi}$ and $\pi^* = \frac{P^2}{2\phi}$, respectively. Hence, along the optimal production path the firm's equity value is given by the second order differential equation (SDE)

$$(1-\tau)\left[\frac{P^2}{2\phi} - C \right] - rV + V_P \mu P + \frac{1}{2} V_{PP} \sigma^2 P^2 = 0. \tag{7}$$

Solving the SDE in (7) with the boundary conditions (5)-(6) yields

$$V(P) = \frac{(1-\tau)P^2}{2\phi(r-\alpha)} + \frac{\tau C}{r} - \frac{C}{r} + HP^{-x}, \tag{8}$$

$\alpha \equiv 2\mu + \sigma^2$ and $(r-\alpha) > 0$. Moreover, $x > 0$ is the positive root of the quadratic equation

$$r = -x\mu + 0.5x(x+1)\sigma^2. \tag{9}$$

The positive root exists since $r > \mu$. Furthermore,

$$H = -\frac{C}{r(1-\gamma)}[1-(1-\gamma)(1-\tau)] < 0. \tag{10}$$

In (8), conditional on the state P, the first term represents the indirect (or optimized) asset value of the firm, that is, the present value of after-tax operational profits V^u. The second term is the present value of the tax shield from debt and the third term is the present value of the fixed coupon costs. The last term is the value of the default option, say, V^D where equity holders exchange ownership of the firm with bondholders (at $V^u = V^u_B$) in return for release from the the debt obligation (Toft and Prucyck (1997)). Because $H < 0$, equity holders are shorting (or selling) this option with the payment of $(V^u_B - \frac{(1-\tau)C}{r})$.

We can also deduce the conditional equity beta of the firm, that is $\beta = \frac{d\ln V(P;C)}{d\ln P}$ from Equation (8), that is,

$$\beta_t = 1 + \frac{V^u_t}{V_t} + \frac{(1-\tau)C}{rV_t} + \frac{V^D_t}{V_t}(x-1)$$

The first two terms represent the after-tax profit beta. In our case, the profit beta exceeds 1 and is, hence, greater than the usual revenue beta because with endogenous output, operating profits are no longer linear in the state, as is usually assumed in literature (e.g., Carlson, Fisher and Giamarrino (2004), Gomes and Schmid (2010)).

3.4 Risk Neutral Returns and Higher Moments

Applying Ito's Lemma to (8) yields the stochastic process for equity value as the diffusion

$$dV = \theta(P)dt + \xi(P)dWt, \tag{11}$$

where[6]

$$\theta(P) \equiv \left(\frac{(1-\tau)P}{\phi(r-\alpha)} - xHP^{-(x+1)}\right)\mu P + 0.5\left(\frac{(1-\tau)}{\phi(r-\alpha)} + x(x+1)HP^{-(x+2)}\right)\sigma^2 P^2, \tag{12}$$

$$\xi(P) \equiv \left(\frac{(1-\tau)P}{\phi(r-\alpha)} - xHP^{-(x+1)}\right)\sigma P. \tag{13}$$

Dividing through (11) by V then yields the equity return process $dR = \frac{dV}{V}$.

To derive the equity return process under risk-neutral measure, we assume (in the standard fashion) existence of a risky asset $\{Z_t : 0 \leq t < \infty\}$ that has the same transitions as the product price process, except possibly different drift rates, that is,

$$dZ_t = \upsilon Z_t dt + \sigma Z_t dW_t. \tag{14}$$

The traded riskless and risky assets allow a replicating portfolio such that the measure $\tilde{W}_t = W_t + \frac{\upsilon - r}{\sigma}t$ is a standard Brownian motion. Defining $q \equiv \upsilon - \mu > 0$, under this risk-neutral measure, the product price process follows

$$dP_t = (r-q)P_t dt + \sigma P_t d\tilde{W}_t. \tag{15}$$

[6] We recall that $x > 0$ and $H < 0$, and hence $\xi > 0$.

Under the risk-neutral measure, equity value is

$$\tilde{V}(P_t) = \frac{(1-\tau)P^2}{2\phi q} + \frac{\tau C}{r} - \frac{C}{r} + HP^{-x}. \tag{16}$$

Using (11) and setting

$$\tilde{\theta}(P) \equiv \left(\frac{(1-\tau)P}{\phi(r-\alpha)} - xHP^{-(x+1)}\right)(r-q)P + 0.5\left(\frac{(1-\tau)}{\phi(r-\alpha)} + x(x+1)HP^{-(x+2)}\right)\sigma^2 P^2, \tag{17}$$

we can then write the risk-neutral return process as

$$d\tilde{R}_t = \left(\frac{1}{\tilde{V}(P_t)}\right)[\tilde{\theta}(P_t)dt + \xi(P_t)d\tilde{W}t]. \tag{18}$$

Of course, empirically we can measure risk-neutral returns and their moments over some fixed intervals. Furthermore, we will derive the higher moments—that is, volatility, skew and kurtosis—of risk-neutral returns from traded calls and put options of firms. We, therefore, compute these higher moments in the form that can be recovered from option prices. It is notationally convenient to set the drift and instantaneous volatility of the risk-neutral returns as $g_t \equiv \frac{\tilde{\theta}(P_t)}{\tilde{V}(P_t)}$ and $\omega_t \equiv \frac{\xi(P_t)}{\tilde{V}(P_t)}$, and define

$$M_{t,t+\Delta} \equiv \mathbb{E}_t[\tilde{R}_{t+\Delta}] = \tilde{R}_t \exp\left(\int_t^{t+\Delta} g_s ds\right), \tag{19}$$

$$S_{t,t+\Delta} \equiv \mathbb{E}_t[\tilde{R}^2_{t+\Delta}] = \tilde{R}^2_t \exp\left(\int_t^{t+\Delta} \left[2g_s + \omega_s^2\right] ds\right), \tag{20}$$

$$U_{t,t+\Delta} \equiv \mathbb{E}_t[\tilde{R}^3_{t+\Delta}] = \tilde{R}^3_t \exp\left(\int_t^{t+\Delta} 3\left[g_s + \omega_s^2\right] ds\right), \tag{21}$$

$$Q_{t,t+\Delta} \equiv \mathbb{E}_t[\tilde{R}^4_{t+\Delta}] = \tilde{R}^4_t \exp\left(\int_t^{t+\Delta} \left[6g_s + 4\omega_s^2\right] ds\right). \tag{22}$$

We then compute the recoverable higher moments of risk-neutral returns scaled by appropriate powers of return variance (e.g., Bakshi, Kapadia and Madan (2003)).

Proposition 1 *Conditional on P_t, the scaled conditional higher moments of risk-neutral equity returns over $(t, t+\Delta)$, $\tilde{R}_{t,t+\Delta}$, are:*

$$VARIANCE_{t,t+\Delta} = S_{t,t+\Delta} - M_{t,t+\Delta}^2, \tag{23}$$

$$SKEW(t, t+\Delta) = \frac{U_{t,t+\Delta} - 3M_{t,t+\Delta}S_{t,t+\Delta} + 2M_{t,t+\Delta}^3}{(VARIANCE_{t,t+\Delta})^{3/2}}, \tag{24}$$

$$KURT(t, t+\Delta) = \frac{Q_{t,t+\Delta} - 4M_{t,t+\Delta}U_{t,t+\Delta} + 6M_{t,t+\Delta}^2 S_{t,t+\Delta} - 3M_{t,t+\Delta}^4}{(VARIANCE_{t,t+\Delta})^2}. \tag{25}$$

These derivations follow from a straightforward application of the moment generating function for the Brownian motion. Because the focus of our study is risk management of the commodity price risk, the following comparative statics of the higher moments of (risk-neutral) equity returns with respect to the commodity risk parameter σ will be useful in further analysis.[7]

3.5 Hedging

Recall, from Jensen's inequality, that risk management or hedging would improve equity value $\tilde{V}$ if it is strictly concave in P. From Equation (8), we get

$$\tilde{V}_{PP}(P_t) = \frac{(1-\tau)}{\phi q} + x(x+1)HP_t^{-(x+2)}. \tag{26}$$

Using (10) and the fact that $x > 0$, $\tilde{V}_{PP}(P_t) < 0$ if (using the value of H from (10))

$$\frac{(1-\tau)}{\phi q} < x(x+1)\frac{C}{r(1-\gamma)}[1 - (1-\gamma)(1-\tau)]P_t^{-(x+2)}. \tag{27}$$

It follows from (27) that

[7] In our empirical analysis we use (option-implied) variance as one of the dependent variables. We obtain similar results if we use standard deviation instead of variance.

Proposition 2 *There exists a threshold price level*

$$\bar{P} \equiv \left[\frac{\phi q x(x+1)}{(1-\tau)} \frac{C}{r(1-\gamma)} [1-(1-\gamma)(1-\tau)] \right]^{\frac{1}{x+2}},$$

such that hedging for solvent firms is optimal if $P_t < \bar{P}$. Furthermore, $\bar{P}$ is increasing with the firm's total debt repayment C, production cost ϕ, and bankruptcy costs (as measured by γ).

The first part of Proposition implies that firms are more likely to hedge when their revenues are low. The firm's total coupon payment C is a proxy for the firm's leverage or debt level, since for a given coupon rate, C is increasing with debt principal F. Hence, firms are also more likely to hedge if there leverage is higher, other things being equal. Moreover, firms are ceteris paribus more likely to hedge is their costs are higher or profits lower. Finally, firms are also more likely to hedge if their economic costs of bankruptcy are higher, other things being equal.

3.6 Model Implications: A Simulation Exercise

Because hedging is optimal for an open interval of product prices, we can develop empirical hypotheses regarding the effects of hedging on the higher moments of risk-neutral equity returns specified in Proposition 1. To see the effects of hedging, suppose that hedging firms at t use swap contracts to fix the output price in the interval $(t, t+\Delta)$. Hence, $\omega_s = 0$, $s \in (t, t+\Delta)$. It therefore follows from Proposition 1, that variance of returns falls to zero. From continuity, it can be shown that if hedging reduces ω_s to some neighborhood of zero, the variance and kurtosis of returns will fall, while negative skewness will rise.

To show the role of hedging on higher moments of equity returns, we next implement a simulation exercise using our dynamic framework. Our objective is to study the variation in the return distribution as the firm's changes its hedging policy rules. We simulate the industry output price for one-month horizon under the risk-neutral measure using equation (15). We follow Leland (1998) and set $r = 2\%, q = 1\%, \sigma = 20\%, \phi = 0.2, \tau = 0.2, \gamma = 0.1$ and $C = 0.1$.[8] Using the simulated distribution of the industry output price, we generate the distribution of equity value using equation (16).

We assume that a firm can implement different risk management policies or hedging rules, deciding when to hedge based on changes in the current product price. Specifically, the representative firm hedges output price anywhere from one standard deviation to four standard deviations below the current price using derivatives. Assuming the hedge is performed using a put option, the strike price for the put option ranges from one to four standard deviations below the current price. In the event of an output price drop below the strike price, the derivative contract covers the losses. Thus, the output price distribution is constrained below by the put strike price. We generate the equity value distribution using the constrained output price distribution and use it to compute equity return moments: standard deviation, skewness, and kurtosis.[9]

We compare the equity return distribution with and without the hedging policies. In Figure 1, we show the variation in the equity return moments as a function of the firm hedging. The black dashed line shows the equity return moments without hedging in place. The green solid line shows the equity return moments for various levels of hedging policy rules. The horizontal axis ranges from -4 standard deviations (less strict hedging rule) to -1 standard deviation (more strict hedging rule), representing the output price hedge from 4 to 1 standard deviation below the current price.

[Insert Figure 1 Here]

[8] See also Leland (1994) and Toft and Prucyck (1997).

[9] Note that in the simulations, a firm hedges the price level. In our empirical analysis below, we measure hedging activity as the proportion of output hedged. Since the dynamic model does not carry a production quantity, the two representations are isomorphic in that both capture the overall hedging intensity of the firm.

In Panel A, we observe that the firm equity's standard deviation (its volatility of returns) is significantly reduced as the firm implements stricter hedging policies. A firm that implements no hedging policies (the dashed black line) exhibits volatility in its returns of around 16.8%. A firm with a risk management rule that triggers hedging activity if the product price is one-standard deviation below its mean generates a reduction in its return volatility of more than two percentage points (from 16.8% to 14.6%). In addition, as the firm's risk management rule becomes more lax, the benefits of hedging in reducing the firm's return volatility decrease.

In Panels B and C of Figure 1 we obtain similar conclusions about the impact of hedging on the higher moment of returns. A firm that implements hedging rules reduces its negative skewness and reduces its kurtosis, and these effects are amplified with stricter hedging rules. These results indicate that corporate hedging has material impact on the higher moments of equity returns.

From Proposition 2, it also follows that the relationship between hedging and higher return moments described in the previous paragraph is likely to be more significant for firms with high leverage and rollover risk ratios as well as low profitability or operating margins and, hence, have low market-to-book ratios.

3.7 Capital Investment, Hedging and Higher Moments

Our dynamic model also has implications for firms' capital investment, which is a central driver of their cash flows. Suppose that the firm has a real option to invest in a cost-saving technology. Specifically, the firm can exercise the option at any time by undertaking capital investment of K, and realizing cost savings of $\delta\phi$, $\delta \in (0, 1)$, thereafter. Thus, if the exercise time is T, then got $t > T$ the firm's instantaneous profits are:

$$\pi_t = P_t Y_t - \frac{\phi(1-\delta)Y_t^2}{2}. \tag{28}$$

Investment is financed through an increase in (perpetual) debt that raises the instantaneous coupon payment by k. Hence, following exercise of the real option, the firm's equity value is given by (see (8)):

$$\hat{V}(P) = \frac{(1-\tau)P^2}{2\phi(1-\delta)(r-\alpha)} + \frac{\tau(C+k)}{r} - \frac{(C+k)}{r} + \hat{H}P^{-x}, \tag{29}$$

$$\hat{H} = -\frac{(C+k)}{r(1-\gamma)}[1-(1-\gamma)(1-\tau)], \tag{30}$$

and x still satisfies (9). Using (11)-(17), the coefficients of the firm's risk neutral distribution in (18) are then straightforwardly adapted to post-investment time periods.

Using (8) and (29), it is straightforward to show that $\hat{V}(P) - V(P)$ is increasing in P. Hence, there exists a critical price $\hat{P}$ such that $\hat{V}(P) > V(P)$ for all $P \geq \hat{P}$. The optimal exercise time is thus the first passage time $T = \inf\{t > 0 : P_t \geq \hat{P}\}$. Relative to the pre-investment phase, the firm's cash flows are therefore increased in high price states and reduced in low price states after exercising the real option. The empirical implication is that capital investment raises variance and kurtosis of future stock return distribution, other things being equal. The implications for skew are more ambiguous because it depends on whether the firm was facing negative or positive return slew prior to capital investment.

We now empirically test the hypotheses developed in this section. We first describe the data and methodology in Section 4 and then present the results in Section 5.

4 Data and Methodology

Our empirical analysis uses accounting and financial data from U.S. firms in the energy sector (SIC 1311). The reason to focus on these firms is that it allows us to explicitly compute hedging levels for individual entities. Several studies use textual analysis measures to determine implied degrees of hedging by corporations (e.g. see Hoberg and Moon (2017) and Campello, Lin, Ma and Zou (2011)). For our purposes, we require a direct, quantifiable level of hedging to then determine its impact on the distribution of individual stock returns.

We begin with all U.S. listed firms and use information on four different industry classifications from Compustat. The four industry classifications are: North American Industry Classification System (NAICS), Standard Industry Classification (SIC), S&P industry sector code (SPCINDCD), and the Global Industry Classification System Code (GSECTOR). A firm is classified as oil & gas and included in our sample if all four industry classifications suggest that the firm belongs to the upstream oil and gas sector.[10] Using 10Q filings from SEC, we collect information on total production volume and hedging activities of each firm in our sample. We compute a firm's hedging intensity (*HED*) as the proportion of total oil production that is hedged. We require at least 8 quarters of Compustat data of equity options data and hedging activity data for a firm to be included in our sample. This leads to 63 firms in our sample from January 1996 to January 2014. Our final sample is based on the availability of hedging data and liquidity in the cross-section of equity options data.

Our main variables of interest are end-of-month higher moments computed using equity options data. We obtain data on equity options and the underlying stock prices from OptionMetrics. We follow the procedure discussed in Goyal and Saretto (2009) in order to discard observations due to liquidity or arbitrage issues. We compute a firm's option-implied variance, skewness and kurtosis using the method proposed by Bakshi and Madan (2000)

[10]For a firm to be classified as belonging to oil and gas sector, its NAICS code must equal 211111, its SIC code must equal 1311, its SPCINNDCD must equal 380, and its GSECTOR must equal 10.

and Bakshi, Kapadia and Madan (2003). We provide additional information about the computations in Appendix B. We focus on short-term options to avoid liquidity constraints contaminating our empirical analysis (see for example Ilhan, Sautner and Vilkov (2021) and Muravyev and Pearson (2020)). Therefore, we estimate model-free higher moments for all traded maturities and interpolate these moments to generate a 30-day constant maturity time-series for each of the higher moments.

The estimation of model-free variance, skewness, and kurtosis require information on a large cross-section of option prices. Specifically, we require option prices for out-of-the-money puts with moneyness (defined as the ratio of strike price to the underlying stock price) ranging from 0 to 1 and out-of-the-money calls with moneyness ranging from 1 to infinity. In practice, we do not have options traded for such a wide range of moneyness. To obtain option prices for non-traded moneyness, we interpolate implied volatilities across moneyness. For moneyness levels above or below the available moneyness in the market, we use the implied volatility of the highest or lowest available moneyness. We perform intrapolation and extrapolation of implied volatilities for maturities for which we have at least two out-of-the-money put and two out-of-the-money call options traded.

In addition to hedging intensity, we include a set a control variables that can potentially influence firms' future return distributions. The selection of these variables is based on the dynamics of the model in Section 2 and follows the existing literature (e.g., see Denis and Mayhew (2002) and Morellec and Zhdanov (2019)). We obtain firm-level quarterly accounting data from Compustat and monthly securities price data from CRSP.

We next define the firm-level quarterly control variables used in the empirical tests. Size is the logarithm of the market capitalization (log(prccq $\times$ cshoq)). Leverage is the ratio of total debt to total capitalization ((dlttq + dlcq) / (dlttq + dlcq + cshoq $\times$ prccq)). Market-to-Book is the ratio of the market value to book value of equity (prccq $\times$ cshoq) / ceqq). Rollover Risk is the ratio of debt in current liabilities to total debt (dlcq /(dlttq+dlcq)).

Profitability is the ratio of revenues minus cost of goods sold to total assets ((revtq - cogsq) / atq). Investment is capital expenditures over total assets (capxq) / (atq). Return is the six-month cumulative firm return from CRSP. Implied Volatility is the at-the-money option implied volatility for contracts with 30 days to maturity and obtained from OptionMetrics. Table 1 defines all variables used in this paper.

[Insert Table 1 Here]

In Table 2, we report the summary statistics for all the variables using energy-related firms (SIC 1311). All variables are computed at the firm-level and the sample period is from January 1996 to January 2014.

[Insert Table 2 Here]

For our main variables of interest (variance, skewness and kurtosis), main explanatory variable (*HED*) and control variables we report their mean, median, standard deviation and percentiles 25 and 75. The top panel reports the summary statistics for the risk-neutral distributional moments. The average of firms' variance is 0.0192, which represents an annualized volatility of 48% ($\sqrt{0.0192 \times 12}$). The skewness of firms' returns is negative, with a mean of -0.4, median of -0.39 and percentiles between of -0.52 and -0.27. Note that a more negative skewness (e.g., a change from -0.4 to -0.5) indicates that the mass under the risk-neutral density shifts from the right tail of the distribution to the left tail of the distribution. The observed negative skewness is in line with the literature and implies that investors expect few large negative returns but frequent small positive returns. Black (1976) relates the negative skewness observed in stock returns to firm's changes in leverage. We also find that firms exhibit excess kurtosis. Average (median) kurtosis equals to 3.89 (3.72), close to unit a above a normally distributed random variable. Overall, the summary statistics for risk-neutral moments are consistent with the asset pricing literature using option implied moments (see for example, Bali and Murray (2013), Bali, Hu and Murray (2019), Conrad, Dittmar, and Ghysels (2013) and Denis and Mayhew (2002)).

The bottom panel reports the statistics for the percentage of hedged oil production (*HED*) along with the control variables. The summary statistics for *HED* indicate that the average (median) firm hedges about 33% (29%) of its oil production. There is substantial cross-sectional variation in hedging activity across firm-quarters, as indicated by the 25th and 75th percentile values of 4% and 54%, respectively; that is, more than one-fourth of the firm-quarter observations in our sample involve almost no hedging, whereas at the other extreme, one-fourth of the firm-quarter observations feature firms that hedge more than half their oil production. The summary statistics for the accounting measures using energy-related firms are broadly in line with existing studies (see for instance, Doshi, Kumar and Yerramili (2018), Gilje (2016) and Gilje and Taillard (2017)), with differences attributed to the final set of firms (restricted by availability of options prices) and the sample period.

5 Empirical Results

In this section, we empirically test the predictions of the model derived in Section 2. First, we investigate the effects of hedging on firms' returns distributions (i.e., variance, skewness and kurtosis) after controlling for a battery of firms characteristics. Second, based on firms' different profiles, we study when is hedging more effective at taming these distributional risks. Third, we interact firms' hedging and investment policies to study the overall impact on higher moments.

5.1 Hedging and Higher Moments of Stock Returns

The main hypothesis of the model derived in Section 2 is that hedging has a significant impact on firms' future return distributions, a result we summarize as the *pull-to-normality* effect. Specifically, our conjecture is that firm-level hedging reduces variance, reduces excess negative skewness and reduces excess kurtosis.[11]

In this section, we empirically test this hypothesis. We construct the explanatory variables (*HED* and accounting ratios) at a quarterly frequency, but given that our dependent variables are estimated at a monthly frequency, we estimate the regressions using monthly observations. Our results are largely unchanged using annual observations. We therefore estimate monthly predictive regressions where the dependent variable is the firm's distributional moment, estimated using option prices

$$Y_{k,i,t+1} = \lambda_1 + \lambda_2 HED_{i,t} + \lambda_3 X_{i,t} + \upsilon_t + \varepsilon_{i,t+1} \tag{31}$$

The dependent variable $Y_{k,i,t+1}$ is the risk-neutral moment k (with k=variance, skewness, kurtosis) of firm i in month t. The main explanatory variable is $HED_{i,t}$, the firm-level percentage of hedged oil obtained from the firms' 10Q filings and defined as the ratio of the number of hedged oil barrels to the number of oil barrels produced. We control for firm-level variables $X_{i,t}$ that can potentially impact on firms returns distributions. Control variables include monthly at-the-money option implied volatility and six-month cumulative return, and quarterly leverage, rollover risk, size, market-to-book and profitability ratio. All variables are described in Table 1. We include time fixed effects υ_t to account for economy-wide shocks to returns distributions. Finally, since all variables are defined at the firm-level, we cluster standard errors by firm to control for potential serial correlation in the residuals $\varepsilon_{i,t+1}$. Our interest is in the significance of λ_2, and we conjecture it is negative for the case

[11] The excess is with respect to a (Laplace-Gauss) normally distributed random variable.

of variance and kurtosis but positive for the case of skewness.

Table 3 reports the main empirical results of the paper. We report the panel regression coefficients along with their the t-statistics in parentheses, computed with firm-clustered standard errors. All explanatory variables are one-period lagged.

[Insert Table 3 Here]

In column 1 of Table 3, we report the panel regression using firms' risk-neutral variance as the dependent variable. Consistent with the model of Section 2, hedging reduces the future variance of firms' returns. The *HED* coefficient is negative and statistically significant (-0.002 and t=-2.63).

The economic significance of the *HED* coefficient is important: using the summary statistics of Table 2, a one-standard-deviation shock to *HED* reduces firms' variance by 6 basis points in the following month (-0.002×0.297). Note this result is robust to the inclusion of lagged option implied volatility. In line with our priors, firms variance is increases with higher levels leverage, consistent with the positive link found in Christie (1982). Variance also increases with rollover risk (He and Xiong (2012)), while it decreases with higher levels of profitability.

Column 2 of Table 3 reports the regression results using risk-neutral skewness as the dependent variable. Hedging loads with positive sign and significantly reduces the negative skewness of firms' returns (0.065 and t=2.98). Stated differently, higher levels of hedging turns firms' return distributions less negatively skewed.

A change in the *HED* coefficient from the 25th to the 75th percentile generates a reduction in excess negative skewness of 0.032 in the following month ((0.537-0.043)×0.065). This is about 8.3% of average skewness. We also find that leverage and market-to-book significantly impact on future skewness and carry the expected sign. However, their effect pales compared to *HED*, as a one-standard deviation shock in each predictor amounts to a change of 2.4% and 4.8% average skewness. Our results on the second distributional moment of returns is related to recent work by Morellec and Zhdanov (2019), who find that competition increases excess negative skewness of returns.

In column 3 of Table 3, we repeat the analysis but this time use firms' risk-neutral kurtosis as the variable to predict. The *HED* coefficient is economically and statistically significant (-0.19 and t=-2.37). The effect on firms' kurtosis of leverage, market-to-book and rollover risk is also significant.

To further analyze the importance of hedging for firms future return distributions, we now examine its impact at different time horizons. This analysis is motivated by managers' pressure to mitigate an increase in the perceived risk of the company, as it manifests in expected distributional moments.

We therefore estimate firm-level risk-neutral variance, skewness and kurtosis using option contracts with different maturities, which in turns generates a term-structure of risks. We then take the difference between the long horizon and short horizon option contracts. Specifically, we define the slope of a distributional moment as the difference between the three-months to maturity contract and the one-month to maturity contract.[12] We construct firm-level, monthly slopes for the risk-neutral variance, skewness and kurtosis.

Armed with these new set of variables, we then ask what is the impact of increasing levels of hedging on the future term structure of variance, skewness and kurtosis. We therefore implement panel regressions where the dependent variable is the firm-level variance (skewness, kurtosis) slope and the main explanatory variable is *HED*, the percentage of oil production hedged. As with Table 3, we control for the at-the-money option implied volatility, six-month cumulative return, leverage, rollover risk, size, market-to-book and profitability ratios. Table 4 reports the regression results, which include time-fixed effects and firm-clustered standard

[12] We obtain similar results using six-months (instead of three-months) to maturity option contracts.

errors.

[Insert Table 4 Here]

The results can be summarized as follows. Increasing levels of hedging seem to have relatively larger impact on shorter horizon distributional moments. This is reflected in the positive loadings for the slopes of variance and kurtosis, and the negative loading for the slope of skewness. Statistically, this conclusion is significant in the case of skewness, with a loading of -0.051 and t-statistic of -2.14. The impact of hedging on variance, skewness and kurtosis slopes is also consistent with anecdotal evidence of firms in the oil and gas industry using short term derivatives contracts to hedge, given that firms avoid locking themselves into low crude oil prices for too long given its volatility.

Firms' perceived risk, based on option prices distributional moments, seem to react faster to increasing levels of hedging in the short run. And as reported by the results on skewness, this is particularly significant for extreme negative events, which translate in large declines in the equity price of the company. This indicates that managers can observe the results of stricter risk-management policies relatively sooner than later, with hedging being an effective tool for controlling misalignments in firms' perceived future risks.

Taken together, the results from Tables 3 and 4 are consistent with the predictions of the model in Section 2. Firm-level hedging generates a *pull-to-normality* effect on the firm's distribution of stock returns, as it significantly reduces variance, excess negative skewness and excess kurtosis in the following month.

5.2 Who Benefits from Hedging?

Having confirmed the effects of hedging on firms' distributional moments, we now turn to a related important question: Who benefits the most from hedging? This exercise allows to answer when is hedging more effective at reducing firms' variance, reducing excess negative skewness and reducing excess kurtosis. Based on our theoretical model, our prior is that hedging is a more effective tool for firms that face a relatively more challenging environment for their financial management. Thus, we expect for these firms to be smaller in size, carry larger levels of leverage and rollover risk, and exhibit lower levels of market-to-book and profitability.

To approach this task, we split the sample into firms with above and below median levels of different firm characteristics. We therefore estimate predictive regressions by splitting the sample into firms with below median and above median levels of firms' size, leverage, market-to-book, rollover risk and profitability. The dependent variable is the monthly firm-level risk-neutral moment (variance, skewness and kurtosis). The main explanatory variable is the firm-level percentage of hedged oil (*HED*) and control variables are defined in Table 1. We report in Table 5 the regression results.

[Insert Table 5 Here]

Size. We first split the sample into firms with below median size (small firms) and above median size (large firms), with firm size defined as the logarithm of the firm's market capitalization.

In Panel A, we report the predictive regression coefficients for the effects of hedging on firms' variance using small size firms (column 1) and large size firms (column 2). The *HED* coefficient is negative and statistically significant for small firms (-0.006 and t=-1.96) whereas the effect on large firms is not statistically significant.[13] The economic impact on small firms is important: a percentage increase in *HED* reduces firms' variance by 0.006, which is about 40% of its median (0.006/0.0176). This result suggests that small size firm seem to be particularly benefited from implementing hedging policies. We repeat the analysis

[13] In all specifications, we report Newey and West (1987) corrected t-statistics using five lags.

in columns 3 and 4, this time using return skewness as the dependent variable. Similar for the case of variance, the effect of hedging on firms' skewness is economically and statistically significant for small size firms (0.191 and t=3), turning firms less negatively skewed. Columns 5 and 6 confirm the important effects of hedging on the return distribution of small firms, as *HED* significantly lowers future kurtosis (-0.62 and t=-2.15).

The results from Panel A confirm the important implications of hedging for smaller firms. Doshi, Kumar and Yerramili (2018) find that small size firms lower capital expenditures and debt issuance instead of increasing hedging to mitigate uncertainty. Our findings suggest that hedging could be a more effective tool at reducing firms' return variance, excess negative skewness and excess kurtosis.

Leverage. We next study the impact of hedging on firms differentiated by their level of leverage, the firm's total debt over total capitalization.

In Panel B of Table 5, we report the monthly predictive regressions in which, based on firms' leverage, we split the sample into firms with below median leverage (low) and above median leverage (high). For the case of variance, hedging loads negatively but insignificantly in both cases (columns 1 and 2). In the case for the firm's risk-neutral skewness, column 4 reports that hedging is particularly important at reducing excess negative skewness for firms with high leverage levels, with a positive coefficient of 0.28 (t=4.48). Lastly, column 6 of Panel B reports similar results for the case of kurtosis. Hedging helps reduce kurtosis in firms with relative high leverage levels, with a negative coefficient of -0.61 (t=-2.56).

Market-to-Book. We test for the effectiveness of hedging by splitting firms based on their level of market to-book, the ratio of the market value to book value of equity. Note that the inverse of this ratio proxies for financial distress (Chan and Chen (1991); Griffin and Lemon (2002)), and therefore we expect hedging effects to be stronger among firms with low market-to-book ratios.

In Panel C of Table 5, columns 1, 3 and 5 report the regression coefficients for low market-to-book (high financial distress) firms and confirm our priors. In all cases, *HED* carries the expected sign and significantly loads on firms' distributional moments. For low market-to-book firms, hedging significantly reduces firms variance (-0.004 and t=-2.23), reduces firms' excess negative skewness (0.22 and t=3.43) and reduces firms' excess kurtosis (-0.36 and t=-2.02).

Rollover Risk. In Panel D of Table 5, we report the effects of hedging firms' returns distribution once we differentiate between firms with low and high rollover risk ratios. Rollover risk is the firm's debt in current liabilities divided by total debt.

Comparing columns 1 and 2, variance return predictability of HED for firms with high rollover risk is -0.003, with a Newey-West t-statistic of -1.9, while it is not significant for firms with low rollover risk. We obtain similar qualitative conclusions for the impact of hedging on skewness, as firms with higher level of rollover risk reduce excess negative skewness with higher levels of hedging, but the statistics are no significantly different than zero. Coefficients are not statistically significant in the case of kurtosis return (columns 5 and 6). In line with the previous panels, the results from Panel D suggest that firms with higher rollover risk benefit the most from implementing hedging policies.

Profitability. We also study the impact of hedging on firms variance, skewness and kurtosis depending on the level of the firm's profitability ratio, defined as the ratio between the firm's revenues minus cost of goods sold and total assets (Novy-Marx (2013)). We expect for a firm with relatively low levels of profitability to benefit the most from hedging, as it would allow for this firm to be perceived as more likely to incur in financial distress in the near term. In Panel E, column 1 reports that hedging lowers the variance of firms with low profitability ratios but t-statistic is not significant. Column 3 reports that hedging significantly reduces excess negative skewness, while columns 5 and 6 do not report significant loadings on firms' kurtosis.

The results from Table 5 support the predictions of our model derived in Section 3 . The effects of hedging at reducing variance, excess negative skewness and excess kurtosis are particularly stronger among firms that are smaller in size and facing more challenging outlooks: higher leverage and rollover risk and lower market-to-book and profitability ratios. Our findings complement Bolton, Chen and Wang (2011), who demonstrate that firms in worse financial conditions increase hedging levels to avoid higher financing costs. From Table 5, we find that these are precisely the type of firms that benefit the most from implementing stricter risk-management policies, as higher levels of hedging make their returns more normally distributed.

In all, the implications of our results are important for understanding the relevance of risk management within corporations. While the previously documented literature finds that hedging impacts firms' access to and use of funds, we show that the effects of hedging directly translate into firms' carrying future lower overall risk (the *pull-to-normality* effect of hedging). The findings from this section can be summarized as follows. First, we find that hedging reduces firms return's variance, negative skewness and kurtosis. Second, we document this effect of hedging on returns' distributions to be stronger among firms with high leverage, high rollover-risk, low market-to-book, low profitability and small size.

5.3 Investment and its Impact on Higher Moments

Section 3.7 discusses the implications of incorporating capital expenditures in our dynamic model. In this Section, we empirically examine the effect of capital expenditures on future changes in firms' higher moments, based on the real options analysis in Section 3.7. We also analyze the combined effect of capital expenditures and firm's hedging policies on the firm's returns distribution.

Following the empirical analysis of Section 4, we collect quarterly data on firms in the oil and gas sector. We proxy for firms' investments with the ratio of quarterly capital expenditures to total assets (capxq/atq). Using options data, we estimate firms' risk-neutral moments (variance, skewness and kurtosis). We compute firms' hedging intensities (HED), defined as the percentage of hedged oil production. All variables used in the paper are described in Table 1. The dependent variable is the firm's risk-neutral variance, skewness and kurtosis, while the explanatory variable is the firm's investments. We implement quarterly predictive cross-sectional regressions for each risk-neutral moment individually (i.e., variance, skewness and kurtosis). We interact each risk-neutral moment with the firm's level of hedging intensity (HED). The interaction is a dummy variable that takes the value of one if HED is above the sample median in each quarter and it is zero otherwise. All specifications include the dummy variable itself. We report the results from the predictive regressions in Table 6.

[Insert Table 6 Here]

The results in columns 1, 3 and 5 indicate that the impact of investments on future variance, skewness and kurtosis is positive and statistically significant (Newey-West corrected t-statistics of 2.08, 1.93 and 1.99 respectively). These findings are novel to the literature, and they support the hypotheses derived from the real options analysis in Section 3.7. To see the implications of these results, consider the impact of investments on even moments (variance and kurtosis) from a real options perspective. An increase in investments can lead to positive or negative future cash-flows, increasing the tails of the return distribution, thus raising future variance and kurtosis. This is precisely what Table 6 reports in columns 1 and 5, respectively. As discussed earlier, the impact of investments on future skewness depends on the firm's current financial situation. Empirically, column 3 reports that the impact of changing investments on future skewness is positive (1.087), suggesting that it mitigates the likelihood of future large and negative return events. Columns 2, 4 and 6, interact investments with firm's hedging intensity levels. The coefficient for investments is statistically for future variance (t=1.99), skewness (t=2.15) and kurtosis (t=2.01). While the interaction terms are not statistically significant, they show opposite sign to the investment term, highlighting the offsetting effects of risk-management policies on investments policies.

In summary, our analysis indicates that the effects of capital investment on higher moments are diluted by risk-management policies. We find that capital investment tends to move the firm's stock return distribution *away* from normal, and this in turn raises the incentives for hedging, other things being equal.

6 Conclusion

Higher moments of stock return distributions play an important role in equity markets. There is long-standing evidence of excess negative skewness and excess positive kurtosis in equity returns, complemented by accumulation of evidence against the single factor capital asset pricing model (CAPM) based on the assumption of multivariate normality of returns. But while there is an extensive literature on higher moments in security markets, the analysis of the effects of *firm-level* production, investment and financial policies on the higher moments of their stock return distributions is relatively unexplored. We contribute to the literature by theoretically and empirically studying the effects of changing risk-management and capital investment policies of levered firms on the higher moments of their future stock return distributions.

We construct a dynamic model of levered firms exposed to default risk through uncertain product prices and, hence, cash flows. Even though the product price follows Brownian motion, the presence of a default boundary implies that the risk-neutral equity value distribution along the firm's optimal production path is generally asymmetric; that is, it is characterized by excess negative skewness and excess positive kurtosis (relative to the normal distribution). We characterize the value-maximizing hedging policy and relate its effects to the variance, excess negative skewness, and excess positive kurtosis. Hedging is predicted to reduce not only variance but also excess skewness and kurtosis of the firm's future stock return distributions, a set of results we coin as the *pull-to-normality* effect. Thus, hedging tends to reduce the asymmetric characteristics of the firm's risk-neutral return distribution and, hence, lower the deviation of stock return distribution from a normally distributed random variable. Our model also generates the empirical hypotheses that the reduction in variance, excess negative skewness, and excess positive kurtosis will be stronger, other things being equal, among firms with high leverage, small size, and high rollover-risk, as well as low profitability and low market-to-book. Finally, our model also shows that capital investment, financed through additional debt, increases variance and kurtosis, while the effect on excess skew is theoretically ambiguous. Thus, the effect of capital investment on the firm's higher moments is opposite to that of hedging. It is in this sense that capital investment generates a *pull-from-normality* effect on firms' future returns distribution.

Using the cross-section of U.S. equity options prices and hand-collected hedging data for a sample of firms in the oil and gas industry, our empirical tests find strong support for the predictions of the model. Raising hedging intensity significantly reduces future variance, negative skewness and kurtosis of firms' returns; these effects are both statistically and economically significant. And the *pull-to-normality* effect of hedging is stronger among firms with high leverage, high rollover-risk, low profitability, low market-to-book, and small size. But consistent with our theoretical framework, we find that investment raises variance, excess skewness and kurtosis, that is we confirm the *pull-from-normality* effect of investment; hedging ameliorates this effect, however. Our analysis extends the literature on higher moments of equity returns as well as the literature on corporate hedging and capital investment.

Appendix

A Proofs

Proof of Proposition 1: The expressions (23)-(25) follow from using Equations (19)-(22) in the higher moments for Ito processes (see e.g. Theorem 1 of Bakshi, Kapadia, and Madan (2003)). ■

Proof of Proposition 2: We compute $\bar{P}$ such that

$$\frac{(1-\tau)}{\phi q} = x(x+1)\frac{C}{r(1-\gamma)}[1-(1-\gamma)(1-\tau)]\bar{P}^{-(x+2)}. \tag{A.1}$$

It follows then from Equation (26) that $\tilde{V}_{PP}(P_t) < 0$ for all $P_t < \bar{P}$. Next, applying the implicit function theorem on (A.1), we can show that $\frac{\partial \bar{P}}{\partial C} > 0$, $\frac{\partial \bar{P}}{\partial \phi} > 0$, and $\frac{\partial \bar{P}}{\partial \gamma} > 0$.

■

B Risk Neutral Variance, Skewness and Kurtosis

We follow Bakshi and Madan (2000) and Bakshi, Kapadia, and Madan (2003) to estimate the variance, skewness and kurtosis of the risk-neutral density function of individual securities. The risk-neutral variance ($VAR_t^{\mathbb{Q}}$) and skewness ($SKE_t^{\mathbb{Q}}$) and kurtosis ($KUR_t^{\mathbb{Q}}$) at time t for a τ-maturity contract are given by

$$VAR_t^{\mathbb{Q}} = e^{r\tau}V_t(\tau) - \mu_t(\tau)^2$$

$$SKE_t^{\mathbb{Q}} = \frac{e^{r\tau}W_t(\tau) - 3\mu_t(\tau)^2 e^{r\tau}V_t(\tau) + 2\mu_t(\tau)^3}{\left[e^{r\tau}V_t(\tau) - \mu_t(\tau)^2\right]^{\frac{3}{2}}}$$

$$KUR_t^{\mathbb{Q}} = \frac{e^{r\tau}W_t(\tau) - 4\mu_t(\tau)^2 e_t^{r\tau}W(\tau) + 6e^{r\tau}\mu_t(\tau)^2 V_t(\tau) - 3\mu_t(\tau)^4}{\left[e^{r\tau}V_t(\tau) - \mu_t(\tau)^2\right]^2}$$

where $\mu_t(\tau) = e^{r\tau} - 1 - e^{r\tau}V_t(\tau)/2 - e^{r\tau}W_t(\tau)/6 - e^{r\tau}X_t(\tau)/24$ and r is the risk free rate. Bakshi, Kapadia, and Madan (2003) show that one can express the τ-maturity price of a security that pays the quadratic, cubic, and quartic return on the base security as

$$V_t(\tau) = \int_{F_t}^{\infty} \frac{2\left(1 - \ln\left(\frac{K}{F_t}\right)\right)}{K^2} C_t(\tau;K)\,dK + \int_0^{F_t} \frac{2\left(1 - \ln\left(\frac{K}{F_t}\right)\right)}{K^2} P_t(\tau;K)\,dK \tag{B.3}$$

$$W_t(\tau) = \int_{F_t}^{\infty} \frac{6\ln\left(\frac{K}{F_t}\right) - 3\ln\left(\frac{K}{F_t}\right)^2}{K^2} C_t(\tau;K)\,dK + \int_0^{F_t} \frac{6\ln\left(\frac{K}{F_t}\right) - 3\ln\left(\frac{K}{F_t}\right)^2}{K^2} P_t(\tau;K)\,dK \tag{B.4}$$

$$X_t(\tau) = \int_{F_t}^{\infty} \frac{12\ln\left(\frac{K}{F_t}\right)^2 - 4\ln\left(\frac{K}{F_t}\right)^3}{K^2} C_t(\tau;K)\,dK + \int_0^{F_t} \frac{12\ln\left(\frac{K}{F_t}\right)^2 - 4\ln\left(\frac{K}{F_t}\right)^3}{K^2} P_t(\tau;K)\,dK \tag{B.5}$$

where (B.3)-(B.5) are the time t prices of $\tau-$maturity quadratic, cubic, and quartic contracts, respectively. $C_t(\tau;K)$ and $P_t(\tau;K)$ are the time t prices of European calls and puts written on the underlying asset with strike price K and expiration τ periods from time t. We use a trapezoidal approach to numerically approximate equations (B.3)-(B.5) (see for example, Bali and Murray (2013) and Conrad, Dittmar, and Ghysels (2013)).

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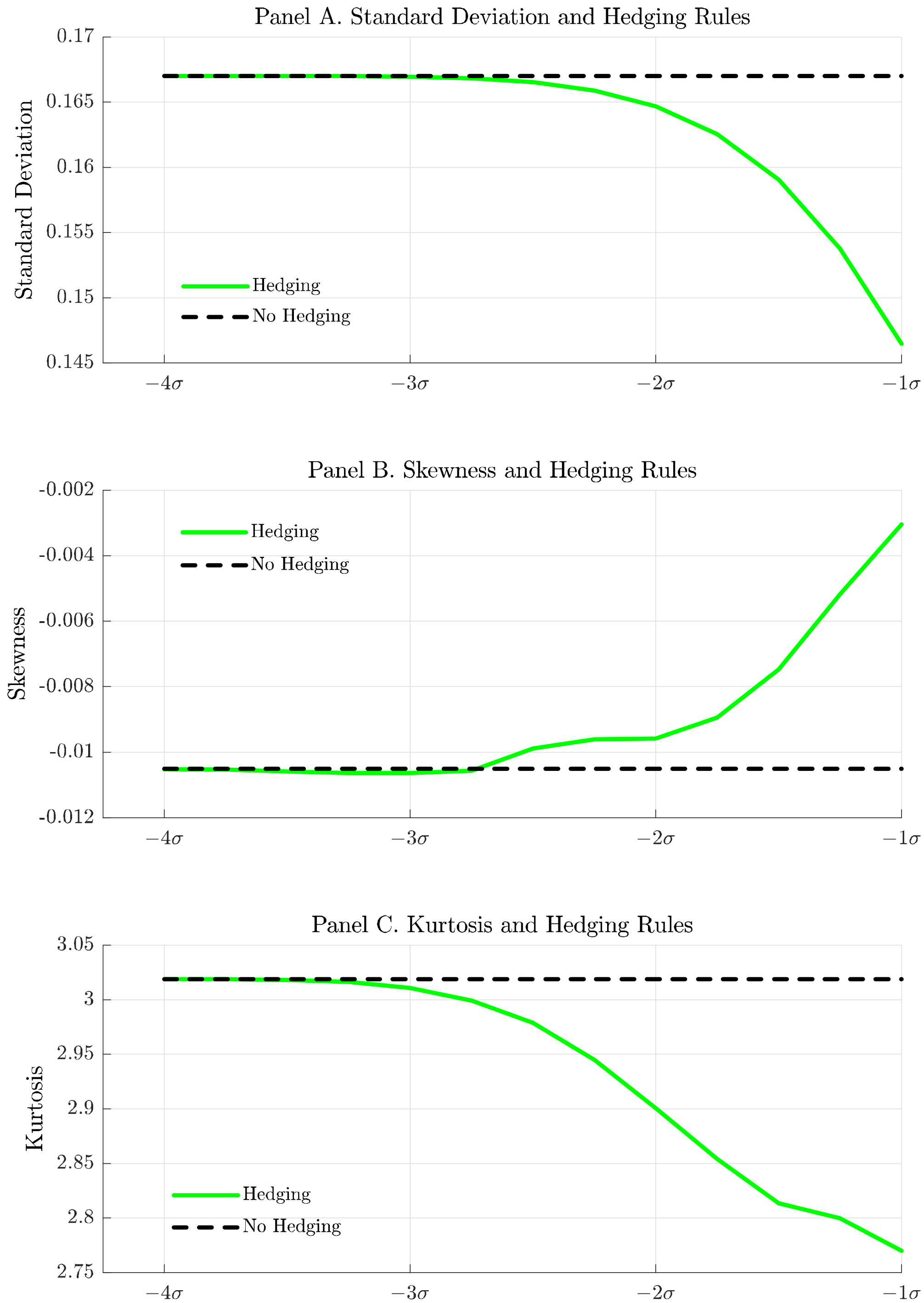
Figure 1: Hedging Rules and Distributional Moments



Notes to Figure: We plot simulated distributional moments based on the firm's risk management policies with respect to the industry output price. We simulate the industry output price for one-month horizon under the risk-neutral measure using equation (15) with the following parameterization: r=2%, q=1%, σ=20%, ϕ=0.2, τ=0.2, γ=0.1 and C=0.1. Hedging rules are based on standard deviations shocks in the product price. Panel A reports the effect of hedging on the firm's standard deviation. Panel B reports the effect of hedging on the firm's skewness. Panel C reports the effect of hedging on the firm's kurtosis. The dashed black line represents a firm with no hedging rules. The solid green line represents a firm with hedging rules in place. The horizontal axis ranges from -4 standard deviations (less strict hedging rule) to -1 standard deviation (more strict hedging rule).

Table 1: Description of Variables

Notes to Table: We report the description of variables used in the paper.

HED	Number of barrels of oil hedged to the number of barrels of total oil production. The ratio is hand-collected for each fiscal quarter from firms' 10-Q filings. Source: SEC EDGAR.
Variance	Option implied risk-neutral variance (Bakshi, Kapadia and Madan (2003)). The Appendix provides derivation details. Source: OptionMetrics.
Skewness	Option implied risk-neutral skewness (Bakshi, Kapadia and Madan (2003)). The Appendix provides derivation details. Source: OptionMetrics.
Kurtosis	Option implied risk-neutral kurtosis (Bakshi, Kapadia and Madan (2003)). The Appendix provides derivation details. Source: OptionMetrics.
Implied Volatility	At-the-money option implied volatility. Source: OptionMetrics.
Return	Six-month cumulative firm return. Source: CRSP.
Investment	Ratio of capital expenditures to total assets (capxq) / (atq). Source: Compustat.
Leverage	Ratio of total debt to total capitalization ((dlttq + dlcq) / (dlttq + dlcq + cshoq * prccq)). Source: Compustat.
Size	Logarithm of the market capitalization (log(prccq * cshoq)). Source: Compustat.
Market-to-Book	Ratio of the market value to book value of equity ((prccq * cshoq) / ceqq). Source: Compustat.
Rollover Risk	Ratio of debt in current liabilities to total debt (dlcq /(dlttq+dlcq)). Source: Compustat.
Profitability	Ratio of revenues minus cost of goods sold to total assets ((revtq - cogsq) / atq). Source: Compustat.

Table 2: Summary Statistics

Notes to Table: We report the summary statistics for energy related firms (SIC 1311): mean, median, standard deviation and percentiles 25th and 75th. The top panel reports the option-implied risk-neutral moments: variance, skewness and kurtosis. The bottom panel reports the summary statistics for the firm-level percentage of hedged oil production (HED) and control variables: at-the-money option implied volatility, six-month cumulative return, investment intensity, leverage, size, rollover risk, market-to-book and profitability ratios. All variables are defined in Table 1. The sample period is from January 1996 to January 2014.

	Mean	Median	Std. Dev.	Perc.25	Perc.75
Variance	0.0192	0.0176	0.0061	0.0147	0.0224
Skewness	-0.4002	-0.3875	0.1732	-0.5192	-0.2763
Kurtosis	3.8906	3.7247	0.5768	3.4750	4.1897
HED	0.3287	0.2892	0.2971	0.0430	0.5369
Implied Volatility	0.4343	0.4226	0.0619	0.3878	0.4740
Return	0.1056	0.0930	0.2467	-0.0431	0.2389
Investment	0.0236	0.0209	0.0117	0.0145	0.0301
Leverage	0.3079	0.2822	0.1767	0.2205	0.3845
Rollover Risk	0.0518	0.0135	0.1318	0.0010	0.0745
Size	6.9928	7.1060	1.5534	6.2876	7.7150
Market-to-Book	2.4613	2.4629	3.2326	1.4658	3.3961
Profitability	0.0488	0.0524	0.0403	0.0324	0.0706

Table 3: Firm Hedging and Risk-Neutral Moments

Notes to Table: We report the monthly predictive regressions using energy-related firms (SIC 1311). The dependent variable is the monthly firm-level risk-neutral variance, skewness and kurtosis, respectively in columns 1, 2 and 3. The main explanatory variable is the firm-level percentage of hedged oil production (HED). Control variables include the following: at-the-money option implied volatility, six-month cumulative return, leverage, rollover risk, size, market-to-book and profitability ratios. All variables are computed at the firm-level and defined in Table 1. We report in parentheses the t-statistics with firm-clustered standard errors. All explanatory variables are one-month lagged. All specifications include time fixed effects. The sample period is from January 1996 to January 2014.

Dep. Variable	Risk-Neutral Moments		
	Variance	Skewness	Kurtosis
	(1)	(2)	(3)
Intercept	-0.031	-0.070	-0.150
	(-4.00)	(-0.55)	(-0.31)
HED	-0.002	0.065	-0.191
	(-2.63)	(2.98)	(-2.37)
Implied Volatility	0.102	0.128	0.684
	(9.12)	(1.05)	(1.55)
Return	0.001	-0.121	0.273
	(0.67)	(-3.53)	(2.26)
Size	0.001	-0.054	0.394
	(1.39)	(-5.98)	(9.60)
Leverage	0.010	-0.150	1.376
	(2.83)	(-2.07)	(5.36)
Market-to-Book	0.000	0.026	-0.044
	(-0.10)	(4.05)	(-2.17)
Rollover Risk	0.010	-0.105	1.477
	(3.16)	(-1.32)	(3.49)
Profitability	-0.033	-0.160	0.101
	(-4.50)	(-1.18)	(0.19)
$R^2_{Adj.}$	0.88	0.44	0.28

Table 4: Firm Hedging and the Slope of Risk-Neutral Moments

Notes to Table: We report the monthly predictive regressions using energy-related firms (SIC 1311). The dependent variable is the monthly firm-level risk-neutral variance slope, skewness slope and kurtosis slope, respectively in columns 1, 2 and 3. For each distributional moment, slopes are defined as the difference between the 90 days to maturity option contract and the 30 days to maturity option contract. The main explanatory variable is the firm-level percentage of hedged oil production (HED). Control variables include the following: at-the-money option implied volatility, six-month cumulative return, leverage, rollover risk, size, market-to-book and profitability ratios. All variables are computed at the firm-level and defined in Table 1. We report in parentheses the t-statistics with firm-clustered standard errors. All explanatory variables are one-month lagged. All specifications include time fixed effects. The sample period is from January 1996 to January 2014.

Dep. Variable	Slope of Risk-Neutral Moments		
	Variance	Skewness	Kurtosis
	(1)	(2)	(3)
Intercept	-0.113	-0.210	0.444
	(-1.47)	(-1.97)	(1.25)
HED	0.001	-0.051	0.116
	(0.16)	(-2.14)	(1.25)
Implied Volatility	0.203	0.321	-0.460
	(5.42)	(4.25)	(-1.86)
Return	-0.005	0.109	-0.179
	(-1.65)	(4.28)	(-2.01)
Size	0.007	-0.009	-0.008
	(0.98)	(-1.08)	(-0.25)
Leverage	0.035	-0.112	-0.182
	(2.12)	(-1.35)	(-0.55)
Market-to-Book	-0.001	0.002	-0.039
	(-1.10)	(0.39)	(-2.02)
Rollover Risk	0.008	-0.055	0.122
	(0.94)	(-0.65)	(0.37)
Profitability	-0.045	-0.160	0.594
	(-2.05)	(-1.15)	(1.44)
$R^2_{Adj.}$	0.89	0.07	0.01

Table 5: Firm Hedging and Firm Type

Notes to Table: We report the monthly predictive regressions using energy-related firms (SIC 1311). The dependent variable is the monthly firm-level risk-neutral variance, skewness and kurtosis. The main explanatory variable is the firm-level percentage of hedged oil production (*HED*). For each risk-neutral moment, we split the sample into firms with below median and above median level of a firm's characteristic: size, leverage, market-to-book, rollover risk, profitability. Columns 1 and 2 report the cases for the risk-neutral variance. Columns 3 and 4 report the cases for the risk-neutral skewness. Columns 5 and 6 report the cases for the risk-neutral kurtosis. Panel A reports the sample split based on firms' size, the logarithm of the market cap. Panel B reports the sample split based on firms' leverage, the ratio of total debt to total capitalization. Panel C reports the sample split based on firms' market-to-book, the market value to book value of equity. Panel D reports the sample split based on firms' rollover risk, the ratio of debt in current liabilities to total debt. Panel E reports the sample split based on firms' profitability, revenues minus cost of goods sold over total assets. Control variables include at-the-money option implied volatility, six-month cumulative return, rollover risk, size, leverage, profitability and market-to-book ratio. All variables are computed at the firm-level and defined in Table 1. We report the Newey-West corrected t-statistics in parentheses. All explanatory variables are one-month lagged. The sample period is from January 1996 to January 2014.

Dep. Variable	Risk-Neutral Moments					
	Variance		Skewness		Kurtosis	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Size						
	Small	Large	Small	Large	Small	Large
Intercept	-0.038	-0.027	-0.473	-0.445	3.978	4.728
	(-4.52)	(-5.17)	(-4.54)	(-8.86)	(7.76)	(26.21)
HED	-0.006	-0.001	0.191	-0.048	-0.623	0.154
	(-1.96)	(-0.69)	(3.00)	(-1.66)	(-2.15)	(1.83)
Controls	Y	Y	Y	Y	Y	Y
$R^2_{Adj.}$	0.71	0.69	0.23	0.12	0.09	0.07

Dep. Variable	Risk-Neutral Moments					
	Variance		Skewness		Kurtosis	
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel B. Leverage					
	Low	High	Low	High	Low	High
Intercept	-0.014	-0.064	0.455	0.022	0.375	1.848
	(-1.51)	(-2.75)	(2.54)	(0.14)	(0.77)	(3.58)
HED	-0.003	-0.003	-0.022	0.279	0.152	-0.608
	(-1.89)	(-1.29)	(-0.79)	(4.48)	(1.67)	(-2.56)
Controls	Y	Y	Y	Y	Y	Y
$R^2_{Adj.}$	0.70	0.73	0.25	0.19	0.23	0.23
	Panel C. Market-to-Book					
	Low	High	Low	High	Low	High
Intercept	-0.031	-0.034	0.568	0.621	0.346	0.297
	(-1.56)	(-2.19)	(3.28)	(3.24)	(0.59)	(0.49)
HED	-0.004	0.000	0.216	-0.049	-0.355	0.086
	(-2.23)	(-0.37)	(3.43)	(-1.53)	(-2.02)	(0.78)
Controls	Y	Y	Y	Y	Y	Y
$R^2_{Adj.}$	0.72	0.68	0.11	0.15	0.24	0.16
	Panel D. Rollover risk					
	Low	High	Low	High	Low	High
Intercept	-0.013	-0.022	-2.048	0.312	2.123	1.269
	(-0.37)	(-1.12)	(-0.22)	(1.53)	(1.27)	(1.79)
HED	-0.023	-0.003	-2.594	0.061	0.848	0.009
	(-0.76)	(-1.90)	(-0.61)	(1.30)	(1.38)	(0.06)
Controls	Y	Y	Y	Y	Y	Y
$R^2_{Adj.}$	0.46	0.68	0.39	0.18	0.57	0.16
	Panel E. Profitability					
	Low	High	Low	High	Low	High
Intercept	-0.037	-0.029	0.294	0.399	0.202	0.709
	(-1.55)	(-3.59)	(1.69)	(3.11)	(0.33)	(1.68)
HED	-0.003	0.000	0.174	-0.098	-0.096	0.068
	(-1.62)	(0.29)	(3.30)	(-3.00)	(-0.57)	(0.56)
Controls	Y	Y	Y	Y	Y	Y
$R^2_{Adj.}$	0.69	0.76	0.18	0.20	0.20	0.26

Table 6: Investments, Risk Neutral Moments and Hedging

Notes to Table: We report the quarterly predictive regressions using energy-related firms (SIC 1311). The dependent variable is the quarterly risk-neutral variance, skewness and kurtosis. The independent variable is the firm's ratio of capital expenditures to total assets (capxq/atq). We interact investments with the firm-level percentage of hedge oil (*HED*). The interaction term is based on the indicator variable that takes the value of one if *HED* is above the sample median in each quarter and zero otherwise. Columns 1 and 2 report the cases for the risk-neutral variance. Columns 3 and 4 report the cases for the risk-neutral skewness. Columns 5 and 6 report the cases for the risk-neutral kurtosis. All regressions also include the dummy variable itself. All variables are computed at the firm-level and defined in Table 1. We report the Newey-West corrected t-statistics in parentheses. All explanatory variables are one-quarter lagged. The sample period is from January 1996 to January 2014.

Dep. Variable	Risk-Neutral Moments					
	Variance		Skewness		Kurtosis	
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	0.044	0.042	-0.497	-0.589	3.742	3.384
	(4.15)	(2.80)	(-15.95)	(-11.28)	(54.14)	(23.15)
Investments	0.536	1.299	1.087	1.829	18.58	86.89
	(2.08)	(1.99)	(1.93)	(2.15)	(1.99)	(2.01)
Investments × HED		-0.408		-2.223		-60.99
		(-0.35)		(-1.27)		(-1.45)