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Résumé de l'article

Cette étude réexamine la question de savoir si la gestion des risques a des implications réelles sur la valeur, le risque et les performances comptables des entreprises en utilisant un nouvel ensemble de données sur les activités de couverture des producteurs de pétrole américains. À la lumière des résultats controversés dans la littérature, cet article propose une estimation de la question des primes de couverture pour les entreprises en utilisant une méthodologie économétrique plus robuste, à savoir des modèles d'hétérogénéité essentiels, permettant de contrôler les biais liés à la sélection sur les non-observables et à l'auto-sélection dans l'estimation des effets de traitements marginaux. Nous constatons que les producteurs de pétrole avec des scores de propension plus élevés pour l'utilisation d'activités de couverture plus étendues tendent à avoir une valeur d'entreprise marginale plus élevée et une réduction du risque marginal plus élevée et à réaliser une performance comptable marginale plus forte. Ces producteurs de pétrole ayant des scores de propension plus élevés ont également des effets de traitement moyens significatifs sur la valeur financière de l'entreprise, le risque idiosyncratique et le risque systématique.

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REAL IMPLICATIONS OF CORPORATE RISK MANAGEMENT: REVIEW OF MAIN RESULTS AND NEW EVIDENCE FROM A DIFFERENT METHODOLOGY*

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RÉSUMÉ – Cette étude réexamine la question de savoir si la gestion des risques a des implications réelles sur la valeur, le risque et les performances comptables des entreprises en utilisant un nouvel ensemble de données sur les activités de couverture des producteurs de pétrole américains. À la lumière des résultats controversés dans la littérature, cet article propose une estimation de la question des primes de couverture pour les entreprises en utilisant une méthodologie économétrique plus robuste, à savoir des modèles d'hétérogénéité essentiels, permettant de contrôler les biais liés à la sélection sur les non-observables et à l'auto-sélection dans l'estimation des effets de traitements marginaux. Nous constatons que les producteurs de pétrole avec des scores de propension plus élevés pour l'utilisation d'activités de couverture plus étendues tendent à avoir une valeur d'entreprise marginale plus élevée et une réduction du risque marginal plus élevée et à réaliser une performance comptable marginale plus forte. Ces producteurs de pétrole ayant des scores de propension plus élevés ont également des effets de traitement moyens significatifs sur la valeur financière de l'entreprise, le risque idiosyncratique et le risque systématique.

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ABSTRACT – This study revisits the question of whether risk management has real implications on firm value, risk, and accounting performance using a new dataset on the hedging activities of U.S. oil producers. In light of the controversial results in the literature, this paper estimates the hedging premium question for firms by using a more robust econometric methodology, namely essential heterogeneity models, that controls for bias related to selection on unobservables and self-selection in the estimation of marginal treatment effects (MTE). We find that oil producers with higher propensity scores for the use of more extensive hedging activities tend to have higher marginal firm value and higher marginal risk reduction and realize stronger marginal accounting performance. These oil producers with higher propensity scores also have significant average treatment effects (ATE) for firm financial value, idiosyncratic risk and systematic risk.

INTRODUCTION

In the frictionless world of Modigliani and Miller (1958), there are no rationales for corporate risk management because it cannot enhance firm value. However, risk management through derivative instruments is becoming increasingly widespread in the imperfect real world. The Bank of International Settlements (BIS) reports that, by the end of June 2013, notional amounts outstanding of US$ 10.6 trillion and US$ 35.8 trillion account for, respectively, over-the-counter foreign exchange (FX) and interest rate (IR) derivatives held by non-financial entities. At the same date, over-the-counter commodity contracts have a notional amount outstanding of about US$ 2 trillion, gold not included. At the beginning of the millennium, these figures were only about US$ 2.8 trillion, US$ 5.5 trillion, and US$ 0.3 trillion for FX, and IR and commodity contracts (gold not included). Empirical evidence (e.g., Haushalter, 2000; Jin and Jorion, 2006; Kumar and Rabinovitch, 2013) shows an increasing fraction of production protected from price fluctuations using derivatives for the petroleum industry, for example[1].

In the last three decades, the risk management literature has been bolstered considerably by data availability and particularly improvements in theoretical research of corporate demand for protection. Mayers and Smith (1982) and Stulz (1984) are the first to build a hedging theory that incorporates the introduction of frictions into financial markets, and show that market frictions (e.g., default costs, tax shields, agency costs) enable firms to create value by hedging actively. The subsequent empirical literature extends the knowledge on hedging determinants (e.g., Tufano, 1996; Haushalter, 2000; Dionne and Garand, 2003; Adam and Fernando, 2006). More recent lines in the literature focus on hedging value and risk implications for firms (e.g., Guay, 1999; Allayannis and Weston, 2001; Jin and Jorion, 2006). Yet empirical findings on the value implications of risk management are fairly mixed and inconclusive. Methodological problems related to endogeneity of derivative use and other firm decisions, sample selection, sample

1. Haushalter (2000) reports an average fraction of production hedged of 30% for each year 1992, 1993, and 1994. Jin and Jorion (2006) find that an average firm hedges 33% (41%) of next-year oil (gas) production. Kumar and Rabinovitch (2013) report an average fraction of production hedged of 46% for the current quarter. Their measure combines both oil and gas production. We provide more details on our sample firms' hedging ratios in a subsequent section.

size, and the existence of other potential hedging mechanisms (e.g., operational hedge) are often blamed for this mixed empirical evidence.

This paper revisits the question of hedging virtues in a more comprehensive and multifaceted manner for a sample of U.S oil producers, and uses a different econometric methodology. To better gauge the real implications of hedging, we examine its effects on the following firm objectives:

1. Firm value, measured by the Tobin's q, to verify if hedging is associated with value creation for shareholders.
2. Firm risk, as measured by idiosyncratic and systematic risk, and sensitivity of firms' stock returns to oil price fluctuations. One would expect that hedging should attenuate firms' exposure to the underlying market risk factor, which leads to lower firm riskiness. We will analyze in particular whether firms are hedging or speculating by using derivatives.
3. Firms' accounting performance, as measured by the return on equity (ROE). We will check whether hedging effects translate into higher accounting profits.

To overcome the major source of inconsistency in the findings in the empirical literature (i.e., endogeneity), we use an econometric approach based on instrumental variables applied to models with *essential heterogeneity* inspired by the work of Heckman *et al.* (2006), which controls for the individual-specific unobserved heterogeneity in the estimation of marginal treatment effects of using high hedging ratios (i.e., upper quartile) versus low hedging ratios (i.e., lower quartile). Heckman *et al.* (2006) confirm that the plain method of instrumental variables, as used previously, appears to be inappropriate when there are heterogeneous responses to treatment. In our application of the *essential heterogeneity* model, we identify a credible instrument arising from the economic literature pertaining to the macroeconomic responses to crude oil price shocks, namely the Kilian (2009) index, which gives a measure of the demand for industrial commodities driven by the economic perspective.

Our evidence suggests that marginal firm financial value (marginal treatment effect, MTE), as measured by the Tobin's q, is increasing in oil producers' propensity to hedge their oil production to a greater extent (i.e., upper quartile). This finding corroborates one strand in the previous literature that argues for the existence of a hedging premium for non-financial firms (Allayannis and Weston, 2001; Carter *et al.*, 2006; Adam and Fernando, 2006; Pérez-González and Yun, 2013, among others). Consistent with the literature (e.g., Guay, 1999; Bartram *et al.*, 2011), we find that marginal firm riskiness, as measured by its systematic and idiosyncratic risks, is decreasing with oil producers' propensity to be high intensity hedgers rather than low intensity hedgers. Oil beta, representing firms' stock returns' sensitivity to fluctuations in oil prices, is decreasing with the propensity to hedge to larger extents, albeit with no statistical significance. Altogether, these findings suggest that any potential positive effects associated with oil hedging should translate into value enhancement for shareholders because of the decrease in the required cost of equity due to the lower riskiness of the oil producers, in particular lower systematic risk as suggested by Gay *et al.* (2011). We also find that the firm's marginal accounting performance, as measured by the return on equity, is lower for oil producers that are low intensive hedgers. Finally, we obtain a significant average treatment effect (ATE) for Tobin's q (positive), idiosyncratic risk (negative), and systematic risk (negative).

The remainder of this article is organized as follows. Section 1 presents the main motivations for risk management for non-financial firms. It is based on Stulz (1996) and Dionne (forthcoming). Section 2 reviews the related literature on real implications of risk management on firm value and risk. Section 3 describes our instrumental variable and the essential heterogeneity model used to measure the marginal and average effects of risk management on firm objectives. Section 4 presents our sample and its characteristics. Section 5 discusses our estimation results. Last section concludes the paper.

1. Motivations for risk management

When there are no market imperfections, market prices contain all information, making it impossible to generate a profit based on informational advantages. Although this concept is widespread, many managers continue to believe that they possess comparative advantages in certain markets. Consequently, firms use their resources to develop investment strategies that are risky because a high return is generally accompanied by a high risk. However, these practices are not followed by firms that realize they do not actually possess comparative advantages within their sector or those that had bad experiences resulting from the inappropriate use of hedging instruments. In fact, firms do not necessarily need to hedge against all the financial risks they may face, particularly when they are already well diversified internally.

The main goal of risk management is to increase firm value by reducing risk when there are market imperfections. The three main sources of market imperfections are default costs, agency costs, and taxes. Managers' risk behavior and corporate governance problems may also explain risk management of non-regulated firms.

Default costs: Market imperfections generate default costs. Default costs refer to the costs associated with default, not bankruptcy. Default costs can be divided into two categories: direct costs such as lawyer fees, consultant fees and court-related expenses, and indirect costs incurred when a firm is under bankruptcy protection laws, such as reorganizational costs. Both these categories of costs are directly reflected in a firm's valuation. The goal of an efficient risk management strategy is to maintain these costs at an optimal level, while taking into consideration the cost of hedging instruments.

Figure 1 illustrates how risk management contributes to reducing the volatility of firm value. The firm will default when its gross value (without distress or default costs) is less than its face value F. We observe two probability density functions of firm value. The density function represented by the dotted line corresponds to the density of firm value without hedging, whereas the full line represents the frequency with hedging. The first density function corresponds to a positive default probability, whereas the second function corresponds to a null default probability. We can see that the surface of the second density function seldom crosses F, implying that firm value is always greater than F; this firm will thus never default. In this extreme example, hedging reduces the volatility of firm value and eliminates the default probability.

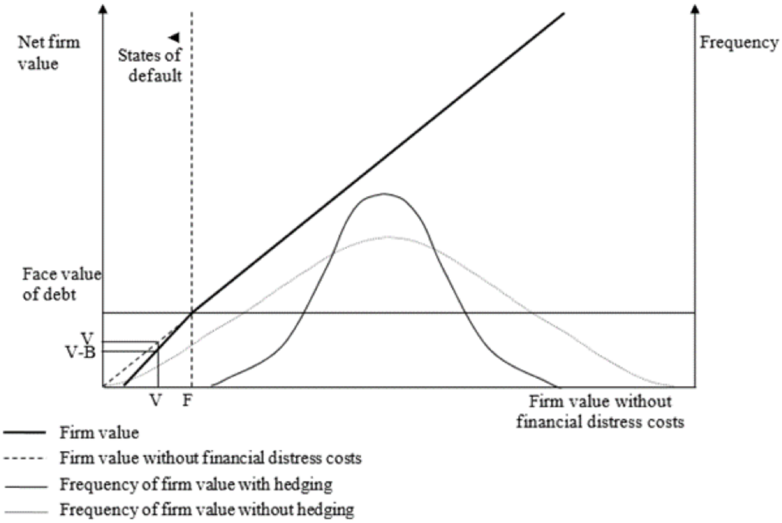
Figure 1 also shows that the firm's net value (dark line) goes below the dotted line to the left of F. This signifies that the difference between the dotted line and the dark line to the left of F represents the financial distress costs. To the right of F, both values are identical; they overlap on the 45-degree line. To the left of F, the firm defaults and needs to disburse the required restructuring costs (for example B for firm value V), which can be interpreted as conditional default costs. Consequently, we observe that the least diversified firm has a positive default probability and therefore positive expected default costs. Its firm value is consequently lower than that of a diversified firm.

Similar arguments can be made regarding stakeholders' costs, which may correspond to higher salaries or risk premiums paid when a firm is less diversified because stakeholders face a higher risk of losing their job or their investment. Suppliers may also be less lenient with respect to credit terms and may charge a premium for this risk. These costs can be represented in the same manner as default costs, which is why we will not repeat the discussion here.

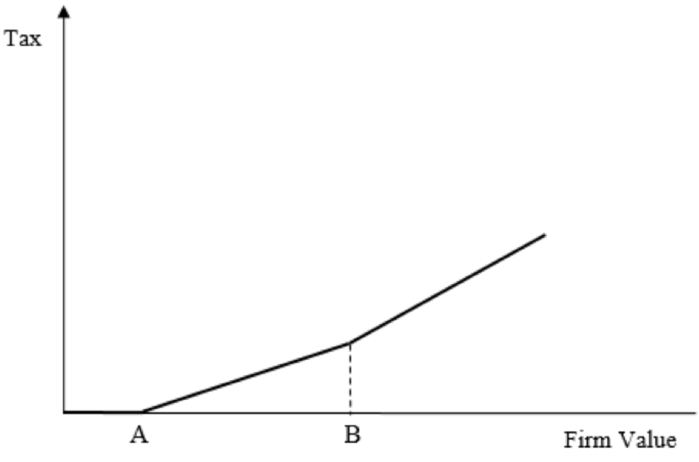
Expected tax payments: Risk management can allow a firm to reduce the expected tax payments when the taxation function is convex with respect to profits or firm value. Figure 2 illustrates this point and provides a realistic representation of the tax code observed in several countries. First, suppose that all the potential end-of-year values are to the right of point B. The local or effective tax function of the firm is therefore linear. Even though, on average, the firm pays a high amount in taxes, it does not have any incentive to hedge its risks in order to reduce its tax payment, because reducing the spread of firm values will not affect the average tax payment. However, a firm whose value can be to the right or left of point B (or A) would be motivated to hedge because its taxation function becomes convex when two or three linear sections are combined. It is the local convexity of the tax function that matters, not the average amount of taxes to be paid, which means that researchers must compute the local convexity of the tax function when they evaluate the effects of tax on risk management. Hedging is beneficial only when

FIGURE 1

HEDGING AND FIRM VALUE



Source: Stulz, 1996.



the local tax function of the firm is convex (Graham and Rogers, 2002; Graham and Smith, 1999; Dionne and Triki, 2013).

Risk management and capital structure: A good risk management strategy may increase a firm's debt capacity. In other words, risk management can be interpreted as a substitute for equity, by reducing the default probability and hence the default risk premium imposed by banks or investors. By reducing the risk premium, hedging can create new investment opportunities financed by debt (Dionne and Triki, 2013; Campello *et al.*, 2011).

Inversely, capital structure can also impact how a firm approaches risk management. To support this argument, Figure 3 shows three density functions corresponding to three firms with very different valuation distributions. The AAA firm has a default probability of 0. BBB has a higher cost of capital, due to its higher default probability. Suppose that BBB's default probability is 5%. Finally, firm C is in financial difficulty with a high default probability, which we estimate at 95%.

Firm AAA does not need risk management to protect itself from financial distress. The firm can borrow easily if necessary and may even speculate if its managers hold private specialized information. The situation of the firm BBB is very different. This firm should hedge in order to decrease its default probability and increase its value. Also, it should not engage in speculative activities. The causality may even go in the other direction for that firm.

What about firm C? It is seemingly impossible for this firm to use risk management as a tool to rectify its financial situation because hedging will actually increase its default probability. Some managers may even speculate in the hopes of being very lucky (last chance) in order to help the firm find a way out. Speculation would consequently have the opposite effect of hedging because it increases the probability of non-default (greater surface to the right of F) by increasing the volatility of the firm's value.

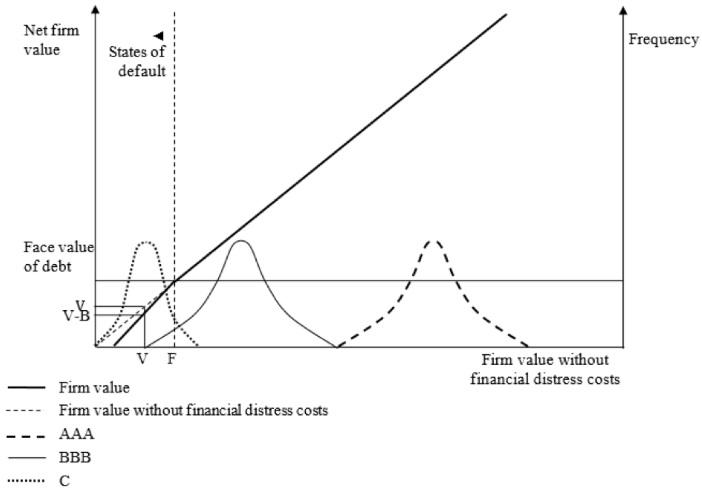
Investment financing: Under asymmetric information, external financial costs of investment are much higher than internal financial costs (Froot *et al.*, 1993). This situation increases the incentives to protect internal financing with risk management.

Risk behavior and corporate governance: Firms whose managers are also shareholders (meaning that they also benefit from the firm's profits) are apparently poorly diversified. Tufano (1996) tested this premise for firms in the gold mining industry. He found that managers who have a large portion of their human capital and compensation invested within their firm wish to protect themselves more. Attributing firm equity to managers is beneficial when it comes to risk management, yet this incentive is often more costly than stock options.

Stulz (1996) explains why firms that compensate managers with stock options may be more lax with respect to risk management. His argument is shown in Figure 4. Managers who hold stock options with a strike price equal to F' are less inclined to hedge, because hedging decreases both the volatility of the firm's shares (which consequently lowers the value of the stock options) and the probability of undertaking personal projects after having exercised the options. This

FIGURE 2

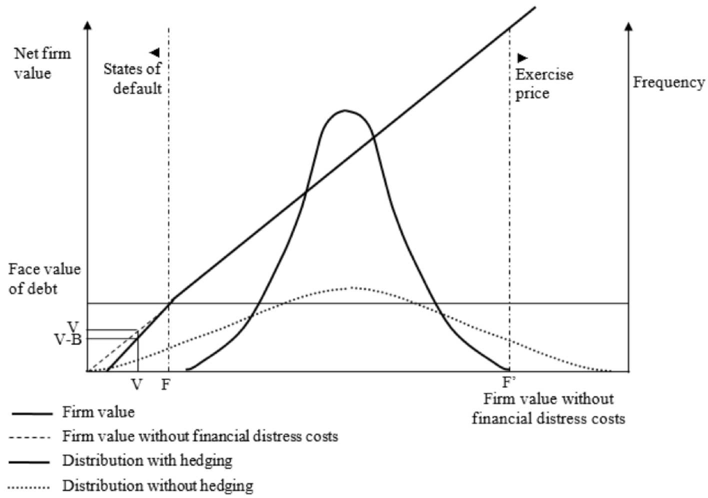
HEDGING AND FIRM CAPITAL STRUCTURE



Source: Stulz, 1996.

FIGURE 3

IMPACT OF MANAGER CALL OPTIONS ON RISK MANAGEMENT



Source: Stulz, 1996.

situation may introduce a corporate governance problem between officers and investors (Dionne *et al.*, 2018b).

The darker density corresponds to a null default probability (to the right of F), but also to a null probability of exercising the managers' stock options (to the left of F'), hence the conflict of interest between managers and shareholders. Given that managers hold stock options, they may prefer the dotted density function, whereas shareholders may prefer the darker density function. This potential conflict of interest is more significant when options are out-of-the-money.

Other motivations: There are many other motivations for firm risk management. They include dividend payments, lack of liquidity, mergers and acquisitions, higher productivity in producing goods and services, and other strategic behaviors (Dionne, forthcoming). The main question is to what extent risk management increases firm value and reduces its risk. We will see in the next section that the current empirical evidence is ambiguous. We argue that this is mainly due to methodological problems.

2. Real implications of corporate risk management: A review

One strand of the corporate hedging literature finds no support for the risk reduction argument and firm value maximization theory. Using a sample of 425 large US corporations from 1991 to 1993, Hentschel and Kothari (2001) concluded that derivative users display economically small differences in their stock return volatility compared with non-users, even for firms with larger derivative holdings. Guay and Kothari (2003) studied the hedging practices of 234 large non-financial firms and found that the magnitude of the derivative positions is economically small compared with firm-level risk exposures and movements in equity values. Jin and Jorion (2006) revisited the question of the hedging premium for a sample of 119 US oil and gas producers from 1998 to 2001. Although they noted that oil and gas betas are negatively related to hedging extent, they also showed that hedging has no discernible effect on firm value. Fauver and Naranjo (2010) studied derivative usage by 1,746 US firms from 1991 to 2000 and asserted that firms with greater agency and monitoring problems exhibited an economically significant negative association of 8.4% between firms' Tobin's q and derivative usage.

In contrast, Tufano (1996, 1998) studied hedging activities of 48 North American gold mining firms from 1990 through March 1994, and found that gold firm exposures (i.e., gold betas) are negatively related to the firm's hedging production. Guay (1999) looked at a sample of 254 non-financial corporations that began using derivatives in the fiscal year of 1991, and reported that new derivative users experienced a statistically and economically significant 5% reduction in stock return volatility compared with a control sample of non-users. Using a sample of S&P 500 non-financial firms for 1993, Allayannis and Ofek (2001) found strong evidence that foreign currency hedging reduces firms' exchange-rate exposure.

Allayannis and Weston (2001) gave the first direct evidence of a positive relationship between currency derivative usage and firm value, (as defined by Tobin's q) and showed that for a sample of 720 non-financial firms, the market value of foreign currency hedgers is 5% higher on average than for non-hedgers.

Carter *et al.* (2006) investigated jet fuel hedging behavior of firms in the US airline industry during the period of 1993-2003 and found an average hedging premium of 12%-16%. Adam and Fernando (2006) examined the outstanding gold derivative positions for a sample of North American gold mining firms for the period of 1989-1999 and observed that derivative use translated into value gains for shareholders because there was no offsetting increase in firms' systematic risk. Bartram *et al.* (2011) explored the effect of hedging on firm risk and value for a large sample of 6,888 non-financial firms from 47 countries in 2000 and 2001. Their evidence suggest that derivatives reduced both total and systematic risk, and are associated with higher firm value, abnormal returns, and larger profits.

Recently, Choi *et al.* (2013) examined financial and operational hedging activities of 73 U.S pharmaceutical and biotech firms during the period of 2001-2006. They found that hedging was associated with higher firm value, and that this enhancement was greater for firms subjected to higher information asymmetry and more growth options. For their sample, they estimated a hedging premium of approximately 13.8%. Pérez-González and Yun (2013) exploited the introduction of weather derivatives in 1997 as a natural experiment for a sample of energy firms. As measured by the market-to-book ratio, they obtain that weather derivatives have a positive effect on firm value. Gay *et al.* (2011) investigated the relationship between derivative use and firms' cost of equity. From a large sample of non-financial firms during the two sub-periods 1992-1996 and 2002-2004, they found that hedgers had a lower cost of equity than non-hedgers by about 24-78 basis points. This reduction mainly came from lower market betas for derivative users. Their results were robust to endogeneity concerns related to derivative use and capital structure decisions. Finally, Hoyt and Liebenberg (2015) find that enterprise risk management increase the value of insurance firms. In their sample of 687 observations, they verify that insurers with ERM have a Tobin's q value 4% higher than other insurers. Aretz and Bartram (2010) reviewed the empirical literature on corporate hedging and firm value.

More recently, Mnasri *et al.* (2017) and Dionne *et al.* (2018a) both demonstrate that using non-linear financial derivatives and short-time horizon derivatives increased firm value by considering a methodology similar to that described in this paper. To our knowledge, this methodology has not yet been applied to analyze the effect of hedging intensity on firm value and risk.

3. Methodology

Endogeneity due to any reverse causality between firm hedging behavior and other firm financial decisions is a crucial concern in hedging studies; it is identified as the major source of inconsistency in past findings. To control for this endogeneity, we study the real effects of hedging using an instrumental variable applied to the essential heterogeneity model. We control for biases related to selection on unobservables and self-selection in the estimation of the Marginal Treatment Effects (MTEs) of hedging extent choice on firm value, risk and accounting performance. A formal discussion of these models will be presented below. We also estimate the Average Treatment Effects (ATEs), which can be interpreted as the mean of the MTEs.

To obtain insight into the true implications of hedging activities on firm value, risk and accounting performance, we classify hedging ratios for oil production during the current fiscal year as the following:

- Low intensity hedging: Below the 25^{th} percentile, which corresponds to a hedging ratio of about 24%;
- High intensity hedging: Exceeds the 75^{th} percentile, which corresponds to a hedging ratio of about 64%.

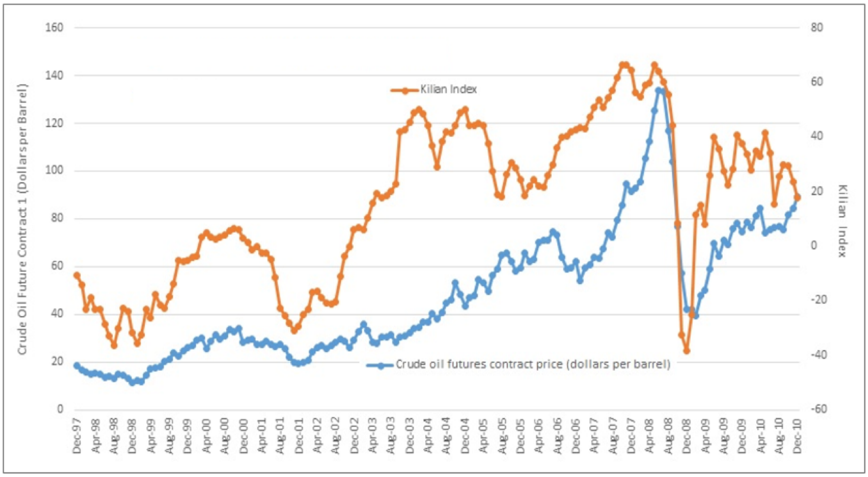
We create a dummy variable that takes the value of one for high intensity hedging and zero for low intensity hedging. We can thus attribute true implications of hedging to either low or high intensity hedging ratios.

3.1 *Instrumental variable*

For the choice of our candidate instrument, we build on our previous research showing a significant impact of oil market conditions (oil spot price and volatility) on oil hedging design in terms of maturity and vehicles (Mnasri *et al.*, 2017; Dionne *et al.*, 2018a). Armed with this empirical evidence, we look for an instrument that can explain the fluctuations of the real oil price and that cannot directly affect the value, riskiness and accounting performance of an oil producer. A large body of economic literature affirms that one of the most important fundamental factors that determines industrial commodity prices is demand pressures or shocks induced by real economic activity. Consequently, we chose the Kilian (2009) index as our instrument. This instrument measures the component of true global economic activity that derives demand for industrial commodities. This index is based on dry cargo (grain, crude oil, coal, iron ore, etc.), single-voyage ocean freight rates, and captures demand shifts in global industrial commodity markets. The Kilian index, constructed monthly, accounts for fixed effects for different routes, commodities and ship sizes. It is also deflated with the US consumer price index and linearly detrended to remove the decrease in real term over time of the dry cargo shipping cost. Kilian (2009) shows that aggregate shocks for industrial commodities cause long swings in the real oil prices. This differs from the increases and decreases in the price of oil induced by oil market-specific supply shocks, which are more transitory. They also differ from shocks related to shifts in the precautionary demand for oil, which arise from uncertainty about expected supply shortfalls relative to expected demand. For our purposes, we calculate the changes in the Kilian (2009) index for each fiscal quarter in the sample. These changes in the index are calculated by taking the index's level at the end of the current fiscal quarter (i.e., at the end of the fiscal quarter's last month), minus its level at the end of the previous fiscal quarter. Figure 5 shows a high correlation of 76.7% between the Kilian index and the crude oil near-month futures contract price, meaning that an increase in demand for industrial commodities is correlated with an increase in futures contract prices. Consequently, oil hedging intensity should have a negative relationship with the Kilian index[2].

FIGURE 4

KILIAN INDEX VERSUS OIL FUTURES CONTRACT PRICE



3.2 *Essential heterogeneity model*

The *essential heterogeneity model* usually begins with a Mincer-like equation (Mincer, 1974), as follows:

$$y_{i,t} = \alpha + \beta \times d_{i,t} + \sum \beta_i \text{Control variables}_{i,t-1} + u_{i,t}, \tag{1}$$

where $y_{i,t}$ is the firm target or the risk and value of an oil producer i at the end of quarter t, and $d_{i,t}$ is the observed value of a dummy variable $D = (0,1)$ rep-

2. As a robustness check, we individualize our instrument by multiplying the changes in the Kilian aggregate index by the individual marginal tax rate, which represents the present value of current and expected future taxes paid on an additional dollar of income earned today as in Shevlin (1990). The marginal tax rate is used as a proxy for the firm's tax structure that measures the tax incentive for hedging (Haushalter, 2000). The marginal tax rate is constructed following the nonparametric procedure developed by Blouin *et al.* (2010). Our results are qualitatively the same, and still MTEs statistically significant albeit with lower significance. They are available from the authors.

resenting whether the oil producer i uses low (0) or high (1) intensity hedging during quarter t. The control variables include a set of observable covariates, namely the earnings per share from operations, investment opportunities, leverage ratio, liquidity, a dividend payout dummy, quantity of oil reserves, oil production uncertainty, geographical diversification in oil production, gas hedging ratio, gas reserves, gas production uncertainty, oil and gas spot prices and volatilities, institutional ownership, CEO shareholding and option-holding, and the number of analysts following the firm (See Table 1 for the definitions of these variables). The term $u_{i,t}$ is an individual-specific error term and β represents the average return from using high intensity hedging.

Two sources of bias could affect the estimates of β. The first is related to the standard problem of selection bias, when $d_{i,t}$ is correlated with $u_{i,t}$. However, this bias should be resolved using instrumental variable (IV) methods, among others. The second source of bias occurs if the returns from using high intensity hedging vary across oil producers (i.e., β is random because of firm non-observed factors that can influence both the firm target and the hedging decision, such as governance or manager risk aversion), even after conditioning on observable characteristics leading to heterogeneous treatment effects. Moreover, oil producers make their hedging level choice (low versus high intensity) with at least partial knowledge of the expected idiosyncratic gains from this decision (i.e., β is correlated with D), leading to selection into treatment or sorting on the gain problem.

Heckman *et al.* (2006) developed an econometric methodology based on IVs to solve the problem of essential heterogeneity (i.e., β is correlated with D) in the estimation of MTEs. Their methodology is built on the generalized Roy model, which is an example of treatment effects models for economic policy evaluation. The generalized Roy model involves a joint estimation of an observed continuous outcome and its binary treatment. Let (Y_0, Y_1) be the potential outcomes observed under the counterfactual states of treatment (Y_1) and no treatment (Y_0); these outcomes are supposed to depend linearly upon observed characteristics X and unobservable characteristics (U_0, U_1) as follows:

$$Y_1 = \alpha_1 + \beta + \beta_1 X + U_1, \tag{2}$$

$$Y_0 = \alpha_0 + \beta_0 X + U_0, \tag{3}$$

where β is the benefit related to the treatment $D = 1$.

The selection process is represented by $I_D = \gamma Z - V$, which depends on the observed values of the Z variables and an unobservable disturbance term V. The selection process, related to whether low or high intensity hedging is used, is

TABLE 1

VARIABLE DEFINITIONS, CONSTRUCTION AND SOURCES

Variable definition	**Construction**	**Source**
EPS from operations	Earnings Per Share from operations calculated on a quarterly basis.	Compustat
Investment opportunities	Quarterly capital expenditure (CAPEX) scaled by net property, plant and equipment at the beginning of the quarter.	Compustat
Leverage ratio	Book value of total debts scaled by the book value of total assets.	Compustat
Liquidity	Book value of cash and cash equivalents divided by the book value of current liabilities.	Manually constructed
Dividend payout	Dummy variable for dividends declared during the quarter.	Manually constructed
Oil reserves	The quantity (in millions of barrels) of the total proved developed and undeveloped oil reserves (in logarithm). This variable is disclosed annually. We repeat the same observation for the same fiscal year quarters.	Bloomberg and 10-K reports
Institutional ownership	Percentage of firm shares held by institutional investors.	Thomson Reuters
Geographical diversification in oil (gas) production activities	Equals $1-\sum_{i=1}^{N}\left(\frac{q_i}{q}\right)^2$, where q_i is the daily oil (gas) production in region i (Africa, Latin America, North America, Europe and the Middle East) and q is the firm's total daily oil (gas) production.	Manually constructed
Oil production risk	Coefficient of variation of daily oil production. This coefficient is calculated for each firm by using rolling windows of 12 quarterly observations. Daily oil production is disclosed annually. We repeat the same observation for the same fiscal year quarters.	Manually constructed Bloomberg and 10-K reports
Oil spot price	Oil spot price represented by the WTI index on the NYMEX at the end of the current quarter.	Bloomberg
Oil price volatility	Historical volatility (standard deviation) using daily spot prices during the quarter.	Manually constructed
Hedging ratio of the expected future gas production	The average hedging ratio of the expected future gas production over the subsequent five fiscal years. For each fiscal year, we measure the gas hedging ratio by the Fraction of Production Hedged (FPH) calculated by dividing the notional hedged gas quantity by the expected gas production. We then average these five hedging ratios.	Manually constructed
Gas spot price	Constructed as an average index established from principal locations' indices in the United States (Gulf Coast, Henry Hub, etc.).	Bloomberg
Gas price volatility	Historical volatility (standard deviation) using the daily spot prices during the quarter.	Manually constructed

TABLE 1 (continued)

VARIABLE DEFINITIONS, CONSTRUCTION AND SOURCES

Variable definition	Construction	Source
Gas reserves	The quantity of the total proved developed and undeveloped gas reserves. This variable is disclosed annually. We repeat the same observation for the same fiscal year quarters. The raw value of this variable (in billions of cubic feet) is used in Table 2 (Summary Statistics). The logarithm transformation of this variable is used elsewhere.	Bloomberg and 10-K reports
Gas production risk	Coefficient of variation of daily gas production. This coefficient is calculated for each firm by using rolling windows of 12 quarterly observations. Daily gas production is disclosed annually. We repeat the same observation for the same fiscal year quarters.	Manually constructed Bloomberg and 10-K reports
CEO stockholding	The percentage of firm's stocks held by the CEO at the end of the quarter.	Thomson Reuters
CEO option holding	Number of stock-options held by the firm's CEO ($\times$ 10,000) at the end of the quarter.	Thomson Reuters
Number of analysts	Number of analysts following a firm and issued a forecast of the firm's quarterly earnings.	I/B/E/S
	Dependent variables	
Firm Tobin's *q* (in log)	Calculated by the ratio of the market value of equity plus the book value of debt plus the book value of preferred shares divided by the book value of total assets(in log).	CRSP/Compustat
Return on equity	Quarterly net income divided by the book value of common equity.	Compustat
Systematic risk	Measure of the oil producer stock return's sensitivity to the CRSP value weighted portfolio estimated using the Fama and French (1993) and Carhart (1997) four factors and the daily returns on the one-month crude oil futures and the one-month natural gas futures. The estimation is based on daily returns during each quarter in the sample.	CRSP/Bloomberg
Idiosyncratic risk	Measured by the Fama and French (1993) and Carhart (1997) four factors residual estimation's volatility and the daily returns on the one-month crude oil futures and the one-month natural gas futures. The estimation is based on daily returns during each quarter in the sample.	CRSP/Bloomberg
Oil beta	Measure of the oil producer stock return's sensitivity to the daily changes in the oil futures price estimated using the same methodology employed for the systematic risk.	CRSP/Bloomberg

linked to the observed outcome through the latent variable I_D, which gives the dummy variable D representing the treatment status:

$$D = \begin{cases} 1 \text{ if } I_D > 0, \\ 0 \text{ if } I_D \leq 0, \end{cases} \tag{4}$$

where the vector of Z variables observed includes the variable Z_{IV} and all the components of X in the outcome equation. The variable Z_{IV} satisfies the following constraints: $Cov(Z_{IV}, U_0) = 0$, $Cov(Z_{IV}, U_1) = 0$, and $\gamma \neq 0$. The unobservable set of (U_0, U_1, V) is assumed to be statistically independent of Z, given X. We must first estimate the probability of participation in high intensity hedging or the propensity score and then analyze how this participation affects firm values and risks. To do so, we apply the parametric estimation method.

We can assume the joint normality of the outcome's unobservable components and decision equations $(U_0, U_1, V) \sim N(0, \Sigma)$, where Σ is the variance-covariance matrix of the three unobservable variables and $\sigma_{1V} = Cov(U_1, V)$, $\sigma_{0V} = Cov(U_0, V)$, and $\sigma_{VV} = 1$, following standard hypotheses. Under this parametric approach, the discrete choice model is a conventional probit with $V \sim N(0, 1)$ and where the propensity score is given by:

$$P(z) = Pr(D = 1|Z = z) = Pr(\gamma z > V) = \Phi(\gamma z), \tag{5}$$

where $\Phi(\cdot)$ is the cumulative distribution of a standard normal variable. The term $P(z)$, called the probability of participation in hedging activity or propensity score, denotes the selection probability of using high intensity hedging conditional on $Z = z$ (i.e., $D = 1$). We can therefore write:

$$\Phi(\gamma Z) > \Phi(V) \Leftrightarrow P(Z) > U_D, \tag{6}$$

where

$$U_D = \Phi(V) \text{ and } P(Z) = \Phi(\gamma Z) = Pr(D = 1|Z).$$

The term U_D is a uniformly distributed random variable between zero and one representing different quantiles of the unobserved component V in the selection process. These two quantities, $P(Z)$ and U_D, play a crucial role in essential heterogeneity models. The quantity $P(Z)$ could be interpreted as the probability of going into treatment and U_D, interpreted as a measure of individual-specific resistance to undertaking treatment (or, alternatively, the propensity to not being treated as a high intensity hedger). In our case, the higher the $P(Z)$, the more the oil producer is induced to hedging its oil production to a larger extent due to Z. Conversely, the higher the U_D the more resistant the oil producer is to using higher hedging extents due to a larger unobserved component. $P(Z) = U_D$ is thus the margin of indifference for oil producers that are indifferent between low and high intensity hedging.

The marginal treatment effects (MTEs) can be defined as follows:

$$\text{MTE}(X=x,U_D=u_D)=(\alpha_1+\beta-\alpha_0)+(\beta_1-\beta_0)x+(\sigma_{1V}-\sigma_{0V})\Phi^{-1}(u_D). \tag{7}$$

In our application, estimation of the parameters follows the parametric method proposed by Brave and Walstrum (2014) by using the *MARGTE* (Stata) command (see also Carneiro *et al.*, 2010, for a description of the different estimation techniques that allow the computation of treatment effects in the context of *essential heterogeneity* models). Under the assumption of joint normality, σ_{1V} and σ_{0V} are the inverse Mills ratios coefficients. They are estimated separately along with the other parameters in the two following equations:

$$E(Y|X=x,D=1,P(Z)=p)=\alpha_1+\beta+X\beta_1+\sigma_{1V}\left(-\frac{\phi(\Phi^{-1}(p))}{p}\right), \tag{8}$$

$$E(Y|X=x,D=0,P(Z)=p)=\alpha_0+\beta+X\beta_0+\sigma_{0V}\left(\frac{\phi(\Phi^{-1}(p))}{1-p}\right), \tag{9}$$

to obtain the MTE values. Using the estimated propensity score:

$$\text{MTE}(X=x,U_D=u_D)=\alpha_1+\beta-\alpha_0+\left(\hat{\beta}_1-\hat{\beta}_0\right)x'+(\hat{\sigma}_{1V}-\hat{\sigma}_{0V})\Phi^{-1}(u_D). \tag{10}$$

Intuitively, how the MTE evolves over the range of U_D informs us about the heterogeneity in treatment effects among oil producers. That is, how the coefficient β is correlated with the treatment indicator D in (1). Equivalently, the estimated MTE shows how the increment in the marginal firm value, risk and performance by going from choice 0 to choice 1 varies with different quantiles of the unobserved component V in the choice equation. In our case, whether MTE increases or decreases with U_D tells us whether the coefficient β in (1) is negatively or positively correlated with the latent tendency of using high intensity hedging for oil production.

4. Sample construction and characteristics

4.1 *Sample construction*

A preliminary list of 413 US oil producers with the primary Standard Industrial Classification (SIC) code 1311 (crude petroleum and natural gas) was extracted from Bloomberg. Only firms that met the following criteria were retained: They have at least five years of oil reserve data during the period 1998-2010, their

10-K and 10-Q reports are available from the EDGAR website, and the firm is covered by Compustat. The filtering process produced a final sample of 150 firms with an unbalanced panel of 6,326 firm-quarter observations.

Data on these firms' financial and operational characteristics was gathered from several sources. Data regarding financial characteristics was taken from the Compustat quarterly dataset held by Wharton Research Data Services (WRDS). Other items related to institutional shareholding were taken from the Thomson Reuters dataset maintained by WRDS. Data related to oil and gas reserves and production quantities was taken from Bloomberg's annual data set, and subsequently verified and supplemented by data hand-collected directly from 10-K annual reports. Quarterly data about oil producers' hedging activities were hand-collected from 10-K and 10-Q reports.

4.2 *Descriptive statistics*

Descriptive statistics were computed for the pooled quarterly dataset. Table 2 gives the mean, median, first quartile, third quartile, and standard deviations for the 150 US oil producers in the sample. Table 2 shows that oil producers report average earnings per share from operations of US$ 8 with a highly right-skewed distribution. Oil producers in the sample invest on average the equivalent of 13% of their net property, plant, and equipment in capital expenditure; however, there is a wide variation. Interestingly, statistics also indicate that oil producers have high leverage ratios and maintain high levels of liquidity reserves, as measured by cash on hand and short-term investments. The average leverage ratio is about 52% and the average quick ratio is about 1.55. One-fourth of the oil producers in the sample pay dividends. The mean quantity of developed and undeveloped oil (gas) reserves, in log, is 2.135 (4.503), which corresponds to a quantity of about 276 million barrels of oil for oil reserves and 1,504 billion cubic feet for gas reserves.

The Herfindahl indices, which measure geographical dispersion of daily oil and gas production, have an average value of 0.10 for oil and 0.063 for gas, indicating that oil and gas producing activities are highly concentrated in the same region. Table 2 further shows relatively stable oil and gas production quantities, with an average coefficient of variation in daily production of 0.27 for both oil and gas. Institutional ownership has a mean (median) of about 34% (22%), and varies from no institutional ownership for the first quartile to higher than 69% for the top quartile. On average, the CEO holds 0.4% of the oil producer's outstanding common shares and about 17,500 stock options, albeit with substantial dispersion as measured by the standard deviation. The mean (median) number of analysts following an oil producer on a quarterly basis is 5 (2) analysts.

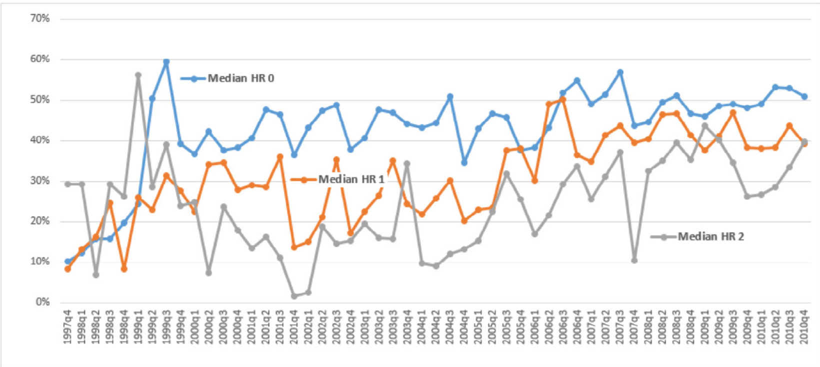
Table 3 provides pairwise correlations of oil producers' characteristics. Except for the correlation coefficients for the number of analysts with respectively oil reserves, gas reserves and institutional ownership, all of the pairwise correlations are below 0.5.

4.3 *Oil hedging activity*

Oil hedging occurred in 2,607 firm-quarters, which represents 41.21% of the firm-quarters in the sample. Following Haushalter (2000), the oil hedging ratio for each fiscal year is calculated by dividing the hedged notional quantities by the predicted oil production quantities. We collect data relative to hedged notional quantities for each fiscal year from the current year to five years ahead. Oil production quantities are predicted for each fiscal year based on the daily oil production realized in the current fiscal year. Table 4 shows descriptive statistics for these hedging ratios by horizon and indicates an average hedging ratio for near-term exposures (i.e., hedging ratio for the current fiscal year, HR0) of around 46%. Oil hedging for subsequent fiscal years is decreasing steadily across horizons in terms of extent and frequency. Figure 6 provides time series plots of median hedge ratios and shows that hedging intensities follow a median reverting process, particularly for near-term hedges (HR0). Figure 6 also indicates higher variability in the hedging intensities for subsequent years (HR1 and HR2).

FIGURE 5

MEDIAN OIL HEDGING RATIOS BY HORIZON



NOTE : This figure plots how the median hedging ratios for the aggregate oil hedging portfolio evolved over time from quarter 4-1997 to 4-2010. *HR0* stands for the hedging ratio of the current fiscal year, *HR1* for the subsequent year and *HR2* for two years ahead.

TABLE 2

VARIABLE DEFINITIONS, CONSTRUCTION AND SOURCES

Variables	Obs.	Mean	Median	1st quartile	3rd quartile	STD
EPS from operations	6,127	8.181	0.090	−0.030	0.490	284.693
Investment opportunities	6,295	0.129	0.062	0.035	0.107	2.333
Leverage	6,044	0.516	0.523	0.342	0.659	0.285
Liquidity	6,069	1.555	0.275	0.079	0.850	5.334
Dividend payout	6,326	0.265	0.000	0.000	1.000	0.442
Oil reserves (in log)	6,180	2.135	2.158	0.151	4.041	2.882
Institutional ownership	6,326	0.337	0.216	0.000	0.687	0.345
Geographic diversification (oil)	6,178	0.101	0.000	0.000	0.000	0.233
Geographic diversification (gas)	6,180	0.063	0.000	0.000	0.000	0.183
Oil price volatility	6,318	3.280	2.371	1.608	3.655	2.829
Oil spot price	6,318	49.265	43.450	26.800	69.890	28.044
Oil production risk	6,246	0.272	0.169	0.080	0.344	0.302
Gas hedge ratio	6,326	0.070	0.000	0.000	0.070	0.153
Gas spot price	6,318	5.139	4.830	3.070	6.217	2.617
Gas price volatility	6,318	0.733	0.500	0.289	1.111	0.560
Gas reserves (in log)	6,196	4.503	4.664	2.764	6.396	2.836
Gas production risk	6,222	0.273	0.181	0.092	0.360	0.281
CEO % of stockholding	6,028	0.004	0.000	0.000	0.002	0.017
CEO number of options (× 10,000)	6,326	17.439	0.000	0.000	12.000	68.176
Number of analysts	6,326	5.108	2.000	0.000	8.000	6.914

NOTE : This table provides financial and operational statistics for the 150 US oil producers, and oil price and volatility for the 1998 to 2010 period. See Table 1 for more details on the construction of these variables.

TABLE 3

CORRELATION MATRIX

	EPS from operations	**Investment opportunities**	**Leverage**	**Liquidity**	**Dividend payout**	**Oil reserves (in log)**	**Institutional ownership**	**Geographic diversification (oil)**	**Geographic diversification (gas)**	**Oil production risk**
EPS from operations	1									
Investment opportunities	−0.000442	1								
Leverage	0.00731	−0.0233	1							
Liquidity	−0.00298	0.0261	−0.314***	1						
Dividend payout	−0.00862	−0.0560***	0.0486***	−0.0587***	1					
Oil reserves (in log)	0.00536	−0.0840***	0.239***	−0.231***	0.518***	1				
Institutional ownership	−0.0164	−0.0398**	0.168***	−0.174***	0.308***	0.575***	1			
Geographic diversification (oil)	−0.00573	−0.0438***	0.0258	−0.0660***	0.404***	0.525***	0.278***	1		
Geographic diversification (gas)	−0.00436	−0.0382**	0.0247	−0.0631***	0.353***	0.475***	0.185***	0.753***	1	
Oil production risk	−0.0105	0.118***	−0.00154	0.0422**	−0.193***	−0.300***	−0.175***	−0.159***	−0.147***	1
Gas hedge ratio	−0.00793	0.0284*	0.167***	−0.105***	0.0854***	0.0693***	0.0757***	−0.0859***	−0.104***	0.0719***

TABLE 3 (continued)

CORRELATION MATRIX

	EPS from operations	**Investment opportunities**	**Leverage**	**Liquidity**	**Dividend payout**	**Oil reserves (in log)**	**Institutional ownership**	**Geographic diversification (oil)**	**Geographic diversification (gas)**	**Oil production risk**
Gas reserves (in log)	0.00625	−0.0627***	0.335***	−0.312***	0.538***	0.759***	0.583***	0.352***	0.297***	−0.229***
Gas production risk	−0.0147	0.137***	−0.0757***	0.0526***	−0.245***	−0.232***	−0.219***	−0.173***	−0.165***	0.441***
CEO % of stockholding	−0.00427	−0.00617	−0.00320	−0.0326*	−0.0704***	−0.0287*	−0.0376**	−0.0372**	−0.0224	0.0349**
CEO number of options (× 10,000)	−0.00477	−0.0118	0.0226	−0.0427**	0.0260	0.0690***	0.0453***	0.0513***	0.0379**	0.0160
Number of analysts	−0.0116	−0.0569***	0.149***	−0.174***	0.493***	0.688***	0.647***	0.480***	0.346***	−0.194***
Oil price volatility	−0.00968	0.00680	−0.00430	0.0175	0.00975	0.0232	0.145***	−0.00447	0.00170	0.0306*
Oil spot price	−0.0149	0.0147	−0.0323*	0.0331*	0.00413	0.0375**	0.230***	0.00596	0.00365	0.0320*
Gas spot price	−0.0123	0.0585***	−0.0366**	0.0144	−0.0100	0.00497	0.149***	0.0136	−0.00450	0.0442***
Gas price volatility	−0.00973	0.0588***	−0.0335*	0.0168	−0.0184	0.00797	0.107***	0.00985	−0.00590	0.0167

TABLE 3 (continued)

CORRELATION MATRIX

	Gas hedge ratio	**Gas reserves (in log)**	**Gas production risk**	**CEO % of stockholding**	**CEO number of options (× 10,000)**	**Number of analysts**	**Oil price volatility**	**Oil spot price**	**Gas spot price**	**Gas price volatility**
Gas hedge ratio	1									
Gas reserves (in log)	0.215***	1								
Gas production risk	0.0554***	−0.269***	1							
CEO % of stockholding	−0.0109	−0.0338*	0.00917	1						
CEO number of options (× 10,000)	−0.00556	0.0721***	0.00593	0.815***	1					
Number of analysts	0.0813***	0.733***	−0.266***	−0.0856***	0.0440***	1				
Oil price volatility	0.182***	0.0307*	0.0500***	−0.0586***	−0.0259	0.110***	1			
Oil spot price	0.254***	0.0378**	0.0721***	−0.0758***	−0.0280*	0.150***	0.573***	1		
Gas spot price	0.0988***	0.0132	0.0749***	−0.00896	0.0362**	0.0904***	0.378***	0.635***	1	
Gas price volatility	0.0601***	0.0117	0.0469***	−0.00421	0.0292*	0.0553***	0.273***	0.388***	0.605***	1

NOTE : * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

TABLE 4

SUMMARY STATISTICS FOR OIL HEDGING RATIOS BY HORIZON

Variables	Obs.	Mean	Median	1st quartile	3rd quartile	STD
HR0	2,587	46.070%	44.564%	24.315%	63.889%	27.876%
HR1	1,723	38.328%	36.043%	16.437%	54.737%	27.338%
HR2	907	30.848%	26.798%	9.526%	46.392%	25.680%
HR3	431	27.352%	19.946%	7.340%	43.654%	25.777%
HR4	185	23.254%	14.686%	7.215%	33.860%	24.589%
HR5	61	21.887%	19.685%	4.563%	38.933%	18.171%

NOTE : This table reports summary statistics for oil hedging ratios (HR) by horizon (from the current fiscal year HR0 to five fiscal years ahead HR5).

4.4 *Univariate tests*

Table 5 reports tests of differences between the means and medians of independent variables by oil hedging intensity. We classify the hedging ratios for the oil production over the current fiscal year (HR0) as (1) low hedging intensity, i.e., below the 25th percentile, and (2) high hedging intensity, which exceeds the 75th percentile. We also create a dummy variable that takes the value of zero for low hedging intensity and one for high hedging intensity. The means are compared by using a t-test that assumes unequal variances; the medians are compared by using a nonparametric Wilcoxon rank-sum Z-test.

The univariate analysis reveals considerable differences in oil producers' characteristics between hedging intensities. Results show that oil producers with less operational profitability and higher investment opportunities hedge to a greater extent. These findings corroborate the prediction of Froot *et al.* (1993) that firms hedge to protect their investment programs' internal financing. Results further indicate that oil hedging intensity is positively related to the level of financial constraints. In fact, oil producers with high hedging intensities have higher leverage ratios, lower liquidity levels, and pay smaller dividends. These findings corroborate the conjecture that financially constrained firms hedge more in order to decrease their default probability and increase their value. Univariate tests also show that oil producers that hedge to higher extents have lower oil and gas reserves, higher production uncertainty, and are less diversified geographically, thus suggesting that operational constraints motivate more hedging.

TABLE 5

OIL PRODUCERS' CHARACTERISTICS BY OIL HEDGING INTENSITY

	(1)			(2)			(1) vs. (2)
	High quartile			Low quartile			
Variables	**Obs.**	**Mean**	**Median**	**Obs.**	**Mean**	**Median**	**t-Stat** **Z-score**
EPS from operations	626	0.257	0.180	631	0.425	0.370	1.889* 5.769***
Investment opportunities	629	0.099	0.062	632	0.080	0.059	−2.170** −0.330
Leverage	627	0.655	0.621	632	0.548	0.530	−8.449*** −10.245***
Liquidity	631	0.335	0.104	632	0.484	0.211	2.240** 8.057***
Dividend payout	641	0.282	0.000	632	0.523	1.000	9.045*** 8.778***
Oil reserves (in log)	641	3.498	3.464	632	4.137	4.292	6.384*** 5.600***
Institutional ownership	641	0.473	0.511	632	0.578	0.726	5.768*** 5.287***
Geographic diversification (oil)	641	0.046	0.000	632	0.227	0.000	13.997*** 12.662***
Geographic diversification (gas)	635	0.028	0.000	632	0.135	0.000	10.857*** 11.431***
Oil production risk	641	0.259	0.167	632	0.195	0.129	−4.816*** −3.940***
Gas hedge ratio	641	0.229	0.163	632	0.040	0.000	−17.498*** −17.556***
Gas reserves (in log)	632	5.623	5.586	630	6.364	6.382	7.245*** 8.043***
Gas production risk	641	0.268	0.193	632	0.193	0.142	−6.185*** −7.113***

TABLE 5 (continued)

OIL PRODUCERS' CHARACTERISTICS BY OIL HEDGING INTENSITY

	(1)			(2)			(1) vs. (2)
	High quartile			Low quartile			
Variables	**Obs.**	**Mean**	**Median**	**Obs.**	**Mean**	**Median**	**t-Stat** **Z-score**
CEO % of stockholding	626	0.007	0.000	630	0.003	0.000	−2.307** 2.755***
CEO number of options (in log)	641	30.123	0.000	632	20.798	6.000	−1.524 4.196***
Number of analysts	641	6.566	4.000	632	10.710	9.500	9.500*** 9.262***

Regarding risk behavior and corporate governance, we find that managerial stockholdings are, on average, greater for oil producers using high intensity oil hedging. Managers with greater equity stakes are poorly diversified (i.e., their human capital and wealth depend on firm performance) and tend to protect themselves by directing their firms to engage in risk management, as Smith and Stulz (1985) advance. The mean comparison for managerial stockholding reveals no significant differences across hedging intensities. However, the median comparison indicates that managerial option holding is greater for low intensity hedgers. This finding corroborates Smith and Stulz (1985) and Tufano (1998) conjecture that risk-averse managers with higher option holdings will prefer less (or even no) hedging to increase the utility of their options due to the convexity of the option's payoff. However, this depends on the moneyness of the option contracts. Looking at institutional ownership and the number of analysts, we find that they are, on average, lower for users with higher hedge intensities, suggesting that oil producers may engage in more hedging to alleviate problems related to weak governance and monitoring, and information asymmetry. With the exception of managerial stockholding, the comparison of medians gives the same results.

5. MULTIVARIATE RESULTS

In Table 6, we estimate the choice equation by a probit model, leading to the estimation of the propensity score of using high intensity oil hedging. The dependent variable is a dummy variable that takes the value of one for high intensity hedging and zero for low intensity hedging, as defined previously. Regressors in the choice equation are our candidate instrument (the change in the Kilian index) and the set of control variables presented above. The results show that the Kilian index appears to be a strong predictor of hedging intensity choice, with an economically and statistically significant negative coefficient, suggesting that oil producers tend to use low intensity hedging in periods of increasing aggregate demand for industrial commodities. This occurs because crude oil prices and consequently, derivative prices, are more likely to increase when driven by vigorous real economic activity. We also observe that many other firm variables are statistically significant, with signs consistent with risk management theory such as leverage, liquidity, dividend payout, oil reserves, geo-diversification, and market variables used as controls.

TABLE 6

FIRST-STEP OF THE ESSENTIAL HETEROGENEITY MODELS

Variables	Tobin's *q*	ROE	Systematic risk	Oil beta	Idiosyncratic risk
Δ Kilian index	−0.5910**	−0.6733**	−0.6283**	−0.6283**	−0.6283**
	(0.301)	(0.305)	(0.307)	(0.307)	(0.307)
EPS from operations	−0.0117	−0.0276	−0.0110	−0.0110	−0.0110
	(0.033)	(0.034)	(0.034)	(0.034)	(0.034)
Investment opportunities	0.3001	0.2723	0.2070	0.2070	0.2070
	(0.428)	(0.430)	(0.433)	(0.433)	(0.433)
Leverage	0.9687***	1.0191***	1.1282***	1.1282***	1.1282***
	(0.238)	(0.239)	(0.266)	(0.266)	(0.266)
Liquidity	−0.1451***	−0.1482***	−0.1449***	−0.1449***	−0.1449***
	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)
Dividend payout	−0.3878***	−0.4002***	−0.3963***	−0.3963***	−0.3963***
	(0.115)	(0.115)	(0.116)	(0.116)	(0.116)
Oil reserves	0.2766***	0.2719***	0.2842***	0.2842***	0.2842***
	(0.040)	(0.041)	(0.042)	(0.042)	(0.042)
Institutional ownership	0.1037	0.1114	0.0197	0.0197	0.0197
	(0.170)	(0.171)	(0.175)	(0.175)	(0.175)
Geo diversification (oil)	−1.1723***	−1.1766***	−1.1884***	−1.1884***	−1.1884***
	(0.265)	(.266)	(0.266)	(0.266)	(0.266)
Geo diversification (gas)	−1.3415***	−1.3287***	−1.3203***	−1.3203***	−1.3203***
	(0.378)	(0.379)	(0.379)	(0.379)	(0.379)
Oil volatility	−0.0576***	−0.0529**	−0.0613***	−0.0613***	−0.0613***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Oil spot price	0.0068***	0.0069***	0.0067**	0.0067**	0.0067**
	(0.002)	(.002)	(0.002)	(0.002)	(0.002)
Oil production risk	0.2000	0.1964	0.2490	0.2490	0.2490
	(0.239)	(0.239)	(0.244)	(0.244)	(0.244)
Gas hedging ratio	4.6209***	4.5688***	4.5824***	4.5824***	4.5824***
	(0.401)	(0.402)	(0.405)	(0.405)	(0.405)

TABLE 6 (continued)

FIRST-STEP OF THE ESSENTIAL HETEROGENEITY MODELS

Variables	Tobin's *q*	ROE	Systematic risk	Oil beta	Idiosyncratic risk
Gas spot price	−0.0164	−0.0138	−0.0192	−0.0192	−0.0192
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
Gas volatility	0.0006	−0.0061	0.0070	0.0070	0.0070
	(0.098)	(0.099)	(0.100)	(0.100)	(0.100)
Gas reserves	−0.1096**	−0.1035**	−0.1402***	−0.1402***	−0.1402***
	(0.045)	(.045)	(0.047)	(0.047)	(0.047)
Gas production risk	−0.2050	−0.1562	−0.2894	−0.2894	−0.2894
	(0.265)	(0.268)	(0.272)	(0.272)	(0.272)
CEO % of stockholding	10.6998	10.5728	10.8800*	10.8800*	10.8800*
	(6.546)	(6.556)	(6.592)	(6.592)	(6.592)
CEO number of options	0.0018	0.0018	0.0018	0.0018	0.0018
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of analysts	−0.0231**	−0.0235**	−0.0155	−0.0155	−0.0155
	(0.009)	(.009)	(0.010)	(0.010)	(0.010)
Constant	−1.0224***	−1.0801***	−0.9402***	−0.9402***	−0.9402***
	(0.278)	(0.281)	(0.287)	(0.287)	(0.287)
Observations	1,178	1,173	1,133	1,133	1,133
R^2	0.3190	0.3237	0.3177	0.3177	0.3177

NOTE : This table provides the results of the probit regressions corresponding to the first step of the essential heterogeneity model related to oil hedging extent choice. The dependent variable takes the value of one if the oil producer has high intensity oil hedging and zero if it has low intensity oil hedging. High intensity oil hedging exceeds the 75^{th} percentile, which corresponds to a hedging ratio of 64% of the oil production for the current fiscal year, and low intensity hedging are below the 25^{th} percentile, which corresponds to a hedging ratio of 24%. The instrument variable used is the changes in the Kilian index. All the variables are defined in Table 1. Independent variables are included in lagged values (first lag). Standard errors are reported in parentheses. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

5.1 *Firm value*

Table 7 reports the results of the outcome equation's estimation with respect to firm value. The output in Table 7 gives the estimations for both the treated and untreated groups[3]. The outcome equation also indicates the average treatment effect (ATE), which captures the expected average benefit associated with the inducement in the treatment (i.e., high intensity hedging in our case), conditional on observable independent variables. The ATE coefficient is positive and highly statistically significant, meaning that observable factors influence firm value. Further, Table 7 shows that oil volatility is significantly related to Tobin's q for both user types, as well as gas spot price and number of analysts. The negative sign for oil price volatility indicates that investors prefer lower exposure to oil price fluctuations. This negative effect is statistically similar for the two groups.

Importantly, gas spot price is significantly negatively related to firm value for oil producers using high intensity hedging only. When gas price is higher, investors tend to penalize oil producers with high intensity hedging that do not allow them to benefit from this upward potential. Importantly, the propensity of non-inducement in high intensity oil hedging is positively affected by the inverse Mills ratio (K variable), and the difference in the sigma coefficients is statistically significant. Similar results are observed for the significance of observable variables in Table 7 for the risk measures (systematic risk, idiosyncratic risk and oil beta) and ROE, but the average treatment effect (ATE) of hedging with intensity is not statistically significant for oil beta and ROE.

3. The treated group consists of high intensity hedgers, whereas the untreated group consists of low intensity hedgers. We use the Stata routine MARGTE developed by Brave and Walstrum (2014) to estimate the model of essential heterogeneity. We use the parametric normal approximation of the MTE with bootstrapped standard errors corrected for within-firm clustering. We run 500 replications.

TABLE 7

SECOND-STEP OF THE ESSENTIAL HETEROGENEITY MODELS

	(1)		(2)		(3)		(4)		(5)	
	Tobin's *q*		Systematic risk		Idiosyncratic risk		Oil Beta		ROE	
Variables	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**
EPS from operations	0.0013	−0.0021	0.0305**	0.0457**	0.0004	−0.0004	0.0032	−0.0027	0.0051	0.0068
	(0.008)	(0.011)	(0.015)	(0.022)	(0.001)	(0.001)	(0.006)	(0.007)	(0.021)	(0.025)
Investment opportunities	0.0427	0.2631	0.2029	−0.2217	−0.0017	−0.0112	−0.1090*	−0.0750	−0.1432	0.1957
	(0.215)	(0.240)	(0.134)	(0.290)	(0.004)	(0.008)	(0.056)	(0.130)	(0.528)	(0.127)
Leverage	0.0941	−0.2703	−0.0257	0.6315*	0.0254***	0.0379***	0.0174	0.1644	0.2391*	−0.0857
	(0.196)	(0.215)	(0.238)	(0.370)	(0.009)	(0.007)	(0.096)	(0.101)	(0.134)	(0.201)
Liquidity	0.0379	0.0679	−0.1322**	−0.0530	−0.0002	−0.0017	−0.0133	−0.0171	−0.0170	0.0331
	(0.039)	(0.050)	(0.059)	(0.068)	(0.002)	(0.001)	(0.028)	(0.022)	(0.023)	(0.027)
Dividend payout	0.1049	0.0343	−0.2486**	−0.3112**	−0.0058*	−0.0081**	−0.0732**	−0.1026**	0.0062	0.0535
	(0.074)	(0.085)	(0.100)	(0.121)	(0.004)	(0.003)	(0.034)	(0.046)	(0.048)	(0.057)
Oil reserves	−0.0593*	−0.0391	0.0181	0.1034	−0.0018	−0.0001	−0.0035	0.0403	0.0802***	0.0025
	(0.031)	(0.042)	(0.055)	(0.066)	(0.001)	(0.002)	(0.016)	(0.026)	(0.028)	(0.023)
Institutional ownership	0.1735*	0.1145	0.2306	0.1319	−0.0022	−0.0111***	0.0669	0.0486	0.0326	−0.0226
	(0.091)	(0.097)	(0.190)	(0.132)	(0.003)	(0.004)	(0.044)	(0.039)	(0.054)	(0.065)
Geo diversification (oil)	−0.0610	0.2242	0.4692	−0.5295**	0.0047	−0.0001	−0.0093	0.0193	−0.2029	0.0120
	(0.212)	(0.161)	(0.310)	(0.239)	(0.007)	(0.006)	(0.114)	(0.085)	(0.124)	(0.120)
Geo diversification (gas)	0.1857	0.0600	−0.6668	−0.1478	−0.0100	−0.0128	0.0353	−0.1382	−0.3187	0.0106
	(0.237)	(0.164)	(0.975)	(0.298)	(0.026)	(0.009)	(0.731)	(0.106)	(0.585)	(0.098)
Oil volatility	−0.0292***	−0.0229***	0.0235**	0.0011	0.0021***	0.0017***	−0.0033	−0.0062*	−0.0467**	−0.0291***
	(0.008)	(0.006)	(0.011)	(0.012)	(0.000)	(0.000)	(0.004)	(0.003)	(0.020)	(0.010)
Oil spot price	0.0001	−0.0003	0.0034**	0.0038**	−0.0000	0.0000	0.0015***	0.0024***	0.0026	−0.0008
	(0.001)	(0.001)	(0.002)	(0.002)	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)	(0.001)
Oil production risk	0.0112	−0.1408	−0.0896	0.2582	−0.0019	0.0017	−0.0152	0.0920	−0.0113	−0.0882
	(0.126)	(0.209)	(0.171)	(0.263)	(0.004)	(0.006)	(0.051)	(0.097)	(0.103)	(0.139)
Gas hedging ratio	−0.2422	−1.2567**	−0.5909	1.7059	0.0118	0.0322	−0.0448	0.3048	0.4432**	−0.2406
	(0.310)	(0.623)	(0.472)	(1.040)	(0.021)	(0.029)	(0.192)	(0.466)	(0.222)	(0.587)
Gas spot price	0.0312***	0.0413***	0.0215	−0.0062	−0.0015***	−0.0016***	−0.0044	−0.0026	0.0104	0.0227***
	(0.010)	(0.008)	(0.018)	(0.013)	(0.000)	(0.000)	(0.004)	(0.004)	(0.014)	(0.008)

TABLE 7 (continued)

SECOND-STEP OF THE ESSENTIAL HETEROGENEITY MODELS

	(1)		(2)		(3)		(4)		(5)	
	Tobin's *q*		**Systematic risk**		**Idiosyncratic risk**		**Oil Beta**		**ROE**	
Variables	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**
Gas volatility	0.0164	−0.0435**	−0.0922	0.0524	0.0017	0.0031**	−0.0576***	−0.0359**	−0.0277	−0.0281
	(0.020)	(0.021)	(0.062)	(0.073)	(0.001)	(0.001)	(0.022)	(0.018)	(0.058)	(0.028)
Gas reserves	−0.0614**	−0.0003	0.1264**	−0.0177	−0.0031**	−0.0034***	−0.0270	−0.0209	−0.0286	0.0003
	(0.029)	(0.034)	(0.051)	(0.052)	(0.001)	(0.001)	(0.019)	(0.014)	(0.021)	(0.017)
Gas production	−0.0547	0.0628	−0.2068	−0.2472	0.0064	−0.0084	0.0367	−0.0857	0.0478	−0.0261
risk	(0.112)	(0.195)	(0.223)	(0.271)	(0.004)	(0.007)	(0.056)	(0.108)	(0.090)	(0.170)
CEO % of	−2.1151	0.8073	−7.7093	−1.9575	−0.0494	0.2422*	−4.7087**	1.4543	1.9361	−7.8252
stockholding	(4.411)	(4.332)	(6.837)	(6.221)	(0.129)	(0.137)	(1.968)	(2.524)	(3.248)	(7.453)
CEO number	0.0002	−0.0006	0.0034**	0.0010	0.0000	−0.0000	0.0006	0.0004	0.0004	0.0004
of options	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
Number of	0.0153***	0.0142***	−0.0321***	−0.0138*	−0.0001	−0.0000	0.0043	−0.0007	−0.0016	−0.0001
analysts	(0.005)	(0.005)	(0.008)	(0.007)	(0.000)	(0.000)	(0.003)	(0.003)	(0.004)	(0.004)
Constant	0.6511**	0.0650	0.2052	0.9264***	0.0307***	0.0468***	0.3455**	0.1459*	−0.5894**	0.0619
	(0.262)	(0.176)	(0.342)	(0.248)	(0.011)	(0.007)	(0.156)	(0.076)	(0.239)	(0.125)
K	0.1231	0.5185***	−0.0720	−0.7773**	−0.0073	−0.0168*	−0.0180	−0.1556	−0.3415***	0.0294
	(0.141)	(0.185)	(0.228)	(0.357)	(0.009)	(0.009)	(0.092)	(0.140)	(0.117)	(0.186)
$\hat{\sigma}_{1V} - \hat{\sigma}_{0V}$	−0.3954*		0.7053*		0.0096		0.1377		−0.3709*	
	(0.236)		(0.414)		(0.013)		(0.167)		(0.211)	
ATE	0.4970**		−0.7900**		−0.0238**		−0.1424		−0.2098	
	(0.207)		(0.393)		(0.011)		(0.162)		(0.218)	
Observations	1,193		1,148		1,148		1,148		1,188	

NOTE : This table provides the results of the second-step regressions (outcome equation) of the essential heterogeneity models. The dependent variables are: 1) firm value represented by the Tobin's q, calculated by the ratio of the market value of equity, plus the book value of debt, plus the book value of preferred shares to the book value of total assets, 2) firms' systematic risk represented by its market beta, 3) firms' idiosyncratic risk represented by the standard deviation of the residuals, 4) oil beta representing the sensitivity of firms' stock returns to oil price fluctuations. Systematic risk, idiosyncratic risk and oil beta are estimated simultaneously from a Fama-French 4-factor model supplemented by the changes in oil and gas 1-month futures contract prices. All the variables are defined in Table 1. Independent variables are included in lagged values (first lag). K is $\left(-\frac{\phi(\Phi^{-1}(p))}{p}\right)$ for the treated group (see Eq. 8) and $\left(\frac{\phi(\Phi^{-1}(p))}{1-p}\right)$ for the untreated group (see Eq. 9). $\hat{\sigma}_{1V}\,(\hat{\sigma}_{0V})$ is K's coefficient for the treated (untreated) group. The term ATE stands for the average treatment effect. Treated is for users of high intensity hedging and untreated is for users of low intensity hedging. Bootstrapped standard errors clustered at the firm level using 500 repetitions are reported in parentheses. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

The differences between firms can be greater when non-observable factors are considered. Applying the standard IV approach with the two groups reveals only the effect of observable differences on firm value. All firms are considered homogeneous (with respect to unobserved factors) in deriving an average hedging intensity effect (one coefficient) on firm value. With the marginal treatment effect (MTE) methodology, we may find that the marginal effect differs between firms that have to be categorized in either group (high versus low intensity hedgers) by adding the possibility of self-selection explained by unobserved factors.

Figure 7 plots the estimated MTEs with 95% confidence intervals, evaluated at the means of the independent (observable) characteristics of oil producers over different quantiles of the unobserved resistance to use high intensity hedging (namely, U_D). The ATE is also plotted (dashed line) as a reference point. In addition, estimated MTEs on firm value with their respective standard errors are reported in Table A1 for different evaluation quantile points of U_D, from 0.01 to 0.99. Estimated MTEs in the lower percentiles are positive and statistically significant. Figure 7 also shows that estimated MTEs are decreasing with different quantiles of U_D, implying that the marginal Tobin's q is highest for oil producers that are more likely to use high intensity hedging (i.e., lower values of the unobserved component U_D). Table A1 shows that estimated MTEs range from 1.42% for high propensities to using high intensity hedging to −42% (not significant) for high propensities to using low intensity hedging. Overall, our results show that marginal firm value increases with the propensity to use hedging, or equivalently, increases with the propensity to use high intensity hedging.

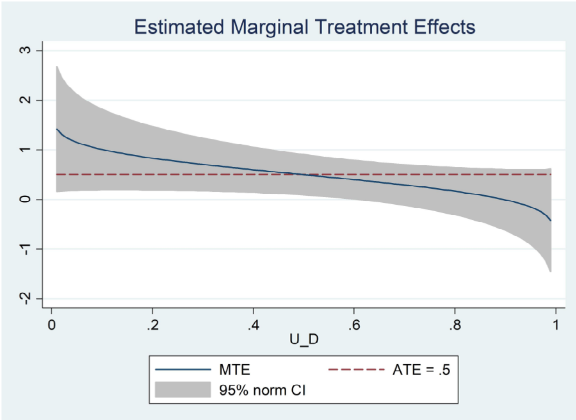
In conclusion, the curvature of the depicted MTEs in Figure 7 with respect to the decision processes' different quantiles of unobserved components when using high intensity hedging exhibits substantial heterogeneity in marginal treatment effects. This provides evidence of selection into treatment or a self-selection bias, indicating that the causal effects of the hedging intensity structure on firm value also vary across oil producers due to unobserved factors.

5.2 *Firm riskiness and Firm accounting performance*

From Table A2 (A3) and Figure 8 (9), we observe that high intensity hedging marginally reduces systematic and idiosyncratic risks (MTE). Firms that actively hedge do not seem to use derivatives for speculation. The marginal coefficients vary significantly from −2.4% at the first quartile to −0.60% at the sixtieth quartile in Table A2 and become non-statistically significant when resistance to hedging becomes more important. We observe similar results for idiosyncratic risk, although the effects are less significant and are mainly concentrated between the tenth and sixteenth quartiles. There is no significant MTE for the oil beta (Figure 10), and managers that are very reluctant to use derivatives to larger extents (U_D higher than 0.64) reduce the firm's accounting results or return on equity (Figure 11).

FIGURE 6

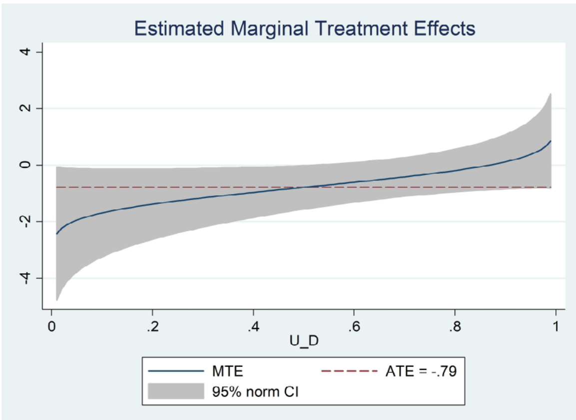
ESTIMATED MTES FOR TOBIN'S q



NOTE : This figure plots the estimated MTE for firm value, measured by the Tobin's q with respect to the common support of the unobserved resistance among US oil producers to using high intensity hedging represented by U_D. Average treatment effect (ATE) and 95% normal confidence interval are also plotted.

FIGURE 7

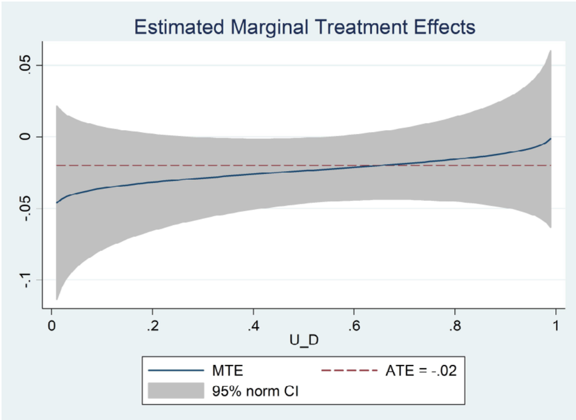
ESTIMATED MTES FOR FIRM'S SYSTEMATIC RISK



NOTE : This figure plots the estimated MTE for firm's systematic risk with respect to the common support of the unobserved resistance among US oil producers to using high intensity hedging represented by U_D. Average treatment effect (ATE) and 95% normal confidence interval are also plotted.

FIGURE 8

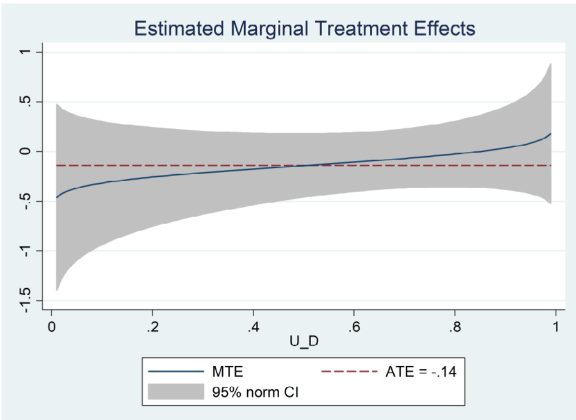
ESTIMATED MTES FOR FIRM IDIOSYNCRATIC RISK



NOTE : This figure plots the estimated MTE for firm's idiosyncratic risk with respect to the common support of the unobserved resistance among US oil producers to using high intensity hedging represented by U_D. Average treatment effect (ATE) and 95% normal confidence interval are also plotted.

FIGURE 9

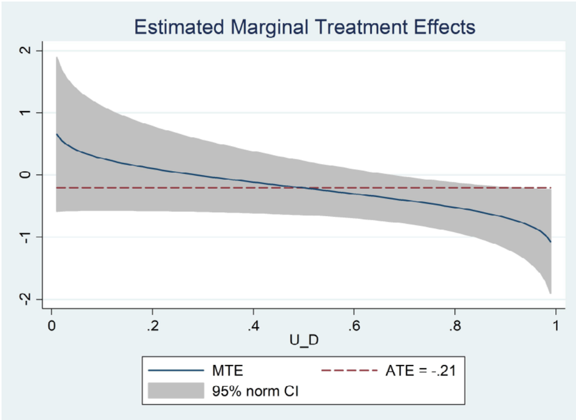
ESTIMATED MTES FOR OIL BETA



NOTE : This figure plots the estimated MTE for firm's oil beta with respect to the common support of the unobserved resistance among US oil producers to using high intensity hedging represented by U_D. Average treatment effect (ATE) and 95% normal confidence interval are also plotted.

FIGURE 10

ESTIMATED MTEs FOR FIRM ROE



NOTE : This figure plots the estimated MTE for firm's ROE with respect to the common support of the unobserved resistance among US oil producers to using high intensity hedging represented by U_D. Average treatment effect (ATE) and 95% normal confidence interval are also plotted.

CONCLUSION

A substantial body of theoretical corporate risk management literature has increased our understanding of the motivations, virtues, and value implications of hedging. This literature derives its theoretical and empirical predictions based on the extent of, or participation in, hedging activities. In this study, we go beyond the classical questions in corporate hedging literature to investigate the real marginal effects of hedging activities on firm value and risk. We also measure the average effects obtained by computing the mean of the marginal effects.

To obtain further insight into the dynamics of these real implications, we consider heterogeneity between firms in the evaluation of the impact of hedging intensity on firm value. We use a newly developed methodology that deals with both sources of selection bias, namely, selection on unobservable variables and selection on gain into treatment. Our results show that marginal firm value is positively related to more intense hedging activities, while marginal firm risk is negatively related to more intense hedging. More importantly, our results show an evident selection on gain into treatment due to unobserved factors in the choice of hedging intensity design (high versus low intensity hedging). Selection on gain into treatment means that the causal effects of hedging intensity on firm value and risk vary across oil producers due to hidden characteristics. We also obtain significant results with the average treatment effect for firm financial value, idiosyncratic risk, and systematic risk.

Our results seem to indicate that using a more appropriate methodology based on instrumental variables applied to models with essential heterogeneity reduces problems of inconsistency related to the effect of risk management on firm value, risk, and accounting performance.

Extensions of the model open future research avenues. In the empirical part of the article, we do not consider oil producers that do not hedge, nor the tax advantage of hedging. Adding zero-hedging firms creates technical difficulties because we must consider them as homogeneous under the current methodology, although they may differ substantially. The taxation variable also introduces challenges because it is the convexity of the tax function that matters, not the level of tax. Finally, we can extend the model to take into account additional random variables that oil producers face such as exchange rate, interest rate, and other risks in an integrated enterprise risk management (ERM) framework.

ANNEXE

TABLE A1

ESTIMATED MTEs FOR TOBIN'S q

(1) U_D	(2) Tobin's q	(3) U_D	(4) Tobin's q	(5) U_D	(6) Tobin's q	(7) U_D	(8) Tobin's q
u1	1.4168** (0.642)	*u26*	0.7513*** (0.290)	*u51*	0.4871** (0.205)	*u76*	0.2177 (0.225)
u2	1.3090** (0.581)	*u27*	0.7393*** (0.285)	*u52*	0.4771** (0.204)	*u77*	0.2049 (0.228)
u3	1.2406** (0.542)	*u28*	0.7274*** (0.280)	*u53*	0.4672** (0.202)	*u78*	0.1917 (0.232)
u4	1.1892** (0.514)	*u29*	0.7158*** (0.275)	*u54*	0.4573** (0.201)	*u79*	0.1781 (0.237)
u5	1.1473** (0.491)	*u30*	0.7043*** (0.271)	*u55*	0.4473** (0.200)	*u80*	0.1642 (0.241)
u6	1.1117** (0.472)	*u31*	0.6930*** (0.266)	*u56*	0.4373** (0.199)	*u81*	0.1499 (0.246)
u7	1.0805** (0.455)	*u32*	0.6819*** (0.262)	*u57*	0.4272** (0.199)	*u82*	0.1351 (0.252)
u8	1.0525** (0.440)	*u33*	0.6709*** (0.257)	*u58*	0.4172** (0.198)	*u83*	0.1197 (0.258)
u9	1.0271** (0.426)	*u34*	0.6601*** (0.253)	*u59*	0.4070** (0.198)	*u84*	0.1038 (0.264)
u10	1.0037** (0.414)	*u35*	0.6493*** (0.249)	*u60*	0.3968** (0.198)	*u85*	0.0872 (0.270)
u11	0.9819** (0.402)	*u36*	0.6387*** (0.246)	*u61*	0.3865* (0.198)	*u86*	0.0698 (0.278)
u12	0.9615** (0.392)	*u37*	0.6282*** (0.242)	*u62*	0.3762* (0.198)	*u87*	0.0516 (0.285)
u13	0.9423** (0.382)	*u38*	0.6178*** (0.238)	*u63*	0.3658* (0.199)	*u88*	0.0324 (0.294)
u14	0.9241** (0.373)	*u39*	0.6074*** (0.235)	*u64*	0.3552* (0.199)	*u89*	0.0120 (0.303)

TABLE A1 (continued)

ESTIMATED MTES FOR TOBIN'S q

(1) U_D	(2) Tobin's q	(3) U_D	(4) Tobin's q	(5) U_D	(6) Tobin's q	(7) U_D	(8) Tobin's q
u15	0.9068** (0.364)	*u40*	0.5971*** (0.232)	*u65*	0.3446* (0.200)	*u90*	−0.0097 (0.313)
u16	0.8902** (0.356)	*u41*	0.5869** (0.229)	*u66*	0.3339* (0.201)	*u91*	−0.0331 (0.324)
u17	0.8742** (0.348)	*u42*	0.5768** (0.226)	*u67*	0.3230 (0.203)	*u92*	−0.0586 (0.336)
u18	0.8589** (0.340)	*u43*	0.5667** (0.223)	*u68*	0.3121 (0.204)	*u93*	−0.0865 (0.350)
u19	0.8441** (0.333)	*u44*	0.5567** (0.220)	*u69*	0.3009 (0.206)	*u94*	−0.1177 (0.365)
u20	0.8297** (0.326)	*u45*	0.5467** (0.218)	*u70*	0.2896 (0.208)	*u95*	−0.1534 (0.383)
u21	0.8158** (0.320)	*u46*	0.5367** (0.215)	*u71*	0.2782 (0.210)	*u96*	−0.1952 (0.405)
u22	0.8023** (0.313)	*u47*	0.5267** (0.213)	*u72*	0.2665 (0.212)	*u97*	−0.2466 (0.432)
u23	0.7891** (0.307)	*u48*	0.5168** (0.211)	*u73*	0.2547 (0.215)	*u98*	−0.3150 (0.469)
u24	0.7762** (0.302)	*u49*	0.5069** (0.209)	*u74*	0.2426 (0.218)	*u99*	−0.4228 (0.528)
u25	0.7637*** (0.296)	*u50*	0.4970** (0.207)	*u75*	0.2303 (0.221)		

NOTE : This table gives the estimated MTEs related to the choice of oil hedging intensity, high versus low. The MTEs are for firm value measured by the Tobin's q. U_D reflects different estimation points of the unobserved resistance to using high intensity hedging. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

TABLE A2

ESTIMATED MTES FOR SYSTEMATIC RISK

(1) U_D	(2) Syst. risk	(3) U_D	(4) Syst. risk	(5) U_D	(6) Syst. risk	(7) U_D	(8) Syst. risk
u1	−2.4307** (1.199)	*u26*	−1.2437** (0.569)	*u51*	−0.7723** (0.389)	*u76*	−0.2918 (0.364)
u2	−2.2385** (1.091)	*u27*	−1.2222** (0.559)	*u52*	−0.7546** (0.384)	*u77*	−0.2689 (0.368)
u3	−2.1165** (1.023)	*u28*	−1.2011** (0.549)	*u53*	−0.7369* (0.380)	*u78*	−0.2454 (0.373)
u4	−2.0247** (0.973)	*u29*	−1.1803** (0.540)	*u54*	−0.7191* (0.376)	*u79*	−0.2212 (0.379)
u5	−1.9501** (0.932)	*u30*	−1.1598** (0.531)	*u55*	−0.7014* (0.372)	*u80*	−0.1964 (0.385)
u6	−1.8866** (0.898)	*u31*	−1.1397** (0.522)	*u56*	−0.6835* (0.368)	*u81*	−0.1708 (0.391)
u7	−1.8308** (0.868)	*u32*	−1.1198** (0.513)	*u57*	−0.6656* (0.365)	*u82*	−0.1444 (0.399)

TABLE A2 (continued)

ESTIMATED MTEs FOR SYSTEMATIC RISK

(1) U_D	(2) Syst. risk	(3) U_D	(4) Syst. risk	(5) U_D	(6) Syst. risk	(7) U_D	(8) Syst. risk
u8	−1.7810** (0.841)	*u33*	−1.1002** (0.505)	*u58*	−0.6476* (0.362)	*u83*	−0.1170 (0.407)
u9	−1.7356** (0.817)	*u34*	−1.0809** (0.497)	*u59*	−0.6295* (0.359)	*u84*	−0.0886 (0.416)
u10	−1.6939** (0.795)	*u35*	−1.0617** (0.489)	*u60*	−0.6113* (0.356)	*u85*	−0.0590 (0.425)
u11	−1.6550** (0.774)	*u36*	−1.0428** (0.481)	*u61*	−0.5930* (0.354)	*u86*	−0.0280 (0.436)
u12	−1.6187** (0.755)	*u37*	−1.0240** (0.473)	*u62*	−0.5745 (0.352)	*u87*	0.0045 (0.448)
u13	−1.5844** (0.737)	*u38*	−1.0054** (0.466)	*u63*	−0.5559 (0.351)	*u88*	0.0387 (0.461)
u14	−1.5519** (0.721)	*u39*	−0.9870** (0.459)	*u64*	−0.5372 (0.349)	*u89*	0.0751 (0.475)
u15	−1.5210** (0.705)	*u40*	−0.9687** (0.452)	*u65*	−0.5182 (0.348)	*u90*	0.1139 (0.491)
u16	−1.4914** (0.690)	*u41*	−0.9505** (0.445)	*u66*	−0.4991 (0.348)	*u91*	0.1556 (0.508)
u17	−1.4629** (0.675)	*u42*	−0.9324** (0.439)	*u67*	−0.4797 (0.348)	*u92*	0.2010 (0.528)
u18	−1.4356** (0.662)	*u43*	−0.9144** (0.432)	*u68*	−0.4601 (0.348)	*u93*	0.2509 (0.551)
u19	−1.4092** (0.648)	*u44*	−0.8965** (0.426)	*u69*	−0.4403 (0.348)	*u94*	0.3066 (0.576)
u20	−1.3836** (0.636)	*u45*	−0.8786** (0.420)	*u70*	−0.4201 (0.349)	*u95*	0.3701 (0.607)
u21	−1.3587** (0.624)	*u46*	−0.8608** (0.414)	*u71*	−0.3997 (0.351)	*u96*	0.4448 (0.643)
u22	−1.3346** (0.612)	*u47*	−0.8431** (0.409)	*u72*	−0.3789 (0.352)	*u97*	0.5365 (0.689)
u23	−1.3111** (0.601)	*u48*	−0.8254** (0.403)	*u73*	−0.3578 (0.355)	*u98*	0.6585 (0.752)
u24	−1.2881** (0.590)	*u49*	−0.8077** (0.398)	*u74*	−0.3362 (0.357)	*u99*	0.8508 (0.853)
u25	−1.2657** (0.579)	*u50*	−0.7900** (0.393)	*u75*	−0.3143 (0.360)		

NOTE : This table gives the estimated MTEs related to the choice of oil hedging intensity, high versus low. The MTEs are for firm systematic risk. U_D reflects different estimation points of the unobserved resistance to using high intensity hedging. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

TABLE A3

ESTIMATED MTEs FOR IDIOSYNCRATIC RISK

(1) U_D	(2) Idiosyn. risk	(3) U_D	(4) Idiosyn. risk	(5) U_D	(6) Idiosyn. risk	(7) U_D	(8) Idiosyn. risk
u1	−0.0460 (0.034)	*u26*	−0.0299** (0.015)	*u51*	−0.0235** (0.011)	*u76*	−0.0170 (0.014)
u2	−0.0434 (0.031)	*u27*	−0.0296** (0.015)	*u52*	−0.0233** (0.011)	*u77*	−0.0167 (0.014)
u3	−0.0417 (0.029)	*u28*	−0.0293** (0.015)	*u53*	−0.0230** (0.011)	*u78*	−0.0164 (0.014)
u4	−0.0405 (0.027)	*u29*	−0.0290** (0.014)	*u54*	−0.0228** (0.011)	*u79*	−0.0160 (0.015)
u5	−0.0395 (0.026)	*u30*	−0.0288** (0.014)	*u55*	−0.0226** (0.011)	*u80*	−0.0157 (0.015)
u6	−0.0386 (0.025)	*u31*	−0.0285** (0.014)	*u56*	−0.0223* (0.011)	*u81*	−0.0154 (0.015)
u7	−0.0379 (0.024)	*u32*	−0.0282** (0.014)	*u57*	−0.0221* (0.011)	*u82*	−0.0150 (0.016)
u8	−0.0372 (0.023)	*u33*	−0.0280** (0.014)	*u58*	−0.0218* (0.011)	*u83*	−0.0146 (0.016)
u9	−0.0366 (0.022)	*u34*	−0.0277** (0.013)	*u59*	−0.0216* (0.011)	*u84*	−0.0142 (0.016)
u10	−0.0360* (0.022)	*u35*	−0.0274** (0.013)	*u60*	−0.0213* (0.012)	*u85*	−0.0138 (0.017)
u11	−0.0355* (0.021)	*u36*	−0.0272** (0.013)	*u61*	−0.0211* (0.012)	*u86*	−0.0134 (0.017)
u12	−0.0350* (0.021)	*u37*	−0.0269** (0.013)	*u62*	−0.0208* (0.012)	*u87*	−0.0130 (0.018)
u13	−0.0345* (0.020)	*u38*	−0.0267** (0.013)	*u63*	−0.0206* (0.012)	*u88*	−0.0125 (0.018)
u14	−0.0341* (0.020)	*u39*	−0.0264** (0.013)	*u64*	−0.0203* (0.012)	*u89*	−0.0120 (0.019)
u15	−0.0337* (0.019)	*u40*	−0.0262** (0.012)	*u65*	−0.0201* (0.012)	*u90*	−0.0115 (0.019)
u16	−0.0333* (0.019)	*u41*	−0.0259** (0.012)	*u66*	−0.0198* (0.012)	*u91*	−0.0109 (0.020)
u17	−0.0329* (0.018)	*u42*	−0.0257** (0.012)	*u67*	−0.0195 (0.012)	*u92*	−0.0103 (0.021)
u18	−0.0325* (0.018)	*u43*	−0.0254** (0.012)	*u68*	−0.0193 (0.012)	*u93*	−0.0096 (0.021)
u19	−0.0321* (0.017)	*u44*	−0.0252** (0.012)	*u69*	−0.0190 (0.012)	*u94*	−0.0089 (0.022)
u20	−0.0318* (0.017)	*u45*	−0.0250** (0.012)	*u70*	−0.0187 (0.013)	*u95*	−0.0080 (0.023)
u21	−0.0315* (0.017)	*u46*	−0.0247** (0.012)	*u71*	−0.0185 (0.013)	*u96*	−0.0070 (0.025)
u22	−0.0311* (0.016)	*u47*	−0.0245** (0.012)	*u72*	−0.0182 (0.013)	*u97*	−0.0058 (0.026)
u23	−0.0308* (0.016)	*u48*	−0.0242** (0.012)	*u73*	−0.0179 (0.013)	*u98*	−0.0041 (0.028)

TABLE A3 (continued)

ESTIMATED MTEs FOR IDIOSYNCRATIC RISK

(1) U_D	(2) Idiosyn. risk	(3) U_D	(4) Idiosyn. risk	(5) U_D	(6) Idiosyn. risk	(7) U_D	(8) Idiosyn. risk
u24	−0.0305* (0.016)	*u49*	−0.0240** (0.012)	*u74*	−0.0176 (0.013)	*u99*	−0.0015 (0.031)
u25	−0.0302* (0.016)	*u50*	−0.0238** (0.011)	*u75*	−0.0173 (0.014)		

NOTE : This table gives the estimated MTEs related to the choice of oil hedging intensity, high versus low. The MTEs are for firm idiosyncratic risk. U_D reflects different estimation points of the unobserved resistance to using high intensity hedging. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

TABLE A4

ESTIMATED MTEs FOR OIL BETA

(1) U_D	(2) Oil Beta	(3) U_D	(4) Oil Beta	(5) U_D	(6) Oil Beta	(7) U_D	(8) Oil Beta
u1	−0.4626 (0.477)	*u26*	−0.2309 (0.227)	*u51*	−0.1389 (0.160)	*u76*	−0.0451 (0.159)
u2	−0.4251 (0.434)	*u27*	−0.2267 (0.223)	*u52*	−0.1355 (0.159)	*u77*	−0.0407 (0.160)
u3	−0.4013 (0.407)	*u28*	−0.2226 (0.220)	*u53*	−0.1320 (0.158)	*u78*	−0.0361 (0.163)
u4	−0.3834 (0.386)	*u29*	−0.2185 (0.216)	*u54*	−0.1285 (0.156)	*u79*	−0.0314 (0.165)
u5	−0.3688 (0.370)	*u30*	−0.2146 (0.212)	*u55*	−0.1251 (0.155)	*u80*	−0.0265 (0.168)
u6	−0.3564 (0.356)	*u31*	−0.2106 (0.209)	*u56*	−0.1216 (0.154)	*u81*	−0.0215 (0.170)
u7	−0.3455 (0.344)	*u32*	−0.2067 (0.206)	*u57*	−0.1181 (0.153)	*u82*	−0.0164 (0.174)
u8	−0.3358 (0.334)	*u33*	−0.2029 (0.203)	*u58*	−0.1146 (0.152)	*u83*	−0.0110 (0.177)
u9	−0.3269 (0.324)	*u34*	−0.1991 (0.200)	*u59*	−0.1110 (0.151)	*u84*	−0.0055 (0.181)
u10	−0.3188 (0.315)	*u35*	−0.1954 (0.197)	*u60*	−0.1075 (0.150)	*u85*	0.0003 (0.185)
u11	−0.3112 (0.307)	*u36*	−0.1917 (0.194)	*u61*	−0.1039 (0.150)	*u86*	0.0063 (0.189)
u12	−0.3041 (0.300)	*u37*	−0.1880 (0.191)	*u62*	−0.1003 (0.149)	*u87*	0.0127 (0.194)
u13	−0.2974 (0.293)	*u38*	−0.1844 (0.188)	*u63*	−0.0967 (0.149)	*u88*	0.0194 (0.199)
u14	−0.2911 (0.286)	*u39*	−0.1808 (0.185)	*u64*	−0.0930 (0.149)	*u89*	0.0265 (0.205)
u15	−0.2850 (0.280)	*u40*	−0.1772 (0.183)	*u65*	−0.0893 (0.149)	*u90*	0.0340 (0.212)
u16	−0.2793 (0.274)	*u41*	−0.1737 (0.180)	*u66*	−0.0856 (0.149)	*u91*	0.0422 (0.219)

TABLE A4 (continued)

ESTIMATED MTES FOR OIL BETA

(1) U_D	(2) Oil Beta	(3) U_D	(4) Oil Beta	(5) U_D	(6) Oil Beta	(7) U_D	(8) Oil Beta
u17	−0.2737	*u42*	−0.1702	*u67*	−0.0818	*u92*	0.0510
	(0.268)		(0.178)		(0.149)		(0.227)
u18	−0.2684	*u43*	−0.1666	*u68*	−0.0780	*u93*	0.0608
	(0.263)		(0.176)		(0.150)		(0.236)
u19	−0.2632	*u44*	−0.1631	*u69*	−0.0741	*u94*	0.0717
	(0.258)		(0.174)		(0.150)		(0.246)
u20	−0.2582	*u45*	−0.1597	*u70*	−0.0702	*u95*	0.0841
	(0.253)		(0.171)		(0.151)		(0.258)
u21	−0.2534	*u46*	−0.1562	*u71*	−0.0662	*u96*	0.0986
	(0.248)		(0.169)		(0.152)		(0.273)
u22	−0.2487	*u47*	−0.1527	*u72*	−0.0621	*u97*	0.1165
	(0.244)		(0.167)		(0.153)		(0.292)
u23	−0.2441	*u48*	−0.1493	*u73*	−0.0580	*u98*	0.1403
	(0.239)		(0.166)		(0.154)		(0.317)
u24	−0.2396	*u49*	−0.1458	*u74*	−0.0538	*u99*	0.1779
	(0.235)		(0.164)		(0.155)		(0.358)
u25	−0.2352	*u50*	−0.1424	*u75*	−0.0495		
	(0.231)		(0.162)		(0.157)		

NOTE : This table gives the estimated MTEs related to the choice of oil hedging intensity, high versus low. The MTEs are for firm oil beta. U_D reflects different estimation points of the unobserved resistance to using high intensity hedging. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

TABLE A5

ESTIMATED MTES FOR ROE

(1) U_D	(2) ROE	(3) U_D	(4) ROE	(5) U_D	(6) ROE	(7) U_D	(8) ROE
u1	0.6531	*u26*	0.0288	*u51*	−0.2191	*u76*	−0.4718**
	(0.631)		(0.310)		(0.215)		(0.191)
u2	0.5520	*u27*	0.0175	*u52*	−0.2284	*u77*	−0.4838**
	(0.576)		(0.305)		(0.213)		(0.193)
u3	0.4878	*u28*	0.0064	*u53*	−0.2377	*u78*	−0.4962**
	(0.542)		(0.300)		(0.210)		(0.195)
u4	0.4396	*u29*	−0.0045	*u54*	−0.2470	*u79*	−0.5089***
	(0.516)		(0.295)		(0.208)		(0.197)
u5	0.4003	*u30*	−0.0153	*u55*	−0.2564	*u80*	−0.5220***
	(0.495)		(0.290)		(0.206)		(0.199)
u6	0.3669	*u31*	−0.0259	*u56*	−0.2658	*u81*	−0.5354***
	(0.478)		(0.286)		(0.203)		(0.202)
u7	0.3376	*u32*	−0.0363	*u57*	−0.2752	*u82*	−0.5493***
	(0.463)		(0.281)		(0.201)		(0.205)
u8	0.3114	*u33*	−0.0466	*u58*	−0.2847	*u83*	−0.5637***
	(0.449)		(0.277)		(0.199)		(0.208)
u9	0.2875	*u34*	−0.0568	*u59*	−0.2942	*u84*	−0.5786***
	(0.437)		(0.273)		(0.198)		(0.212)

TABLE A5 (continued)

ESTIMATED MTEs FOR ROE

(1) U_D	(2) ROE	(3) U_D	(4) ROE	(5) U_D	(6) ROE	(7) U_D	(8) ROE
	(0.437)		(0.273)		(0.198)		(0.212)
u10	0.2656	*u35*	−0.0669	*u60*	−0.3038	*u85*	−0.5942***
	(0.425)		(0.268)		(0.196)		(0.217)
u11	0.2451	*u36*	−0.0768	*u61*	−0.3134	*u86*	−0.6105***
	(0.415)		(0.264)		(0.194)		(0.221)
u12	0.2260	*u37*	−0.0867	*u62*	−0.3231*	*u87*	−0.6276***
	(0.405)		(0.261)		(0.193)		(0.227)
u13	0.2080	*u38*	−0.0965	*u63*	−0.3329*	*u88*	−0.6456***
	(0.396)		(0.257)		(0.192)		(0.233)
u14	0.1909	*u39*	−0.1062	*u64*	−0.3427*	*u89*	−0.6647***
	(0.388)		(0.253)		(0.191)		(0.239)
u15	0.1746	*u40*	−0.1158	*u65*	−0.3527*	*u90*	−0.6851***
	(0.379)		(0.249)		(0.190)		(0.247)
u16	0.1591	*u41*	−0.1254	*u66*	−0.3628*	*u91*	−0.7071***
	(0.372)		(0.246)		(0.189)		(0.255)
u17	0.1441	*u42*	−0.1349	*u67*	−0.3730**	*u92*	−0.7310***
	(0.364)		(0.242)		(0.188)		(0.264)
u18	0.1297	*u43*	−0.1444	*u68*	−0.3833**	*u93*	−0.7572***
	(0.357)		(0.239)		(0.188)		(0.275)
u19	0.1158	*u44*	−0.1538	*u69*	−0.3937**	*u94*	−0.7865***
	(0.351)		(0.236)		(0.188)		(0.288)
u20	0.1024	*u45*	−0.1632	*u70*	−0.4043**	*u95*	−0.8199***
	(0.344)		(0.232)		(0.187)		(0.302)
u21	0.0893	*u46*	−0.1725	*u71*	−0.4150**	*u96*	−0.8591***
	(0.338)		(0.229)		(0.188)		(0.320)
u22	0.0766	*u47*	−0.1819	*u72*	−0.4260**	*u97*	−0.9074***
	(0.332)		(0.226)		(0.188)		(0.343)
u23	0.0643	*u48*	−0.1912	*u73*	−0.4371**	*u98*	−0.9716***
	(0.326)		(0.223)		(0.188)		(0.374)
u24	0.0522	*u49*	−0.2005	*u74*	−0.4484**	*u99*	−1.0727**
	(0.321)		(0.220)		(0.189)		(0.425)
u25	0.0404	*u50*	−0.2098	*u75*	−0.4600**		
	(0.315)		(0.218)		(0.190)		

NOTE : This table gives the estimated MTEs related to the choice of oil hedging intensity, high versus low. The MTEs are for firm ROE. U_D reflects different estimation points of the unobserved resistance to using high intensity hedging. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

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