Dynamic Corporate Risk Management: Motivations and Real Implications

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Abstract

We investigate the dynamics of corporate hedging programs by US oil producers and examine the effects of hedging maturity choice on firm value. We find evidence of a concave relation between hedging maturity and the likelihood of financial distress and oil spot prices. We further investigate the motivations of the early termination of outstanding hedging contracts. We evaluate the causal effects of hedging and show that hedging maturity increases firm value. Using the essential heterogeneity approach, we find that firms value is more strongly related to short-term hedging maturities. This is the first time this approach is applied in corporate finance.

Keywords*:* Hedging maturity, early termination of contracts, firm value, heterogeneous treatment effects, essential heterogeneity models, oil industry.

JEL classification*:* D8, G32.

I. Introduction

We explore the dynamics of corporate risk management through which firms could create value by considering the following questions: How far ahead do firms hedge? What are the determinants of the maturity structure of firms' hedging programs? What are the motivations for the early termination of hedging contracts? What are the real effects of hedging maturities on firm value? These questions related to the dynamics of corporate hedging are largely unexplored because of the lack of empirical analysis due to limitations of the appropriate data. Using an extensive and new hand-collected dataset on the risk management activities of 150 US oil producers with quarterly observations over the period 1998–2010, we fill this gap in the literature and answer the above questions. It is important to understand why firms within the same industry and with the same risk exposure differ in terms of their hedging maturity structure.

We contribute to the literature on corporate hedging in several ways. Previous studies, with the exception of Fehle and Tsyplakov (2005), discuss the maturity structure of hedging but do not investigate its determinants.[1] Our first contribution is to provide empirical evidence of the determinants of the maturity structure of hedging contracts. We are also the first researchers who study empirically the rationales for the early termination of hedging contracts. We then apply a new econometric

[1] Dolde (1993) surveys the hedging practices of 244 Fortune 500 companies and finds that the common practice is to hedge cash flow exposures within a horizon of two to four quarters. In line with Dolde (1993), Tufano (1996) provides statistics about the percentage of the production hedged for North American gold mining firms for 1991–1993 and finds that they hedge 61.2% of their gold production for the current year (1991) and 10% and 11% for the subsequent two years. In a Wharton survey of the financial risk management practices and derivatives of 399 US nonfinancial firms, Bodnar, Hayt, and Marston (1998) report that 82% of the questioned firms use foreign currency derivatives with an initial maturity of 91 days or less and only 12% use foreign currency derivatives with maturities exceeding three years. They also find that hedging ratios at longer maturities decreased dramatically during 1998. Adam and Fernando (2006, 2008) study the cash flow gains from selective hedging for a sample of 92 North American gold producers from 1989 to 1999 and report the descriptive statistics of hedging ratios up to five years. They find that gold producers use hedging programs with one-year maturities in 90% of firm–quarters with nonzero hedging with a mean hedging ratio of 54% of the expected gold production, hedging programs with three-year maturities in 51% of hedging quarters with an average hedging ratio of 25%, and programs with five-year maturities in 18% with an average hedging ratio of 28%. The authors also point out that near-term hedging ratios are more volatile than those with longer horizons. Carter, Rogers, and Simkins (2006) investigate the jet fuel hedging activities of US airline firms during 1992–2003 and find that hedging maturities vary significantly between firms (e.g., from one year to six years ahead) and that the hedging ratios of the next year's fuel consumption are very disparate (e.g., from 1% to 43%).

methodology, namely, the *essential heterogeneity* model of Heckman, Urzua, and Vytlacil (2006), to evaluate the causal effects of hedging maturity structure on oil producers' values. To the best of our knowledge, this is the first time this methodology is used in corporate finance. Our data, collected from publicly disclosed information, provide detailed information about hedging activities. This detailed information allows us to study maturity structure by hedging instrument, namely, swap contracts, put options, and costless collars, which provides deeper insight into the hedging behavior of oil producers.

Some of our findings corroborate the predictions and findings drawn from the theoretical model developed by Fehle and Tsyplakov (2005) based on simulations and calibrated for the gold mining industry. They also estimated some relationships with real data. In line with their prediction and empirical results, we obtain strong evidence of a non-monotonic (concave) relation between the hedging maturity and likelihood of financial distress measured by the leverage ratio. This non-monotonic relation means that hedging maturities increase and then decrease with the likelihood of financial distress and this is more evident for swap contracts and costless collars.

Also, in line with their theoretical contribution, we observe strong evidence of the impact of oil spot prices on the oil hedging maturity structure. In particular, the maturities of swaps contracts and costless collars increase and then decrease with oil spot prices and are even terminated prematurely when oil prices are significantly high. Oil price volatilities motivate the use of longer swap positions. Accordingly, higher price volatility makes firms reluctant to incur the costly early termination of their hedging contracts unless spot prices increase considerably.

We also find that the likelihood of financial distress has a convex relationship with the early termination of swap contracts in particular, indicating that oil producers with significantly higher leverage ratios prematurely terminate their swap positions. Our results further indicate that distressed oil producers (i.e., those with insufficient cash inflows and higher leverage ratios) enter longer put options as a risk-shifting strategy. Costly put options with long maturities increase rather than eliminate the firm's payoff volatility and decrease assets available for debtholders.

Additional results show that hedging contract features (i.e., moneyness and strike prices) have a significant impact on hedging maturity dynamics. Oil producers keep in-the-money hedging contracts until they mature and terminate out-the-money contracts prematurely. The results further imply that a hedging contract initiated at a sufficiently higher strike price is more likely to be kept for longer periods. Despite the difficulty in precisely forecasting future produced quantities, oil production uncertainty motivates the use of longer hedging contracts to avoid shortfalls in future revenues. With respect to maturity matching, we find that oil producers match the maturities of their swap contracts and put options with the expected life of their developed oil reserves (i.e., assets). On the contrary, there is no evident matching with debt maturity. However, debt maturity prevents the premature termination of put options.

Using an instrumental variable (IV) approach to alleviate endogeneity concerns, we provide evidence of the real implications of oil hedging maturity on firm value. We identify credible instruments arising from seminal works in the corporate finance and economics literatures. A first instrument is obtained from the influential work of Froot, Scharfstein, and Stein (1993) in the corporate risk management literature, namely, the differential in the sensitivities of a firm's investment opportunities and cash flows to risk factor fluctuations. A second instrument comes from the economics literature studying the macroeconomic responses to crude oil price shocks (Kilian, 2009). The validity of the two instruments is tested with appropriate statistical methods. Our evidence suggests that predicted oil hedging maturity is significantly positively related to firm value measured by Tobin's *q*.

To gain further insight on the causal effects of the hedging maturity on firm value, we estimate the marginal treatment effects (MTEs) of using short-term versus long-term hedging contracts. After controlling for unobserved heterogeneity using the IV model of Heckman, Urzua, and Vytlacil (2006), we show that the previous favorable effects on firm value are more strongly related to the use of short-term hedging contracts than to the use of longer contracts. This newly developed methodology allows us to better gauge the effects of hedging maturity choice on oil producers' values because it controls for bias arising from selection on unobservables (i.e., omitted variables) and selection on gain into treatment (i.e., self-selection) due to hidden background attributes.

Overall, the weighted-average hedging maturity is a more refined measure of the hedging activities of nonfinancial firms. It simultaneously combines both sides of hedging programs, namely, hedging extents and hedging horizons. It then appears to capture more efficiently the motivations and real implications of the hedging activities of nonfinancial firms.

The rest of the paper is organized as follows. Section II states our hypotheses. Section III describes our data and variables. Section IV reports univariate results and Section V investigates the empirical evidence of the maturity structure of corporate risk management. Section VI studies the early termination of hedging contracts. Section VII examines the real implication of hedging maturity on firm value. Section VIII concludes the paper.

II. Hypotheses

The lack of testable theoretical predictions of hedging maturity structure is compensated for by Fehle and Tsyplakov (2005) who present an infinite-horizon continuous time model of a firm that can dynamically adjust the hedge ratio and maturity of its hedging instruments in response to fluctuations in firm output price. Their model is calibrated to replicate empirical observations for a gold mining firm and produces a number of new theoretical predictions pertaining to the optimal timing, adjustment, and rollover of hedging contracts and their maturities, which we will describe in depth to develop our hypotheses in this section and test empirically later.

A. Financial Distress

A large body of the empirical literature has analyzed the positive relation between financial constraints and firms' hedging activities (e.g., Nance, Smith, and Smithson (1993), Géczy, Minton, and Schrand (1997), Tufano (1996), Gay and Nam (1998), Adam (2002, 2009)). In line with this literature, Fehle and Tsyplakov (2005) analyze the implications of financial distress on risk management adjustments. Based on simulations of gold spot prices, they find, in presence of transaction costs, a nonmonotonic relation between hedging maturity and measures of financial distress probability. This nonmonotonicity means that hedging maturity first increases and then decreases with the probability of financial distress. To put it another way, firms near distress are often observed with short-run hedging contracts and could terminate longer contracts at a high cost due to the risk-shifting behavior. Firms far from distress opt for short-term contracts because of the low marginal benefits of hedging for wealthy firms (e.g., Stulz, 1996).

Fehle and Tsyplakov (2005) also find, theoretically, that financial distress costs are negatively related to hedging maturity. Distress costs increase when the firm's cash inflows are insufficient to cover production costs and debt payments. Their simulations show that firms with high distress costs tend to use shorter maturity hedging. Hence we posit the following empirical hypothesis:

Hypothesis 1: Hedging maturity is negatively related to i) either the high or low likelihood of financial distress, and ii) higher distress costs.

Fehle and Tsyplakov (2005) also tested empirically part (i) of the above hypothesis with data from the gold mining industry. To further verify the empirical relevance of this prediction, we use the leverage ratio as measured by the book value of liabilities scaled by the book value of total assets. We add leverage squared to capture nonlinearity between financial soundness and hedging maturity. We predict a positive sign for the leverage ratio and a negative sign for its squared values.

We measure a firm's incurred distress costs by the product $I[\ Leverage - L]\ Max[0, -p + c + d]$, where I is an indicator function, *Leverage* is the leverage ratio, and L is the median leverage ratio of our oil producers' sample, with $I[Leverage - L] = 1$ if $Leverage > L$ and zero otherwise. $Max[0, -p + c + d]$ indicates that a firm incurs distress costs that are proportional to the shortfall of its realized selling prices p compared with its production costs, represented by cash costs c and debt payments d. These realized prices include the monetary effects of hedging activities, if any. Debt payments d are measured by quarterly interest expenses and the outstanding proportion of long-term debt in current liabilities at the end of the quarter. The variables p, c, and d are expressed per barrel of oil equivalent (BOE). Therefore, a firm incurs distress costs when its leverage is above the industry's median and its actual cash inflows (i.e., realized selling prices net of production costs) are insufficient to meet debt requirements. These distress costs could entail higher future external financing costs.

B. Market Conditions

The corporate hedging literature shows that market conditions, namely, spot prices and their volatilities, play a crucial role in why firms hedge, how much they hedge, and how they hedge (e.g., Stulz (1996), Bodnar, Hayt, and Marston (1998), Brown and Toft (2002), Adam (2009)). Fehle and Tsyplakov (2005) investigate the evolution of risk management contracts and spot price history by simulating the stochastic process of gold spot prices. Basically, they find strong evidence of a nonmonotonic relationship between spot prices and hedging contract maturity. This result means that, when spot prices are very high or very low, firms choose short maturity hedging. For the range of spot prices between these two extremes, firms tend to adjust their risk management instruments more frequently and then tend to enter into newly initiated contracts with longer maturities. Moreover, Fehle and Tsyplakov (2005) find that firms with higher price volatility tend to choose longer hedging contracts. In a higher price uncertainty environment, firms tend to refrain from costly early termination of their outstanding contracts unless spot prices increase significantly. These firms, in a higher-volatility environment, often conclude long-run contracts. We therefore posit the following hypothesis, which has not yet been tested with real data:

Hypothesis 2: Hedging maturity is negatively related to either very high or very low spot prices. Moreover, firms prefer longer-maturity contracts when product price volatility is higher.

We extract the oil spot prices observed at the end of each quarter from the Bloomberg Financial Markets Information database.[2] We calculate the volatility of oil for each quarter as the standard deviation of daily spot prices within the quarter. We expect a positive sign for spot prices and volatilities and a negative sign for spot prices squared.

C. Hedging Contract Features

Fehle and Tsyplakov (2005) find that the moneyness, remaining maturity, and strike prices of existing hedging contracts play an important role in optimal rollover and adjustment decisions. Regarding these features, they derive the following prediction, which we are the first to investigate empirically.

[2] We use the West Texas Intermediate (WTI) crude oil index as a proxy for oil spot prices.

Hypothesis 3: Hedging contracts initiated at higher strike prices are more likely to be kept until maturity because they are more likely to be in the money for a longer period.

As a proxy for the strike price at the initiation of hedging contracts, we calculate the mean of oil spot prices during the quarter of the initiation. To capture initiation dates, we skim the time series of the weighted-average maturity and detect initiation dates by choosing observations where maturity at time t is superior to that at time t - 1. This proxy will provide information at the level of the strike price of the initiated contract. Until another initiation date, the moneyness of the hedging contract is calculated by the strike price as previously mentioned minus the mean spot price during the current quarter.[3] We predict a positive sign for both the strike price and moneyness on hedging maturity.

D. Other Control Variables

1. Production Uncertainty

Several studies,[4] mostly theoretical, investigate the role of production activity characteristics on firm hedging behavior. These studies demonstrate the importance of production uncertainty (i.e., quantity risk) on firms' hedging programs. By deriving the optimal hedge analytically, Brown and Toft (2002) show that firms tend to hedge less for longer exposures because of the difficulty in accurately forecasting their future production. Consequently, production uncertainty should accentuate the inability of making accurate forecasts for future production. We explore the effects of production uncertainty and expect hedging maturity to be negatively related to production uncertainty. For each firm, we measure production uncertainty by the coefficient of the variation of daily production of oil with rolling windows of 12 quarterly observations available until the current quarter.

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[3] For the regressions, we create a dummy variable that takes the value of one if the moneyness of the hedging contract is greater than or equal to zero and the value -1 otherwise.

[4] These studies include those of Moschini and Lapan (1995), Brown and Toft (2002), Gay, Nam, and Turac (2002, 2003), and Adam (2009).

2. Maturity Matching

Maturity matching is a common best practice in corporate finance. We estimate the effect of the following two measures: 1) the weighted average maturity of debt, and 2) the expected life duration (in years) of developed oil reserves. The average debt maturity is calculated as the book value-weighted average maturities of debt that mature within one year to five years. The expected life of reserves is calculated by dividing the current quantity of developed oil reserves by current annual oil production. These two variables allow us to capture any maturity matching between the firm's hedging positions and its major assets and future debt commitments.

III. Sample Construction and Characteristics

A. Sample Construction

Our study is implemented on a sample of 150 US oil producers over the period 1998–2010. The oil industry is an excellent laboratory to test corporate risk management motivations and implications for several reasons. First, firms in this industry share homogeneous risk exposures (i.e., fluctuations in crude oil prices). Hence, diversity in hedging strategies is not due to differences in market exposure and is more likely to result from differences in firm characteristics. Second, financial derivatives on crude oil offer these firms several price hedging methods. Third, improvements in accounting disclosure related to petroleum producing activities have made operational data available. These data pertain to exploration, production and reserve quantities, cash costs, and so forth.

A preliminary list of 413 US oil producers with the primary Standard Industrial Classification (SIC) code 1311[5] (crude petroleum and natural gas) was extracted from Bloomberg. Only firms that

[5] The SIC code 1311, crude petroleum and natural gas, comprises companies primarily involved in the operation of properties for the recovery of hydrocarbon liquids and natural gas.

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. To our knowledge, this sample is the most recent and the largest in the empirical literature on risk management in the petroleum industry.

Data on these firms' financial and operational characteristics were gathered from several sources. Data regarding financial characteristics were taken from the Compustat quarterly dataset held by Wharton Research Data Services (WRDS). Other items related to institutional shareholding are taken from the Thomson Reuters dataset maintained by WRDS. Data related to oil reserves, production quantities, cash costs, and realized selling prices are taken from Bloomberg's annual data set and 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. Table 1 summarizes the definitions, construction, and data sources of the variables.

[Table 1 here]

B. Sample Characteristics

1. Descriptive Statistics: Dependent Variable

Our dependent variable is hedging maturity measured by the average remaining maturity weighted by the hedged notional quantity, as follows:

(1) $$HM_{i,j,t} = \sum_{T=g}^{g+5} \frac{N_{j,T} \times T}{\sum_{T=g}^{g+5} N_{j,T}}$$

where $HM_{i,j,t}$ is the weighted-average remaining maturity for firm i at quarter t and hedging instrument j. The hedging instrument could be swap contracts, put options, costless collars, forward or futures contracts, and three-way collars; $N_{j,T}$ is the hedged notional quantity[6] for instrument j and horizon T; and T ranges from the current fiscal year to five years ahead. We retain a maximum of five years ahead because we rarely find firms with hedging positions exceeding this horizon. The term g takes the value of one at the beginning of the current fiscal year or a fraction of the year otherwise (e.g., 0.75 for nine months). We then have a maximum of six years covered when g takes the value of one at the beginning of the current year.

Table 2 contains descriptive statistics of the weighted-average hedging maturity by hedging instruments. Overall, Table 2 shows average maturities (in years) of 1.227, 1.221, 1.083, 0.818, and 1.448 for swap contracts, costless collars, put options, forward/futures contracts, and three-way collars, respectively. It seems that oil hedgers adopt different hedging horizons for each hedging instrument. We also calculate the weighted-average maturity for the entire oil hedging portfolio, which could include two or more instruments used simultaneously. In this case, the weighted-average maturity for each instrument is weighted by its hedging ratio. Oil hedging portfolio has an average remaining maturity of 1.204. The statistics in Table 2 are in line with previous empirical findings that firms tend to hedge near-term positions.

[Table 2 here]

[6] We follow Haushalter (2000) and use notional quantities for put options because we lack detailed information to calculate a delta percentage for these options. At least we have three attributes of our sample that could mitigate this shortcoming in our study: i) Put options are used, on average, in 12% of firm–quarters with oil hedging; ii) put options are used most with either swap/or collars; and iii) the fraction of the quantity hedged by put options does not exceed 50%.

Table 2 also shows that oil hedging occurred in 2,607 firm–quarters (41.21% of the firm–quarters in the sample) and presents a breakdown of the frequency of use for each hedging instrument. The most common hedging vehicles are swap contracts, with 45.25% of use (i.e., 1,711 firm–quarters out of 3,781 instrument–quarters of oil hedging). The second most frequently used instrument is costless collars, with 37.11% out of all instrument–quarters of oil hedging. Next are put options. with 11.85% of use. The least used instruments are forward or futures contracts, with only 2.78%, and three-way collars, with only 3.02% of use.

2. Descriptive Statistics: Independent Variables

Descriptive statistics are computed for the pooled dataset. Table 3 gives the mean, median, first quartile, third quartile, and standard deviations for the 150 US oil producers in the sample. Statistics show that oil producers have leverage ratios with a mean and median of about 52%, which indicates little variation in the financial solvency of the sample firms. The statistics also indicate that oil producers incurred, on average, distress costs of $3 per barrel. However, there are only 306 firm–quarters with positive financial distress costs (i.e., with a leverage ratio above the median and where the realized selling prices of oil are insufficient to cover production costs and debt requirements). For these observations, the average incurred distress cost incurred is about $57 per barrel. The statistics further show relatively moderate oil production uncertainty, as measured by the coefficient of variation in daily production, with a mean (median) of 0.27 (0.17) and one-fourth of the coefficients of variation exceeding 0.34. This finding implies that oil producers have relatively stable production quantities. Debt maturity has a mean and median of two years. Proved developed oil reserves have expected life durations with a mean (median) of nine (7.5) years. Firm size has a mean (median) of about $10 billion ($481 million), indicating that our sample is constituted by a majority of small oil producers and a few larger ones.

[Table 3 here]

IV. Univariate Results

Table 4 presents univariate results comparing oil producers' characteristics and oil market conditions based on the remaining maturities of the outstanding hedging portfolios. We then classify the remaining weighted-average maturities as (1) short-term maturities (i.e., below the 33rd percentile, which corresponds to one year ahead), (2) medium-term maturities if between the 33rd and 67th percentiles (i.e., between one and 1.33 years ahead), and (3) long-term maturities, exceeding the 67th percentile (i.e., more than 1.33 years ahead). We conduct tests of the differences between the means and medians of relevant variables to contrast short-term to long-term maturities. We compare means by using a *t*-test assuming unequal variances; medians are compared with a nonparametric Wilcoxon rank-sum *Z*-test and two-sided *p*-values.

[Table 4 here]

The univariate tests show considerable differences in firm characteristics and oil market conditions between firm–quarters with long-term hedging maturities and those with short-term hedging maturities. The results indicate that oil producers with higher leverage ratios tend to choose longer maturities. This finding corroborates the prediction that hedging maturity increases with a firm's financial distress. The results further show no significant differences for distress costs. Contrary to our predictions, higher production uncertainty is related more with long-run hedging maturities contracts. The results also provide empirical evidence of maturity matching between either firms' assets or liabilities and hedging positions. In fact, oil producers with a longer debt structure and a higher expected reserve life tend to use longer hedging horizons. As predicted, the results pertaining to market conditions suggest that higher oil spot prices and volatilities are associated more with longer oil hedging positions. Overall, the mean and median comparisons yield closely similar results.

Table 5 presents our results, comparing the moneyness and strike prices of hedging instruments based on their remaining maturities. For conciseness, we concentrate our analysis on the three major hedging instruments used by oil producers: swap contracts, put options, and costless collars.[7] As before, for each of the three instruments, we classify the hedging maturity as short, medium, or long term, based on the 33rd and 67th percentiles. Tests contrast short- with long-term maturities. In line with the predictions, the comparisons reveal that hedging contracts with the shortest maturities have the lowest moneyness as measured by the strike price minus the oil spot price during the current quarter. This finding should show that oil producers tend to terminate their hedging positions that become deeply out of the money early, despite the incurred termination costs. In addition, the results indicate that oil producers maintain their hedging contracts initiated at higher strike prices for longer periods.

[Table 5 here]

V. Maturity Structure of Corporate Risk Management

To investigate the determinants of hedging maturity choice by oil producers, we estimate fixed effects regressions where the weighted-average remaining maturity is regressed on variables that measure financial distress likelihood and costs, production uncertainty, oil market conditions (oil spot price and volatility), asset-liability management and hedging contract features. To obtain more insights into the hedging dynamics of oil producers, we estimate the regressions reported in Table 6 for the entire

[7] We skip the observations related to forward/futures contracts and three-way collars because they do not contribute enough to oil hedging.

oil hedging portfolio and for the following major hedging instruments: swap contracts, put options, and costless collars.[8]

In line with our first hypothesis, the results pertaining to financial distress provide strong evidence of a nonmonotonic (concave) relation between hedging horizons and the likelihood of financial distress. We find that the leverage ratio and leverage squared have highly significant positive and negative coefficients, respectively, for the entire oil hedging portfolio. At the level of individual hedging instruments, we find that the maturities of swap contracts and costless collars also exhibit a similar nonmonotonic relation. These findings mean that hedging maturities should first increase and then decrease with the likelihood of financial distress. It appears that oil producers that are either far from financial distress or deeply financially distressed neither initiate new hedging contracts nor roll over their expiring contracts and are then observed with shorter hedging positions.

Distressed oil producers do so because they do not seek the maximum insulation of firm value from oil price fluctuations as a risk-shifting strategy. On the other hand, oil producers far from financial distress do not seek maximum protection in terms of maturity because their marginal benefit from oil hedging cannot outweigh the incurred transaction costs. The comparison with the empirical findings of Fehle and Tsyplakov (2005) for the gold mining industry indicates a lower magnitude of the coefficients related to financial distress proxies. In addition, the coefficients of leverage squared are markedly lower than those of the leverage ratio itself. It seems that the nonmonotonic relation between financial distress

[8] To control for the possibility of sample selection bias, our regressions are derived in the context of the two-step Heckman regression with selection. This procedure captures the sequential decisions of oil producers: first, a decision to hedge oil or not and, second, a decision about hedging maturity. In the first step, we model the oil hedging decision as a function of the following variables: firm size, taxes, distance to default as a measure of the likelihood of financial distress, liquidity, dividend payout, investment opportunities, institutional ownership, geographical diversification in oil production, and managerial shareholding. The results of the first step are reported in Table A.1. This first step leads to the estimation of the inverse Mills ratio for the second step. Apart the dividend payout, we find that all other variables are statistically significant and with appropriate signs, consistent with the previous literature on the decision to hedge (Tufano (1996), Géczy, Minton, and Schrand (1997), Graham and Rogers (2002), Dionne and Garand (2003)).

and hedging maturities is more pronounced for the gold mining industry than for the petroleum industry[9]. Figure 1 illustrates this nonmonotonic relation for the whole oil hedging portfolio, swap contracts, and costless collars and contrasts our findings with those of Fehle and Tsyplakov (2005) for their sample of gold mining firms.

[Table 6 and Figure 1 here]

Surprisingly, the results show the reverse situation for put options. In fact, the relationship is now convex with a negative coefficient for the leverage ratio and a positive coefficient for leverage squared. It appears then that distressed and wealthy oil producers tend to hedge longer horizons with put options. In addition, we find that distressed oil producers incurring a higher dollar loss per BOE tend to use put options with longer maturities. Jensen and Meckling's (1976) risk-shifting theory is a possible explanation for these findings. By entering costly long-term put options, distressed oil producers increase their firms' payoff volatility, decrease assets available for debtholders, and preserve any upside potential for shareholders. Oil producers with very low leverage have sufficient resources to incur the upfront payments related to put options.

Our results also provide strong evidence of a nonmonotonic (concave) relation between oil spot prices and hedging maturities for the entire hedging portfolio, swap contracts, and costless collars, as predicted in our second hypothesis. Oil spot prices and spot prices squared have highly significant positive and negative coefficients, respectively. When spot prices are very high or very low, firms are more likely to be far from or deep in financial distress, respectively, and, accordingly, more likely to choose short-term hedging contracts. This result corroborates our previous findings for the leverage

[9] The leverage ratio for the gold mining firms studied by Fehle and Tsyplakov (2005) has an average (median) of 18% (17%). This leverage ratio is lower than that observed in our sample. Adam (2009), who studies relatively the same sample as Fehle and Tsyplakov (2005), asserts that the leverage levels in the gold mining industry are characteristically low and considers this a sign of financial constraint, because most of the gold mining firms are not sufficiently creditworthy to attract significant amounts of debt.

ratio. Figure 2 illustrates this nonmonotonic relation for the whole oil hedging portfolio, swap contracts, and costless collars and shows that it is more pronounced for costless collars. Oil price volatility is negatively related to hedging maturity; however, this is only significant for the entire hedging portfolio.

[Figure 2 here]

Hedging contract features appear to have an obvious impact on hedging maturity choice, as predicted. The results in Table 6 indicate that when hedging contracts are initiated at sufficiently higher strike prices, they are more likely to be kept for longer periods, particularly for swap contracts and costless collars. For put options, the strike price has no significant impact. As predicted, the results also show that hedging contracts with higher moneyness tend to have longer maturities. Oil producers tend to keep in-the-money hedging contracts until they mature. Interestingly, the results further indicate that oil production uncertainty has a significant positive impact on hedging maturity for either the entire oil hedging portfolio or each of the instruments, namely, swap contracts, put options, and costless collars. Economically, the effect on put options' maturities is significantly higher. These findings differ from those of Brown and Toft (2002), who propose that firms could be reluctant to lock in a large hedge for the distant future due to the difficulty of making accurate exposure forecasts. One explanation is that oil producers facing higher cash flow volatility due to oil production uncertainty tend to use longer hedging positions to avoid shortfalls in their future revenues. In addition, the significant positive impact of production uncertainty on put options maturities corroborates previous theoretical literature on hedging strategy choice; that is, when a firm is facing increasing non-hedgeable risks (i.e., quantity risk), its total exposure becomes nonlinear and the convexity of its hedge increases.

The results for variables pertaining to maturity matching show that the expected life of developed oil reserves has a statistically significant positive impact on hedging maturity through swap contracts and put options. This finding provides empirical evidence of maturity matching between oil producers' major assets and hedging horizons. Average debt maturity appears to have no significant impact on hedging maturity. The results further indicate that larger oil producers, in terms of size, tend to use longer oil hedging portfolios. This finding adds some support to economies of scale in hedging maturity choices due to transaction costs. To further gauge the relevance of our findings, we re-calculate hedging maturities by using the maximum hedging horizon without accounting for the notional quantities for each point in time for oil hedging activity. Table A.2 reports the results of these additional regressions and reveals fairly similar results as before, and with greater economic and statistical significance.

VI. Early Termination of Hedging Contracts

In this section, we present a closer look at risk management dynamics by studying the determinants of the early termination of outstanding hedging contracts. Termination of a hedging contract is considered an early termination when the outstanding hedging contract has a remaining weighted-average maturity greater than or equal to six months. For each instrument, we create a dummy variable that takes the value of one when we pick up observations of no hedging preceded by an outstanding hedging contract with remaining maturity equal to or above six months and zero otherwise. We after run random effects logit regressions of these dummy variables on the firm covariates previously used and the moneyness and remaining maturity of the terminated hedging contract. Table 7 reports the results.

[Table 7 here]

We find evidence of a nonmonotonic (convex) relation between the early termination of swap contracts and leverage ratios in particular. This finding means that the likelihood of early termination of swap contracts decreases and then increases with the probability of financial distress. Put options also exhibit a similar convex relation with financial leverage, but with no statistical significance. The results further show a surprising inversion in the nonmonotonic relation between oil spot prices and the early termination of swap contracts and coatless collars. In fact, the relationship becomes convex, indicating that when oil spot prices attain higher levels, outstanding swaps and collars are actively terminated prematurely to profit from the rising oil prices or to lock in higher strike prices for new contracts. The payoff structure of swaps and collars does not allow oil producers to profit from the upside potential when oil prices increase significantly. Oil price volatility has no significant effect on the early termination of hedging contracts.

Results in Table 7 also show that in-the-money swap contracts and put options are less likely to be prematurely terminated. The remaining weighted maturity seems to have no significant impact on early termination decisions. In untabulated results, we rerun regressions using the remaining maturity without weighting by hedged quantities and find a significant negative impact on early termination decisions. This result indicates that hedging contracts with longer remaining maturity are less likely to be prematurely terminated. A possible explanation could be that the early termination of longer contracts generates higher termination costs. Interestingly, production uncertainty prevents the early termination of swap contracts in particular. It seems that, during periods of economic uncertainty, oil producers refrain from the early termination of their swap contracts to stabilize their generated cash flows. Finally, we find that debt maturity and oil reserve life are negatively related to the early termination of outstanding put options. These two effects indicate that oil producers are willing to protect future productions that make them a profit from any upside potential to meet future debt commitments.

VII. Real Implications of Hedging Maturity Structure

In this section, we extend the controversial literature that focuses on the relationship between corporate hedging and firm value. One strand of this empirical literature finds no support for the firm value maximization theory (Guay and Kothari (2003), Jin and Jorion (2006), Fauver and Naranjo (2010)). In contrast, another strand of the literature shows that firm's derivative transactions translate into increases in shareholder value (Allayannis and Weston (2001), Graham and Rogers (2002), Adam and Fernando (2006), Carter, Rogers, and Simkins (2006), Bartram, Brown, and Conrad (2011)). Aretz and Bartram (2010) review the empirical literature on corporate hedging and firm value.

We complement the empirical literature by going into further detail and investigating the real implications of the maturity structure of corporate risk management on firm value. Firm value is measured by 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. Tobin's *q* is expressed with a logarithmic transformation because its distribution is strongly right skewed.

Endogeneity due to any reverse causality between firm hedging behavior and other firm financial decisions is a crucial concern in such a study and it is identified as the major source of inconsistency in some of the previous findings. To control for this endogeneity, we first use an IV approach in the context of the two-stage least squares (2SLS) regressions. In a more elaborate test, we study the effects of choosing short-term versus long-term hedging maturities on firm value using an econometric methodology that controls for biases related to omitted variables and self-selection, namely, *essential heterogeneity* models.

A. Instrumental Variable Approach

We identify two candidate instruments coming from the corporate finance and economics literatures. Our first candidate instrument is advocated to be closely related to the hedging behaviors of non-financial firms, namely, the differential between sensitivities of firms' cash flows and investment opportunities to oil price fluctuations. These sensitivities are exogenous when making hedging decisions. In the context of random investment and financing opportunities, Froot, Stein, and Scharfstein (1993) argue that when investment opportunities and generated cash flows have *similar* sensitivities to the exogenous risk factor, the firm is almost naturally hedged and has less financing pressure. She has fewer needs for sophisticated financial risk management and can hedge with simple linear (i.e., forwards and futures) contracts. On the contrary, when these sensitivities are *dissimilar*, firms are more exposed to risks and financial risk management with options is more optimal to align their internally generated cash flows to their investment funding. In this case, options are more valuable because they are more flexible and permit hedge ratios to be "customized" on a state-by-state basis (page 1645). In other words, the use of options allows investment to be completely covered from shocks to financing opportunities. Extending their framework to our maturity environment we make the assumption that shorter maturities are more convenient when sensitivities are dissimilar because they are more flexible and permit to change the hedge ratios more easily over time when states change.

We calculate the correlation between firms' free cash flows[10] and oil spot prices and the correlation between costs incurred, as a proxy for investment opportunities, and oil spot prices. In the oil industry, costs incurred include oil properties acquisition, exploration expenses, and development costs. These correlation coefficients are calculated using rolling windows of 12 quarterly observations. Subsequently, we calculate the absolute value of the differential between both sensitivities (i.e., sensitivity of costs incurred minus the sensitivity of free cash flows). A smaller differential means that the firm's investment opportunities and internally generated funds have similar sensitivities to oil price

[10] We follow Lehn and Poulsen (1989) and calculate free cash flow before investment expenditures as operating income before depreciation less total income taxes plus changes in deferred taxes from the previous quarter to the current quarter less gross interest expenses on short- and long-term debt less the total amount of preferred dividends less the total dollar amount of dividends declared on common stock. These free cash flows are not contaminated by the monetary effects of hedging because these effects are reported in comprehensive income, as suggested by the new derivative accounting standard FAS 133, effective since 1998.

fluctuations and a bigger differential means dissimilar sensitivities. Differential should affect negatively the probability to use longer maturities and should not affect directly the firm value.

For the second candidate instrument, we build on our previous results in Table 6 showing a significant impact of crude oil prices on the maturity structure of oil hedging. Armed with this strong empirical evidence, we look for an instrument that can explain the fluctuations of the real price of oil. This instrument cannot affect directly the value of an oil producer. A large literature evidences that one of the most important fundamentals deriving industrial commodity prices are demand pressures or shocks induced by real economic activity. Recently, Kilian (2009) introduces a novel measure of the component of global real economic activity that derives demand for industrial commodities. This new measure is based on dry cargo (grain, crude oil, coal, iron ore...) single voyage ocean freight rates that captures demand shifts in global industrial commodity markets.

The Kilian index, constructed monthly, accounts for different fixed effects for different routes, commodities and ship size. It is also deflated with the U. S consumer price index and linearly detrended to remove the decrease in real term over time of the cost of shipping of dry cargoes. Kilian (2009) shows that aggregate shocks for industrial commodities causes long swings in the real prices of oil which differ from the fairly increases and decreases in the price of oil induced by the oil market specific demand shocks that are more transitory. For our purposes, we calculate the changes in the Kilian (2009) index for each fiscal quarter in the sample[11]. Our prediction is that this index should have a positive impact on long maturity hedging and no impact on oil producer value.

[11] The Kilian index is constructed monthly and is publicly available on the personal web site of Lutz Kilian. For each firm in the sample, we calculate changes in the Kilian index by taking the level of the index at the end of the current fiscal quarter (i.e., at the end of the last month in the fiscal quarter) minus its level at the end of the previous fiscal quarter.

The IV estimation is performed in the context of the 2SLS regressions. We use the following regression model for the firm value:

(2) $$Oil\ hedging\ maturity_{i,t} = \beta_0 + \beta_1 \times Differential_{i,t-1} + \beta_2 \times Changes\ in\ Kilian\ index_{i,t-1} + \sum Control\ variables_{i,t-1} + Firm\ fixed - effects + \varepsilon_{i,t},$$

and

(3) $$Firm\ outcome_{i,t} = \alpha_0 + \alpha_1 \times Predicted\ oil\ hedging\ maturity_{i,t} + \sum Control\ variables_{i,t-1} + Firm\ fixed - effects + \upsilon_{i,t}.$$

In the first step, represented by Eq. (2), the oil hedging maturity is regressed on the lagged value of the candidate IV (i.e., differential in sensitivities and changes in the Kilian index) and the lagged values of other control variables. This first step leads to the estimation of a predicted oil hedging maturity. In the second step of the IV approach, represented by Eq. (3), the firm value is regressed on the predicted oil hedging maturity and lagged values of the control variables. Firm-level controls include return on assets, investment opportunities, quantity of oil reserves, oil production uncertainty, leverage ratio, liquidity, a dividend payout dummy, geographical diversification in oil production, and institutional ownership. Control variables also include oil basis and oil price volatility. We further control for the recent financial crisis, accompanied by a markedly higher oil volatility, by including dummy variable for the year 2008 and 2009 respectively. Table 1 gives a description of the construction of these control variables.

The two steps of the IV regressions are estimated using firm fixed effects and correcting standard errors for within-firm correlation and heteroskedasticity using the Huber–White consistent estimator. This approach allows us to account for time-invariant unobservable firm characteristics and explore within-firm differences. To statistically confirm the validity of our instruments, we perform a panoply of relevant statistical tests related to the first-stage regression, endogeneity, and over-identification. These tests statistics and their respective null hypotheses are reported in Table 8.

First, the *C* statistic test rejects the null hypothesis that oil hedging maturity can already be treated as exogenous in the main structural equations for the firm value (*p*-value of 0.0060), indicating the need to use IV approach. The *F*-tests of the significance of the instruments in the first-stage regressions are highly significant with *p*-values lower than 0.001, indicating the higher relevance of our instruments (inclusion restriction of instrument). Using the Hansen *J* statistics, we cannot reject the null hypothesis that the differential in sensitivities and changes in the Kilian index are joint valid instruments for the oil hedging maturity with a *p*-value of 0.2439. Finally, the Anderson-Rubin Wald test rejects the null hypothesis that the predicted oil hedging maturity has a coefficient equal to zero in the main structural equation for the firm value (*p*-value of 0.0046). In sum, all these tests statistically validate our two candidate instruments.

[Table 8 here]

Table 8 also presents the results from the second-stage estimations and obtains very important findings. Results for the first-stage are presented in Table A3, where we observe that the two instruments are significant with the appropriate signs. The results in Table 8 show a highly significant relationship between predicted hedging maturity and firm value measured by Tobin's *q*. On average, a one-year increase in oil hedging maturity increases firm value by more than 63.13%. Relative to the sample average Tobin's *q* of 1.73, this result translates into an increase of about 1.09 (= 1.73 × 63.13%). Our finding corroborates empirical evidence of value enhancement by derivatives (e.g., Allayannis and

Weston (2001), Carter, Rogers, and Simkins (2006), Bartram, Brown, and Conrad (2011), Choi, Mao, and Upadhyay (2013), Pérez-Gonzales and Yun (2013)).

B. Short-Term versus Long-Term Hedging Maturity

To gain deeper insight into the dynamics of oil hedging maturities and their related real implications, we distinguish between short- and long-term hedging maturities. As before, we classify the remaining weighted-average maturities as short-term maturities (i.e., below the 33rd percentile, which corresponds to one year ahead) and long-term maturities (i.e., exceeding the 67th percentile, which corresponds to 1.33 years ahead). We then create a dummy variable that takes the value of one for long-term maturities and zero for short-term maturities. In doing so, we are able to distinguish either short- or long-term hedging maturities' contributions to higher value enhancement for oil producers. To overcome the endogeneity problem outlined previously, we use a newly developed IV methodology that controls for bias related to omitted variables and self-selection in the estimation of the MTEs of hedging maturity choice, namely, the *essential heterogeneity* model of Heckman, Urzua, and Vytlacil (2006).

1. Essential Heterogeneity Models

Practically, *essential heterogeneity* models usually begin with a Mincer-like (Mincer, 1974) equation, as follows:

$$y_{i,t} = \alpha + \beta \times d_{i,t} + \sum Control\ variables_{i,t-1} + u_{i,t}, \qquad (4)$$

where $y_{i,t}$ is the observed value of oil producer *i* at the end of quarter *t* and $d_{i,t}$ is the observed value of a dummy variable $D = (0,1)$ representing whether the oil producer *i* uses short- or long-term hedging contracts at the end of quarter *t*. The control variables include the same set of observable covariates as in Eq. (3). The term $u_{i,t}$ is an individual-specific error term and β represents the average return from using long-term hedging contracts.

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 $u_{i,t}$, but it should be resolved using IV methods, among others. The second source of bias occurs if the returns to using long-term hedging positions vary across oil producers (i.e., β is random), even after conditioning on observable characteristics leading to heterogeneous treatment effects. Moreover, oil producers make their hedging maturity choice (short-term versus long-term maturity) 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, Urzua, and Vytlacil (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 and is as follows. 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 unobservables (U_0, U_1), as follows:

(5) $$Y_1 = \alpha_1 + \beta_1 X + U_1,$$

(6) $$Y_0 = \alpha_0 + \beta_0 X + U_0.$$

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 short- or long-term hedging positions are used, is linked to the observed outcome through the latent variable I_D, which gives the dummy variable D representing the treatment status:

$$D = \begin{cases} 1 \text{ if } I_D > 0, \\ 0 \text{ if } I_D \leq 0, \end{cases} \tag{7}$$

where the vector of the observed values of the Z variables includes IV variables Z_{IV} and all the components of X in the outcome equation. The variables Z_{IV} satisfy the following constraints: $\text{Cov}(Z_{IV}, U_0) = 0$, $\text{Cov}(Z_{IV}, U_1) = 0$, and $\gamma \neq 0$. As before, our candidate IV Z_{IV} are the differential between the sensitivities of firms' cash flows and investment opportunities to oil price fluctuations, and changes in the Kilian index. The unobservable set of (U_0, U_1, V) is assumed to be statistically independent of Z, given X.

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

$$Pr(D = 1|Z) \Leftrightarrow I_D > 0 \Leftrightarrow \gamma Z > V \Leftrightarrow \mathbf{\Phi}(\gamma Z) > \mathbf{\Phi}(V) \Leftrightarrow P(Z) > U_D, \tag{8}$$

with $\mathbf{\Phi}(\cdot)$ as the cumulative distribution of a standard normal variable. The term $P(Z)$, called the probability of participation or *propensity score*, denotes the selection probability of using long-term hedging maturity conditional on Z (i.e., $D = 1$). 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 is a measure of individual-specific resistance to undertake treatment or, alternatively, the propensity to not be treated. In our case, the higher $P(Z)$, the more the oil producer is induced to use long-term hedging maturities because of *Z*. On the contrary, the higher U_D, the greater the resistance of the oil producer to use long-term maturities due to a larger unobserved component. Then $P(Z) = U_D$ is the margin of indifference for oil producers that are indifferent between long- and short-term hedging horizons.

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

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

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 Eq. (4). Equivalently, the estimated MTE shows how the marginal increment in the outcome 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 Eq. (4) is negatively or positively correlated with the latent tendency of using long-term contracts for oil hedging.[12]

2. Results and Interpretation

In Table A.4, we estimate the choice equation by a probit model, leading to the estimation of the propensity score of using long-term hedging maturities. The dependent variable is a dummy variable

[12] 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.

that takes the value of one for long-term maturities and zero for short-term maturities, as defined previously. Regressors in the choice equation are our two candidate instruments and the same set of control variables used previously (see Table 8). The results show that the differential in sensitivities appears to be a strong predictor of hedging maturity choice, with economically and statistically significant negative coefficient. This indicates that oil producers tend to use short-term hedging positions when their internally generated cash flows and investment opportunities have dissimilar sensitivities to oil price fluctuations. Changes in the Kilian index have an economically and statistically significant positive coefficient, indicating that oil producers tend to enter long-term hedging contracts in periods of increasing aggregate cumulative demand for industrial commodities. Overall, this finding indicates that if oil producers' managers believe that oil prices are more likely to rise in the long run driven by a vigorous global real economic activity, they would prefer to lock in higher strike prices by entering longer hedging contracts to prevent any future downturn in oil prices due to business cycles.

Table 9 reports the results of the estimation of the outcome equation with respect to firm value. The output in Table 9 gives the estimations for both the treated and untreated groups.[13] The outcome equation indicates also the average treatment effect (ATE) which captures the expected average benefit associated with the inducement in the treatment (i.e., using long-term hedging maturities in our case) conditional on observable independent variables. The ATE coefficient is not statistically significant.

[Table 9 here]

Fig. 3 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

[13] The treated group consists of users of long-term hedging positions. The untreated group consists of users of short-term hedging positions.

resistance to use long-term hedging positions, namely, U_D. The ATE is also plotted as the dashed line as a reference point. In addition, estimated MTEs with their respective standard errors are reported in Table A.5 for different evaluation points of U_D, from 0.01 to 0.99. Almost all of them are statistically significant. Fig. 3 shows that estimated MTEs are increasing with different quantiles of U_D, reflecting that the marginal Tobin's q is lowest for oil producers that are more likely to use long-term hedging maturities (i.e., lower values of the unobserved component U_D). Table A.5 shows that estimated MTEs range from -233% for high propensities to use long–term hedging positions to 200% for high propensities to use short–term hedges. This finding indicates that an oil producer's value increases with hedging short-term horizons. Thus the positive impact of hedging maturity on firm value appears to be more strongly related to the use of short-term hedging contracts.

[Figure 3 here]

Furthermore, the better effects of short-term hedges on oil producers' value are channeled through the impacts of oil market conditions on this value. In fact, oil price volatility has a statistically significant negative impact on firm value, indicating that investors prefer a higher exposure to oil price fluctuations and tend to penalize hedging efforts at the firm level. However, this negative effect is more evident (almost the double) for oil hedgers using longer contracts than users of short-term contracts. In addition, when oil price tend to be higher, investors tend to penalize oil producers with longer hedging positions and reward those with shorter hedging contracts. Longer hedging contracts do not allow benefit from this upward potential, particularly for hedging positions with linear like payoffs. Moreover, the early termination of long-term hedging contracts, to profit from the oil price increase, is more costly than shorter contracts.

Interestingly, the curvature of the depicted MTEs in the Fig. 3, with respect to different quantiles of the unobserved component of the decision process of using long-term hedging positions, exhibits substantial heterogeneity in treatment effects. This provides evidence of selection into treatment or a self-selection bias, indicating that the causal effects of the hedging maturity structure on firm value vary across oil producers due to unobserved factors.

VIII. Concluding Remarks

A substantial body of the theoretical corporate risk management literature has increased our understanding of the motivations, virtues, and value implications of hedging. This literature derives its theoretical or empirical predictions based on the extent of hedging or participation in hedging activities. Due to the lack of data, the dynamics structure of corporate risk management is discussed in a largely descriptive manner in the previous empirical literature. In this study, we go beyond the classical questions in the corporate hedging literature and investigate the following questions: How far ahead do firms hedge? What are the determinants of the maturity structure of hedging programs of nonfinancial firms? What are the effects of hedging maturities on firm value?

Using an extensive and new hand-collected dataset on the risk management activities of 150 US oil producers, we provide strong evidence that hedging maturities for swap contracts and costless collars increase and then decrease with the likelihood of financial distress, as determined by Fehle and Tsyplakov (2005). Highly distressed oil producers enter longer put options as a risk-shifting strategy. Consistent with the prediction, our results show a nonmonotonic (concave) relationship between oil spot prices and hedging maturities, particularly for swap contracts and costless collars. In addition, hedging contract features (i.e., moneyness, strike price) have an obvious impact on hedging maturity structure. Oil production uncertainty motivates oil producers to use longer hedging to avoid shortfalls in their future cash flows. Oil producers appear to match the maturities of their hedging positions through swap contracts and put options and the expected life duration of their developed oil reserves.

We also provide the first direct evidence of the motivations for the early termination of hedging contracts, which appears to be influenced by the likelihood of financial distress, oil spot prices, oil production uncertainty, debts maturity and the expected life of developed oil reserves, and the contract's moneyness. However, the impact of these determinants depends upon the nature of the hedging contract (swap, put option, collar).

Finally, we explore the real effects of hedging maturity on firm value. We use an IV approach to control for the endogeneity problem and find that the predicted oil hedging maturity increases firm value in a significant manner. To gain further insight into the dynamics of these real implications, we distinguish between short-term and long-term hedging horizons. 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. Interestingly, our results show that the favorable effects of oil hedging on firm value are essentially due to the use of short-term hedging positions. More importantly, our results show an evident selection on gain into treatment due to unobserved factors in the choice decision about the hedging maturity design (long- versus short-term horizon). The selection on gain into treatment means that the causal effects of the hedging maturity structure on firm value vary across oil producers.

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Table 1: Variables' Definitions, Construction, and Sources

This table presents the definitions, construction, and data sources for the independent variables.

Variable Definition	Variable Name	Construction	Source
Leverage ratio	Leverage	Book value of total debts scaled by the book value of total assets.	Compustat
Financial distress costs	Distress Costs	Measured by $I[\,Lev - L]\,Max[0, -p + c + d]$, where Lev is the leverage ratio, L is the median leverage ratio of the oil producers in the sample, p is realized selling price, c is production cost, and d is debt payments, including interest payments and debt reimbursements, with p, c and d expressed per BOE. This variable is $I[Lev - L] = 1$if $Lev > L$ and zero otherwise.	Manually constructed
Oil spot price	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	Oil Volatility	Historical volatility (standard deviation) using the daily spot prices during the quarter.	Manually constructed
Oil production uncertainty	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
Firm size	Firm Size	The logarithm of number of common shares outstanding × end-of-quarter per share price + book value of assets - book value of equity.	Compustat
Weighted-average maturity of debt (in years)	Debt Maturity	Calculated as the book value-weighted average maturities of debt that mature within one, two, three, four, and five years.	Manually constructed
Expected life of oil reserves (in years)	Oil Reserve Life	Calculated by dividing the current quantity of developed oil reserves by the current annual oil production.	Manually constructed
Contract strike price	Strike Price	Measured by the average spot price during the quarter of the initiation of the hedging contract.	Manually constructed
Contract moneyness	Moneyness	A dummy variable that takes the value of one if the strike price at the inception of the hedging contract is greater than or equal to the average spot price during the current quarter. Otherwise, it takes the value of -1.	Manually constructed
Contract's remaining maturity	Remaining Maturity	The remaining weighted-average maturity at the termination date of the hedging contract (in years).	Manually constructed
		Variables in the real implications regression	
Firm value	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 divided by the book value of total assets.	Manually constructed
Return on assets	ROA	Quarterly net income divided by the book value of total assets.	Manually constructed
Investment opportunities	Investment Opportunities	Total costs incurred in property acquisition, exploration, and development, scaled by net property, plant, and equipment at the beginning of the quarter.	Bloomberg and 10-K reports
Liquidity	Liquidity	Book value of cash and cash equivalents divided by the book value of current liabilities.	Manually constructed
Dividend payout	Dvd Payout	Dummy variable for dividends declared during the quarter.	Manually constructed
Institutional ownership	Inst Ownership	Percentage of firm shares held by institutional investors.	Manually constructed
Oil reserves	Oil Reserves	The logarithm of the quantity of the total proved developed and undeveloped oil reserves (in millions of barrels).	Bloomberg and 10-K reports
Oil basis	Oil Basis	The logarithm of (oil future price / oil spot price) at the end of the current quarter. Oil future price is the oil price for exchange-traded 12 months futures contracts.	Bloomberg

Table 1 (continued)

Variable Definition	Variable Name	Construction	Source
Geographical diversification in oil production activities	Geo Diversification	Equals $1-\sum_{i=1}^{N}\left(\frac{q_i}{q}\right)^2$, where q_i is the daily oil production in region i (Africa, Latin America, North America, Europe, and the Middle East) and q is the firm's total daily oil production.	Manually constructed
Financial crisis	2008 and 2009	Dummy variable for each year 2008 and 2009.	Manually constructed
		Instrumental variables	
Changes in Kilian (2009) index	*Δ* Kilian Index	Variations in the Kilian (2009) Index. This index is publicly available in a monthly frequency (http://www-personal.umich.edu/~lkilian). For each firm in the sample, we calculate changes in the Kilian index by taking the level of the index at the end of the current fiscal quarter (i.e., at the end of the last month in the fiscal quarter) minus its level at the end of the previous fiscal quarter.	Personal web site of the author Lutz Kilian
Differential in sensitivities of firm's costs incurred and cash flows to oil prices	Differential	Absolute value of costs incurred-oil spot price correlation minus free cash flows-oil spot price correlation. These correlation coefficients are calculated for each firm by using rolling windows of twelve quarterly observations.	Bloomberg and 10–K reports

Table 2: Weighted-Average Maturity by Hedging Instrument (in years)

This table presents summary statistics pertaining to the weighted-average maturity by hedging instrument and for the whole oil hedging portfolio.

Hedging instrument	Obs	% of use	Mean	Median	1st Quartile	3rd Quartile	Min	Max	Std Dev
Swap contracts	1711	45.25%	1.227	1.061	0.750	1.530	0.250	3.758	0.644
Costless collars	1403	37.11%	1.221	1.050	0.799	1.500	0.250	4.439	0.621
Put options	448	11.85%	1.083	1.000	0.750	1.416	0.250	2.970	0.548
Forwards or futures	105	2.78%	0.818	0.750	0.500	1.000	0.250	1.750	0.332
3-way collars	114	3.02%	1.448	1.230	0.855	1.840	0.250	4.212	0.878
Oil hedging portfolio maturity	2607		1.204	1.061	0.820	1.489	0.250	3.935	0.575

Table 3: Summary Statistics

This table provides quarterly summary statistics for the 150 US oil producers for the period 1998-2010. Variables are defined in Table I.

Variables	Obs	Mean	Median	1st Quartile	3rd Quartile	Std.Dev
Leverage	6,044	0.516	0.523	0.342	0.658	0.285
Distress Costs ($/BOE)	5,732	3.056	0.000	0.000	0.000	34.167
Production Risk	6,246	0.272	0.168	0.079	0.344	0.302
Debt Maturity (in years)	6,116	2.000	2.000	0.000	3.349	1.640
Oil Reserve Life (in years)	6,157	9.055	7.542	5.050	10.639	10.846
Firm Size (in $millions)	5,920	9,782.407	480.944	91.262	2,901.53	44,541.91

Table 4: Characteristics of Oil Producers and Market Conditions by Hedging Maturity

This table provides the mean and median values of oil producer characteristics and market conditions according to the weighted-average maturity of the oil hedging portfolio. For each firm–quarter with hedging activity, a hedging portfolio maturity is classified as short term if it is less than the 33rd percentile of the weighted-average maturity (i.e., one year ahead), medium term if it is between the 33rd and 67th percentiles (i.e., between one and 1.33 years ahead), and long term if it exceeds the 67th percentile (i.e., more than 1.33 years ahead). The variables are defined in Table 1. Comparison of means is constructed using a *t*-test assuming unequal variances; comparison of medians is constructed by using the nonparametric Wilcoxon rank sum *Z*-score. Two sided *p*-values are reported. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Short Maturity			Medium Maturity			Long Maturity			Short vs. Long Maturity	
Variables	Obs	Mean	Median	Obs	Mean	Median	Obs	Mean	Median	Mean	Median
Leverage	837	0.595	0.568	889	0.580	0.567	858	0.618	0.595	-2.089**	-3.500***
Distress Costs	814	0.689	0.000	857	1.166	0.000	828	1.113	0.000	-1.197	0.555
Production Risk	846	0.219	0.154	894	0.220	0.154	867	0.269	0.171	-4.171***	-0.977
Debt Maturity	846	2.281	2.537	894	2.576	3.000	867	2.804	3.021	-6.665***	-6.738***
Oil Reserve Life	846	7.779	6.927	894	8.119	7.426	867	9.634	8.892	-7.595***	-9.760***
Firm Size	828	5,280.539	1,080.28	879	6,082.382	1,662.12	852	8,006.757	2,180.026	-4.504***	-6.089***
Oil Spot price	845	46.924	32.5	894	53.724	49.64	867	68.509	69.89	-16.799***	-16.702***
Oil Volatility	845	3.092	2.371	894	3.672	2.738	867	4.617	3.548	-10.618***	-13.729***

Table 5: Contract Features by Hedging Maturity

This table provides the mean and median values of the hedging instruments features (i.e., moneyness and strike price) according to the weighted-average maturity. Hedging instruments are swap contracts, put options, and costless collars. The variable Strike Price is measured by the average spot price during the quarter of initiation of the hedging contract. The variable Moneyness is calculated as the contract strike price minus the average spot price during the current quarter. For each instrument, hedging maturity is classified as short term if it is less than one year ahead, medium term if between one year and two years ahead, and long term if it exceeds two years ahead. Comparison of means is constructed using a *t*-test assuming unequal variances; comparison of medians is constructed by using the nonparametric Wilcoxon rank sum *Z*-score. Two sided *p*-values are reported. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Short Maturity			Medium Maturity			Long Maturity			Short vs. Long Maturity	
Variables	Obs	Mean	Median	Obs	Mean	Median	Obs	Mean	Median	Mean	Median
Swap contracts											
Moneyness	564	-3.521	-2.817	582	-2.138	0.000	565	-3.349	0.000	-0.182	-2.290**
Strike price	564	41.237	31.155	582	47.976	43.182	565	62.502	60.048	-14.822***	-14.712***
Put options											
Moneyness	148	-1.083	-1.153	145	-3.177	0.000	152	3.227	0.000	-1.897*	-2.920***
Strike price	148	49.435	38.314	145	52.470	48.305	152	66.316	64.952	-4.755***	-4.729***
Costless collars											
Moneyness	468	-3.783	-3.287	472	-1.612	0.000	463	-0.475	0.000	-2.483**	-2.638***
Strike price	468	50.266	43.908	472	55.040	59.685	463	67.996	63.181	-10.129***	-10.359***

Table 6

Oil Hedging Maturity Structure

This table provides the results of the fixed effects regressions for the determinants of the weighted-average remaining maturity for the whole oil hedging portfolio, swap contracts, put options, and costless collars, respectively. All the variables are defined in Table 1. Independent variables related to oil producer characteristics are included in lagged values. The inverse Mills ratio is obtained from the first-step Heckman regression (Table A.1). Heteroskedasticity-consistent standard errors clustered at the firm level are reported in parentheses. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Oil Hedging	Oil Hedging	Swap Contracts	Swap Contracts	Put Options	Put Options	Costless Collars	Costless Collars
Leverage	1.0731***	1.3066***	1.7493***	2.0489***	-0.6979	-0.3744	1.2233*	1.2391*
	(0.387)	(0.399)	(0.459)	(0.456)	(0.549)	(0.555)	(0.673)	(0.662)
Leverage Squared	-0.6744**	-0.7868***	-1.2212***	-1.3524***	0.7651**	0.5946	-0.7786**	-0.7880**
	(0.272)	(0.273)	(0.289)	(0.284)	(0.376)	(0.406)	(0.338)	(0.332)
Distress Costs	0.0013	0.0011	0.0030	0.0033	0.0091***	0.0062*	0.0003	-0.0002
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)
Oil Spot Price		0.0219***		0.0253***		0.0026		0.0143***
		(0.004)		(0.006)		(0.005)		(0.004)
Spot Squared		-0.0001***		-0.0001***		-0.0000		-0.0001***
		(0.000)		(0.000)		(0.000)		(0.000)
Oil Volatility	-0.0139***		-0.0088		-0.0031		-0.0119	
	(0.004)		(0.006)		(0.008)		(0.010)	
Strike Price	0.0046***		0.0070***		-0.0005		0.0043**	
	(0.001)		(0.002)		(0.002)		(0.002)	
Moneyness		0.0816***		0.1118***		0.1020***		0.1163***
		(0.011)		(0.014)		(0.027)		(0.015)
Production Risk	0.1592*	0.2286***	0.3310*	0.3868**	0.5643**	0.5520***	0.3222**	0.3528**
	(0.082)	(0.082)	(0.178)	(0.161)	(0.213)	(0.203)	(0.157)	(0.160)
Debt Maturity	0.0078	0.0017	0.0083	-0.0022	0.0007	-0.0067	0.0029	-0.0021
	(0.014)	(0.012)	(0.016)	(0.015)	(0.026)	(0.026)	(0.026)	(0.026)
Oil Reserve Life	0.0048	0.0050	0.0163*	0.0141*	0.0122*	0.0122**	-0.0034	-0.0018
	(0.004)	(0.004)	(0.009)	(0.008)	(0.006)	(0.006)	(0.007)	(0.007)
Firm Size	0.0801**	-0.0037	0.0087	-0.0929	0.1394	0.0883	0.0465	0.0106
	(0.037)	(0.035)	(0.056)	(0.067)	(0.089)	(0.081)	(0.055)	(0.056)
Inverse Mills Ratio	0.0519	0.0981	0.0993	0.1102	-0.0273	-0.1159	0.0408	-0.0310
	(0.064)	(0.078)	(0.072)	(0.094)	(0.110)	(0.131)	(0.179)	(0.183)
Constant	-0.0977	-0.1483	-0.0388	0.0727	-0.0340	0.1237	0.1679	0.1586
	(0.310)	(0.296)	(0.397)	(0.365)	(0.517)	(0.555)	(0.534)	(0.569)
Observations	2,413	2,413	1,585	1,585	396	399	1,314	1,314
R-Squared	0.1027	0.1833	0.1083	0.1852	0.1197	0.1709	0.0649	0.1233
Number of firms	101	101	89	89	36	39	80	80
Rho	0.5054	0.4990	0.6014	0.6244	0.5954	0.5524	0.4639	0.4789
Sigma of random effects	0.4181	0.3939	0.5700	0.5721	0.4597	0.4091	0.4327	0.4320
Sigma of error terms	0.4136	0.3946	0.4641	0.4438	0.3789	0.3683	0.4652	0.4506

Table 7

Determinants of the Early Termination of Hedging Contracts

This table provides the results of random effects logit regressions of the determinants of the early termination of swap contracts, put options, and costless collars, respectively. The dependent variable is a dummy variable that takes the value of one when there is an early termination of the hedging contract and zero otherwise. All the variables are defined in Table 1. Independent variables related to oil producer and hedging contract features are included in lagged values. Heteroskedasticity-consistent standard errors clustered at the firm level are reported in parentheses. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Swap Contracts	Swap Contracts	Put Options	Put Options	Costless Collars	Costless Collars
Leverage	-2.3120	-3.5440*	-1.1722	-2.1151	5.8737	3.8701
	(1.874)	(2.009)	(2.302)	(3.768)	(3.909)	(3.113)
Leverage Squared	1.5316*	2.0512*	0.6169	1.2791	-4.3015	-3.0387
	(0.919)	(1.073)	(2.070)	(3.235)	(3.375)	(2.505)
Distress Costs	-0.0745	-0.0777	0.0012	0.0072	-0.0425	-0.0363
	(0.055)	(0.065)	(0.027)	(0.026)	(0.030)	(0.033)
Oil Spot Price		-0.0663***		-0.0394		-0.0780***
		(0.023)		(0.040)		(0.024)
Spot Squared		0.0003*		0.0003		0.0004**
		(0.000)		(0.000)		(0.000)
Oil Volatility	-0.0138		0.0750		-0.0256	
	(0.064)		(0.068)		(0.075)	
Remaining Maturity	-0.2875		0.5565		-0.0705	
	(0.185)		(0.457)		(0.208)	
Moneyness		-0.9013***		-0.6355***		-0.3717
		(0.303)		(0.238)		(0.232)
Production Risk	-3.0546***	-2.6867**	-1.6493	-1.3941	-0.7512	-0.6589
	(0.925)	(1.108)	(1.153)	(1.112)	(0.723)	(0.767)
Debt Maturity	-0.0210	-0.0202	-0.2773**	-0.2631*	-0.0153	0.0540
	(0.096)	(0.107)	(0.126)	(0.141)	(0.087)	(0.097)
Oil Reserve Life	-0.0201	-0.0311	-0.1999*	-0.1600	-0.0046	-0.0061
	(0.034)	(0.037)	(0.116)	(0.107)	(0.025)	(0.028)
Firm Size	-0.0783	0.0740	-0.3771	-0.2868	-0.2445	-0.0810
	(0.101)	(0.118)	(0.272)	(0.269)	(0.156)	(0.131)
Constant	-0.9316	-0.3568	1.4657	2.3277	-3.2680**	-1.6991
	(1.239)	(1.256)	(1.698)	(1.670)	(1.325)	(1.455)
Observations	1,660	1,660	430	430	1,399	1,399
Number of firms	89	89	40	40	80	80
Log Likelihood	-223.8298	-205.6000	-77.6522	-75.0663	-200.3022	-190.0526

Table 8

Real Implications of Oil Hedging Maturity

This table provides the results of the fixed effects regressions corresponding to the second step of the IV approach for the real implications of the predicted oil hedging maturity on firm value. The instrument for oil hedging maturity are the differential in sensitivities of a firm's investment opportunities and cash flows to fluctuations in oil prices, and changes in Kilian index. The dependent variable is 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. All the variables are defined in Table 1. Independent variables related to firm characteristics, oil basis, and oil price volatility are included in lagged values. Heteroskedasticity-consistent standard errors clustered at the firm level are reported in parentheses. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Variables	(1) Tobin's *q*
Predicted Oil Hedging Maturity	0.6313**
	(0.264)
ROA	0.2476*
	(0.146)
Investment Opportunities	0.0890***
	(0.009)
Leverage	0.2788**
	(0.112)
Liquidity	0.0069
	(0.005)
Dividend Payout	-0.0739
	(0.115)
Oil Reserves	-0.1115***
	(0.042)
Inst ownership	0.0140
	(0.121)
Geo Diversification	0.1327
	(0.158)
Oil Volatility	-0.0209***
	(0.004)
Oil Basis	0.3779**
	(0.174)
Production Risk	0.1730**
	(0.079)
2008	-0.0366
	(0.038)
2009	-0.1696***
	(0.043)
Observations	5,379
Number of firms	146
Log likelihood	-3323.0971
Second-stage *F*-test (*p*-value)	0.0000
Endogeneity diagnostics	
p-value of *C* statistic test of the endogenous regressor	0.0060
H0: The endogenous regressor can actually be treated as exogenous	
First-stage *F*-test (*p*-value)	0.0000
H0: The coefficients of independent variables in the first-stage equation are jointly equal to zero	
First-stage *F*-test (*p*-value) of excluded instruments	0.0000
H0: The coefficients of instrumental variables in the first-stage equation are jointly equal to zero	
p-value of Hansen *J* statistic	0.2439
H0: All over-identifying restrictions are correct	
p-value of Anderson-Rubin Wald test of the endogenous regressor	0.0046
H0: The coefficient of the endogenous regressor in the structural equation is equal to zero	

Table 9
Real implications of Short-Term versus Long-Term Hedging Maturities

This table provides the results of the second-step regressions (outcome equation) of the *essential heterogeneity* models for the real implications of using long-term versus short-term hedging maturities. The dependent variable is 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. All the variables are defined in Table 1. Independent variables related to firm characteristics, oil basis, and oil price volatility are included in lagged values. The inverse Mills ratio is from the first-step Heckman regression (Table A.1). The term ATE stands for the average treatment effect. Treated is for user of long-term hedging positions and Untreated is for user of short-term hedging positions. 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.

	(1)	(2)
	Tobin's *q*	
Variables	Treated	Untreated
ROA	-0.2978	1.2900***
	(0.216)	(0.315)
Investment Opportunities	-0.0330	0.8783***
	(0.103)	(0.294)
Leverage	0.0377	0.1251
	(0.106)	(0.121)
Liquidity	0.0285	0.1010**
	(0.029)	(0.041)
Dividend Payout	0.0759	0.0586
	(0.048)	(0.068)
Oil Reserves	-0.0471**	-0.0004
	(0.023)	(0.021)
Inst ownership	0.2061*	-0.3599**
	(0.124)	(0.144)
Geo Diversification	-0.0681	0.2630*
	(0.110)	(0.158)
Oil Volatility	-0.0320***	-0.0163**
	(0.005)	(0.007)
Oil Basis	-0.8473*	2.1879***
	(0.488)	(0.651)
Production Risk	-0.0961	0.1347
	(0.089)	(0.129)
Inverse Mills ratio	0.0028	-0.6520***
	(0.124)	(0.172)
2008	-0.0861*	0.1749*
	(0.049)	(0.093)
2009	-0.1079**	-0.0252
	(0.049)	(0.085)
Constant	0.8518***	1.1950***
	(0.219)	(0.263)
ATE	-0.1646	
	(0.184)	
Observations	1,623	

Figure 1: Nonmonotonic Relation between Oil Hedging Maturity and the Leverage Ratio

This figure illustrates the relation between hedging maturity and the leverage ratio: $Maturity = \alpha \times Leverage + \beta \times Lverage^2 + \sum Controls,$ with α and β calculated from the estimation of the fixed effects regressions reported in Table 6. The coefficients α and β, respectively, equal 1.07 and -0.67 for the oil hedging portfolio, 1.75 and -1.22 for swap contracts, and 1.22 and -0.78 for costless collars (see Table 6, columns 1, 3, and 7). For Fehle and Tsyplakov (2005), α and β equal 4.30 and -5.10 (see Table 16, pp. 41 from Fehle and Tsyplakov, 2005).

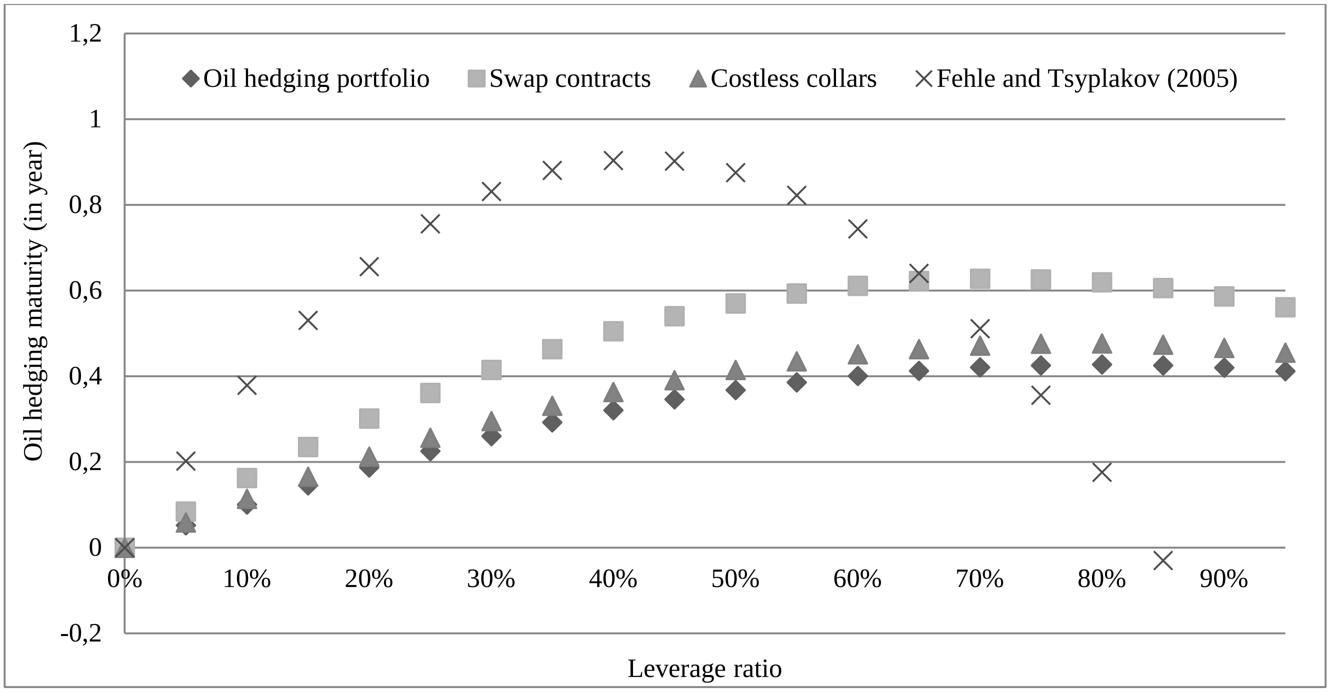


Figure 2: Nonmonotonic Relation between Oil Hedging Maturity and Oil Spot Prices

This figure illustrates the relation between hedging maturity and oil spot prices: $Maturity = \alpha \times Oil\ spot\ price + \beta \times Oil\ spot\ price^2 + \sum Controls,$ with α and β calculated from the estimation of the fixed effects regressions reported in Table 6. The coefficients α and β, respectively, equal 0.0219 and -0.0001 for the oil hedging portfolio, 0.0253 and -0.0001 for swap contracts, and 0.0143 and -0.0001 for costless collars (see Table 6, columns 2, 4, and 8).

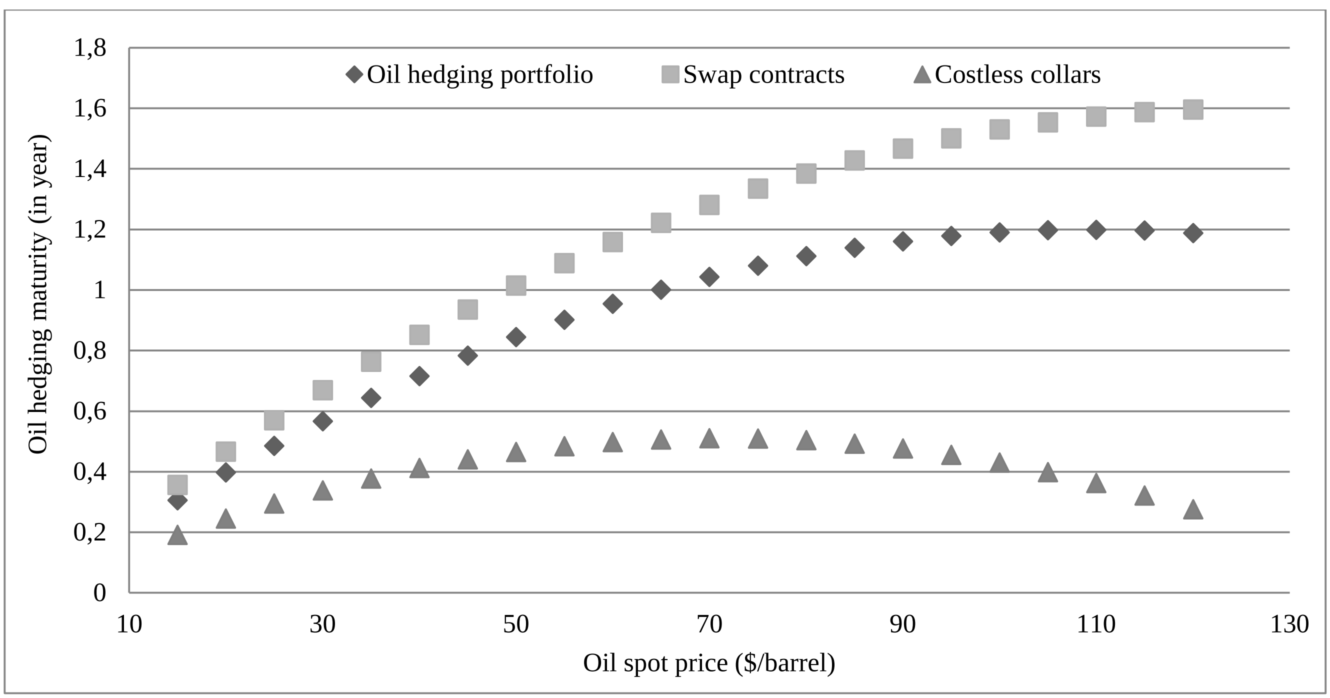
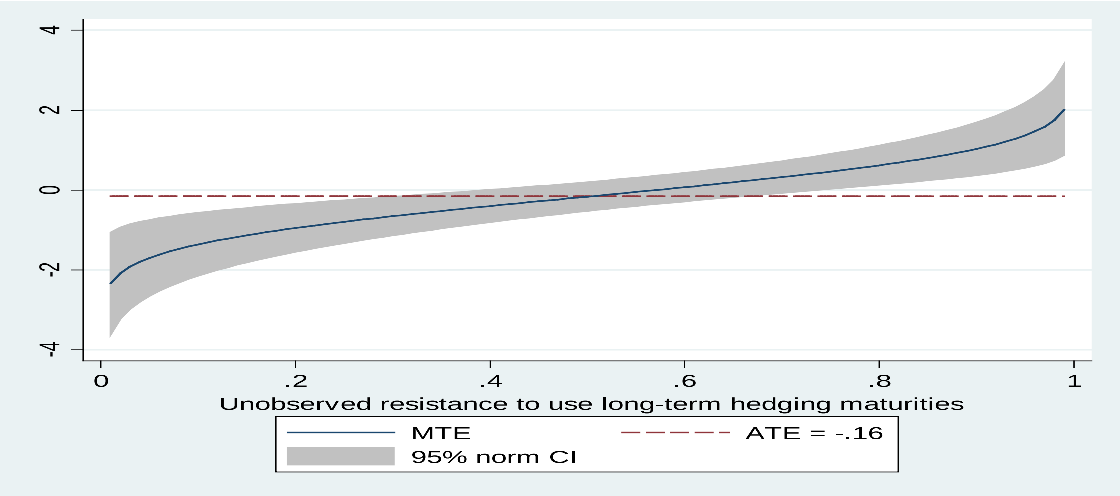


Figure 3: Estimated MTEs

This Figure plots the estimated MTE for the firm value, measured by the Tobin's *q*, over the common support of the unobserved resistance to use long-term hedging maturities by US oil producers. Average treatment effect (ATE) and 95% normal confidence interval are also plotted.



Dynamic Corporate Risk Management: Motivations and Real Implications

July 6, 2016

Online Appendix

Table A.1: Determinants of the Oil Hedging Decision

This table reports the coefficients estimates of the probit model. The dependent variable is the hedging decision dummy variable, which takes the value of one if the oil producer has any oil hedging position for the quarter and zero otherwise. The independent variables are as follows: Firm Size is measured by the market value of equity plus the book value of assets minus the book value of equity (as a logarithm), Tax Save is the expected percentage of tax savings, DTD stands for the distance to default, Liquidity is the quick ratio measured by the book value of cash and cash equivalents scaled by the book value of current liabilities, Dvd Payout is a dummy variable for dividends declared during the quarter, Investment Opportunities are measured by the ratio of costs incurred including property acquisitions, exploration, and development expenses divided by net property, plant, and equipment, Institutional Ownership is the percentage of shares owned by institutional investors, Geographic Diversification is a Herfindahl index measuring geographical dispersion in oil production activities, and CEO Ownership is the market value of shares owned by the firm's CEO. The independent variables are included in lagged values. Heteroscedasticity-consistent standard errors clustered at the firm level are reported in parentheses. Time dummies for quarters are not reported. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Variables	Oil Hedge
Firm Size	0.1828***
	(0.065)
Tax Save	0.9667*
	(0.584)
DTD	-0.1142**
	(0.055)
Liquidity	-0.1818***
	(0.047)
Dvd Payout	-0.1866
	(0.210)
Investment Opportunities	0.1332***
	(0.044)
Institutional Ownership	0.7746***
	(0.299)
Geographic Diversification	-0.7193*
	(0.393)
CEO Ownership	2.2290**
	(0.882)
Constant	-1.6489***
	(0.356)
Observations	5,384
Pseudo-R squared	0.2254
Chi-squared	305.1534
Significance	0.0000

Table A.2: Oil Hedging Maturity Structure—Alternative Specification

This table provides the results of the fixed effects regressions for the determinants of remaining maturity for the oil hedging portfolio, swap contracts, put options, and costless collars, respectively. For each firm–quarter with oil hedging activity, this maturity is determined by taking the maximum horizon of hedging without weighting by the hedged quantity. All the variables are defined in Table 1. The independent variables related to oil producer characteristics are included in lagged values. The inverse Mills ratio is from the first-step Heckman regression (Table A.1). Heteroskedasticity-consistent standard errors clustered at the firm level are reported in parentheses. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Oil Hedging	Oil Hedging	Swap Contracts	Swap Contracts	Put Options	Put Options	Costless Collars	Costless Collars
Leverage	2.1561***	2.5503***	3.0520***	3.5333***	0.0306	0.8178	2.2224*	2.2204*
	(0.811)	(0.810)	(0.917)	(0.910)	(1.223)	(1.177)	(1.278)	(1.191)
Leverage Squared	-1.3627**	-1.5203***	-2.0997***	-2.3085***	0.7371	0.2304	-1.3566**	-1.3684**
	(0.537)	(0.525)	(0.555)	(0.546)	(0.807)	(0.770)	(0.652)	(0.606)
Distress Costs	0.0034	0.0031	0.0072	0.0072	0.0133**	0.0149**	0.0010	0.0003
	(0.003)	(0.003)	(0.006)	(0.006)	(0.006)	(0.006)	(0.002)	(0.002)
Oil Spot Price		0.0352***		0.0434***		0.0076		0.0261***
		(0.008)		(0.011)		(0.010)		(0.009)
Spot Squared		-0.0002***		-0.0002***		-0.0000		-0.0001***
		(0.000)		(0.000)		(0.000)		(0.000)
Oil Volatility	-0.0289***		-0.0263**		0.0141		-0.0379**	
	(0.010)		(0.011)		(0.015)		(0.018)	
Strike Price	0.0084***		0.0137***		0.0000		0.0090**	
	(0.003)		(0.005)		(0.005)		(0.004)	
Moneyness		0.0940***		0.1551***		0.1736***		0.1769***
		(0.024)		(0.027)		(0.043)		(0.028)
Production Risk	0.4289**	0.5297***	0.7345**	0.7837***	0.9506**	0.8794**	0.5043*	0.5703**
	(0.179)	(0.172)	(0.296)	(0.280)	(0.441)	(0.412)	(0.256)	(0.251)
Debt Maturity	0.0085	-0.0079	-0.0274	-0.0352	-0.0173	-0.0296	0.0156	0.0082
	(0.032)	(0.029)	(0.035)	(0.031)	(0.047)	(0.045)	(0.053)	(0.050)
Oil Reserve Life	0.0139	0.0139*	0.0281**	0.0245*	0.0237**	0.0205**	0.0067	0.0074
	(0.010)	(0.008)	(0.014)	(0.013)	(0.010)	(0.009)	(0.015)	(0.015)
Firm Size	0.1353	-0.0227	0.1340	-0.0433	0.2770*	0.1366	0.1231	0.0517
	(0.087)	(0.085)	(0.118)	(0.121)	(0.150)	(0.132)	(0.108)	(0.119)
Inverse Mills ratio	-0.0612	0.0568	0.1409	0.1525	-0.2973	-0.4541*	0.1344	0.0466
	(0.174)	(0.181)	(0.206)	(0.236)	(0.225)	(0.249)	(0.332)	(0.327)
Constant	-0.5027	-0.4922	-1.1729	-0.8984	-1.1682	-0.5715	-0.6387	-0.5920
	(0.729)	(0.700)	(0.961)	(0.891)	(1.245)	(1.157)	(1.060)	(1.078)
Observations	2,309	2,413	1,585	1,585	396	399	1,314	1,314
R-Squared	0.0992	0.1289	0.1248	0.1597	0.1730	0.2329	0.0806	0.1139
Number of firms	101	101	89	89	36	39	80	80
Rho	0.5467	0.5538	0.6147	0.6095	0.6141	0.5824	0.4891	0.4897
Sigma of random effects	0.8799	0.8723	1.1247	1.0904	0.7640	0.6899	0.8010	0.7875
Sigma of error terms	0.8013	0.7829	0.8905	0.8728	0.6056	0.5841	0.8186	0.8039

Table A.3: First–Step of the 2-SLS regression for the IV approach

This table provides the results of the fixed effects regression corresponding to the first step of the 2-SLS regression. The dependent variable is the oil hedging maturity for the entire sample. The instruments used are: i) the differential in sensitivities of the firm's investment opportunities and cash flows to fluctuations in oil spot prices, and ii) changes in the Kilian index. All the variables are defined in Table 1. The instrumental variables and other independent variables are included in lagged values. Heteroskedasticity-consistent standard errors clustered at the firm level are reported in parentheses. Shea's (1997) partial R-Squared is a measure of IV relevance. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)
Variables	Oil hedging maturity
Differential	-0.1628***
	(0.043)
Δ Kilian index	0.1898***
	(0.044)
ROA	0.2297**
	(0.104)
Investment Opportunities	-0.0127
	(0.014)
Leverage	0.0518
	(0.128)
Liquidity	-0.0035
	(0.003)
Dividend Payout	0.0589
	(0.099)
Oil Reserves	0.1246***
	(0.031)
Inst Ownership	0.2846***
	(0.091)
Geo Diversification	0.0033
	(0.157)
Oil Volatility	0.0211***
	(0.005)
Oil Basis	0.2189***
	(0.205)
Production Risk	-0.0047
	(0.091)
2008	0.0113
	(0.042)
2009	-0.0653
	(0.046)
Observations	5,379
Number of firms	146
R-Squared	0.1296
Shea's (1997) partial R-Squared	0.0200

Table A.4: First Step of the Essential Heterogeneity Models

This table provides the results of the probit regressions corresponding to the first step of the essential heterogeneity models related to the oil hedging maturity choice. The dependent variable is the Maturity choice which takes the value of one if the oil producer has a long-term oil hedging position and zero if it has a short-term oil hedging position. Short-term hedging maturities are below the 33rd percentile, which corresponds to one year ahead, and long-term hedging maturities exceed the 67th percentile, which corresponds to 1.33 years ahead. The instruments used are: i) the differential in sensitivities of the firm's investment opportunities and cash flows to fluctuations in oil prices, and ii) changes in the Kilian index. All the variables are defined in Table 1. The instrumental variables and other independent variables are included in lagged values. Standard errors are reported in parentheses. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)
Variables	Maturity Choice
Differential	-0.1872**
	(0.094)
Δ Kilian index	0.5893***
	(0.212)
ROA	1.3964***
	(0.487)
Investment Opportunities	1.2232***
	(0.245)
Leverage	0.4306***
	(0.166)
Liquidity	0.0412
	(0.046)
Dividend Payout	-0.0374
	(0.081)
Oil Reserves	0.1183***
	(0.028)
Inst Ownership	-0.8638***
	(0.155)
Geo Diversification	0.7013***
	(0.176)
Oil Volatility	0.0512**
	(0.021)
Oil Basis	5.4374***
	(0.644)
Production Risk	0.6439***
	(0.165)
Inverse Mills Ratio	-0.6983***
	(0.184)
2008	0.1861
	(0.149)
2009	-0.2443
	(0.158)
Constant	-0.2700
	(0.268)
Observations	1,606
R-Squared	0.1454

Table A.5: Estimated MTEs

This table gives the estimated MTEs related to the choice of oil hedging maturity, long-term versus short-term. The MTEs are for firm value measured by the Tobin's *q*. U_D reflects different estimation points of the unobserved resistance to use long-term hedging maturity. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
U_D	Tobin's *q*	U_D	Tobin's *q*	U_D	Tobin's *q*	U_D	Tobin's *q*
u1	-2.3329***	*u26*	-0.7642***	*u51*	-0.1412	*u76*	0.4937**
	(0.646)		(0.268)		(0.183)		(0.228)
u2	-2.0788***	*u27*	-0.7358***	*u52*	-0.1179	*u77*	0.5240**
	(0.580)		(0.262)		(0.182)		(0.233)
u3	-1.9176***	*u28*	-0.7078***	*u53*	-0.0944	*u78*	0.5551**
	(0.539)		(0.257)		(0.181)		(0.238)
u4	-1.7963***	*u29*	-0.6804***	*u54*	-0.0710	*u79*	0.5870**
	(0.509)		(0.252)		(0.181)		(0.244)
u5	-1.6977***	*u30*	-0.6534***	*u55*	-0.0475	*u80*	0.6198**
	(0.484)		(0.247)		(0.180)		(0.250)
u6	-1.6137***	*u31*	-0.6268***	*u56*	-0.0239	*u81*	0.6536**
	(0.463)		(0.242)		(0.180)		(0.257)
u7	-1.5401***	*u32*	-0.6005**	*u57*	-0.0002	*u82*	0.6886***
	(0.445)		(0.237)		(0.180)		(0.263)
u8	-1.4742***	*u33*	-0.5746**	*u58*	0.0236	*u83*	0.7247***
	(0.429)		(0.233)		(0.181)		(0.271)
u9	-1.4143***	*u34*	-0.5490**	*u59*	0.0475	*u84*	0.7623***
	(0.414)		(0.229)		(0.181)		(0.278)
u10	-1.3591***	*u35*	-0.5237**	*u60*	0.0715	*u85*	0.8014***
	(0.401)		(0.224)		(0.182)		(0.286)
u11	-1.3078***	*u36*	-0.4987**	*u61*	0.0957	*u86*	0.8423***
	(0.389)		(0.220)		(0.183)		(0.295)
u12	-1.2598***	*u37*	-0.4739**	*u62*	0.1201	*u87*	0.8853***
	(0.377)		(0.217)		(0.184)		(0.304)
u13	-1.2145***	*u38*	-0.4493**	*u63*	0.1447	*u88*	0.9306***
	(0.367)		(0.213)		(0.186)		(0.314)
u14	-1.1715***	*u39*	-0.4249**	*u64*	0.1695	*u89*	0.9786***
	(0.357)		(0.210)		(0.188)		(0.325)
u15	-1.1306***	*u40*	-0.4007*	*u65*	0.1945	*u90*	1.0299***
	(0.347)		(0.206)		(0.190)		(0.336)
u16	-1.0915***	*u41*	-0.3767*	*u66*	0.2198	*u91*	1.0851***
	(0.338)		(0.203)		(0.192)		(0.349)
u17	-1.0539***	*u42*	-0.3528*	*u67*	0.2454	*u92*	1.1450***
	(0.330)		(0.200)		(0.194)		(0.363)
u18	-1.0178***	*u43*	-0.3290*	*u68*	0.2713	*u93*	1.2109***
	(0.322)		(0.198)		(0.197)		(0.378)
u19	-0.9828***	*u44*	-0.3053	*u69*	0.2976	*u94*	1.2845***
	(0.314)		(0.195)		(0.200)		(0.396)
u20	-0.9490***	*u45*	-0.2817	*u70*	0.3242	*u95*	1.3685***
	(0.307)		(0.193)		(0.203)		(0.416)
u21	-0.9162***	*u46*	-0.2582	*u71*	0.3512*	*u96*	1.4671***
	(0.299)		(0.191)		(0.207)		(0.440)
u22	-0.8843***	*u47*	-0.2348	*u72*	0.3786*	*u97*	1.5884***
	(0.293)		(0.189)		(0.211)		(0.470)
u23	-0.8532***	*u48*	-0.2113	*u73*	0.4066*	*u98*	1.7496***
	(0.286)		(0.187)		(0.214)		(0.510)
u24	-0.8229***	*u49*	-0.1880	*u74*	0.4350**	*u99*	2.0037***
	(0.280)		(0.185)		(0.219)		(0.574)
u25	-0.7933***	*u50*	-0.1646	*u75*	0.4641**		
	(0.274)		(0.184)		(0.223)		