How do firms hedge risks?
Empirical evidence from U.S. oil and gas producers

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ABSTRACT

Using a unique, hand-collected data set on hedging activities of 150 US oil and gas producers, we study the determinants of hedging strategy choice. We also examine the economic effects of hedging strategy on firms' risk, value and performance. We model hedging strategy choice as a multi-state process and use several dynamic discrete choice frameworks with random effects to mitigate the unobserved individual heterogeneity problem and the state dependence phenomena. We find strong evidence that hedging strategy is influenced by investment opportunities, oil and gas market conditions, financial constraints, the correlation between internal funds and investment expenditures, and oil and gas production specificities (i.e., production uncertainty, production cost variability, production flexibility). Finally, we present novel evidence of the real implications of hedging strategy on firms' stock return and volatility sensitivity to oil and gas price fluctuations, along with their accounting and operational performance.

Keywords*:* Risk management, derivative choice determinants, hedging strategies, linear and non-linear hedging, state dependence, dynamic discrete choice models, economic effects, oil and gas industry.

JEL classification*: D8,* G32

1. Introduction

To date, scant empirical research has attempted to explore how hedging programs are structured by non-financial firms (e.g. Tufano, 1996; Géczy et al, 1997; Brown, 2001; Adam, 2009). The goal of this study is to add to the literature by shedding light on how firms hedge risks and on the determinants and consequences of their choices. We answer the following questions: What are the determinants of hedging strategy choice? What are the real implications of hedging strategy choice on the firm's stock return and volatility sensitivity relative to the underlying risk factor, and on firms' operational and financial performance? It is important to understand why firms within the same industry and with the same risk exposure vastly differ in terms of their hedging strategy. Differences in firms' hedging practices seem to come from differences in firm-specific characteristics rather than differences in their underlying risk exposures. Therefore, explaining how firms structure their hedging portfolios and measuring their related economic effects should provide a better understanding of how hedging affects corporate value.

This study contributes to the literature on corporate hedging in several ways. We use an extensive and new hand-collected data set on the risk management activities of 150 US oil and gas producers with quarterly observations over the period 1998-2010. Relative to the empirical literature, our data collected from publicly disclosed information avoid the non-response bias associated with questionnaires and provide detailed information about hedging activities. Moreover, unlike other previous studies on risk management in the oil and gas industry, our data set is quarterly rather than annual and covers a far longer period. In addition, we study hedging activities of both commodities (oil and gas) separately, which gives deeper insight into oil and gas producers' hedging dynamics. Finally, the study period coincides with the application of the new derivative accounting standard FASB 133 in the United States, which is expected to influence corporate risk management, as well as the new SOX and NYSE regulations introduced in 2002 after the Enron collapse.

In addition, we innovate in terms of the econometric methodology, which better captures hedging dynamism and improves the reliability of the statistical inference of our findings. We consider derivative choice as a multi-state process and examine the effects of firm-specific characteristics and oil and gas market conditions on the choice of hedging strategy. To alleviate the effects of unobserved individual heterogeneity and state dependence, we use dynamic discrete choice methodologies with random effects that account for the initial condition problem (Heckman, 1981). We thus distinguish the effects of past hedging strategy choice and observable and unobservable firm characteristics on current hedging behavior. We use a dynamic panel random effects probit model to explore the determinants of hedging strategies based on one instrument only (i.e., swap contracts only, put options only, costless collars only). In addition, we use a dynamic random effect multinomial mixed logit to explore the determinants of hedging strategies based on a combination of two or more instruments (i.e., hedging portfolios). For the multinomial mixed logit, we chose swap contracts as our base outcome, which allows us to determine why firms chose hedging portfolios with payoffs departing from strict linearity. Finally, we use a dynamic generalized random effect ordered probit model to answer the question of why firms chose linear or non-linear instruments. To our knowledge, all the previous empirical studies were conducted in a static framework.

In addition to the standard hypotheses pertaining to underinvestment costs, tax incentives, financial distress costs and managerial risk aversion, our comprehensive data set allows us to reliably test the empirical relevance of some theoretical arguments and predictions that have been explored slightly or not at all. In particular, we test the implications of the prediction of Froot et al (1993) and Spano (2004) related to the impact of the correlation between internally generated cash flows and investment opportunities. We also test the empirical relevance of the overinvestment problem as theorized by Morellec and Smith (2007) and identified empirically by Bartram et al (2009), namely that large profitable firms with few investment opportunities face overinvestment problems. In addition, we test the real effects of the quantity-price correlation as theoretically suggested by Brown and Toft (2002) and Gay et al (2002 and 2003). We also test the empirical relevance of the existence of other hedgeable (i.e., IR, FX and basis risks) and non-hedgeable (production uncertainty, production cost variability) risks on hedging strategy of the principal market risk related to oil and gas prices, as theorized by Moschini and Lapan (1995), Franke, Stapleton and Subrahmanyam (1998), Brown and Toft (2002) and Gay et al (2002 and 2003). Further, our data set allows us to verify the implications of production flexibility suggested by Moschini and Lapan (1992). We also explore the impacts of the economic conditions of the oil and gas market on derivative choice. Finally, we empirically investigate the real implications of hedging strategy choice on the firm's stock return and volatility sensitivity to oil (gas) price fluctuations, and the accounting, market and operating performances of oil and gas producers.

Our results reveal significant state dependence effects in the hedging strategy that should be accounted for when studying firms' risk management behaviors. Accounting for this state dependence allows us to better distinguish the effects of observable and unobservable characteristics on hedging preferences. Overall, we find that oil and gas producers with higher investment programs tend to use more hedging strategies with non-linear payoffs (i.e., put options only, mixture of swap contracts with put options and/or costless collars) and to avoid strict linear hedging (i.e., swap contracts only). This result is consistent with the argument of Froot et al (1993) and the empirical finding of Adam (2009) that firms with larger investment programs tend to use non-linear strategies to preserve any upside potential. In contrast, oil and gas producers, which have larger undeveloped proved reserves, tend to avoid non-linear strategies because the investment expenditures (i.e., development costs) are less pressing. Moreover, we provide the first direct empirical evidence of the impact of the correlation between internally generated cash flows and investment expenditures, as theorized by Froot et al (1993) and Spano (2004). Particularly, for gas hedgers, we find that the higher this correlation (i.e., firms are benefiting from a natural hedge), the more gas producers tend to use linear hedging strategies, as predicted. For oil hedgers, the impact of this correlation is unclear. Using a more robust methodology, we find strong evidence of the relationship between this correlation and more linear strategies, as predicted.

We also find that hedging strategies are strongly correlated to the economic conditions of the oil and gas market. As predicted, the use of put options and collars is related to higher volatilities and higher future expected prices. Swap contracts are positively related to higher spot prices. Consistent with the production flexibility argument of Moschini and Lapan (1992), our results indicate that firms with relatively higher geographical dispersion in their oil production tend to use more collars and to avoid swaps only. We find that more focused oil and gas producers (i.e., ones that derive their revenues primarily from either oil or gas production) tend to use more non-linear strategies. This latter finding corroborates the empirical finding of Adam (2009) that more focused gold producers use more put options.

As predicted, our results suggest that higher gas production uncertainty is related to the use of non-linear hedging portfolios (i.e., higher production uncertainty induces higher non-linearity in the firm's exposure). However, the impact of oil production uncertainty is contrary to expectations. Results related to the variability in production costs are significant and mixed. With regard to the existence of additional hedgeable risks, we find that foreign exchange (FX) risk is significantly related to the use of put options, and basis risk is negatively related to swaps and collars. As predicted, the existence of FX and basis risks creates nonlinearity in the firm's exposure, which requires more non-linear hedging. The impact of interest rate (IR) risk is significant and mixed. For gas hedgers, a higher gas price-quantity correlation is positively related to linear hedging instruments and negatively related to nonlinear hedging portfolios, as predicted. In contrast, oil price-quantity correlation is negatively related to collars.

Consistent with our predictions, we find that higher managerial shareholding is positively related to linear instruments and negatively related to nonlinear instruments. In addition, managers with higher optionholding use more nonlinear hedging strategies and avoid linear strategies. Surprisingly, results indicate that both higher managerial stockholding and optionholding are positively related to the use of collars only. Interestingly, we find that the existence of institutional investors induces more elaborate hedging programs with nonlinear payoffs.

Oil and gas producers that are more leveraged but not yet close to financial distress tend to use more swap contracts to insure predetermined revenues. More solvent producers use more collars only and avoid swaps only. In line with the risk-shifting theory, producers close to financial distress use more hedging portfolios with nonlinear payoffs and avoid linear instruments. Consistent with the theoretical prediction of Morellec and Smith (2007), our results give the first direct empirical evidence of the role of the overinvestment problem on firms' hedging behavior. Particularly for gas hedgers, we find that it is more closely associated with the use of linear instruments, as predicted. For oil hedgers, the impact of the overinvestment problem is significant and mixed. Tax function convexity seems to motivate the use of more linear hedging strategies, as predicted. In contrast, tax loss carryforward is negatively related to swaps. As suggested by Graham and Rogers (2002), tax loss carryforward appears to be uncorrelated with tax function convexity.

Finally, we present novel evidence of the economic effects of hedging strategy choice on firms' stock return and volatility sensitivity to oil and gas price fluctuations, realized oil and gas prices (i.e., prices including the monetary effects of the hedging activities) and accounting performance (i.e., return on equity and return on assets), market performance (i.e., Tobin's Q) and operational performance (i.e., earnings per share from operations) of oil and gas producers.

The remainder of the paper is divided into eight sections. In section 2, we review the existing theoretical predictions and previous empirical studies. In section 3, we describe our data, state our hypotheses and construct the independent variables that might be related to derivative choice. Section 4 describes our dependent variables. Section 5 presents the retained econometric methodologies. Section 6 reports our results and discussions. In section 7, we check the robustness of our multivariate results by using an alternative econometric specification. In section 8, we investigate the real implications of hedging strategy choice empirically. Section 9 concludes the paper.

2. Prior research on derivative choice

The financial economics literature classifies financial derivatives into linear and non-linear instruments. Linear instruments, including swaps, futures contracts, and forward contracts, have a payoff function with a linear relationship to the price of the underlying asset. Non-linear instruments, including options (i.e., put and call options) and other products with sophisticated structures (e.g., costless collars, three-way collars, strangle), generate cash flows in certain states of nature only. At the inception, it is costless to enter into linear derivatives to mitigate downside risks, but there is a cost of losing upside benefits in the future. In contrast, non-linear instruments can avoid downside risk and allow for upside benefits but at the price of paying a higher premium.

A number of theoretical models and empirical studies have been developed to explain derivative choices. Detemple and Adler (1988) show in a portfolio context that poorly diversified managers who face no borrowing or short-selling constraints will adopt linear strategies (i.e. futures contracts) to achieve optimal hedging. Otherwise, borrowing or short selling constraints can create non-linear exposures. Non-linear instruments are then required in addition to linear instruments, to implement optimal hedging. Applying Detemple and Adler's model to gold mining firms, Tufano (1996) predicts that firms with higher cash costs and those with lower market values and smaller gold reserves might be more likely to use options. Contrary to Detemple and Adler's prediction, Tufano (1996) finds no difference in the cash costs between firms that use options and those that do not. He concludes that option users tend to be larger in terms of market value and reserves rather than smaller.

In the context of firm-value maximization, Froot et al (1993) show that managers facing one source of hedgeable risk (i.e., price risk) will choose an optimal hedging strategy depending on the sensitivities of internally generated cash flows and investment opportunities to the underlying source of risk. If these sensitivities are similar, the firm benefits from ‘‘natural diversification,’’ and a linear strategy will suffice to attain the optimal level of investment; otherwise a non-linear strategy is required. In addition, Froot et al (1993) argue that when future capital expenditures are a non-linear function of some hedgeable risk (i.e., an oil and gas company will develop new reserves only if oil and gas prices are above a certain level), a non-linear strategy is required.

Adam (2002) extends the work of Froot et al (1993) and Mello and Parsons (2000) to a multi-period framework. He argues that financially constrained firms with future investment opportunities should hedge. The structure of the hedging portfolio adopted will depend on the level of cost differential between internal and external funds as measured by the firm’s credit risk premium. When the marginal cost of external funding is relatively high, Adam asserts that the payoff of the hedging portfolio is concave, suggesting the writing of call options because the firm has a precarious financial condition, and is concerned mostly with funding its current investment programs. When this cost differential is relatively low, the structure of the hedging portfolio is convex, meaning long positions on put options because the firm has a sound financial condition, and focuses on averting shortage in future cash flows to fund its future investment expenditures. In intermediate cases between those two situations, the hedging portfolio will contain both instruments (i.e., costless collars) because such firms are focused on both current and future capital requirements. He concludes that unlevered firms with few future investment opportunities and low levels of non-hedgeable risks (i.e., production uncertainty) are more likely to use hedging portfolios with a linear structure. In a more recent paper, Adam (2009) studies the options used in gold-mining firms, and strongly supports the findings in Adam (2002). In addition, Adam (2009) maintains that firms facing large capital expenditures, which are a non-linear function of some exposure (i.e., future oil and gas prices), are more likely to use an insurance strategy (i.e., buying put options).

Adam (2003) concludes that the non-linear instrument choice is driven mainly by market conditions. When the gold spot price is low, firms are more likely to use non-linear instruments (i.e., buying put options) because they are anticipating that the price will rise, hence they maintain the upside potential. In contrast, when gold price volatility is relatively high, firms are less likely to buy non-linear instruments to avoid a greater volatility risk; those instruments also become more expensive as market volatility rises. Brown (2001) investigates the foreign exchange risk management program of an anonymous US-based manufacturer of durable equipment, and finds empirical evidence that when the exchange rate volatility is higher, firms tend to replace options with forward contracts. Brown (2001) also finds a significant impact of spot exchange rates on hedging portfolio characteristics (i.e., delta and gamma). The findings of Adam (2009) largely support the negative correlation between gold spot price and the use of put options. In addition, Adam (2009) observes no significant correlation between the use of non-linear instruments and gold price volatility or gold basis (i.e., difference between the future and the spot price of gold).

Departing from the firm-value maximization framework, some authors studied the impact of production characteristics on derivative choice. Moschini and Lapan (1992) conclude that when the firm has sufficient production flexibility (in the sense that it is able to change its production parameters after observing the future price of the output, and assuming that this future price is unbiased), it should make use of options by shorting a put and call option with the same strike price and maturity (shorting a straddle position). To hedge the convexity of its real option (i.e., production flexibility), the firm is subsequently required to sell convexity (short straddle). In contrast, when all the production parameters are fixed ex-ante (before observing the future price of the output), there is no production flexibility and options will be useless. Adam (2009) retained the number of mines in operation and the standard deviation of mine production cost as proxies for production flexibility in the gold-mining industry, and finds no evidence of the correlation between production flexibility and the use of option strategies.

In the same context, some authors argue that the existence of some non-hedgeable risks (i.e. uncertainties in the quantities produced and/or in the production costs) makes exposure non-linear and hence motivates the use of non-linear instruments. Moschini and Lapan (1995) show that a risk-averse firm, facing both price risk and production risk, will use more long straddle positions in addition to shorting future contracts. In a pure exchange economy, Franke, Stapleton and Subrahmanyam (1998) affirm that the risk-sharing rule tends to be convex for agents who face higher background (non-insurable) risks. In addition, the authors pointed out that the convex sharing rule could be achieved by buying put options and that the non-linearity in the risk-sharing vehicle is attributable to the differential background risk. Brown (2001) suggests that the uncertainty in the underlying foreign currency exposure is not significantly positively related to option use. By modeling a profit-maximizing firm facing both price and quantity uncertainties and financial distress, Brown and Toft (2002) conclude that simply selling the expected output forward is never the optimal hedging strategy. They suggest that the optimal hedge is affected by the volatilities of prices and quantities and more importantly by the correlation between quantities produced and spot prices. Further, they find that firms with a negative price-quantity correlation can benefit from options and more sophisticated exotic instruments. This benefit is magnified by higher volatility in quantities or low price volatility. In contrast, a positive price-quantity correlation significantly reduces the benefit of using options. Firms with a negligible price-quantity correlation might use only forward contracts.

Gay et al (2002 and 2003) argue that firms facing only price risk could achieve optimal hedging with linear contracts. Otherwise, as quantity uncertainty increases, non-linear strategies will be implemented as substitutes for linear strategies to overcome the over-hedging problem. Over-hedging would consist in selling more quantities under linear derivatives than the already produced output. The degree of substitution between linear and non-linear strategies is strongly influenced by the price-quantity correlation. With a negative price-quantity correlation, the firm benefits from a natural hedge, but the over-hedging problem is more likely in those circumstances with declining quantities and increasing prices. Thus, firms will reduce linear strategies in favor of non-linear strategies. If prices are increasing, long put positions are more profitable because they will expire worthless, but shorting linear contracts will generate losses. In contrast, a positive price-quantity correlation motivates the use of linear instruments because quantities and prices are moving in the same direction and over-hedging is now less likely.

Table I summarizes the theoretical predictions arising from the literature review and illustrates their expected empirical implications, which we will investigate for each of the hedging strategies adopted by oil and gas producers.

[Table I about here]

3. Data, hypotheses and independent variables

Our empirical study focuses on the following question: what are the rationales for the choice of each hedging strategy in the oil and gas industry? In this section, we present our data, develop some testable hypotheses and discuss the construction of our independent variables.

3.1 Data

This study is implemented on a sample of 150 US oil and gas producers over the period of 1998 to 2010. The oil and gas industry is an excellent laboratory to test the different corporate risk management motivations and implications for several reasons. First, firms in this industry share homogenous risk exposures (i.e. fluctuations in crude oil and natural gas prices). Hence, diversity in the hedging strategies implemented does not come from differences in risk exposure, but is more likely to result from differences in firm characteristics. Second, the existence of financial derivatives on crude oil and natural gas offer these firms several price hedging methods. Futures contracts and options in oil and gas are traded in the NYMEX and forward contracts and swaps are traded in the over-the-counter market. Third, improvements in accounting disclosure related to oil and gas producing activities have made operational data available. These data pertain to exploration, production and reserve quantities, cash costs, etc.

A first list of 413 US oil and gas producers with the primary Standard Industrial Classification (SIC) code 1311[1] (i.e., Crude Petroleum and Natural Gas) was extracted from Bloomberg. Next, only firms that met the following criteria were retained: have at least five years of historical data of oil and gas reserves during the period 1998-2010; the 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 one in the empirical literature on risk management in the oil and gas industry.[2]

Data on these firms' financial and operational characteristics were gathered from several sources. Data regarding financial characteristics were taken from the Compustat quarterly data set held by Wharton Research Data Services (WRDS). Other items related to the institutional and managerial share holdings and option holdings were taken from the Thomson Reuters data set maintained by WRDS. Data related to oil and gas producers' reserves, production quantities, cash costs, geographical dispersion, exploration, development and property acquisitions were

[1] SIC code 1311 ''Crude Petroleum and Natural Gas,'' which comprises companies primarily involved in the operation of properties for the recovery of hydrocarbon liquids and natural gas.

[2] Jin and Jorion (2006) studied a sample of 119 US oil and gas producers with 330 firm-year observations over the period of 1998-2001. Haushalter (2000) used a sample of 100 U.S oil and gas producers with 292 firm-year observations over the period 1992-1994. Haushalter et al (2002) used a sample of 68 US oil producers with 155 firm-year observations over the period 1992-1994.

taken from Bloomberg's annual data set and verified and completed by hand-collecting data directly from 10-K annual reports. Quarterly data about oil and gas producers' hedging activities are hand-collected from 10-K and 10-Q reports.

3.2 Hypotheses and independent variables

3.2.1 Investment opportunities

Froot et al (1993) point out that firms with future capital expenditures and higher marginal costs of external financing (with a concave payoff) should hedge. They add that ''non-linear hedging instruments, such as options, will typically allow firms to coordinate investment and financing plans more precisely than linear instruments, such as futures and forwards'' (p. 1655). They argue that non-linear instruments are more efficient if capital expenditures are a non-linear function of the underlying risk factor. Normally, firms in the oil and gas industry undertake capital expenditures that are step functions and depend on oil and gas prices (driven by development of new reserves, exploration, etc.).The larger the investment opportunities, the higher the non-linearity of oil and gas producers' capital expenditures. Adam (2003, 2009) finds that, with relatively larger investment programs, gold-mining firms tend to use more non-linear strategies.

Hypothesis 1.a: *Oil and gas producers with larger investment opportunities are more likely to use non-linear hedging strategies because these firms face non-linear capital expenditures that depend on oil and gas prices. In addition, non-linear instruments allow for future upside benefits.*

We measure the future investment opportunities by the following two proxies: the ratio of the cost incurred over the net property, plant and equipment at the beginning of the quarter. In the oil and gas industry, the cost incurred includes the total costs of oil and gas property acquisition, exploration and development. The second proxy is the quantity of proved undeveloped reserves for oil and gas respectively.[3] These reserves could be seen as unexercised real options (Grulon et al, 2012) because oil and gas producers have the option but not an obligation to produce their undeveloped reserves after paying the development costs.

[3] Undeveloped reserves are expected to be recovered: (1) from new wells on undrilled acreage, (2) from deepening existing wells to a different reservoir, or (3) where a relatively large expenditure is required to (a) recomplete an existing well or (b) install production or transportation facilities for primary or improved recovery projects (World Petroleum Council).

An additional argument was stipulated by Froot et al (1993) to explain hedging strategy choice. They argue that when internally generated cash flows are closely correlated to future investment opportunities, firms benefit from a natural hedge, and linear strategies alone can provide value-maximizing hedges. Otherwise, firms should use non-linear strategies to achieve more optimal hedges. In the oil and gas industry, the contemporaneous oil and gas prices determine the cash flows generated from operations. These prices also dictate the future rents associated with the exploration, development and acquisition of oil and gas reserves. To our knowledge, this latter argument was not tested empirically due to the lack of data, as Tufano (1996) notes.

Hypothesis 1.b*: Firms with a higher correlation between internal cash flows and investment opportunities are more likely to use linear hedging strategies because they are already naturally diversified.*

We calculate the correlation coefficient between internal cash flows and investment opportunities. Internally generated cash flows are measured by the Free Cash Flow before capital expenditures, as in Lehn and Poulsen (1989).[4] Investment opportunities are measured by the ratio of the cost incurred over the net property, plant and equipment at the beginning of the quarter for each firm; these correlation coefficients are calculated in a rolling window by taking all the observations available until the current quarter.[5]

3.2.2 Market conditions

Dolde (1993) and Bodnar et al (1998), in their surveys of corporate risk management practices, find that managers incorporate their market views of future price movements by frequently altering either the size or the timing of their hedging positions. Stulz (1996) reports strong evidence of this view-taking, which he refers to as speculative hedging. As mentioned above, Adam (2003, 2009) concludes that market conditions impact derivative choice.

Hypothesis 2.a: *When spot prices are low, firms believe that they are more likely to rise; hence they tend to use non-linear instruments. Non-linear instruments allow firms to protect their*

[4] Lehn and Poulsen (1989) calculate Free Cash Flow before investment as operating income before depreciation less total income taxes plus changes in the 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.

[5] We take all the observations available until the current quarter because the cost incurred is given on a yearly basis.

downside risk and to benefit from any potential upside at a fixed cost (i.e., premium). In contrast, linear instruments protect downside risk but at a cost increasing with the potential increase in oil and gas prices. Conversely, when oil and gas spot prices are high, firms tend to lock-in the current prices by using linear instruments because they believe that prices are more likely to decrease in the future.

In addition, Adam (2009) shows that when gold price volatility is high, managers could refrain from buying options because those options become more expensive. Moreover, firms will be exposed to additional volatility risk because the value of their options is now affected. However, when this additional volatility risk is not large and prices are more likely to increase, firms tend to use non-linear instruments to preserve any potential upside.

Hypothesis 2.b: *When the volatility of oil and gas prices is high, firms are more likely to use non-linear instruments.*

The following hypothesis concerns future oil and gas prices (as observed in the Futures contracts market).

Hypothesis 2.c: *When expected oil and gas prices are higher; firms are more likely to use non-linear instruments to preserve any potential upside.*

We extract the oil and gas spot prices observed at the end of each quarter from the Bloomberg Financial Markets database. We use the West Texas Intermediate crude oil (WTI) index as proxy for the oil spot prices. For natural gas spot prices, we use an average index established by Bloomberg Financial Markets database from different locations indices (Gulf Coast, Henry Hub, Rocky Mountains, etc.).

We calculate the volatility of oil and gas for each quarter as the standard deviation of spot prices within the quarter. For future oil and gas prices, we use (i) Bloomberg NYMEX Crude Oil 12-Month Strip futures price, and (ii) Bloomberg NYMEX Henry Hub Natural Gas 12-Month Strip futures price. These two indices are established by the Bloomberg Financial Markets database as the arithmetic averages of oil (gas) futures contract prices over the next 12 months.

3.2.3 Production function characteristics

Moschini and Lapan (1992) argue that firms with sufficient production flexibility (i.e., the firm has the option to choose certain production parameters after product prices are observed) are more likely to use non-linear instruments (i.e., short straddle position) to raise expected utility and preserve this flexibility option. Testing this argument empirically, Adam (2009) finds no evidence that production flexibility motivates gold-mining firms to use non-linear instruments. Mello et al (1995), by constructing an integrated model for a multinational firm with production flexibility (in the sense that the firm can shift its production to low-cost countries) and with the ability to use the financial market to hedge foreign exchange rate risk, show that the need for hedging is closely related to production flexibility. Indeed, Mello et al (1995) suggest that viewing production flexibility and hedging as substitutes is misleading.

Generally, oil and gas firms operate in different regions of the world, and the operating costs (i.e., development costs, production costs) vary significantly between these regions. This geographical dispersion of oil and gas reserves could be seen as production flexibility because firms can shift their production operations from one location to another to adjust their profit margins to market prices. Another aspect of this production flexibility comes from the complementary nature of oil and gas operations. Hence, firms operating in both the oil and gas segments could be seen as practicing industrial diversification.

Hypothesis 3.a: *Firms with more production flexibility (i.e., higher geographical diversity in their production and higher industrial diversification) are more likely to use non-linear instruments because this operative flexibility could be seen as a real option that has a convex payoff by definition and that requires non-linear instruments to be hedged.*

We measure the geographical diversity of oil or gas production by 1- Herfindahl index. A higher value implies that the oil or gas production has higher geographical dispersion and hence the firm has more production flexibility. We construct two additional indices measuring the fraction of revenues derived from oil and gas production separately. These indices allow us to distinguish between producers operating primarily in the oil segment and those operating primarily in gas segment.

Moschini and Lapan (1995), Franke, Stapleton and Subrahmanyam (1998), Brown and Toft (2002) and Gay et al (2002 and 2003) suggest that when a firm is facing some non-hedgeable risks (i.e., production uncertainty and production cost variability), its total exposure becomes non-linear and the optimal hedging should be non-linear. The authors argue that the higher the production uncertainty, the greater the motivation to use non-linear instruments. Indeed, Brown and Toft (2002) show that in the presence of risks that are not hedged, firms are more likely to use non-linear instruments. Firms operating in the petroleum industry face several risks in addition to oil and gas price risks. Some of these additional risks are non-hedgeable with the existing marketable derivative instruments: these include quantity risk caused by uncertainties in the quantities produced and production cost risk due to variability in production costs. Some additional risks could be hedged with marketable derivatives: foreign exchange risk, interest rate risk and basis risk.

Hypothesis 3.b: *Firms facing higher additional risks have more incentive to use non-linear instruments because their total exposures become non-linear and the optimal hedging should be non-linear. In contrast, firms facing lower levels of additional risks tend to use linear instruments.*

Production uncertainty is measured by the coefficient of variation of the quarterly observations of the daily production for oil and gas respectively. For each firm, we calculate the coefficient of variation on a rolling window beginning with the first observation for the firm until the current quarter. The production cost risk is measured by the coefficient of variation of the cash cost (i.e., lifting cost given by Barrel of Oil Equivalent[6]), on a rolling window beginning with the first observation for the firm until the current quarter. Foreign exchange risk, interest rate risk and basis risk are measured by one dummy for each risk. This dummy variable takes the value of 1 if the firm hedges the given risk and 0 otherwise.

Moreover, Brown and Toft (2002) and Gay et al (2002, 2003) emphasize that the impact of the additional risks (more specifically production uncertainty) on derivatives choice is closely related to the level of the correlation between the output quantities and current prices. In fact, a positive correlation will increase the volatility of revenues because quantities and prices are moving in the same direction. Thus, keeping the level of production uncertainty constant, the higher the

[6] The lifting cost per Barrel of Oil Equivalent (BOE) is given on annual basis. We repeat the same observation for each quarter of the year. Oil and gas producers typically quote production in Barrels of Oil Equivalent. Naturally, one barrel of oil =1 BOE. For natural gas production, 6 thousand cubic feet (Mcf) of gas is counted as one BOE.

positive correlation, the greater the benefits of using linear instruments. A negative correlation will reduce variability in revenues and produce a natural hedge for the firm, but then over-hedging is more likely to happen, and hence non-linear instruments are more advantageous.

Hypothesis 3.c: *Firms with a negative quantity-price correlation are more likely to use non-linear instruments because over-hedging is more likely. Conversely, firms with a positive quantity-price correlation are more likely to use linear instruments to reduce the volatility of revenues because quantities and prices are moving in the same direction.*

We calculate the correlation coefficient between daily oil production and oil spot prices and the correlation coefficient between daily gas production and gas spot prices. For each firm, the correlation coefficients are constructed by taking all the firm's observations available until the current quarter.

3.2.4 Compensation policy and ownership structure

In a value-maximizing framework, Stulz (1984) points out the crucial role of the nature of managerial compensation contracts in optimal hedging policies. In a subsequent seminal work, Smith and Stulz (1985) show that if the manager's end-of-period utility is a concave function of the firm's end-of-period value, the optimal hedging policy involves complete insulation of the firm's value from the underlying risks (if it is feasible). Accordingly, a risk-averse manager owning a significant fraction of the firm's shares is unlikely to hold a well-diversified[7] portfolio and hence has more incentives to use linear hedging strategies. Linear strategies can better eliminate volatilities of the firm's payoffs that directly affect the manager's wealth.

Hypothesis 4.a: *Firms with large manager shareholding are more likely to use linear instruments.*

Moreover, Smith and Stulz (1985) point out that if a manager's end-of-period utility is a convex function of a firm's end-of-period value, the manager has less incentive to completely eliminate the underlying risks. The more a compensation package includes stock option grants, the more

[7] Testing the stock compensation incentives for hedging and the poorly diversified characteristic of the manager, as suggested by Smith and Stulz (1985), requires further information about the manager's total wealth. Acquiring such information is not an easy task, but it can be done by controlling for the existence of presumably well-diversified outside blockholders (Tufano, 1996).

a manager’s expected utility tends to be a convex function of the firm value and hence he has more motivation to use non-linear instruments that reduce rather than eliminate the volatilities of the firm’s payoffs.

Hypothesis 4.b: *Firms with large stock option compensations are more likely to use non-linear instruments.*

We focus on the CEO compensation package because the CEO plays a crucial role in the corporate hedging decision. We measure the manager’s firm-specific wealth by the logarithm of one plus the market value of common shares held by the CEO at the end of each quarter. Following Tufano (1996), we use the logarithm specification to reflect that managers’ risk aversion should decrease as their firm-specific wealth increases. We also use the number of options held by the firm’s CEO at the end of each quarter. To check whether the hedging strategy choice is due to risk-averse poorly diversified managers, Tufano (1996) controls for the existence of large outside blockholders, and argues that they should be well-diversified investors that are less interested in risk hedging. We subsequently control for the existence of outside large block-holders by taking the percentage of common shares held by institutional investors.

3.2.5 Financial distress

Adam (2002) extends the work of Froot et al (1993) to an inter-temporal setting, and argues that hedging strategy depends on the firm’s credit risk premium (i.e., marginal cost of external financing). When this cost differential is relatively low, the firm buys nonlinear instruments to avert a shortfall in future cash flows to fund its future investment programs. He asserts that unlevered firms with low levels of non-hedgeable risks are more likely to use linear hedging strategies, as conjectured by Detemple and Adler (1988). In intermediate cases between those two situations, Adam (2002) confirms that hedging portfolios will contain both instruments (i.e., costless collars). In Jensen and Meckling’s (1976) risk shifting (or asset substitution) approach, the convexity of shareholders’ expected utility motivates them to increase risk when the firm nears bankruptcy. It is then expected that highly distressed firms have more incentives to use nonlinear hedging strategies that increase rather than eliminate the firm’s payoff volatility. Unlike linear instruments, non-linear instruments, which are costly, decrease assets available for debtholders and preserve any upside potential for shareholders. Altogether, there will be a non-monotonic relationship between firms’ financial soundness and nonlinear hedging strategies.

Hypothesis 5.a: *Firms that are either far from financial distress or deep in financial distress are more likely to use nonlinear hedging strategies, while firms between those two extremes tend to use more linear instruments (i.e., swap contracts) and costless collars.*

We construct the following three variables as proxies for financial distress: (1) Following Drucker and Puri (2009) and Campello et al (2011), we implement Distance-to-Default as a measure of the future likelihood of default. Distance-to-Default is a market-based measure originating from Merton's (1974) approach and used by Moody's-KMV, as described in Croshie and Bohn (2003). It is simply the number of standard deviations that the firm is away from default (see Table 1 for more details). (2) Leverage is measured as the ratio of long-term debts in current liabilities plus one-half of long-term debt over the book value of total assets. (3) Financial constraints measured by a binary variable that takes the value of 1 when both leverage ratio and quick ratio are above and below the industry's median and 0 otherwise, as in Dionne and Garand (2003).

Recently, Morellec and Smith (2007) show that the firm's hedging policy is derived not only by the underinvestment incentives arising from the shareholder-debtholder conflict but also by the overinvestment incentives arising from the shareholder-manager conflict. The overinvestment problem is due to managers' tendency to overinvest because they derive private benefits from the investment (i.e., the agency cost of free cash flow as identified by Jensen, 1986). This problem is more observable in the case of firms with larger free cash flows and fewer investment opportunities. Morellec and Smith's (2007) argument is consistent with the empirical evidence reported by Bartram et al (2009) that large profitable firms with fewer growth options tend to hedge more, which runs counter to the financial distress and underinvestment hypotheses. To reduce the costs of both overinvestment and underinvestment, Morellec and Smith (2007) suggest that the optimal hedging policy must reduce the free cash flow volatility. Hence the following hypothesis:

Hypothesis 5.b: *Large profitable firms with fewer investment opportunities are more likely to use linear instruments because of their capability to decrease the free cash flow volatility to avoid the overinvestment problem.*

The overinvestment problem is measured by a binary variable that takes the value of 1 when both the ratio of free cash flows scaled by book value of total assets, and investment opportunities are above and below the industry's median and 0 otherwise.

3.2.6 Tax incentives

The tax argument for corporate hedging analyzed by Mayers and Smith (1982), Smith and Stulz (1985) and Graham and Smith (1999) shows that in the presence of a convex tax function, hedging reduces the variability of pre-tax firm values and reduces the expected corporate tax liability. Moreover, the presence of tax preference items (i.e., tax loss carryforwards, foreign tax credits and investment tax credits) extends the convex region. As for the choice of what derivative instruments to use, we expect firms facing convex tax function to use linear instruments because of their ability to eliminate the volatility of pre-tax incomes. Indeed, firms having more tax preference items -which increase the convexity of the tax function- have more incentives to use linear instruments to preserve the tax shields.

Hypothesis 6.a: *Firms in the convex tax region that have more tax preference items are more likely to use linear instruments.*

For this hypothesis, we use two measures for tax function convexity. Following Géczy, Minton and Schrand (1997), Gay and Nam (1998) and Graham and Rogers (2002), we use the book value of tax loss carryforwards scaled by the book value of total assets. Because the sample consists of US firms, we employ the simulation procedure proposed by Graham and Smith (1999) to measure the expected percentage of tax savings arising from a 5% reduction in the volatility of pre-tax income. This measure is already used in some empirical research, as in Dionne and Triki (2013) and Campello et al (2011).

Table II summarizes the definitions, construction and data sources of the variables.

[Table II about here]

4. Dependent variables: construction and characteristics

Table III breaks down the sample of 6,326 firm-quarters into observations with and without gas and/or oil hedging. Oil and gas producers report hedging activities for 3,489 firm-quarters, which represents almost 55% of the whole panel. Out of these 3,489 firm-quarters, 2,255 report hedging activities for both oil and gas; almost 64.63% of the hedging subsample. Firm-quarters with only gas hedging represent 25.27% of the hedging subsample with 882 observations. Finally, there are 352 firm-quarters with only oil hedging or 10% of the hedging subsample.

[Table III about here]

To analyze the hedging behavior of oil and gas producers in greater depth, we collected information about the nature of hedging instruments already in use. Essentially, the hedging instruments consist of swap contracts, put options, costless collars, forward or futures contracts and three-way collars. Table IV presents a breakdown of the frequency of use for each hedging instrument. The most common hedging vehicles used in the oil and gas industry are Swap contracts, with 45.58% (45.25%) of use in gas (oil) hedging. The second most frequently used instrument is costless collars, with 37.19% (37.11%) for gas (oil) hedging. Next are Put options, with 10.55% for gas hedging and 11.85% for oil hedging. The least used instruments are forward or Futures contracts, with only 3.25% (2.78%) for gas (oil) hedging and 3-way collars, with only 3.42% (3.02%) for gas (oil). These observations show that oil and gas producers adopt quite similar strategies in their hedging, and that they prefer linear instruments.

[Table IV about here]

We now analyze hedging strategies. To save space, we skip the observations related to Forward/Futures contracts because they contribute to only 3.25% of gas hedging activity and 2.78% of oil hedging activity. We also omit observations related to three-way collars because they are used only in 3.42% of cases for gas hedging activity and 3.02% for oil hedging. Table V shows that there are two major hedging behaviors adopted by oil and gas hedgers: using only one hedging instrument and using more than one hedging instrument simultaneously to form hedging portfolios with different payoff structures. For the subsample of gas hedgers, Panel A of Table V illustrates that swap contracts are used separately 41.33% of the time (i.e., 932 out of 2,255 firm-quarters), with put options 6.08% of the time, with costless collars 44.30% of the time and with put options and costless collars simultaneously 8.29% of the time. Put options are used separately 24.14% of the time (i.e., 126 out of the 522 firm-quarters of use), with swap contracts 26.25% of the time, with costless collars for 13.79% of the time and simultaneously with swaps and collars 35.82% of the time. In addition, gas hedgers use costless collars only 31.63% of the time (i.e., 582 out of the 1840 firm-quarters of use), with swaps 54.29% of the time, with put options for 3.91% of the time and simultaneously with swaps and puts 10.16% of the time.

For the subsample of oil hedgers, Panel B of Table V indicates that swap contracts are used only 49.62% of the time (i.e., 849 out of 1,711 firm-quarters of use), with put options 5.79% of the time, with costless collars 36.65% of the time and with put options and costless collars 7.95% of the time. Put options are used separately 33.48% of the time (i.e., 150 out of the 448 firm-quarters), with swaps 22.10% of the time, with costless collars 14.06% of the time and simultaneously with swaps and collars 30.36% of the time. Costless collars are employed separately 41.13% of the time (i.e., 577 out of the 1403 firm-quarters), with swaps 44.69% of the time, with put options 4.49% of the time and with swaps and puts simultaneously 9.69% of the time.

Overall, Table V shows that the most common hedging strategies are using swap contracts only, using costless collars only and using a portfolio formed by swaps and collars. Put options are used generally in association with the other two instruments. Turning to the distribution of the notional quantity for each hedging portfolio, Table VI indicates that on average oil and gas producers take quite similar notional positions for the instruments that they use simultaneously in their hedging portfolios.

[Tables V and VI about here]

5. Econometric methodologies

The transition probabilities reported in Table VII show an extreme state dependence in the derivative choice for the sample hedgers. The elements of Table VII could be interpreted as conditional probabilities under the Markov model. The magnitude of the diagonal elements clearly shows the persistence or the state dependence in hedging strategy choice. The persistence in hedging behavior arises from two main sources. One possibility is that persistence is caused by unobserved decision-maker-specific preferences for derivatives that are time-invariant, which creates unobserved time-invariant individual heterogeneity (i.e., spurious state dependence as stated by Heckman, 1981). Alternatively, persistence can be due to unobserved but time-variant characteristics of hedging strategies, which creates a true state dependence. These unobserved time-variant characteristics could be transaction costs associated with the different hedging strategies.

[Table VII about here]

To disentangle the effects of unobserved individual heterogeneity and state dependence, we employ several dynamic discrete choice frameworks with random effects, retaining a first-order Markov process (i.e., including the first lagged dependent variable) and accounting for the initial condition problem. We consider derivative choice as a multi-state process and examine the effects of investment opportunities, taxes, agency costs, distress costs, managerial risk aversion, overinvestment, production function characteristics and market conditions on the choice of hedging strategy. Estimating these econometric dynamic settings will allow us to distinguish the effects of past hedging strategy choice and observable and unobservable firm characteristics on current hedging behavior.

To control for the possibility of sample selection bias, the estimation of all our models was derived in the context of the Two-Step Heckman Regression with Selection. This procedure captures the sequential decisions of oil and gas producers: a first decision to hedge or not and a second decision about the nature of the hedging strategy. In the first step, we follow the literature and model the existence of hedging activity as a function of variables that are conjectured to be determinants of the hedging decision: tax incentives, leverage, liquidity, cash costs, book value of convertible debt, firm size, sales, and oil and gas reserve quantities. Appendix A reports the estimation results of the first step, which allow us to obtain the estimated Inverse Mills Ratio that will be used in the second step.

5.1 A dynamic probit specification for hedging strategy choice

This model is used for hedging strategies based on one instrument only, as identified in Table IV (i.e., swap contracts only, put options only, and costless collars only). We will include the first lagged value of the dependent variable to account for this state dependence in hedging strategy choice, which leads to a Dynamic Panel Random Effects Probit Model. The main focus of this model is to capture the derivative choice dynamics: how does the derivative choice in the previous period affect the choice in the current period? The model for hedging strategy choice is given by the following expression and is estimated for each hedging strategy separately:

$$y_{i,j,t} = I\left[\beta X_{i,t} + \rho y_{i,j,t-1} + \varepsilon_{i,j,t} + u_{i,j} > 0\right] \qquad \left(i = 1,\ldots,N : t = 1,\ldots,T_i\right), \tag{1}$$

where $y_{i,j,t}$ is a dummy variable that takes the value of 1 when the hedging strategy *J* is used by the firm *i* at time *t* and 0 otherwise. $X_{i,t}$ is a set of observed exogenous variables related to investment opportunities, taxes, agency costs, distress costs, managerial risk aversion, overinvestment problem, production function characteristics and market conditions, which may be associated with hedging strategy choice by the firm *i* at time *t*. $X_{i,t}$ also includes the Inverse Mills Ratio coming from the first step of the Heckman regression with sample selection. $y_{i,j,t-1}$ is the observation of the dummy variable in the previous period, which allows us to capture state dependence. $u_{i,j}$ is the firm *i* and hedging strategy *j* specific factors that are time invariant and thus represent the unobserved heterogeneity. $\varepsilon_{i,j,t}$ is the idiosyncratic error term that is assumed to be strictly exogenous and is normally distributed and uncorrelated across firms and times.

In this dynamic setting, lagged effects or persistence can arise from the unobserved individual heterogeneity, u_i, (i.e. spurious state dependence; Heckman, 1981) or true state dependence through the term $\rho y_{i,j,t-1}$. In addition, this dynamic specification raises the initial condition problem as identified by Heckman (1981).[8] Because our focus is on true state dependence, we follow Wooldridge (2005) and model the distribution of the unobserved individual heterogeneity conditional on the initial values and the within-individual means of the exogenous variables. This is Mundlak's (1978) device to project the unobserved heterogeneity into the means of the explanatory variable with the addition of a dummy variable reflecting the initial state. Accordingly, we parameterize the distribution of the unobserved individual heterogeneity u_i as:

$$u_{i,j} = \alpha_0 + \alpha_1 y_{i,j,0} + \alpha_2 \bar{X}_i + \upsilon_{i,j} \qquad \left(i = 1,\ldots,N\right), \tag{2}$$

[8] The initial condition problem arises whenever the sample period does not coincide with the starting of the stochastic process generating the individual's choice dynamics (Heckman, 1981).

$y_{i,j,0}$ is the first observation or the starting observation of the hedging instrument choice. $\bar{X}_i$ is a set of means over the sample period of the exogenous variables of firm *i*. $\upsilon_{i,j}$ is assumed to be distributed $N\left(0,\sigma^2_{\upsilon_j}\right)$ and independent of the exogenous variables, the initial condition and the error term $\left(\varepsilon_{i,j,t}\right)$. Substituting equation (2) for equation (1) produces an augmented random effects probit model that could be estimated by a Gauss-Hermite quadrature as in Butler and Moffitt (1982)[9] or maximum simulated likelihood (see Wooldridge, 2005, or Greene, 2003 for more details).

5.2 A dynamic generalized ordered specification for hedging strategy choice

To further analyze the dynamics of hedging strategy choice, we implement a Dynamic Panel Generalized Random Effect Ordered Probit. This model is more flexible and relaxes the single index or parallel-line assumption (i.e., same coefficient vector β for all categories of the dependent variable) by making threshold parameters a linear function of the covariates (Maddala 1983, Terza 1985). We ordered hedging instruments in terms of their payoffs' linearity as follows: (1) Put options only, (2) Costless collars only and (3) Swaps only. The starting point for the econometric model is an unobserved latent dependent variable $h^*_{(i,t)}$, which describes the choice of hedging instrument given that possible choices are $h_{i,t}=\{1,2,3\}$. The reduced form of the estimated model is given by:

$$h^*_{i,t}=\beta X_{i,t}+\rho h_{i,t-1}+\varepsilon_{i,t}+u_i \quad \left(i=1,\ldots,N:t=1,\ldots,T_i\right), \tag{3}$$

$X_{i,t}$, u_i and $\varepsilon_{i,t}$ are, as in equation (1), in the dynamic random effect probit specification. $h_{i,t-1}$ is the observed instrument choice in the previous period that allows state dependence to be captured. To overcome the initial condition problem, we parameterize the unobserved heterogeneity u_i as in Wooldridge (2005):

[9] The model is estimated by the command *xtprobit.re* implemented in *STATA.SE* (Release 11.0, Stata Corporation), after the inclusion of all means of exogenous variables and initial observations.

$$u_i = \alpha_1 h_{i,0} + \alpha_2 \bar{X}_i + \upsilon_i \quad \left(i = 1,\ldots,N\right), \tag{4}$$

where $h_{i,0}$ is the first observation of hedging strategy choice for firm *i*. $\bar{X}_i$, and υ_i are, as in equation (2), for dynamic probit specification. Because the latent outcome $h_{i,t}^*$ is not observed, only an indicator of the hedging instrument, in which the latent variable falls, is observed $h_{i,t}$ with:

$$h_{i,t} = j \text{ if } \mu_{j-1} < h_{i,t}^* \le \mu_j, \tag{5}$$

where μ_j with $j = \{1,2,3\}$ are the threshold parameters. We allow these threshold parameters to be a linear function of observable characteristics $X_{i,t}$, $h_{i,t-1}$, $h_{i,0}$ and $\bar{X}_i$ (Terza, 1985). The conditional probability of observing each category $j = \{1,2,3\}$ is then given by:

$$\begin{aligned}&P\left(h_{i,t} = j \mid X_{i,t}, h_{i,t-1}, \bar{X}_i, h_{i,0}, \beta, \rho, \alpha_1, \alpha_2, \nu_i\right) = \\ &\Phi\left(\tilde{\mu}_j - \upsilon_i - \beta_j X_{i,t} - \rho_j h_{i,t-1} - \alpha_{2,j}\bar{X}_i - \alpha_{1j} h_{i,0}\right) - \Phi\left(\tilde{\mu}_{j-1} - \upsilon_i - \beta_{j-1} X_{i,t} - \rho_{j-1} h_{i,t-1} - \alpha_{2,j-1}\bar{X}_i - \alpha_{1,j-1} h_{i,0}\right)\end{aligned} \tag{6}$$

Where $\Phi(\cdot)$ denotes the cumulative density of the standard normal distribution. This formulation produces an augmented generalized ordered probit with random effects including the lagged dependent variable and the initial observation. This approach, as in Williams (2006), leads to the estimation of $J-1$ dynamic random effects probit models. The first model contrasts category 1 with categories $2,\ldots,J$; the second model contrasts categories 1 and 2 with categories $3,\ldots,J$. The model $J-1$ does the same regarding categories $1,\ldots,J-1$ versus category *J*. This model could be estimated by a Gauss-Hermite quadrature[10] or maximum simulated likelihood (see Boes, 2007 for more details).

5.3 A dynamic multinomial specification for hedging portfolio choice

Here we focus our attention on hedging portfolio choice (i.e., using simultaneously more than one instrument). Table V reveals that these hedging portfolios are constructed mainly from

[10] The model is estimated using *regoprob,* a user-written program developed by Boes (2007) based on Gauss-Hermite quadrature. We augment the model by including the lagged dependent variable, the means of the exogenous variable and the initial observation.

combinations of swap contracts with put options and/or costless collars. The transition probabilities reported in Table VI indicate higher persistence in these hedging portfolios, which motivates the use of a dynamic multinomial choice framework. Our econometric framework takes the form of a dynamic Mixed Multinomial Logit (MMNL) with random coefficients and correlated random effects. We allow random effects to be correlated with the firm's time-variant characteristics. This specification is less restrictive than a standard random effects model because it does not exhibit the restrictive assumption of Independence from Irrelevant Alternatives (IIA) and is more consistent with the Random Utility Maximization (RUM) assumption, where each hedging portfolio is associated with a given level of utility. The Mixed Logit also effectively captures random taste variation and habit formation.

The utility for the firm *i* from choosing hedging portfolio *j* at time *t*, $U_{i,j,t}$, is given by[11]:

$$U_{i,j,t} = X_{i,t}\beta_j + L_{i,j,t-1}\varphi_j + \varepsilon_{i,j,t} + u_{i,j} \quad \left(i = 1,\ldots,N; t = 1,\ldots,T_i; j = 1,\ldots,J\right), \tag{7}$$

where $X_{i,t}$ is a set of observed exogenous variables related to hedging portfolio choice as in equation (1) with unknown weight β_j. $L_{i,j,t-1}$ is a binary dummy variable indicating lagged hedging portfolio choice with parameter φ_j, with $L_{i,j,t-1} = 1$ if firm *i* chooses hedging portfolio *j* at time $t-1$, and $L_{i,j,t-1} = 0$ otherwise. Oil and gas producers have a set of four alternative hedging portfolios: swap contracts only $\left(j = 1\right)$, which is our base outcome in the model; swap contracts combined with put options $\left(j = 2\right)$; swap contracts combined with costless collars $\left(j = 3\right)$; swap contracts combined with put options and costless collars $\left(j = 4\right)$. $u_{i,j}$ represents the firm *i* and alternative *j* specific factors that are time invariant (i.e. unobserved heterogeneity). $\varepsilon_{i,j,t}$ is the idiosyncratic error term that is assumed to be independent from everything else in the model; it follows a Type I extreme value distribution.

Assume that at each time period $\left(t > 1\right)$ a firm chooses the hedging portfolio associated with the highest level of utility. Then, $L_{i,j,t} = 1$ if $U_{i,j,t} > U_{i,k,t}$ for all $k \neq j \left(k = 1,\ldots,J\right)$. Hence, the probability of making choice *j* at time $t > 1$ conditional on $X_{i,t}$, $L_{i,j,t-1}$ and $u_{i,j}$ takes the following logit form:

[11] The notation in this section is largely adapted from Zucchelli et al (2012).

$$P_{i,j,t} = P\left(L_{i,j,t} = 1 | X_{i,t}, L_{i,j,t-1}, u_{i,1}, \ldots, u_{i,J}\right) = \frac{\exp\left(X_{i,t}\beta_j + L_{i,j,t-1}\varphi_j + u_{i,j}\right)}{\sum_{k=1}^{J}\exp\left(X_{i,t}\beta_k + L_{i,k,t-1}\varphi_k + u_{i,k}\right)} \tag{8}$$

For identification purposes, all coefficients for the first category $(j=1)$ and its unobserved heterogeneity are set to zero (i.e., hedging with swap contracts only is our base outcome for this model). We assume that the individual unobserved heterogeneity for the remaining three hedging portfolios follows a trivariate normal distribution with zero means and a variance-covariance matrix with non-zero correlation across unobserved heterogeneity for alternative hedging portfolios.

Train (2009) suggests approximating the sample likelihood (*SL*) for the multinomial logit with random effects using simulated maximum likelihood methods. The simulated sample likelihood (*SLL*) is then given by:

$$SLL = \prod_{i=1}^{N}\frac{1}{R}\sum_{r=1}^{R}\prod_{t=2}^{T}\prod_{j=1}^{J}\left(\frac{\exp\left(X_{i,t}\beta_j + L_{i,j,t-1}\varphi_j + u_{i,j}^{r}\right)}{\sum_{k=1}^{3}\exp\left(X_{i,t}\beta_k + L_{i,k,t-1}\varphi_k + u_{i,k}^{r}\right)}\right)^{L_{i,j,t}} \tag{9}$$

where R values represent the quasi-random draws from the distribution of the unobserved heterogeneity using the Halton sequence technique. After R repetitions the *SLL* values are averaged over the R draws and the simulation is repeated until convergence.[12] To account for the initial condition problem, we parameterize the distribution of the individual unobserved heterogeneity for each firm as a function of the means of the exogenous variables over the sample period and the hedging portfolio choice in the initial period (see Train, 2009 for more details).

6. Results and discussion

6.1 Descriptive statistics: Independent variables

Descriptive statistics are computed on the pooled dataset. Table VIII gives summary statistics about the financial and operational characteristics for the 150 U.S. oil and gas producers in the

[12] The model is estimated by the user-written Stata program *mixlogit* developed by Arne Risa Hole (2007), which performs simulations using Halton sequences. We use 200 Halton draws.

sample. The findings suggest that U.S oil and gas producers are not intensive hedgers. In fact, the hedging indicator variables show that gas hedging occurred in 49.58% of the firm-quarters in the sample and oil hedging occurred in 41.21% of the firm-quarters. Interest rate, foreign exchange and basis risk hedging occurred respectively in 17.18%, 4.5% and 9.48% of the firm-quarters.

[Table VIII about here]

The measure of firms' investment programs shows that oil and gas producers are intensive investors. On average, firms expend the equivalent of 22.37% of the book value of their net property, plant and equipment in exploration and reserve acquisition and development. The correlation between internal cash flows and investment opportunities has a mean (median) of 0.055 (0.046), with one fourth of these firms having a correlation less than -0.18 and another fourth with a correlation greater than 0.30. The tax preference item, measured by the ratio of the book value of tax loss carryforwards scaled by the book value of total assets, has a mean (median) of 13.42% (0.00%). The expected tax saving benefits of hedging have a mean (median) of 5.24% (4.80%), which are quite close to the findings of Graham and Smith (1999).

The Distance-to-Default of the sample has a mean (median) of 2.234 (2.052), which reflects little variation in the financial safety of the oil and gas producers in the sample. Those results are similar to statistics reported by Drucker and Puri (2009) and Campello et al (2011).[13] Oil and gas producers maintain low leverage levels with a mean (median) of 15.8% (14.2%). Overall, oil and gas producers maintain relatively high levels of cash balances (quick ratio) and have quite similar cash costs (lifting cost per barrel of oil equivalent). Statistics also indicate that in 32% of the firm quarters in our sample, producers are in a situation of financial constraints with a leverage ratio and quick ratio that are both above and below the industry's median. The manager's stock and option ownership varies considerably, with a mean (median) of 28.983 MM$ (1.125 MM$) for stockholding and 174,386 (0.000) options. Institutional ownership has a mean (median) of 37.17% (29.86%) and varies from no institutional ownership for the first quartile to higher than 74% for the top quartile of the firm-quarters in the panel. The market value of firms' outstanding common shares shows that the oil and gas industry mainly

[13] Drucker and Puri examine the secondary market for loan sales in the USA over the period 1999-2004. Using a sample of 7261 loans, they find a mean (median) for the Distance-to-Default of 2.304 (1.929). Campello et al (2011) study the implications of hedging for corporate financing and investment. Using a dataset of 1185 firms over the period 1996-2002, they find a mean (median) for the Distance-to-Default of 2.464 (1.861).

comprises relatively small firms and a few large producers. In addition, this market value varies strongly within the sample with a mean (median) of $6,028 Million ($220 Million). The same conclusion is validated by the means and medians of oil and gas sales and reserve quantities.

The two Herfindahl indices, measuring the geographical dispersion of daily production of oil and gas respectively, indicate that oil and gas producing activities are largely concentrated in the same region. The mean Herfindahl index is 0.06 for daily oil production and 0.10 for daily gas production. Results further show that oil and gas producers derive almost 87% of their total revenues from oil and gas production. On average, gas production contributes to 52% of total revenue and oil production to 32%. Production uncertainty, measured by the coefficient of variation in daily production, has a mean (median) of 0.41 (0.31) for oil and 0.41 (0.30) for gas production respectively. In addition, the coefficient of variation of the cash cost per barrel of oil equivalent has a mean (median) of 0.29 (0.25). This implies that oil and gas producers face higher additional risks related to input costs and output quantities.

6.2 Multivariate Results[14]

6.2.1 Hedging Instrument Choice

Tables IX and X report the estimation results for many specifications of the Dynamic Panel Random Effect Probit Model in equation (1). The estimation was done for the subset of oil hedgers and gas hedgers separately and for each hedging instrument: swap contracts, put options and costless collars. The estimation results allow us to test the predictions concerning the incentives and rationales for derivative choices by oil and gas hedgers. The inspection of regressions reported in Tables IX and X clearly demonstrates the state dependence or state preference in derivative choice. Hence, the coefficients of the lagged dependent variables, for all the instruments, are significant at the 1% level. The investigation of the coefficients of the initial observations further shows that this state preference is more evident for swap contracts for the subset of oil hedgers and costless collars for the subset of gas hedgers with significant coefficients at conventional levels. These findings provide evidence of state dependence in

[14] Appendix B discusses the results of the univariate analysis we performed. Appendix C, D, E and F report descriptive statistics of the independent variables and tests of differences between means and medians of relevant variables for gas and oil hedgers separately. The univariate analysis is carried out by derivative instruments (Appendix C and D) and by hedging portfolios (Appendix E and F).

hedging behavior in terms of derivative choice, and suggest that recognizing the presence of this phenomenon could provide insight into management behavior.

[Tables IX and X about here]

Consistent with predictions, multivariate results show that put options are positively related to investment opportunities (INV_OPP) and swap contracts are significantly negatively related to investment opportunities[15] for the subset of gas hedgers. However, for the subset of oil hedgers, put options and swaps have the predicted sign but with no significant economic impact. The relationship between investment opportunities and collar use is unclear and insignificant. Overall, these findings are consistent with the univariate results, and with Froot et al's (1993) argument that firms with larger investment programs tend to use more non-linear instruments, along with the empirical findings of Gay and Nam (1999) and Adam (2002, 2003, 2009). Results related to undeveloped proved reserves suggest that oil reserves (UND_OIL) are significantly negatively related to collars, and particularly put options. One explanation could be that because oil producers already have larger undeveloped reserves, they face less pressure related to future development expenditures. Interestingly, for gas hedgers, the proxy CORR_1 for the correlation between free cash flows and the firm's investment programs are significantly positively related to swaps and negatively related to the use of put options and costless collars, as predicted. For the subset of oil hedgers, CORR_1 is related positively to swaps and negatively to collars and has an unpredicted positive association with put options. Overall, this is an empirical validation of the theoretical prediction of Froot et al (1993) and Spano (2004) that firms with a higher correlation between internal cash flows and future investment opportunities are more likely to use linear instruments because they benefit from a natural hedge and linear strategies suffice to provide value-maximizing hedges.

The multivariate results underline an evident impact of the economic conditions of the oil and gas markets on derivative choice. Consistent with the univariate results and our prediction, gas price volatility (VOL_GAS) is significantly positively associated with the use of put options and costless collars and significantly negatively related to swap contracts. Oil price volatility (VOL_OIL) has the predicted signs with swaps and collars, and unpredicted and insignificant signs with put options. This contradicts the prediction and the finding of Adam (2003) suggesting

[15] This last finding must be interpreted in light of the fact that swap users carry higher leverage ratios and that most of those loan agreements include investment restrictions, as evidenced by Campello et al (2011).

that gold price volatility has a negative impact on the decision to use non-linear strategies. The divergence could be explained mainly by the larger difference in the prices of the two commodities (natural gas and oil versus gold), hence the relative impact of their respective volatilities. Future prices (FUTURE_GAS and FUTURE_OIL) are significantly negatively related to the use of swaps and positively associated with the use of put options or collars. Consistent with our prediction, this finding means that when expected prices are higher, oil and gas producers are more interested in maintaining any potential upside than protecting the downside risk. In line with our expectations, spot prices (SPOT_OIL and SPOT_GAS) are significantly positively related to swap contracts and significantly negatively related to costless collars. Results related to put options are significant and mixed. Although put options are negatively related to oil spot prices as predicted, they are positively associated with gas spot prices. These findings imply that market conditions seem to be an important determinant in corporate hedging.

The results also show that geographical diversification (HERF_GAS) has no significant impact on derivative choice by the subset of gas hedgers, as in Adam (2009). For the subset of oil hedgers, the impact of geographical diversification in oil production (HERF_OIL) is mixed. Although higher geographic flexibility in oil production seems to be significantly negatively related to the use of swaps and positively related to collars, as conjectured by Moschini and Lapan (1992), it is negatively related to put options. Firms primarily engaged in gas production (i.e., higher GAS_REV) tend to use more put options and collars and to use less swaps. In addition, firms primarily engaged in oil production (i.e., higher OIL_REV) tend to use more put options. This is consistent with the empirical finding of Adam (2009), who confirms that more focused gold mining firms are 30% more likely to use options strategies than are diversified firms. Tufano (1996) finds no differences in the level of diversification between option users and non-users. The results pertaining to production cost risk (COST_CV) are mixed. Although production cost risk is positively related to collars and negatively related to swaps for oil hedgers as predicted, it appears to be negatively related to the use of put options. The unexpected negative relation between production cost risk and put options might be explained by the fact that higher variations in cash cost induce variations in realized margins and hence more financial constraints, which could deter firms from using costly hedging strategies (i.e., premium of put options). Surprisingly, the cash cost risk has no significant impact on gas hedging strategy. The explanation could be that cash cost is expressed in terms of barrel of oil equivalent, which means that it is more influenced by fluctuations of costs related to oil production more than gas production.

Interestingly, gas production uncertainties or quantity risks (UNCER_GAS) are significantly negatively related to swaps and collars. Results related to oil production uncertainties (UNCER_OIL) are mixed. Although these uncertainties are significantly negatively associated with collar use as predicted, they appear to be positively related to swaps but with lower significance. Overall, these findings corroborate the theoretical conjectures of Moschini and Lapan (1995), Brown and Toft (2002) and Gay et al (2002, 2003) suggesting that when a firm is facing non-hedgeable risks, its total exposure becomes nonlinear and the optimal hedging should depart from strict linearity. However, the association between oil (gas) quantity risk and put options is positive as predicted, but with no economic significance, which corroborates the empirical findings of Adam (2009), who finds no evidence that uncertainty of gold production motivates the use of option strategies for gold mining producers.

Results pertaining to the existence of additional hedged risks show that interest rate hedging (IR_HEDG) is negatively associated with the use of swaps, put options and collars. The raison for this intriguing finding comes from the costly external financing conjecture. Firms might consider the hedging of their core business risk or interest rate risk hedging as substitutes because both might alleviate the costly external capital problem. Foreign exchange risk hedging (FX_HEDG) is positively associated with the use of put options and negatively related to collars. Basis risk hedging (BASIS_HEDG) seems to be negatively associated with the use of swap contracts and collars. Consistent with our expectation, these findings suggest that the existence of additional hedgeable risks adds more non-linearity to the firm’s global exposure, which requires more non-linear hedging strategies

Interestingly, multivariate results pertaining to the quantity-price correlation indicate that when gas production quantities and spot prices are highly correlated (PQ_COR_GAS), gas producers tend to use more swaps and collars. This result is consistent with Brown and Toft (2002) and Gay et al (2002, 2003) conjectures that when production quantity and spot prices are positively correlated, over-hedging is less likely, and more linear instruments could achieve optimal hedging. The oil quantity-price correlation (PQ_COR_OIL) is strongly negatively related to collars. Although with similar production uncertainties, oil hedgers and gas hedgers react differently to the price-quantity correlation. A possible explanation of this result could be the differences in terms of unitary production costs, spot prices and price volatility of both commodities.

Regarding managerial risk aversion, particularly for gas hedgers, results show that a CEO with higher firm-specific wealth (MV_CS_CEO) tends to avoid put options, as predicted. However, we did not find a significant association between the CEO's equity stake value and swap contracts. Consistent with our expectations, results also suggest that CEO optionholding (OPT_CEO) is negatively related to the use of swaps. Interestingly, we find that higher managerial stockholding and optionholding are strongly positively related to costless collars. A possible explanation for this surprising finding is linked to the payoff structure of costless collars (i.e., buying put options and selling call options). Overall, the latter findings are consistent with the literature (Smith and Stulz, 1985) that a risk-averse manager with a concave utility function (i.e., higher stockholding), tends to use linear instruments and to avoid non-linear ones. Managers with a convex utility function (i.e., higher optionholding) will do the inverse. The percentage of institutional shareholding (%_CS_INST) is significantly negatively related to the use of the three instruments. This could be explained by the fact that institutional investors are less interested in risk management because they are large and well diversified.

Results pertaining to financial distress show that swap contracts are positively related to leverage ratio (LEV), negatively associated with financial constraints (CONSTRAINT) and negatively related to Distance-to-Default measure (DTD) in a statistically significant manner. This interesting finding reveals that oil and gas producers with higher leverage and lower Distance-to-Default but not yet in a financial distress situation (i.e., the negative association between swaps and CONSTRAINT) tend to use more swap contracts. In light of descriptive statistics, this latter finding corroborates theoretical predictions that linear instruments are optimal when there are average financial constraints (Adam, 2002). Surprisingly, results do not provide evidence of a relation between put options and firm's debt levels and financial constraints proxy. Results further show, particularly for oil hedgers, that put options are negatively related to Distance-to-Default in a significant manner. Although contrary to the expectation that firms that are far from financial distress could use non-linear instruments (Adam, 2002), this latter finding corroborates the risk-shifting theory (Jensen and Meckling, 1976). To further test the non-monotonicity between financial distress proxies and non-linear instrument use, we re-estimate regressions using the leverage squared and the Distance-to-Default squared and find no evidence of this non-monotonic relationship. The relationship between costless collar use and leverage ratio is mixed. Interestingly, oil hedgers that are far from financial distress use more costless collars. This finding appears to be consistent with

Detemple and Adler's (1988) prediction that more linear instruments are optimal for firms with no financial constraints.

Overinvestment (OVER_INV), a problem identified by Morellec and Smith (2007) and Bartram et al (2009), seems to be largely supported by the multivariate results. Overinvestment is more likely for large profitable firms that have fewer investment opportunities. Managers at these firms tend to overinvest because they derive private benefits from the investment. Interestingly, the overinvestment is significantly positively related to swap contracts and is significantly negatively related to put options and collars. Hence, when overinvestment is more likely to occur, firms tend to use more swap contracts to avoid it. To our knowledge, the overinvestment problem has not been empirically investigated in the corporate risk management context.[16]

With regard to tax function convexity (TAX_SAVE), measured by the approach proposed by Graham and Smith (1999), results indicate that the convexity of the tax function is significantly negatively related to put options for the subsample of oil hedgers. Although we did not find a significant positive relation between TAX_SAVE and swaps or collars, this finding empirically confirms the conjecture of the tax incentive to hedge, namely that firms tend to avoid non-linear instruments to eliminate volatility in pre-tax incomes. The empirical implications with respect to the tax loss carryforwards (TLCF) are unclear. While TLCF have a significant negative impact on the use of swap contracts and a significant positive association with the use of costless collars, this finding contradicts the prediction that firms with more tax preference items are more likely to use linear instruments to preserve the tax benefits of hedging. Géczy, Minton, and Schrand (1997) find a positive but insignificant association between linear instruments (swaps and forwards contracts) and tax loss carryforwards when studying currency derivative use. An explanation for this finding was put forth by Graham and Rogers (2002), who suggest that tax loss carryforwards are uncorrelated with tax function convexity. They conclude that the existence of this item might measure financial distress or other corporate characteristics.

6.2.2 Hedging Portfolio Choice

Tables XI and XII report the estimation results of the determinants of hedging portfolio choice for many specifications of the Dynamic Mixed Multinomial Logit model with random effects (MMNL).

[16] As a robustness check, we proxy the overinvestment problem by creating a dummy variable that equals 1 for firms whose ratio of free cash flow to total assets are in the top quartile, and 0 otherwise, and interact this dummy variable with investment opportunities. We obtain the same results.

The estimation was done for the subset of oil hedgers and gas hedgers separately. Because the main focus here is on oil and gas producers' rationales for choosing hedging portfolios with payoffs that depart from linearity to non-linearity by the combination of swap contracts with put options and/or costless collars, swap contracts are chosen as our base outcome and all the results must be interpreted relative to choosing swap contracts. However, the level of non-linearity depends on the percentage of the notional hedged quantity of each instrument forming the portfolio. Table VI summarizes those hedging portfolios and breaks down the notional quantity hedged between the different instruments.

[Tables XI and XII about here]

Each table reports the estimated coefficients' means for explanatory variables, as well as estimated means (uj), estimated standard deviations (Sigma_uj) and correlation coefficients (Rho_1_2, Rho_1_3 and Rho_2_3) of unobserved heterogeneity terms for the remaining three hedging portfolios: (1) swap contracts combined with put options, (2) swap contracts combined with costless collars and (3) swap contracts combined with put options and costless collars. Results (see lower parts of Tables XI and XII) show a statistically non-zero standard deviation of the unobserved heterogeneity effects justifying the random effects specification. They also indicate higher correlations between random effects of the three hedging portfolios for gas and oil hedgers respectively. This higher correlation of random effects across hedging portfolios implies that the firm-specific unobserved factors driving hedging portfolio choices overlap but are not the same. This appears to suggest that firm-specific random effects are a crucial element to take into account, and that our model should outperform other models without random effects.

Lagged hedging portfolio choice exhibits a great degree of persistence in all hedging portfolios. In line with Froot et al (1993), results show that oil and gas producers with higher investment opportunities are more likely to use put options and collars in their hedging portfolios in addition to swap contracts. This confirms our findings in the Dynamic Probit model. Results further show that undeveloped oil and gas reserves have no significant impact on hedging portfolio choice. Contrary to predictions, the correlation between internal cash flows and investment opportunities is positively related to the use of put options and collars for gas hedgers.[17] For the

[17] This unexpected result should be interpreted in light of the fraction of the notional quantity hedged by each instrument (Table VI). For hedging portfolios constituted by swap contracts combined with put options and costless

subset of oil hedgers, this correlation is negatively related to put options in a statistically significant manner. Higher gas future prices and higher gas price volatilities are significantly positively associated with costless collars. Furthermore, results show that put options are negatively related to higher oil spot prices and positively impacted by oil future prices. These findings, pertaining to market conditions, corroborate our predictions and are consistent with the Dynamic Probit model above.

Results further indicate that oil hedgers with higher geographical diversification tend to include costless collars in their hedging portfolios. For gas hedgers, the geographic diversification has the predicted sign but no significant impact. Surprisingly, producers more engaged in natural gas production tend to use more put options or collars in addition to swaps. This result is consistent with the empirical finding of Adam (2009) for gold mining firms and our previous results. For the subset of gas hedgers, gas production uncertainty seems to be significantly positively related to the use of put options and collars, as predicted. Conversely, oil production uncertainty is negatively related to collars as in the Dynamic Probit model. However, production cost risk (i.e., cash cost variability) appears to be significantly negatively related to the use of put options for the subset of gas hedgers. The explanation for this might be that higher cash cost variability implies more financial constraints. Thus, firms tend to avoid costly put options, as Adam (2002) predicted.

Results further show that the existence of additional hedgeable risk (i.e., FX and IR risks) is significantly positively related to the use of put options and/or collars in addition to swaps. This corroborates the theoretical predictions of Moschini and Lapan (1995), Brown and Toft (2002) and Gay et al (2002, 2003) that additional risks make total exposure non-linear and therefore the hedging strategy should also tend to be non-linear. Consistent with the theoretical predictions of Brown and Toft (2002) and Gay et al (2002, 2003), the price-quantity correlation, for gas hedgers, appears to have a significant negative impact on the use of put options and/or collars in combination with swaps. Hence, gas producers with a higher price-quantity correlation tend to use more swap contracts only to mitigate adverse movements in revenues because prices and quantities are moving in the same direction. However, there is no evidence of this relation for oil hedgers.

collars, the quantity of gas hedged by put options has a mean (median) of 19% (14%). These portfolios could thus be seen as having linear-like payoffs because almost 80% of the quantity is hedged by swaps and collars, which explains the positive sign for this variable.

Consistent with the literature, CEO optionholding is positively related to the use of put options in a statistically significant manner (in particular for oil hedgers). Consistent with our findings above, CEO's equity stake value in the firm is positively related to the use of collars. Overall, these results are consistent with Smith and Stulz's (1985) prediction. In addition, gas hedgers with higher percentages of institutional shareholding tend to use more collars in combination with swaps. Results also show, for gas hedgers in particular, that collars are negatively related to leverage in a statistically significant manner. This suggests that gas producers that are more leveraged, but not yet in financial distress, tend to lock-in predetermined revenues to satisfy their future commitments by resorting to swap contracts. The financial constraint proxy seems to be significantly related to the use of put options and/or collars. This corroborates the risk-shifting theory. Surprisingly, Distance-to-default appears to have no real impact on hedging portfolio choice. The impact of the overinvestment problem on hedging portfolio choice is unclear. Although overinvestment is significantly negatively associated with put options, as Morellec and Smith (2007) conclude for the subset of gas hedgers, it appears to be positively related to put options for oil hedgers. Contrary to expectations and our previous findings, tax function convexity is positively associated with the use of put options in addition to swaps for the subset of oil hedgers. Tax loss carryforwards appear to have no real impact on hedging portfolio choice.

7. Robustness checks: An ordered specification for hedging instrument choice

In this section, we examine the robustness of our results to an alternative econometric approach toward hedging instrument choice. In a previous section, we used a Dynamic Panel Random Effects Probit model, as in equation (1), to study the determinants of the use of each instrument separately (i.e., swaps only, put options only, costless collars only). In this section, we run a first robustness test on the determinants of the choice of linear or non-linear hedging instruments by employing an alternative econometric approach: a Dynamic Generalized Random Effects Ordered Probit, as in equation (3). This model relaxes the parallel-line assumption and permits estimated coefficients to vary across hedging instruments.

The three hedging instruments are now classified in terms of their linearity as follows: 1) put options, 2) costless collars and 3) swap contracts. By nature, costless collars are situated between strict linear instruments (i.e., swap contracts) and strict non-linear instruments (i.e., put options). This flexible model allows us to refine the association between each hedging instrument and observed firm characteristics. Tables XIII and XIV report the regression results of this model for four specifications for oil and gas hedgers separately. For each specification, we report the estimations EQ1 and EQ2. EQ1 estimates put options versus swap contracts and costless collars. EQ2 estimates swap contracts versus put options and costless collars.

[Place Tables XIII and XIV about here]

Again, results clearly show the state dependence in hedging instrument choice. The estimated coefficients of the lagged dependent variables range between 0.49 and 0.81 for oil hedgers and between 0.51 and 0.90 for gas hedgers and are highly significant. This shows that managers maintain almost invariable hedging strategies for long periods. Interestingly, results highlight that investment opportunities appear to be associated more with the use of costless collars. Further, undeveloped proved oil and gas reserves seem to be more related to the use of swap contracts and costless collars. Overall, these findings are as predicted and emphasize the role of costless collars, which was not as evident with our first model. Consistent with Froot et al (1993), the correlation between internally generated cash flows and investment programs is significantly positively related to the use of more linear instruments. Particularly for oil hedgers, the association between this correlation and swaps is now more evident compared with our first results. For gas hedgers, this correlation is positively related to swaps and collars.

The results pertaining to the impact of market conditions are highly consistent with our predictions and the findings produced by the Dynamic Probit model. Accordingly, higher volatility and higher future prices are related to the use of put options and collars, and higher spot prices are associated more with the use of swap contracts. These findings highlight the significant role of market conditions in derivative choice, which might explain firms' hedging behavior.

In line with the production flexibility argument of Moschini and Lapan (1992), results further suggest that higher geographical diversification is associated more with the use of put options and costless collars. The ordered specification better distinguishes the association between production flexibility and the use of non-linear instruments than in our first model. Overall, producers deriving their revenues primarily from oil production tend to use more put options, and those specializing in gas production tend to use more collars, as determined in our previous regressions. However, in the second model for oil hedgers, there is a positive relationship between oil revenues and swaps. Interestingly, the association between higher production uncertainty and the use of non-linear instruments is now as predicted, and is more apparent with the ordered specification. For gas hedgers, gas production uncertainty appears to be related to put options and costless collars. For oil hedgers, oil production uncertainty is associated more with put options.[18]

Results related to production cost variability are significant and still mixed. Although higher production cost risk has a positive impact on costless collars as predicted, it is positively related to swaps for gas hedgers, which runs counter to the prediction that additional non-hedgeable risks make non-linear hedging more optimal. Results further show that when oil and gas producers hedge both commodities and basis risk, they tend to use more swaps and collars. A possible explanation for this interesting finding could be that hedging the primary source of business risk (i.e. oil (gas) price risk) attenuates the non-linearity of the firm's total exposure, which makes more linear instruments optimal. Regarding IR risk, results are significant and still mixed. For oil hedgers, hedging FX risk is linked more to put options. The existence of foreign exchange risk thus makes firms' total exposure more non-linear, which requires non-linear instruments to be hedged.

For gas hedgers, the gas price-quantity correlation has the predicted sign, with a positive significant impact on the use of collars, as in our previous regressions. Surprisingly, for oil hedgers the oil price-quantity correlation has no significant impact on hedging instrument choice. Results related to managerial risk aversion indicate that CEO optionholding is more related to the use of put options and collars, as predicted. In addition, CEO stockholding is more associated with collars, particularly for gas hedgers. Overall, these findings are as predicted and corroborate our previous results.

Consistent with the findings of the Dynamic Probit model, the ordered specification shows that more leveraged oil hedgers tend to use swaps, whereas more solvent oil and gas producers (i.e., higher Distance-to-Default) tend to use costless collars specifically. This indicates again that more leveraged firms tend to lock in predetermined revenues, while more solvent ones tolerate more variability in their future revenues by avoiding strict linear hedging positions. In line with risk-shifting theory, results show that gas hedgers close to financial distress use more

[18] Model 1, Table XIV, illustrates an unexpected positive coefficient for oil production uncertainty and swap use, albeit with a lower significance level.

put options. Interestingly, we find that when overinvestment is more likely, oil and gas producers tend to use more collars and swap contracts. This finding also confirms the overinvestment conjecture of Morellec and Smith (2007). Surprisingly, tax function convexity and tax loss carryforwards seem to be more closely related to the use of costless collars. This result corroborates our expectations and confirms the conjecture of the tax incentive to hedge, namely that firms tend to avoid non-linear instruments to eliminate volatility in pre-tax incomes.

Table XV summarizes our predictions and findings arising from the three models used in the previous sections.

[Table XV about here]

8. A closer look at the economic effects of hedging strategy choice

In this section, we extend the controversial existing literature that focuses on the relation between corporate hedging and firms' risks and value. One strand of this empirical literature finds no support for the risk reduction argument and firm value maximization theory. Using a sample of 425 large US corporations from 1991 to 1993, Hentschel and Kothari (2001) find that derivative users display economically small difference in their stock return volatility compared with non-users, even for users with larger derivatives holdings. Guay and Kothari (2003) study the hedging practices of 234 large non-financial firms, and find that the magnitude of the derivative positions is economically small compared with firm-level risk exposures and movements in equity values. Jin and Jorion (2006) revisit the question of the hedging premium for a sample of 119 US oil and gas producers from 1998 to 2001. Although they find that oil and gas betas are negatively related to hedging extent, they show that hedging has no discernible effect on firm value. For a sample of gold producers, Jin and Jorion (2007) find no evidence of a positive association between hedging and firm value maximization. Recently, Fauver and Naranjo (2010) studied derivative usage by 1,746 US firms during 1991-2000, and assert that firms with greater agency and monitoring problems exhibit an economically significant negative association of -8.4% between firms' Tobin's Q and derivative usage.

In contrast, Guay (1999) looks at a sample of 254 non-financial corporations that began using derivatives in the fiscal year 1991, and reports that new derivative users experience a statistically and economically significant 5% reduction in stock return volatility compared with a control sample of non-users. Using a sample of S&P 500 non-financial firms for 1993, Allayannis and Ofek (2001) find strong evidence that foreign currency hedging reduces firms' exchange-rate exposure. Allayannis and Weston (2001) give the first direct evidence of the positive relation between currency derivative usage and firm value (as defined by Tobin's Q) and show that for a sample of 720 non-financial firms, the market value of foreign currency hedgers is 5% higher on average than non-hedgers. Graham and Rogers (2002) find that derivatives usage increases debt capacity and hence firm value by approximately 1.1%. Carter et al (2006) investigate jet fuel hedging behavior of firms in the US airline industry during 1993-2003, and find an average hedging premium of 12%-16%. Adam and Fernando (2006) examine the outstanding gold derivative positions for a sample of 92 North American gold mining firms for the period 1989-1999 and find that firms' derivatives transactions translate into increases in shareholder value. Bartram et al (2011) explore the effect of derivative use on firm risk and value for a large sample of 6,888 non-financial firms from 47 countries during 2000-2001. Their evidence suggests that using derivatives reduces both total risk and systematic risk, and is associated with higher firm value, abnormal returns and larger profits. Recently, Dionne et al (2012) studied a sample of gold mining firms during 1993-1999, and concluded that hedging is associated with a higher return on equity, return on assets and Tobin's Q when controlling for corporate governance. Aretz and Bartram (2010) review all of the existing empirical literature on corporate hedging and shareholder value.

We complement this empirical literature by going into further detail and investigating the real implications of hedging strategy choice on: (i) firms' stock return sensitivity; (ii) firms' stock volatility sensitivity; and, (iii) firms' financial and operational performance (i.e., realized oil and gas prices, return on equity, return on assets, Tobin's Q and earnings per share from operations). Because it is impossible to identify a single measure that fully captures the implications of hedging strategy choices, we examine the effects of hedging strategies relative to each of these measures. In addition, our study does not suffer from the endogeneity concern related to derivatives use as advanced by Jin and Jorion (2006) to explain the controversial results in the literature. This is because we select firms within the same industry; they have the same exposure to commodity risks and they vastly differ in terms of their hedging behaviors. Following Dionne et al (2012), we use a two-stage methodology based on instrumentation to mitigate the endogeneity issue. In the first stage, we estimate the predicted value of the hedging strategy using the dynamic probit model with random effects. In the second stage, we examine the effects of the predicted values on firms' performances. To our knowledge, no empirical study to date gives direct evidence of the effects of hedging strategy choice on firm performance.

8.1 Effects of hedging strategy choice on stock return sensitivity

Our tests expand on those of Rajgopal (1999) and Jorion and Jin (2006), who run pooled cross-sectional time-series regressions of firms' stock returns on the market, oil and gas price changes, and control for commodity risk hedging and proved oil and gas reserves. We then estimate the following models with interaction variables reflecting the impact of each hedging strategy in the oil (gas) beta:

$$R_{i,t} = \alpha_0 + \beta_m \times R_{m,t} + \sum_{j=1}^{7} \beta_j \times \left(Predicted\ HS_{j,i,t} \times R_{oil,t} \right) + \beta_{gas} \times R_{gas,t} + \varepsilon_{i,t} \qquad (10)$$

and

$$R_{i,t} = \alpha_0 + \beta_m \times R_{m,t} + \sum_{j=1}^{7} \beta_j \times \left(Predicted\ HS_{j,i,t} \times R_{gas,t} \right) + \beta_{oil} \times R_{oil,t} + \varepsilon_{i,t}, \qquad (11)$$

where $R_{i,t}$ is the total stock rate of return for firm *i* in quarter *t*, $R_{m,t}$ is the quarterly rate of change in the S&P 500 index, $R_{oil,t}$ is the quarterly rate of change in the price of the NYMEX crude oil three-month strip futures, $R_{gas,t}$ is the quarterly rate of change in the price of the NYMEX Henry Hub natural gas three-month strip futures. Predicted $HS_{j,i,t}$ is the linear prediction of each hedging strategy *j* for firm *i* (i.e., swap contracts only, put options only, costless collars only, swaps and put options, swaps and costless collars, collars and put options, and swaps, put options and collars) in quarter *t*. These predictions come from the estimation of a dynamic probit with random effects for each strategy (see equation 1). The presented models in (10) and (11) allow us to detect which hedging strategy is associated with lower sensitivity of firms' stock return to oil (gas) price fluctuations.

Panel A of Table XVI reports the estimations of the models in (10) and (11) for oil hedgers and gas hedgers separately (models with interactions). Panel A also reports the estimation of the three-factor models (without interactions) including the stock market return, the rate of change in the NYMEX oil futures price and the rate of change in the NYMEX gas futures price observed at the end of each quarter. We expect firms that hedge with derivatives to have relatively low sensitivity to oil and gas price fluctuations (i.e., lower oil and gas betas). Overall, regression results of the three-factor model (specifications 1, 2 and 3) show that oil and gas producers in the sample have exposures to oil (gas) price fluctuations that are positive and statistically significant. Results indicate that a 1% increase in the gas price leads to a 0.275% increase in the stock price for the entire sample (specification 1), a 0.345% increase in the stock price for the subsample of gas hedgers (specification 2), and a 0.155% increase in the stock return for the subsample of non-gas hedgers (not reported). Surprisingly, this latter finding shows that gas hedging increases firms' stock sensitivity to gas price fluctuations rather than mitigates it. This finding could also mean that gas hedgers are speculating rather than effectively hedging gas price risk. This corroborates the conjecture that sometimes managers take a view of the movements of financial markets (spot and future prices, and volatility).

Results reported in Panel A also show that a 1% increase in the oil price leads to a 0.704% increase in the stock return for the entire sample (specification 1), a 0.50% increase in the stock return for the subsample of oil hedgers (specification 3), and an increase of 0.865% in the stock return for the subsample of non-oil hedgers (not reported). Oil hedging appears to be associated with lower stock return sensitivity to oil price fluctuations, as expected. This implies that oil hedgers use derivatives to effectively hedge oil price risk rather than to speculate. Surprisingly, we find that the initiation of derivatives programs is not associated with a decrease in market risk. Hence, market beta increases from 0.823 for the entire sample to 1.108 for the subsample of gas hedgers and 1.136 for the subsample of oil hedgers. In unreported results, we find that derivatives users have significantly higher market risk than non-users (i.e., 1.05 versus 0.646). Although these findings are in line with those of Hentschel and Kothari (2001), who maintain that firms with derivatives have higher market betas than firms without derivatives, they contradict those of Bartram et al (2011), who observe that derivatives users have market betas that are on average 6% lower than those of non-users. In sum, the numbers reported in Panel A of Table XVI are higher than those reported in Rajgopal (1999) over the period 1993-1996, those of Jin and Jorion (2006) over the period 1999-2002 and those of Haushalter et al (2002) for a sample of U.S oil producers over the period 1992-1994.

[Table XVI about here]

Next, we investigate whether hedging strategy choice affects oil and gas betas. Our aim is to see which hedging strategy is associated with lower sensitivity to oil (gas) price fluctuations and vice versa. For gas hedgers (specification 4), results confirm that hedging strategies constituted by swap contracts only or costless collars only are significantly related to higher stock price sensitivity to gas price fluctuations. This latter finding contradicts the expectation that more linear hedging strategies should be associated with lower uncertainty about firms' revenues, and hence lower stock price sensitivity to gas price fluctuations. One explanation could be that linear strategies do not allow gas hedgers to profit from the upward potential, and hence accentuate the sensitivity of firms' stocks to gas price fluctuations. This finding could explain why gas hedging increases stock price sensitivity (i.e., gas beta) because swaps only and collars only are used for more than 82% of the firm-quarters of gas hedging.

Results also indicate that more complex hedging strategies based on a combination of different instruments seem to be associated more with lower stock price sensitivity to gas price fluctuations. Hence, swap contracts in combination with put options and swap contracts in combination with costless collars could mitigate the gas price risk with statistically negative coefficients. Interestingly, these hedging strategies have payoffs that depart from strict linearity. For oil hedgers (specification 5), results indicate that hedging strategies based on put options only reduce sensitivity, with a significantly negative coefficient, as expected. Overall, these findings strongly suggest that hedging strategies with non-linear payoffs reduce the stock price sensitivity to oil (gas) price fluctuations, and that more linear strategies based on one instrument only (i.e., swaps only and collars only) increase this sensitivity.

8.2 Effects of hedging strategy choice on stock volatility sensitivity

This sub-section provides detailed evidence of the relation of firms' total risk measured by total stock return volatility, and firms' hedging strategies. Our aim is to examine which hedging strategy better mitigates the effects of the exposure to oil (gas) price risks on firms' total risk. We partition the total stock return volatility into market risk, oil and gas risks and firm-specific risk. We then estimate the following models with interaction variables:

$$\sigma_{i,t} = \omega_0 + \omega_m \times \sigma_{m,t} + \sum_{j=1}^{7} \omega_j \times \left(Predicted\ HS_{j,i,t} \times \sigma_{oil,t} \right) + \omega_{gas} \times \sigma_{gas,t} + \sum_{j=8}^{12} \omega_j \times Control_{j,i,t} + \varepsilon_{i,t} \quad (12)$$

and

$$\sigma_{i,t} = \omega_0 + \omega_m \times \sigma_{m,t} + \sum_{j=1}^{7} \omega_j \times \left(Predicted\ HS_{j,i,t} \times \sigma_{gas,t} \right) + \omega_{oil} \times \sigma_{oil,t} + \sum_{j=8}^{12} \omega_j \times Control_{j,i,t} + \varepsilon_{i,t}, \quad (13)$$

where $\sigma_{i,t}$ is the annualized standard deviation of daily stock returns for firm *i* during quarter *t* to capture the aggregate firm risk, $\sigma_{m,t}$ is the annualized standard deviation of daily S&P 500 index returns during quarter *t*, $\sigma_{oil,t}$ is the annualized standard deviation of daily returns of the WTI crude oil spot prices during quarter *t*, and $\sigma_{gas,t}$ is the annualized standard deviation of daily returns of the Henry Hub natural gas spot prices during quarter *t*. Predicted $HS_{j,i,t}$ is the linear prediction of each hedging strategy as previously defined. $Control_{j,i,t}$ are a set of exogenous variables related to firms' characteristics. We retain firm size, leverage and liquidity, which Bartram, Brown and Stulz (2012) find to be important determinants of both firm total risk and systematic risk. We also use Distance-to-Default, defined above, and the dividend yield. This specification partitions total stock return volatility into firm-specific exposures to oil and gas volatilities, global market index risk and firm-specific characteristics.

Panel B of Table XVI reports the estimations of models in (12) and (13) for oil hedgers and gas hedgers separately (i.e., models with interactions). Panel B also reports the estimation of a regression of firm stock return volatility on market, oil and gas return volatilities and control variables (i.e., model without interactions). Results pertaining to the model without interactions show that oil return volatility has a significant positive effect on stock return volatility. Thus, a 1% increase in oil return volatility leads to a 0.275% increase in stock return volatility for the entire sample (specification 6), a 0.419% increase in stock return volatility for the subsample of oil hedgers, and an increase of 0.166% in stock return volatility for the subsample of non-oil hedgers (not reported). Surprisingly, results also show that gas return volatility has a negative but not significant impact on stock return volatility. In unreported results, we find that gas return volatility has a significant (i.e., at the level of 10%) negative impact on stock return volatility. Unexpectedly, these findings are inconsistent with firms that use derivatives to hedge (Guay, 1999, Bartram et al, 2011). As predicted, we find that larger firms with higher Distance-to-Default should have lower stock return volatility, and firms with higher financial leverage should have higher volatility.

We now look at the effects of the hedging strategy choice on stock return volatility as tabulated in specifications 9 and 10 of Panel B of Table XVI. For gas hedgers, results indicate that hedging strategies constituted by swap contracts only, costless collars only and collars in combination with put options are significantly related to higher stock return volatility. In contrast, put options only and put options in combination with swap contracts are significantly associated with a decline in stock return volatility. For oil hedgers, we find that collars only and put options in combination with swaps are significantly associated with higher stock return volatility. However, results also suggest that put options only, put options in combination with collars, swap contracts in combination with collars, and swaps in combination with collars and put options constitute hedging strategies that are negatively and significantly associated with stock return volatility. As shown above, larger firms that are far from financial distress have lower stock return volatility and firms with higher financial leverage have higher stock return volatility.

8.3 Economic implications of hedging strategy choice

In this sub-section, we look at the real implications of hedging strategy choice on financial and operational performance of oil and gas producers. To this end, we retain the following dependent variables: (1) realized oil and gas prices including the monetary effects of hedging activities as reported yearly by oil and gas producers; (2) return on equity; (3) return on assets; (4) earnings per share from operations; and (5) Tobin's Q. Our study thus provides novel evidence of the real implications of hedging strategy choice on firms' operational and financial performance. Table XVII reports the estimation results of the fixed effects regression of each dependent variable in the predicted value of each hedging strategy and other control variables related to firm characteristics (i.e., sales, market value, investment opportunities, leverage, cash costs, liquidity and daily production) and oil and gas spot prices and volatilities. These regressions are conducted separately for gas hedgers (Panel A) and oil hedgers (Panel B).

[Place Table XVII about here]

Results in Panel A of Table XVII show that realized gas prices are significantly and positively impacted by the use of three hedging strategies: costless collars only, costless collars in combination with swap contracts, and costless collars in combination with put options and swap contracts. Involving a short call and long put positions, costless collars allow managers to profit from any potential upside within a certain range with full protection of downside risk, with little or no upfront payment. Results further show that realized gas prices are negatively impacted by the use of the following three strategies: swap contracts only, put options only, and swaps in combination with put options. Although hedging strategies based on swaps provide full protection from downside risk, they do not allow any upside potential. Unexpectedly, put options are associated with lower realized gas prices. One explanation could be that the options' premiums might be higher than their monetary effects on gas prices.

Surprisingly, hedging strategy choice seems to have no real impact on the return on equity for the subsample of gas hedgers. Results in Panel A also illustrate that return on assets is positively impacted by hedging strategies involving put options only, put options in combination with collars and swaps in combination with collars, and appear to be negatively impacted by using swaps only. Regarding operational performance of gas hedgers, we find that earnings per share from operations are positively related to put options in combination with collars and put options in combination with swaps, and they are negatively related to swap only and collars only. Further, market performance (i.e., Tobin's Q) of gas hedgers is positively associated with the use of collars only, collars in combination with put options and swaps in combination with put options, and it is negatively impacted by put options only and swaps in combination with collars.

Results in Panel B of Table XVII indicate that realized oil prices are positively impacted by the use of swaps in combination with put options and swaps in combination with collars and put options, and negatively related to the use of swaps only and put options only. Return on equity for oil hedgers seems to be negatively related to put options only. However, return on assets is positively related to put options only and swaps in combination with collars, and is negatively related to swaps only, collars only, swaps in combination with put options and collars in combination with put options. Concerning operational performance of oil hedgers, results show that earnings per share from operations are positively related to hedging strategies involving put options only and swap contracts in combination with collars, and are negatively impacted by swaps only, collars only, collars in combination with put options and swaps in combination with put options. Finally, the market performance of oil hedgers is positively associated with the use of put options only and is negatively impacted by swaps only and swaps in combination with collars and put options.

9. Conclusion

A rich body of empirical literature on corporate risk management explores the incentives, determinants and virtues of hedging. While this empirical literature gives comprehensive answers to why firms hedge risks, and identifies the determinants of hedging extent and effects, the question of how firms hedge risks was of less concern. Using a unique and hand-collected dataset of detailed quarterly publicly available information on the risk management activity of 150 US oil and gas producers during the period 1998-2010, we extended the existing empirical literature by answering the following questions: What are the determinants of derivative choice? What are the real implications of hedging strategy choice on firms' stock return and volatility sensitivity to the underlying risk factor, and firms' operational and financial performance?

We employed dynamic panel discrete choice econometric settings that effectively capture hedging behavior. Besides the usual hypotheses already suggested in the empirical literature (underinvestment costs, tax incentives, financial distress, managerial risk aversion), we tested the empirical implications of theoretical predictions that had been explored little or not at all. In particular, we examined the empirical relevance of the prediction of Froot et al (1993) and Spano (2004) pertaining to the correlation between internal cash flows and investment opportunities. We also looked at the implications of the overinvestment problem theorized by Morellec and Smith (2007). In addition, we investigated the empirical implications of the quantity-price correlation evidenced theoretically by Brown and Toft (2002) and Gay et al (2002 and 2003). Moreover, we tested the effects of the existence of additional hedgeable and non-hedgeable risks and the production flexibility theorized by Moschini and Lapan (1992) and subsequent papers. We also tested the impact of the market condition on derivative choice. Finally, we empirically investigated the real implications of hedging strategy choice.

Overall, our results show the state dependence characteristic in hedging strategy choice. Managers seem to adopt a hedging strategy and maintain it for relatively longer periods. The state preference should be taken into account when explaining firms' hedging behavior. In line with predictions, we find that oil and gas producers with larger investment programs tend to use more non-linear strategies: put options only or hedging portfolios with non-linear payoffs (i.e., swaps in combination with put options and/or collars). Oil and gas producers with larger undeveloped proved reserves tend to avoid non-linear instruments because they have no pressing development costs. We find also that higher correlation between internally generated funds and investment expenditures motivates gas hedgers to use more swap contracts and to avoid put options, as theorized by Froot et al (1993) and Spano (2004). For oil hedgers, the impact of this correlation is unclear. However, our robustness check provides strong evidence of the relationship between this correlation and more linear strategies (i.e., swaps only, collars only). Further, we find that hedging strategy choice is strongly correlated to the economic conditions of the oil and gas market (i.e., spot prices, future expected prices and volatilities). Impacts of market conditions are as predicted.

As theorized by Moschini and Lapan (1992), we observe that producers with higher geographical diversification, particularly in their oil production, tend to use more costless collars and to avoid swaps contracts. Consistent with Adam (2009), we find also that more focused firms generally use more put options only and collars only or hedging portfolios with non-linear payoffs (i.e., swaps in combination with put options and/or collars). As predicted, results pertaining to the impact of additional nonhedgeable risks show that higher gas production uncertainty is related to the use of non-linear hedging portfolios. However, the impact of oil production uncertainty is contrary to expectations. The ordered specification used as robustness checks makes the relationship between production uncertainty and the use of non-linear instruments more evident. Results pertaining to production cost risk are significant and mixed. With regard to additional hedgeable risks, results indicate that FX risk is significantly related to the use of put options only, and that basis risk is negatively related to swaps and collars. As predicted, the existence of FX and basis risks makes the firm's total exposure more non-linear. The impact of IR risk is significant and mixed.

Consistent with predictions, producers with higher gas price-quantity correlations tend to use more swaps contracts and costless collars, and to avoid hedging portfolios with non-linear payoffs. In contrast, the oil price-quantity correlation is negatively related to collars in a significant manner. In line with our predictions, we find that CEOs with higher shareholding use more swaps in combination with collars and tend to avoid put options. We find also that CEOs with higher optionholding tend to use more hedging portfolios with non-linear payoffs (i.e., put options in combination with swaps) and to avoid swaps only. Interestingly, results show that CEOs with higher stockholding and optionholding tend to use collars only. Institutional shareholding is negatively related to the use of hedging strategies based on one instrument (i.e., swaps only, put options only and collars only) and has a positive impact on the use of hedging portfolios with non-linear payoffs (i.e., swaps in combination with collars). The presence of institutional investors thus induces more elaborate hedging programs.

Our results further indicate that oil and gas producers that are more leveraged but not yet in financial distress tend to use swap contracts more frequently because they are seeking predetermined revenues to satisfy their future debt commitments. More solvent oil and gas producers (i.e., with higher Distance-to-Default) tend to use collars only and to avoid swaps only. Consistent with the risk-shifting theory, we find that oil and gas producers close to financial distress use more hedging portfolios with non-linear payoffs (i.e., swaps in combination with put options and/or collars) and avoid using swaps only or collars only. The robustness checks also suggest a significant positive association between financial distress and the use of put options.

Interestingly, overinvestment appears to be a real concern when choosing hedging strategies. Thus, we find that gas hedgers with a greater potential for overinvestment tend to use swaps only and avoid using hedging strategies departing from strict linearity, such as put options only, collars only and swaps in combination with put options. However, for oil hedgers, the impact of overinvestment is mixed. Altogether, we give the first direct evidence of the impact of the overinvestment problem on hedging portfolio choice. Tax function convexity appears to be negatively related to put options only and positively related to swaps in combination with put options. Tax function convexity thus motivates the use of more linear hedging strategies, as predicted. We also find an evident positive relation between the tax loss carryforward and the use of costless collars only and a negative relation with swaps only. Hence, tax loss carryforwards are uncorrelated with tax function convexity, as suggested by Graham and Rogers (2002).

Finally, we provide novel evidence of the real implications of hedging strategy choice on stock price and risk sensitivity to oil and gas price fluctuations, realized oil and gas prices including the monetary effects of hedging positions, and the accounting, market and operating performance of oil and gas producers. Interestingly, we find that more complex hedging strategies, based on a combination of different derivatives, reduce the firm's stock price and volatility sensitivity to oil (gas) price fluctuations. These complex hedging programs have payoffs departing from strict linearity. We also observe that linear strategies based on one instrument only (i.e., swaps only and collars only) increase this sensitivity, which contradicts the prediction that linear strategies eliminate risks. Surprisingly, hedgers using swaps only have lower realized prices (i.e., prices including the monetary effects of the hedging), and poorer accounting, market and operating performance. Hedging strategies based on put options are negatively related to realized prices and return on equity, and are positively related to return on assets. However, results related to Tobin's Q are mixed. Users of collars only have higher realized gas prices, lower returns on assets and lower operating income. We find that more complex hedging programs based on a combination of instruments have significant effects on realized oil and gas prices and on producers' performance. However, these effects are mixed when comparing the results for the subsample of oil hedgers and gas hedgers respectively. This confirms that although they belong to the same industry, oil and gas have specific characteristics (price, volatility, production cost, production uncertainty, etc.) that cause their respective hedging programs to diverge.

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Table I: Summary of theoretical predictions

This table summarizes the theoretical predictions for each of the seven hedging strategies adopted by US oil and gas producers.

Theoretical predictions	Author(s)	Swap contracts only	Put options only	Costless collars only	Swaps and put options	Swaps and collars	Swaps, put options and collars	Collars and put options
Investment opportunities (expenditures)	Froot, Scharfstein and Stein (1993)	-	+	-/+	+	-/+	+	+
Correlation between internal funds and investment opportunities (expenditures)	Froot, Scharfstein and Stein (1993)	+	-	-/+	-	-/+	-	-
Market conditions:								
Spot prices		+	-	-	-	-	-	-
Future prices	Adam (2003 and 2009)	-	+	+	+	+	+	+
Volatilities		-	+	+	+	+	+	+
Production flexibility	Moschini and Lapan (1992)	-	+	+	+	+	+	+
Existence of additional hedgeable and non-hedgeable risks	Moschini and Lapan (1995), Franke, Stapleton and Subrahmanyam (1998), Brown and Toft (2002) and Gay et al (2002 and 2003).	-	+	-/+	+	-/+	+	+
Quantity-Price correlation	Brown and Toft (2002) and Gay et al (2002 and 2003).	+	-	-/+	-	-/+	-	-
Managerial shareholding	Smith and Stulz (1985) and Tufano (1996)	+	-	-/+	-	-/+	-	-
Managerial optionholding	Smith and Stulz (1985) and Tufano (1996)	-	+	-/+	+	-/+	+	+
Financial constraints	Adler and Detemple (1988)	-	+	+	+	+	+	+
Financial constraints	Adam (2002)	+	-	+	+	+	+	+
Overinvestment	Morellec and Smith (2007); Bartram et al (2009)	+	-	+	-	+	-	-
Tax function convexity	Mayers and Smith (1982), Smith and Stulz (1985)	+	-	-/+	-	-/+	-	-

Table II: Variables' definitions, construction and data sources

Variable definition	Variable name	Construction	Data source
Variables that proxy for hedging activity			
Hedging dummy	GAS_HEDG, OIL_HEDG, IR_HEDG, FX_HEDG, BASIS_HEDG	For CR (oil and gas), FX and IR hedging activities for a specified fiscal quarter. This variable is coded as follows: 0 (no hedging), 1(hedging).	10-K and 10-Q reports
Variables that proxy for tax advantage of hedging			
Tax Loss Carryforwards	TLCF	Book value of the Tax Loss Carryforward scaled by the book value of total assets	Compustat
Tax save	TAX_SAVE	The tax liability saving arising from a reduction of 5% of the taxable income. Graham and Smith (1999).	Compustat
Variables that proxy for financial distress costs			
Leverage	LEV	The book value of the long-term debt in current liabilities + one half of the long-term debt scaled by the book value of total assets.	Compustat
Distance-to-Default	DTD	A market-based measure of the default risk based on Merton's (1974) approach and used by Moodys-KMV. DTD is equal to $\frac{V_a - D}{V_a \sigma_a}$ where D is defined as long-term debt in current liabilities plus one-half long-term debts. V_a is the market value of assets and o_a is one year asset volatility. V_a and o_a are unobservable and they are approximated from Merton's (1974) model by using the market value and volatility of equity, the 3-month Treasury bill rate and debts (D). See Croshie and Bahn (2003) for more details on the construction of the DTD.	Manually constructed
Financial constraint	CONSTRAINT	Binary variable. It equals 1 when both leverage ratio and quick ratio are respectively above and below the industry's median and 0 otherwise.	Compustat
Cash Cost	CASH_COST	Production cost of a Barrel of Oil Equivalent	Bloomberg and 10-K reports
Variables that proxy for underinvestment costs			
Investment opportunities	INV_OPP	Total costs incurred in oil and gas property acquisition, exploration and development, scaled by the net property, plan, and equipment at the beginning of the quarter.	Bloomberg and 10-K reports
Correlation FCF and IO	CORR_1	The correlation coefficient between Free Cash Flow and investment opportunities. This coefficient is calculated, for each firm, in a rolling window by taking all the observations until the current quarter.	Bloomberg and 10-K reports
Undeveloped proved reserves (oil)	UND_OIL	Quantity of proved undeveloped oil reserves at the end of the quarter (In Millions of Barrels).	Bloomberg and 10-K reports
Undeveloped proved reserves (gas)	UND_GAS	Quantity of proved undeveloped gas reserves at the end of the quarter (In Billions of Cubic Feet).	Bloomberg and 10-K reports
Variables that proxy for overinvestment			
Overinvestment problem	OVER_INV	Binary variable. It equals 1 when both the ratio of free cash flows scaled by book value of total assets and investment opportunities are respectively above and below the industry's median and 0 otherwise.	Compustat
Variables that proxy for production characteristics			
Fraction of revenues from oil production	OIL_REV	It equals the fraction of oil production (i.e., oil daily production in Barrel of Oil Equivalents, divided by daily oil and gas production in BOE) multiplied by the fraction of oil and gas revenues (oil and gas revenues divided by the firm's total revenues).	Bloomberg and 10-K reports
Fraction of revenues from gas production	GAS_REV	It equals the fraction of gas production (i.e., gas daily production in Barrel of Oil Equivalents, divided by daily oil and gas production in BOE) multiplied by the fraction of oil and gas revenues (oil and gas revenues divided by the firm's total revenues).	Bloomberg and 10-K reports
Herfindahl index (oil production)	HERF_OIL	It equals 1- $\sum_{i=1}^{N}\left(\frac{q_i}{q}\right)^2$, where q_i is the daily oil production in the region (i) (Africa, Latin America, North America, Europe and Middle East). q is the total daily oil production.	Bloomberg and 10-K reports

Continued

Table II-*Continued*

Variable definition	Variable name	Construction	Data source
Herfindahl index (gas production)	HERF_GAS	It equals 1- $\sum_{i=1}^{N}\left(\frac{g_i}{g}\right)^2$, where g_i is the daily gas production in the region (i) (Africa, Latin America, North America, Europe and Middle East). g_i is the total daily gas production	Bloomberg and 10-K reports
Oil production uncertainty	UNCER_OIL	Coefficient of variation of daily oil production. This coefficient is calculated, for each firm, by taking all the observations of daily oil production until the current quarter.	Bloomberg and 10-K reports
Gas production uncertainty	UNCER_GAS	Coefficient of variation of daily gas production. This coefficient is calculated, for each firm, by taking all the observations of daily gas production until the current quarter.	Bloomberg and 10-K reports
Cash cost variability	COST_CV	Coefficient of variation of the cash (lifting) cost by Barrel of Oil Equivalent. This coefficient is calculated, for each firm, by taking all the observations of cash costs until the current quarter.	Bloomberg and 10-K reports
Price-Quantity correlation (oil)	PQ_COR_OIL	Correlation coefficient between daily oil productions and oil spot prices.	Bloomberg and 10-K reports
Price-Quantity correlation (gas)	PQ_COR_GAS	Correlation coefficient between daily gas productions and gas spot prices.	Bloomberg and 10-K reports
Variables that proxy for firm size			
Sales	SALES	Total revenues from oil and gas sales (In Millions of $)	Compustat
Market Value	MKT_VALUE	Number of common shares outstanding * the end-of-quarter per share price (In Millions of $).	Compustat
Oil Reserves	RES_OIL	Quantity of the total proved developed and undeveloped oil reserves (In Millions of Barrels).	Bloomberg and 10-K reports
Gas Reserves	RES_GAS	Quantity of the total proved developed and undeveloped gas reserves (In Billions of Cubic Feet).	Bloomberg and 10-K reports
Variables that proxy for managerial risk aversion			
Market value of CEO shareholding	MV_CS_CEO	Measured by the logarithm of 1 plus the market value of common shares held by the CEO at the end of each quarter.	Thomson Reuters
# CEOs' stock options	OPT_CEO	Number of CEOs' stock options (in 000).	Thomson Reuters
Variables that proxy for information asymmetry			
% Institutions CS	%_CS_INST	Percentage of institutions' common shares held.	Thomson Reuters
Variables that proxy for Market conditions			
Oil Future price	FUTURE_OIL	The average oil future prices for exchange-traded Futures for the next 12 months.	Bloomberg
Oil Spot price	SPOT_OIL	Oil spot price represented by the WTI in the NYMEX	Bloomberg
Gas Future price	FUTURE_GAS	The average gas future prices for exchange-traded Futures for the next 12 months.	Bloomberg
Gas Spot price	SPOT_GAS	Constructed as an average index established from principal locations' indices in the USA (Gulf Coast, Henry Hub, etc.)	Bloomberg
Oil price volatility	VOL_OIL	Historical volatility (standard deviation) using the spot price of the previous 60 days.	Bloomberg
Gas price volatility	VOL_GAS	Historical volatility (standard deviation) using the spot price of the previous 60 days.	Bloomberg
Variables that proxy for hedging substitutes			
Quick ratio	Q_RATIO	Cash and cash equivalents scaled by current liabilities.	Compustat
BVCD	BVCD	Book value of convertible debts scaled by the book value of total assets.	Compustat

Table III: Distribution of hedging decisions by firm-quarter

This table breaks down the total sample of 6,326 firm-quarters into observations with and without oil hedging and with and without gas hedging.

	Hedging activity: firm-quarter		
	Oil hedgers	**Non-oil hedgers**	**Total**
Gas hedgers	2,255	882	3,137
Non-gas hedgers	352	2,837	3,189
Total	2,607	3,719	6,326

Table IV: Hedging instruments used by oil and gas producers

This table reports the different types of financial instruments used by the sample firms that report some oil and gas hedging activities in a given firm-quarter observation. The values for each instrument indicate the number of firm-quarters and the fraction (in percentage) of use.

	Gas hedging		**Oil hedging**	
Financial instrument	**Number of firm-quarters**	**Percentage of use**	**Number of firm -quarters**	**Percentage of use**
Swap contracts	2,255	45.58%	1,711	45.25%
Put options	522	10.55%	448	11.85%
Costless collars	1,840	37.19%	1,403	37.11%
Forwards or Futures	161	3.25%	105	2.78%
Three-way collars	169	3.42%	114	3.02%
Total	4,947	100%	3,781	100%

Table V: Hedging strategies adopted by oil and gas producers

This table reports the hedging strategies adopted by the sample firms. An oil and gas producer can use one or more instruments simultaneously. Overall, we distinguish seven hedging strategies: swap contracts only, put options only, costless collars only, swaps and puts, swaps and collars, puts and collars, swaps, put and collars for oil hedgers and gas hedgers respectively. The value for each strategy represents the number of firm-quarter observations in which a firm reports the use of that strategy. The percentage of use for each instrument represents the number of firm-quarters of use of a given strategy scaled by the total number of firm-quarters of use of that instrument as given in Table III.

Panel A: Gas hedging strategies							
	Swap only	**Put only**	**Collar only**	**Swap+put**	**Swap+collar**	**Put+collar**	**Swap+put+collar**
Number of firm-quarters	932	126	582	137	999	72	187
Percentage of use							
Swap contracts	41.33%			6.08%	44.30%		8.29%
Put options		24.14%		26.25%		13.79%	35.82%
Costless collars			31.63%		54.29%	3.91%	10.16%
Panel B: Oil hedging strategies							
	Swap only	**Put only**	**Collar only**	**Swap+put**	**Swap+collar**	**Put+collar**	**Swap+put+collar**
Number of firm-quarters	849	150	577	99	627	63	136
Percentage of use							
Swap contracts	49.62%			5.79%	36.65%		7.95%
Put options		33.48%		22.10%		14.06%	30.36%
Costless collars			41.13%		44.69%	4.49%	9.69%

Table VI: Fraction of the notional position by instrument

For a given hedging strategy, this table gives summary statistics of the fraction of notional position hedged by each instrument.

Panel A: Gas hedging (%)

Strategy	**Swap+put**		**Swap+collar**		**Collar+put**		**Swap+put+collar**		
Instrument	**Swap**	**Put**	**Swap**	**Collar**	**Collar**	**Put**	**Swap**	**Put**	**Collar**
Mean	59.3	40.7	53.1	46.9	58.2	41.8	33.1	19.3	47.7
Median	64.9	35.1	55	45	60	40	30.6	13.8	46.5
SD	26.3	26.3	30	30	20.8	20.8	24.2	15.9	.25.3
Min	7.2	0.5	0.2	0	2.6	1.1	0.1	0.4	3.1
Max	99.5	92.8	100	99.8	98.9	97.4	91.7	66.4	96.9

Panel B: Oil hedging (%)

Strategy	**Swap+put**		**Swap+collar**		**Collar+put**		**Swap+put+collar**		
Instrument	**Swap**	**Put**	**Swap**	**Collar**	**Collar**	**Put**	**Swap**	**Put**	**Collar**
Mean	48.7	51.3	50.7	49.3	62.3	37.7	36.5	17.9	45.6
Median	49.2	50.8	51.6	48.4	66.6	33.4	30.3	15.8	48.6
SD	25.2	25.2	28.1	28.1	27	27	26.2	12.8	26.5
Min	4.4	2.3	0.02	1.3	0.5	2.1	1.4	0.5	0.8
Max	97.7	95.6	98.7	99.8	97.9	99.5	93	62.9	93.6

Table VII: Transition probabilities matrix for oil and gas hedging strategies

	Put only	Put+collar	Put+swap	Collar only	Collar+put+swap	Collar+swap	Swap only	Total
				Panel A: Gas hedging strategies (%)				
Put only	**85.45**	3.64	4.55	2.73	0.91	1.82	0.91	100
Put+collar	8.57	**71.43**	0.00	11.43	5.71	2.86	0.00	100
Put+swap	3.76	0.00	**84.96**	0.75	3.76	0.75	6.02	100
Collar only	0.73	1.81	0.00	**87.84**	0.73	7.62	1.27	100
Collar+put+swap	1.10	2.20	0.55	1.10	**79.67**	14.29	1.10	100
Collar+swap	0.00	0.10	0.10	4.29	1.99	**88.28**	5.23	100
Swap only	0.11	0.21	0.54	0.86	0.11	5.91	**92.27**	100
				Panel B: Oil hedging strategies (%)				
Put only	**89.76**	3.94	2.36	0.00	0.79	0.79	2.36	100
Put+collar	5.17	**72.41**	1.72	13.79	6.90	0.00	0.00	100
Put+swap	3.13	0.00	**87.50**	0.00	6.25	0.00	3.13	100
Collar only	0.18	1.10	0.00	**90.83**	0.73	6.42	0.73	100
Collar+put+swap	0.00	3.91	2.34	0.78	**79.69**	12.50	0.78	100
Collar+swap	0.17	0.00	0.17	6.35	1.67	**85.45**	6.19	100
Swap only	0.24	0.00	0.48	1.19	0.36	4.30	**93.44**	100

Table VIII: Summary statistics for firm financial and operational characteristics

This table provides financial and operational statistics for the 150 US oil and gas producers for the period 1998-2010. GAS_HEDG, OIL_HEDG, IR_HEDG, FX_HEDG and BASIS_HEDG are dummy variables for the gas, oil, interest rate, foreign exchange and basis risk hedging. TLCF for tax loss carryforwards scaled by the book value of total assets, TAX_SAVE for the expected percentage of tax saving, LEV for the leverage ratio, DTD for distance-to-default, CASH_COST for production cost per barrel of oil equivalent, INV_OPP for investment opportunities, CORR_1 for the correlation between free cash flows and investment opportunities, UND_OIL and UND_GAS for the undeveloped proved oil (in MM of barrel) and gas (in billion cubic feet) reserves respectively, OVER_INV for the overinvestment problem, OIL_REV and GAS_REV for fractions of revenues from oil (gas) production, HERF_OIL and HERF_GAS indices that measure the geographical dispersion of oil (gas) production, UNCER_OIL and UNCER_GAS measure the production uncertainty for oil and gas respectively, PQ_COR_OIL and PQ_COR_GAS measure the quantity-price correlation for oil and gas respectively, SALES for sales, MKT_VALUE for the common shares market value (in MM$), RES_OIL and RES_GAS for the total reserves for oil and gas respectively, MV_CS_CEO for the market value of common shares held by firm's CEO (in MM$), OPT_CEO for the number of stock options held by firm's CEO (in 000), %_CS_INST for the percentage of common shares held by institutional investors, FUTURE_OIL, SPOT_OIL and VOL_OIL for oil future and spot prices and volatility, FUTURE_GAS, SPOT_GAS and VOL_GAS for gas future and spot prices and volatility, Q_RATIO for the quick ratio and BVCD for the book value of convertible debts scaled by the book value of total assets. COST_CV is the coefficient of variation of the cash cost per barrel of oil equivalent.

Variable	Obs	Mean	Median	1st quartile	3rd quartile	STD
Variables that proxy for hedging activity						
GAS_HEDG	6,326	0.496	0.000	0.000	1.000	0.500
OIL_HEDG	6,326	0.412	0.000	0.000	1.000	0.492
BASIS_HEDG	6,326	0.095	0.000	0.000	0.000	0.293
IR_HEDG	6,326	0.172	0.000	0.000	0.000	0.377
FX_HEDG	6,326	0.045	0.000	0.000	0.000	0.207
Variables that proxy for underinvestment costs						
INV_OPP	6,006	0.224	0.075	0.041	0.129	3.619
UND_OIL	6,326	95.153	2.109	0.118	19.106	450.444
UND_GAS	6,326	503.631	31.799	2.742	193.048	2028.157
CORR_1	6,196	0.055	0.046	-0.179	0.305	0.383
Variables that proxy for overinvestment						
OVER_INV	5,855	0.259	0.000	0.000	1.000	0.438
Variables that proxy for tax advantage						
TLCF	6,066	0.134	0.000	0.000	0.064	0.438
TAX_SAVE	6,160	0.052	0.048	0.029	0.070	0.051
Variables that proxy for financial distress costs						
DTD	5,686	2.234	2.052	1.323	2.862	1.361
LEV	6,063	0.158	0.142	0.053	0.220	0.153
CONSTRAINT	6060	0.321	0.000	0.000	1.000	0.467
CASH_COST	6,241	9.860	7.527	4.684	12.230	8.441
Variables that proxy for managerial risk aversion						
MV_CS_CEO	6,326	28.983	1.125	0.000	11.563	152.159
OPT_CEO	6,326	174.386	0.000	0.000	120.000	681.760

Continued

Table VIII-*Continued*

Variable	Obs	Mean	Median	1st quartile	3rd quartile	STD
Variables that proxy for information asymmetry						
%_CS_INST	6,326	0.372	0.299	0.000	0.742	0.353
Variables that proxy for production characteristics						
UNCER_OIL	6,058	0.416	0.313	0.141	0.587	0.388
PQ_COR_OIL	6,119	0.229	0.455	-0.287	0.723	0.587
UNCER_GAS	6,078	0.408	0.303	0.146	0.582	0.359
COST_CV	6,167	0.292	0.252	0.148	0.396	0.556
PQ_COR_GAS	6,112	0.154	0.230	-0.174	0.504	0.419
OIL_REV	6,204	0.351	0.273	0.107	0.526	0.350
GAS_REV	6,204	0.519	0.566	0.242	0.785	0.311
HERF_GAS	6,180	0.063	0.000	0.000	0.000	0.183
HERF_OIL	6,178	0.100	0.000	0.000	0.000	0.233
Variables that proxy for firm size						
MKT_VALUE	6,326	6,027.862	220.008	31.993	1,412.968	3,2010.780
SALES	6,326	1,379.558	22.071	2.762	162.717	7,771.860
RES_OIL	6,326	276.710	8.010	0.948	53.352	1,277.726
RES_GAS	6,326	1,504.194	99.463	13.711	571.699	5,888.217
Variables that proxy for hedging substitutes						
BVCD	6,065	0.025	0.000	0.000	0.000	0.102
Q_RATIO	6,069	1.555	0.275	0.079	0.850	5.334

Table IX: Hedging instrument choice by gas hedgers

This table reports the coefficient estimates of the Dynamic Panel Random Effects Probit Model for the hedging instrument choice for the subsample of gas hedgers. For each instrument, the dependent variable is a dummy variable that takes the value of 1 if the instrument (Swap contracts, Put options, Costless collars) is used and 0 otherwise. LAG_SWAP, LAG_PUT, LAG_COLLAR are the lagged dependent dummy variables. SWAP_0, PUT_0, COLLAR_0 are the initial conditions (the first observation for each instrument). OIL_HEDG, IR_HEDG, FX_HEDG and BASIS_HEDG are dummy variables for oil, interest rate, foreign exchange and basis risk hedging. TLCF for tax loss carryforwards scaled by the book value of total assets, TAX_SAVE for the expected percentage of tax saving, LEV for the leverage ratio, DTD for distance to default, CONSTRAINT for financial constraint, INV_OPP for investment opportunities, CORR_1 for the correlation between free cash flows and investment opportunities, UND_GAS for undeveloped proved reserves for gas, GAS_REV for revenues from gas production, HERF_GAS measures the geographical dispersion of gas production, UNCER_GAS measures gas production uncertainty, PQ_COR_GAS measures the quantity-price correlation for gas, MV_CS_CEO for the market value of common shares held by the CEO, OPT_CEO for the number of stock options held by the CEO, %_CS_INST for the percentage of common shares held by institutional investors, FUTURE_GAS, SPOT_GAS and VOL_GAS for gas future and spot prices and volatility. COST_CV for the coefficient of variation of the cash cost per barrel of oil equivalent, OVER_INV measures overinvestment. IMR_GAS is the Inverse Mills Ratio from the first-step Heckman regression (Appendix A). Coefficients of the exogenous variables' means are not reported for conciseness. Standard errors are in parentheses. ***Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level.

Variable	(1) Swap	(2) Swap	(3) Swap	(4) Swap	(5) Put	(6) Put	(7) Put	(8) Put	(9) Collar	(10) Collar	(11) Collar	(12) Collar
CONSTANT	1.4679	0.8105	-0.3889	-0.3242	-4.0789**	-5.7321**	-3.8333**	-6.9740***	-1.5281	-5.8847***	-0.5455	-7.0967***
	(1.573)	(1.993)	(1.413)	(1.927)	(1.946)	(2.396)	(1.653)	(2.276)	(1.773)	(2.226)	(1.521)	(2.110)
INV_OPP	-1.0854***	-0.5866			0.9633**	1.1227**			0.0174	-0.1490		
	(0.369)	(0.396)			(0.462)	(0.539)			(0.274)	(0.256)		
UND_GAS			-0.0041	-0.0382			-0.2390	0.0226			0.1379	0.0979
			(0.058)	(0.061)			(0.503)	(0.440)			(0.095)	(0.091)
CORR_1	0.4680***	0.2273*	0.3677***	0.2344*	-0.8728**	-0.8760***	-0.7570**	-0.7833**	-0.0487	-0.2355	-0.0044	-0.2385
	(0.133)	(0.129)	(0.127)	(0.127)	(0.339)	(0.331)	(0.325)	(0.331)	(0.176)	(0.179)	(0.175)	(0.179)
VOL_GAS	-0.2168***		-0.2489***		0.3533***		0.3156**		0.1165		0.1218*	
	(0.062)		(0.062)		(0.137)		(0.133)		(0.071)		(0.072)	
FUTURE_GAS		-0.1918***		-0.1919***		-0.1178		-0.0756		0.1030**		0.0849*
		(0.038)		(0.038)		(0.087)		(0.085)		(0.043)		(0.044)
SPOT_GAS		0.0911***		0.0846***		0.1463**		0.1160*		-0.0690*		-0.0694*
		(0.033)		(0.033)		(0.069)		(0.068)		(0.037)		(0.038)
HERF_GAS	0.0427		-0.0211		-0.7928		-0.9635		-0.6264		-0.8546	
	(0.633)		(0.635)		(0.807)		(0.779)		(0.672)		(0.685)	
GAS_REV	-1.6987***		-1.6748***		1.5441**		0.9107		1.0976**		1.2957***	
	(0.363)		(0.375)		(0.771)		(0.748)		(0.445)		(0.450)	
COST_CV		0.1630	-0.1000	0.1128		-0.0604	-0.5828	-0.2593		-0.2343	-0.0074	-0.1451
		(0.138)	(0.262)	(0.120)		(0.572)	(0.424)	(0.471)		(0.311)	(0.162)	(0.314)
UNCER_GAS	-1.8510***		-2.0391***		0.3975		0.6549		-1.5775***		-1.5663***	
	(0.261)		(0.308)		(0.744)		(0.759)		(0.319)		(0.343)	
OIL_HEDG	-0.2277**				-0.8895***				-0.2931**			
	(0.097)				(0.215)				(0.120)			
IR_HEDG		-0.3739***				-0.1170				-0.2410**		
		(0.094)				(0.264)				(0.116)		
FX_HEDG			-0.1160				1.6753**				-0.2883	
			(0.203)				(0.762)				(0.426)	
BASIS_HEDG				-0.2025*				-0.3124				-0.7884***
				(0.117)				(0.410)				(0.172)

Continued

Table IX-*Continued*

Variable	(1) Swap	(2) Swap	(3) Swap	(4) Swap	(5) Put	(6) Put	(7) Put	(8) Put	(9) Collar	(10) Collar	(11) Collar	(12) Collar
PQ_COR_GAS		0.1759		0.2393*		-0.1206		-0.1167		0.5179***		0.6118***
		(0.140)		(0.142)		(0.315)		(0.316)		(0.191)		(0.196)
OPT_CEO	-0.0020**	-0.0023**	-0.0019**	-0.0026***	0.0043	0.0028	0.0034	0.0024	0.0052***	0.0042**	0.0034	0.0042**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
MV_CS_CEO	-0.5599	-0.3885	-0.5638	0.0170	-20.3546**	-12.8546	-15.0856*	-12.1550	1.8033***	1.2405**	1.5883***	1.6220***
	(0.437)	(0.470)	(0.439)	(0.483)	(9.543)	(8.285)	(8.584)	(7.852)	(0.564)	(0.575)	(0.586)	(0.582)
%_CS_INST		-1.2378***		-1.1857***		-0.9514		-0.9467*		-0.2165		-0.0891
		(0.214)		(0.217)		(0.584)		(0.569)		(0.268)		(0.268)
LEV		0.8857**		0.8727**		-0.1875		-0.3945		0.9969*		0.9548*
		(0.398)		(0.398)		(1.079)		(1.081)		(0.520)		(0.517)
CONSTRAINT		-0.1890**		-0.1983**		-0.0494		-0.0267		0.0076		-0.0440
		(0.082)		(0.082)		(0.203)		(0.201)		(0.100)		(0.101)
DTD	-0.0855**		-0.0955***		-0.0138		-0.0031		0.0189		0.0167	
	(0.034)		(0.034)		(0.097)		(0.095)		(0.044)		(0.044)	
OVER_INV		0.1429		0.1745*		-0.4372**		-0.5306**		-0.1961*		-0.1836*
		(0.094)		(0.092)		(0.218)		(0.214)		(0.106)		(0.106)
TAX_SAVE		-1.4106		-1.4424		1.6713		1.4518		2.1223		2.1628
		(0.884)		(0.877)		(1.706)		(1.851)		(1.298)		(1.339)
TLCF	-0.9751***		-1.0150***		0.0618		0.5620		0.4713		0.4939	
	(0.371)		(0.367)		(0.500)		(0.533)		(0.318)		(0.321)	
IMR_GAS	0.7884***	0.4948**	0.5998***	0.5214**	0.9499**	0.5084	0.8784***	0.6314	0.0179	0.4179	0.0106	0.3873
	(0.193)	(0.210)	(0.152)	(0.216)	(0.417)	(0.456)	(0.300)	(0.445)	(0.214)	(0.256)	(0.180)	(0.257)
LAG_SWAP	1.0217***	0.9619***	0.9982***	0.9748***								
	(0.105)	(0.104)	(0.103)	(0.104)								
SWAP_0	0.3181	0.0749	0.2547	0.1421								
	(0.445)	(0.427)	(0.425)	(0.444)								
LAG_PUT					2.2322***	2.2389***	2.1345***	2.1698***				
					(0.206)	(0.200)	(0.194)	(0.195)				
PUT_0					-0.0112	-1.0045*	-0.1124	-0.8876				
					(0.595)	(0.576)	(0.571)	(0.575)				
LAG_COLLAR									1.3995***	1.3361***	1.4165***	1.3567***
									(0.107)	(0.109)	(0.107)	(0.109)
COLLAR_0									0.7508	0.9140*	0.8174	1.2346**
									(0.507)	(0.524)	(0.504)	(0.525)
Observations	2,905	2,873	2,851	2,873	2,905	2,873	2,851	2,873	2,905	2,873	2,851	2,873
Number of firms	108	105	105	105	108	105	105	105	108	105	105	105
Log Likelihood	-1167.8846	-1147.2939	-1173.8810	-1156.9260	-213.4431	-213.6897	-217.1877	-216.8524	-838.0898	-812.4556	-815.5129	-799.5815
Wald Stat	257.4978	281.2807	250.9606	266.9531	144.0724	148.3352	150.6652	147.7882	216.5522	207.3950	221.1073	222.8399
Significance	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rho	0.6669	0.6526	0.6437	0.6608	0.4985	0.4448	0.4481	0.4611	0.6765	0.6762	0.6609	0.6675
Panel-level standard deviation	1.4151	1.3705	1.3441	1.3958	0.9971	0.8951	0.9011	0.9249	1.4461	1.4450	1.3960	1.4169

Table X: Hedging instrument choice by oil hedgers

This table reports the coefficient estimates of the Dynamic Panel Random Effects Probit Model for the hedging instrument choice for the subsample of oil hedgers. For each instrument, the dependent variable is a dummy variable that takes the value of 1 if the instrument (Swap contracts, Put options, Costless collars) is used and 0 otherwise. LAG_SWAP, LAG_PUT and LAG_COLLAR are the lagged dependent dummy variables. SWAP_0, PUT_0, COLLAR_0 are the initial conditions (the first observation for each instrument). GAS_HEDG, IR_HEDG, FX_HEDG and BASIS_HEDG are dummy variables for gas, interest rate, foreign exchange and basis risk hedging. TLCF for tax loss carryforwards scaled by the book value of total assets, TAX_SAVE for the expected percentage of tax saving, LEV for the leverage ratio, DTD for distance to default, CONSTRAINT for financial constraints, INV_OPP for investment opportunities, CORR_1 for the correlation between free cash flows and investment opportunities, UND_OIL for the undeveloped proved reserves of oil, and OIL_REV revenues from oil production, HERF_OIL measures the geographical dispersion of oil production, UNCER_OIL measures oil production uncertainty, PQ_COR_OIL measures the quantity-price correlation for oil, MV_CS_CEO for the market value of common shares held by the CEO, OPT_CEO for the number of stock options held by the CEO, %_CS_INST for the percentage of common shares held by institutional investors, FUTURE_OIL, SPOT_OIL and VOL_OIL for oil future and spot prices and volatility. COST_CV for the coefficient of variation of the cash cost per barrel of oil equivalent, OVER_INV measures the overinvestment problem. IMR_OIL is the Inverse Mills Ratio from the first-step Heckman regression (Appendix A). Coefficients of the exogenous variables' means are not reported for conciseness. Standard errors are in parentheses. ***Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level.

Variable	(1) Swap	(2) Swap	(3) Swap	(4) Swap	(5) Put	(6) Put	(7) Put	(8) Put	(9) Collar	(10) Collar	(11) Collar	(12) Collar
CONSTANT	4.7882**	-3.7389	-0.5819	-4.8180*	-8.7859***	-3.6228	-6.6588**	-5.3129	-0.6477	-5.9331***	-1.9168	-6.1695***
	(1.884)	(2.786)	(1.543)	(2.840)	(3.355)	(4.037)	(2.782)	(3.993)	(1.922)	(2.258)	(1.443)	(2.293)
INV_OPP	-0.5259	-0.2887			0.9153	0.3572			-0.0767	0.0347		
	(0.326)	(0.314)			(0.648)	(0.820)			(0.281)	(0.233)		
UND_OIL			-0.0518	-0.5013			-8.6283*	-6.0433			-2.4315*	-0.8710
			(1.355)	(1.360)			(4.475)	(3.899)			(1.281)	(1.330)
CORR_1	0.0334	0.2889*	-0.0350	0.2448	0.7236**	0.0342	0.6866*	0.2411	-0.1328	-0.3130	-0.2062	-0.3854*
	(0.168)	(0.166)	(0.166)	(0.165)	(0.350)	(0.359)	(0.354)	(0.355)	(0.192)	(0.199)	(0.189)	(0.199)
VOL_OIL	-0.0555***		-0.0422**		-0.0408		-0.0316		0.0291*		0.0322*	
	(0.016)		(0.017)		(0.036)		(0.039)		(0.016)		(0.017)	
FUTURE_OIL		-0.0508***		-0.0526***		0.0855**		0.0936**		0.0383**		0.0535***
		(0.014)		(0.015)		(0.038)		(0.038)		(0.015)		(0.016)
SPOT_OIL		0.0413***		0.0429***		-0.0846**		-0.0904**		-0.0358**		-0.0485***
		(0.014)		(0.015)		(0.036)		(0.036)		(0.015)		(0.016)
HERF_OIL	-1.7915***		-1.8719***		-1.2180		-2.9419*		0.8046*		0.7722	
	(0.408)		(0.420)		(1.623)		(1.773)		(0.460)		(0.471)	
OIL_REV	-0.3076		0.1319		0.9129		1.9694**		-0.8129		-0.6863	
	(0.435)		(0.427)		(0.901)		(0.931)		(0.505)		(0.496)	
COST_CV		0.0926	-1.4119***	0.0637		-2.5530**	-2.3783**	-2.0884*		0.1552	0.2640**	0.1088
		(0.191)	(0.399)	(0.193)		(1.256)	(1.034)	(1.235)		(0.184)	(0.126)	(0.214)
UNCER_OIL	0.2130		0.6573*		0.1882		1.2106		-2.0438***		-2.1054***	
	(0.325)		(0.351)		(0.990)		(1.031)		(0.340)		(0.348)	
GAS_HEDG	-0.3417*				-1.1378***				-0.6163***			
	(0.184)				(0.305)				(0.182)			
IR_HEDG		-0.1372				-0.8188**				-0.1520		
		(0.116)				(0.339)				(0.125)		
FX_HEDG			-0.2215				1.4545**				-1.0206***	
			(0.276)				(0.664)				(0.330)	
BASIS_HEDG				0.1938				-0.3791				-0.7243***
				(0.144)				(0.347)				(0.158)

Continued

Table X-*Continued*

Variable	(1) Swap	(2) Swap	(3) Swap	(4) Swap	(5) Put	(6) Put	(7) Put	(8) Put	(9) Collar	(10) Collar	(11) Collar	(12) Collar
PQ_COR_OIL		-0.1702		-0.1387		0.4081		0.5262		-0.7748***		-0.7293***
		(0.127)		(0.129)		(0.409)		(0.407)		(0.149)		(0.152)
OPT_CEO	0.0002	-0.0017	-0.0003	-0.0018	0.0052	-0.0002	-0.0028	-0.0020	-0.0024	-0.0009	-0.0014	-0.0009
	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.005)	(0.005)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
MV_CS_CEO	-0.5533	0.0994	-0.7896	0.0746	-8.5490*	-4.6368	-1.6199	-2.8492	0.1608	-0.6164	0.2451	-0.2322
	(0.618)	(0.633)	(0.619)	(0.638)	(4.645)	(3.749)	(3.463)	(3.718)	(0.475)	(0.506)	(0.486)	(0.499)
%_CS_INST		-0.2860		-0.2394		-1.7309**		-1.4452**		-0.7092**		-0.7154**
		(0.274)		(0.276)		(0.708)		(0.687)		(0.345)		(0.344)
LEV		1.6201**		1.7125***		-2.8448		-1.8156		-1.1950*		-1.1470*
		(0.650)		(0.654)		(1.935)		(1.828)		(0.623)		(0.629)
CONSTRAINT		-0.0797		-0.0874		0.2778		0.2751		-0.3806***		-0.3531***
		(0.102)		(0.102)		(0.245)		(0.244)		(0.110)		(0.111)
DTD	-0.1117**		-0.1105**		-0.2068**		-0.1333		0.1362***		0.1506***	
	(0.046)		(0.047)		(0.098)		(0.107)		(0.049)		(0.051)	
OVER_INV		-0.0473		-0.0315		-0.6594***		-0.6140**		0.0081		0.0149
		(0.112)		(0.111)		(0.248)		(0.245)		(0.113)		(0.113)
TAX_SAVE		-1.3269		-1.2898		-11.6435**		-11.5699**		1.2068		1.2311
		(0.929)		(0.914)		(5.306)		(5.047)		(1.661)		(1.698)
TLCF	-1.8248***		-1.7878***		-0.4893		-0.1843		1.2475***		1.0732***	
	(0.492)		(0.507)		(1.103)		(1.133)		(0.337)		(0.305)	
IMR_OIL	1.1019***	0.4478	0.7931***	0.4954*	1.5474**	0.2971	0.9632*	0.8807	0.0808	-0.2248	0.0268	-0.1904
	(0.224)	(0.279)	(0.220)	(0.281)	(0.609)	(0.839)	(0.500)	(0.777)	(0.215)	(0.302)	(0.212)	(0.305)
LAG_SWAP	1.4070***	1.3954***	1.3766***	1.3639***								
	(0.115)	(0.114)	(0.114)	(0.115)								
SWAP_0	1.0895**	1.5019**	1.5047***	1.7065***								
	(0.505)	(0.616)	(0.539)	(0.625)								
LAG_PUT					2.1863***	2.2099***	2.1889***	2.2230***				
					(0.203)	(0.207)	(0.209)	(0.208)				
PUT_0					1.5434	1.5512	1.5467	1.8568				
					(1.006)	(1.071)	(1.123)	(1.150)				
LAG_COLLAR									1.2600***	1.2661***	1.2585***	1.2185***
									(0.108)	(0.109)	(0.111)	(0.109)
COLLAR_0									0.1769	0.3743	0.0143	0.2600
									(1.004)	(0.950)	(1.064)	(0.972)
Observations	2,402	2,409	2,375	2,409	2,402	2,409	2,375	2,409	2,402	2,409	2,375	2,409
Number of firms	101	99	99	99	101	99	99	99	101	99	99	99
Log Likelihood	-828.2913	-821.5812	-810.4447	-821.1071	-192.2647	-186.8094	-192.6126	-189.9448	-741.3202	-719.4538	-718.3412	-709.1148
Wald Stat	249.7851	247.9265	247.7702	246.1133	137.6785	133.3503	126.5703	132.2096	213.2022	200.8963	203.3644	215.5304
Significance	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rho	0.7082	0.7599	0.7329	0.7610	0.7306	0.7255	0.7717	0.7538	0.7130	0.6744	0.7373	0.6841
Panel-level standard deviation	1.5578	1.7790	1.6564	1.7843	1.6469	1.6258	1.8386	1.7499	1.5761	1.4391	1.6754	1.4715

Table XI: Hedging portfolio choice by gas hedgers

This table reports means of coefficient estimates of the Dynamic Random Effects Multinomial Mixed Logit to select one of the following three hedging portfolios: (1) Swap and put options, (2) Swaps and Collars and (3) Swaps, Put options and Costless collars for the subsample of gas hedgers. The base case is using swap contracts only. OIL_HEDG, IR_HEDG, FX_HEDG and BASIS_HEDG are dummy variables for oil, interest rate, foreign exchange and basis risk hedging. TLCF for tax loss carryforwards scaled by the book value of total assets, TAX_SAVE for the expected percentage of tax saving, LEV for the leverage ratio, DTD for distance to default, CONSTRAINT for financial constraints, INV_OPP for investment opportunities, CORR_1 for the correlation between free cash flows and investment opportunities, UND_GAS for the undeveloped proved reserves of gas, GAS_REV for revenues from gas production, HERF_GAS measures the geographical dispersion of gas production, UNCER_GAS measures gas production uncertainty, PQ_COR_GAS measures the quantity-price correlation for gas, MV_CS_CEO for the market value of common shares held by the CEO, OPT_CEO for the number of stock options held by the CEO, %_CS_INST for the percentage of common shares held by institutional investors, FUTURE_GAS, SPOT_GAS and VOL_GAS for gas future and spot prices and volatility. COST_CV for the coefficient of variation of the cash cost per barrel of oil equivalent, OVER_INV measures the overinvestment problem. IMR_GAS is the Inverse Mills Ratio from the first step Heckman regression (Appendix A). LAG is the lagged dependent variable. LAG_0 is the first observation. Coefficients of the exogenous variables' means are not reported for conciseness. Standard errors are in parentheses. ***Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level.

	Model 1			Model 2			Model 3			Model 4		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Variable	Swaps + Put options	Swaps + Collars	Swaps + Collars + Put options	Swaps + Put options	Swaps + Collars	Swaps + Collars + Put options	Swaps + Put options	Swaps + Collars	Swaps + Collars + Put options	Swaps + Put options	Swaps + Collars	Swaps + Collars + Put options
INV_OPP	2.2211**	1.8193**	2.1679*	1.6198	1.9128	0.8811						
	(1.112)	(0.788)	(1.136)	(1.380)	(1.173)	(0.930)						
UND_GAS							-1.3290	0.0593	-0.1530	-1.2261	0.0909	0.1699
							(1.271)	(0.153)	(0.341)	(1.952)	(0.164)	(0.340)
CORR_1	0.1587	-0.4873	0.5000	0.4293	-0.2054	1.4151**	0.2622	-0.3965	0.6820	0.3626	-0.1519	1.3159**
	(0.798)	(0.353)	(0.659)	(0.846)	(0.353)	(0.665)	(0.807)	(0.346)	(0.636)	(0.872)	(0.350)	(0.657)
VOL_GAS	0.4982	0.2629*	0.3655				0.5271	0.3138**	0.3294			
	(0.387)	(0.157)	(0.298)				(0.395)	(0.159)	(0.300)			
FUTURE_GAS				0.0064	0.2581**	0.2822				-0.0390	0.2500**	0.2701
				(0.299)	(0.104)	(0.198)				(0.316)	(0.104)	(0.191)
SPOT_GAS				-0.0106	-0.1080	-0.1661				0.0384	-0.0983	-0.1576
				(0.244)	(0.088)	(0.183)				(0.256)	(0.088)	(0.175)
HERF_GAS	5.6000	0.6124	3.8470				6.6783	0.3125	3.7546			
	(5.830)	(1.491)	(3.026)				(5.612)	(1.498)	(3.056)			
GAS_REV	7.1128***	1.9334*	1.7740				9.0750***	1.5953	2.7445			
	(2.496)	(0.987)	(2.037)				(3.066)	(1.058)	(2.125)			
COST_CV				-3.9733*	-0.7083	0.8668	-2.2789	-0.1849	1.2712	-2.7916	-0.4681	1.2027
				(2.095)	(0.757)	(0.993)	(1.586)	(0.721)	(0.991)	(1.816)	(0.720)	(0.939)
UNCER_GAS	1.1570	1.8972***	5.5793***				0.8685	2.0719***	4.9724***			
	(1.776)	(0.682)	(1.406)				(1.911)	(0.756)	(1.648)			
OIL_HEDG	-0.1000	0.4263	1.2311**									
	(0.590)	(0.273)	(0.562)									
IR_HEDG				1.1310	0.3743	1.1073**						
				(0.915)	(0.247)	(0.478)						
FX_HEDG							0.3080	0.4211	1.0414			
							(2.064)	(0.498)	(0.863)			
BASIS_HEDG										-2.1393	0.0652	0.0929
										(1.422)	(0.295)	(0.586)

Continued

Table XI-*Continued*

Variable	Model 1 (1) Swaps + Put options	Model 1 (2) Swaps + Collars	Model 1 (3) Swaps + Collars + Put options	Model 2 (1) Swaps + Put options	Model 2 (2) Swaps + Collars	Model 2 (3) Swaps + Collars + Put options	Model 3 (1) Swaps + Put options	Model 3 (2) Swaps + Collars	Model 3 (3) Swaps + Collars + Put options	Model 4 (1) Swaps + Put options	Model 4 (2) Swaps + Collars	Model 4 (3) Swaps + Collars + Put options
PQ_COR_GAS				-0.2411	-0.6961*	-1.4700**				-0.2072	-0.7796**	-1.5082**
				(0.819)	(0.392)	(0.716)				(0.854)	(0.396)	(0.728)
OPT_CEO	-0.0117	0.0009	0.0065*	-0.0140	0.0028	0.0003	-0.0128	0.0004	0.0051	-0.0141	0.0031	0.0002
	(0.012)	(0.002)	(0.004)	(0.013)	(0.002)	(0.002)	(0.013)	(0.002)	(0.004)	(0.013)	(0.002)	(0.002)
MV_CS_CEO	-4.0146	1.0181	-0.0421	-7.2996	1.3072	1.5108	-5.2502	1.0619	0.2951	-9.9613	0.9361	0.7024
	(7.073)	(1.086)	(3.629)	(9.097)	(1.259)	(3.059)	(8.163)	(1.104)	(3.310)	(11.096)	(1.264)	(3.270)
%_CS_INST				0.5147	1.4699**	-0.1865				0.5325	1.3982**	-0.3489
				(1.583)	(0.591)	(1.018)				(1.630)	(0.600)	(1.013)
LEV				-0.7111	-3.2276**	-0.8418				-1.0500	-3.2655**	-1.5442
				(1.735)	(1.350)	(2.114)				(1.789)	(1.346)	(2.243)
CONSTRAINT				0.0067	0.6903***	-0.6279				0.0198	0.6756***	-0.5603
				(0.566)	(0.228)	(0.389)				(0.593)	(0.230)	(0.383)
DTD	-0.2966	0.0443	-0.1564				-0.3682	0.0544	-0.0632			
	(0.207)	(0.089)	(0.168)				(0.231)	(0.089)	(0.166)			
OVER_INV				-1.5085**	0.0040	0.6479				-1.6354**	-0.0560	0.4625
				(0.690)	(0.251)	(0.480)				(0.737)	(0.248)	(0.472)
TAX_SAVE				-11.3358	2.0227	-8.8088				-11.8664	2.0916	-7.6186
				(13.873)	(1.387)	(10.348)				(14.014)	(1.409)	(9.719)
TLCF	0.5614	0.3886	0.9566				1.0216	0.3481	1.6292			
	(1.739)	(0.954)	(1.851)				(1.919)	(0.971)	(1.739)			
IMR_GAS	0.8591	-0.8247	-0.6898	0.2746	-0.6466	-1.3389	0.4013	-1.1196**	-0.2771	0.1380	-0.6983	-1.6001
	(1.098)	(0.514)	(1.000)	(1.173)	(0.610)	(1.112)	(1.141)	(0.568)	(1.077)	(1.240)	(0.651)	(1.139)
LAG	4.8491***	3.8356***	3.1484***	4.2207***	3.8633***	3.2324***	4.6935***	3.8528***	3.0547***	4.1282***	3.8411***	3.2357***
	(0.525)	(0.180)	(0.388)	(0.557)	(0.189)	(0.387)	(0.650)	(0.183)	(0.371)	(0.682)	(0.189)	(0.373)
LAG_0	-0.1002	0.2200	2.3247**	2.9400*	-0.4745	3.1734***	0.0418	0.6110	2.2957**	3.2006	0.2136	2.8169***
	(1.005)	(0.765)	(0.926)	(1.669)	(1.143)	(0.980)	(1.275)	(1.018)	(0.929)	(2.300)	(1.031)	(0.889)
uj	-8.0634*	-8.1426***	-4.0618	-10.7790	-4.0450*	-6.1800	-5.1669	-4.7398***	-0.6227	-7.3354	-1.9742	-4.3276
	(4.719)	(2.061)	(4.035)	(6.655)	(2.333)	(4.841)	(4.489)	(1.801)	(3.562)	(7.457)	(2.346)	(3.998)
Sigma_uj	1.9645***	1.3458***	2.4797***	2.2569***	1.4661***	2.0832***	2.3419***	1.3438***	1.9622***	3.0565**	1.5299***	1.9774***
	(0.456)	(0.202)	(0.450)	(0.649)	(0.221)	(0.432)	(0.707)	(0.202)	(0.439)	(1.262)	(0.239)	(0.399)
Rho_1_2		0.935			0.154			0.735			0.410	
Rho_1_3		0.993			0.793			0.999			0.929	
Rho_2_3		0.897			0.705			0.734			0.715	
Observations		2,188			2,168			2,134			2,168	
Log Likelihood		-889.3674			-860.5163			-875.4408			-870.0853	
LL Constant only		-945.7635			-910.7239			-920.7931			-920.4412	
Wald Stat		112.7922			100.4151			90.7046			100.7117	
Significance		0.0000			0.0000			0.0000			0.0000	

Table XII: Hedging portfolio choice by oil hedgers

This table reports means of coefficient estimates of the Dynamic Random Effects Multinomial Mixed Logit to select one of these three hedging portfolios: (1) Swap and put options, (2) Swaps and Collars and (3) Swaps, Put options and Costless Collars for the subsample of oil hedgers. The base case is using swap contracts only. GAS_HEDG, IR_HEDG, FX_HEDG and BASIS_HEDG are dummy variables for oil, interest rate, foreign exchange and basis risk hedging. TLCF for tax loss carryforwards scaled by the book value of total assets, TAX_SAVE for the expected percentage of tax saving, LEV for the leverage ratio, DTD for distance to default, CONSTRAINT for financial constraints, INV_OPP for investment opportunities, CORR_1 for the correlation between free cash flows and investment opportunities, UND_OIL for the undeveloped proved oil reserves, OIL_REV for revenues from oil production, HERF_OIL measures the geographical dispersion of oil production, UNCER_OIL measures oil production uncertainty, PQ_COR_OIL measures the oil quantity-price correlation, MV_CS_CEO for the market value of common shares held by the CEO, OPT_CEO for the number of stock options held by the CEO, %_CS_INST for the percentage of common shares held by institutional investors, FUTURE_OIL, SPOT_OIL and VOL_OIL for oil future and spot prices and volatility. COST_CV for the coefficient of variation of the cash cost per barrel of oil equivalent, OVER_INV measures the overinvestment problem. IMR_OIL is the Inverse Mills Ratio from the first step Heckman regression (Appendix A). LAG is the lagged dependent variable. LAG_0 is the first observation. Coefficients of the exogenous variables' means are not reported for conciseness. Standard errors are in parentheses. ***Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level.

	Model 1			Model 2			Model 3			Model 4		
Variable	(1) Swaps + Put options	(2) Swaps + Collars	(3) Swaps + Collars + Put options	(1) Swaps + Put options	(2) Swaps + Collars	(3) Swaps + Collars + Put options	(1) Swaps + Put options	(2) Swaps + Collars	(3) Swaps + Collars + Put options	(1) Swaps + Put options	(2) Swaps + Collars	(3) Swaps + Collars + Put options
INV_OPP	1.2251	1.3159*	1.7185*	0.3801	0.8754	1.0355						
	(1.463)	(0.712)	(0.895)	(1.800)	(0.742)	(0.824)						
UND_OIL							11.4982	0.7859	2.0579	6.3964	1.7266	4.5504
							(23.887)	(3.407)	(5.484)	(15.515)	(3.483)	(5.058)
CORR_1	-2.7309	-0.0486	0.0425	-4.2599**	-0.1835	-0.4804	-2.7180	0.1298	0.2752	-2.8437*	0.0247	-0.3498
	(1.850)	(0.431)	(0.746)	(1.688)	(0.436)	(0.707)	(1.910)	(0.429)	(0.752)	(1.511)	(0.435)	(0.699)
VOL_OIL	0.1668	-0.0308	0.0071				0.2411	-0.0416	-0.0356			
	(0.135)	(0.042)	(0.083)				(0.167)	(0.045)	(0.082)			
FUTURE_OIL				0.3404*	-0.0169	0.0927				0.2288*	-0.0142	0.0749
				(0.177)	(0.038)	(0.074)				(0.127)	(0.038)	(0.071)
SPOT_OIL				-0.2962*	0.0299	-0.0789				-0.2091*	0.0297	-0.0630
				(0.162)	(0.038)	(0.073)				(0.122)	(0.038)	(0.070)
HERF_OIL	-0.9574	2.7762***	0.9429				-1.2176	3.0714***	1.5233			
	(3.814)	(1.045)	(1.827)				(3.727)	(1.063)	(1.807)			
OIL_REV	2.2294	0.7476	3.1159				0.7369	0.5417	1.1714			
	(4.157)	(1.303)	(2.416)				(4.063)	(1.284)	(1.993)			
COST_CV				-7.5344	0.0743	-0.7213	-4.3151	1.5133	1.3351			
				(5.694)	(0.337)	(1.109)	(4.412)	(0.996)	(1.027)			
UNCER_OIL	-0.8425	-1.3400	-0.4906				0.7025	-2.3167**	-0.3717			
	(2.567)	(0.819)	(1.399)				(2.413)	(0.922)	(1.408)			
GAS_HEDG	-0.3332	0.4399	2.9815**									
	(1.382)	(0.557)	(1.451)									
IR_HEDG				-0.4810	0.1372	0.7083						
				(1.132)	(0.304)	(0.517)						
FX_HEDG							-3.2237	1.3204**	0.5769			
							(4.656)	(0.672)	(1.107)			
BASIS_HEDG										-1.8850	-0.5905	-0.4051
										(1.690)	(0.363)	(0.710)

Continued

Table XII-*Continued*

Variable	Model 1 (1) Swaps + Put options	Model 1 (2) Swaps + Collars	Model 1 (3) Swaps + Collars + Put options	Model 2 (1) Swaps + Put options	Model 2 (2) Swaps + Collars	Model 2 (3) Swaps + Collars + Put options	Model 3 (1) Swaps + Put options	Model 3 (2) Swaps + Collars	Model 3 (3) Swaps + Collars + Put options	Model 4 (1) Swaps + Put options	Model 4 (2) Swaps + Collars	Model 4 (3) Swaps + Collars + Put options
PQ_COR_OIL				-1.8948	0.2817	0.2435				-1.8978	0.2664	-0.0109
				(1.661)	(0.328)	(0.700)				(1.485)	(0.328)	(0.661)
OPT_CEO	0.0501**	-0.0022	0.0043	0.0400*	0.0012	0.0015	0.0592***	-0.0040	0.0050			
	(0.020)	(0.005)	(0.014)	(0.021)	(0.003)	(0.003)	(0.021)	(0.005)	(0.013)			
MV_CS_CEO	-8.0300	2.2892*	0.2434	-7.7560	1.4191	0.0496	-8.0806	2.6113**	1.0862			
	(16.948)	(1.331)	(5.148)	(16.331)	(1.392)	(4.682)	(18.848)	(1.327)	(4.826)			
%_CS_INST				2.8521	0.0920	-0.2079						
				(2.903)	(0.712)	(1.330)						
LEV				-8.0969	0.0268	1.4242				-7.2524	-0.1088	0.7652
				(7.121)	(1.632)	(2.607)				(6.500)	(1.568)	(2.440)
CONSTRAINT				0.6528	-0.0117	0.8732*				0.3328	-0.0198	0.9003**
				(0.897)	(0.274)	(0.447)				(0.840)	(0.271)	(0.433)
DTD	-0.1652	-0.0162	0.1090				-0.0758	-0.0232	0.0347			
	(0.411)	(0.120)	(0.227)				(0.439)	(0.122)	(0.229)			
OVER_INV				2.3335*	0.2800	-0.6270				2.4165**	0.2073	-0.5909
				(1.192)	(0.299)	(0.545)				(1.149)	(0.293)	(0.542)
TAX_SAVE				17.8661**	1.9370	-4.4769				16.8294*	1.7214	-1.7231
				(8.191)	(2.306)	(12.410)				(9.588)	(2.381)	(11.280)
TLCF	-0.1810	1.3681	-0.5394				0.8270	1.5653	-0.3020			
	(4.333)	(1.346)	(2.631)				(5.048)	(1.305)	(2.595)			
IMR_OIL	0.2289	-1.1030*	-1.8762	1.6797	0.2603	0.4796	-0.2946	-0.7839	-1.8701	0.3296	0.3457	0.2947
	(1.817)	(0.659)	(1.238)	(2.578)	(0.772)	(1.110)	(1.939)	(0.705)	(1.208)	(2.019)	(0.730)	(1.082)
LAG	4.6163***	3.6750***	3.2885***	4.1698***	3.6499***	3.3325***	4.3804***	3.6805***	3.3783***	3.6572***	3.6687***	3.3198***
	(0.932)	(0.225)	(0.449)	(0.837)	(0.232)	(0.431)	(0.940)	(0.228)	(0.441)	(0.696)	(0.226)	(0.429)
LAG_0	(X)	(X)	-0.1268	(X)	(X)	1.6318	(X)	(X)	-0.0691	(X)	(X)	0.2900
			(1.513)			(1.380)			(1.372)			(1.632)
uj	-3.3900	-10.3039***	-8.4440**	-22.7548	0.6415	3.2016	2.9837	-5.2764**	-2.5449	1.0114	1.2818	2.2034
	(8.459)	(2.883)	(4.183)	(16.762)	(4.123)	(5.998)	(9.226)	(2.270)	(3.115)	(14.282)	(3.290)	(4.274)
Sigma_uj	3.2093**	2.0000***	2.3607***	6.2914**	2.3399***	2.9545***	3.8441**	1.9688***	2.1166***	7.1710**	2.4725***	3.0574***
	(1.634)	(0.322)	(0.559)	(2.586)	(0.381)	(0.578)	(1.933)	(0.327)	(0.487)	(3.266)	(0.393)	(0.614)
Rho_1_2		0.498			0.312			0.237			0.484	
Rho_1_3		0.862			0.786			0.652			0.855	
Rho_2_3		0.860			0.832			0.891			0.867	
Observations		1,632			1,650			1,605			1,678	
Log Likelihood		-619.8875			-628.8506			-615.5335			-653.7601	
LL Constant-only		-668.3723			-705.3281			-670.4718			-740.2093	
Wald Stat		96.9697			152.9549			109.8766			172.8985	
Significance		0.0000			0.0000			0.0000			0.0000	

(X) This variable was omitted by Stata software because of collinearity.

Table XIII: Hedging instrument choice by gas hedgers

This table reports the coefficient estimates of the Dynamic Generalized Random Effects Ordered Probit Model for the hedging instrument choice for the subsample of gas hedgers. The dependent variables are the hedging instruments classified in terms of the linearity of their final payoffs (1) Put options only, (2) Costless collars only, (3) Swap contracts only. LAG_LINEARTY is the lagged dependent variables, LINEARTY_0 is the initial condition. OIL_HEDG, IR_HEDG, FX_HEDG and BASIS_HEDG are dummy variables for oil, interest rate, foreign exchange and basis risk hedging. TLCF for tax loss carryforwards scaled by the book value of total assets, TAX_SAVE for the expected percentage of tax saving, LEV for the leverage ratio, DTD for distance to default, CONSTRAINT for financial constraints, INV_OPP for investment opportunities, CORR_1 for the correlation between free cash flows and investment opportunities, UND_GAS for undeveloped proved gas reserves, GAS_REV for revenues from gas production, HERF_GAS measures the geographical dispersion of gas production, UNCER_GAS measures gas production uncertainty, PQ_COR_GAS measures the gas quantity-price correlation, MV_CS_CEO for the market value of common shares held by the CEO, OPT_CEO for the number of stock options held by the CEO, %_CS_INST for the percentage of common shares held by institutional investors, FUTURE_GAS, SPOT_GAS and VOL_GAS for gas future and spot prices and volatility, COST_CV for the coefficient of variation of the cash cost per barrel of oil equivalent, OVER_INV measures overinvestment. IMR_GAS is the Inverse Mills Ratio from the first step Heckman regression (Appendix A). Coefficients of the exogenous variables' means are not reported for conciseness. Standard errors are in parentheses. ***Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. **EQ1** estimates Put options versus collars and swaps. **EQ2** estimates swaps versus put options and collars.

	Model 1		Model 2		Model 3		Model 4	
Variable	EQ1	EQ2	EQ1	EQ2	EQ1	EQ2	EQ1	EQ2
CONSTANT	-1.2893	-1.8507**	2.5375*	-3.4419***	1.7583*	-1.3599**	4.6938***	-0.9407
	(1.461)	(0.796)	(1.325)	(0.852)	(1.036)	(0.676)	(1.124)	(0.834)
LAG_LINEARTY	0.9050***	0.5171***	0.7999***	0.5536***	0.8237***	0.5241***	0.8176***	0.5656***
	(0.098)	(0.047)	(0.095)	(0.050)	(0.096)	(0.049)	(0.092)	(0.049)
LINEARTY_0	0.4744***	0.3447***	0.2875***	0.2460***	0.2316	0.1781*	0.3004***	0.2747***
	(0.132)	(0.070)	(0.104)	(0.061)	(0.168)	(0.105)	(0.105)	(0.067)
INV_OPP	0.1880	-1.7308***	-0.2869	-1.7637***				
	(0.642)	(0.528)	(0.708)	(0.618)				
UND_GAS					0.1043	-0.1332	1.2887**	-0.0904
					(0.254)	(0.115)	(0.518)	(0.111)
CORR_1	0.8547**	0.3906*	0.4023	0.5527***	0.9114***	0.2810	0.4913*	0.3787*
	(0.341)	(0.203)	(0.354)	(0.205)	(0.339)	(0.214)	(0.283)	(0.194)
VOL_GAS	-0.4262***	-0.2158**			-0.3275**	-0.2768***		
	(0.140)	(0.098)			(0.128)	(0.100)		
FUTURE_GAS			0.0257	-0.3946***			0.0513	-0.4428***
			(0.085)	(0.062)			(0.081)	(0.062)
SPOT_GAS			0.0003	0.1799***			-0.0116	0.1992***
			(0.065)	(0.052)			(0.064)	(0.051)
HERF_GAS	-1.5110*	-1.2259			-1.1656	-1.5755		
	(0.845)	(1.209)			(0.880)	(1.473)		
GAS_REV			-0.9040	-1.9288***			0.2793	-2.1248***
			(0.759)	(0.573)			(0.717)	(0.567)
COST_CV			1.5396*	1.1404**	1.3530*	1.3005***	1.4621*	1.0445**
			(0.786)	(0.462)	(0.766)	(0.488)	(0.760)	(0.478)
UNCER_GAS	-2.8398***	-0.9969**			-3.2470***	-1.7510***		
	(0.807)	(0.419)			(0.848)	(0.519)		
OIL_HEDG	0.8111***	0.0291						
	(0.208)	(0.139)						
IR_HEDG			-0.8117***	-0.0132				
			(0.252)	(0.167)				
FX_HEDG					-0.5379	0.2274		
					(0.792)	(0.565)		
BASIS_HEDG							-0.1312	0.2792
							(0.454)	(0.255)
PQ_COR_GAS			0.4927*	0.1033			0.3515	0.2871
			(0.298)	(0.213)			(0.284)	(0.211)
OPT_CEO	-0.0019	-0.0070***	-0.0078**	-0.0056***	-0.0046	-0.0053***	-0.0070**	-0.0051***
	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
MV_CS_CEO	7.6396*	0.0335	14.2617**	0.7586	15.7783**	0.2278	13.4854**	1.3690
	(4.556)	(0.816)	(7.154)	(0.907)	(7.945)	(0.890)	(6.313)	(0.958)
%_CS_INST	2.4206***	-0.2793			2.5528***	-0.1002		
	(0.578)	(0.336)			(0.629)	(0.360)		
LEV			0.6896	0.0879			1.5010	-0.1194
			(0.974)	(0.488)			(0.969)	(0.487)
CONSTRAINT			-0.2590	-0.1184			-0.3311*	-0.0560
			(0.207)	(0.132)			(0.190)	(0.125)
DTD	-0.1458	-0.1894***			-0.1075	-0.1983***		
	(0.104)	(0.059)			(0.105)	(0.062)		
OVER_INV	0.3928*	0.1315			0.1286	0.1932		
	(0.238)	(0.148)			(0.228)	(0.147)		
TAX_SAVE			2.7050	-3.9638**			4.4549	-3.9816***
			(4.009)	(2.002)			(3.688)	(1.480)
TLCF	-0.3503	-1.2245**			-0.0821	-1.1772**		
	(0.408)	(0.542)			(0.375)	(0.541)		
IMR_GAS	-0.3785	0.7645***	-0.2795	0.1406	-0.3495	0.7458**	0.0165	0.1285
	(0.450)	(0.276)	(0.411)	(0.271)	(0.410)	(0.296)	(0.384)	(0.203)
Rho	0.7364***		0.8564***		0.7452***		0.8092***	
	(0.028)		(0.017)		(0.027)		(0.019)	
Observations	1,630		1,601		1,597		1,615	
Log Likelihood	-691.9547		-642.5038		-673.5852		-663.3446	
LL constant-only	-938.0734		-948.0657		-897.5861		-963.1919	
Wald Stat	492.2374		611.1238		448.0017		599.6946	
Significance	0.0000		0.0000		0.0000		0.0000	

Table XIV: Hedging instrument choice by oil hedgers

This table reports the coefficient estimates of the Dynamic Generalized Random Effects Ordered Probit Model for the hedging instrument choice for the subsample of oil hedgers. The dependent variables are the hedging instruments classified in terms of the linearity of their final payoffs (1) Put options only, (2) Costless collars only, (3) Swap contracts only. LAG_LINEARTY is the lagged dependent variables, LINEARTY_0 is the initial condition. GAS_HEDG, IR_HEDG, FX_HEDG and BASIS_HEDG dummy variable for gas, oil, interest rate, foreign exchange and basis risk hedging. TLCF for tax loss carryforwards scaled by the book value of total assets, TAX_SAVE for the expected percentage of tax saving, LEV for the leverage ratio, DTD for distance to default, CONSTRAINT for financial constraints, INV_OPP for investment opportunities, CORR_1 for the correlation between free cash flows and investment opportunities, UND_OIL for undeveloped proved oil reserves, OIL_REV for revenues from oil production, HERF_OIL measures the geographical dispersion of oil production, UNCER_OIL measures oil production uncertainty, PQ_COR_OIL measures the oil quantity-price correlation, MV_CS_CEO for the market value of common shares held by the CEO, OPT_CEO for the number of stock options held by the CEO, %_CS_INST for the percentage of common shares held by institutional investors, FUTURE_OIL, SPOT_OIL and VOL_OIL for oil future and spot prices and volatility. COST_CV for the coefficient of variation of the cash cost per barrel of oil equivalent, OVER_INV measures the overinvestment problem. IMR_OIL is the Inverse Mills Ratio from the first step Heckman regression (Appendix A). Coefficients of the exogenous variables' means are not reported for conciseness. Standard errors are in parentheses. ***Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level**. EQ1** estimates put options versus collars and swaps**. EQ2** estimates swaps versus put options and collars.

	Model 1		Model 2		Model 3		Model 4	
Variable	**EQ1**	**EQ2**	**EQ1**	**EQ2**	**EQ1**	**EQ2**	**EQ1**	**EQ2**
CONSTANT	1.5749	1.6030*	-1.8533	-0.3196	0.2078	0.8690	-2.2690*	-0.7764
	(1.120)	(0.958)	(1.193)	(0.896)	(0.813)	(0.630)	(1.255)	(0.863)
LAG_LINEARTY	0.8105***	0.4950***	0.7590***	0.5549***	0.7930***	0.5448***	0.8104***	0.5218***
	(0.084)	(0.049)	(0.084)	(0.049)	(0.084)	(0.049)	(0.083)	(0.049)
LINEARTY_0	-0.0451	0.1490**	-0.0091	0.2210***	0.3347***	0.6320***	0.0037	0.1660**
	(0.087)	(0.067)	(0.100)	(0.077)	(0.090)	(0.080)	(0.097)	(0.070)
INV_OPP	0.1216	-1.2814***	0.1710	-1.3633***				
	(0.579)	(0.451)	(0.536)	(0.442)				
UND_OIL					1.0730	3.3914*	4.8559**	1.3811
					(2.690)	(1.925)	(2.373)	(1.858)
CORR_1	-0.4057	0.5639**	-0.3155	0.9665***	-0.2421	0.5257**	-0.3260	0.6227***
	(0.284)	(0.249)	(0.291)	(0.240)	(0.286)	(0.248)	(0.271)	(0.226)
VOL_OIL	-0.0250	-0.0522**			-0.0303	-0.0237		
	(0.031)	(0.022)			(0.032)	(0.024)		
FUTURE_OIL			-0.1159***	-0.0149			-0.1175***	-0.0571**
			(0.033)	(0.023)			(0.032)	(0.023)
SPOT_OIL			0.1097***	0.0148			0.1094***	0.0504**
			(0.033)	(0.022)			(0.031)	(0.022)
HERF_OIL	-1.9644**	-1.8431***			-1.5977	-2.0155***		
	(0.844)	(0.546)			(1.041)	(0.606)		
OIL_REV			-1.7321**	1.3136**			-2.0957**	0.6999
			(0.784)	(0.586)			(0.819)	(0.580)
COST_CV			3.1899***	-1.1992*	1.0124	-1.5153***	3.1940***	-0.2282
			(0.936)	(0.646)	(0.848)	(0.523)	(0.876)	(0.637)
UNCER_OIL	-1.5136**	0.6957*			-2.3282***	0.5672		
	(0.637)	(0.380)			(0.663)	(0.408)		
GAS_HEDG	0.8166***	0.1904						
	(0.252)	(0.190)						
IR_HEDG			0.8970***	0.3789**				
			(0.270)	(0.162)				
FX_HEDG					-1.1081***	0.5099		
					(0.413)	(0.371)		
BASIS_HEDG							0.0767	1.0981***
							(0.333)	(0.195)
PQ_COR_OIL			-0.2065	0.1530			-0.4315	0.0947
			(0.289)	(0.182)			(0.274)	(0.181)
OPT_CEO	0.0066	0.0027	0.0061	-0.0004	0.0099**	0.0006	0.0068	-0.0012
	(0.005)	(0.003)	(0.005)	(0.003)	(0.004)	(0.003)	(0.005)	(0.003)
MV_CS_CEO	-0.0796	-0.5522	4.0040*	0.0796	-0.2164	-0.6244	2.3725	-0.0503
	(1.784)	(0.802)	(2.312)	(0.846)	(2.010)	(0.853)	(1.960)	(0.832)
%_CS_INST	0.1454	-0.1763			0.2683	-0.1662		
	(0.522)	(0.366)			(0.541)	(0.396)		
LEV			0.3348	2.0412**			-0.4624	2.5572***
			(1.211)	(0.808)			(1.171)	(0.784)
CONSTRAINT			-0.2526	0.1381			-0.2456	0.0197
			(0.214)	(0.135)			(0.203)	(0.134)
DTD	0.2232**	-0.2352***			0.2040**	-0.2818***		
	(0.096)	(0.066)			(0.098)	(0.071)		
OVER_INV	0.4060**	0.0342			0.5614***	0.1129		
	(0.202)	(0.151)			(0.207)	(0.153)		
TAX_SAVE			16.3462***	-2.4470			14.6409***	-2.1517
			(4.821)	(1.505)			(4.681)	(1.618)
TLCF	-0.6855	-2.8766***			-0.8622	-2.2270***		
	(0.490)	(0.683)			(0.547)	(0.711)		
IMR_OIL	-1.1546**	0.2843	-0.5734	1.1021***	-0.8629	0.3470	-1.0220**	0.8544***
	(0.512)	(0.307)	(0.576)	(0.367)	(0.541)	(0.342)	(0.404)	(0.293)
Rho	0.7852***		0.7754***		0.7775***		0.7747***	
	(0.021)		(0.027)		(0.024)		(0.024)	
Observations	1,572		1,547		1,550		1,564	
Log Likelihood	-685.9948		-659.9249		-654.5332		-660.7962	
LL constant-only	-945.5503		-878.7359		-884.8251		-894.4599	
Wald Stat	519.1109		437.6220		460.5838		467.3274	
Significance	0.0000		0.0000		0.0000		0.0000	

Table XV: Summary of our predictions and findings

This table presents a summary of our predictions and findings pertaining to the hypotheses tested in our models. (***), (**) and (*) mean that the sign is significant at the 1% level, 5% level and 10% level respectively. (?) means that we are unable to make a prediction about the sign associated with the hedging strategy (in particular for costless collars only). (-/+) means that the given variable takes the sign (-) in some specifications and (+) in others but with no significant effects.

		Hedging strategies based on one instrument only						Hedging portfolios		
Dynamic Discrete Choice Models		**Dynamic RE Probit**			**Dynamic RE Generalized Ordered Probit**			**Dynamic RE Mixed Multinomial Logit**		
Hedging strategies		**Swap contracts only**	**Put options only**	**Costless Collars only**	**Swap contracts only**	**Put options only**	**Costless Collars only**	**Swaps and put options**	**Swaps and collars**	**Swaps, put options and collars**
Investment programs and real options										
Investment opportunities	Predicted	-	+	?	-	+	?	+	+	+
	Gas Hedgers	-***	+**	-/+	-***	-/+	+***	+**	+**	+*
	Oil Hedgers	-	+	-/+	-***	-	+***	+	+*	+*
Undeveloped reserves	Predicted	-	+	?	-	+	?	+	-/+	+
	Gas Hedgers	-	-/+	+	-	-**	+**	-	+	-/+
	Oil Hedgers	-	-*	-*	+*	-**	+**	+	+	+
Correlation between internal funds and Investment programs	Predicted	+	-	?	+	-	?	-	-	-
	Gas Hedgers	+***	-***	-	+***	-***	+***	+	-	+**
	Oil Hedgers	+*	+**	-*	+***	+	-***	-**	-/+	-/+
Oil and Gas market conditions										
Spot price	Predicted	+	-	-	+	-	-	-	-	-
	Gas Hedgers	+***	+**	-*	+***	-/+	-***	-/+	-	-
	Oil Hedgers	+***	-**	-***	+***	-***	+***	-*	+	-
Future price	Predicted	-	+	+	-	+	+	+	+	+
	Gas Hedgers	-***	-	+**	-***	-	+***	-/+	+**	+
	Oil Hedgers	-***	+**	+***	-**	+***	+**	+*	-	+
Price Volatility	Predicted	-	+	+	-	+	+	+	+	+
	Gas Hedgers	-***	+***	+*	-***	+***	+***	+	+**	+
	Oil Hedgers	-***	-	+*	-**	+	+**	+	-	-/+
Oil and Gas Production function characteristics										
Geographic diversification	Predicted	-	+	?	-	+	?	+	+	+
	Gas Hedgers	-/+	-	-	-*	+*	-	+	+	+
	Oil Hedgers	-***	-*	+*	-***	+**	+***	-	+***	+
Industrial diversification	Predicted	-	+	?	-	+	?	+	+	+
	Gas Hedgers	-***	+**	+***	-***	-/+	+***	+***	+*	+
	Oil Hedgers	-/+	+**	-	+**	+**	-**	+	+	+
Production uncertainty	Predicted	-	+	?	-	+	?	+	+	+
	Gas Hedgers	-***	+	-***	-***	+***	+***	+	+***	+***
	Oil Hedgers	+*	+	-***	+*	+***	-***	-/+	-**	-
Production cost variability	Predicted	-	+	?	-	+	?	+	+	+
	Gas Hedgers	-/+	-	-	+***	-*	-***	-*	-	+
	Oil Hedgers	-***	-**	+**	-***	-***	+***	-	+	-/+

Continued

Table XV-*Continued*

		Hedging strategies based on one instrument only						Hedging portfolios		
Dynamic Discrete Choice Models		**Dynamic RE Probit**			**Dynamic RE Generalized Ordered Probit**			**Dynamic RE Mixed Multinomial Logit**		
Hedging strategies		**Swap contracts only**	**Put options only**	**Costless Collars only**	**Swap contracts only**	**Put options only**	**Costless Collars only**	**Swaps and put options**	**Swaps and collars**	**Swaps, put options and collars**
Price-Quantity correlation	Predicted	+	-	?	+	-	?	-	-	-
	Gas Hedgers	+*	-	+***	+*	-	+*	-	-**	-**
	Oil Hedgers	-	+	-***	+	+	-	-	+	-/+
Financial distress										
Leverage	Predicted	+	-	?	+	-	?	-	-	-
	Gas Hedgers	+**	-	+*	-/+	-	+	-	-**	-
	Oil Hedgers	+***	-	-*	+***	-/+	-***	-	-/+	+
Distance to default	Predicted	-	+	?	-	+	?	+	+	+
	Gas Hedgers	-***	-	+	-***	+	+***	-	+	-
	Oil Hedgers	-**	-**	+***	-***	-**	+***	-	-	+
Financial constraint	Predicted	-	+	?	-	+	?	+	+	+
	Gas Hedgers	-**	-	-/+	-	+*	-*	+	+***	-
	Oil Hedgers	-	+	-***	+	+	-	+	-	+**
Overinvestment problem										
Overinvestment	Predicted	+	-	?	+	-	?	-	-	-
	Gas Hedgers	+*	-**	-*	+*	-*	+*	-**	-/+	+
	Oil Hedgers	-	-***	+	+***	-***	+***	+**	+	-
Tax incentives										
Tax loss carryforward	Predicted	+	-	?	+	-	?	-	-	-
	Gas Hedgers	-***	+	+	-**	+	+**	+	+	+
	Oil Hedgers	-***	-	+***	-***	+	+***	-/+	+	-
Tax save	Predicted	+	-	?	+	-	?	-	-	-
	Gas Hedgers	-	+	+	-***	-	+***	-	+	-
	Oil Hedgers	-	-**	+	-	-***	+***	+**	+	-
Compensation policy										
Managerial shareholding	Predicted	+	-	?	+	-	?	-	-	-
	Gas Hedgers	-/+	-**	+***	+	-**	+**	-	+	-/+
	Oil Hedgers	-/+	-*	-/+	-/+	-*	+*	-	+**	+
Managerial option holding	Predicted	-	+	?	-	+	?	+	+	+
	Gas Hedgers	-***	+	+***	-***	+**	+***	-	+	+*
	Oil Hedgers	-/+	-/+	-	-/+	-**	+**	+***	-/+	+

Table XVI: Effect of hedging strategy choice on stock return and volatility sensitivity

This table reports the coefficient estimates of the fixed effects regressions of the effect of hedging strategy choice on oil and gas Betas. The dependent variables are (i) the total stock rate of return for firm *i* in quarter *t* (Panel A), and (ii) the total stock risk measured by the annualized standard deviation of stock daily returns for firm *i* during quarter *t* (Panel B). R_MKT is the quarterly rate of change in the stock market index, taken here to be the S&P 500 index. R_OIL is the quarterly rate of change of the NYMEX three-month futures contract for oil. R_GAS is the quarterly rate of change of the NYMEX three-month futures contract for natural gas. SIG_MKT is the annualized standard deviation of the market index daily returns during the current quarter. SIG_OIL and SIG_GAS are the annualized standard deviations of the oil (gas) daily returns during the current quarter (these daily returns are calculated from the oil (gas) spot prices). SWAP, PUT, COLLAR, COLLAR_PUT, SWAP_PUT, SWAP_COLLAR and SWAP_COLLAR_PUT are the predicted values, coming from the dynamic random effects probit model, of the seven hedging strategies used by oil and gas producers. MKT_VALUE measured by the logarithm of the market value of common shares outstanding (i.e., closing price at the end of the quarter multiplied by the number of common shares outstanding). LEV for the leverage ratio measured by the book value of long-term debt in current liabilities plus one-half long-term debt scaled by the book value of total assets; Q_RATIO for the quick ratio measured by the book value of cash and equivalent of cash scaled by the book value of current liabilities; DTD for distance to default; DVD_YIELD for the dividend yield measured by the declared dividend (per share) scaled by the close price at the end of each quarter. Standard errors are in parentheses. ***Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level.

	Panel A Return sensitivity					Panel B Volatility sensitivity				
	Model without interactions			Model with interactions		Model without interactions			Model with interactions	
Variable	(1) All sample	(2) Gas hedgers	(3) Oil hedgers	(4) Gas hedgers	(5) Oil hedgers	(6) All sample	(7) Gas hedgers	(8) Oil hedgers	(9) Gas hedgers	(10) Oil hedgers
R_MKT	0.8228***	1.1082***	1.1359***	1.1090***	1.0739***					
	(0.222)	(0.175)	(0.210)	(0.175)	(0.217)					
R_OIL	0.7044***	0.4251***	0.5004***	0.4647***						
	(0.133)	(0.103)	(0.121)	(0.103)						
R_GAS	0.2750***	0.3450***	0.3291***		0.3376***					
	(0.083)	(0.065)	(0.075)		(0.077)					
SIG_MKT						0.4746***	0.6280***	0.6191***	0.6412***	0.6410***
						(0.043)	(0.053)	(0.056)	(0.053)	(0.053)
SIG_OIL						0.2756***	0.3342***	0.4196***	0.3169***	
						(0.030)	(0.037)	(0.040)	(0.037)	
SIG_GAS						-0.0047	-0.0046	-0.0104		-0.0063
						(0.006)	(0.008)	(0.008)		(0.008)
SWAP x				0.1536**	-0.0769				0.0088*	-0.0065
(R/SIG)_(OIL/GAS)				(0.060)	(0.061)				(0.005)	(0.009)
PUT x				-0.0273	-0.0986**				-0.0121***	-0.0690***
(R/SIG)_(OIL/GAS)				(0.048)	(0.050)				(0.004)	(0.007)
COLLAR x				0.1199*	-0.0363				0.0115**	0.0308***
(R/SIG)_(OIL/GAS)				(0.064)	(0.075)				(0.005)	(0.011)
COLLAR_PUT x				-0.0685	0.0152				0.0181***	-0.0275**
(R/SIG)_(OIL/GAS)				(0.073)	(0.099)				(0.005)	(0.013)
SWAP_PUT x				-0.0610*	0.0234				-0.0103***	0.0373***
(R/SIG)_(OIL/GAS)				(0.035)	(0.057)				(0.003)	(0.009)
SWAP_COLLAR_PUT x				-0.0293	-0.0054				0.0004	-0.0463***
(R/SIG)_(OIL/GAS)				(0.067)	(0.115)				(0.005)	(0.015)
SWAP_COLLAR x				-0.0841*	-0.0401				0.0022	-0.0322***
(R/SIG)_(OIL/GAS)				(0.051)	(0.093)				(0.004)	(0.010)
MKT_VALUE						-0.1017***	-0.0422***	-0.0555***	-0.0536***	-0.0742***
						(0.007)	(0.010)	(0.011)	(0.011)	(0.012)
LEV						0.2086***	0.4849***	0.3557***	0.4633***	0.3641***
						(0.031)	(0.041)	(0.050)	(0.041)	(0.055)
DTD						-0.1621***	-0.1472***	-0.1406***	-0.1486***	-0.1459***
						(0.003)	(0.005)	(0.005)	(0.005)	(0.005)
Q_RATIO						-0.0012*	0.0073	0.0019	0.0024	-0.0130**
						(0.001)	(0.005)	(0.004)	(0.006)	(0.006)
DVD_YIELD						0.1442	0.2983	0.0701	0.3268	-0.0152
						(0.242)	(0.246)	(0.244)	(0.245)	(0.261)
CONSTANT	0.0730***	0.0452***	0.0543***	0.0377**	0.0552***	1.0024***	0.6717***	0.7016***	0.7082***	0.8103***
	(0.021)	(0.016)	(0.019)	(0.016)	(0.020)	(0.025)	(0.037)	(0.042)	(0.041)	(0.050)
Observations	5,777	3,023	2,525	2,962	2,413	5,595	2,999	2,506	2,946	2,399
R-squared	0.0148	0.0442	0.0440	0.0480	0.0464	0.5084	0.6102	0.6464	0.6192	0.6610
Number of firms	150	108	102	108	99	149	108	102	108	99
F statistic	28.2195	44.8641	37.1270	15.9365	12.4612	702.8765	564.2264	547.5260	328.0454	318.4403
Rho	0.0585	0.2883	0.2282	0.2901	0.2360	0.3591	0.3736	0.6249	0.3982	0.6383
Sigma_U	0.3840	0.5510	0.5006	0.5467	0.5121	0.1650	0.1464	0.2275	0.1531	0.2303
Sigma_E	1.5410	0.8657	0.9207	0.8552	0.9215	0.2204	0.1895	0.1763	0.1883	0.1734

Table XVII: Economic implications of the hedging strategy choice

This table reports the coefficient estimates of the fixed effects regressions of the impact of hedging strategy choice on financial and operational performances of oil and gas producers. The dependent variables are: (1) oil and gas realized prices including the monetary effects of the hedging positions. Those realized prices are reported by oil and gas producers on an annual basis; (2) ROA is the Return On Assets; (3) ROE is the Return On Equity; (4) EPS_OP is the earnings per share from operations; (5) TOBIN Q is measured as the sum of market value of common shares plus book value of total liabilities plus book value of preferred shares scaled by book value of total assets. The independent variables SWAP, PUT, COLLAR, COLLAR_PUT, SWAP_PUT, SWAP_COLLAR and SWAP_COLLAR_PUT are the predicted values, coming from the dynamic random effects probit model, of the seven hedging strategies used by oil and gas producers; LEVERAGE is the leverage ratio measured by the book value of long-term debt scaled by the book value of total assets; CASH_COST is the production cost per Barrel of Oil Equivalent (BOE); Q_RATIO is the quick ratio measured by the book value of cash and equivalent of cash scaled by the book value of current liabilities; MKT_VALUE measured by the logarithm of the market value of common shares outstanding (i.e., closing price at the end of the quarter multiplied by the number of common shares outstanding); SALES measured by the logarithm of sales at the end of the quarter; SPOT (OIL/GAS) are oil (gas) spot prices at the end of each quarter; VOL (OIL/GAS) are oil (gas) prices volatilities measured as the standard deviations over the last 60 days; INV_OPP are investment opportunities; DAILY_PROD (OIL/GAS) are the daily oil (gas) production. Standard errors are in parentheses. ***Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level.

	Panel A Gas hedgers					**Panel B Oil hedgers**				
Variable	**(1) Realized prices**	**(2) ROA**	**(3) ROE**	**(4) EPS_OP**	**(5) TOBIN Q**	**(1) Realized prices**	**(2) ROA**	**(3) ROE**	**(4) EPS_OP**	**(5) TOBIN Q**
SWAP	-0.5573***	-0.0138***	0.0291	-0.2060**	0.0157	-1.7950***	-0.0158***	0.0513	-0.1723***	-0.0765***
	(0.037)	(0.003)	(0.062)	(0.090)	(0.018)	(0.269)	(0.002)	(0.038)	(0.050)	(0.013)
PUT	-0.0921***	0.0067***	-0.0125	0.0625	-0.0530***	-1.1229***	0.0098***	-0.0488*	0.1728***	0.0409***
	(0.031)	(0.002)	(0.040)	(0.062)	(0.014)	(0.233)	(0.002)	(0.030)	(0.040)	(0.011)
COLLAR	0.1790***	-0.0048	-0.0625	-0.1633*	0.0337*	-0.1553	-0.0156***	-0.0131	-0.1392**	0.0024
	(0.040)	(0.003)	(0.057)	(0.087)	(0.018)	(0.328)	(0.003)	(0.044)	(0.057)	(0.015)
COLLAR_PUT	0.0415	0.0084**	0.0503	0.2328**	0.0620***	0.2024	-0.0132***	0.0269	-0.1981***	0.0110
	(0.047)	(0.004)	(0.079)	(0.111)	(0.022)	(0.353)	(0.003)	(0.058)	(0.061)	(0.016)
SWAP_PUT	-0.4764***	0.0051	-0.0079	0.2104***	0.0320*	1.0189***	-0.0079***	-0.0259	-0.2477***	-0.0130
	(0.044)	(0.003)	(0.038)	(0.073)	(0.019)	(0.353)	(0.003)	(0.032)	(0.058)	(0.015)
SWAP_COLLAR_PUT	0.2994***	-0.0030	0.0259	-0.0568	-0.0279	1.1177***	0.0025	-0.0039	-0.0629	-0.0667***
	(0.039)	(0.003)	(0.064)	(0.087)	(0.018)	(0.416)	(0.003)	(0.067)	(0.072)	(0.019)
SWAP_COLLAR	0.1130***	0.0035*	-0.0560	0.0926	-0.0550***	-0.0194	0.0112***	-0.0332	0.1098**	0.0108
	(0.026)	(0.002)	(0.047)	(0.062)	(0.012)	(0.251)	(0.002)	(0.044)	(0.043)	(0.011)
SALES		-0.0007	0.1120*	0.0624	-0.2916***		0.0074**	0.0462	0.3857***	-0.2577***
		(0.003)	(0.063)	(0.090)	(0.019)		(0.003)	(0.063)	(0.066)	(0.017)
INV_OPP		0.0019	0.4813	0.0115	0.6050***		-0.0109	0.0823	0.0137	0.5035***
		(0.013)	(0.339)	(0.392)	(0.072)		(0.009)	(0.240)	(0.188)	(0.050)
MKT_VALUE		0.0119*	-0.2463*	0.0751	0.8493***		0.0021	-0.2129	-0.2401*	0.8697***
		(0.006)	(0.144)	(0.185)	(0.036)		(0.006)	(0.148)	(0.138)	(0.036)
SPOT (OIL/GAS)	0.2191***	0.0000	0.0463**	0.0139	0.0581***	0.3915***	0.0004***	0.0019	0.0082***	0.0011*
	(0.011)	(0.001)	(0.022)	(0.026)	(0.005)	(0.011)	(0.000)	(0.002)	(0.002)	(0.001)
VOL (OIL/GAS)	0.2381***	0.0051	-0.2396**	0.1708	-0.0032	1.7371***	-0.0062***	0.0087	-0.0622***	-0.0161***
	(0.045)	(0.003)	(0.094)	(0.107)	(0.020)	(0.078)	(0.001)	(0.017)	(0.013)	(0.004)
LEV		-0.1023***	-0.5794**	-3.6781***	0.0380		-0.0637***	-0.3214	-1.2047***	0.1466**
		(0.011)	(0.256)	(0.334)	(0.064)		(0.012)	(0.305)	(0.271)	(0.071)
CASH_COST	0.0986***	-0.0016***	0.0118	-0.0152	-0.0186***	0.9264***	-0.0013***	0.0062	-0.0193**	-0.0145***
	(0.006)	(0.000)	(0.009)	(0.014)	(0.003)	(0.057)	(0.000)	(0.010)	(0.009)	(0.002)
Q_RATIO		0.0033	-0.0598	-0.0189	0.0036		0.0008	-0.0336	0.0263	-0.0250*
		(0.003)	(0.063)	(0.081)	(0.015)		(0.002)	(0.062)	(0.052)	(0.014)
DAILY_PROD (OIL/GAS)	0.0005***					0.0844***				
	(0.000)					(0.012)				
CONSTANT	1.3237***	0.0573**	0.2295	1.9697***	0.2488*	8.9921***	-0.0576**	0.1168	-1.8917***	0.1262
	(0.240)	(0.025)	(0.474)	(0.693)	(0.142)	(2.717)	(0.029)	(0.465)	(0.623)	(0.164)
Observations	2,880	2,918	2,912	2,917	2,918	2,356	2,382	2,375	2,381	2,382
R-squared	0.6307	0.0748	0.0132	0.1821	0.3357	0.7881	0.1523	0.0515	0.0919	0.3852
Number of firms	108	108	108	108	108	99	99	99	99	99
Rho	0.6348	0.1482	0.0356	0.3177	0.5640	0.5567	0.3034	0.0236	0.2375	0.5829
Sigma_U	1.3472	0.0327	0.4301	1.6904	0.5141	9.9061	0.0447	0.3251	0.8239	0.4605
Sigma_E	1.0219	0.0785	2.2383	2.4772	0.4520	8.8393	0.0677	2.0929	1.4762	0.3895

APPENDIX A: First Step of the Two-Step Heckman regressions with sample selection: Determinants of the oil or gas hedging decision

This table reports the coefficients estimates of the Probit model. The dependent variable is the hedging decision dummy variable that takes the value of 1 if the oil and gas producer have any oil and gas hedging position for the quarter and 0 otherwise. The independent variables are: TAX_SAVE for the expected percentage of tax saving; LEVERAGE for the leverage ratio measured by the book value of long-term debt scaled by the book value of total assets; CASH_COST is the production cost per Barrel of Oil Equivalent (BOE); BVCD for the book value of convertible debts scaled by the book value of total assets. Q_RATIO for the quick ratio measured by the book value of cash and equivalent of cash scaled by the book value of current liabilities; RESERVE are the quantities of proved reserves for oil (for oil hedgers) and gas (for gas hedgers); MKT_VALUE measured by the logarithm of the market value of common shares outstanding (i.e., closing price at the end of the quarter multiplied by the number of common shares outstanding); SALES measured by the logarithm of sales at the end of the quarter. Standard errors are in parentheses. ***Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level.

Variable	(1) Oil hedge	(2) Gas hedge
TAX_SAVE	0.9005**	0.1232
	(0.366)	(0.428)
LEVERAGE	1.5843***	1.9170***
	(0.091)	(0.096)
CASH_COST	0.0398***	0.0605***
	(0.003)	(0.005)
BVCD	-1.2947***	-1.2417***
	(0.246)	(0.214)
Q_RATIO	-0.1056***	-0.1288***
	(0.014)	(0.014)
RESERVE	-0.0009***	-0.0001***
	(0.000)	(0.000)
MKT_VALUE	0.3924***	0.5700***
	(0.043)	(0.043)
SALES	0.1994***	0.0894***
	(0.019)	(0.017)
CONSTANT	-2.2678***	-2.1663***
	(0.088)	(0.089)
Observations	5,798	5,798
Pseudo-R squared	0.3025	0.3129
Chi-squared	2399.4838	2512.4946
Significance	0.0000	0.0000

APPENDIX B: Univariate analysis

Appendix C and D report descriptive statistics of the independent variables and tests of differences between means and medians of relevant variables by derivative instrument for gas and oil hedgers separately. Comparison of means is constructed using a t-test assuming unequal variances; comparison of medians is constructed using a non-parametric Wilcoxon rank-sum Z-test and two-sided p-values are used. As suggested above, we retain only the major three derivative instruments used: Put options, costless collars and swap contracts (the three instruments used more than 93% of the time for oil and gas hedging). These major instruments could be classified according to their payoffs' linearity. Put options are the most non-linear instruments, swap contracts are the most linear and costless collars fall in between. Overall, the univariate results support the premise that firms with greater investment opportunities tend to use more non-linear instruments (i.e., put options and costless collars) than linear instruments (i.e. swap contracts). Unexpectedly, higher undeveloped proved oil and gas reserves appear to be associated more with the use of swap contracts. On average, firms using more swap contracts and costless collars seem to have a higher correlation between internal cash flows and investment opportunities than those using put options as predicted. Interestingly, the univariate results support the prediction that large profitable oil and gas producers with fewer growth options tend to use more linear instruments to avoid the overinvestment problem, as suggested by Morellec and Smith (2007) and Bartram et al (2009). The results related to tax incentives are mixed. Although tax function convexity and tax preference items (i.e., tax loss carryforwards) tend to be more related to the use of swaps for the subsample of oil hedgers as predicted, they are unpredictably more associated with put options and costless collars for the subsample of gas hedgers. On average, users of put options have relatively lower Distance-to-Default and lower leverage ratios. Interestingly, these findings suggest that there is a non-monotonic relationship between the use of put options and firms' financial health. Hence, firms either close to or far from financial distress tend to use more non-linear hedging strategies. In contrast, swap contracts are associated more with relatively higher Distance-to-Default, and higher leverage ratios.

On average, swap contracts are associated with higher CEO's equity stake value in the firm, as predicted. Unexpectedly, put options are associated with less CEO's option holding, in particular for the subsample of oil hedgers. Results also show that a higher percentage of institutional shareholding is more related to the use of put options and costless collars. Results of the comparison of means concerning the impact of additional non-hedgeable risks (i.e., production uncertainty, cash cost risk) are mixed. Although higher cash cost risk is more related to the use of costless collars and put options as predicted, oil and gas production uncertainties seem to be more associated with the use of swaps. Results for the price-quantity correlation and the geographical and industrial diversification are mixed. However, the use of put options is more closely related to lower price-quantity correlation and higher geographical for the subsample of gas hedgers as predicted. The use of put options by oil hedgers is more strongly associated with a higher price-quantity correlation and lower geographical. Tests further show that firms operating primarily in gas production use more collars and those operating primarily in oil production use more put options. Surprisingly, results show no significant differences in the economic conditions of the oil and gas markets between swap contracts and put options. In fact, higher volatility, higher spot prices and higher future prices are largely associated with the use of costless collars.

We now analyze financial and operational characteristics by hedging portfolios when oil and gas hedgers use more than one instrument simultaneously. Appendix E and F report univariate results related to those portfolios. We retain comparisons involving the next two hedging portfolios: Swaps combined with put options versus swaps combined with costless collars. The first portfolio is supposed to have a more non-linear payoff. As predicted, results show that users of swap and collar portfolios have lower investment opportunities and larger undeveloped proved oil and gas reserves. Unexpectedly, swap and collar portfolios are associated with a lower correlation between internal cash flows and investment opportunities, lower expected tax saving and lower tax preference items (tax loss carryforwards). In addition, users of swap and collar portfolios have fewer financial constraints coupled with higher Distance-to-Default and lower leverage ratios. Consistent with the predictions, swap and collar portfolios are associated with higher CEO equity stake value in the firm. Counter to predictions, these portfolios seem to be associated with higher stock optionholding. As predicted, results indicate that swap and collar portfolios are related to lower production uncertainty and higher price-quantity correlation. Nonetheless, swaps and collars portfolios' users have higher cash cost variability and higher geographical diversification contradicting the conjecture. For the subsample of gas hedgers, the univariate results show, unexpectedly, that swaps and collars portfolios are associated with higher gas price volatility and with higher gas future prices. As predicted, they are related to higher gas spot prices.

APPENDIX C: Financial and operational characteristics of gas hedgers by hedging instrument

This table reports univariate analysis for the independent variables proposed to explain the use of the hedging instrument by gas hedgers. OIL_HEDG, IR_HEDG, FX_HEDG and BASIS_HEDG are dummy variable for gas, oil, interest rate, foreign exchange and basis risk hedging. TLCF for tax loss carryforwards scaled by the book value of total assets, TAX_SAVE for the expected percentage of tax saving, LEV for the leverage ratio, DTD for distance to default, CONSTRAINT for financial constraints, INV_OPP for investment opportunities, CORR_1 for the correlation between free cash flows and investment opportunities, UND_OIL and UND_GAS for the undeveloped proved reserves of oil and gas respectively, OVER_INV for overinvestment, OIL_REV and GAS_REV measure the fraction of revenues from oil (gas) production, HERF_OIL and HERF_GAS indices that measure the geographical dispersion of oil and gas production, UNCER_OIL and UNCER_GAS measure the production uncertainty for oil and gas respectively, COST_CV is the coefficient of variation of the cash cost per barrel of oil equivalent, PQ_COR_OIL and PQ_COR_GAS measure the quantity-price correlation for oil and gas respectively, MV_CS_CEO for the market value of common shares held by CEO, OPT_CEO for the number of stock options held by CEO, %_CS_INST for the percentage of common shares held by institutional investors, FUTURE_OIL, SPOT_OIL and VOL_OIL for oil future and spot prices and volatility, FUTURE_GAS, SPOT_GAS and VOL_GAS for gas future and spot prices and volatility. Comparison of means is constructed using a *t*-test assuming unequal variances; comparison of medians is constructed by using the non-parametric Wilcoxon rank sum Z-score. Two sided *p*-values are reported.

Gas hedging instruments firm-quarter																					
	Swap			Put			Collar			Swap vs put				Swap vs collar				Collar vs put			
Variable	Obs	Mean	Median	Obs	Mean	Median	Obs	Mean	Median	t-Stat	p-Value	Z-Score	p-Value	t-Stat	p-Value	Z-Score	p-Value	t-Stat	p-Value	Z-Score	p-Value
Variables that proxy for hedging activity																					
OIL_HEDG	932	0.630	1.000	126	0.540	1.000	582	0.741	1.000	1.906	0.059	-1.955	0.051	-4.593	0.000	4.464	0.000	-4.172	0.000	-4.479	0.000
BASIS_HEDG	932	0.152	0.000	126	0.063	0.000	582	0.060	0.000	3.585	0.000	-2.683	0.007	6.003	0.000	-5.431	0.000	0.140	0.889	0.143	0.886
IR_HEDG	932	0.276	0.000	126	0.159	0.000	582	0.196	0.000	3.267	0.001	-2.803	0.005	3.625	0.000	-3.514	0.000	-1.015	0.311	-0.964	0.335
FX_HEDG	932	0.065	0.000	126	0.040	0.000	582	0.003	0.000	1.339	0.182	-1.122	0.262	7.329	0.000	-5.876	0.000	2.056	0.042	3.726	0.000
Variables that proxy for underinvestment costs																					
INV_OPP	927	0.092	0.068	126	0.129	0.086	555	0.116	0.086	-2.101	0.038	3.401	0.001	-2.974	0.003	4.841	0.000	0.679	0.498	0.207	0.836
UND_OIL	932	40.745	4.170	126	26.793	17.597	582	19.549	4.569	2.648	0.009	2.394	0.017	5.535	0.000	0.522	0.602	1.494	0.137	3.042	0.002
UND_GAS	932	371.744	89.290	126	228.131	124.412	582	193.096	46.350	2.827	0.005	-1.433	0.152	5.204	0.000	-5.830	0.000	0.677	0.499	2.540	0.011
CORR_1	932	0.146	0.154	126	-0.026	0.018	582	0.087	0.086	5.188	0.000	4.860	0.000	3.114	0.001	3.063	0.002	-3.435	0.000	-3.743	0.000
Variables that proxy for overinvestment																					
OVER_INV	932	0.328	0.000	126	0.230	0.000	552	0.225	0.000	2.411	0.017	2.221	0.026	4.402	0.000	4.249	0.000	0.132	0.895	0.134	0.894
Variables that proxy for the tax advantage of hedging																					
TLCF	928	0.044	0.000	126	0.092	0.000	571	0.085	0.000	-3.087	0.002	3.737	0.000	-3.547	0.000	4.563	0.000	0.343	0.732	1.143	0.253
TAX_SAVE	928	0.047	0.044	126	0.052	0.052	573	0.054	0.050	-1.733	0.084	3.266	0.001	-2.790	0.005	5.011	0.000	-0.551	0.582	0.305	0.761

Continued

APPENDIX C-*Continued*

	Swap			Put			Collar			Swap vs put				Swap vs collar				Collar vs put			
Variable	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**
Variables that proxy for financial distress costs																					
DTD	915	2,338	2,206	126	2,148	2,105	564	2,150	2,123	2.1573	0.0321	0.929	0.353	2.930	0.003	1.910	0.056	-0.027	0.978	0.098	0.922
DISTRESS	928	0.471	0.000	126	0.405	0.000	571	0.375	0.000	1.411	0.160	1.397	0.162	3.686	0.000	3.645	0.000	0.620	0.536	0.627	0.531
LEV	928	0.207	0.185	126	0.163	0.180	571	0.209	0.170	4.491	0.000	2.514	0.012	-0.248	0.804	1.454	0.146	-4.155	0.000	-1.360	0.174
Variables that proxy for managerial risk aversion																					
MV_CS_CEO	932	42.241	4.151	126	6.578	4.007	582	44.470	3.394	5.800	0.000	1.635	0.102	-0.214	0.830	2.561	0.010	-4.469	0.000	-0.095	0.924
OPT_CEO	932	229952	5000	126	173357	22500	582	197251	0.000	1.406	0.161	0.026	0.979	0.805	0.420	2.209	0.027	-0.457	0.647	1.382	0.167
Variables that proxy for information asymmetry																					
%_CS_INST	932	0.451	0.475	126	0.557	0.663	582	0.493	0.543	-3.227	0.002	3.440	0.001	-2.294	0.022	2.228	0.026	1.868	0.063	2.003	0.045
Variables that proxy for production characteristics																					
UNCER_OIL	887	0.409	0.286	126	0.365	0.358	562	0.435	0.374	1.768	0.079	0.138	0.890	-1.558	0.120	3.620	0.000	-2.802	0.006	-2.327	0.020
PQ_COR_OIL	900	0.213	0.450	126	0.330	0.579	562	0.375	0.565	-2.172	0.031	2.516	0.012	-5.520	0.000	5.637	0.000	-0.815	0.417	-0.660	0.509
UNCER_GAS	932	0.409	0.308	126	0.335	0.224	582	0.379	0.294	2.493	0.014	-2.714	0.007	1.781	0.075	-0.767	0.443	-1.445	0.150	-2.470	0.014
PQ_COR_GAS	932	0.225	0.312	126	0.024	0.027	582	0.249	0.374	5.232	0.000	-5.039	0.000	-1.187	0.235	2.192	0.028	-5.651	0.000	-5.449	0.000
COST_CV	913	0.243	0.194	126	0.260	0.217	568	0.275	0.262	-0.955	0.341	0.737	0.461	-3.856	0.000	4.167	0.000	-0.865	0.388	-1.443	0.149
OIL_REV	926	0.254	0.204	126	0.391	0.416	582	0.324	0.299	-6.245	0.000	-6.180	0.000	-6.183	0.000	-6.776	0.000	2.995	0.003	3.137	0.001
GAS_REV	926	0.587	0.656	126	0.562	0.541	582	0.638	0.638	1.139	0.255	1.702	0.088	-3.852	0.000	-1.885	0.059	-3.535	0.000	-3.693	0.000
HERF_GAS	932	0.044	0.000	126	0.142	0.000	582	0.028	0.000	-4.598	0.000	-5.443	0.000	2.735	0.006	4.623	0.000	5.407	0.000	8.358	0.000
HERF_OIL	897	0.100	0.000	126	0.140	0.000	567	0.085	0.000	-1.707	0.089	-2.584	0.009	1.324	0.186	2.498	0.012	2.302	0.022	4.245	0.000
Variables that proxy for market conditions																					
VOL_OIL	929	3.200	2.371	126	3.123	2.233	581	3.520	2.674	0.306	0.760	-0.070	0.944	-2.117	0.035	3.147	0.002	-1.490	0.138	-1.896	0.058
SPOT_OIL	929	49.140	35.760	126	47.959	32.520	581	54.813	56.500	0.450	0.654	-0.428	0.669	-3.816	0.000	4.139	0.000	-2.531	0.012	-2.912	0.004
FUTURE_OIL	929	49.212	33.311	126	47.983	30.298	581	54.985	58.710	0.454	0.651	-0.227	0.821	-3.785	0.000	4.068	0.000	-2.512	0.013	-2.758	0.006
VOL_GAS	929	0.687	0.456	126	0.784	0.543	581	0.828	0.695	-1.840	0.068	2.277	0.023	-4.766	0.000	5.532	0.000	-0.796	0.427	-0.850	0.395
SPOT_GAS	929	4.833	4.602	126	5.139	4.830	581	5.674	5.700	-1.256	0.211	1.326	0.185	-6.302	0.000	7.163	0.000	-2.116	0.036	-2.555	0.011
FUTURE_GAS	929	5.340	5.070	126	5.677	5.149	581	6.467	6.213	-1.441	0.152	1.704	0.088	-8.443	0.000	8.888	0.000	-3.242	0.001	-3.259	0.001

APPENDIX D: Financial and operational characteristics of oil hedgers by hedging instrument

This table reports univariate analysis for the independent variables proposed to explain the use of the hedging instrument by oil hedgers. GAS_HEDG, IR_HEDG, FX_HEDG and BASIS_HEDG are dummy variables for gas, oil, interest rate, foreign exchange and basis risk hedging. TLCF for tax loss carryforwards scaled by the book value of total assets, TAX_SAVE for the expected percentage of tax saving, LEV for the leverage ratio, DTD for distance to default, CONSTRAINT for financial constraints, INV_OPP for investment opportunities, CORR_1 for the correlation between free cash flows and investment opportunities, UND_OIL and UND_GAS for the undeveloped proved reserves of oil and gas respectively, OVER_INV for overinvestment, COST_CV is the coefficient of variation of the cash cost per barrel of oil equivalent, OIL_REV and GAS_REV for the fraction of revenues from oil (gas) production, HERF_OIL and HERF_GAS the indices that measure the geographical dispersion of oil and gas production, UNCER_OIL and UNCER_GAS measure the production uncertainty for oil and gas respectively, PQ_COR_OIL and PQ_COR_GAS measure the quantity-price correlation for oil and gas respectively, MV_CS_CEO for the market value of common shares held by the CEO, OPT_CEO for the number of stock options held by the CEO, %_CS_INST for the percentage of common shares held by institutional investors, FUTURE_OIL, SPOT_OIL and VOL_OIL for oil future and spot prices and volatility, FUTURE_GAS, SPOT_GAS and VOL_GAS for gas future and spot prices and volatility. Comparison of means is constructed using a *t*-test assuming unequal variances; comparison of medians is constructed by using the non-parametric Wilcoxon rank sum Z-score. Two sided *p*-values are reported.

	Oil hedging instruments firm-quarter																				
	Swap			Put			Collars			Swap vs put				Swap vs collar				Collar vs put			
Variable	Obs	Mean	Median	Obs	Mean	Median	Obs	Mean	Median	t-Stat	p-Value	Z-Score	p-Value	t-Stat	p-Value	Z-Score	p-Value	t-Stat	p-Value	Z-Score	p-Value
Variables that proxy for hedging activity																					
GAS_HEDG	849	0.826	1.000	150	0.787	1.000	577	0.818	1.000	1.084	0.280	-1.145	0.252	0.370	0.712	-0.371	0.711	-0.843	0.400	-0.874	0.382
BASIS_HEDG	849	0.221	0.000	150	0.060	0.000	577	0.045	0.000	6.693	0.000	-4.579	0.000	10.578	0.000	-9.150	0.000	0.702	0.484	0.761	0.447
IR_HEDG	849	0.335	0.000	150	0.080	0.000	577	0.243	0.000	9.254	0.000	-6.290	0.000	3.810	0.000	-3.724	0.000	-5.704	0.000	-4.361	0.000
FX_HEDG	849	0.121	0.000	150	0.093	0.000	577	0.012	0.000	1.063	0.289	-0.982	0.326	9.021	0.000	-7.582	0.000	3.347	0.001	5.286	0.000
Variables that proxy for underinvestment costs																					
INV_OPP	842	0.105	0.073	146	0.118	0.070	560	0.130	0.080	-0.767	0.444	0.333	0.739	-1.979	0.048	1.724	0.085	-0.617	0.538	-0.868	0.385
UND_OIL	849	43.351	6.178	150	44.958	12.545	577	46.770	6.332	-0.250	0.803	1.161	0.246	-0.604	0.546	-2.189	0.029	-0.239	0.812	2.388	0.017
UND_GAS	849	441.004	112.765	150	344.652	57.215	577	362.649	56.098	1.503	0.134	-3.289	0.001	1.615	0.107	-5.990	0.000	-0.256	0.798	0.413	0.680
CORR_1	849	0.125	0.095	150	0.072	0.041	577	0.042	0.058	1.838	0.067	1.589	0.112	4.192	0.000	3.477	0.000	1.014	0.311	0.488	0.625
Variables that proxy for overinvestment																					
OVER_INV	838	0.285	0.000	146	0.226	0.000	558	0.339	0.000	1.554	0.122	1.475	0.140	-2.106	0.035	-2.123	0.034	-2.809	0.005	-2.607	0.009
Variables that proxy for the tax advantage of hedging																					
TLCF	844	0.077	0.000	146	0.045	0.000	577	0.101	0.000	2.762	0.006	-5.196	0.000	-1.794	0.073	0.119	0.905	-3.491	0.001	-5.390	0.000
TAX_SAVE	845	0.052	0.048	146	0.046	0.047	577	0.045	0.044	2.298	0.022	-1.871	0.061	3.689	0.000	-3.825	0.000	0.373	0.710	0.372	0.710

Continued

APPENDIX D-*Continued*

	Swap			Put			Collars			Swap vs put				Swap vs collar				Collar vs put			
Variable	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**
Variables that proxy for financial distress costs																					
DTD	819	2.390	2.530	146	2.127	2.048	576	2.276	2.214	2.893	0.004	2.159	0.031	1.748	0.080	1.250	0.211	-1.604	0.109	-1.393	0.164
DISTRESS	844	0.515	1.000	146	0.301	0.000	577	0.310	0.000	5.118	0.000	4.776	0.000	7.939	0.000	7.665	0.000	-0.207	0.836	-0.207	0.836
LEV	844	0.214	0.191	146	0.136	0.134	577	0.184	0.154	8.539	0.000	7.166	0.000	3.776	0.000	6.904	0.000	-4.699	0.000	-2.818	0.005
Variables that proxy for managerial risk aversion																					
MV_CS_CEO	849	68.804	4.661	150	11.598	3.572	577	53.203	3.731	5.402	0.000	2.819	0.005	1.163	0.245	2.773	0.005	-4.847	0.000	-0.996	0.319
OPT_CEO	849	230427	75000	150	98734	0.000	577	99958	0.000	5.855	0.000	4.976	0.000	8.080	0.000	7.221	0.000	-0.065	0.948	-0.533	0.594
Variables that proxy for information asymmetry																					
%_CS_INST	849	0.505	0.602	150	0.519	0.672	577	0.559	0.668	-0.452	0.652	1.016	0.310	-2.974	0.003	4.146	0.000	-1.220	0.224	-1.536	0.125
Variables that proxy for production characteristics																					
UNCER_OIL	846	0.408	0.288	150	0.332	0.259	577	0.460	0.448	2.821	0.005	-1.670	0.095	-2.972	0.003	5.176	0.000	-4.743	0.000	-5.824	0.000
PQ_COR_OIL	849	0.237	0.459	150	0.363	0.638	577	0.416	0.589	-2.461	0.015	3.912	0.000	-6.420	0.000	6.331	0.000	-1.039	0.300	0.419	0.675
UNCER_GAS	840	0.413	0.260	150	0.354	0.335	570	0.408	0.322	2.266	0.024	-0.618	0.537	0.282	0.778	2.552	0.011	-2.092	0.037	-1.836	0.066
PQ_COR_GAS	849	0.203	0.287	150	0.127	0.214	577	0.257	0.363	1.932	0.055	-1.531	0.126	-2.675	0.008	2.974	0.003	-3.252	0.001	-2.866	0.004
COST_CV	844	0.191	0.220	150	0.263	0.216	560	0.310	0.300	-1.629	0.104	0.791	0.429	-2.812	0.005	7.862	0.000	-2.790	0.006	-3.606	0.000
OIL_REV	842	0.311	0.250	145	0.459	0.519	577	0.387	0.320	-7.388	0.000	-7.340	0.000	-5.435	0.000	-5.751	0.000	3.389	0.008	4.215	0.000
GAS_REV	842	0.520	0.573	145	0.454	0.454	577	0.561	0.612	3.599	0.000	3.511	0.000	-2.715	0.006	-2.475	0.013	-5.554	0.000	-5.602	0.000
HERF_GAS	845	0.080	0.000	150	0.098	0.000	570	0.039	0.000	-1.013	0.312	-0.429	0.668	4.781	0.000	5.839	0.000	3.362	0.000	4.401	0.000
HERF_OIL	849	0.110	0.000	150	0.129	0.000	577	0.089	0.000	-0.822	0.412	-1.050	0.2936	1.785	0.074	2.253	0.024	1.745	0.082	2.547	0.011
Variables that proxy for Market conditions																					
VOL_OIL	849	3.272	2.371	150	3.469	2.445	576	3.864	3.271	-0.764	0.446	0.785	0.433	-3.741	0.000	6.566	0.000	-1.475	0.141	-2.804	0.005
SPOT_OIL	849	47.999	32.520	150	51.612	44.600	576	59.790	61.050	-1.366	0.174	0.527	0.598	-8.101	0.000	8.483	0.000	-3.022	0.003	-3.788	0.000
FUTURE_OIL	849	47.768	30.298	150	51.797	46.388	576	60.371	64.847	-1.496	0.136	0.763	0.445	-8.410	0.000	8.366	0.000	-3.115	0.002	-3.642	0.000
VOL_GAS	849	0.710	0.458	150	0.747	0.526	576	0.857	0.760	-0.795	0.428	1.181	0.238	-4.972	0.000	6.216	0.000	-2.257	0.025	-2.386	0.017
SPOT_GAS	849	4.945	4.740	150	5.194	5.050	576	5.852	5.771	-1.042	0.299	0.720	0.471	-6.735	0.000	7.199	0.000	-2.639	0.009	-3.189	0.001
FUTURE_GAS	849	5.443	5.106	150	5.804	5.388	576	6.654	6.280	-1.557	0.121	1.581	0.114	-9.217	0.000	9.483	0.000	-3.520	0.001	-3.621	0.000

APPENDIX E: Financial and operational characteristics of gas hedgers by hedging portfolio

This table reports univariate analysis for the independent variables proposed to explain the hedging portfolio choice by gas hedgers. OIL_HEDG, IR_HEDG, FX_HEDG and BASIS_HEDG are dummy variables for gas, oil, interest rate, foreign exchange and basis risk hedging. TLCF for tax loss carryforwards scaled by the book value of total assets, TAX_SAVE for the expected percentage of tax saving, LEV for the leverage ratio, DTD for the distance to default, CONSTRAINT for financial constraints, INV_OPP for the investment opportunities, CORR_1 for the correlation between free cash flows and investment opportunities, UND_OIL and UND_GAS for the undeveloped proved reserves of oil and gas respectively, OVER_INV for overinvestment, COST_CV is the coefficient of variation of the cash cost per barrel of oil equivalent, OIL_REV and GAS_REV for the fraction of revenues from oil (gas) production, HERF_OIL and HERF_GAS the indices that measure the geographical dispersion of oil and gas production, UNCER_OIL and UNCER_GAS measure the production uncertainty for oil and gas respectively, PQ_COR_OIL and PQ_COR_GAS measure the quantity-price correlation for oil and gas respectively, MV_CS_CEO for the market value of common shares held by the CEO, OPT_CEO for the number of stock options held by the CEO, %_CS_INST for the percentage of common shares held by institutional investors, FUTURE_OIL, SPOT_OIL and VOL_OIL for oil future and spot prices and volatility, FUTURE_GAS, SPOT_GAS and VOL_GAS for gas future and spot prices and volatility. Comparison of means is constructed using a *t*-test assuming unequal variances; comparison of medians is constructed by using the non-parametric Wilcoxon rank sum Z-score. Two sided *p*-values are reported.

Gas hedging strategies firm-quarter																								
	Swap+Put			Swap+Collar			Put+Collar			Swap+Put+Collar			Swap+Put vs Swap+Collar				Swap+Put vs Put+Collar				Swap+Collar vs Put+Collar			
Variable	Obs	Mean	Median	Obs	Mean	Median	Obs	Mean	Median	Obs	Mean	Median	t-Stat	p-Value	Z-Score	p-Value	t-Stat	p-Value	Z-Score	p-Value	t-Stat	p-Value	Z-Score	p-Value
Variables that proxy for hedging activity																								
OIL_HEDG	137	0.810	1.000	999	0.792	1.000	72	0.806	1.000	187	0.802	1.000	0.512	0.609	0.500	0.617	0.081	0.936	0.081	0.935	-0.283	0.778	0.278	0.781
BASIS_HEDG	137	0.153	0.000	999	0.284	0.000	72	0.069	0.000	187	0.299	0.000	-3.849	0.000	-3.243	0.001	1.942	0.054	1.741	0.082	6.437	0.000	-3.965	0.000
IR_HEDG	137	0.358	0.000	999	0.401	0.000	72	0.361	0.000	187	0.358	0.000	-0.996	0.321	-0.981	0.327	-0.049	0.961	-0.049	0.961	0.682	0.497	-0.674	0.500
FX_HEDG	137	0.007	0.000	999	0.063	0.000	72	0.000	0.000	187	0.107	0.000	-5.258	0.000	-2.653	0.008	1.000	0.319	0.725	0.469	8.196	0.000	-2.195	0.028
Variables that proxy for underinvestment costs																								
INV_OPP	137	0.141	0.077	982	0.109	0.077	72	0.106	0.077	184	0.132	0.091	1.841	0.068	0.547	0.585	1.642	0.102	0.537	0.592	0.202	0.841	-0.186	0.853
UND_OIL	137	21.872	11.089	999	54.792	6.983	72	10.047	6.748	187	28.092	6.711	-7.587	0.000	-0.852	0.395	3.950	0.000	1.256	0.209	12.537	0.000	-1.111	0.267
UND_GAS	137	180.869	71.715	999	593.408	209.100	72	80.778	45.638	187	474.645	124.706	-9.142	0.000	-6.339	0.000	2.985	0.003	2.275	0.023	15.422	0.000	-6.703	0.000
CORR_1	137	0.116	0.030	999	0.074	0.053	72	0.056	0.055	187	0.138	0.123	1.254	0.211	0.754	0.450	1.333	0.183	0.585	0.558	0.540	0.590	0.292	0.770
Variables that proxy for overinvestment																								
OVER_INV	137	0.212	0.000	973	0.319	0.000	72	0.222	0.000	183	0.197	0.000	2.807	0.005	-2.543	0.011	-0.174	0.862	-0.176	0.860	1.869	0.065	1.702	0.088
Variables that proxy for the tax advantage of hedging																								
TLCF	137	0.095	0.000	989	0.050	0.000	72	0.028	0.000	184	0.073	0.000	2.385	0.018	-3.009	0.003	3.357	0.001	0.361	0.718	2.677	0.009	-2.680	0.007
TAX_SAVE	137	0.044	0.041	994	0.049	0.046	72	0.054	0.052	187	0.055	0.049	-2.025	0.044	-1.429	0.153	-2.271	0.025	-2.953	0.003	-1.224	0.224	2.306	0.021

Continued

APPENDIX E-*Continued*

	Swap + Put			Swap + Collar			Put + Collar			Swap + Put + Collar			Swap + Put versus Swap + Collar				Swap + Put versus Put + Collar				Swap + Collar versus Put + Collar			
Variables	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**
Variables that proxy for financial distress costs																								
DTD	130	2,680	2,609	955	2,567	2,451	72	2,147	2,090	174	2,431	2,264	0.981	0.327	1.091	0.275	3.687	0.000	3.051	0.002	4.135	0.000	3.007	0.002
DISTRESS	137	0.577	1.000	988	0.424	0.000	72	0.500	0.500	184	0.554	1.000	3.375	0.000	3.367	0.000	1.051	0.295	1.056	0.291	-1.236	0.219	-1.256	0.209
LEV	137	0.210	0.190	989	0.173	0.158	72	0.216	0.195	184	0.211	0.179	4.603	0.000	5.395	0.000	-0.353	0.724	0.024	0.981	-2.762	0.007	-2.630	0.008
Variables that proxy for managerial risk aversion																								
MV_CS_CEO	137	23.560	8.370	999	50.261	6.496	72	49.032	13.645	187	40.922	8.725	-4.061	0.000	-1.381	0.167	-1.912	0.059	-2.478	0.013	0.086	0.930	-2.679	0.007
OPT_CEO	137	78611	42563	999	262719	40000	72	55811	0.000	187	224892	25050	-4.587	0.000	-1.050	0.294	1.227	0.221	2.618	0.008	4.963	0.000	3.214	0.001
Variables that proxy for information asymmetry																								
%_CS_INST	137	0.579	0.668	999	0.629	0.760	72	0.550	0.562	187	0.563	0.684	-1.889	0.060	-2.728	0.006	0.743	0.458	1.112	0.266	2.514	0.014	-3.114	0.002
Variables that proxy for production characteristics																								
UNCER_OIL	117	0.384	0.349	982	0.429	0.373	72	0.560	0.497	179	0.530	0.313	-1.862	0.064	-1.156	0.248	-4.256	0.000	-4.507	0.000	-3.628	0.001	3.617	0.000
PQ_COR_OIL	117	0.318	0.578	982	0.352	0.563	72	0.626	0.699	179	0.286	0.621	-0.618	0.538	-1.053	0.293	-4.935	0.000	-4.158	0.000	-7.206	0.000	4.310	0.000
UNCER_GAS	137	0.504	0.601	999	0.468	0.339	72	0.391	0.441	187	0.509	0.328	1.171	0.243	2.317	0.021	3.047	0.003	2.778	0.006	2.747	0.007	-0.055	0.956
PQ_COR_GAS	137	0.240	0.316	999	0.314	0.413	72	0.235	0.263	187	0.232	0.273	-2.072	0.040	-1.639	0.101	0.099	0.921	0.341	0.733	1.752	0.084	-1.600	0.110
COST_CV	137	0.179	0.174	988	0.285	0.254	72	0.309	0.245	159	0.255	0.267	-3.553	0.001	-6.368	0.000	-3.681	0.000	-5.237	0.000	-1.152	0.252	1.035	0.301
OIL_REV	129	0.355	0.326	993	0.246	0.245	72	0.410	0.480	184	0.246	0.232	4.983	0.000	4.557	0.000	-1.623	0.106	-1.505	0.132	-6.050	0.000	-6.177	0.000
GAS_REV	129	0.533	0.583	993	0.653	0.673	72	0.510	0.489	184	0.645	0.714	-5.188	0.000	-4.786	0.000	0.762	0.447	1.437	0.151	6.659	0.000	5.996	0.000
HERF_GAS	137	0.011	0.000	999	0.051	0.000	72	0.024	0.000	187	0.035	0.000	-5.889	0.000	-3.634	0.000	-1.029	0.305	-0.591	0.554	2.166	0.032	2.169	0.030
HERF_OIL	137	0.016	0.000	986	0.122	0.000	72	0.026	0.000	187	0.093	0.000	-9.625	0.000	-5.180	0.000	-0.685	0.494	-1.276	0.202	6.942	0.000	3.128	0.002
Variables that proxy for Market conditions																								
VOL_OIL	137	3.389	2.371	999	4.115	3.271	72	3.470	3.271	187	4.044	2.808	-2.630	0.009	-3.792	0.000	-0.217	0.829	-2.076	0.038	2.215	0.029	-0.668	0.504
SPOT_OIL	137	48.449	35.760	999	59.514	61.040	72	58.030	61.980	187	57.435	56.500	-4.249	0.000	-4.887	0.000	-2.896	0.004	-3.521	0.000	0.619	0.537	0.258	0.797
FUTURE_OIL	137	48.458	33.311	999	59.994	63.099	72	59.094	65.784	187	58.090	58.710	-4.331	0.000	-4.880	0.000	-3.061	0.003	-3.468	0.001	0.349	0.728	0.205	0.837
VOL_GAS	137	0.725	0.500	999	0.836	0.760	72	0.862	0.760	187	0.781	0.508	-2.276	0.024	-2.602	0.009	-1.706	0.090	-1.942	0.052	-0.379	0.706	0.415	0.678
SPOT_GAS	137	5.047	4.830	999	5.779	5.700	72	5.783	5.780	187	5.427	4.895	-3.097	0.002	-3.454	0.001	-2.060	0.041	-2.571	0.010	-0.011	0.991	0.396	0.692
FUTURE_GAS	137	5.617	5.264	999	6.507	6.072	72	6.709	6.304	187	6.170	5.872	-3.876	0.000	-3.927	0.000	-3.254	0.001	-3.331	0.001	-0.755	0.453	1.070	0.285

APPENDIX F: Financial and operational characteristics of oil hedgers by hedging portfolio

This table reports univariate analysis for the independent variables proposed to explain the hedging portfolio choice by oil hedgers. GAS_HEDG, IR_HEDG, FX_HEDG and BASIS_HEDG are dummy variables for gas, oil, interest rate, foreign exchange and basis risk hedging. TLCF for tax loss carryforwards scaled by the book value of total assets, TAX_SAVE for the expected percentage of tax saving, LEV for the leverage ratio, DTD for the distance to default, CONSTRAINT for financial constraints, INV_OPP for investment opportunities, CORR_1 for the correlation between free cash flows and investment opportunities, UND_OIL and UND_GAS for the undeveloped proved reserves for oil and gas respectively, OVER_INV for overinvestment, COST_CV is the coefficient of variation of the cash cost per barrel of oil equivalent, OIL_REV and GAS_REV for the fraction of revenues from oil (gas) production, HERF_OIL and HERF_GAS the indices that measure the geographical dispersion of oil and gas production, UNCER_OIL and UNCER_GAS measure the production uncertainty for oil and gas respectively, PQ_COR_OIL and PQ_COR_GAS measure the quantity-price correlation for oil and gas respectively, MV_CS_CEO for the market value of common shares held by the CEO, OPT_CEO for the number of stock options held by the CEO, %_CS_INST for the percentage of common shares held by institutional investors, FUTURE_OIL, SPOT_OIL and VOL_OIL for oil future and spot prices and volatility, FUTURE_GAS, SPOT_GAS and VOL_GAS for gas future and spot prices and volatility. Comparison of means is constructed using a *t*-test assuming unequal variances; comparison of medians is constructed by using the non-parametric Wilcoxon rank sum Z-score. Two sided *p*-values are reported.

Oil hedging strategies firm-quarter																								
	Swap+Put			Swap+Collar			Put+Collar			Swap+Put+Collar			Swap+Put vs Swap+Collar				Swap+Put vs Put+Collar				Swap+Collar vs Put+Collar			
Variable	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**
Variables that proxy for hedging activity																								
GAS_HEDG	99	0.879	1.000	627	0.955	1.000	63	0.968	1.000	136	0.949	1.000	-2.253	0.026	-3.100	0.002	-2.249	0.026	-1.970	0.049	-0.544	0.588	-0.479	0.632
BASIS_HEDG	99	0.020	0.000	627	0.290	0.000	63	0.063	0.000	136	0.324	0.000	-11.719	0.000	-5.737	0.000	-1.271	0.207	-1.418	0.156	6.319	0.000	3.864	0.000
IR_HEDG	99	0.374	0.000	627	0.442	0.000	63	0.175	0.000	136	0.456	0.000	-1.290	0.199	-1.269	0.204	2.901	0.004	2.698	0.007	5.125	0.000	4.097	0.000
FX_HEDG	99	0.000	0.000	627	0.056	0.000	63	0.000	0.000	136	0.037	0.000	-6.084	0.000	-2.408	0.016	NA	NA	NA	NA	6.084	0.000	1.923	0.054
Variables that proxy for underinvestment costs																								
INV_OPP	99	0.146	0.079	622	0.131	0.081	61	0.113	0.058	133	0.114	0.064	0.653	0.515	0.636	0.525	1.182	0.239	1.987	0.047	0.898	0.371	1.638	0.101
UND_OIL	99	27.384	25.029	627	64.751	12.526	63	48.239	8.048	136	48.647	12.061	-7.072	0.000	0.248	0.804	-1.748	0.085	0.644	0.520	1.311	0.194	0.161	0.872
UND_GAS	99	81.416	57.054	627	436.400	136.510	63	300.440	44.932	136	322.188	62.288	-13.250	0.000	-5.883	0.000	-2.421	0.018	-0.328	0.743	1.451	0.151	3.466	0.001
CORR_1	99	0.181	0.133	627	0.090	0.070	63	0.100	0.085	136	0.074	-0.004	2.814	0.005	2.400	0.016	1.961	0.051	1.445	0.148	-0.365	0.716	-0.481	0.630
Variables that proxy for overinvestment																								
OVER_INV	99	0.242	0.000	621	0.273	0.000	61	0.295	0.000	132	0.166	0.000	-0.668	0.505	-0.652	0.514	-0.720	0.472	-0.733	0.463	-0.346	0.729	-0.355	0.722
Variables that proxy for the tax advantage of hedging																								
TLCF	99	0.100	0.000	624	0.062	0.000	62	0.068	0.000	133	0.072	0.000	1.874	0.064	0.063	0.950	1.150	0.252	1.189	0.235	-0.347	0.730	1.304	0.192
TAX_SAVE	99	0.055	0.059	627	0.053	0.049	61	0.060	0.065	136	0.057	0.050	0.531	0.596	1.371	0.170	-1.167	0.245	-1.713	0.087	-2.095	0.038	-3.324	0.001

Continued

APPENDIX F-*Continued*

	Swap+Put			Swap+Collar			Put+Collar			Swap+Put+Collar			Swap+Put vs Swap+Collar				Swap+Put vs Put+Collar				Swap+ Collar vs Put+Collar			
Variable	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**Obs**	**Mean**	**Median**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**	**t-Stat**	**p-Value**	**Z-Score**	**p-Value**
Variables that proxy for financial distress costs																								
DTD	99	2.243	2.082	610	2.532	2.423	58	2.296	2.299	122	2.404	2.327	-2.483	0.014	-2.289	0.022	-0.276	0.782	-0.309	0.757	1.427	0.158	1.318	0.187
DISTRESS	99	0.545	1.000	624	0.463	0.000	62	0.452	0.000	133	0.639	1.000	1.520	0.131	1.523	0.128	1.156	0.249	1.155	0.248	0.172	0.863	0.174	0.862
LEV	99	0.215	0.197	624	0.181	0.166	62	0.233	0.194	133	0.220	0.196	3.988	0.000	4.140	0.000	-0.885	0.378	-0.212	0.832	-2.903	0.005	-2.671	0.007
Variables that proxy for managerial risk aversion																								
MV_CS_CEO	99	24.552	2.642	627	55.189	8.789	63	49.133	21.196	136	53.081	7.155	-3.265	0.001	-2.608	0.010	-1.963	0.053	-2.465	0.014	0.411	0.681	-1.289	0.197
OPT_CEO	99	53879	23333	627	228965	25000	63	610305	0.000	136	485481	0.000	-3.598	0.000	-2.261	0.024	-1.718	0.090	1.813	0.069	-1.165	0.248	3.301	0.001
Variables that proxy for information asymmetry																								
%_CS_INST	99	0.662	0.715	627	0.621	0.760	63	0.560	0.512	136	0.477	0.441	1.402	0.163	0.517	0.605	2.207	0.029	2.103	0.036	1.527	0.131	1.603	0.109
Variables that proxy for production characteristics																								
UNCER_OIL	92	0.502	0.376	627	0.455	0.375	63	0.446	0.447	124	0.367	0.202	1.311	0.192	1.747	0.081	1.331	0.185	0.193	0.847	0.292	0.771	-1.182	0.237
PQ_COR_OIL	93	0.415	0.651	627	0.448	0.670	63	0.553	0.748	124	0.399	0.650	-0.550	0.583	-1.493	0.135	-1.737	0.085	-2.552	0.011	-1.759	0.082	-1.760	0.078
UNCER_GAS	99	0.593	0.649	627	0.483	0.340	63	0.408	0.439	136	0.480	0.353	3.329	0.001	5.698	0.000	4.717	0.000	4.080	0.000	2.263	0.025	-0.625	0.532
PQ_COR_GAS	99	0.218	0.284	627	0.274	0.368	63	0.324	0.441	136	0.137	0.103	-1.431	0.155	-1.726	0.084	-2.109	0.037	-2.067	0.039	-1.327	0.188	-0.801	0.423
COST_CV	99	0.285	0.252	604	0.366	0.256	63	0.312	0.243	136	0.286	0.221	-2.155	0.032	-1.017	0.309	-1.104	0.272	-1.019	0.308	1.426	0.155	-1.011	0.312
OIL_REV	86	0.523	0.583	625	0.353	0.329	63	0.516	0.574	134	0.457	0.452	6.212	0.000	5.903	0.000	0.207	0.835	0.594	0.552	-6.900	0.000	-6.257	0.000
GAS_REV	86	0.430	0.396	625	0.564	0.609	63	0.446	0.397	134	0.517	0.548	-5.358	0.000	-4.841	0.000	-0.531	0.595	-0.832	0.405	5.750	0.000	4.827	0.000
HERF_GAS	99	0.096	0.000	627	0.062	0.000	63	0.072	0.000	136	0.063	0.000	1.568	0.119	0.160	0.873	0.773	0.440	0.543	0.587	-0.468	0.641	0.713	0.476
HERF_OIL	99	0.020	0.000	627	0.154	0.000	63	0.066	0.000	136	0.136	0.000	-9.116	0.000	-2.815	0.005	-1.845	0.068	0.415	0.678	3.452	0.000	2.435	0.015
Variables that proxy for Market conditions																								
VOL_OIL	99	4.343	3.271	627	4.180	3.307	63	4.487	3.471	136	4.233	3.307	0.420	0.675	-0.364	0.716	-0.264	0.792	-1.234	0.217	-0.714	0.477	-1.256	0.209
SPOT_OIL	99	60.126	62.910	627	62.934	65.870	63	67.144	69.890	136	59.592	61.045	-0.871	0.386	-1.052	0.293	-1.609	0.110	-1.832	0.067	-1.257	0.213	-1.372	0.170
FUTURE_OIL	99	60.689	66.721	627	63.458	66.815	63	68.344	71.653	136	60.521	63.973	-0.849	0.398	-1.041	0.298	-1.736	0.085	-1.973	0.049	-1.441	0.154	-1.494	0.135
VOL_GAS	99	0.794	0.543	627	0.853	0.760	63	0.868	0.760	136	0.778	0.543	-1.038	0.301	-1.043	0.297	-0.828	0.409	-0.736	0.462	-0.199	0.843	-0.036	0.971
SPOT_GAS	99	5.554	5.530	627	5.937	5.771	63	5.870	5.780	136	5.384	4.602	-1.379	0.170	-1.486	0.137	-0.804	0.423	-1.021	0.307	0.211	0.834	0.137	0.891
FUTURE_GAS	99	6.414	6.129	627	6.729	6.280	63	6.816	6.213	136	6.067	5.264	-1.159	0.249	-1.079	0.281	-1.042	0.299	-1.035	0.301	-0.281	0.779	-0.352	0.725