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The use of nonlinear hedging strategies by US oil producers: Motivations and implications

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ABSTRACT

This paper investigates the motivations and value effect of nonlinear hedges. Using a new dataset on the hedging activities of 150 U.S. oil producers, we present empirical evidence that nonlinear hedging strategies are motivated by sensitivities of firm's investment expenditures and revenues to oil price fluctuations, and quantity–price correlation. We also find a non–monotonic relationship between the use of nonlinear hedges and financial constraints. Investment opportunities, production uncertainty, and changes in oil prices and volatilities also play a significant role in hedging strategy choice. Controlling for bias related to omitted variables and self–selection in the estimation of marginal treatment effects of hedging strategy choice, we find that oil producers with a higher propensity to use pure nonlinear hedging strategies tend to have higher marginal firm value.

1. Introduction

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 new light on how oil producers hedge their oil price exposures by answering the two following questions: what are the motivations behind hedging strategy choice? And what are the real implications of hedging strategy choice on firm value? It is important to understand why firms within the same industry and with the same risk exposure differ considerably in terms of their hedging strategy. Disparate hedging practices seem to come from differences in firm–specific characteristics rather than differences in firms' underlying risk exposures. Therefore, explaining how firms structure their hedging programs and determining their related impacts on firm value provide better guidance on how to implement successful corporate risk management.

This study contributes to the literature on corporate hedging in several ways. We use an extensive and new hand–collected dataset on risk management activities of 150 US oil producers with quarterly observations covering a relatively long period from 1998 to 2010. Our data, hand–collected from publicly disclosed information, allow us to reliably test the empirical relevance of some theoretical arguments and predictions related to derivative choice that have not yet been explored. In particular, we test the implications of the prediction of Froot et al. (1993) related to the impact of the sensitivities of firm's investment costs and revenues to underlying risk factors. Further, our dataset allows us to verify the implications of production characteristics (i.e., production flexibility and price–quantity correlation) as suggested by Moschini and Lapan (1992), Brown and Toft (2002), Gay et al. (2003) and Dionne and Santugini (2015). We also revisit other predictions studied by Adam (2009) for a sample of gold-mining firms. In particular, we investigate the effects of investment expenditures, oil production uncertainty, financial constraints, and oil market conditions (i.e., oil spot price, volatility, and basis). Finally, we identify the effects of hedging strategy choice on firm value.

There are very few articles on hedging instruments in the empirical literature. Two of them are from Tufano (1996) and Adam (2009). Our research differs from these two contributions in three aspects. First, we analyze the oil industry instead of the gold mining industry. Second, we study the effect of derivatives choice on the firm value. Moreover, we have access to a much larger dataset. It is not clear that the results

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from the gold mining industry apply to the oil industry. In fact, the two markets differ significantly. In the oil industry, speculators play an important role in price determination and price volatility. Moreover, the supply of oil is dominated by a cartel, which is not the case in the gold mining industry. Finally, oil price variation is subject to political risk that often affects oil production. We did also study the gas industry and the results are similar to those presented in this paper. They are available from the authors.

We categorize hedging contracts into linear and nonlinear strategies. Linear contracts include swap, forward, and futures contracts. Nonlinear instruments comprise put options, costless collars, and three–way collars. We distinguish between firms using: (i) only linear contracts, (ii) a combination of linear and nonlinear contracts, and (iii) only nonlinear contracts. We run multivariate regressions based on discrete choice models and we perform Tobit regressions as robustness checks. Finally, we estimate marginal treatment effects related to hedging strategy choice on firm value using the novel econometric methodology developed by Heckman et al. (2006) based on instrumental variables applied to models with *essential heterogeneity*. This is to control for bias related to omitted variables (i.e., selection bias) and self–selection (i.e., selection on gains to treatment). This methodology allows much better control for the endogeneity concern than other approaches do. Endogeneity may have led to mixed results in previous empirical studies. To our knowledge, we are the first authors who apply this methodology in the corporate finance literature.

Our results give empirical evidence for some theoretical predictions not yet estimated in the literature. Consistent with the prediction of Froot et al. (1993), our results provide the first empirical evidence of the impact of the sensitivities of both firm's investment expenditures and generated cash flows to changes in oil prices. We find that dissimilar sensitivities motivate the use of nonlinear contracts, particularly put options, to achieve value–maximizing hedges. More importantly, we find empirical evidence of a non–monotonic relationship between the likelihood of financial constraints and the use of put options. Moreover, oil producers in a situation of a momentary default, that is, with low cash inflows net of production costs to cover debt requirements, tend to use put options in a higher extent. These findings mean that oil producers with either lower or higher financial constraints should use costly put options. These findings corroborate the predictions made by Adam (2002).

Our results do not show a significant impact of geographical diversification in oil producing activities on the use of nonlinear hedges. This finding does not give supportive empirical evidence of the production flexibility theory of Moschini and Lapan (1992). We further find that investment opportunities are positively related to the use of nonlinear contracts. This result confirms the argument of Froot et al. (1993) and the empirical finding of Adam (2009) that firms with larger investment programs tend to use nonlinear strategies to preserve upside potential and ensure sufficient internal financing of future investment expenditures. In addition, oil producers with higher investment expenditures hedge more quantities with costless collars. Regarding non–hedgeable risks, we find that oil production uncertainty is negatively related to nonlinear contracts. This finding contradicts the theoretical predictions of Moschini and Lapan (1995) and Brown and Toft (2002). Thus, it appears that oil producers do not consider oil production uncertainty as a source of additional convexity in their global exposure. Furthermore, production uncertainty has no material effects on the intensity of put options or collars.

Our results further emphasize the important role of oil market conditions in hedging strategy choice. In fact, when oil prices are increasing and oil price volatility is high, oil producers tend to rely more on nonlinear contracts to profit from upside potential. Results also show that when produced quantities and oil spot prices are highly correlated, oil producers tend to hedge more with put options. This empirical evidence contradicts the theoretical prediction by Brown and Toft (2002) and Gay et al. (2003). Our empirical results also underscore noticeable differences in the determinants of the use of put options or costless collars. These differences come notably from their payoff profiles and upfront payment needed.

To gain further insight on the causal effects of the hedging dynamics on firm value, we estimate the marginal treatment effects (MTEs) of using pure linear versus pure nonlinear hedging strategies. We use *essential heterogeneity* models of Heckman et al. (2006), which control for the individual-specific unobserved heterogeneity in the estimation of marginal treatment effects. We then identify a candidate instrumental variable obtained from Froot et al. (1993), namely, the differential in the sensitivities of a firm's investment costs and revenues to oil price fluctuations. The sensitivities to the exogenous oil price fluctuations are measured by correlation coefficients calculated by using rolling windows of twelve quarterly observations. A higher differential indicates dissimilar sensitivities of firm's investments costs and revenues to oil price fluctuations, and nonlinear hedging instruments should be used to achieve value-maximizing hedges.

This instrument should affect directly the hedging strategy choice and not been directly related to firm value. Estimated marginal treatment effects suggest that oil producers with higher probabilities to hedge with pure nonlinear strategies tend to have higher marginal firm value measured by the Tobin's *q*. Finally, results reveal substantial variations in marginal treatment effects over the support of predicted probabilities of using pure nonlinear strategies, reflecting a significant heterogeneity in responses to strategy choice induced by unobserved characteristics of oil producers. These new results are in line with those of Phan et al. (2014) who reported in their robustness checks section that options are more valuable than linear hedging contracts. However, we provide a more extensive analysis of nonlinear strategies and their effects on firm value.

The remainder of the paper is divided into six sections. Section 2 reviews the existing theoretical and empirical literature and develops testable hypotheses. Section 3 outlines the data and dependent variables. Section 4 reports summary statistics and univariate results. Section 5 presents multivariate results and robustness tests regarding our testable hypotheses. Section 6 examines the real implication of the hedging strategy choice. Section 7 concludes the paper.

2. Related literature and hypotheses

In this section, we review the related literature, develop new testable hypotheses, and discuss the construction of independent variables.

2.1. Sensitivity of firms' revenues and investment costs to the risk factor

Froot et al. (1993) explicitly discuss the choice of optimal hedging strategy and argue that the optimal hedge is linear if firms' cash inflows and investment expenditures have equal sensitivities to changes in the underlying risk exposure. In this case, firms benefit from natural diversification, and linear strategies alone can provide value–maximizing hedges. Otherwise, firms should use nonlinear strategies to achieve more optimal hedges. Hence, we posit the following hypothesis:

Hypothesis 1. The use of nonlinear contracts is positively related to the differentials in sensitivities of firms' revenues and investment costs to oil price fluctuations.

To test this hypothesis, we calculate the correlation between firms' free cash flows[1] and oil spot prices and the correlation between

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