Price Risk Management in Oil and Gas Development Projects

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Abstract

This paper empirically studies the effects of the volatility of oil and gas prices on the price risk management in oil and gas development projects. Oil and gas project companies can hedge the oil/gas price risk by adopting offtake contracts that fix the delivery price and volume of sales in the future. Such a hedging decision varies substantially across companies and over time. Our findings are twofold: First, an increase in the volatility of oil and gas prices is significantly associated with an increase in the likelihood of hedging, especially to the greater extent for a case in which the sponsor company's stock returns are less sensitive to changes in the oil and gas prices. These results suggest that energy development companies actively react to the market-oriented risks by using the market arrangements to hedge such risks, for which the main equity holder's risk tolerance matters substantially.

Keywords: Project finance, Oil price risk, Risk management, Sensitivity to oil price shocks

3. Introduction

Oil and gas are one of the most important energy sources. However, an oil and gas development project is financially challenging given the large amount of funding at stake and high risk. In particular, the high level of various risks involved in the project calls for an effective risk management; otherwise, the cost of funding would be too high for the project to be profitable. A textbook project finance theory suggests market arrangements as an effective risk management tool such that the project risk should be optimally allocated to both financial and non-financial stakeholders related to the project (Gatti, 2007).[1]

In practice, for oil and gas development projects, risk management behaviors vary substantially across companies and over time. Less is known about the causes of their differences across companies and changes over time.[2] Given the importance of oil and gas development, governments need to arrange policies effective in inducing companies to efficiently manage risks involved in oil and gas development projects, for which it is imperative to understand well the incentives and constraints faced by such companies; otherwise, these policies would be ineffective in achieving the desired goals. This paper aims to fill this gap by empirically studying the determinants of the price risk management in oil and gas development projects.

More specifically, we investigate the determinants of the decision for an oil and gas project company to hedge the price risk of oil and gas. Prices of oil and gas are, as is well known,

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[1] For instance, the sponsor company, which is the main equity holder and in charge of developing the project, carves out the project as an independent project company and lets the project company issue its own debt (i.e., non-recourse debt) so as to alleviate the sponsor's own risk. At the same time, the sponsor company reduces the debt holders' risk to a bearable level via arrangements such that non-financial stakeholders—e.g., suppliers of input materials, designers and developers of the production facility, and buyers of the finished goods—participate in taking over various aspects of the project risk via legally binding contracts.

[2] A project company refers to a special purpose vehicle (SPV), i.e., a company that is established solely for purpose of running one particular investment project rather than multiple different projects. By contrast, there are also oil and gas production companies that operate multiple lines of business: manage and develop many oil and gas projects. Throughout this paper, we focus on the case of SPV project companies.

highly volatile. Such a price risk is one of the main sources of risks faced by oil and gas project companies given the fact that these companies' cash flows are generated almost entirely from the sales of produced oil and gas. As such, the price risk management is one of the most important factors that determine a success in funding an oil and gas project.

The price risk is, by and large, oriented from the market and hence may be handled best by market arrangements.[3] For instance, an offtake contract is a legally binding agreement, voluntarily signed by the buyer and seller, such that the buyer will purchase in the future a certain amount of oil (or gas) at the agreed delivery price. Thus, both parties signing on the offtake contract can hedge almost perfectly the price risk of oil and gas. Arranging an offtake contract, however, involves costs, e.g., hiring specialists to run a risk management team to negotiate well the terms of contracts (e.g., delivery price, volume, and date). As such, the decision for a project company to use an offtake contract is likely to vary substantially across companies and over time.

We empirically investigate the determinants of the likelihood that offtake contracts are arranged in project finance deals for oil and gas development projects. An offtake contract is, as mentioned earlier, a bilateral agreement between buyer and seller, and hence the availability and merits of an offtake contract are determined by the market conditions, e.g., demand and supply in the current period as well as the expected changes in the future demand and supply. Thus, in our regression analysis of the hedging likelihood, we control for a number of independent variables: (i) time-varying global factors such as volatility of oil and gas prices and growth in the expected level of oil and gas prices[4]; (ii) macroeconomic factors

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[3] Oil and gas are standardized products and traded over the world rather than locally, and hence their prices are almost impossible to be directly controlled either by an individual project company or by even an individual country's government.

[4] We measure, as discussed in more detail later, the volatility of oil and gas prices as the six-month moving average volatility based on the daily price series of oil and gas, respectively, whereas we use the one-year maturity futures price as the expected level of the price of oil and gas, respectively.

specific to the host country where the project's production facility is located; (iii) microeconomic loan characteristics that are likely to affect the cost of funding and hence the profitability of the project. In particular, it is of our main interest to investigate how such global factors (e.g., price volatility) affect the likelihood of the oil and gas project company's hedging decision, especially which project company reacts more sensitively to the changes in these global factors.

More specifically, we run a logit regressions of the likelihood that offtake contracts are used in oil and gas project finance deals by controlling for a number of independent variables: loan/tranche-, project-, host country-, and global-level variables. First, the data on the loan/tranche-level microeconomic characteristics (e.g., loan size, refinancing, etc.) comes from the *ProjectWare* database that provides the detailed information in the level of individual loans/tranches. This database covers a total of 150 project finance deals and 328 loan tranches over 30 host countries, whereas the sample period is from January 1996 to May 2012. In the data, a project is often financed by multi-tranche loans. As such, we also control for the project-level variables (e.g., total size of loans for a given project). Second, we use *Thomson Reuters' DataStream* and the *ProjectWare* databases to measure the host country-level variables (e.g., credit rating and sovereign bond spread) in order to control for the geopolitical factors that affect the project risk. Third, global-level control variables are as follows: We measure the price volatility as the 6-month moving average, since six-months before and until the financial closure date, volatility of daily price series of oil and gas, respectively, where we use the crude oil (WTI) spot price series for the oil price, and the Henry Hub (HH) natural gas spot price for the gas price. We also control for growth in the one-year maturity futures prices of oil and gas, respectively, so that we can control for the changes in the levels of oil and gas prices that are expected to prevail in the future by the market participants.[5]

We find that the oil price risk is indeed significantly positively associated with the likelihood that a project company hedges the oil price risk by using an offtake contract. This indicates that project companies actively react to the changes in the market-oriented price risk by using the market arrangements such as offtake contracts to shift such a risk to others who are more suitable to take the risk.

Furthermore, we proceed to addressing a more detailed question of which project company reacts more sensitively to the changes in the oil price risk. In particular, we investigate whether or not the project company's *current* hedging sensitivity to the oil price risk varies systematically over the sponsor company's *past* stock-return sensitivity to the oil price risk. The reason is as follows: Consider the impact of an increase in the oil and gas price risk on the project company's cash-flow volatility. The offtake contract helps to stabilize the project company's cash flow and hence eventually contributes to stabilizing the sponsor company's cash flow given the fact that the project company's cash flow after the interest payment is paid as a dividend income to the sponsor company that is the project company's main equity holder. This indicates that the project company's current hedging decision affects the extent to which the sponsor company's stock-return is exposed to the oil price risk in the future. Note that the sponsor company is in charge of making the project company's hedging decision. Therefore, the project company's *current* hedging decision essentially depends on the sponsor company's willingness to insure its future stock returns against the oil price risk, which is in turn likely to be related with the sponsor company's *past* stock-return sensitivity

[5] The price volatility measures the second moment (i.e., riskiness) of the price, whereas the futures price measures the first moment (i.e., expected level) of the price. More specifically, a futures contract specifies the delivery date, price and volume of a product (e.g., oil and gas). Therefore, the delivery price of the futures contract is often used as a good measure of the expected level of the price after adjusting the required risk premium component, e.g., risk-neutral measure of the expected price. Thus, beyond the volatility, we also control for the annual growth rate of the futures price in the regression of the offtake likelihood.

to the oil price risk.

The key issue here is how the sponsor company's past stock-return sensitivity to the oil price risk is related with this company's current willingness to insure its future stock returns against the oil price risk: is such a relationship positive or negative? The reason is that there might be the tradeoff between two opposing forces that differently predict the sign of this relationship. On the one hand, the higher the sponsor's past stock-return sensitivity to the oil price risk, the greater the *magnitude* of the hedging effect on the sponsor's future cash-flow risk. That is, the greater the past stock-return sensitivity to the oil price risk, the greater the magnitude of the effect of one unit reduction in the cash-flow exposure to the oil price risk on the future stock-return volatility, and hence the higher the likelihood that the project company adopts an offtake contract, holding all else constant. This view is dubbed as the *magnitude channel* and implies a positive relationship between the sponsor company's past stock-return sensitivity to the oil price risk and the likelihood of the project company's current hedging. Note that the aforementioned magnitude channel assumes that the sponsor's risk tolerance (i.e., preferences to avoid the oil and gas price risk) is the same across different project companies. On the other hand, the smaller sensitivity of the sponsor's stock returns to the oil price risk may indicate the sponsor company's stronger *preferences* to avoid the oil price risk, i.e., the smaller sensitivity is the *outcome* of the sponsor's better risk management. In this case, the smaller the sponsor's past stock-return sensitivity to the oil price risk, the higher the likelihood that the subsidiary project company arranges an offtake contract, i.e., negative relationship between these two variables. This hypothesis is dubbed as the *preferences channel,* which focuses on the different levels of risk tolerance of sponsor companies given the same magnitude of the hedging effect. In reality, both of the two views are in play, and hence it is called for to investigate which one of these two opposite views (i.e., magnitude vs. preferences channels) is dominant in the data.

Thus, we proceed to estimating the relationship between the sponsor's past stock-return sensitivity to the oil price risk and the subsidiary project company's current offtake-adoption sensitivity to the oil price risk by using the two-stage regression method as follows: First, we measure the sponsor company's stock-return sensitivity to the oil price risk by running the two-factor regressions of the sponsor company's daily stock returns: the first factor is the return to the market portfolio, and the second factor is the return to the oil and gas price (i.e., change in the logged price), respectively; in this estimation stage, we use daily returns during the six-months period, from 547 days (i.e., about one and half years) to 365 days (i.e., about one year) *before* the financial closing date. The estimated sensitivity of the sponsor company's stock return to oil and gas price returns is labeled *sponsor's oil & gas beta*. Second, we run the main logit regression of the project company's offtake-adoption likelihood by now additionally controlling for the interaction term between the oil/gas price risk and the sponsor's oil/gas beta. This interaction term essentially measures how systematically the sponsor company's risk tolerance is associated with the sensitivity of the project company's offtake-adoption likelihood to the oil/gas price risk.

We find that the smaller the sponsor company's past stock-return sensitivity to the oil price risk, the greater the sensitivity of the subsidiary project company's offtake-adoption likelihood to the oil price risk. This indicates that the response of a project company's risk management practices to the changes in the market-oriented risk is substantially affected by the sponsor's risk tolerance, especially in the way that the preferences channel dominates the magnitude channel in the data. That is, the project company's hedging decision tends to make the sponsor's stock-return sensitivity to the oil price risk diverge further rather than converge. This implies that differences and changes in the risk tolerance are one of the key determinants of the project companies' risk management behaviors. Thus, in designing policies related to the risk management in oil and gas sector, governments need to take into consideration factors that are likely to affect the firm-level risk tolerance, e.g., investors' attitude toward bearing risks.

Interestingly, we also find that sponsor company's past stock-return sensitivity to the oil price risk is better in measuring the sponsor's tolerance of the oil price risk than two alternative measures are: (i) sponsor's stock-return volatility (i.e., total risk) and (ii) sponsor's stock-return sensitivity to returns to the market portfolio (i.e., market beta). More specifically, we find that the interaction term between the oil/gas price volatility and each of these two variables is not significant as determinants of the project company's offtake-hedging decision.

This paper contributes to the literature that studies the determinants of the risk management practices of energy companies (Berkeley et al., 1991; Zhi, 1995; Thuyet et al., 2007). Berkeley et al. (1991) and Zhi (1995) discuss the ex-ante risk management techniques which can assist clients and project managers to assess and pre-empt potential sources of risk, and how the technique can support project managers in the formulation of project strategies, planning and the achievement of project objectives. Thuyet et al. (2007) attempt to identify the major project risks based on a questionnaire survey in oil and gas industries in Vietnam. This paper finds a close link between the ex-ante risk management (i.e., a sponsor's previous oil and gas beta) and the likelihood of the hedging decisions (i.e., a subsidiary project company's decision to use an offtake contract) in oil and gas industries.

This paper also contributes to the literature on project finance deals. Many extant papers have studied how project companies optimally manage country-specific risks—e.g., political risk and legal risks—to deter strategic default (Esty and Megginson, 2003; Vaaler et al., 2008; Corieli et al., 2010; Haniz and Klemeier, 2012). In particular, Hainz and Kleimeier (2012) study the likelihood of the project vs. non-project financing across a number of loans. Corieli et al. (2010) study the relationships between the cost of capital and various non-financial contractual arrangements. We mainly improve the identification of estimating the determinants of the hedging decision (i.e., likelihood of adopting offtake contracts) by using the observed changes in the price volatility of oil and gas as exogenous shocks to the incentives to hedge the price risk. Regarding to oil and gas project studies, Dailami and Hausewald (2007) empirically study the determinants of the credit spread to mitigate the sales risk for a single case of gas projects in Qatar, which this paper complements by systematically analyzing a larger database. Pierru et al. (2013) study the capital structure of project financed LNG infrastructures and gas pipeline projects; this paper focuses on estimating the likelihood of the hedging decision, which might affect in turn the capital structure decision.

This paper proceeds as follows. Section 2 provides testable hypothesis, Section 3 describes data, descriptive statistics and the model. Section 4 gives the regression result. Section 5 summarizes the paper.

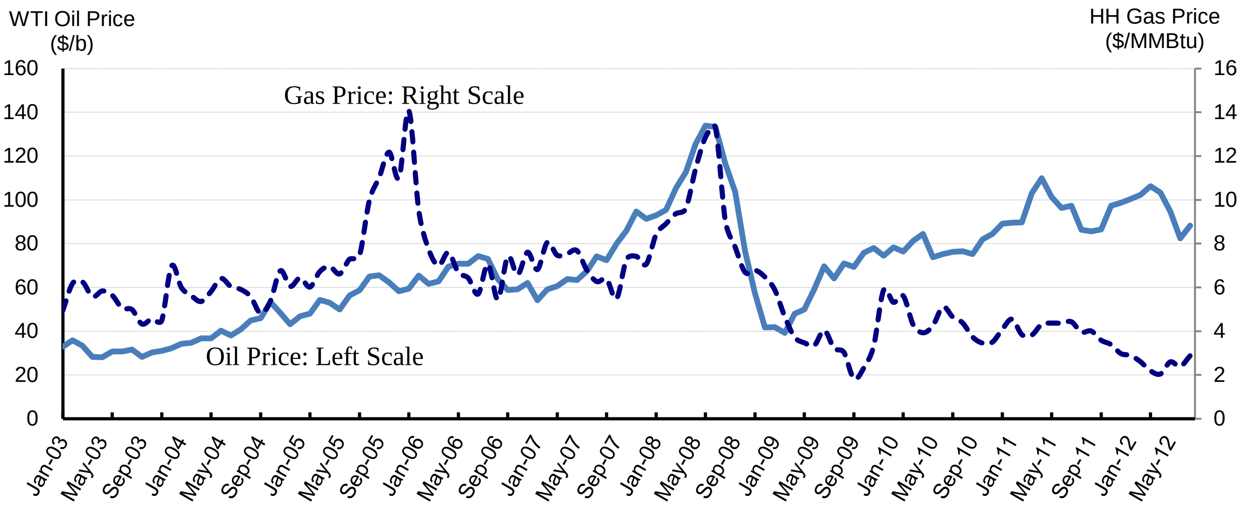
2. Overview: Price Risk and Project Finance in Oil and Gas Development Projects

2.1. Observation

The price uncertainty in the global oil and gas markets is highly likely to affect the systematic risks borne by investors in oil and gas markets. In turn, this may affect the cost of capital in oil and gas development projects. Facing the increased difficulty in raising capital, oil and gas project companies would more actively engage in mitigating its business risk by shifting it, if possible, to other stakeholders.

We examine the actual movements in the oil and gas prices and then discuss the observed changes in the risk management practices of oil and gas project companies. Oil and gas prices have exhibited a great deal of changes around the 2007-2008 financial crisis period.

Figure 1: Monthly Time Series of Oil and Gas Prices, 2003-2012



Note: this figure plots monthly time series of prices of oil (WTI, left scale) and gas (HH, right scale) traded in the U.S. (spot) markets.

Figure 1 plots the monthly time series of oil and gas prices during the period from 2003 to 2012. We can see that both oil and gas prices were quite volatile: Both the oil (WTI spot) and gas (Henry Hub spot) prices in the US increased almost threefold during the period from January 2003 to May 2008, and then plunged substantially until May 2009.

Table 1: Monthly Volatility of Oil and Gas Prices, 2003-2012

Year	Volatility of Gas Price (Henry Hub)	Volatility of Oil Price (WTI)
2003	0.046	0.138
2004	0.037	0.055
2005	0.036	0.027
2006	0.054	0.020
2007	0.032	0.017
2008	0.029	0.047
2009	0.129	0.045
2010	0.039	0.020
2011	0.035	0.015
2012	0.093	0.016

Note: The monthly volatility of oil and gas prices, respectively, is measured as the standard deviation of the logged prices of oil and gas for a given month, respectively. The crude oil (WTI) spot price series is used in measuring the oil price volatility, and the Henry Hub (HH) natural gas spot price series is used in measuring the gas price volatility.

Table 1 presents the monthly volatility of oil and gas prices (measured as the standard deviation of the log of the price, respectively) on average for a given year. We can see that for both oil and gas, the price volatility has substantially increased during the period from 2003 to 2009 and thereafter substantially decreased. Such an increase in the price volatility is likely to increase the cash-flow volatility of oil and gas development projects and hence to make funding these projects more difficult. This might have led to the more active risk management in oil and gas development projects in order to attenuate the difficulty of raising funds. For instance, the sponsor company, which is mainly in charge of the project development, would more frequently choose, as a way of funding, project finance rather than traditional corporate finance so as to alleviate the sponsor's own risk; and at the same time, it would also more actively search counterparties to arrange offtake contracts in order to alleviate further the project risk so that the lenders' concern about the project's credit risk is reduced.

We examine the overall trend in the risk management practices in oil and gas development projects. Note that a textbook project finance theory typically suggests that project risks should be allocated optimally between all parties involved in the transaction, with the objective of assigning risks to the contractual counterparties best able to control and manage them (Gatti, 2007). Therefore, the best way to mitigate the market-oriented price risk of oil and gas might be to use offtake contracts that fix the delivery price and volume of oil and gas in the future. The reason is that the reduced cash-flow volatility would, in turn, attenuate the difficulty of capital raising faced by the project company. Thus, it is of our interest to look at how risk management behaviors fluctuate over the sample period.

Table 2: Likelihood of Contractual Arrangements in Oil and Gas Projects, 2003-2012

Year	Number of Loan Tranches	Offtake Contract	EPC Contract	O&M Contract	Supply Contract	Construction Contract
2003	99	0.293	0.273	0.091	0.071	0.000
2004	159	0.201	0.516	0.119	0.038	0.189
2005	134	0.299	0.299	0.127	0.060	0.067
2006	125	0.096	0.184	0.000	0.000	0.000
2007	133	0.331	0.173	0.000	0.045	0.000
2008	167	0.539	0.575	0.096	0.108	0.000
2009	168	0.435	0.518	0.000	0.018	0.024
2010	147	0.170	0.401	0.061	0.061	0.027
2011	195	0.174	0.303	0.005	0.031	0.000
2012	49	0.061	0.184	0.000	0.000	0.061

Note: this table presents the annual likelihood of various contractual arrangements to manage risks in oil and gas project finance deals over the period 2003-2012. For a given risk management contract, its likelihood is measured as the ratio of the total number of contracts that are actually arranged to the total number of loan tranches that are made for a given year. The data source is the *ProjectWare* database provided by *Dealogic*.

Table 2 provides the annual empirical likelihood of each of various contractual arrangements in oil and gas project finance deals over the period 2003-2012, where the likelihood of a given risk management contract is measured as the ratio of the number of loan tranches for which the risk management contract is arranged to the total number of loan tranches that are made for a given year. In project finance deals, a number of different contracts are arranged to manage various risks: (i) either construction agreement or engineering, procurement and construction (EPC) agreement to hedge the construction risk, (ii) operation and management (O&M) agreement to hedge the operational risk after completion of the production facility, and (iii) offtake agreement to hedge the price risk of output, and supply agreement to hedge the price risk of inputs.

From Table 2, we can see that overall, the number of loan tranches has increased over this period and that for each of various contractual arrangement, the empirical likelihood fluctuate substantially during this period.[6] In particular, sponsors were the most likely to

[6] The ratio of project finance deals in oil and gas sectors to those in other sectors substantially increased over the period 2003-2012. For instance, the ratio of the project loan commitment in oil and gas sectors to that in

arrange the offtake contract to hedge the risk of oil and gas prices during the period 2008-2009 when the volatility of oil and gas prices were of the highest level. This suggests that oil and gas project companies may actively react to changes in the market-oriented risks by using various contractual arrangements.

2.2. Sponsor's Past Stock-Return Sensitivity to the Oil and Gas Price Risk

In this section, we discuss how the sponsor's past stock-return sensitivity to the oil and gas price risk can be related with the current sensitivity of the subsidiary project company's risk management to the price risk of oil and gas. Note that in response to an increase in the price risk of oil and gas, every project company is likely to increase the use of risk management tools to hedge the price risk, especially to the greater extent for the case in which the sponsor company has the stronger incentive to stabilize its cash flow. The reason is that the more effective risk management of the project company would make the project company's dividend payment to its sponsor company, which is the project company's main equity holder, more stabilized, implying that the sponsor company's cash flow is also more stabilized.

2.2.1. Two Views on the Relationship between Hedging and Stock-Return Sensitivity

The key issue is which sponsor company has the stronger incentive to stabilize its dividend income from its subsidiary project company. For instance, we can ask the question of whether the sponsor company's past stock-return sensitivity to the oil/gas price risk affects positively/negatively its current willingness to stabilize its dividend income from its subsidiary project company.[7] The sign of such a relationship could be, in theory, either

all sectors (based on authors' calculation) was less than 10 percent in 2003, substantially rose to about 12.9 percent in 2010, and slightly dropped to 31 percent in 2012. (Authors' calculation. The source of the data is Thomson Reuters Project Finance International.)

[7] Previous degree of exposure to risks can be a good predictor for a company's willingness to actively hedge risks. For instance, Perez-Gonzalez and Yun (2013) find that the extant exposure to weather is a strong

positive or negative essentially due to the tradeoff between the two opposing forces. More specifically, for a given sponsor company, the equity holder's marginal benefit of reduction in the company's cash flow volatility is determined by the two components: (i) effect on the stock return volatility and (ii) marginal utility of one unit reduction in the stock return volatility. The key point is that these two components could be related with the sponsor's past stock-return sensitivity in the opposite directions. Here we assume the plausible case in which equity holders, more generally investors, prefer to avoid risks.

The reason is as follows: On the one hand, the greater the sponsor's past stock-return sensitivity to the oil/gas price risk, the greater the magnitude of the effect of reduction in the cash flow volatility (caused by the price risk) on the stock returns in the future, and hence the higher the current willingness to hedge the oil/gas price risk under the condition that the sponsor's risk tolerance (i.e., preferences to avoid the oil and gas price risk) is held constant. This view is dubbed as the *magnitude channel*. On the other hand, the smaller sensitivity of the sponsor's stock returns to the oil price risk may indicate the sponsor company's stronger preferences to avoid the oil price risk, i.e., the smaller sensitivity is the outcome of the sponsor's better risk management (mainly driven by the equity holder's higher marginal utility of one unit reduction in the price risk). In this case, the smaller the sponsor's past stock-return sensitivity to the oil price risk, the higher the likelihood that the subsidiary project company arranges an offtake contract, i.e., negative relationship between these two variables. This hypothesis is dubbed as the *preferences channel*, which focuses on the different levels of risk tolerance of sponsor companies under the condition that the magnitude of the hedging effect is held constant. In reality, both of the two views are in play; we need to empirically test which one of the two views is dominant in the data.

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predictor of weather derivative use for the U.S. energy firms.

2.2.2. Estimation of the Sponsor's Sock-Return Sensitivity

More specifically, for a given project company, we estimate the sponsor company's stock-return sensitivity to the changes in logged prices of oil and gas, labeled *oil and gas beta*, as follows: The data source of sponsor companies is *Energy Intelligence*. The sample period for the sponsor company's oil and gas beta regression is daily and spans a six-month period from 548 days (i.e., about one and half year) before the financial closure date to 365 days (i.e., about one year) before the financial closure date.

Consider the oil and gas betas for a sponsor firm *I* of an oil/gas project *j* that is financed on the financial closure date *t*. For a given oil and gas project *I*, let $\mathrm{R}_{i,j,t}$ denote the sponsor company *j*'s stock return on a date *t*. Following Jin and Jorion (2006), we write the two-factor regression model of the sponsor company's stock returns, depending on whether the project belongs to oil vs. gas sector, as:

$$\mathrm{R}_{i,j,t} = \alpha + \beta_{m,t} R_{mkt,t} + \beta_{oil} R_{oil,t} + \varepsilon_{i,j,t} \quad , \qquad (1)$$

$$\mathrm{R}_{i,j,t} = \alpha + \beta_{m,t} R_{mkt,t} + \beta_{gas} R_{gas,t} + \varepsilon_{i,j,t} \qquad (2)$$

where $R_{mkt,t}$ is the daily return to the stock market index in the corresponding host country (where the project is developed), $R_{oil,t}$ the daily return to the futures price of oil (WTI), and $R_{gas,t}$ the daily return to the futures price of gas (HH); for both oil and gas, the 3-month maturity futures contract is used in measuring the futures price. (See, Jin and Jorion (2006), who use near-month futures price.) The equation (1) is used for an oil development project, and the equation (2) for a gas development project.

2.2.3. Data

The data on the stock returns of a sponsor company and market portfolio is provided by *Thomson Reuters' DataStream*. Table 3 provides, for the top-20 sponsor companies (ordered by total sizes of their project loans, reported by *Energy Intelligence*), summary statistics of the sponsor's stock returns and the two risk factors: returns to the market portfolio, and returns to the prices of oil and gas, where all these returns are at the daily frequency. In particular, returns to the market portfolio are conditional on the stock market where the given sponsor's stocks are traded: for instance, returns to the NYMEX (US) index are used as the market-portfolio returns for the case in which the given sponsor's stocks are mainly traded in NYMEX (US) market.[8]

Table 3: Statistics of the Sponsor's Stock Returns and Market and Oil & Gas Risks

Panel A: Summary Statistics

	Mean	Median	SD	Min	Max
Sponsor company's stock return	0.1%	0.0%	13.1%	-71.1%	7,482.1%
First risk factor: return to the market portfolio					
Return to the market portfolio: NYMEX (US)	0.3%	0.3%	1.1%	-9.0%	11.5%
Return to the market portfolio: FTSE100 (UK)	0.2%	0.4%	1.5%	-9.9%	12.7%
Return to the market portfolio: NIKKEI (Japan)	0.0%	0.0%	1.3%	-8.6%	12.1%
Return to the market portfolio: KOSPI (Korea)	0.0%	0.0%	2.2%	-19.2%	30.1%
Second risk factor					
Return to the futures price of oil (WTI)	0.0%	0.0%	2.2%	-15.2%	17.8%
Return to the futures price of gas (HH)	0.0%	0.0%	3.5%	-31.3%	18.1%

Panel B: Correlation Coefficients

	NYMEX (US)	FTSE100 (UK)	NIKKEI (Japan)	KOSPI (Korea)	Oil Futures Price	Gas Futures Price
NYMEX (US)	1					
FTSE100 (UK)	0.512*	1				
NIKKEI (Japan)	0.026*	0.183*	1			
KOSPI (Korea)	0.133*	0.247*	0.360*	1		
Oil Futures Price	0.142*	0.197*	0.051*	0.073*	1	
Gas Futures Price	0.027*	0.039*	0.038*	0.022	0.221*	1

Note: returns are measured as the daily changes in the log of prices, whereas stock returns take dividend payment, if any, into consideration. * indicates significance at the 5% level.

[8] For the same reason, returns to the FTSE100 (UK) index are used for the two sponsor companies, ROYAL DUTCH SHELL and Shell; returns to NIKKEI (Japan) index are used for four sponsor companies, ITOCHU, MARUBENI, MITSUI, and MITSUI OSK LINES; returns to KOSPI (Korea) index are used for three sponsor companies, SAMSUNG ENGINEERING, SK HOLDINGS, and SK INNOVATION.

From Table 3, we can see that sponsor's stock returns are quite volatile: its standard deviation is about 13 percent, whereas the standard deviation of returns to the market portfolio is about 1.1 percent. Moreover, we can see that oil and gas prices are more volatile than the market portfolios and that they are weakly correlated with returns to the market portfolio, indicating that changes in the oil and gas prices might be an important risk factor to the sponsor company's investors.

2.2.4. Results: Sponsor's Sock-Return Sensitivity to the Oil and Gas Price Risk

Table 4 presents the results for the OLS estimation of the oil and gas beta for top 20 sponsors (based on total loan sizes of projects) in our sample of project finance deals; this table also provides information on the sponsor-level likelihood of each of various risk-management contractual arrangements. Note that oil and gas beta represents the sensitivity of the sponsor company's stock returns to the (percentage) changes in the oil and gas prices and that oil and gas price shocks are global-level non-diversifiable systematic risks. Thus, the higher oil and gas beta means that the sponsor company's equity holder is exposed to such a systematic risk to the greater extent. Note that in the financial market, the higher exposure to the systematic risk requires the higher (expected) return to compensate for the additional risk borne by the investor. Thus, it follows that the higher the sponsor company's oil and gas beta, the higher the cost of capital for the sponsor company, i.e., the greater the level of the sponsor company's difficulty in raising funds for running its business. That is, sponsor companies would try to reduce their exposure to the oil and gas price risk, if they can, to lower the cost of capital in running their business, especially to the greater extent as their preference to avoid oil and gas price risk is stronger.

Table 4: Oil/Gas Beta and Likelihood of Risk Management Contracts, Top 20 Sponsors

Rank	Name of Sponsor Company	Project Size	Oil & Gas Beta	Stock Return Volatility	Market Beta	Offtake Likelihood
1	GAZPROM	60,861	0.100	3.302	0.566	31%
2	TOTAL	52,173	0.090	1.417	0.678	47%
3	EXXON MOBIL	25,619	0.053	0.857	1.088	40%
4	MOBIL	11,522	0.095	1.345	0.786	10%
5	MARUBENI	11,004	-0.020	0.214	0.772	33%
6	ROYAL DUTCH SHELL	8,733	0.039	0.832	0.490	82%
7	CHEVRON	6,988	0.106	0.908	0.389	0%
8	PETROBRAS	5,960	0.094	0.624	0.665	11%
9	PETRONAS GAS	5,896	0.047	0.197	0.559	24%
10	COASTAL CRBN.OILS&MRLS.	5,836	-0.039	0.314	0.179	60%
11	AMER. ELEC. PWR.	5,655	0.021	1.418	0.717	10%
12	PHILLIPS	5,424	-0.006	1.075	0.545	38%
13	SK	5,134	0.191	12.291	0.605	25%
14	E ON	5,033	-0.022	1.929	0.593	45%
15	REPSOL YPF	4,853	0.021	0.693	0.584	71%
16	GOLDMAN SACHS	4,769	0.055	8.828	0.402	17%
17	ENBRIDGE	4,607	0.025	0.451	0.734	30%
18	EL PASO ELEC.	4,380	-0.025	0.987	0.346	33%
19	CHENIERE EN.	3,540	0.149	1.101	0.799	40%
20	MITSUI	3,334	0.052	0.910	0.691	18%
	Mean	12,066	0.051	1.985	0.609	33%
	Standard Deviation	16,022	0.061	3.064	0.197	21%
	Corr. w/ Oil & Gas Beta	0.235	1.000	0.510	0.288	-0.349
	Corr. w/ Stock-Return Volatility	0.002	0.510	1.000	-0.135	-0.201
	Corr. w/ Market Beta	0.190	0.288	-0.135	1.000	-0.146

Note: this table provides the estimated oil and gas beta of a sponsor company, depending on whether the project is in oil and gas industry, where oil and gas beta refers to the coefficient of the changes in the logged price of oil and gas, respectively, in the two-factor regression model of the sponsor company's stock returns. This model regress stock returns on changes in the logged oil/gas price and returns to the host country's market portfolio. Oil and gas betas are reported for the top 20 sponsor companies (sorted by the total project loan sizes).

Table 4 shows that top sponsors, which are of relatively large sizes and hence presumably comparable, exhibit substantial variations in (i) their levels of estimated oil and gas beta (it has sample mean of 5.1 percent and standard deviation of 6.1 percent) and (ii) levels of the likelihood of the use of offtake contracts (it has sample mean of 33 percent and standard deviation of 21 percent). It is interesting to see that for sponsor companies, the stock-return volatility is highly positively correlated with the oil & gas beta (i.e., the correlation coefficient between the two is 0.510), while it is weakly and negatively correlated with the market beta (i.e., the correlation coefficient between the two is -0.135), suggesting that oil & gas price risk might be an important source of risks, beyond the risk commonly faced by firms in all other industries, to which these sponsor companies' market values are exposed. Furthermore, we can also see that sponsor's oil and gas beta is highly and negatively correlated with the likelihood that its subsidiary project companies hedge the oil and gas price risk by adopting offtake contracts (i.e., the correlation coefficient between the two is -0.349), suggesting that sponsor's oil & gas beta might be an important factor in determining its willingness to let its subsidiary project company hedge the oil and gas price risk, an empirical issue to be tested later.

2.3. Testable Hypotheses

If a firm applies for a loan, then a bank evaluates the riskiness of the to-be-financed project. Depending on the results of credit risk assessment, the bank may charge different levels of interest rate to compensate different levels of the risk borne by the bank. To reduce the cost of borrowing, the borrowing project company may arrange, if it can, a number of risk-management tools. As a result, each loan contract has many features (i.e., contractual bundles) that are supposed to manage the riskiness of the project. Such contractual bundles, if optimally designed, would lead to the lenders' high assessment of the loan and hence successful financial deals, e.g., loans granted at a lower interest rate.

In project finance deals, a loan is made to a project company rather than to a sponsor company; in case of the default (i.e., violation of the borrower in making the loan payment according to the payment schedule), the lenders have the right to take over the assets owned by the project company but can not force the sponsor company to pay any shortfalls, i.e., a project finance loan is a non-recourse (or limited-recourse) debt. By contrast, in case of the traditional corporate debt financing, the loan to finance the project would be made to a sponsor company; thus, in this case, a lending bank can directly force the sponsor to make the payment and hence would be exposed to the lower level of credit risk than in case of a project finance loan.

Thus, in project finance loans, the loan interest rate is high so as to compensate the high credit risk borne by the lender. Given the quite large amount of funding at stake, a small increase in the loan interest rate would substantially increase a project company’s financial burden. Therefore, in project finance deals, it is particularly important to reduce the cash-flow volatility of the project, one of the key determinants of the credit risk, via a bundle of contractual arrangements.

Arranging risk-management contracts may be, of course, costly. For instance, an offtake contract is an effective way to hedge the price risk of oil and gas that will be produced and sold in the future. However, it is not always easy to find counterparties of an offtake contract given the large amount of oil and gas that will be produced by a given project. In such a case, the project company might have to suggest a substantially discounted sales price, despite the decreased expected profit, in order to attract a counterparty into the offtake deal. In this case, an offtake contract would be arranged if and only if the hedging benefit (i.e., reduction in risks) exceeds or equals its cost (i.e., reduction in the expected profit). Therefore, an offtake contract may be arranged for some projects at certain periods but not for other projects and at other periods.

We expect that in response to an increase in the hedging benefit of an offtake contract, the more project companies are likely to arrange offtake contracts. To empirically test this hypothesis, we need exogenous changes in some variables that determine the hedging benefit of an offtake contract. We take changes in the volatility of oil and gas prices as exogenous shocks to the hedging benefit of an offtake contract. The reason is that changes in the oil and gas prices are events exogenous to an individual oil and gas producer and that the hedging benefit is greater if the underlying price risk is higher.

Thus, the main testable hypothesis is as follows:

Hypothesis 1: An increase in the volatility of oil and gas prices causes the likelihood of the offtake contract to increase.

Moreover, as discussed earlier, we expect that the sponsor company's past stock-return sensitivity to the oil and gas price risk (i.e., sponsor's past oil & gas beta) is systematically associated with the sensitivity of the project company's hedging likelihood to the oil and gas price risk. In particular, the sign of this relationship is, as discussed earlier, determined by the tradeoff between the two opposing forces, i.e., magnitude vs. preferences channels. This motivates us to test the second hypothesis as follows:

Hypothesis 2 (the *magnitude channel vs.* the *preferences channel*): The sponsor company's past stock-return sensitivity to the oil and gas price risk is systematically associated with the sensitivity of the project company's hedging likelihood to the oil and gas price risk.

The first hypothesis is intended to clarify whether or not the risk management practices in oil and gas development projects are proactive, and hence sensitive, to the business environment including the market-oriented price risk. Thus, it would shed some lights on the issue of whether the risk management practices prevalent in oil and gas development projects are either the equilibrium outcome of energy firms' optimal responses to business opportunities and challenges or simply constant institutional conventions. The second hypothesis is essentially intended to answer the question of which characteristics of a project/sponsor company are systematically associated with the sensitivity of the willingness to manage the price risk. Understanding the causes of differences in energy firms' risk management practices may help the government to introduce more effective policies by taking into consideration the energy firm-level incentives and challenges.

3. Data and Methodology

3.1. Micro Data: Project- and Loan-level Variables

The data on project finance deals comes from the *ProjectWare* database, which is provided by *Dealogic*. This database provides comprehensive descriptions about project finance loans: characteristics of an individual project and details about counterparties and sponsors of a given project.

Project finance loans are often used to fund a large-scale development project. The three main sectors, by the project loan size, are power plant, transportation infrastructure, and oil and gas development (based on the authors' calculation, data source: *Thomson Reuters* Project Finance International). In this paper, we focus on project finance deals in the oil and gas sectors. More specifically, industries that belong to the oil and gas sectors are as follows: First, the oil sector includes oil pipeline, oil refinery, oilfield exploration and development industries. Second, the gas sector includes gas distribution, gas exploration and development, and gas pipeline industries. As a result, 328 project finance deals are included in our sample during the period from January 1996 to May 2012.

The unit of a sample observation is a loan tranche, whereas a project is often financed via multi-tranche loans. Main characteristics of a given project (e.g., whether a project is financed via single- vs. multiple-tranche loans) are written in the text format. For a given project, we read the text descriptions and extract and encode all relevant information. For instance, we collect information on the characteristics of sponsoring firms, labeled *sponsors*, and on the key contractual arrangements.

3.1.1. Hedging Decision Variables

The *ProjectWare* database reports information on various types of contractual arrangements that are widely used in project development to hedge various risks: e.g., construction agreement, EPC agreement, O&M agreement, offtake agreement, and supply agreement. For a given project, we assign dummy variables to indicate whether or not a particular contractual agreement has been signed on. For instance, the dummy for an offtake agreement is set to one if an offtake agreement is signed on by counterparties, and zero otherwise. An offtake agreement is of our main interest given that this agreement can be used for the price risk management.

3.1.2. Microeconomic Loan Characteristics

Moreover, we also collect information on other factors that are likely to significantly affect the project company's risk management practices, e.g., dummy indicating whether or not a project belongs to a gas sector. We also control for the microeconomic loan characteristics that include financial closing date, loan amount (in millions of constant 2012 U.S. dollars), whether or not the loan is subject to the currency risk (i.e., whether or not the currency of the loan denomination is different from the local currency of the project's host country), and whether or not the loan is a part of refinancing of a project that had been already financed previously. More specifically, the currency risk dummy is set to one if the loan denomination currency differs from the currency of the local currency of the host country, and zero otherwise. Similarly, the refinancing dummy is set to one if the loan tranche is used to refinancing an existing project, and zero otherwise.

3.2. Macro Data: Global and Host Country's Risk Factors

3.2.1. Global Risk Factors: Volatility and Level of Oil/Gas Price

Note that prices of oil and gas are quite volatile, whereas an increase in such a price volatility may worsen the credit risk (i.e., the default probability) of an oil and gas project and hence increase the benefit of hedging such a risk. Time series of oil (WTI, spot market) and gas (Henry Hub, spot market) prices are collected and used in constructing the time series of the volatility of logged oil and gas price, respectively. More specifically, for a given loan tranche, we calculate the price volatility of oil and gas, respectively, as the sample standard deviation of the logged price over the six months period, since six-months before and until the financial closure date when the loan tranche is made.

The price volatility is of our interest as one of determinants of the risk management practices. Note that such a price risk measures the second moment of the price movement, i.e., volatility. The first moment of the price movement may also affect the risk management practices; thus, we need to control for it, measured by the delivery price, labeled *futures price*, of the one-year maturity futures contract that fixes the price and volume of oil/gas that will be delivered at the maturity date (one year later since the time when the contract is signed on). The one-year maturity futures price reflects the level of the price that is expected (by the market participants) to prevail in one year later.[9]

[9] The one-year maturity futures price can be thought of as the expected level of the price to prevail in one year later and then adjusted by the required compensation for the long position holder's risk, i.e., the risk-neutral measure of the expected price.

3.2.2. Host Country's Risk Factors

We need to control for the host country's risk factors, which are likely to affect the riskiness, and hence hedging likelihood, of the project. First, the time-varying component of the host country's risk is measured as the host country's 10-year government bond yield relative to the 10-year U.S. Treasury bond yield.[10] Second, the time-invariant component (i.e., fixed-effect) of the host country's risk is measured as the host country's credit rating provided by the *Standard & Poor's*. More specifically, we encode the host country's *S&P* credit rating such that a higher value corresponds to a better credit quality as follows: five for the best grade (from AAA to A+); four for the investment grade (from A to BBB−); three for the speculative grade (from BB+ to BB); two for the poor grade (from BB− to CC); and one for other grades such as default, unrated, or undisclosed.

Table 5: Statistics of Key Variables of Project Loans, Jan. 1998 – May 2012

Panel A: Descriptive Statistics						
	Obs.	Mean	Median	SD	Min	Max
Project company-level characteristics						
Project Loan Size (constant US$ millions)	150	847	396	1,377	5.8	9,289
Sponsor's oil & gas beta	150	0.053	0.039	0.120	-0.363	0.707
Microeconomic loan tranche-level characteristics						
Tranche size/Project Loan Size (%)	328	37.7	26.7	32.4	0.1	100.0
Tranche size (constant US$ millions)						
Unconditional	328	184	109	238	0.3	1,905
conditional on w/ currency risk	191	203	119	267	1	190
conditional on w/ refinancing	70	194	115	200	5	986
Maturity (years)	328	8.1	7.0	6.1	0.5	30.0
Host country-level risk factors						
Credit quality (*S&P* rating): constant	150	4.32	5	0.96	2	5
Gov't bond spread (bps): time-varying	150	3.09	0.9	6.20	-4.15	40.60
Global factors						

[10] We construct the (relative) government bond yield by using government bond yield data, taken from Thomson Reuters' DataStream. For countries which do not have information of government bond yield --- e.g., Brazil and China, we use JP Morgan global bond index instead.

Price volatility of oil and gas	150	0.192	0.130	0.173	0.007	0.957
Growth in futures price of oil and gas	150	0.045	0.111	0.308	-0.725	0.734

Panel B: Correlation Coefficients among Key Variables

	Tranche Size	Maturity	Project Loan Size	Sponsor's Oil & Gas Beta	Price Volatility	Growth in Futures Price
Tranche Size	1					
Maturity	0.205*	1				
Project Loan Size	0.550*	0.334*	1			
Sponsor's Oil & Gas Beta	0.064	-0.062	0.004	1		
Price Volatility	0.035	0.204*	0.021	0.131*	1	
Growth in Futures Price	-0.065	-0.008	-0.095	-0.113*	0.005	1

Note: this table provides summary statistics of the key variables that enter the regression equation of the project company's hedging decision to adopt an offtake contract. Project size measures the total size of multiple loan tranches issued for a given project, and tranche size the size of an individual loan tranche. Currency risk refers to the case in which the denomination of the loan differs from the host country's local currency, and refinancing the case in which the project of a loan was previously financed already. Sponsor's oil & gas beta refers to the sponsor company's estimated stock-return sensitivity to changes in oil and gas prices. Global factors refer to the volatility of oil and gas (spot) prices and annual growth rate of oil and gas (futures) prices.

Table 5 presents summary statistics for project- and loan-level variables, where one project is often financed by multi-tranche loans. The sample includes a total of 150 projects and a total of 328 loan tranches. The project loan size (i.e., sum of loan tranches made to a given project) is \$847 million on average (\$396 million for the median), while the size of an individual loan tranche is \$184 million on average (\$109 million for the median). For a given project, the ratio of the single loan size to total is 37.7 percent on average (26.7 percent for the median). This indicates that on average, two or three loan tranches are issued for a given project. For both cases of projects which are refinanced or under the currency risk, the loan tranches are (on average) of the larger size than all loans are.

3.3. Methodology: Logit Regression

We use a logit regression method to estimate the probability that an offtake arrangement is used (i.e., the offtake dummy variable is equal to one in this case) in an oil and gas development project. Let p denote such a probability. The logit regression equation is written as:

$$\log(\, p/[1-p]\,) = \alpha_1 + \alpha_2 \times \ Price\, Volatility$$

$$+\, \alpha_3 \times \ Price\, Volatility \times \ Sponsor\ Oil\ \&\ Gas\ Beta\ + \boldsymbol{X}'\boldsymbol{\gamma} + \varepsilon. \quad (3)$$

The control variable *Price Volatility* refers to the volatility of (logged) price of oil and gas, respectively, as discussed earlier, and *Sponsor Oil & Gas Beta* the estimated sensitivity of the sponsor's stock returns to the oil and gas price risk. The vector, denoted by $\boldsymbol{X}$, of other control variables are as follows: (i) the total loan size of a project, (ii) microeconomic characteristics of the individual loan tranche of observation (e.g., size, maturity, currency risk dummy, and refinancing dummy), (iii) the host country's credit quality (constant *S&P* credit rating) and government bond spread, (iv) global factors such as annual growth rate of the one-year maturity futures price, and (v) the dummy indicating whether or not the sample belongs to the period after the 2007-2008 financial crisis episode, where this after-crisis dummy variable is essentially intended to capture the effect, if any, of substantial changes (brought on by the government regulation) in the loan market environment after this crisis.

Moreover, for robustness check, we also control for the unobserved component related with the project company's credit risk that might affect the project company's decision to adopt an offtake contract. For this purpose, we run the logit regression of the project company's decision to adopt an EPC contract on the same control variables as those used in the logit regression of the offtake-adoption decision (i.e., price volatility, interaction term between the price volatility and sponsor's oil & gas beta, and other control variable vector ***X***), and then take the residual as our measure of the unmeasured component of the project company's credit risk. Note that an EPC contract is a turnkey-based contract such that a third-party company takes over all of the pre-completion risks, i.e., this third-party company guarantees to complete the design and construction process of the production facility. Given that conditional on the occurrence of a default event, it occurs mostly at the pre-completion stage, i.e., before the production facility is completed and ready for an operation, an EPC contract is arguably one of the most important ways to reduce the project company's default risk. Thus, the residual from the EPC-adoption logit regression, labeled *EPC-likelihood residual*, is highly likely to capture the unmeasured component, if any, of a project company's credit risk. Therefore, we additionally control for, if needed, this EPC-likelihood residual so as to examine whether or not the main results of the offtake logit regression are biased due to an omitted variable that is related with the unobserved component of the project company's credit risk.

4. Results and Discussion

We begin by running the baseline logit regression of the offtake-hedging decision with focus on estimating the coefficient of the price volatility. In the baseline regression, we do not control for the interaction term between the price volatility and the sponsor's oil & gas beta. In the extension, we examine whether or not the interaction term between the price volatility and the sponsor's oil & gas beta significantly enters the logit regression of the hedging decision to arrange offtake contracts.

4.1. Regression Results

Table 6 presents the results of the logit regressions of the likelihood that an offtake contract is used in an oil and gas development project. Column (1) in Tale 6 provides the regression results in the baseline case, and columns (2) and (3) the case of the extended specification in which the interaction term between the price volatility and sponsor's oil & gas beta is additionally controlled for.

Table 6: Logit Regression of the Offtake Adoption

Dependent variable	Log of odds of offtake adoption		
Regression	**(1)**	**(2)**	**(3)**
Price volatility	2.353**	3.593***	4.112***
	[0.190]	[1.355]	[1.476]
Price volatility * Sponsor Oil & Gas Beta		-8.549**	-10.697**
		[3.883]	[4.814]
Credit risk: EPC-likelihood residual			1.141***
			[0.159]
Growth in futures price	-0.111	-0.149	0.129
	[0.473]	[0.422]	[0.485]
Log of tranche size	-0.347***	-0.338**	-0.451***
	[0.119]	[0.138]	[0.156]
Log of project loan size	0.274*	0.278*	0.324**
	[0.152]	[0.149]	[0.165]
Maturity	0.105***	0.096***	0.126***
	[0.030]	[0.027]	[0.031]
Refinancing	-0.497	-0.423	-0.424
	[0.387]	[0.384]	[0.464]
Currency risk	0.318	0.316	0.366
	[0.353]	[0.381]	[0.454]
Host country: Credit quality	-1.003***	-1.008***	-1.349***
	[0.244]	[0.228]	[0.269]
Host country: Gov't bond spread	-0.068**	-0.065**	-0.081**
	[0.028]	[0.031]	[0.034]
Gas sector	1.798***	1.606***	2.156***
	[0.419]	[0.462]	[0.545]
After-crisis period	1.051**	1.235**	1.827***
	[0.531]	[0.503]	[0.592]
Constant	0.465	0.537	0.857
	[1.134]	[1.131]	[1.254]
Number of observations	328	328	328
Log likelihood	-152.66	-149.82	-116.90
Pseudo *R*-square	0.28	0.30	0.45

Note: this table provides the results of estimating the logit regression of the project company's hedging decision the price risk by adopting an offtake contract. The unit of observation is an individual loan tranche. Project loan size refers to the total size of multiple loans mad for a given project. Price volatility refers to the 6-month moving average of the daily volatility of prices of oil and gas, respectively. Sponsor oil & gas beta refers to the sponsor company's past stock-return sensitivity to changes in the logged prices of oil and gas, estimated during the first-stage estimation sample period. Host country's credit rating refers to the S&P credit rating (higher value for a better credit quality) of a host country where the project's production facility is located, and gov't bond spread the spread of the host country's government bond relative to the maturity-matched U.S. Treasury rate. After-crisis period is the dummy indicating whether or not the observation belongs to the period after the 2007-2008 crisis episode. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

From results for both the two specifications (i.e., regression (1) vs. regressions (2) and (3) in Table 6), we can find some insights as follows: an offtake contract is significantly more likely to be used (i) in the gas sector than in the oil sector, (ii) in the high-risk (i.e., low credit quality) host country than in the low-risk (i.e., high credit quality) host country, (iii) for the long-term maturity loans than for the short-term maturity loans, and (iv) after the 2007-2008 crisis than before. The first finding about the more use of offtake contracts in the gas sector is consistent with the well known fact that in gas development project, the lenders often require the project company to hedge the demand risk mainly due to the complexity of the price determinants (Razavi, 2007). The second and third findings indicate that the offtake agreement could be an attractive tool to lower the project loan's credit risk. The fourth finding indicates that after the 2007-2008 financial crisis, the loan market environment has substantially changed such that the required level of risk management has increased significantly.

We turn to discussing the main results about the impact of the price risk on the offtake-hedging likelihood. For the case of the baseline regression (see regression (1) in Table 6), we can see that the price volatility is significantly positively associated with the likelihood of the use of an offtake contract. Note that an increase in the price volatility would directly increase the project company's cash-flow volatility, which might, in turn, worsen the lenders' assessment of the credit risk of the project and hence lead to an increase in the cost of funding the project. Thus, a project company has a stronger incentive to use an offtake contract so as to mitigate the negative effect of the increased price volatility on the cost of funding.

Moreover, the results of the full logit regression (2) in Table 6 suggest another interesting finding: the smaller the sponsor's past stock-returns sensitivity to changes in the oil and gas prices (i.e., sponsor's oil & gas beta), the greater the current sensitivity of the project company's offtake likelihood to the volatility of oil and gas prices. The coefficient of the interaction term between the price volatility and the sponsor's oil & gas beta is negative and significant at the significance level of five percent. This finding indicates that the response of a project company's risk management practices to the changes in the market-oriented risk is substantially affected by the sponsor's risk tolerance, especially in the way that the preferences channel dominates the magnitude channel in the data. That is, the project company's hedging decision tends to make the sponsor's stock-return sensitivity to the oil price risk diverge further rather than converge.

This finding implies that differences and changes in the risk tolerance are one of the key determinants of the project companies' risk management behaviors. Thus, in designing policies related to the risk management in oil and gas sector, governments need to take into consideration factors that are likely to affect the firm-level risk tolerance, e.g., investors' attitude toward bearing risks. For example, the World Bank requires a government or public guarantee for financing high-risk project. As such, the government must carefully assess the credit risk of a project company, for which the sponsor company's past stock-return sensitivity to the price risk of oil and gas can provide a valuation information.

Note that the efficient ex-ante risk management techniques (e.g., risk action managements discussed in Berkeley et al. (1991) and Zhi (1995)) can assist clients and project managers to assess and pre-empt potential sources of risk. Our findings suggest further long-run implications of the efficient ex-ante risk management techniques: Consider a sponsor company with a low oil & gas beta, which values risk management highly and hence has successfully managed to insure the company's own stock returns against the changes in oil and gas prices. Our findings suggest that for such a sponsor company, its subsidiary project company is highly likely to manage the price risk of oil and gas via offtake contracts, implying that the sponsor company's cash flow is further protected against the price risk of oil and gas via the channel of the dividend income from the project company. Thus, the sponsor company considered here is expected, by the investors, to manage the price risk of oil and gas for a long time horizon, which then might help for this sponsor company to reduce its cost of raising funds.

4.2. Robustness Check I: Longer Period in Estimating Oil & Gas Beta and Price Volatility

In this section, we discuss how the main results are affected by the length of sample period for which sponsor's oil & gas beta and price volatility. Recall that in our baseline case, we consider six months as the length of the sample period in estimating these two key control variables. We now consider one year as the length of the sample period in estimating these variables and accordingly the futures price, too. More specifically, consider one-year period ending at the financial closure date: During this sample period, (i) the two-factor regression model of the sponsor's stock returns is estimated again so that the sponsor' company's one-year horizon oil & gas beta is kept; (ii) one-year volatility of the logged price of oil and gas, respectively, is calculated; (iii) one-year average of the daily futures price is calculated and then logged, of which difference from the counterpart as of one year before the financial closure date is computed, i.e., *annual growth rate* of the one-year moving average of futures price. Finally, we run the main logit regression of the project company's hedging decision on the aforementioned newly measured variables.

Table 7: Logit Regression of the Offtake Adoption, Case of Longer Period in Estimating Oil & Gas Beta and Price Volatility

Dependent variable	Log of odds of offtake adoption		
Regression	**(1)**	**(2)**	**(3)**
Price volatility	1.494	2.507***	2.940***
	[0.916]	[0.914]	[1.008]
Price volatility * Sponsor Oil & Gas Beta		-10.488***	-15.450***
		[3.924]	[5.388]
Credit risk: EPC likelihood residual			1.166***
			[0.167]
Growth in futures price	0.364	0.004	-0.169
	[0.534]	[0.509]	[0.580]
Log of tranche size	-0.327***	-0.300**	-0.361**
	[0.119]	[0.140]	[0.158]
Log of project loan size	0.296*	0.328**	0.362**
	[0.157]	[0.155]	[0.171]
Maturity	0.107***	0.091***	0.122***
	[0.032]	[0.027]	[0.032]
Refinancing	-0.469	-0.441	-0.260
	[0.376]	[0.380]	[0.459]
Currency risk	0.367	0.404	0.475
	[0.358]	[0.386]	[0.456]
Host country: Credit quality	-0.990***	-1.060***	-1.397***
	[0.256]	[0.234]	[0.274]
Host country: Gov't bond spread	-0.066**	-0.069**	-0.087**
	[0.029]	[0.032]	[0.035]
Gas sector	1.891***	1.649***	2.093***
	[0.430]	[0.473]	[0.544]
After-crisis period	0.979*	1.163**	1.559***
	[0.528]	[0.508]	[0.569]
Constant	0.277	0.691	1.100
	[1.154]	[1.172]	[1.290]
Number of observations	328	328	328
Log likelihood	-153.12	-147.97	-116.79
Pseudo *R*-square	0.28	0.30	0.45

Note: this table provides the results of estimating the logit regression of the project company's decision to hedge the price risk by adopting an offtake contract. The unit of observation is an individual loan tranche. Project loan size refers to the total size of multiple loans mad for a given project. Price volatility refers to the one-year moving average volatility of daily spot prices of oil and gas, respectively. Growth in futures price refers to the annual growth rate of the futures price, where the futures price is measured as the one-year moving average of its daily price during one-year period ending at the financial closure date, Sponsor oil & gas beta refers to the sponsor company's past stock-return sensitivity to changes in the logged prices of oil and gas, estimated during the one-year sample period ending at the financial closure date. Host country's credit quality refers to the S&P credit rating (higher value for a better credit quality) of a host country where the project's production facility is located, and gov't bond spread the spread of the host country's government bond relative to the maturity-matched U.S. Treasury rate. After-crisis period is the dummy indicating whether or not the observation belongs to the period after the 2007-2008 crisis episode.

Regression results in this case (provided by Table 7) are qualitatively almost the same as those in the baseline case (presented in Table 6) except that in this case, the price volatility becomes insignificant if the interaction term between the price volatility and the sponsor's oil & gas beta is not additionally controlled for (see regression (1) in Table 7). However, if we additionally control for the interaction term between the price volatility and the sponsor's oil & gas beta, the qualitative results (both regression (2) and (3) in Table 7) are very similar to those in the baseline case (regression (2) and (3) in Table 6) in terms of both significance and sign of the key variables' coefficients.

4.2. Robustness Check II: Alternative Measures of Sponsor's Risk Tolerance

In this section, we investigate how our main regression results are affected by other measures of the sponsor's risk tolerance on behalf of our benchmark measure (i.e., the sponsor's oil & gas beta). More specifically, we consider two alternative measures of the sponsor's risk tolerance as follows: (i) volatility of the sponsor's stock returns, and (ii) sponsor's stock-return sensitivity to the market risk, i.e., sponsor's market beta. We proceed to running the hedging-decision logit regression again by using the two alternative measures of the sponsor's risk tolerance above instead of the benchmark measure (i.e., sponsor's oil & gas beta). More specifically, we replace the interaction term between the price volatility and sponsor's oil & gas beta by the interaction term between the price volatility and each of the two alternative measures of the sponsor's risk tolerance.

Table 8: Logit Regression of the Offtake Adoption, Case of Alternative Measures of Sponsor's Risk Tolerance

Dependent variable	Log of odds of offtake adoption			
Regression	**(1)**	**(2)**	**(3)**	**(4)**
Price volatility	2.729**	3.129**	2.243*	2.707*
	[1.348]	[1.531]	[1.251]	[1.412]
Price volatility * Sponsor Volatility	-0.017	-0.009		
	[0.038]	[0.041]		
Price volatility * Sponsor Market Beta			0.190	0.247
			[0.967]	[1.037]
Credit risk: EPC likelihood residual		1.155***		1.155***
		[0.159]		[0.158]
Growth in futures price	-0.170	0.046	-0.104	0.127
	[0.427]	[0.496]	[0.413]	[0.478]
Log of tranche size	0.297**	-0.475***	-0.348***	-0.477***
	[0.148]	[0.155]	[0.135]	[0.155]
Log of project loan size	0.297**	0.351**	0.275*	0.325**
	[0.148]	[0.166]	[0.147]	[0.164]
Maturity	0.111***	0.141***	0.105***	0.134***
	[0.027]	[0.032]	[0.026]	[0.031]
Refinancing	-0.604	-0.730	-0.493	-0.542
	[0.403]	[0.491]	[0.380]	[0.464]
Currency risk	0.214	0.221	0.312	0.400
	[0.380]	[0.454]	[0.373]	[0.447]
Host country: Credit quality	-0.914***	-1.304***	-1.004***	-1.353***
	[0.226]	[0.265]	[0.228]	[0.269]
Host country: Gov't bond spread	-0.064**	-0.080**	-0.068**	-0.084**
	[0.031]	[0.034]	[0.032]	[0.035]
Gas sector	1.708***	2.216***	1.814***	2.369***
	[0.456]	[0.534]	[0.458]	[0.541]
After-crisis period	0.983**	1.513***	1.056**	1.566***
	[0.492]	[0.576]	[0.469]	[0.547]
Constant	0.334	0.653	0.453	0.774
	[1.127]	[1.254]	[1.128]	[1.256]
Number of observations	323	323	328	328
Log likelihood	-149.58	-116.55	-152.64	-118.09
Pseudo *R*-square	0.29	0.44	0.28	0.44

Note: this table provides the results of estimating the logit regression of the project company's hedging decision the price risk by adopting an offtake contract. The unit of observation is an individual loan tranche. Project loan size refers to the total size of multiple loans mad for a given project. Sponsor Volaltility refers to the volatility of the sponsor's stock returns, whereas Sponsor Market Beta refers to the sensitivity of the sponsor's stock returns to the market portfolio's returns, estimated in the first-stage two-factor regression of the sponsor's stock returns. Host country's credit quality refers to the S&P credit rating (higher value for a better credit quality) of a host country where the project's production facility is located, and gov't bond spread the spread of the host country's government bond relative to the maturity-matched U.S. Treasury rate. After-crisis period is the dummy indicating whether or not the observation belongs to the period after the 2007-2008 crisis episode.

Table 8 provides the results of the hedging-decision logit regression. As for main control variables such as price volatility, project size, maturity, and host country's credit quality, their coefficients are still significant and of the same sign as in the baseline results in Table 6. We focus on the coefficient of the interaction term between the price volatility and each of the two alternative measures of the sponsor's risk tolerance. For both the cases of sponsor's stock-return volatility (both regression (1) and (2) in Table 8) and sponsor's market beta (both regression (3) and (4) in Table 8), the coefficient of such an interaction term is insignificant. This indicates that sponsor's oil & gas beta seems to be the best in capturing the sponsor's tolerance of the oil & gas price risk, which, as shown by the results in Table 6, greatly affects the sensitivity of the project company's hedging decision to the volatility of oil and gas prices.

5. Conclusions and Policy Implications

This paper empirically studies the determinants of the risk management practices in oil and gas development project. We take the changes in the volatility of oil and gas prices (labeled *oil price risk*) as exogenous shocks to the credit risk of oil and gas project companies of which cash flows are generated almost entirely from the sales of produced oil and gas. An offtake contract that fixes the delivery price and volume of sales in the future is an effective market arrangement to hedge such a market-oriented price risk. As such, we investigate whether or not an increase in the oil and gas price volatility increases the likelihood that an offtake contract is used in oil and gas development projects.

We find that the oil and gas price volatility is indeed significantly and positively associated with the offtake likelihood in oil and gas projects. Moreover, we find that the smaller the sponsor's past stock-returns sensitivity to the oil and gas price risk, the greater the current sensitivity of the project company's offtake likelihood to the oil and gas price volatility.

Our findings suggest that market arrangements such as an offtake contract may be an effective way for energy development companies to react to the market-oriented risk such as the volatility of oil and gas prices. Furthermore, our findings also suggest that the sponsor company's risk tolerance is one of the key determinants of the difference in the price risk management across project companies.

Our findings suggest several policy implications. Note that oil and gas development companies actively react to the market-oriented risks by changing participation to market arrangements to allocate such market risks. Such a hedging decision varies substantially across companies and over time and is likely to critically depend on the firm-level incentives and challenges. Thus, it might be better for a government to focus on improving the risk market environment so that various firms and investors freely participate in the voluntary trade of risks. For instance, the government might provide energy development projects with subsidies (e.g., tax cuts) conditional on that a project company's risk management achieves a certain level enough to hedge the possible market-oriented risks. Moreover, in designing such policies related to the risk management in oil and gas sector, governments need to take into consideration firm-level factors that are likely to affect the firm-level risk tolerance, e.g., investors' attitude toward bearing risks.

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Appendix

Table A1: Logit Regression of the EPC Adoption

Dependent variable	Log of odds of EPC adoption			
Regression	**(1)**	**(2)**	**(3)**	**(4)**
Corresponding Second-Stage Regression	**Table 6 Reg (3)**	**Table 7 Reg (3)**	**Table 8 Reg (2)**	**Table 8 Reg (4)**
Price volatility	0.437	0.812	0.645	0.638
	[1.328]	[0.911]	[1.402]	[1.307]
Price volatility * Sponsor Oil & Gas Beta	-3.409	-3.674		
	[3.833]	[0.812]		
Price volatility * Sponsor Volatility			-0.056	
			[0.059]	
Price volatility * Sponsor Market Beta				-1.384
				[1.120]
Growth in futures price	0.541	0.237	0.503	0.530
	[0.428]	[0.518]	[0.434]	[0.424]
Log of tranche size	-0.274**	-0.248*	-0.284**	-0.275**
	[0.130]	[0.130]	[0.129]	[0.129]
Log of project loan size	0.689***	0.711***	0.686***	0.690***
	[0.161]	[0.163]	[0.162]	[0.161]
Maturity	0.102***	0.096***	0.110***	0.106***
	[0.026]	[0.026]	[0.026]	[0.026]
Refinancing	-1.429***	-1.482***	-1.357***	-1.501***
	[0.414]	[0.419]	[0.417]	[0.421]
Currency risk	0.916**	1.028***	0.865**	0.935**
	[0.377]	[0.384]	[0.378]	[0.378]
Host country: Credit quality	0.365	0.381*	0.375	0.365
	[0.228]	[0.229]	[0.229]	[0.228]
Host country: Gov’t bond spread	0.092**	0.096**	0.093**	0.091**
	[0.039]	[0.041]	[0.039]	[0.039]
Gas sector	0.692*	0.596	0.697*	0.679*
	[0.402]	[0.408]	[0.403]	[0.399]
After-crisis period	1.461***	1.105**	1.271***	1.407***
	[0.518]	[0.524]	[0.519]	[0.504]
Constant	-5.081***	-5.204***	-5.164***	-5.035***
	[1.261]	[1.292]	[1.267]	[1.265]
Number of observations	328	328	323	328
Log likelihood	-156.92	-157.35	-155.68	-156.63
Pseudo *R*-square	0.29	0.29	0.29	0.30

Note: this table provides the results of estimating the logit regression of the project company’s decision to adopt an EPC contract. The unit of observation is an individual loan tranche. Project loan size refers to the total size of multiple loans mad for a given project. Price volatility refers to the 6-month moving average of the daily volatility of prices of oil and gas, respectively. Sponsor oil & gas beta refers to the sponsor company's past stock-return sensitivity to changes in the logged prices of oil and gas, estimated during the first-stage estimation sample period. Host country's credit rating refers to the S&P credit rating (higher value for a better credit quality) of a host country where the project's production facility is located, and gov't bond spread the spread of the host country's government bond relative to the maturity-matched U.S. Treasury rate. After-crisis period is the dummy indicating whether or not the observation belongs to the period after the 2007-2008 crisis episode. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Regression (1) in Table A1 is the first-stage regression of the EPC adoption for the regression (3) in Table 6, regression (2) in Table A1 for the regression (3) in Table 7, regression (3) in Table A1 for the regression (2) in Table 8, and regression (4) in Table A1 for the regression (4) in Table 8.