Price Volatility and Risk Management of Oil and Gas Companies: Evidence from Oil and Gas Project Finance Deals

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Abstract

We investigate how the oil and gas project companies' decisions to hedge the risk of future prices of oil and gas respond to the changes in the price volatility of oil and gas, especially the role of the exposure of the sponsor company's stock returns to the risk of oil and gas prices. With a sample of 328 loans made to oil and gas development projects in 30 countries during 1996-2011 period, we find that the oil (or gas) price volatility increases the oil (or gas) project company's hedging likelihood, especially to a greater extent for the case in which the sponsor company's oil (or gas) exposure is smaller. Our findings suggest that the sponsor company's willingness to reduce its exposure to the risk of oil and gas prices increases the likelihood that the subsidiary project company will hedge the risk of future prices of oil and gas.

Keywords: Risk management; Price volatility; Project finance; Oil risk exposure; Oil and gas development.

JEL: G32; G12; L71; Q40.

1. Introduction

Motives for and consequences of corporate risk management have received a great deal of attention (Nance et al., 1993; Tufano, 1996; Haushalter, 2000; Allayannis and Ofek, 2001; Allayannis and Weston, 2001; Graham and Rogers, 2002; Jin and Jorion, 2006; Campello et. al, 2011). But, less is known about the oil and gas firms' incentives to hedge the risk of future prices of oil and gas, albeit the importance of such a price risk in determining these firms' cash-flow volatilities. This paper investigates the determinants of oil and gas firms' decisions to hedge the risk of future prices of oil and gas for the case of oil and gas development projects.

Oil and gas development projects are often financed via project finance loans: For instance, an energy firm (e.g., *Exxon Mobil*), creates a standalone subsidiary project company (i.e., spin-off), provides it with the equity capital (often less than 30 percent of the total capital raising), and arranges loans from the lenders. By doing this, such an energy firm, labeled *sponsor company*, can avoid the rise of its own leverage ratio and effectively transfer to the lenders (e.g., a consortium of international banks) a large fraction of the risk associated with the oil and gas development project, while retaining management control and ownership of the project. As a result, the lenders are subject to a high level of credit risks given that a project loan's repayment is mainly made from the project's future cash flows, without much collateral assets. Given the large amount of funding and high level of risks involved in a project loan, the lenders often require the sponsor company to arrange various contracts with the third parties related to the project (e.g., buyers of the produced oil and gas) to reduce the project's future cash-flow risk to a bearable level.

The risk of future prices of oil and gas is one of the most important risk factors that determine the project company's credit risk (Keefe and Yaghoubi, 2016). The reason is that an oil (or gas) project company's cash flows are generated almost entirely from the sales of oil (or gas). As such, at the time of a loan application, an increase in the oil price volatility observed in the near past, predicting the persistently high volatility of future oil prices, is likely to increase the oil project company's incentive for hedging the risk of future oil prices (Jin and Jorion, 2006) so as to mitigate the effect of such a price volatility on the borrowing cost. This has not been, however, studied much in the literature. We fill this gap by examining how an increase in the price volatility affects the likelihood of hedging in oil and gas development projects.

Importantly, oil and gas project companies exhibit substantial differences in their decisions to hedge the price risk, despite the readily available hedging tools (e.g., oil and gas derivatives, actively traded globally).[1] For instance, an oil project company can effectively hedge the risk of future oil prices by arranging an oil offtake contract that fixes the price, volume, and delivery date of the future sales of oil. The adoption rate of such an offtake contracts, as documented in this paper, varies greatly both across companies and over time. Energy firms may, in theory, differ in their costs and benefits of hedging the price risk of oil and gas. We aim to empirically investigate the determinants of the oil and gas project companies' decisions to hedge the price risk.

In particular, we focus on the sponsor company's stock-return sensitivity to the changes in the price of oil (or the price of gas for a gas project), labeled sponsor's *oil (or gas) beta*, as a determinant of the sensitivity of the project company's hedging likelihood to the price volatility. More specifically, we estimate the sponsor's oil (or gas) beta over a one-year

[1] The trading volume of oil and gas derivatives has already grown rapidly in the 1980s, whereas our sample period begins in 1996.

period (ending six months before the project loan date) by regressing the sponsor's daily stock returns on the two factors (Sadorsky, 2001; Basher and Sadorsky, 2006; Jin and Jorion, 2006): (i) return to the market portfolio (where the sponsor's stock is traded) and (ii) return to the oil (or gas) price.

Our estimation results show that for the top-20 sponsor companies (sorted by the total size of their project loans), the correlation coefficient between the sponsor's oil and gas beta and the hedging likelihood of oil and gas projects owned by the sponsor is negative, about -0.35. This suggests that the sponsor's oil beta negatively affects the likelihood that the subsidiary oil project company will hedge the risk of future oil prices.

We proceed to formally investigating the determinants of the likelihood that an oil and gas project company hedges the price risk of oil (or gas) by using an offtake contract. We run a logit regression of the hedging dummy (indicating whether or not an offtake contract is adopted as of the loan date) on the two key variables: (i) one-year moving average of the oil (or gas) price volatility and (ii) interaction term between such a price volatility and the sponsor's oil (or gas) beta. We also control for loan/tranche-, industry-, host country-, and global-level variables that might affect the project company's credit risk and hence incentive for hedging (Corielli et al., 2010; Hainz and Klemeier, 2012).

The data on the loan/tranche-level microeconomic characteristics (e.g., loan size, maturity, refinancing, etc.) comes from *Dealogic ProjectWare* database (Corielli et al., 2010); it provides information on 328 loan tranches made to 150 oil and gas development projects in 30 host countries over the monthly sample period, from April 1996 to October 2011. We control for (constant) credit rating and (time-varying) government bond spread as proxies for the regional risk factors specific to the host country where the project is located.

Our logit regression results show that for an increase in the oil price volatility, an oil project company is more likely to adopt an offtake contract to hedge the risk of future oil prices, especially to the extent greater for the case in which the sponsor company's oil beta is smaller. The marginal effect of an increase in the interaction term between the price volatility and the sponsor's oil and gas beta on the probability of offtake adoption is economically significant: an increase in this interaction term from 25th percentile to 75th percentile is associated with a decrease of 5.13 percentage points in the probability of offtake adoption. For comparison, the marginal effect of an increase (from 25th percentile to 75th percentile) in the price volatility increases the offtake-adoption probability by 0.39 percentage points.

Our findings support that an energy firm's hedging policy responds sensitively to the changes in the market environment relevant to the risk of the company's future cash flows. Furthermore, note that a sponsor company with the stronger willingness to manage its own exposure to the oil price risk would have exerted more effort to insure its business and hence its frim value against the oil price shocks so that the company's stock returns would have been less sensitive to the oil price shock. Thus, our findings also suggest that a sponsor company's willingness to reduce its own exposure to the oil price risk is also persistently observed in the case of its subsidiary project company's risk management practices: the smaller the sensitivity of the sponsor company's stock returns to the oil price risk, the higher the likelihood that its subsidiary project company will also hedge the oil price risk. Put differently, a sponsor company's oil beta, which is easily observable, can be useful in predicting the subsidiary project company's decision to hedge the oil price risk, which is valuable information to lenders, other investors and third parties involved in the project.

This paper contributes to the literature that studies the determinants of energy companies' risk management practices (Berkeley et al., 1991; Zhi, 1995; Thuyet et al., 2007). Berkeley et al. (1991) and Zhi (1995) discuss how the ex-ante risk management techniques can support project managers in development of projects. Thuyet et al. (2007) identify the major project risks based on a questionnaire survey in oil and gas industries in Vietnam, whereas our sample covers a number of oil and gas project companies in 30 countries. As for empirical studies of oil and gas project finance loans, Dailami and Hauswald (2007) investigate the determinants of the credit spread for a single gas project in Qatar, and Pierru et al. (2013) study the capital structure of LNG infrastructures and gas pipeline projects financed by project loans. This paper investigates determinants of the project company's hedging decision, which might affect this firm's credit spread and capital structure (Haushalter et al., 2002).

This paper also contributes to the literature that studies the determinants of risk management practices in project finance deals. Many extant papers have studied how project companies optimally manage country-specific risks—e.g., political risk and legal risks—to reduce the default risk (Esty and Megginson, 2003; Vaaler et al., 2008; Corieli et al., 2010; Haniz and Klemeier, 2012). This paper complements this literature by studying determinants of the corporate hedging decision for the case of oil and gas development project finance.

This paper also contributes to the literature that studies determinants of corporate risk management (Nance et al., 1993; Tufano, 1996; Haushalter, 2000; Allayannis and Ofek, 2001; Graham and Rogers, 2002; Kleffner et al., 2003; Keefe and Yaghoubi, 2016). Many papers in this literature have focused on non-energy firms, while we contribute to this literature by studying the determinants of an energy firm's decision to hedge an oil price risk.

This paper proceeds as follows. Section 2 discusses the overview of the recent trend in oil and gas project financing and develops main hypotheses. Section 3 discusses the methodology, Section 4 the data, and Section 5 the regression result. Section 6 concludes.

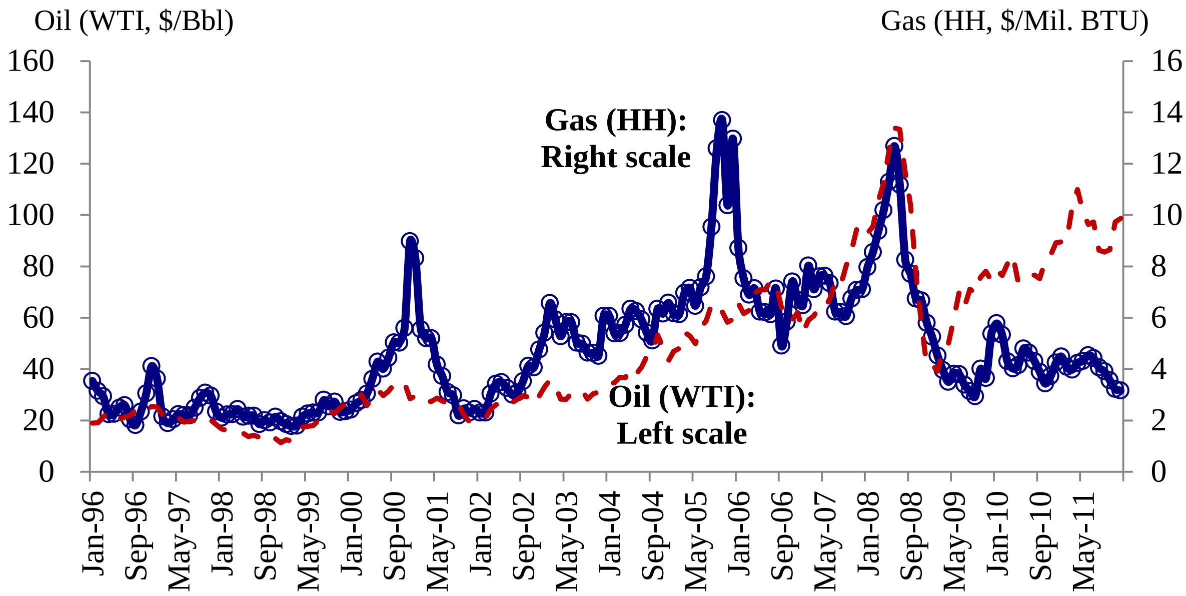
2. Overview and Hypotheses: Price Risk and Hedging in Oil and Gas Projects

In this section, we discuss how the price risks of oil and gas as well as the likelihood of hedging such price risks in oil and gas development projects have fluctuated during our sample period. The price risk in the global oil and gas markets is highly likely to affect the systematic risks borne by investors in oil and gas markets, which would in turn increase the cost of funding oil and gas development projects. Facing the increased difficulty in raising capital, oil and gas project companies are likely to more actively engage in mitigating their business risks by shifting these risks to other stakeholders (e.g., buyers of oil and gas). As such, we develop hypotheses about determinants of the project company's hedging likelihood, i.e., how global risk factors and firm characteristics are likely to affect the company's incentive for hedging the price risk.

2.1. Risk of Oil and Gas Prices

We begin by examining how the oil and gas prices fluctuated during the sample period from January 1996 to October 2011. Figure 1 plots the monthly time series of oil and gas prices in the US spot markets, where we use *West Texas Intermediate* crude oil (WTI) spot price as the oil price, and *Henry Hub* natural gas (HH) spot price as the gas price. We can see that both oil and gas prices were quite volatile. For instance, both the oil and gas prices increased almost sixfold during the period from January 2002 to June 2008, and then plunged substantially until May 2009.

Figure 1: Monthly Series of Oil and Gas Prices, January 1996-October 2011



Note: this figure plots monthly series of prices of oil (WTI, in US dollars per barrel, left scale) and gas (HH, in US dollars per million BTU, right scale), respectively, traded in the U.S. (spot) markets.

We proceed to examining how the price volatility of oil and gas, respectively, has changed over time. We calculate the monthly volatility of oil and gas prices as the standard deviation of the log of the daily price of oil and gas, respectively, for a given month. Table 1 presents such monthly price volatilities, on average for a given year.

Table 1: Volatility of Oil and Gas Prices, 1996-2011

Year	Oil Price Volatility	Gas Price Volatility
1996	0.041	0.099
1997	0.034	0.081
1998	0.044	0.032
1999	0.108	0.063
2000	0.037	0.155
2001	0.062	0.176
2002	0.054	0.090
2003	0.031	0.051
2004	0.058	0.034
2005	0.047	0.126
2006	0.034	0.061
2007	0.075	0.038
2008	0.147	0.099

2009	0.101	0.077
2010	0.025	0.061
2011	0.033	0.051
Average	0.058	0.081
Standard Deviation	0.034	0.042

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

Table 1 shows that for both oil and gas, the price volatility has changed substantially over time: its standard deviation is about 3.4 percentage points, compared to its mean of 5.8 percentage points. Indeed, the price volatility exhibits ups and downs, especially peaks in 2001 and in 2008, respectively. In particular, consider the period around the peak in 2008: the price volatility has greatly increased from 2003 to 2009 and then substantially decreased thereafter. An increase in the price volatility is likely to increase the cash-flow volatility of oil and gas development projects, making it more difficult to fund these projects. This might have provided oil and gas project companies with stronger incentives to hedge the price risk. As such, we examine the changes in the oil and gas project companies' hedging decisions.

2.2. **Risk Management**

In this section, we discuss the key features of a project finance loan and examine the overall trend in the risk management practices in oil and gas development projects. A project finance loan is a non-recourse (or limited-recourse) debt made to a project company that is established for a particular investment project and legally independent of the sponsor company (Esty, 2004; Hainz and Kleimeier, 2012; Byoun et al., 2013); a sponsor refers to the project company's main shareholder. As such, in the event of default, the lender can not force the sponsor to pay the unpaid portion of the project company's debt obligation. Moreover, for a project finance loan, the leverage ratio is often quite high, about 70 percent (Esty and Sesia, 2011). Thus, the lender of a project finance loan bears a high level of credit risks.

Therefore, the lenders usually require the borrower to arrange various risk-management contracts so that the project company's credit risk should be reduced to a bearable level (Corielli et al., 2010). For instance, 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 risk of construction of a production facility, (ii) operation and management (O&M) agreement to hedge the operational risk after the production facility completed, and (iii) offtake agreement to hedge the price risk of produced output, and (iv) supply agreement to hedge the price risk of inputs.

In practice, the usage of such various risk-management contracts differs across companies and over time. The reason is, of course, that the benefits net costs of arranging risk-management contracts might differ among companies and change over time. For instance, the changes in the global risk factors could greatly affect the incentive for hedging these risks: e.g., an increase in the current volatility of the oil price might increase the benefit, and hence likelihood, of hedging the risk of future oil prices.

We examine how oil and gas project companies' decisions to use various risk management contracts have changed over time. Table 2 provides the annual empirical likelihood to use each of various risk management contracts in oil and gas project finance deals over the period 1996-2011. The likelihood to use a particular risk management contract (e.g., offtake contract) is measured as follows: Consider oil and gas project finance loan tranches made for a given year. We calculate the fraction of loan tranches, in terms of the number of tranches, for which the risk management contract is arranged as of the loan date.

Table 2: Likelihood of Risk Management, Oil and Gas Projects, 1996-2011

Year	Number of Project Loan Tranches	Likelihood to Use Risk Management Contracts				
		Offtake Contract	EPC Contract	Construction Contract	O&M Contract	Supply Contract
1996	73	0.137	0.055	0.164	0.068	0.000
1997	82	0.183	0.366	0.183	0.049	0.000
1998	91	0.044	0.165	0.231	0.231	0.033
1999	93	0.258	0.376	0.269	0.226	0.301
2000	95	0.116	0.179	0.105	0.116	0.126
2001	36	0.083	0.306	0.056	0.361	0.000
2002	55	0.455	0.418	0.000	0.109	0.109
2003	98	0.296	0.306	0.000	0.122	0.071
2004	159	0.201	0.497	0.189	0.101	0.038
2005	134	0.299	0.299	0.067	0.127	0.060
2006	125	0.096	0.192	0.016	0.008	0.000
2007	133	0.331	0.173	0.000	0.000	0.045
2008	167	0.539	0.575	0.000	0.096	0.108
2009	168	0.435	0.518	0.024	0.000	0.018
2010	148	0.169	0.399	0.027	0.061	0.061
2011	195	0.174	0.303	0.000	0.005	0.031
Avgerage	116	0.238	0.320	0.083	0.105	0.063
Std Dev	45	0.144	0.144	0.094	0.098	0.076

Note: this table presents the annual likelihood to use each of various risk management contracts in oil and gas project finance loans over the period 1996-2011. The likelihood of an offtake contract is measured as the number of project loan tranches for which an offtake contract is arranged as of the loan date, divided by the total number of project loan tranches made for a given year. Likelihood of other types of risk management contracts is calculated in the same way. The data source is *Dealogic ProjectWare*. Std Dev refers to the standard deviation across years.

Table 2 shows that for each of various risk management contracts, its empirical likelihood fluctuates substantially over time. For instance, the likelihood to use an offtake contract has the standard deviation of about 14 percentage points, sizable compared to its sample mean of 24 percentage points. In particular, the likelihood to use an offtake contract exhibits peaks in 2002 and in 2008, synchronous with the price volatility peaks in 2001 and in 2008, respectively. This motivates us to investigate the effect of the oil price volatility on the likelihood that a project company hedges the risk of future oil prices.

2.3. Incentives for Hedging: Oil and Gas Projects

In this section, we discuss hypotheses about the determinants of the oil and gas project company's likelihood to hedge the risk of future prices of oil and gas.

2.3.1. Price Volatility and Corporate Incentive for Hedging

We expect that in response to an increase in the hedging benefit of an offtake contract, every project company is more likely to adopt an offtake contract. To empirically test this hypothesis, we need the exogenous changes in the determinants of the hedging benefit of an offtake contract. The changes in the volatility of oil and gas prices are suitable for this purpose. As such, we present the main testable hypothesis as follows:

Hypothesis 1: The volatility of oil and gas prices increases the likelihood that a project company uses an offtake contract to hedge the risk of future prices of oil and gas.

This hypothesis is intended to clarify whether or not the risk management practices of oil and gas development project companies are proactive, and hence sensitive, to the risk relevant to the company's core business: production and sales of oil and gas. Thus, it would shed light on the issues of whether or not (i) the practices of corporate risk management are firms' optimal responses to their business risks and (ii) shareholders prefer corporate hedging despite the availability of hedging on their own.

2.3.2 Sponsor Company's Willingness to Hedge the Oil Price Risk

Note that in response to an increase in the oil price volatility, an oil project company's hedging likelihood is expected to increase, especially to a greater extent for the case in which the company's shareholders (i.e., the oil project company's sponsor company) have the stronger willingness to reduce their exposures to the oil price risk. The reason is that the project company's hedging helps to stabilize the sponsor's dividend income received from the project.

The key issue is which sponsor company has the stronger willingness to stabilize its dividend income received from its subsidiary project company.[2] We assume that the sponsor's stock return sensitivity to the changes in the oil (or gas) price is *negatively* related to the degree of the sponsor's willingness to avoid the oil (or gas) price risk: i.e., the sponsor's smaller oil beta indicates that the sponsor has more actively managed its exposure to the oil price risk, which is in turn due to the sponsor's stronger willingness to avoid the oil price risk (equivalently, the smaller appetite for the oil price risk). Thus, we expect that the smaller the sponsor's oil beta observed in the near past, the greater the sensitivity of the project company's hedging likelihood to the oil price volatility.

Hypothesis 2: The sponsor company's willingness to reduce its exposure to the risk of oil and gas prices increases the sensitivity of the project company's hedging likelihood to the volatility of oil and gas prices.

3. Methodology: Determinants of the Project Company's Hedging Likelihood

In this section, we discuss (i) how to measure the sponsor company's willingness to avoid the risk of future prices of oil and gas, and (ii) how to estimate the determinants of the project company's hedging likelihood.

3.1. Sponsor Company's Willingness to Hedge the Risk of Oil and Gas Prices

Throughout this paper, a sponsor company indicates the given project company's main shareholder, and we take the sponsor company's stock-return sensitivity to the rate of changes in the oil (or gas) prices, observed in the period before the loan date, as the inverse measure of the sponsor company's willingness to reduce its exposure to the risk of future prices of oil (or gas).

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[2] Understanding the causes of differences in energy firms' risk management practices can help the government to introduce more effective policies tailored by the firm-level incentives and challenges.

More specifically, consider sponsor company *j* of oil (or gas) project company i. Let $R_{i,j,t}$ denote the daily stock return for sponsor company *j* on a date *t*, where sponsor company *j* can have multiple projects over different periods. As in Jin and Jorion (2006) and Sadorsky (2001), 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 (i.e., equation (1) is used for an oil development project, and equation (2) for a gas development project), as:

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

$$\mathrm{R}_{i,j,t} = \alpha_{i,j} + \beta_{mkt,i,j} \times R_{mkt,t} + \beta_{gas,i,j} \times R_{gas,t} + \varepsilon_{i,j,t} \quad (2)$$

where $R_{mkt,t}$ is the daily return to the market portfolio of a stock market where the sponsor's stocks are mainly traded, $R_{oil,t}$ the daily return to the near-month WTI futures price of oil, and $R_{gas,t}$ the daily return to the near-month HH futures price of gas. Sponsor *j*'s oil and gas betas $(\beta_{oil,i,j}, \beta_{gas,i,j})$ are specific to the combination of project and sponsor (*i*,*j*): the sponsor's oil beta is allowed to differ between projects developed at different periods.

3.1.1. Estimation period: One-Year Window, Ending Six Months Before the Loan Date

For a given project *i*, we estimate the sponsor company *j*'s stock-return sensitivity to the changes in the logged prices of oil and gas, labeled *oil and gas beta*, respectively, during a one-year period, ending six months before the loan date. The primary purpose of estimating the sponsor company's oil and gas beta is to use it as an informative predictor of the project company's hedging decision. To this end, the estimation period of the sponsor company's oil and gas beta should be close to the loan date (so that the prediction power of such an estimated oil and gas beta is strong) and sufficiently earlier than the loan date to minimize the concern that during period close to the loan date (e.g., six-month period, ending on the loan date) the sponsor's *observed* exposure to the oil risk could be affected by the news about the *expected hedging policies* of a project company. In our baseline case, this estimation period ends six months before the loan date. As for the length of the estimation period, we choose one-year window. That is, in the estimation, we use the sponsor's stock returns during the period from t = -545 to t = -180, where t refers to the number of calendar days compared to the loan date.[3]

Our choice of the sample period of one year is shorter than those used in the literature that studies the impact of the oil price shocks on the energy firms' stock returns (e.g., one-, two- or five-years). (See, e.g., Basher and Sadorsky (2006)). The reason is that our estimated oil and gas betas are intended to capture the effects of the events occurring near the loan date on the sponsor's stock returns so that our estimated oil and gas betas are informative in predicting the sponsor's decisions made around the loan application period.

3.2. Determinants of the Project Company's Hedging Likelihood

We focus on investigating the determinants of the likelihood that a project company uses an offtake contract to hedge the oil (or gas) price risk. We use a logit regression method to estimate the offtake-adoption likelihood where the offtake dummy is equal to one if an offtake contract is arranged as of the loan date and zero otherwise. Let p denote the offtake-adoption probability. The logit regression equation is written as:

$$\log\left(\frac{p}{[1-p]}\right) = \delta_0 + \delta_1 \times \ Price\ volatility$$

$$+ \delta_2 \times \ Price\ volatility \times \ Sponsor's\ oil\ \&\ gas\ beta$$

$$+\delta_3 \times \ Sponsor's\ oil\ \&\ gas\ beta + \boldsymbol{X}'\boldsymbol{\gamma} + \varepsilon \qquad (3)$$

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[3] We have also considered an alternative estimation window of the sponsor's oil and gas beta: one-year window ending *one day* before the loan date. This case does not make a real difference to the main results, which are presented in section A in Online Appendix.

where the dependent variable is the log of odds that for a given project loan tranche, an offtake contract is used. The control variable *Price volatility* refers to the volatility of (logged) price of oil and gas, respectively, depending on the project's sector, and *Sponsor's oil & gas beta* the (estimated) sensitivity of the sponsor's stock returns to the rate of changes in the oil (or gas) price, depending on the project's sector.

It is of our main interest to examine whether or not the price volatility increases the hedging likelihood. In particular, we aim to investigate whether or not the sponsor company's exposure to the oil (or gas) risk is systemically related to the effect of the price volatility on the subsidiary project company's decision to hedge the oil (or gas) price risk. That is, we aim to test whether or not the interaction term between the price volatility and the sponsor's oil and gas beta significantly enters the logit regression of the hedging likelihood.

The control vector ***X*** includes the standard control variables that could affect the hedging incentives and are as follows: (i) microeconomic characteristics of the individual loan tranche of observation (e.g., size and maturity of a loan tranche, and currency risk and refinancing dummies); (ii) the total size of multiple loan tranches made to a given project as a proxy for the project size (Pierru et al., 2013); (iii) the host country's constant credit quality (*S&P* credit rating) and time-varying government bond spread, where these two are proxies for various regional factors specific to the host country where the project is located; and (iv) global factors such as the annual growth rate of the price of the one-year maturity futures contract, and the after-crisis dummy that indicates whether or not the loan is made during the period after the 2007-2008 financial crisis episode. The after-crisis dummy (set to one for a loan made after 2008) is intended to capture the effect of substantial changes in the loan market environment after this crisis, e.g., stricter risk management requirements imposed on bank loans by the new regulation. (See Appendix for a list of definitions of variables, and Section 4.2 for construction of variables.)

3.2.1 Robustness Check I: Unobserved Credit Risk

For robustness check, we examine whether or not the main regression results are biased due to the omitted variables problem, e.g., an unobserved component of the project company's credit risk, which is likely to affect the company's offtake-adoption decision. It is well known that for a project finance loan, the event of default occurs mostly at the pre-completion stage when the production facility is not yet completed (Sorge, 2004). For instance, the construction cost happens to exceed what was initially expected, which leads to default of the project loan. To reduce a pre-completion default risk, a project company often adopts a turnkey-based engineering, procurement and construction (EPC) contract of which counterparty guarantees that the production facility will be completed by an agreed date at the fixed cost. Given that an EPC contract is effective in reducing the project's default risk, a project company with the higher (unobservable) credit risk is more likely to use an EPC contract. Thus, we run the regression of the EPC-adoption dummy on the control variables that enter the offtake-adoption regression, from which residuals are controlled for, if needed, as a proxy for the project company's unobserved credit risk in the main regression of the offtake-adoption dummy.

3.2.2 Robustness Check II: Upstream vs. Downstream Projects

For robustness check, we also examine how the main results are affected by controlling for the interaction term between the price volatility and the upstream dummy, which captures the difference, if any, between upstream and downstream projects in the effect of the price volatility on the hedging likelihood. The reason is mainly about the possible difference between upstream and downstream energy firms in their capabilities to absorb the price shocks, which might affect their hedging incentives. In the downstream industries of oil and gas, firms are likely to have market power due to strategies for management of distribution channels and inventory adjustment, which would provide downstream firms with operational capabilities to absorb the price shocks. By contrast, upstream firms (i.e., producers of crude oil and natural gas) compete in the global market and hence have almost no room to absorb the price shocks. As such, in the upstream industry, the likelihood of hedging may respond to an increase in the price volatility more sensitively than in the downstream industry.

4. Data

4.1. Data on Sponsor Company's Stock Return and Its Determinants

The data on daily returns to sponsor companies' stocks and the corresponding market portfolio (where the sponsor's stock is traded) comes from the *Thomson Reuters DataStream* database. The sponsor's company code is provided by the *Energy Intelligence* database.

4.1.1. Statistics of Sponsor Company's Stock Returns and Two Risk Factors

Table 3 provides summary statistics, over the period of January 1995–November 2011, of the average stock return across top-20 sponsor companies (sorted by the total size of their project loans) and the two systemic risk factors: (i) return to the market portfolio[4], and (ii) return to the near-month maturity futures price of oil (or gas); all these returns are at the daily frequency over a one-year period, ending six months before the loan date.

From Table 3, we can see that the sponsor's stock return, on average across sponsors for a given day, is quite volatile: its standard deviation is about 0.95 percentage points, whereas the standard deviation of returns to the market portfolio is about 1.1 to 2.2 percentage points; the

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[4] The market portfolio is for the stock market where the sponsor company's stocks are mainly traded.

average sponsor's stock return is positively correlated both with the market returns and with the rates of changes in the futures prices of oil and gas.

Table 3: Daily Returns to Sponsors' Stocks, Market Portfolio, and Oil & Gas Prices

Panel A: Summary Statistics

	Mean	Median	SD	Min	Max
Sponsor company's stock return (average cross companies)	0.06%	0.008%	0.95%	-7.9%	13.5%
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	0.0%	0.0%	2.2%	-15.2%	17.8%
Return to the futures price of gas	0.0%	0.0%	3.5%	-31.3%	18.1%

Panel B: Correlation Coefficients

	Avg. Sponsor's Stock Return	NYMEX (US)	FTSE100 (UK)	NIKKEI (Japan)	KOSPI (Korea)	Oil Futures Price
Avg. Sponsor's Stock Return	1					
NYMEX (US)	0.628**	1				
FTSE100 (UK)	0.597**	0.511**	1			
NIKKEI (Japan)	0.335**	0.026**	0.182**	1		
KOSPI (Korea)	0.192**	0.238**	0.236**	0.005	1	
Oil Futures Price	0.302**	0.142**	0.197**	0.051**	0.037**	1
Gas Futures Price	0.106**	0.027**	0.039**	0.038**	-0.012	0.221**

Note: Sample period is from January 1995 to November 2011. Panel A provides statistics of the average stock return across top-20 sponsors and returns to the two pricing factors. Returns are measured as the daily (not annualized) changes in the log of prices; stock returns includes dividend payments. Panel B provides the correlation coefficients among the average sponsor's stock return and returns to the two pricing factors. ** indicates significance at the 5% level.

4.1.2. Sponsor's Exposures to Oil vs. Non-Oil Risks

We estimate the sponsor's oil and gas betas, which enter the sponsor's return equation (1) and (2), respectively, by using the OLS method. Table 4 presents the estimation results for top-20 sponsors; this table also provides information on the sponsor company's non-oil risks (e.g., total risk and market beta) and the likelihood that oil and gas project companies, owned by a given sponsor company, adopt offtake contracts to hedge the risk of oil and gas prices.

Table 4: Sponsor's Risk Exposures and Project Company's Hedging Likelihood

Rank	Sponsor: Company Name	Project size (constant US$ mil.)	Sponsor's Oil & Gas Beta	Sponsor's Stock Return Volatility (%)	Sponsor's Market Beta	Offtake-Adoption of Projects
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%
	Correlation Matrix					
	Project size	1.00				
	Sponsor's Oil & Gas Beta	0.15	1.00			
	Sponsor's Stock Return Volatility	-0.10	0.51	1.00		
	Sponsor's Market Beta	0.33	0.29	-0.14	1.00	
	Offtake Adoption of Projects	0.17	-0.35	-0.20	-0.15	1.00

Note: this table provides the estimated oil and gas betas of (loans-size-sorted) top-20 sponsor companies where oil and gas beta refers to the sensitivity of the sponsor's stock returns to the changes in the logged (near-moth futures) price of oil and gas, respectively. Sponsor's daily stock returns are regressed on returns to the market portfolio (where the sponsor's stocks are mainly traded) and returns to oil (or gas) prices, over a one-year period, ending six months before the loan date. The size of oil and gas projects owned by a given sponsor company is in terms of constant 1985 US dollars (million).

As shown by Table 4, top-20 sponsors, which are of relatively large sizes and hence presumably comparable across each other, exhibit substantial variations in (i) their levels of estimated oil and gas beta (their sample mean is 5.1 percentage points and standard deviation is 6.1 percentage points) and (ii) the likelihood that project companies, owned by a given sponsor company, use offtake contracts: it has sample mean of 33 percent percentage points and standard deviation of 21 percent percentage points.

It is interesting to see that a sponsor company's stock-return volatility, labeled *sponsor's total risk*, is highly positively correlated with the sponsor's own oil and gas beta (i.e., their correlation coefficient is 0.51), while it is weakly and negatively correlated with the sponsor's own market beta (i.e., their correlation coefficient is -0.14). This suggests that the price risk of oil and gas might be an important source, other than the market risk, of total risks faced by these sponsor companies.

Furthermore, we can see that a sponsor's oil and gas beta is highly and negatively correlated with the likelihood that its subsidiary project companies hedge risks of oil and gas prices by adopting offtake contracts (i.e., their correlation coefficient is about -0.35).

Taken together, these facts suggest that the sponsor's oil and gas beta could be an important factor in determining the hedging decision of its subsidiary project company.[5]

4.2. Data on Project Loans and Hedging Decision

4.2.1. Data Source

The data on project finance loans comes from *Dealogic ProjectWare* database, the same one studied in Corielli et. al (2010). This database provides comprehensive descriptions about

[5] Both the sponsor's total risk and market beta are also negatively correlated with the offtake-adoption of projects (their correlation coefficients are -0.20 and -0.15, respectively). In section B in Online Appendix, we provide the offtake-adoption regression results that the coefficient on the interaction term between the price volatility and the sponsor's total risk (or sponsor's market beta) is not significant.

project finance loans: characteristics of an individual project and details about counterparties and sponsors of a given project. Main characteristics of a given project are written in a text format, which we manually encode.

Project finance loans are often used to fund a large-scale development project. The three main sectors, by the project loan size, are (i) power plant, (2) transportation infrastructure, and (3) oil and gas development (based on the authors' calculation, data source: *Thomson Reuters Project Finance International*).

We focus on project finance loans made to oil and gas development projects. Industries that belong to the oil and gas sectors are as follows: First, the oil sector includes (i) oilfield exploration and development, (ii) oil pipeline, and (iii) oil refinery industries. Second, the gas sector includes (iv) gas exploration and development, (v) gas pipeline, and (vi) gas distribution industries. We set the gas sector dummy to one if a project's industry belongs to the gas sector, and to zero otherwise.

Note that the oil and gas industries can be also classified either as the upstream or as the downstream industry. More specifically, the upstream industry refers to the two industries related to the exploration and extraction of oil and gas: (i) oilfield exploration and development, and (iv) gas exploration and development, for which the upstream dummy is set to one. Meanwhile, the downstream industry is related to refining and marketing and includes the other four industries, for which the upstream dummy is set to zero.

The sample period is from April 1996 to October 2011 (in terms of the loan date). The sample includes 328 loans made to oil and gas development projects in 30 countries.

The unit of a sample observation is a loan tranche as in Corielli et. al (2010), whereas a project is sometimes financed via multi-tranche loans. As such, two or three loan tranches are sometimes observed for a given project. Thus, in our regression analysis, we report standard errors robust to cross-sectional clustering for a given project.

4.2.2. 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. In particular, an offtake agreement is of our main interest because it is an effective instrument to hedge the price risk. For a given project loan, we set the offtake adoption dummy to one if an offtake agreement has been already signed by counterparties as of the loan date, and zero otherwise. Similarly, we set the EPC dummy to one if an EPC agreement has been already signed by counterparties as of the loan date.

4.2.3. Loan Characteristics

We collect information on loan characteristics that are likely to affect the project company's decision to hedge the price risk. For instance, we control for (i) loan tranche amount (in millions of constant 1985 U.S. dollars); (ii) maturity in years; (iii) the currency risk dummy that indicates whether or not the loan is subject to the currency risk: it is set to one if the currency of the loan denomination differs from the local currency of the host country where the project's production facility is located; and (iv) refinancing dummy that indicates whether or not the loan is used in refinancing a project that had been financed previously: it is set to one in case of refinancing.

4.2.4. Host Country's Risk Factors

We also control for the host country-level risk factors that are likely to affect the riskiness, and hence hedging likelihood, of the project. We use two variables to measure such a host country-level riskiness: the country's constant credit rating and time-varying government bond spread, which are proxies for various geopolitical risk factors such as political and legal risks studied in Hainz and Kleimeier (2012). It is of our interest to control for the overall level of a host country's riskiness rather than specific risk sources (Bekaert et al., 2016). Thus, it suffices to control for constant and time-varying components of the country's riskiness.

More specifically, the time-varying component of the host country's riskiness is measured as the spread of the country's 10-year government bond yield relative to the 10-year U.S. Treasury rate, by using *Thomson Reuters DataStream* database; for countries that are not covered by *Datastream, JP Morgan Global Bond Index* database is used. The time-varying spread of the host country's government bond is also supposed to capture the changes in the lenders' risk appetite, if any, due to worsening financial market conditions.

Meanwhile, the constant component (i.e., fixed-effect) of the host country's riskiness is measured as *Standard & Poor's* (*S&P*) credit rating. We encode the *S&P* credit rating by assigning a higher value to a better credit quality (Corielli et. al, 2010): the host country's credit quality is set to 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.

4.2.5. Global Factors: Volatility and Growth of Oil and Gas Prices

Prices of oil and gas are quite volatile. An increase in the oil price volatility is likely to worsen the credit risk (the default probability and recovery rate) of an oil project company and hence increase the benefit of hedging the oil price risk. As such, we construct and control for the volatility of logged spot market prices of oil and gas, respectively, by using WTI crude oil spot price for the oil price and Henry Hub natural gas spot price for the gas price.

More specifically, for a given loan tranche, we calculate the price volatility of oil and gas, respectively, as the standard deviation of the log of the daily price over one-year period, ending one day before the loan date *t*. Oil and gas prices substantially differ in their magnitudes of volatilities. (See Table 1.) As such, we standardize them to have values from zero to one as follows:

$$Oil\ price\ volatility_t = \frac{\sigma_t^{Oil} - \sigma_{Min}^{Oil}}{\sigma_{Max}^{Oil} - \sigma_{Min}^{Oil}}\ ,\ \ Gas\ price\ volatility_t = \frac{\sigma_t^{Gas} - \sigma_{Min}^{Gas}}{\sigma_{Max}^{Gas} - \sigma_{Min}^{Gas}} \qquad (4)$$

where σ_t^{Oil} refers to the standard deviation of the log of the daily oil prices over a one-year period (ending one day before the loan date), and σ_{Max}^{Oil} and σ_{Min}^{Oil} the maximum and minimum values, respectively, over all observations of σ_t^{Oil}. The gas price volatility is measured in the same way.

Note that the changes in the expected *level* of the price in the future (e.g., next year) might also affect the project company's hedging likelihood. Thus, we also control for the change in the futures price from one year ago, labeled *(annual) growth in futures price*, where the futures price refers to the delivery price of the one-year maturity futures contract, on average over the one-year period (ending one day before the loan date). We expect that in the hedging likelihood regression, the coefficient on futures price growth is negative because a higher growth in futures price is likely to reduce the credit risk and hence decrease the incentive for hedging. (See Appendix for a list of definitions of variables.)

5. Results

In this section, we discuss statistics of key variables and main results for the logit regression of the hedging dummy. We also discuss results for robustness check, especially those for the case in which the sponsor's non-oil general risk exposures are used instead of the sponsor's oil and gas exposures.

5.1. Summary Statistics

Table 5 presents summary statistics of project- and loan-level variables, respectively. The sample includes a total of 150 projects and a total of 328 loan tranches. For a given project, the ratio of the single loan size to the total size of loans is 37.7 percentage points on average (26.7 percentage points for the median), similar to those in Corielli et. al (2010) who examine project finance loans in all industries rather than those in the oil and gas industries. Other loan-level characteristics (e.g., maturity) and host country-level variables (e.g., government bond spread) also exhibit substantial variations.

Panel B in Table 5 provides the correlation coefficients among the key variables that enter the hedging regression. We can see that both maturity and price volatility are positively correlated with the hedging dummy.

Table 5: Statistics of Key Variables of Project Loans, April 1996 – October 2011

Panel A: Descriptive Statistics						
	Obs.	Mean	Median	SD	Min	Max
Project company-level characteristics						
Project's total loan size (US$ mil.)	150	847	396	1,377	5.8	9,289
Sponsor's oil & gas beta	150	0.052	0.036	0.105	-0.129	0.962
Microeconomic loan tranche-level characteristics						
Tranche size/Project's total loan size (%)	328	37.7	26.7	32.4	0.1	100.0
Tranche size (US$ mil.)						
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						
Price volatility of oil and gas	150	0.289	0.199	0.258	0.016	0.996
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

	Offtake-adoption dummy	Tranche size	Maturity	Project’s total loan size	Sponsor’s oil & gas beta	Price volatility
Offtake-adoption dummy	1					
Tranche size	-0.045	1				
Maturity	0.334*	0.178*	1			
Project’s total loan size	0.145*	0.613*	0.300*	1		
Sponsor’s oil & gas beta	-0.120*	0.145*	-0.095	0.095	1	
Price volatility	0.318*	-0.091	0.172*	-0.073	0.056	1
Growth in futures price	-0.057	-0.081	-0.008	-0.209*	-0.113*	0.005

Panel C: Statistics for Upstream vs. Downstream Industries

	Obs.	Offtake Dummy	Tranche size (US$ mil.)	Maturity (in years)	Project’s total Loan Size (US$ mil.)	Sponsor's Oil & Gas Beta
Upstream	188	0.35	193	8.8	986	0.066
Downstream	140	0.31	171	7.2	696	0.047

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. SD refers to the standard deviation. Panel C presents averages of variables conditional on upstream vs. downstream industries, respectively. Project’s total loan size measures the total size of multiple loan tranches issued for a given project, and tranche size the size of an individual loan tranche, where such loan sizes are in millions of constant 1985 U.S. dollars. 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 already previously financed. Sponsor’s oil & gas beta refers to the sponsor company’s estimated stock-return sensitivity to the 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.

Panel C in Table 5 presents averages of key variables conditional on upstream vs. downstream industries, respectively. We can see that the average likelihood of hedging by using an offtake contract is not largely different between the two industries: it is slightly higher for the upstream (35 percent) than for the downstream (31 percent). Similarly, in the upstream industry, loan size, maturity, and the sponsor’s oil and gas exposure are also of magnitude slightly greater than in the downstream industry. Nevertheless, the sensitivity of the hedging likelihood to the price volatility could be significantly different between the upstream and downstream industries, which will be examined in a regression analysis.

5.2. Main Results: Determinants of the Offtake Adoption

Table 6 presents the results for the logit regressions of the likelihood that for a given project loan, an offtake contract has been adopted by the project company to hedge the risk of future prices of oil (or gas). Column (1) in Table 6 provides the regression results without the interaction term between the price volatility and sponsor's oil and gas beta, and columns (2)—(4) in Table 6 present the regression results by additionally controlling for such an interaction term.

Table 6: Logit Regression of the Offtake Adoption

Dependent variable	Log of odds of the offtake adoption			
Regression	**(1)**	**(2)**	**(3)**	**(4)**
Price volatility	1.494	2.604**	3.299**	2.093
	[1.028]	[1.229]	[1.296]	[1.542]
Price volatility × Sponsor's oil & gas beta		-14.034***	-23.828***	-23.533***
		[6.260]	[7.754]	[9.169]
Price volatility × Upstream dummy				1.415
				[2.173]
Sponsor's oil & gas beta		2.220	4.864**	4.985*
		[2.089]	[2.119]	[2.552]
Upstream dummy				0.967
				[0.839]
Credit risk: EPC-likelihood residual			1.247***	1.292***
			[0.176]	[0.206]
Growth in futures price	0.364	0.028	0.011	0.134
	[0.605]	[0.645]	[0.640]	[0.689]
Log of tranche size	-0.327***	-0.300**	-0.354***	-0.428***
	[0.125]	[0.132]	[0.136]	[0.141]
Log of project's total loan size	0.296*	0.315*	0.337	0.391*
	[0.173]	[0.173]	[0.214]	[0.234]
Maturity	0.107***	0.093***	0.127***	0.131***
	[0.033]	[0.035]	[0.041]	[0.043]
Refinancing dummy	-0.469	-0.444	-0.220	-0.073
	[0.393]	[0.399]	[0.552]	[0.586]
Currency risk dummy	0.367	0.395	0.532	0.352
	[0.396]	[0.402]	[0.490]	[0.507]
Host country: Credit quality	-0.990***	-1.075***	-1.427***	-1.497***

	[0.275]	[0.278]	[0.367]	[0.371]
Host country: Gov't bond spread	-0.066**	-0.072**	-0.100***	-0.106***
	[0.030]	[0.029]	[0.038]	[0.039]
Gas sector dummy	1.891***	1.744***	2.280***	3.099***
	[0.448]	[0.491]	[0.605]	[0.677]
After-crisis period dummy	0.979	1.178*	1.543**	2.051***
	[0.624]	[0.682]	[0.662]	[0.799]
Constant	0.277	0.628	0.848	0.099
	[1.238]	[1.127]	[1.564]	[1.604]
Number of observations	328	328	328	328
Log likelihood	-153.12	-147.73	-114.96	-110.44
Pseudo *R*-square	0.28	0.31	0.46	0.48

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, over the sample period of April 1996–October 2011. In this case, sponsor's oil & gas beta, referring to the sponsor company's stock-return sensitivity to changes in the logged prices of oil and gas, is estimated during a one-year period, ending six months before the loan date. The unit of observation is an individual loan tranche. Project's total loan size refers to the total size of multiple loan tranches made to a given project. Price volatility refers to the one-year moving average of the daily volatility of prices of oil and gas, respectively. EPC-likelihood residual refers to the residual from the logit regression of the EPC-adoption dummy, a proxy for the project's unobserved credit risk. Growth in futures price refers to the annual growth rate of the one-year maturity futures price of oil and gas, respectively. 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 10-year maturity government bond yield relative to the maturity-matched U.S. Treasury rate. After-crisis period dummy indicates whether or not the loan is made after the 2007-2008 crisis episode, set to one if the loan is made after 2008. Standard errors are inside the bracket and robust to cross-sectional clustering for a given project. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

From Table 6, we can find some insights as follows: an offtake contract is 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 positive coefficient on the gas sector dummy is consistent with the well-known fact that for gas development projects, lenders often require the project company to hedge the demand risk mainly due to the complexity of the price determinants in the natural gas market (Razavi, 2007). The second and third findings about the host country's credit quality (i.e., constant credit rating) and loan maturity indicate that the offtake agreement could be an effective tool to reduce the project loan's credit risk caused either by geopolitical risk factors or by the long maturity. The fourth finding about the after-crisis dummy indicates that after the 2007-2008 financial crisis, the loan market environment has substantially changed such that the required level of risk management has been increased so that after the crisis, oil and gas project companies are more likely to hedge the price risk than before.

We turn to discussing the main results about the impact of the price volatility on the hedging likelihood. We can see that the price volatility increases the likelihood that the project company hedges the risk of future prices of oil and gas. An increase in the oil price volatility would increase the oil project company's cash-flow volatility in the near future, implying that the sponsor company's exposure to the oil price risk would also increase. In response, the sponsor company is more likely to let its subsidiary oil project company to hedge the oil price risk so that the effect of the oil price volatility on the sponsor company's own oil risk exposure is mitigated.

Next, we discuss the coefficient on the interaction term between the price volatility and the sponsor's oil and gas beta.[6] Regression results (2)—(4) in Table 6 show that this coefficient is negative and significant at the one percent level (where the direct effect of the sponsor company's oil beta on the project's hedging likelihood is controlled for). That is, in response to an increase in the oil price volatility, a sponsor with a smaller oil beta is more likely to let its subsidiary oil project company to hedge the oil price risk than an otherwise equivalent sponsor with a larger oil beta is. Note that a sponsor company with the stronger willingness to

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[6] In section B in Online Appendix, we provide the offtake-adoption regression results for the case in which we replace the sponsor's oil and gas beta by two measures of the sponsor's non-oil risk exposure: sponsor's return volatility (labeled *total risk*) and sponsor's market beta. Results in this case (section B in Online Appendix) show that the coefficient on the interaction term between the price volatility and the sponsor's total risk (or sponsor's market beta) is not significant.

manage its own exposure to the oil price risk would have exerted more effort to insure its business and hence its frim value against the oil price shocks so that the company's stock returns would have been less sensitive to the oil price shock. Thus, our findings suggest that a sponsor company's willingness to reduce its own exposure to the oil price risk is also persistently observed in the case of its subsidiary project company's risk management practices: the smaller the sensitivity of the sponsor company's stock returns to the oil price risk, the higher the likelihood that its subsidiary project company will also hedge the oil price risk. Put differently, a sponsor company's oil beta, which is easily observable, can be useful in predicting the subsidiary project company's decision to hedge the oil price risk, which is valuable information to lenders, other investors and third parties involved in the project.

Our findings are robust to controlling for the unobserved component of the project's credit risk. See regression results (3) and (4) in Table 6, compared to those in (2) in Table 6, where we additionally control for the residuals from the regression of an EPC-adoption likelihood as the proxy for the unobserved component of the project's credit risk. (See Table 8 for results for the logit regression of the EPC adoption.) First, we can see that the unobserved component of the project's credit risk itself is significantly and positively associated with the project company's offtake-adoption likelihood. That is, a project's unobservable credit risk, if any, that increases the project's default risk also increases the offtake-adoption likelihood, too. Second, the main estimation results (e.g., the coefficients on other control variables) are almost intact, especially the coefficient on the price volatility and the coefficient on the interaction term between the price volatility and sponsor's oil and gas beta. Thus, our findings are not likely to be biased due to omitted variables correlated with the project's unobserved credit risk.

Our findings are also robust to additionally controlling for the interaction term between the price volatility and the upstream dummy (where the upstream dummy itself is also controlled for). Results in this case, reported by the column regression (4) in Table 6, are almost the same with those in the baseline case of regression (3) in Table 6.

Economic significance of coefficients in Table 6 are provided by Table 7, which presents the predicted probability of the offtake adoption calculated at means and its relative change from 25th percentile to 75th percentile. The marginal effect of an increase in the interaction term between the price volatility and the sponsor's oil and gas beta in the fourth column of Table 6 is associated with a decrease of 5.13 percentage points in the probability of offtake adoption in Panel B of Table 7. For comparison, the marginal effect of an increase in the price volatility itself increases the offtake-adoption probability by 0.39 percentage points.

Table 7: Predicted Probability of The Offtake Adoption

Panel A: Predicted probability of the offtake adoption at means

Variable	**(1)**	**(2)**	**(3)**	**(4)**
Price volatility	0.314	0.549**	0.605***	0.387
Price volatility × Sponsor's oil & gas beta		-2.964***	-4.376***	-5.094***
Price volatility × Upstream dummy				0.261
Sponsor's oil & gas beta		0.468	0.893**	0.922**
Upstream dummy				0.178
Credit risk: EPC-likelihood residual			0.229***	0.239***

Panel B : Change in the predicted probability of the offtake adoption from 25th percentile to 75th percentile

Variable	(1)		(2)		(3)		(4)	
	From	To	From	To	From	To	From	To
Price volatility	0.27*	0.33	0.46***	0.61**	0.26***	0.82***	0.10*	0.49
		[0.06]		**[0.15]**		**[0.56]**		**[0.39]**
Price volatility × Sponsor's oil & gas beta			-2.50**	-3.32**	-1.89**	-5.94***	-1.43	-6.56***
				[-0.82]		**[-4.05]**		**[-5.13]**
Price volatility × Upstream dummy							0.07	0.33
								[0.26]
Sponsor's oil &			0.39	0.52	0.38**	1.21**	0.26	1.18*

gas beta	**[0.13]**		**[0.83]**		**[0.92]**
Upstream dummy				0.05	0.23
					[0.18]
Credit risk: EPC-likelihood residual		0.09***	0.31***	0.06**	0.30***
			[0.20]		**[0.24]**

Note: Panel A reports predicted probabilities calculated when the independent variables are valued at the mean, based on the regression of Table 6. Panel B reports the change in predicted probabilities calculated when the independent variables are valued between 25th percentile and 75th percentile. The differences are inside the bracket. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level..

We have discussed earlier that main regression of the offtake-adoption likelihood are robust to controlling for the unobserved credit risk, for which proxy we have used the residual from the logit regression of the EPC adoption. We discuss the results for this logit regression of the EPC adoption.

Table 8: Logit Regression of the EPC Adoption

Dependent variable	Log of odds of the EPC adoption	
Regression	**(1)**	**(2)**
Corresponding offtake-adoption regression	**Table 6 Reg (3)**	**Table 6 Reg (4)**
Price volatility	0.639	0.669
	[1.083]	[1.290]
Price volatility × Sponsor’s oil & gas beta	3.045	3.283
	[4.896]	[5.005]
Price volatility × Upstream dummy		-0.471
		[1.362]
Sponsor’s oil & gas beta	-4.779	-4.892
	[2.957]	[3.019]
Upstream dummy		0.651
		[0.636]
Growth in futures price	0.274	0.313
	[0.627]	[0.643]
Log of tranche size	-0.255*	-0.270*
	[0.146]	[0.147]
Log of project’s total loan size	0.763***	0.773***
	[0.184]	[0.188]
Maturity	0.093***	0.095***

	[0.027]	[0.026]
Refinancing dummy	-1.465***	-1.456***
	[0.394]	[0.389]
Currency risk dummy	1.023**	0.973**
	[0.376]	[0.377]
Host country: Credit quality	0.400*	0.402*
	[0.224]	[0.225]
Host country: Gov't bond spread	0.106*	0.097*
	[0.056]	[0.055]
Gas sector dummy	0.460	0.802
	[0.441]	[0.541]
After-crisis period dummy	1.133*	1.140*
	[0.596]	[0.593]
Constant	-5.106***	-5.619***
	[1.347]	[1.427]
Number of observations	328	328
Log likelihood	-156.01	-155.09
Pseudo *R*-square	0.30	0.30

Note: this table provides the results of estimating the logit regression of the project company's decision to use an EPC contract to reduce the pre-completion default risk, over the sample period of April 1996–October 2011. The unit of observation is an individual loan tranche. Project's total loan size refers to the total size of multiple loan tranches made to a given project. Price volatility refers to the one-year moving average of the daily volatility of prices of oil and gas, respectively. Sponsor's oil & gas beta refers to the sponsor company's past stock-return sensitivity to changes in the logged prices of oil and gas. Sponsor's market beta refers to the sponsor company's past stock-return sensitivity to returns to the market portfolio. Growth in futures price refers to the annual growth rate of the one-year maturity futures price of oil and gas, respectively. 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 10-year maturity government bond yield relative to the maturity-matched U.S. Treasury rate. After-crisis period dummy indicates whether or not the loan is made after the 2007-2008 crisis episode, set to one if the loan is made after 2008. Standard errors are inside the bracket and robust to cross-sectional clustering for a given project. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 8 presents the results for the logit regression of the EPC adoption: regression (1) and (2) in Table 8 corresponds, respectively, to regression (3) and (4) in Table 6. From Table 8, we can see that the relationships between EPC-adoption likelihood and the loan characteristics (such as maturity, refinancing dummy and currency risk dummy) are significant (at the five percent level), and that the sponsor's oil and gas beta and price volatility are not significantly associated with the EPC-adoption likelihood. These findings suggest that the adoption of EPC arrangements is related to a project's unobserved credit risk, for which loan-specific characteristics matter, but not necessarily related to the project's exposure to the price risk of oil and gas. The reason is that the adoption of EPC arrangements is not effective in hedging the price risk of oil and gas.

5.3. Discussion

5.3.1. Implications for Reputation of Risk Management and Cost of Funding

Efficient ex-ante risk management techniques (e.g., risk 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 efficient ex-ante risk management techniques as follows: Consider a sponsor company with a small oil beta, which highly values risk management and hence has already successfully insured the company's own stock returns against the changes in the oil price. Our findings suggest that for such a sponsor company, its subsidiary project company is also likely to hedge the oil price risk, which would contribute to further protecting the sponsor company's cash flow against the oil price risk. Thus, the sponsor company's cash flow is expected to be protected from the oil price risk not only in the past but also in the future, which can greatly improve the sponsor company's risk management reputation and hence substantially reduce the sponsor's cost of funding projects.

5.3.2. Robustness

We discuss two factors related to the robustness of our findings. First, the delivery price of offtake contracts is important in affecting the demand and supply of offtake arrangements. Unfortunately, information on such a price is unavailable as it is highly confidential between the two counterparties signing each offtake contract. Note that in our regression analysis, we control for growth in the futures price of oil (gas), which reflects changes in the global demand and supply of oil (gas) and may also capture, to some extent, changes in the demand and supply of oil (gas) offtake contracts. If the delivery price of offtake contracts diverges greatly from the futures price, then our analysis can not tell much about how such a price divergence between offtake and futures contracts would affect our main results.

Second, in our study, the offtake decision variable is encoded as a dummy indicating whether or not the offtake arrangement exists. That is, we study the *extensive margin*, i.e., how many projects are likely to adopt offtake arrangements. There is another interesting dimension of the hedging policy: *intensive margin*, i.e., how much fraction of output is hedged, of which information is not provided by our data source. It would be interesting to study how differently the extensive and intensive margins respond to the price volatility, for which our analysis can not suggest anything due to the lack of data on the intensive margin.

6. Conclusion

This paper empirically studies the determinants of oil and gas project companies' decisions to hedge the risk of future prices of oil and gas. We take the changes in volatilities of oil and gas prices as exogenous shocks to the cash-flow risk of oil and gas project companies. With a sample of 328 loans made to oil and gas development projects in 30 countries during 1996-2011 period, we investigate whether or not volatilities of oil and gas prices increase the likelihood that oil and gas project companies hedge the price risk, especially how such a sensitivity of the hedging likelihood to the price volatility is related to the sponsor company's exposure to the risk of oil and gas prices.

We find that the price volatility of oil and gas significantly increases the hedging likelihood of an oil and gas project company. This result supports that corporate hedging sensitively responds to the changes in the market environment relevant to the risk of the company's future cash flows. Importantly, we also find that the sponsor company's willingness to reduce its exposure specifically to the oil (or gas) price risk increases the sensitivity of an oil (or gas) project company's hedging likelihood to the oil (or gas) price volatility.

It would be interesting to investigate various channels through which risk management practices affect the energy firm's market value, especially how differences in such an effect are related to investors' risk appetite. We leave it for future work.

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Appendix: Definitions of Variables

Price volatility: standard deviation of the log of the daily oil (or gas) spot price during the one-year period, ending one day before the loan date, which is standardized so that it has values from zero to one. More specifically, the oil price volatility is measured as follows: $Oil\,price\,volatility_t = (\sigma_t^{Oil} - \sigma_{Min}^{Oil})/(\sigma_{Max}^{Oil} - \sigma_{Min}^{Oil})$, where σ_t^{Oil} refers to the standard deviation of the log of the daily oil prices over a one-year period ending one day before the loan date *t*, and σ_{Max}^{Oil} and σ_{Min}^{Oil} the maximum and minimum values, respectively, over all observations of σ_t^{Oil}.

Sponsor's oil and gas beta: sensitivity of the sponsor company's stock price to the rate of changes in the near-month maturity futures price of oil (or gas), estimated by using the two-factor regression model where the other factor is the returns to the market portfolio. The sponsor's oil and gas beta is estimated using the sponsor's daily stock returns during a one-year period, ending six months before the loan date.

Credit risk: EPC-likelihood residual: the residual from the logit regression of the EPC-adoption dummy.

Growth in futures price: rate of change in the one-year maturity futures price of oil (or gas) from one year ago. The futures price of oil (or gas) is measured as its average during a one-year period, ending one day before the loan date.

Log of tranche size: log of the loan tranche size, measured as the principal value in millions of constant 1985 U.S. dollars.

Log of project's total loan size: log of the total size of multiple loan tranches made to a given project.

Maturity: the length (in years) of time from the loan date to the maturity date when the principle payment is scheduled.

Refinancing dummy: dummy set to one if the loan is used to refinancing an existing project that were financed previously.

Currency risk dummy: dummy set to one if the loan denomination currency differs from the local currency of the host country where the project's production facility is located.

Host country: Credit quality: constant (discrete) credit grade of a given host country assigned by the *S&P*, where a higher value is assigned to a better credit quality.

Host country: Gov't bond spread: time-varying (continuous) spread of the host country's 10-year government bond yield, relative to the 10-year U.S. Treasury rate.

Gas sector dummy: dummy set to one if the project's industry belongs to the gas sector, and zero for the oil sector. The gas sector includes (iv) gas exploration and development, (v) gas pipeline, and (vi) gas distribution industries; the oil sector includes (i) oilfield exploration and development, (ii) oil pipeline, and (iii) oil refinery industries.

Upstream dummy: dummy set to one if the project belongs to the upstream industries and to zero if the project belongs to the downstream industries. More specifically, the upstream industries refer to exploration and extraction of oil and gas and include the two industries: (i) oilfield exploration and development and (iv) gas exploration and development industries. Other industries, related to refining and distribution, are defined as the downstream industry.

After-crisis period dummy: dummy indicating whether or not the loan is made after 2007-2008 financial crisis episode, equal to one if the loan is made after 2008, and zero otherwise.