Credit Spread Determinants and Interlocking Contracts: A Clinical Study of the Ras Gas Project

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A B S T R A C T

A popular approach to modeling and valuing firms views them as webs of contracts between stakeholders. This paper provides an in-depth study of the allocation of residual risks not explicitly managed through such interlocking contracts in the context of project finance. Focusing on the case of the Ras Gas project, we relate its credit spreads as measure of investor risk perceptions to firm-specific risk factors in the context of 25-year supply agreements, debt covenants and a debt-service guarantee contingent on output prices. Consistent with theoretical predictions, we find that unmanaged risk factors affecting the supply agreement drive Ras Gas' credit spreads, but not managed ones. Interpreting our findings as evidence for the nexus of contracts view of the firm, we discuss some implications for financial design and valuation.

1. *Introduction*

Investors' risk perceptions have long been recognized to be a function of firm-specific variables and, in particular, risk factors affecting firm value. In this paper, we analyze the credit-spread determinants of the Ras Laffan Liquefied Natural Gas Company, Ltd. (Ras Gas for short) in terms of the project's contractual structure.[1] We pursue two objectives with this study. On the one hand, we attempt to provide some empirical evidence on credit-spread determinants from the perspective of the firm as a nexus of contracts. On the other, we wish to draw attention to the field of project finance that offers many exciting and unique opportunities to investigate issues of fundamental importance in finance. Indeed, no other practical case corresponds more closely to the standard setting of corporate-finance models in terms of time structure with corresponding resolution of uncertainty, small number of investors and classes of financial claims, actions by contracting parties, a single indivisible investment, etc.

The view of the firm as a nexus of contracts, first formulated in the seminal papers by Alchian and Demsetz (1972) and Jensen and Meckling (1976), underlies much of modern corporate finance. According to this view, the firm is defined in terms of the individual contracts that govern its existence such as labor and other input contracts, financial contracts including debt covenants and guarantees, supply and output purchase contracts. The nature and interaction of these contracts motivate financing choices (Fama, 1990 or Zingales, 2000), determine corporate-governance arrangements (Jensen and Meckling, 1976), and can provide a framework for firm valuation (Kaplan and Ruback, 1995).

From a corporate-finance perspective, this view of the firm begs the question of how financial contracts interact with other contractual relationships, and how capital markets price these interactions. In theory, the firm as a collection of contracts should be worth the sum of its

[1] See Zingales (2000) for a discussion of the necessary conditions for a firm's value to be the sum of its contracts.

constituent contracts. In practice, firms are very complex webs of contractual relationships, whose intricate interplay does not easily lend itself to empirical investigation. Indeed, prior studies of financial and organizational design based on large samples have focused on one contractual relationship at a time and are unable to identify the precise distribution of risks over a longer period. However, there is one particular area where a firm's contractual structure is sufficiently well-documented for such analysis: project finance. This financial technique is defined as the raising of funds to finance a single indivisible large-scale capital investment project whose cash flows are the sole source to meet financial obligations and to provide returns to investors.[2]

The Ras Gas project extracts, processes and sells liquefied natural gas (LNG) from a field off the shore of Qatar. We study the effect of three interlocking contracts on the credit spreads of the project's actively traded bonds that serve as a measure of investors' risk perception: (i) two 25-year output sales and purchase agreements (SPAs) with a dominant output buyer, (ii) the bond covenant, and (iii) a debt-service guarantee by Mobil Corporation, one of the shareholders, to debtholders contingent on output prices. These contracts cannot possibly anticipate all future contingencies, including non-enforceability of liens on assets and receivables. In Ras Gas' case, such contractual incompleteness primarily stems from the very specific nature of the required investment in LNG infrastructure (asset specificity), their location, and the long-term nature of the sales contract.

In such circumstances, the project's debtholders bear the costs of unforeseen contingencies and potential opportunistic behavior by the output buyers ("off-takers") because the LNG supply contract as the major source of revenue effectively secures the debt. Consequently, we would expect debt markets to price any off-take risk not explicitly managed through the firm's nexus of contracts. The Ras Laffan project offers the unique opportunity of

[2] Brealey, Cooper and Habib (1996) contains an excellent survey of the economic issues in project finance; for a

assessing the risk dynamics arising from interlocking contracts on the basis of market information because both the output seller (Ras Gas) and dominant buyer, the Korea Electric Power Company (Kepco for short), have actively traded global bonds outstanding.

Motivated by the structural default model of Merton (1974) we analyze the determinants of Ras Gas' credit risk in terms of firm-specific risk variables that influence the project's underlying (cash) asset value. Using a sample of daily data from January 1997 to March 2000, we relate Ras Gas credit spreads to explanatory variables such as Kepco's credit spreads (proxy for counterparty risk), the Brent oil reference price used to settle LNG sales (output-price risk), Mobil's stock price (debt-service guarantee risk), Korean control variables (country risk), and returns on four regional emerging debt market indices (common economic shocks and spillover effects). This market-based approach to gauging risk perceptions allows us to investigate how the three interlocking contracts allocate project uncertainty between shareholders and debtholders and test for managed vs. unmanaged risks. We repeat the analysis for changes in credit spreads and in a simultaneous-equation setting to distinguish the risk factors' direct and indirect effects.

We find that Ras Gas credit spreads exhibit a very high degree of persistence. By far the most important explanatory variable for both levels and changes in credit spreads is the off-taker's (Kepco) credit spread. Investors rationally anticipate the incidence of the output buyer's financial and economic condition on the riskiness of their bond because any material deterioration in the economic prospects of Kepco increases the likelihood of breach of contract and, hence, Ras Gas' credit risk. However, we also find evidence for over-reaction and market inefficiencies stemming from clientele effects in the lag structure of Kepco credit spreads.

The output price (Brent) comes out largely insignificant: investors seem to disregard commodity-price risk. Since Mobil Corp. has effectively insured the debt service against any

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detailed introduction to project finance, see Finnerty (1996).

revenue shortfall due to low output prices, this result comes as no surprise in light of the minimal price guarantee to debtholders. As predicted by theory, markets do not price risks that are credibly managed through the firm's contractual structure. Similarly, proxies for the credit worthiness of Mobil as the guarantor are mostly insignificant reflecting the parent company's high credit rating (AA to AAA over the sample period).

In terms of Korean country risk factors, we find evidence of Ras Gas exposure to the Korean currency both directly and indirectly through Kepco credit spreads despite the fact that the overall off-take agreement is denominated in US dollars (USD). Since Kepco's revenue accrues almost entirely in Korean Won, any currency depreciation makes USD denominated energy imports more expensive and erodes its financial position, which might call into question contractual commitments. Hence, Ras Gas and its investors bear some Korean currency risk. We also find significant evidence of common economic shocks affecting emerging economies. As returns in European, Middle Eastern and Latin American emerging debt markets fall, Ras Gas spreads widen considerably. In particular, the impact of contemporaneous and past events in European emerging debt markets stands out. This responsiveness reflects spillovers from the 1998 Russian financial crisis, which heavily affected other emerging debt market segments.

To complement our analysis of project risks, we also derive Ras Gas' underlying asset value together with market-based valuations of its non-traded equity and default probabilities. Extending the Merton (1974) framework to a private equity setting, we use an approach similar to Ronn and Verma (1986) to estimate asset values and volatilities from bond rather than equity prices and their volatility. We find that underlying firm value mainly stems from cash assets such as the long-term supply contract rather than physical assets that are of little value to investors due to their geographic location and dedicated use. Implied equity values and default probabilities evolve in close correspondence with Ras Gas credit spreads as expected in a structural default model.

While the theoretical foundations of project finance have received some attention in the literature (see, e.g., Shah and Thakor, 1987, Berkovitch and Kim, 1990, Chemmanur and John, 1996) there are very few empirical studies of project finance. This paper represents a first attempt to fill this gap in the literature.[3] Esty (1999) describes a comparable crude oil project in Venezuela but the existence of a well-developed oil spot market does not lead to a bilateral monopoly with the ensuing contract risk dynamics. Esty and Megginson (2003), who analyze how political risk shapes the syndication process and pricing of project loans, complement our findings from a private debt perspective. Our analysis is also related to the literature on bond covenants going back to Smith and Warner (1979). We show that other contractual relationships besides covenants affect bondholders so that one cannot abstract from their contracting and enforcement costs. Furthermore, our results highlight the interdependence of debt finance and risk distribution recently identified in the context of hedging by Mello and Parsons (2000).

Our main contribution consists in showing how the firm as a nexus of contracts divides fundamental risks into managed and unmanaged ones that it allocates between different stakeholders. By investigating how markets assess the nature of these risks in the pricing of financial claims, we show that bondholders and shareholders share residual risks in spite of covenants otherwise meant to specifically isolate the former from operational uncertainty. This risk bearing stems from the lack of appropriate hedging opportunities, contractual incompleteness and the non-recourse (stand-alone) feature of project finance rather than from a deliberate attempt by management to pursue high risk, low value activities in order to increase shareholder gains at the expense of debtholders (debt agency).[4] A further contribution consists in shedding light on how

[3] See Tufano (2001) for a discussion of the merits and importance of clinical studies in this respect.
[4] See, e.g., Smith and Warner (1979), Green (1984) and John (1987) for more on this point. Note, however, that project managers and shareholders could still exploit their informational advantage in leaving output supply contracts incomplete in a manner beneficial to their private interests.

markets respond to the deliberate modification of fundamental firm risks through a set of interlocking contracts. In particular, the finding that bond prices quickly respond to unmanaged risk factors but do not respond to managed ones provides new evidence both for the informational efficiency of global bond markets and the efficacy of contractual risk-management techniques.

The paper is organized as follows. The next section provides background information on the Ras Gas project and its contractual structure. Section 3 describes the project-specific sources of contractual incompleteness and risk factors. Section 4 contains a description of our data and methodology. In Sections 5 and 6, we summarize the results of our time-series analysis. Section 7 discusses asset values and default probabilities, and Section 8 concludes. We relegate all tables to the Appendix.

2. The Ras Gas Project

The Ras Gas project,[5] while a typical example of its kind, offers rich analytic opportunities in corporate finance through its simple and well-documented financial and contractual design. Its crucial features are the recourse to global bond markets (pricing of firm-specific risks), the long-term reliance on a single customer (long-term sales and purchase agreement), an interlocking contractual structure (debt contracts contingent on long-term supply contracts with unforeseen contingencies), and, last but not least, the presence of significant external shocks that help to statistically identify relations between key variables. Although Ras Gas' equity is privately held, the presence of a large, liquid bond allows us to gauge investor reaction to the changing economic fortunes of the project by relating its credit spreads to default expectations, breach-of-contract risks, output-price risk, and exogenous cash-flow determinants.

The Ras Laffan Natural Liquefied Gas Company, Limited (Ras Gas) is a joint venture between the state-owned Qatar General Petroleum Corporation (current stake: 66.5%) and Mobil Corporation of the US (now 26.5%), located in Qatar (Persian Gulf).[6] Ras Gas, a Qatari company, has the right to develop up to 10m tons of liquefied natural gas (LNG) annually from Qatar's North Field, the world's largest unassociated natural gas field that contains about 9% of the world's gas reserves. To this end, Ras Gas has constructed a liquefication facility to clean, cool, and compress natural gas into LNG, offshore drilling platforms, storage facilities, pipelines and port loading facilities. Construction was completed in late 1999 at a cost of $3.264 billion, slightly below the initially projected $3.4 billion. Table 1 in the Appendix summarizes the project's capital structure and uses of funds during its construction and start-up phase.

Capital-market debt was instrumental in the successful design and financing of this project because it provided financial flexibility not otherwise available through the syndicated loan market. A typical challenge for large projects such as Ras Gas consists in the massive up-front investment coupled with long construction periods that imply insufficient debt-service capacity during the first 6 to 8 years, the maximum maturity typically available for projects in the syndicated loan market. Only the public debt markets offer longer maturities that could stretch out principal repayment significantly beyond the start-up phase, mitigating debtholders' liquidity concerns and assuring the project's financial viability. To put the Ras Gas financing into perspective, its $1.2 billion bond offering ($400m due in 2006, $800m due in 2013) is the largest debt issue for any international project to date, the first for a LNG project, and the first for a Middle Eastern issuer with a maturity beyond 7 years.[7]

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[5] This overview draws on Ras Gas' bond offering circular (Goldman Sachs, 1996), Standard and Poor's (1996, 1999, 2000, 2004), and Randolph and Schrantz (1997). According to Greg Randolph, Goldman Sachs, Ras Gas, whose contractual structure is much copied, exemplifies state-of-the-art project design and financing.

[6] The initial stakes were 70% and 30%, respectively, and fell with the addition of two Japanese output buyers as shareholders. Kogas has the option to acquire a 5% equity stake, which is one of the standard devices to overcome contractual incompleteness and hold-up problems (see Nöldeke and Schmidt, 1995).

[7] The recourse to public debt markets to finance projects is a relatively recent phenomenon. In 1996, the total amount of project bonds issued was $4.79b (with Ras Gas accounting for 25% of this amount) while total bank lending to projects amounted to $42.83b. By 1999, global project lending by banks had increased to $72.392b ($56.65b in

Our analysis focuses on the larger and more liquid of the two Ras Gas bonds that proved to be in unexpectedly high demand. Despite increasing its size, the offering sold out within two hours on the first day (December 16, 1996) and was twice over-subscribed. In fact, Ras Gas could have funded its entire investment in the global bond markets but decided to keep a bank-loan component at an average all-in cost of 9.60%, about 95 basis points above the average all-in cost of the bonds (8.65%), in order to insure easier access to bank debt for future project expansion.[8] The long bond due in 2013 has a total size of $800m and was priced at an issue yield of 8.294% or 187.5 basis points above interpolated US Treasury bond yields. Issued as a global bond, i.e., both as an off-shore (Eurodollar) and 144A foreign (Yankee) debt security, it was sold to institutional investors with strong international demand (20% international, 80% US based investors).[9]

Both bonds are listed on NASD's PORTAL system and their secondary trading activity is reported through Nasdaq's Trade Reporting and Compliance Engine (TRACE).[10] As global offerings, the bonds are fungible across their Eurodollar and Yankee tranches, further enhancing their liquidity. According to Goldman Sachs, who as lead managers have acted until 2001 as *de-facto* market makers in the issues, the 2013 bond trades almost daily with typical trading volumes of up to $15m and has attracted a significant analyst and investor following.[11] As a result, we can use its spread over US Treasuries to gauge market perceptions of changes in Ras Gas' prospects and, hence, the firm's riskiness.

As is customary in project finance, most of the LNG output was sold through two long-

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1998) while global project bond issuance had risen from $9.979b in 1998 to $19.966b (Pepiatt and Rixon, 2000) so that the proportion of project debt raised in bond markets had grown from 10.06% in 1996 to 21.62%. For more data and an excellent overview of the project finance market, see Esty (2000) and Esty and Sesia (2005). For a description of the syndicated loan market's role in more traditional project finance, see Esty and Megginson (2003).

[8] Offering details are based on personal communications by Greg Randolph, Goldman Sachs.

[9] According to Goldman Sachs, about 70 institutional investors and banks excluded from the syndicated and guaranteed loan tranches participated in the bond offerings with typical investments ranging from $15m to 20m (Greg Randolph; the largest single block bought was $125m).

[10] However, most of the trading in Ras Gas bonds takes place over the counter according to TRACE.

term sales and purchase agreements (SPAs) before construction started. The Korea Gas Corporation (Kogas), the principal output buyer ("off-taker"), is a state-owned company whose shareholders include the Republic of Korea (50%), the Korea Electric Power Corporation (Kepco: 34.7%) and regional governments (15.3%). Kogas shares its credit rating with the sovereign rating of South Korea as does Kepco, whose shares trade as American Depositary Receipts (ADR) on the NYSE. Most of the Ras Gas LNG bought by Kogas, which has a legal monopoly on gas sales and purchases in Korea, is for resale to Kepco as fuel for peak-load electricity generation. Consequently, Kogas only serves as an intermediary and transport agent on behalf of Kepco which is Ras Gas' *de facto* off-taker (Standard and Poor's, 1999) and plans to double its existing LNG powered electricity generation in the next years. Figure 6 in the Appendix summarizes Ras Gas' contract and cash-flow structure.

Kogas-Kepco account for more than 75% of the project's expected revenue through the two long-term SPAs that provide most of the collateral because debtholders hold the rights to all receivables as undivided security interest under New York law. Creditors also have a theoretical security interest in the Ras Gas assets in Quatar under Qatari and New York law but rating studies and investors seem to dismiss these rights as too uncertain (Standard and Poor's, 1999). In order to minimize moral hazard in payments, Kogas and other output buyers make payment for each month's gas shipments directly to an off-shore trust account whose administrator then services public and private debt and remits the balance to Ras Gas for operational expenses and dividends on a monthly basis (see Figure 6 in the Appendix).

The two sales and purchase agreements with Kogas stipulate a fixed off-take quantity of 4.8 million (metric) tons annually of LNG. Since August 1999, Kogas is receiving LNG shipments for 25 years on a take-or-pay basis. Under such an agreement, Kogas on behalf of

[11] The smaller 10-year bond due in 2006 has been bought up by Middle-Eastern investors and trades infrequently.

Kepco is obligated to pay for the gas whether or not they take delivery. Kogas can simply make a cash payment in lieu of delivery, which is credited against charges for future deliveries. However, they can vary gas shipments by deferring up to 5% *per annum* (but not more than a cumulative total of 10%) which must be paid for within 5 years whether Kogas accepts delivery or not. Such an arrangement effectively transforms demand risk into breach-of-contract risk: if Kepco is unwilling or unable to take delivery over a longer period, Kogas will have to unilaterally terminate the SPAs on their behalf. The remaining LNG produced is for sale on the nascent LNG spot market and two small off-take agreements with Japanese customers.

Since LNG and its derivatives are close substitutes for crude oil, their prices are effectively indexed to the latter. Following market conventions, crude-oil reference prices such as the Japan Crude Cocktail or the Brent Blend, the most widely used index for LNG pricing, serve as the monthly settlement price for Ras Gas' LNG shipments. One metric ton of LNG has the energy content of about 8.68 barrels of crude oil and is priced accordingly, i.e., as 8.68 times the crude-oil price per barrel. Hence, the value of the Kogas-Kepco SPAs crucially depends on prevailing world oil prices. The revenue from the firm's other products, in particular field condensate, a high-quality crude-oil substitute that naturally occurs in the liquefication process, and some LNG spot sales similarly follow crude-oil spot prices.

Hence, the Korean SPAs pose two principal risks for creditors: breach-of contract by Kogas and output-price variability through the fluctuation of world oil prices, one of the most volatile commodities in recent years. Given the AA credit rating of Kogas and Kepco in 1996 and the high demand for energy in Korea, the former risk looked remote at issue, especially in light of Korea's economic success prior to the issuing of the bonds and the planned doubling of Kepco's electricity generation from LNG over the next decade.[12] To mitigate price risk, Mobil

[12] In fact, Ras Gas deliveries cover Kepco's LNG needs only through 2001 (Standard and Poor's, 2004).

Corporation, the parent company that originally designed and now operates the project, has given an effective minimal price guarantee for debt-service purposes to all senior debtholders, i.e., banks, export credit agencies, and bondholders.

This guarantee takes the form of an unsecured, revolving subordinated $200 million loan for debt-service payments (reaffirmed by ExxonMobil after the firms' merger in November 1999). The loan is triggered if the trust account (see Figure 6 in the Appendix) has insufficient funds for debt service on a due date because monthly LNG settlement prices have fallen below the annual break-even threshold. In this case, the account's trustee can draw down the loan to make good on any debt-service shortfall strictly due to an oil price lower than the minimum price implied by Mobil's guarantee in any given year. Since all debt is of the same seniority (*pari passu*), debtholders share equally in the guarantee over the life of their respective instrument.

Standard and Poor's (1999) estimate that, over the entire project's life, the average break-even Brent oil price activating the guarantee is about $10.15 per barrel (bbl). However, in the early years before 2003, a Brent oil price of $14/bbl might suffice to activate the guarantee. Since the price-guarantee loan is subordinated to any senior debt, it does not create risks for bondholders in the form of additional claims on the project's collateral. By contrast, shareholders do not have any rights against the project until the senior debt has been paid in full. Any loan balance will simply be repaid from the trust account once oil prices have sufficiently recovered to again warrant equity distributions.[13] As a result, the equity exposure to commodity-price risk becomes explicit and path dependent because any triggering of the debt-service guarantee ultimately reduces the value of shareholders' residual income rights.

The nexus of contracts that we study consists of (i) the two long-term sales-and-purchase

[13] From a risk distribution and hedging perspective, this arrangement makes a lot of sense. A large, vertically integrated energy company such as Mobil might easily find a low-cost natural hedge for the guarantee in its downstream activities whereas individual investors would be hard pressed to find appropriate hedging instruments.

agreements between Ras Gas and Kogas-Kepco, (ii) the debt contract between Ras Gas and its bondholders (covenant provisions), and (iii) Mobil's debt-service guarantee to bondholders contingent on break-even (oil) prices.[14] At its heart lies the reliance of the debt contract on future cash flows from Kogas and Kepco that effectively collateralize the project's long-term debt but are uncertain themselves and therefore require additional guarantees. In this sense, Ras Gas forcefully illustrates the point made in Fama (1990) that a firm's capital structure depends on all contracts with stakeholders, including output-purchase agreements and financial guarantees. Since the project is essentially a web of interlocking contracts, the provisions of the long-term supply contract shape its financial structure including the debt service-guarantee loan to the project by shareholders.

A large-scale project such as Ras Gas typically requires huge up-front investments with a high degree of asset (physical infrastructure) and relationship (output buyer) specificity. By their very nature, the necessary physical assets such as pipelines, storage facilities, LNG ship terminals, etc. cannot readily be removed and utilized elsewhere. Hence, the location of the assets in Qatar and the lack of credible legal institutions (contract enforcement) render them inadequate for creditor protection. Instead, the off-taker receivables provide the only effective security to debtholders so that cash-related assets become the focus of investors. The project's contractual structure then suggests the following economic balance sheet that is the starting point for our exploration of contractual risks and their transmission:[15]

[14] Strictly speaking, the offshore trust account that addresses operational risks (moral hazard in payments, maintenance, and operations) and certain sovereign risks (e.g., freezing of funds) is also part of the nexus of contracts.

[15] We are grateful to an anonymous referee for suggesting this particularly useful approach to project finance; Merton and Perold (1993) apply a similar concept to the study of explicit and implicit guarantees in financial firms.

Assets	Liabilities
PV of short-term sales of LNG and condensate net of costs	PV of Royalties and taxes owed to Qatar
Two SPAs with Kogas (Kepco) net of costs	Public debt: bonds Private debt: commercial-bank and export-credit-agency guaranteed loans
Contingent debt-service guarantee by Mobil	Equity (private)

Figure 1. Ras Gas Economic Balance Sheet

Since the Kogas-Kepco contracts account for approximately 75% of annual project revenue, short-term LNG and condensate sales roughly cover operating expenses together with royalties and taxes due to Qatar that are not expected to exceed 20% of revenue on a yearly basis (Standard and Poor's 1999, 2004). The respective cash flows simply net out in the preceding economic balance sheet so that the value of financial claims crucially depends on both the net value of the Kogas SPAs and Mobil's debt-service guarantee contingent on output prices. In essence, the Kogas-Kepco SPAs resemble to a fixed payment bond contingent on commodity prices indirectly issued by the Korean entities to Ras Gas investors. Hence, we would expect that risks affecting the off-take agreements with Kogas feed through to debt claims because the former serve as security for the latter.

3. Risk Factors and Contractual Incompleteness

The economic balance sheet in Figure 1 suggests that default risk primarily arises from direct counterparty risk rather than the general financial condition of the project. From the perspective of Kepco or Kogas, commitment to a long-term off-take contract poses the difficulty of not knowing at the time of contracting the future value of the output, i.e., future settlement prices (Brent oil prices), the availability of re-contracting opportunities, and Korean demand for electricity and gas. Hence, a project such as Ras Gas faces the danger that its dominant buyer reneges on the off-take agreements if alternative sources of LNG supplies are more cheaply available elsewhere or Kepco and Kogas experience financial distress.

In the presence of a well-developed LNG spot market, such opportunistic behavior by the output buyers would hardly matter because Ras Gas could simply sell its output for immediate delivery. However, the lack of transportation capacity and the heavy up-front investments in dedicated facilities by LNG producers and buyers have hampered the emergence of such a spot market.[16] It is precisely this absence of alternative markets and sources of revenue that exacerbates the consequences of contractual incompleteness and non-enforceabilities. Hence, the most important risk for Ras Gas and its investors consists in the breach of contract or the unilateral renegotiation of the SPAs by Kogas or Kepco, the ultimate off-taker. Debtholders are particularly vulnerable to strategic behavior not only from shareholders, but also from Ras Gas' dominant customer because they are locked into the project with only the cash assets, i.e., receivables from the long-term SPAs, as security. Although the off-take agreements include deferral options,[17] meant to pre-empt breach of contract, the demand risk arising from their exercise is directly passed on to investors and, especially, debtholders. Our analysis focuses on the project's key unmanaged risk – the possible failure of the off-takers to honor their obligations – and how capital markets price the factors that drive counterparty risk into the publicly traded bonds.

[16] In 2000, spot deliveries and short-term reselling of LNG cargoes accounted each for less than 2% of the world LNG market (3.8% of worldwide LNG shipments up from 2% in 1996; Tusiani, 2001). Standard and Poor's (1999) reckon that "[l]ong-term contracts for LNG still continue to dominate the LNG trade because of expense and scope of dedicated systems for delivering, receiving, and using LNG. A true short-term spot trading market remains elusive for the foreseeable future." For more on current LNG trading trends, see Banaszak (2001).

[17] In the aftermath of the Asian financial crisis, Korean electricity demand declined in 1998 by about 3.6% after previously growing by 10% annually. As a result, Kepco reduced purchases of LNG, its marginal fuel, from Kogas by as much as 22%. However, electricity demand has recently picked up (8.1% increase in 1999), and, although demand growth is expected to fall short of initial forecasts, Kepco still plans to add about 20,000 MW of generation capacity including LNG fired power stations over the next years (Standard and Poor's, 1999, 2000).

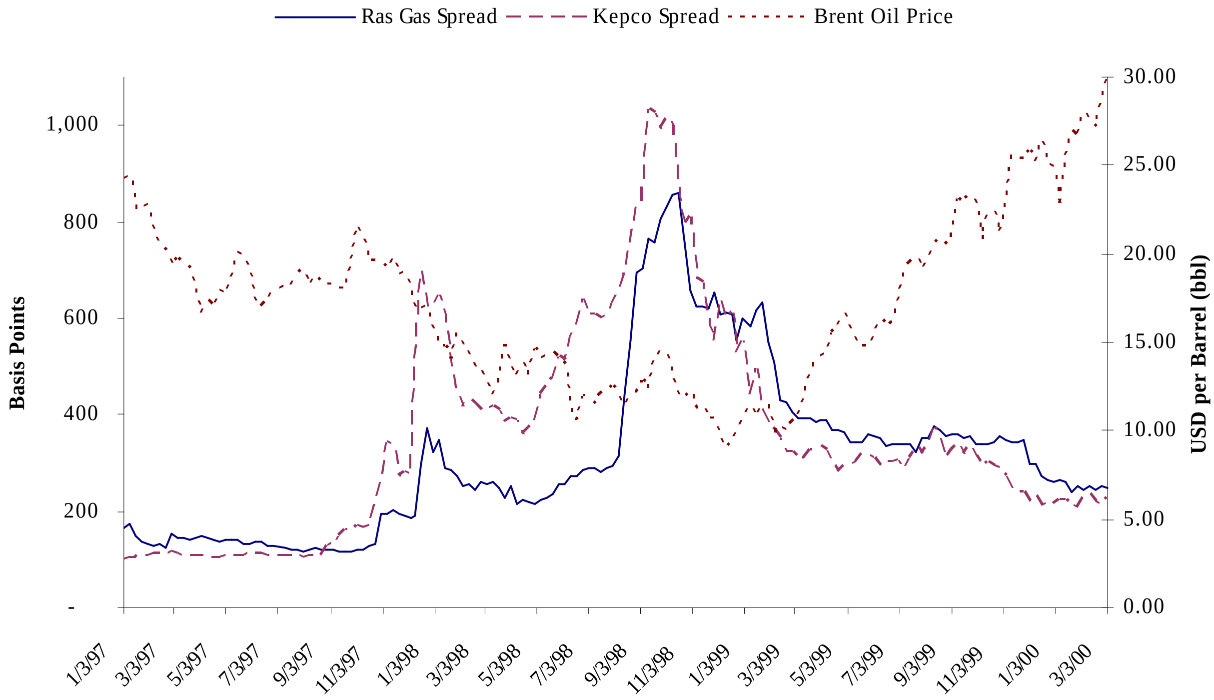

Figure 2. Weekly Ras Gas Credit Spreads, Kepco Credit Spreads and Brent Oil Prices

As economic circumstances change, the absence of enforceable, complete debt or off-take contracts means that investors must constantly reassess their initial financing decisions in light of current risks. Markets have long considered yield spreads over comparable US Treasury securities to be an indicator of a corporate bond's credit risk, a perception made rigorous by Merton (1974). Hence, Ras Gas' credit spreads (over US Treasury yields) should reflect the capital market's collective assessment of the evolution of contractual risks. Figure 2 shows weekly mid-closing yield spreads of Ras Gas' 2013 bond over 10-year US Treasury yields, and the similarly computed spreads of Kepco's global bond maturing in 2013. Throughout most of the sample period, Ras Gas' credit spreads closely track Kepco's although the latter reacted much more strongly to the Korean and Russian financial crises in late 1997 and 1998 than the former.

However, credit spreads are only an aggregate measure of bond risk (see Elton *et al.*, 2001). Since the debt contracts and debt-service guarantee both depend on the off-take agreements, the inherent incompleteness of the interlocking contracts leads to a structural relation between credit spreads and risk factors so that the project passes residual risks on to both shareholders and debtholders.[18] Exploiting Ras Gas' simple contract structure we can identify the principal sources of uncertainty, match them with key risk variables, and investigate how they shape market sentiment as measured by Ras Gas credit spreads. Table 2 in the Appendix presents summary statistics and correlations for the variables that we now discuss.

The first variable behind the postulated chain of contractual risks are output prices, which effectively determine Ras Gas' revenue because annual off-take quantities are virtually fixed. We use the logarithm of the price of Brent (*BRENT*) – one of two commonly used crude oil reference prices for LNG[19] – to analyze the incidence of output prices on the riskiness of Ras Gas.[20] Since the value of Mobil's debt-service guarantee contingent on oil prices (see Figure 1) also depends on the financial state of the guarantor, we proxy the latter by the logarithm of Mobil's stock price *MOBIL* all the more that the parent firm is AA-rated and does not have any liquid bonds outstanding. After Mobil's merger with Exxon on November 30, 1999 the combined AAA-rated entity reaffirmed the guarantee; for consistency, we back out an implied Mobil stock price from the combined ExxonMobil one using the merger's exchange ratio.

The contractual provisions of the two off-take agreements permit us to separate demand from price risk because Kogas, by and large, has committed to buying a fixed amount of output *per annum*. Hence, demand risk essentially translates into breach-of-contract risk. Since Kepco is Ras Gas' effective off-taker and Kogas only an affiliated intermediary,[21] we take the mid-closing yield spread of the Kepco 7.75% global (Eurodollar and Yankee) bond maturing in April 2013 (*KORELES*) over 10 year US Treasury yields to measure the economic and financial prospects of

[18] See Zingales (2000) for a discussion for situations in which there might exist other residual claimants besides shareholders. Projects rarely issue publicly traded equity so that in their absence project riskiness is best assessed by the price of publicly traded debt, whenever available.
[19] Gas prices turn out to be statistically non-significant when included in the regressions together with Brent prices, which is not really surprising given that about 0.11 metric tons of LNG are priced as one barrel of crude oil.
[20] Diagnostic testing reveals that logarithms offer superior fit over levels for several of the explanatory variables.

the LNG buyer as assessed by capital markets.

From a statistical perspective, using Kepco credit spreads has the added benefit that they are an instrumental variable for Kogas spreads, which should be simultaneously determined with Ras Gas spreads. This endogeneity arises from the bilateral-monopoly relationship between Kogas (dominant buyer) and Ras Gas (captive supplier) which results from the parties' investments in relation-specific assets under the SPAs such as project-specific transportation vessels. At the heart of the problem lies the lack of transportation capacity, i.e., LNG vessels not tied to a particular project, and the huge up-front investments in liquefication (Ras Gas) and in receiving facilities (Kogas: terminal, storage, regasification plant, pipelines). Consequently, the parties' credit spreads might be jointly endogenous so that we can view Kepco's spread as an instrument for Kogas' willingness and ability to honor the contract.

Ras Gas' fortunes also depend on Korea's macroeconomic environment because a severe recession might affect Kogas' and Kepco's ability to honor their contractual commitments. We use the logarithm of the Korea Composite Stock Index (*KOSPI*) as a proxy for the state of the Korean economy. To control for Kepco's idiosyncratic (operational, regulatory and financial) risks, we also include *KEPCO*, the logarithm of its stock price.

A related risk factor is the credit quality of the off-taker, which might reflect both systematic changes in the Korean macroeconomic environment, the industry structure (i.e., loss of monopoly, privatization) or purely idiosyncratic risks. The credit rating of Kogas and Kepco (shared with the Republic of Korea) has varied from 'AA' to 'B+' back to 'BBB' over the sample period. According to average yearly transition-probability estimates by Brand and Bahar (2001), 'AA' rated borrowers maintain an 'A' or better rating with 96.14% probability while credit migration such as Kepco's occurs only with 0.09% probability, which appears to be a

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[21] See Standard and Poor's (1999) for Ras Gas' financial dependence on the Korean electricity market and Kepco.

negligible risk.[22] To gauge these effects, we construct a Korea rating index (*KRR*) that reflects not only the changes in S&P credit ratings but also their magnitude. We initialize the index at 0 for Kepco's AA rating at the time of the Ras Gas bonds' issuance. Following standard methodology for converting letter ratings to a cardinal scale (see, e.g., Jorion *et al.*, 2005), each subsequent downgrade (upgrade) by a notch increases (decreases) the index by 1 so that it ranges from 0 (AA) to 10 (B+) over the sample period.

Foreign-currency exposure might appear to be of relatively minor concern for Ras Gas since all revenues and costs accrue in US dollar (USD). However, by the very nature of the off-take agreements, the Korean customers still poses a subtle indirect currency risk. Both Kogas and Kepco generate their revenue in local currency so that an adverse currency movement (depreciation of the Korean Won against the USD) might imperil their ability to honor the SPAs. The 1997 Asian financial crisis was a stark reminder of this fact: as the Korean Won depreciated against the USD, the cost of LNG to Kogas and Kepco doubled in local-currency terms. Hence, exchange rate risk when borne by the off-taker has a tendency to transform itself into a credit risk. To measure this effect, we include *KRW*, the logarithm of the KRW-USD exchange rate.

Finally, we need to control for common economic shocks or financial-contagion effects affecting emerging debt markets. To gauge the incidence of such shocks on Ras Gas credit spreads, we use the continuously compounded returns on the JP Morgan emerging market bond regional indices (EMBI family), i.e., Asia (*ASIA*), Middle East (*MEA*), Europe (*EUR*) and Latin America (*LAT*).

[22] To be precise, Brand and Bahar (2001) estimate that the average yearly transition probability from 'AA' to 'B' is 0.09% while the cumulative average default probability over 15 years, the weighted average life of the 2013 Ras Gas bond, is 1.07% for a 'AA' rated entity. Standard and Poor's rated Ras Gas 'BBB+' and maintaining its rating during

4. Data Description and Methodology

Our analysis relies on daily data that covers the period from January 1997 to March 2000 and is drawn, for the most part, from Bloomberg, IDC and Baseline. All market related data (e.g., oil and stock prices, bond yields, and emerging debt market returns) are based on daily closing prices. The bond yields reflect, as far as we can tell, quotes if not actual transaction prices. Indeed, we cross-checked Bloomberg and IDC trading data to identify discrepancies between quotes and actual trades, taking the latter whenever possible. In case of missing data, we cross-checked the time series with other news sources and filled in the missing information or, if this was not possible, deleted the data point leaving 725 observations before taking lags.

Data providers and their sources often extrapolate prices of thinly traded corporate bonds from other bond prices to generate pseudo-quotes ("matrix prices"). Hence, we verified our price data with Goldman Sachs, who acted as *de facto* market makers (keeping inventory and providing liquidity services) in the Ras Gas issues until spring 2001. Since the IDC data are based on Goldman records we are confident that our Ras Gas credit spreads do not reflect matrix prices but cannot exclude that our Kepco price data do. However, Korean international bonds and, especially, high-quality issues such as Kepco's traded heavily during the sample period because investors rebalanced emerging-market portfolios during the Asian and Russian financial crises. Hence, Kepco prices and yields are more likely than not transaction or quote prices rather than matrix ones. In fact, repeating our analysis for a subsample excluding the two emerging market crises does not alter our results.

In terms of econometric modeling, we appeal to the Merton (1974) framework of risky debt with structural default to motivate our specification. In this setting, the credit spreads are a log-linear function of the firm's underlying asset value neglecting higher order terms. As we

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the Asian and Russian financial crises. For comparison, the estimated 15 year cumulative default probability for argued earlier, these assets are essentially the cash assets represented by the Korean off-take agreements (see the economic balance sheet in Figure 1). Any risk factor affecting their cash value would then feed through into credit spreads in the Merton (1974) model. By positing an exponential relationship between the cash-asset value and its risk factors or simple linearization of a more complex functional relation we obtain Ras Gas credit spreads as a log-linear function of explanatory variables. We can estimate the resulting specification by OLS or Maximum Likelihood methods as long as the variables satisfy the usual statistical assumptions that we verify through diagnostic testing.[23]

Consequently, we take as our dependent variable the mid-closing spread of the 2013 Ras Gas bond yield over the 10 year benchmark US Treasury yield.[24] The explanatory variables are the risk factors affecting the contractual relationships at the heart of the Ras Gas project that we discuss in the preceding section. Since the firm's contractual structure deliberately attempts to modify fundamental risks we gauge the market's assessment of risk-mitigation success in terms of the statistical significance of contract-related explanatory variables and risk proxies. If markets are informationally efficient only unmanaged risk factors should contribute to explaining Ras Gas credit spreads as a measure of overall project riskiness. We estimate variants of the following empirical specification by Ordinary Least Squares:

$$
\begin{aligned}
RGS_t = b_0 &+ \sum_{0\le l\le L} a_{-l} RGS_{t-l} + b_1 BRENT_t + \sum_{0\le l\le L} b_{2,-l} KORELES_{t-l} + b_3 MOBIL_t \\
&+ b_4 KEPCO_t + b_5 KRW_t + b_6 KOSPI_t + b_7 KRR_t \\
&+ \sum_{0\le l\le L} \left[g_{1,-l} MEA_{t-l} + g_{2,-l} ASIA_{t-l} + g_{3,-l} EUR_{t-l} + g_{4,-l} LAT_{t-l} \right] + e_t
\end{aligned}
$$

where L indexes maximal lag length, RGS_t is the spread of the Ras Gas bond over 10 year US

'BBB' rated borrowers is 4.48%.

[23] See Avramov *et al.* (2004) for a related empirical approach. Madan and Unal (2000) derive a similar relationship in a structural hazard rate model by letting structural parameters such as cash asset value or, in our case, the value of the off-take agreements to Ras Gas investors determine the instantaneous probability of borrower default.

Treasury yields, $BRENT_t$ the logarithm of the Brent blend oil price index, $KORELES_t$ the spread of the 2013 7.75% Kepco global bond over 10 year US Treasury yields, $MOBIL_t$ the logarithm of Mobil's stock price, $KEPCO_t$ the logarithm of the Kepco stock price, KRW_t the logarithm of the Korean Won – US Dollar spot rate, $KOSPI_t$ the logarithm of the Korea Composite Stock Price Index, KRR_t a shared credit rating index for Korea, Kepco and Kogas, and $MEA_t, ASIA_t, EUR_t, LAT_t$ the continuously compounded daily returns of the JP Morgan regional total return indices in USD for emerging markets in the Middle East-Africa, Asia, Europe and Latin America, respectively.

Since we measure investors' sensitivity to specific risks in terms of the statistical significance of key variables we start with the contractual risk factors, i.e., the output (Brent oil reference) price, Mobil's stock price, and Kepco bond yield spreads, and successively add explanatory variables to the regression. In terms of estimation strategy, we eliminate highly insignificant control variables through diagnostic testing in the interest of parsimonious specification that also addresses potential collinearity problems. Given the high frequency of the data, it comes as no surprise that daily credit spreads exhibit a large degree of persistence: the coefficient on lagged spreads is close to unity. However, tests for unit roots and cointegration come out inconclusive given the low statistical power of such tests in our case.[25]

Since bilateral relationship-specific investments by both Ras Gas and Kogas-Kepco under the long-term SPAs create the potential for an equilibrium relationship between Ras Gas and Kepco spreads, we also estimate our main specifications in first differences. Similarly, we specify a simultaneous equation model that allows for feed-back effects in the contractual

[24] According to Bim Hundal of Goldman Sachs, the bond is quite actively traded contrary to the 2006 one and, therefore, constitutes a much better measure of investor and market sentiment regarding the project's prospects.

[25] Campbell and Perron (1991) have pointed out that unit root tests are biased in favor of the null hypothesis (existence of a unit root) if the time series suffers from structural breaks such as the emerging market crises of 1997-1998.

relationship between the two firms. As a further robustness check, we repeat the analysis with weekly closing data (140 observations) but do not report the results because they closely mirror the findings of our daily analysis.

5. Credit-Spread Determinants and Contractual Risks

The results in Table 3 verify our conjecture that investors price Ras Gas debt with respect to the perceived creditworthiness of its dominant output buyer: Ras Gas credit spreads vary positively with Kepco spreads that are highly significant. Consistent with the provisions of the bond covenant and the nexus of contracts view of the firm, the non-contractible counterparty risk feeds through to Ras Gas yields. By pricing such non-contracted off-take risk, debt markets indicate that they recognize the incomplete nature of covenants and output supply agreements and that, at least in part, risk is shifted from Ras Gas owners to its bondholders. The size of this effect, about 2.5 basis points for every 100 basis point shift in Kepco spreads, is consistent with the regression results for (residual) credit spreads in Elton *et al*. (2001). They find coefficients between 0.077 and 0.7154 depending on bond rating and maturity for the Fama-French market factor that is the most comparable variable to our counterparty risk proxy.

To explore the credit-spread dynamics, we next include the lagged Kepco spread (Specifications 2 to 4, Table 3). The results reveal that the widening of Ras Gas spreads by 2 to 3 basis points for every 100 basis point increase in Kepco spreads is the net result of the following two-day adjustment mechanism. Initially, Ras Gas spreads rise by about 15 basis points but narrow on the next trading day by approximately 13 basis points (coefficient on the lagged Kepco yield spread) all other things being equal. Further lags of the Kepco spread are statistically insignificant. The results in Table 3 indicate that this pattern is stable across all specifications and, therefore, does not stem from any omitted variable effects.

Since we have argued on the basis of the economic balance sheet in Figure 1 that there is an equilibrium relationship between Ras Gas and Kepco spreads, we can easily recover the steady-state long-run equilibrium effect of the latter on the former as $l = \frac{b_{2,0} + b_{2,-1}}{1 - a_1}$ with $a_1, b_{2,0},$ and $b_{2,-1}$ the coefficients of lagged Ras Gas spreads, contemporaneous and lagged Kepco spreads, respectively. This long-run equilibrium coefficient h_3 ranges from 1.11 in Specification 3.2 to 1.24 in Specification 3.4 so that a 100 basis-point rise in Kepco spreads increases Ras Gas ones by 111 to 124 basis points. Hence, a net effect of about 2 basis points of Kepco on Ras Gas spreads ($ß_{2,0} + ß_{2,-1} \cong 0.02$) in the presence of high persistence ($a_1 \cong 0.98$) translates into an almost one-to-one long-run equilibrium relationship between the buyer's and supplier's spreads and, ultimately, risks. We interpret this result as evidence that markets realize that Ras Gas risk essentially amounts to counterparty risk and update their risk assessments accordingly, albeit with a time lag. In the long run, this key unmanaged risk is the principal source of uncertainty for Ras Gas bondholders who therefore price their securities almost as if they were issued by the Korean off-takers. Given that Kogas-Kepco are responsible for 75% of the project's cash flows and that there are next to no hedging opportunities for such counterparty risks, higher capitalization levels, i.e., less leverage, would probably not change the long-run equilibrium impact of Kepco on Ras Gas spreads.

To further explore the adjustment and equilibrium dynamics we can also express the autoregressive-distributed-lag specifications 2 to 4 in Table 3 as an equivalent error-correction model $\Delta RGS_t = h_1 \Delta KORELES_t + h_2 \left(RGS_{t-1} - l\,KORELES_{t-1}\right) + X_t q + e_t$ with $X_t q$ representing the other explanatory variables and their coefficients in matrix notation. This formulation, which amounts to a simple reparametrization of our original specifications, decomposes the total movement of Ras Gas spreads into short-run ($h_1 \Delta KORELES_t$) and long-run equilibrium

($h_2(RGS_{t-1} - lKORELES_{t-1})$) effects. Since $RGS_{t-1} - lKORELES_{t-1}$ measures the extent to which the long-run (steady-state) equilibrium is not satisfied the coefficient $h_2 = b_{0,-1} - 1$, ranging from -0.017 to -0.033, corresponds to the proportion of the resulting disequilibrium reflected in daily movements of Ras Gas spreads. The very small absolute magnitudes of this proportion suggests that contemporaneous changes in Kepco spreads drive daily changes in Ras Gas spreads (the short-run coefficient h_1 ranges from 0.15 to 0.16) rather than long-run disequilibrium adjustments.

Investment patterns as communicated to us by Goldman Sachs suggest an explanation based on liquidity and clientele effects for the delayed reaction of Ras Gas to Kepco spreads. In late 1997, liquidity in emerging bond markets dried up and the only buyers of Ras Gas bonds were presumably better informed Middle-East based investors who perceived the issues as underpriced and, in the process, completely bought up the 2006 bond. As markets stabilized and yield spreads narrowed in 1999, liquidity improved and other institutional investors showed renewed interest in the 2013 bond. The reversal of the initial spread reaction is also reminiscent of positive stock return reactions after large one-day declines that Cox and Peterson (1994) explain by bid-ask bounce in addition to liquidity effects. Since we use mid-point closing yields we can exclude bid-ask bounce effects as a factor in favor of clientele-induced liquidity effects.

Regarding output prices, we find that the *BRENT* coefficient is marginally significant at best (see Table 3). An increase in the oil reference price by $2.72 actually widens Ras Gas spreads by about 3.5 basis points but the effect is statistically significant only in Specifications 3.2 and 3.3, and even then merely at 10%.[26] Overall, LNG settlement prices do not significantly affect Ras Gas' credit-spread levels and, hence, the bond's riskiness as priced in global markets.

[26] A possible explanation lies in the economics of power production from LNG that becomes uneconomical at oil prices beyond $29/bbl. Hence, the rapidly rising energy prices during the sample period are not necessarily positive for Ras Gas bondholders: while they certainly facilitate debt service, they might also increase counterparty risk.

It seems quite remarkable that markets view output prices as irrelevant although they drive Ras Gas' revenue. However, in light of the implicit price guarantee by Mobil, it is perfectly rational for bondholders to disregard price risk. On a related note, the effect of the guarantor's perceived riskiness as measured by its stock price *MOBIL* is largely insignificant: investors take the debt-service guarantee at face value which is unsurprising given credit ratings of AA (Mobil) and AAA (ExxonMobil) over the sample period. Since we include oil prices (*BRENT*) and proxies for counterparty risk (*KORELES*) together with *MOBIL*, we are confident that our finding does not result from energy-related omitted-variable biases.

These findings provide further evidence for our hypothesis that markets will not price risks that are explicitly part of the projects' contractual arrangements, in this case through the output price contingent debt service guarantee by shareholders to debtholders.

To control for common economic shocks affecting emerging debt markets, we include returns on JP Morgan's EMBI regional emerging-bond indices, successively eliminating the least significant lags (Specifications 3 and 4 in Table 3). Ras Gas spreads vary negatively with emerging debt market returns, which is consistent with Longstaff and Schwartz (1995) and Duffee (1998) who also find a negative relation between credit spreads and short-term interest rates in the US corporate-bond market. On average, a 100 basis point increase in EMBI indices decreases Ras Gas spreads by 1.5 to 3.3 basis points reflecting the strong negative relationship between risk perceptions and returns in the emerging-market segment. While Ras Gas spreads show a particularly strong contemporaneous reaction to European emerging debt markets dominated by energy-sensitive Russian debt the other debt markets' impact is delayed and Asian debt-market factors are insignificant in the presence of Kepco spreads.

Once again, we think that portfolio rebalancing and liquidity effects are responsible for these patterns. Ras Gas bonds belong both to the energy and emerging market segment of global fixed-income markets. Based on information from Goldman Sachs, the Russian financial crisis affected trading in Ras Gas bonds both from a sovereign and sector perspective. Investors negatively reassessed Korea's and, hence, Kepco's prospects after Russia's partial debt default in August 1998 (sovereign spillover). Furthermore, the markets viewed potentially increased oil and gas exports from the former Soviet Union as a financial threat to Ras Gas (sector spillover). The lagged reaction might be due to the lesser informational transparency of emerging markets as well as portfolio rebalancing that often takes place with time-zone induced delays.[27]

Adding Korea-specific variables (Specification 4 in Table 3) to the regression reveals that the Korean rating index *KRR* is insignificant, as is the Kepco share price *KEPCO* in the presence of the stock market index *KOSPI* which is highly significant. Both *KOSPI* as a measure of the overall state of the Korean economy and Kepco spreads serve as indicators of Korean country risk. In fact, both variables lead future rating changes so that the statistical insignificance of *KRR* is a result of rating agency's habit to follow the market who has already incorporated the changed outlook for the Korean economy into Kepco yields and Korean stock prices. Kepco's stock price is highly collinear with the stock market index *KOSPI* (correlation of 0.86: Table 2, Panel B) which explains its insignificance: given the energy-intensive nature of the Korean economy, one serves as a proxy for the other.

Exchange rate exposure as measured by the *KRW* coefficient comes out negative which, at first sight, appears puzzling: one would have expected that breach of contract and, hence, default risk increases as the Korean Won depreciates against the US Dollar, i.e., *KRW* rises. Instead, a daily depreciation of the Won by KRW 2.72 (about 0.3% at average pre-floating exchange rates) reduces Ras Gas spreads by 18 basis points. However, given the currency regime

[27] After all, US investors, who might face a one-day delay in reacting to European or Asian events, initially held 80% of the 2013 bond. The positive relation between Ras Gas credit spreads and lagged Middle Eastern bond returns in the weekly analysis (results not reported) lends further credence to our portfolio rebalancing interpretation.

shift from pegged to floating (November 1997) and, indeed, profound economic changes (IMF stabilization program, financial liberalization) during the sample period both the sign and the magnitude of the effect could reflect forward-looking currency expectations rather than contemporaneous effects. If investors consider the with hindsight artificially low peg of the Won to the Dollar as unsustainable they might prefer the necessary adjustment to take place sooner rather than later and view the regime shift in a positive light. To test this hypothesis, we split our sample into a "peg and crisis" subperiod ranging from January 1997 to April 17, 1998 (return of South Korea to global capital markets: official end of the financial crisis and IMF stabilization program) and a "free-float" subperiod covering the remainder of our sample. We find that the exchange-rate variable *KRW* still comes out negative and is statistically significant (albeit at 10% only) in the peg-and-crisis subsample. Consistent with our expectations conjecture, the variable is not significant for the free-floating period (results not reported). As a further test, we re-estimate Specification 3.4 for the full sample excluding the crisis period as defined by the widening of the Korean Won's peg-bands to 10% on November 19, 1997 up to Korea's return to global capital markets (April 17, 1998). Once again, the *KRW* variable becomes statistically insignificant.

We also estimate our specifications with a proxy for sovereign Korean Credit Default Swap (CDS) spreads to more clearly separate out firm-specific counterparty risk from sovereign default risk. Since this market is a very recent phenomenon so that high-frequency CDS data do not exist for our sample period we rely on actual and estimated asset-swap spreads of the first reference issue for South Korea, the $3,000b 8.88% global note maturing on April 08, 2008. By an ingenious argument in Duffie (1999) asset-swap spreads approximate CDS swaps so that we re-estimate our main specifications for the subperiod from April 1998 to March 2000 with and without Korea asset-swap spreads. We find that a 100 basis-points increase in our CDS-proxy increases Ras Gas spreads by 4 to 7 basis points, mirroring results in Zhu (2004). While the inclusion of the highly significant asset-swap spreads generally reduces the net impact of Kepco spreads (albeit not their statistical significance), they mainly affects the Korean control variables so that we do not report detailed results.

6. Credit-Spread Changes and Equilibrium Relationships

Given potential non-stationarities in the dependent variable and the existence long-run equilibrium relationships, we replicate the preceding analysis for changes in Ras Gas credit spreads to assess the robustness of our results. Diagnostic testing reveals that first differences in the independent variables including Kepco spreads lead to inferior statistical performance so that we keep them in levels except for the Korea rating variable *KRR* and Korean Stock Price Index *KOSPI*.

The results (Specifications 5 to 8, Table 3) confirm our earlier findings in levels, which is unsurprising in light of their error-correction model interpretation. A similar set of explanatory variables, especially Kepco spreads or their changes, drives changes in Ras Gas credit spreads: a 100 basis point change in Kepco spreads increases daily Ras Gas movements by 13 to 15 basis points. *MOBIL* as a proxy for the quality of the debt-service guarantee is significant and negative in the absence of emerging-debt-market controls: a $2.72 increase in Mobil's stock price, decreases daily changes in Ras Gas spreads by approximately 5.7 to 7.6 basis points. A more favorable assessment of the guarantor's economic prospects by markets might imply a higher value of the guarantee and, hence, a reduction in the riskiness of the project reflected in less volatile bond spreads. Similarly, changes in the Korean rating index *KRR* are now significant. While credit ratings have little explanatory power for credit-spread levels, the magnitude of up- or down-grades matters for credit-spread volatility: a one-notch downgrade increases daily spread movements by 4 basis points so that the overall downgrading of Kepco from AA to B+ (10 notches) amplifies spread changes by a maximum of 40 basis points during the sample period. We also note that the magnitudes of our coefficients are roughly in line with the results for comparable bond samples (rated BBB+ or BB-) in Avramov *et al.* (2004) who similarly relate credit-spread changes to firm-specific and common market factors in a Merton-style framework.

We can also view the contractual relationship between Ras Gas and Kepco as a bilateral monopoly: each party acts as the primary counterparty in LNG transactions with the other, heavily invested in relation-specific assets due to nature of LNG technology, and cannot rely on alternative markets because spot markets for liquefied natural gas are lacking. In particular, the off-take agreements with Kogas-Kepco stipulate the construction of landing, storage and regasification facilities in Korea as well as 7 to 8 dedicated LNG vessels (costing around $250m each) that can only be used to transport Ras Gas LNG. By early 2000, Kogas and Kepco had invested about $10 billion in tankers, dedicated power plants and LNG infrastructure (Standard and Poor's, 1999). To protect their respective investments in physical infrastructure in the absence of alternative markets for LNG, the parties sign long-term off-take agreements that institutionalize the bilateral monopoly and are then susceptible to opportunistic behavior.

To the extent that long-term contracts between Ras Gas and Kepco and their relation-specific investment create an equilibrium relationship, we would expect that a common set of factors endogenously determines their credit spreads all the more that both firms fall into the same emerging markets and energy bond categories. Hence, we specify the following simultaneous equation model of the Ras Gas and Kepco yield spreads, which we estimate by full-information Maximum Likelihood:

$$
\begin{aligned}
RGS_t = b_{01} &+ \sum_{0\le l\le L} a_{1,-l} RGS_{t-l} + b_{11} BRENT_t + \sum_{0\le l\le L} b_{21,-l} KORELES_{t-l} + b_{31} MOBIL_t \\
&+ b_{41} KEPCO_t + b_{51} KRW_t + b_{61} KOSPI_t + b_{71} \Delta KRR_t \\
&+ \sum_{0\le l\le L} \left[g_{11,-l} MEA_{t-l} + g_{21,-l} ASIA_{t-l} + g_{31,-l} EUR_{t-l} + g_{41,-l} LAT_{t-l} \right] + e_{t1} \\
KORELES_t = b_{02} &+ \sum_{0\le l\le L} a_{2,-l} RGS_{t-l} + b_{12} BRENT_t + \sum_{0\le l\le L} b_{22,-l} KORELES_{t-l} + b_{32} MOBIL_t \\
&+ b_{42} KEPCO_t + b_{52} KRW_t + b_{62} KOSPI_t + b_{72} \Delta KRR_t \\
&+ \sum_{0\le l\le L} \left[g_{12,-l} MEA_{t-l} + g_{22,-l} ASIA_{t-l} + g_{32,-l} EUR_{t-l} + g_{42,-l} LAT_{t-l} \right] + e_{t2}
\end{aligned}
$$

As before, we use statistical significance and diagnostic tests to determine which risk factors affect Ras Gas bonds directly and which ones operate indirectly through their incidence on Kepco's financial health. Since Kepco's lagged credit spreads are insignificant in the Ras Gas equation and v*ice versa*, we drop them from the specifications. We find that a rise of 100 basis points in Kepco spreads still increase Ras Gas ones by 2.8 to 3.7 basis points corresponding to long-run steady-state effects of approximately 89 to 111 basis points, which is in line with our earlier results (Table 3). By contrast, Ras Gas spreads affect Kepco spreads much less in the long run (approximately 54 to 81 basis points per 100 point increase).

Specification 1 of Table 4 shows that oil prices affect the riskiness of Ras Gas through their effect on the financial position of Kepco rather than directly: while *BRENT* is insignificant in the *RGS* equation it is highly significant in the *KORELES* equation (a \$2.72 increase raises Kepco spreads by 24 basis points). We interpret this result as further evidence that investors discount the direct revenue effect of output prices on Ras Gas due to Mobil's guarantee. Instead, they are more concerned about the impact of energy prices on Kepco's financial health, a non-contractible risk.[28] The statistically significant emerging debt market returns reported in Table 4 confirm both our earlier results in sign and magnitude, and their interpretation in terms of

[28] Such indirect price effects are common in the energy bond sector. A similar example are the Alliance Pipeline LP 2019 and 2023 senior notes collateralized by revenue from a gas pipeline between Northwestern Canada and the Chicago, IL area. While the revenue is purely determined by throughput, rising gas prices negatively affect the notes'

spillover structure. Surprisingly, Kepco credit spreads seem to be unaffected by emerging debt markets (Specification 2). Instead, they are primarily driven by Korean variables such as Kepco's share price as an indicator for Korea's electricity demand and stock market returns *KOSPI*. As economic prospects improve so does the risk profile of Kepco as reflected by its stock price. Hence, its own and, ultimately, Ras Gas credit spreads should narrow.

The second significant country-risk variable is again the Korean Won – US Dollar exchange rate. All specifications in Table 4 (in levels or changes) reveal an intriguing pattern: the *RGS* equation still exhibits the previously identified puzzle that, on average, a weakening Won directly decreases market risk perceptions as spreads decline by 10 to 12 basis points for a W2.72 increase in the US Dollar. However, the indirect impact via Kepco yields in the *KORELES* equation clearly shows the conjectured currency-exposure effect in terms of a positive *KRW* coefficient that increases Kepco spreads by 26 to 34 basis points per W2.72 currency depreciation. In steady state, these results translate into an 11 basis-points decrease of Ras Gas spreads but 359 basis-points increase in Kepco spreads, highlighting the importance of artificially low exchange rates (unsustainable peg of the Won to the Dollar) for Kepco's financial fortunes as an energy importer. As the Won falls, servicing Kepco's foreign debt and its oil, coal and gas purchases - all denominated in USD - become more expensive. Consequently, Kepco's financial position deteriorates, increasing its riskiness and, hence, requiring higher spreads to compensate its own and Ras Gas' bondholders for more credit risk.

When we split our sample into "peg and crisis" and "free-float" subperiods, we now find that the *KRW* variable now comes out positive during the peg and crisis months (up to April 1998) in the Ras Gas equation but is statistically not significant in either subperiods; by contrast, it remains statistically significant (and positive) in the Kepco equation for both subsamples.

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prices and spreads because of their adverse impact on the financial position of Alliance's 35 customers and the re-

Estimating the specifications omitting the financial-crisis period (November 1997 to April 1998) confirms these results (results not reported). These findings suggest the following interpretation of our previously identified currency-expectations effect caused by the regime shift in Korea's economic policy. Investors find reassurance in the IMF's stabilization program (floating exchange rates and economic liberalization) that, while imposing a currency-related losses on Kepco (increase in risk perceptions: positive *KRW* in Kepco equation) in the short run, also guarantees Korean access to foreign currency to service financial commitments, thus reducing overall Ras Gas risk (negative *KRW* in Ras Gas equation). Furthermore, a more realistic exchange rate leads to higher exports in the long run and, hence, increased domestic demand for gas and electricity which decreases the demand uncertainty and, ultimately, Kepco breach-of-contract risk.

We also replicate the simultaneous-equation analysis in first differences (Specifications 3 and 4, Table 4). The results confirm the robustness of our earlier findings and, in particular, the statistical insignificance of output prices *BRENT* and guarantor quality proxied by *MOBIL*. In terms of size and sign, our estimates are again consistent with the firm-specific effects for bonds with average or high credit-spreads (rated BBB+ or lower) in Avramov *et al.* (2004). To further investigate this effect we also decompose the *BRENT* variable into three distinct bands: oil prices below $14/bbl triggering the debt service guarantee, above a threshold of $23/bbl which is Kepco's break-even price for electricity generation for LNG, and an intermediate band. Since none of the three price bands are statistically significant in any of our specifications confirming our conjecture that markets do not price contracted risks we do not report the results.

sulting increased breach of contract (off-take) risk (Greg Randolph, Goldman Sachs and Standard and Poor's, 2001).

7. Asset Values, Counterparty Risk and Default Probabilities

The preceding analysis reveals how contract-related factors shape investors' risk perceptions and determine bond prices. Ras Gas' economic balance sheet (see Figure 1) suggests a second perspective on the transmission of contractual risks in terms of asset values and financial claims. Since LNG spot sales and other minor off-take agreements roughly cover the project's operating costs and royalties, the value of the Korean SPAs should drive the value of the project's financial claims (debt and equity). Using the seminal insight of Merton (1974) that equity in the presence of leverage is equivalent to a call option on the firm's underlying assets, we can recover estimates of the underlying asset value – in our case the cash value of the Kogas-Kepco off-take agreements – by matching the value of this real option to the market value of publicly traded equity (see, e.g., Ronn and Verma, 1986).

However, this approach presupposes that the firm's shares are publicly traded. Ras Gas has only publicly traded debt because the company's equity is privately held by the parents of the project joint venture. Hence, we adapt the Ronn and Verma (1986) methodology to a private-equity setting and extract Ras Gas' weekly asset value and asset volatility by matching the theoretical values of its (risky) debt in the Merton (1974) framework to the market price and volatility of its bonds (see Appendix A for details). Since all debt claims rank *pari passu* and the private debt (banks, export credit agencies) has the same weighted average life as the shorter bond, we can obtain market values for all of Ras Gas' debt.[29] Asset-value estimates then allow us to calculate market-based values for Ras Gas' equity so that our approach can provide a valuable benchmark for valuation and trading purposes in the case of privately held firms with public debt outstanding. Similarly, we can derive implied weekly default probabilities that complement our analysis of credit spreads as a measure of market sentiment.

As a private company, Ras Gas does not publish financial statements; instead we rely on personal communications and public sources (rating data, offering circulars, construction schedules, loan disbursements) that we cross-checked with each other to infer the project's capital structure.[30] Given Ras Gas' debt-equity mix and its evolution over time (quarterly or monthly data whenever available) we use the KMV implementation of the Merton (1974) model[31] to recover asset and equity values on a weekly basis over a one-year and five-year horizon. We estimate return volatilities from bond prices using a 180-day window prior to the weekly analysis date.[32] Table 5 summarizes our results and contains credit spreads and oil prices for comparability.

[29] In addition, the loan covenants are virtually identical to the bond ones because the latter are based on the former (private communication, Greg Randolph). Using book values for the loans does not significantly alter our results because of their disbursement schedule (draw down only started in late 1998).

[30] We are particularly grateful to Rik Rikkola, former Treasurer of Ras Gas, for his assistance in this matter.

[31] Since the original Merton (1974) model assumes that the firm has only one zero-bond outstanding, various approaches have been suggested to compute the face value of corporate debt outstanding for more realistic balance sheets. The KMV approach calculates the face value as the sum of short-term liabilities plus ½ long-term debt outstanding because "the asset value at which the firm will default generally lies somewhere between total liabilities and current, or short-term, liabilities'' (Crosbie and Bohn, 1993). Our normalization follows established practice (see, e.g., Vassalou and Xing, 2004). Sobehart et al. (2000) benchmark of popular credit-risk models including the KMV implementation of the Merton (1974) model.

[32] Estimation windows below 90 days exaggerate the beneficial impact of volatility on asset and equity values during the Asian financial crisis; a 120-day window for volatility estimation yields almost identical results.

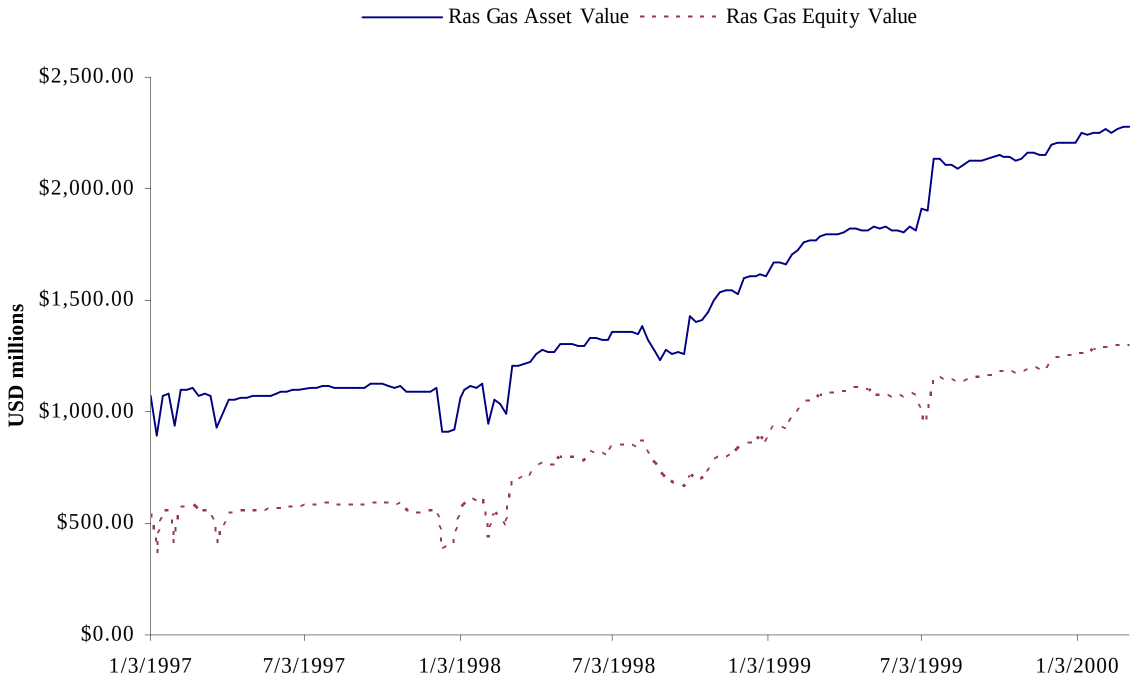

Figure 4. Implied Ras Gas Asset and Private-Equity Values

Figure 4 displays the implied values for Ras Gas' underlying assets and private equity. Two facts stand out: not only do private-equity valuations closely follow asset values but both are also very sensitive to emerging-market conditions. In late October 1997, asset and equity values exhibit a slight downward trend, foreshadowing the onset of the Korean financial crisis, before significantly falling in early December. By contrast, investors only reacted belatedly to the Russian financial crisis in July 1998 as implied asset and equity values are much slower to fall. The brief recovery in early 1998 appears to be an artifact of higher volatility levels that partially offset the fall in underlying asset value. By late March1998, asset and equity values resume their previous time trend primarily driven by the continuing injection of share capital and construction progress that diminish technological and completion risks.

Private-equity values reveal that two opposing volatility effects are at work. On the one hand, falling bond prices signal eroding asset and private equity values; on the other hand, the persistent increase in asset volatility renders shareholders' bankruptcy option more valuable partially offsetting the pure asset-value effect in early 1998. Turning to implied asset values we note that oil-price volatility in conjunction with uncertainty about a second major off-take agreement might be responsible for observed swings in asset and equity values early on. In fact, both exhibit a marked appreciation in April 1997 possibly due to the announcement of the imminent signing of the second SPA with Kogas.

Similarly, we see that the completion of construction in Summer 1999 and the beginning of gas shipments to Korea in August 1999 caused a significant upward jump in asset values but only a relatively minor one in implied equity values. In the absence of any other relevant news, prices of financial claims, i.e., bond prices and derived stock valuation, seem to have anticipated the positive effects of project completion, start of deliveries, and revenue cash flows. This apparent sensitivity of asset values to events related to output-supply contracts provides further evidence for our conjecture that Ras Gas' assets essentially consist of cash receivables from the Korean off-take agreements. Investors justifiably disregard the quality of fixed assets in pricing bonds and valuing the project and, instead, concentrate on risk factors stemming from the underlying cash assets.

To further explore investors' preoccupation with cash-flow quality we now extract (risk-neutral) default probabilities implied by the underlying asset values in the Merton (1974) framework. Although these probabilities are not the statistical (actual) ones they are extremely relevant to debtholders because they provide an upper bound for the latter.[33] Since our analysis of credit-spread determinants identifies counterparty risk (Kogas-Kepco reneging on the off-take agreement) as a major source of investors' risk perception we repeat the default-probability analysis

[33] Intuitively, the change to the risk-neutral (martingale) measure sets the drift term of the underlying asset value process V equal to zero while leaving the diffusion term unchanged. Since the drift function is now strictly smaller for the risk-neutral asset value process the original asset value process is (almost surely) greater. Since default in the KMV-Merton model is defined as $V < F$, the face value of debt, the risk-neutral process is more likely to breach the default point and, hence, the risk-neutral default probability is at least as high as the statistical one.

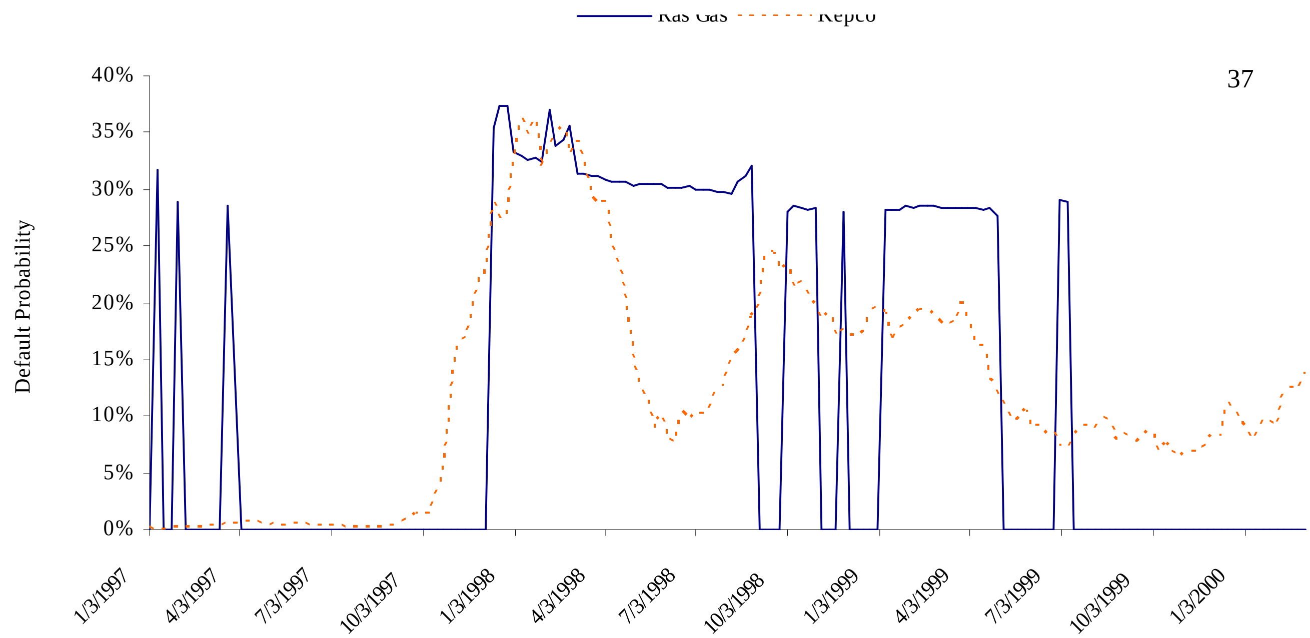

Figure 5. Implied Five-Year Default Probabilities for Ras Gas and Kepco

for Kepco under the exact same assumptions.[34] However, Kepco is a publicly traded company so that we can rely on the market value of its equity (ADRs trading on the NYSE) rather than bond prices to extract its implied default probabilities (see Table 5).

Figure 5 shows the probabilities that Ras Gas or Kepco default on their debt during the next five years on a weekly basis over the sample period. Except for early spikes in the first quarter after issuing debt, Ras Gas' default probability closely tracks Kepco's for most of the year. With the advent of the Asian financial crisis, Kepco's default probability starts to rise in September 1997 well ahead of the onset of Korea's foreign-exchange and balance of payments crisis in December 1997. By November 1997, debt markets seem to have grasped Ras Gas' exposure to Korea's economy in general and Kepco in particular. Having trailed Kepco's default probability by about two weeks, both firm's five-year default probabilities peak in early January 1998 at 42.45% (Kepco) and 55.61% (Ras Gas). By April 1998 it had become clear that the Korean economy would recover and Kepco be able to honor its off-take commitments. Correspondingly, Kepco's five-year default probability falls to under 2% and Ras Gas' to under 0.1% (see also Table 5).

In early summer 1998, Kepco's default probability starts to rise again, presumably on fears that the Russian economy's deterioration might trigger a second round of financial crises in emerging countries. At the height of the Russian financial crisis just after the *de facto* devaluation of the Russian Ruble, Ras Gas' default probability rises to 42% (September 1998) while Kepco's never exceeds 35%. As our time-series analysis shows, other factors in addition to counterparty exposure affect Ras Gas' credit risk. One possible explanation for this apparent overreaction lies again in Russia's role as one of the largest energy exporters. Should the country expand oil exports in response to its crisis, world energy prices might fall, possibly hurting Ras Gas' cash-flow quality and, hence, its creditworthiness. Once the emerging debt markets improve in summer 1999 Kepco's default probabilities fall back to under 10% and, correspondingly, those of Ras Gas become negligible. These very low values are also a reflection of continued equity injections into the project and the dramatic decrease in emerging debt-market volatility.

Mirroring the high volatility in asset and equity values in the first quarter of 1997, perceived credit risk as measured by default probabilities seems quite significant despite positive developments including negligible Kepco default probabilities, negotiations on the second Korean off-take agreement, and good progress on construction. End-of-year effects might again explain the results given that the project's credit spreads tightened at the same time (see Table 5). Having come to market on December 16, 1996 the bonds initially traded very lightly. As a result, our first return-volatility estimates rely on less than 30 data points and are particularly low until the first week of January 1997 when trading in the bonds picked up in response to investors' inability to obtain sufficient quantities in the initial placement. Hence, the early spike in default

[34] Unfortunately, Kogas as a state-owned enterprise did not have any publicly traded equity or sufficiently liquid global bond outstanding to carry out a similar analysis. Since Kepco is the ultimate off-taker, its default probability is the more relevant one to focus on.

probabilities might simply be the result of holiday-distorted volatility estimates and January-type liquidity effects. In addition, the decline in oil prices by more than $7 during the first 4 months of 1997 (see Brent prices in Figure 2) might also have contributed to the flurry of trading activity.

7. Discussion

Much of current corporate-finance theory draws upon the view that a firm is a nexus of contracts. Since this approach is nowhere more valid than in project finance, we use one particular project, the Ras Laffan Liquefied Natural Gas Co., to analyze how the contractual structure modifies firm-specific risks by dividing them into explicitly managed vs. unmanaged risks and how markets price these risks. We show how the purely bilateral contractual relationship between a dominant seller (Ras Gas) and output buyer (Kepco) shapes not only the project's *ex ante* contractual and organizational design but also the *ex post* allocation of risk between different stakeholders. In particular, we find strong evidence for residual-risk bearing by debtholders as part of the contractual web in the sense that unmanaged risks, especially counterparty risk arising from the 25 year sales and purchase agreement, drive the project's credit spreads and default probabilities. Our findings offer strong support for the nexus-of-contract view of the firm and also show that, in the face of contractual incompleteness, stakeholders other than shareholders can bear residual risks.

The particularly simple contractual structure of project finance allows us to take an in-depth look at the credit-spread dynamics that arise from interlocking contracts. In light of a debt-service guarantee contingent on output prices to Ras Gas' debtholders, it is intuitive that markets view output-price risk as secondary to counterparty risk and price the project's bonds accordingly. We find evidence that the risk transmission revealed by credit-spread determinants stems from contractual incompleteness rather than the deliberate attempt by shareholders to enhance project value at the expense of debtholders. In particular, the lack of suitable risk-management devices for all fundamental risks precludes the existence of self-contained contracts within the firm so that debtholders bear and price unmanaged counterparty exposure, while they discount readily managed output- price risk.

Our analysis shows that markets see through the firm as a contractual web and treat its constituent parts as an integrated whole. Their ability to recognize the nature of particular risks and to price them accordingly provides new evidence on the informational efficiency of bond markets. In addition, we find support for the view expressed in Fama (1990) that financial arrangements cannot be viewed in isolation from other parts of the nexus of contracts, such as guarantees and output supply agreements in our case. Since parties often cannot foresee all future contingencies and appropriate hedging instruments might not exist, the contracts' inherent incompleteness transmits risks between stakeholders. Such dependence of debt finance on cash-flow profiles echoes the intertemporal liquidity aspects of risk management analyzed in Mello and Parsons (2000) who show that intertemporal liquidity concerns lead to a pairing of hedging with debt financing strategies. The same liquidity effects drive Ras Gas' capital and, indeed, overall contractual structure in the face of buyer default (counterparty), output price (revenue) and foreign-currency risk. In the absence of appropriate hedging instruments for such risks, the parties have recourse to contractual provisions and shareholder guarantees albeit at the price of debtholders assuming unmanaged risks.

The interdependence of contracts within the same firm through explicit or implicit contingencies holds important lessons for the valuation of financial claims and firms. The dominant corporate valuation paradigm treats the value of each financial claim as independent and determines the firm's total value as the sum of its (financial) contracts. This approach might be inappropriate in the presence of contractual incompleteness as the Ras Gas project shows. Hence, prevailing valuation methods might need to be appended to take into account risk spillovers arising from all contracts, not just the financial arrangements within a firm.

Our analysis also points to the many exciting research opportunities that project finance offers because the setting so closely conforms to standard corporate finance models and the contractual structure is both highly standardized and well documented. As a result, projects allow us to explicitly analyze the firm as a nexus of contracts and to gain valuable insights into corporate valuation, risk management and organizational design. This clinical study represents a first attempt in this direction by focusing on the intertemporal aspects of one particular set of contractual relationships. The next step consists of collecting a cross-sectional sample of bilateral monopolies in project finance in order to analyze the pricing of contracted and non-contracted risks in the context of an explicit model of bond default and credit spread behavior for projects. However, such an analysis is beyond the scope of the present paper.

APPENDIX A: Recovering Asset and Equity Values

Merton (1974) establishes that equity in the presence of risky debt is equivalent to a call option. Hence, risky debt can be viewed as combination of riskless debt of the same face value and a put option – the bankruptcy option. Ronn and Verma (1986) show how one can extract the firm's underlying asset value and volatility by matching equity prices and volatilities under the Merton model to their market analogs. The recovered asset values and volatilities then yield implied equity values, default rates, etc. from their theoretical expressions.

We adapt this procedure to our setting because Ras Gas as a joint venture has only private equity, but its debt trades in global markets. The starting point of our analysis is the Merton (1974) expression for the market value of risky debt D_t with (total) face value F and remaining maturity or default horizon $t = T - t$:

$$D_t = V_t N(-d_1) + e^{-rt} FN(d_2) = e^{-rt} F - N(-d_2)\left[e^{-rt} F - V_t \frac{N(-d_1)}{N(-d_2)}\right]$$

where V_t is the underlying asset value, r the risk-free rate, N the standard normal distribution and $d_1 = \left[\log\frac{V_t}{F} + \left(r + \frac{s_V^2}{2}\right)t\right]\left(s_V\sqrt{t}\right)^{-1}$ and $d_2 = d_1 - s_V\sqrt{t}$ the usual Black-Scholes-Merton parameters, given the underlying assets' volatility s_V. In the preceding expression, the *Merton default probability* is given by $N(-d_2)$ and the loss given default by the term in square brackets.

A simple application of Ito's Lemma to the above equation yields the debt volatility as a function of asset volatility $D_t s_D = N(-d_1)V_t s_V$ so that we obtain the following two (non-linear) equations in the two unknowns V_t and s_V:

$$D_t = V_t N(-d_1) + e^{-rt} FN(d_2)$$
$$s_D = N(-d_1)\frac{V_t}{D_t} s_V$$

We numerically solve the above system of equations for given market values of Ras Gas debt D_t and observed bond-price volatilities s_D using the Gauss-Newton algorithm on a weekly basis to recover *implied asset value* V_t reported in Table 5 and *volatility* s_V. The annualized bond-price volatilities are estimated over the previous 30 trading days for each weekly default calculation. Following KMV (see Crosbie and Bohn, 1993), we define the debt's face value F as the sum of the face value of all short-term liabilities + ½ long-term debt and solve for one-year and five-year default horizons so that $t = 1$ or 5.[35] The Merton (1974) framework also allows us to find the implied value of Ras Gas' private equity S_t in Figure 5 and Table 5 from the underlying asset values and volatilities as $S = V_t N(d_1) - e^{-rt} FN(d_2)$.

Finally, the asset values V_t and volatilities s_V imply weekly risk-neutral KMV *default probabilities* reported in Figure 5 and Table 5 that we simply calculate as $N(-z_t)$ for the *distance to default* $z_t = \frac{V_t - F}{V_t s_V}$.

[35] This normalization is standard reflecting the fact that debt differs in maturity, is amortized over time, pays periodic interest, etc. (see, e.g., Vassalou and Xing, 2004); simply taking the sum of all liabilities as in the original Merton (1974) framework would imply probabilities that presumably overstate default risk (see also Sobehart *et al*., 2000).

APPENDIX B: Tables and Exhibits

Table 1: Capital Structure and Uses of Funds

This table summarizes the Ras Gas' capital structure and its uses of funds (Standard and Poor's, 1999). ECA refers to bank loans and facilities guaranteed by three export credit agencies in conjunction with construction contracts awarded by Ras Gas to firms in the respective countries: the US Exim Bank, the UK's ECGD and Italy's SACE.

Uses of funds	(USD millions)	Sources of funds		% of total
Drilling	239	**Senior debt**	**2,285**	**70.00**
		Commercial banks	382	11.70
Offshore facilities	453	ECA guaranteed	703	21.50
		Bonds due 2006	400	12.30
Onshore facilities	1,670	Bonds due 2013	800	24.50
Venture costs	380	**Equity**	**979**	**30.00**
		QGPC	651	19.90
Financing costs,	593	Mobil	260	8.00
interest during construction		Itochu	39	1.20
		Nissho Iwai	29	0.90
Total costs	3,264	Total funds	3,264	100.00

Figure 6. Financial, Contractual and Cash-flow Structure

This figure summarizes the the project's financial and contractual structure as reflected by its operating cash flows (revenue: Korean off-take agreements, costs: royalties, operations), debt contracts (*pari passu*: banks, export credit agencies, bonds), and oil-price contingent debt-service guaranty (Mobil Corp.). The superscripts denote the order in which payments are made.

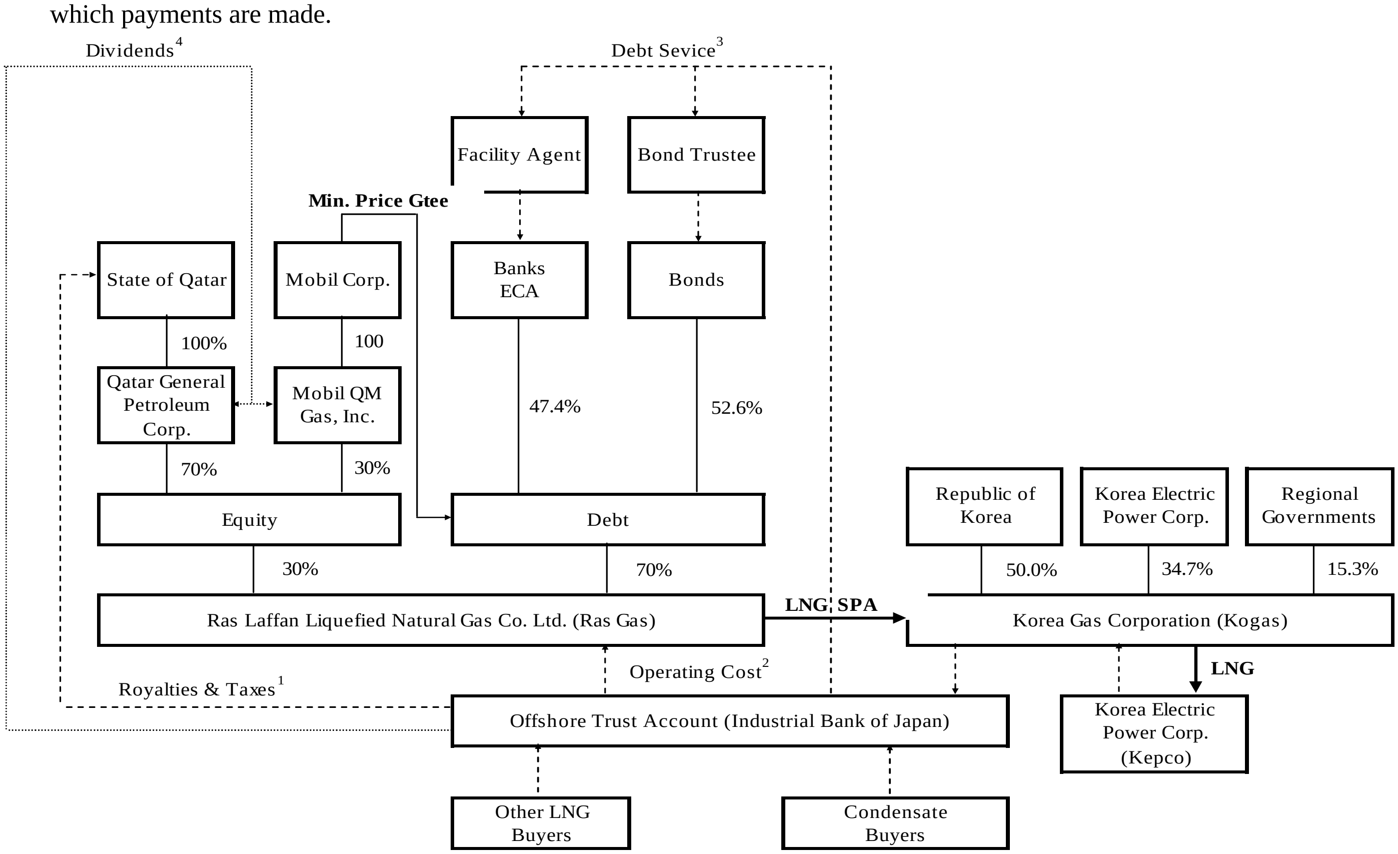

Table 2: Descriptive Statistics of Regression Variables

The two panels report summary statistics for the key variables and their correlations. *RGS* is the Ras Gas credit spread, *BRENT* the logarithm of the Brent blend oil price index, *KORELES* the Kepco credit spread, *KEPCO* the logarithm of Kepco's stock price, *MOBIL* the logarithm of Mobil's stock price, *KRW* the logarithm of the Korean Won – USD spot rate, *KOSPI* the logarithm of the Korea Composite Stock Price Index, *KRR* a rating index for Korea, and *MEA*, *ASIA*, *EUR*, *LAT* the continuously compounded daily returns of the JP Morgan regional indices in USD for emerging markets in the Middle East-Africa, Asia, Europe and Latin America, respectively. The variable descriptions in Panel A also apply to Panel B.

Panel A: Summary Statistics

Variable	Description	Mean	Std.Dev.	Minimum	Maximum	Obs.
RGS	Ras Gas spread over 10Y US Treasuries	3.1525	1.7648	1.1400	8.9580	725
BRENT	(Log) oil price	2.7955	0.2798	2.1972	3.3687	725
KORELES	Kepco yield spread over 10Y US Treasuries	3.5864	2.2631	1.0100	10.9700	725
KEPCO	(Log) Kepco stock price	3.2521	0.3474	2.5572	3.9180	725
MOBIL	(Log) Mobil stock price	4.4009	0.1691	4.1032	4.7270	725
KRW	(Log) Korean Won – US$ FX rate	7.0531	0.1855	6.7349	7.5820	725
KOSPI	(Log) Korea Stock Price Index	6.3963	0.3614	5.6348	6.9651	725
KRR	S&P-based Korea country rating index	4.6828	3.0268	0.0000	10.0000	725
MEA	JP Morgan Emerging debt returns Middle East	0.0003	0.0040	-0.0262	0.0201	724
ASIA	JP Morgan Emerging debt returns Asia	0.0002	0.0081	-0.0610	0.0420	724
EUR	JP Morgan Emerging debt returns Europe	0.0001	0.0069	-0.1147	0.0247	724
LAT	JP Morgan Emerging debt returns Latin America	0.0006	0.0048	-0.0418	0.0263	724

Panel B: Pairwise Correlation Matrix

Variable	RGS	BRENT	KORELES	KEPCO	MOBIL	KRW	KOSPI	KRR	MEA	ASIA	EUR	LAT
RGS	1.00											
BRENT	-0.53	1.00										
KORELES	0.80	-0.62	1.00									
KEPCO	0.06	0.43	-0.42	1.00								
MOBIL	0.26	0.27	-0.04	0.69	1.00							
KRW	0.52	-0.49	0.74	-0.24	0.21	1.00						
KOSPI	-0.37	0.71	-0.74	0.86	0.54	-0.49	1.00					
KRR	0.64	-0.48	0.73	-0.03	0.39	0.94	-0.36	1.00				
MEA	0.03	0.04	-0.03	0.06	0.02	-0.03	0.06	-0.03	1.00			
ASIA	0.13	-0.06	0.08	0.04	0.03	0.03	-0.02	0.07	0.10	1.00		
EUR	-0.01	0.01	0.00	0.02	0.05	0.03	0.04	0.02	0.24	0.08	1.00	
LAT	0.05	-0.01	0.00	0.04	0.05	0.00	0.02	0.00	0.33	0.11	0.10	1.00

Table 3: Contractual Risks, Country Factors and Emerging Market Returns

This table reports the results of the regression in levels (specifications 1 through 4) and first differences (5 through 8)

$$RGS_t = b_0 + \sum_{0\le l \le L} a_{-l} RGS_{t-l} + b_1 BRENT_t + \sum_{0\le l \le L} b_{2,-l} KORELES_{t-l} + b_3 MOBIL_t + b_4 KEPCO_t + b_5 KRW_t$$
$$+ b_6 KOSPI_t + b_7 KRR_t + \sum_{0\le l \le L}\left[g_{1,-l} MEA_{t-l} + g_{2,-l} ASIA_{t-l} + g_{3,-l} EUR_{t-l} + g_{4,-l} LAT_{t-l}\right] + e_t$$

RGS is the Ras Gas credit spread, *BRENT* the logarithm of the Brent blend oil price index, *KORELES* the Kepco credit spread, *MOBIL* and *KEPCO* the logarithms of Mobil's and Kepco's stock price, *KRW* the logarithm of the Korean Won – USD spot rate, *KOSPI* the logarithm of the Korea Composite Stock Price Index, *KRR* a rating index for Korea, and *MEA, ASIA, EUR, LAT* the continuously compounded daily returns of the JP Morgan regional indices in USD for emerging markets in the Middle East-Africa, Asia, Europe and Latin America, respectively. Coefficients statistically significant at 10% or less are indicated by boldface with exact P values given in parentheses.

Specification	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Dependent Variable	*RGS*	*RGS*	*RGS*	*RGS*	ΔRGS	ΔRGS	ΔRGS	ΔRGS
Constant	-0.1429	-0.0520	-0.1227	0.7708	**0.2445**	-0.1213	0.0546	0.0490
	(0.2730)	(0.6776)	(0.3131)	(0.2445)	(0.0285)	(0.5693)	(0.6536)	(0.8583)
Lagged Ras Gas	**0.9752**	**0.9831**	**0.9832**	**0.9671**				
spread RGS_{-1}	(0.0000)	(0.0000)	(0.0000)	(0.0000)				
Log *BRENT* oil price	**0.0414**	**0.0346**	**0.0361**	-0.0128	0.0030	0.0224	0.0148	
	(0.0591)	(0.0999)	(0.0774)	(0.6460)	(0.8519)	(0.2455)	(0.3660)	
Log *MOBIL* stock	0.0037	-0.0132	0.0027	0.0205	**-0.0572**	**-0.0764**	0.0048	-0.0254
price	(0.9104)	(0.6747)	(0.9302)	(0.6616)	(0.0288)	(0.0075)	(0.8865)	(0.5343)
Kepco spread	**0.0251**	**0.1558**	**0.1499**	**0.1627**				**0.1465**
KORELES	(0.0000)	(0.0000)	(0.0000)	(0.0000)				(0.0000)
Lagged Kepco spread		**-0.1370**	**-0.1312**	**-0.1220**				**-0.1331**
$KORELES_{-1}$		(0.0000)	(0.0000)	(0.0000)				(0.0000)
Change in Kepco					**0.1553**	**0.1388**	**0.1327**	
spread $\Delta KORELES$					(0.0000)	(0.0000)	(0.0000)	
Log *KEPCO* stock							**-0.0347**	**-0.0613**
price							(0.0488)	(0.0484)
Log *KRW*-USD spot				**-0.1868**		**0.0560**		-0.0418
rate				(0.0295)		(0.0503)		(0.2452)
Log Korean Stock				**0.0682**				**0.0804**
Price Index *KOSPI*				(0.0378)				(0.0511)
Change in *KOSPI* =						-0.2232	-0.1271	
daily return $\Delta KOSPI$						(0.1326)	(0.3873)	
Korea rating index				0.0039				
KRR				(0.5155)				
Change in Korea Rat-						**0.0397**	**0.0402**	**0.0383**
ing index ΔKRR						(0.0322)	(0.0239)	(0.0309)
EMBI Europe daily			**-2.0407**	**-2.0149**			**-2.0072**	**-2.0545**
return *EUR*			(0.0005)	(0.0005)			(0.0007)	(0.0005)
EMBI Latin American			**-1.5733**	**-1.5547**			**-1.5604**	**-1.7461**
daily return LAT_{-1}			(0.0625)	(0.0640)			(0.0716)	(0.0403)
EMBI Middle-East			**-2.7578**	**-2.7787**			**-2.9815**	**-3.0850**
daily return MEA_{-2}			(0.0060)	(0.0053)			(0.0034)	(0.0023)
EMBI Europe daily			**-3.2623**	**-3.3796**			**-3.1572**	**-3.1856**
return EUR_{-3}			(0.0000)	(0.0000)			(0.0000)	(0.0000)
EMBI Latin American			**-2.1519**	**-2.0512**			**-2.3133**	**-2.3259**
daily return LAT_{-5}			(0.0115)	-0.1868			(0.0074)	(0.0067)
Observations	724	724	719	719	724	724	719	719
Adj. R^2	0.9956	0.9959	0.9963	0.9964	0.1147	0.1247	0.2000	0.2083

Table 4: Equilibrium Relationships and Bilateral Monopoly

This table reports the estimation results (by maximum likelihood) of the following system of equations

$$\begin{aligned} RGS_t &= b_{01} + \sum_{0 \le l \le L} a_{1,-l} RGS_{t-l} + b_{11} BRENT_t + \sum_{0 \le l \le L} b_{21,-l} KORELES_{t-l} + b_{31} MOBIL_t + b_{41} KEPCO_t + b_{51} KRW_t \\ &\quad + b_{61} KOSPI_t + b_{71} \Delta KRR_t + \sum_{0 \le l \le L} \left[g_{11,-l} MEA_{t-l} + g_{21,-l} ASIA_{t-l} + g_{31,-l} EUR_{t-l} + g_{41,-l} LAT_{t-l} \right] + e_{t1} \\ KORELES_t &= b_{02} + \sum_{0 \le l \le L} a_{2,-l} RGS_{t-l} + b_{12} BRENT_t + \sum_{0 \le l \le L} b_{22,-l} KORELES_{t-l} + b_{32} MOBIL_t + b_{42} KEPCO_t + b_{52} KRW_t \\ &\quad + b_{62} KOSPI_t + b_{72} \Delta KRR_t + \sum_{0 \le l \le L} \left[g_{12,-l} MEA_{t-l} + g_{22,-l} ASIA_{t-l} + g_{32,-l} EUR_{t-l} + g_{42,-l} LAT_{t-l} \right] + e_{t2} \end{aligned}$$

in levels (Specifications 1 and 2) and first differences (Specifications 3 and 4); see the previous tables for variable definitions and further explanations. Estimates significant at 10% or better are in bold face, P values in parentheses.

Specification	1		2		3		4	
Dependent Variable	*RGS*	*KORELES*	*RGS*	*KORELES*	ΔRGS	$\Delta KORELES$	ΔRGS	$\Delta KORELES$
Constant	**0.8317**	-0.0911	**0.5525**	**-1.3414**	**1.1772**	-0.4585	**1.1681**	-0.5478
	(0.0061)	(0.8853)	(0.0245)	(0.0144)	(0.0603)	(0.3200)	(0.0530)	(0.2435)
Ras Gas spread *RGS*		**0.0529**		**0.0495**				
		(0.0003)		(0.0009)				
Lagged Ras Gas spread RGS_{-1}	**0.9688**		**0.9669**			**-0.0218**		**-0.0223**
	(0.0000)		(0.0000)			(0.0000)		(0.0000)
Log *BRENT* oil price	0.0335	**0.2401**	-0.0019	0.0632	0.0423	-0.0284	0.0643	-0.0472
	(0.2415)	(0.0000)	(0.9348)	(0.1790)	(0.4019)	(0.4630)	(0.1950)	(0.2538)
Log *MOBIL* stock price	0.0243		0.0223		-0.0074		0.0217	
	(0.5745)		(0.5891)		(0.8602)		(0.5713)	
Kepco spread *KORELES*	**0.0279**		**0.0369**		**1.3835**		**1.3034**	
	(0.0001)		(0.0000)		(0.0000)		(0.0000)	
Lagged Kepco spread $KORELES_{-1}$		**0.9030**		**0.9392**	**-1.3504**		**-1.2713**	
		(0.0000)		(0.0000)	(0.0000)		(0.0000)	
Log *KEPCO* stock price	**0.0976**	0.0866	**0.0583**	**-0.1956**	**0.0502**			**0.0331**
	(0.0210)	(0.3276)	(0.0190)	(0.0001)	(0.0327)			(0.0585)
Log *KRW*-USD spot rate	**-0.1038**	**0.3545**	**-0.1219**	**0.2642**	**-0.2190**	**0.0860**	**-0.2205**	0.0911
	(0.0179)	(0.0000)	(0.0033)	(0.0012)	(0.0106)	(0.1382)	(0.0073)	(0.1226)
Log Korean Stock Price Index *KOSPI*	**-0.0968**	**-0.4974**						
	(0.0792)	(0.0000)						
Change in *KOSPI* = daily return $\Delta KOSPI$			**-0.4298**	**-1.3051**	**1.6486**	**-1.5649**	**1.6566**	**-1.6351**
			(0.0027)	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0000)
Change in Korea Rating index ΔKRR	**0.0723**	**0.2857**	**0.0691**	**0.2819**	**-0.3110**	**0.2804**	**-0.2914**	**0.2842**
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
EMBI Europe daily return *EUR*			**-2.0172**	-1.0627			**-1.9038**	
			(0.0006)	(0.4160)			(0.0009)	
EMBI Latin American daily return LAT_{-1}			**-1.0559**	-1.7391			**-0.8890**	
			(0.0381)	(0.1241)			(0.0724)	
EMBI Middle-East daily return MEA_{-2}			**-2.9595**	-0.5085			**-2.9268**	
			(0.0034)	(0.8206)			(0.0029)	
EMBI Europe daily return EUR_{-3}			**-3.3857**	0.1223			**-3.3300**	
			(0.0000)	(0.9267)			(0.0000)	
EMBI Latin American daily return LAT_{-5}			**-2.2741**	-0.5727			**-2.2559**	
			(0.0081)	(0.7638)			(0.0068)	
Observations	724		719		724		719	
Log-likelihood	570.02		601.37		560.23		586.90	

Table 5. Asset Values, Equity Values and Default Probabilities

This table reports the quarterly and yearly averages of implied asset and private-equity values estimated from the KMV implementation of the Merton (1974) model with a five-year horizon on a week-by-week basis. Similarly, we calculate implied one-year and five-year default probabilities from the extracted asset values and volatilities. For comparability we also report average yearly and quarterly credit spreads for Kepco and Ras Gas as well as Brent prices (per barrel), the leading crude-oil reference price for settling LNG transactions, over the sample period by quarter and year. The lower panel contains weekly summary statistics for the same period.

Year/Quarter	Ras Gas Valuation (in USD millions)		1Y Default Probability		5Y Default Probability		Credit Spread (bps)		Brent (bbl)
	Assets	Private Equity	Ras Gas	Kepco	Ras Gas	Kepco	Ras Gas	Kepco	
1997 1Q	$1,041.92	$518.36	6.23%	0.05%	7.44%	0.19%	144	107	21.38
1997 2Q	$1,075.89	$557.87	0.00%	0.10%	0.00%	0.49%	138	108	18.01
1997 3Q	$1,111.55	$583.24	0.00%	0.18%	0.00%	0.44%	119	124	18.50
1997 4Q	$1,059.07	$528.08	7.06%	3.65%	8.47%	15.71%	194	332	17.68
1997	**$1,071.92**	**$546.73**	**3.33%**	**1.03%**	**3.99%**	**4.36%**	**149**	**170**	**18.85**
1998 1Q	$1,107.93	$596.03	30.94%	10.24%	33.08%	33.37%	271	472	14.13
1998 2Q	$1,297.30	$787.84	30.52%	11.52%	30.44%	14.68%	243	469	12.24
1998 3Q	$1,313.12	$778.63	21.11%	9.02%	20.99%	16.54%	498	761	12.45
1998 4Q	$1,527.09	$797.18	9.20%	6.91%	12.10%	19.26%	676	708	11.18
1998	**$1,315.43**	**$741.00**	**22.68%**	**9.38%**	**23.92%**	**20.93%**	**427**	**604**	**12.47**
1999 1Q	$1,740.45	$1,018.05	29.75%	9.72%	28.39%	18.54%	476	365	11.35
1999 2Q	$1,817.02	$1,080.94	9.12%	8.67%	10.84%	11.75%	358	305	15.45
1999 3Q	$2,088.66	$1,116.70	4.37%	6.20%	4.45%	8.46%	351	327	20.51
1999 4Q	$2,167.42	$1,203.82	0.00%	4.48%	0.00%	8.06%	321	256	22.25
1999	**$1,961.60**	**$1,108.45**	**10.24%**	**7.17%**	**10.37%**	**11.50%**	**374**	**311**	**17.60**
2000 1Q	$2,258.04	$1,281.15	0.00%	4.58%	0.00%	10.66%	251	221	26.99
Weekly Mean	$1,497.80	$827.92	11.59%	5.87%	12.24%	12.33%	315.73	357.93	16.84
Weekly Stddev	$433.18	$264.58	14.75%	4.00%	15.03%	9.79%	176.61	222.33	5.32
Weekly Min	$889.73	$368.68	0.00%	0.03%	0.00%	0.06%	115.00	101.00	0.00
Weekly Max	$2,275.64	$1,297.99	33.53%	12.38%	37.38%	36.39%	861.00	1035.00	30.01

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