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Changing Contract Structures in the International Liquefied Natural Gas Market – A First Empirical Analysis

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Abstract

This paper provides an empirical assessment of long-term liquefied natural gas (LNG) supply contracts to determine optimal contract duration. We study the trade-off between contracting costs due to repeated bilateral bargaining and the risk of being bound in an inflexible agreement in uncertain environments. Furthermore, we add to the theoretical discussion an analysis of different dimensions of transaction frequency and their impact on governance choice. Estimation results of a two-stage model show that the presence of high dedicated asset specificity results in longer contracts thus confirming the predictions of transaction cost economics, whereas the need for flexibility reduces contract duration. With increasing bilateral trading experience between the same trading partners, contract duration decreases. We additionally observe that countries heavily reliant on natural gas imports via LNG are willing to forgo some flexibility in favor of supply security. Contracts dedicated to competitive downstream markets on average are shorter than those concluded with customers in non-liberalized import markets.

JEL-Codes: D23, L22, L95

Keywords: long-term contract, optimal contract duration, transaction cost economics, contracting costs, liquefied natural gas

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1 Introduction

The future role of long-term contracts in the global energy sector is a major topic in recent policy debates. Whereas long-term agreements support investments in capital intensive infrastructures and are a mean to hedge price and quantity risks, they may prevent the development of more competitive market structures. The discussion is fostered by the ongoing liberalization process in Continental Europe's natural gas and electricity markets in a period when import countries have encountered record-high prices, e.g., crude oil has been traded in the US$ 140/bbl range in summer 2008 and liquefied natural gas (LNG) spot cargoes delivered to Japan were above US$ 19/MBTU in January 2008 (Platts, 2008).

Market restructuring has changed contracting practices between importers or domestic producers and downstream distribution companies. The German cartel office for example decided in 2005 to confine the conclusion of long-term contracts between natural gas transmission companies and regional distributors. The IEA (2004, p. 98) points out that whereas long-term contracts are still the dominant contractual form between non-European exporters and importing companies; the last „will have to hedge their long-term minimum pay commitment by having reliable long-term marketing possibilities." On a roundtable on energy security and competition policy organized by the OECD in 2007 it was argued that long-term contracts on the one hand facilitate investments, but on the other hand mitigate market entry; furthermore, restrictions on resale and volume flexibility reduce secondary markets' liquidity.

In the view of institutional economics, long-term contracts are considered a hybrid form of governance on the continuum between spot markets and full vertical integration. Long-term LNG supply contracts are concluded between private oil and gas majors who participate in upstream projects or a consortium of the national oil and gas company (NOC) and a private partner and a downstream importer. Contract duration of these agreements typically were in the range of 15 to 30 years in the early years of the industry. In the last decade there has been an increase in the number of agreements with less than 20 years and even less than ten years duration.

The structure of long-term contracts has changed: contract duration as well as annual contracted volume are decreasing, oil-price indexation is diminishing in importance in favor of gas-to-gas competition, and inflexible clauses (e.g., take-or-pay or destination obligations) have been relaxed or eliminated. Furthermore, we observe a move from contracts in which the seller is responsible for midstream transportation (i.e., „cost-insurance-freight" [cif] or „delivered-ex-ship" [des]) towards contracts in which title transfer occurs at the loading port (i.e., „free-on-board" [fob]). Under a free-on-board contract, buyers have the possibility to manage variations in demand more flexible via cargo re-direction and to benefit from resell options.

This paper analyses the determinants of changes in contract duration in order to investigate the impact of market structure (i.e., level of competition on a regional as well as global scale) on optimal governance choice. There are several dynamic factors currently affecting the global market for natural gas: increasing competition for world reserves in a seller's market, realization of large-scale infrastructure investments (LNG as well as pipelines), new market entrants (countries as well as companies), and changes in trade structures. The past five to ten years have seen the global LNG industry undergoing rapid maturation. Changes in the institutional framework of downstream markets have moved the industry from monopolistic structures towards competition, thus stimulating fundamental changes in the organizational behavior of market participants. Hence, competitive structures gain in importance in downstream markets at the same time that formerly regional markets become linked and importers compete globally for natural gas supplies.

Theoretical literature discussing the structure of long-term contracts can be classified into three main approaches: 1) transaction cost economics, assuming bounded rationality of economic actors as well as asymmetric information, argues that long-term contracts are a way of minimizing transaction costs in bilateral relationships where relationship specific investments occur with complex contracts functioning to overcome the ex-post hold-up problem without integrating vertically (Williamson, 1975, 1985; Klein et al., 1978); 2) the property rights approach is a theory of incomplete contracts assuming rational agents with symmetric information but non-verifiability of actions by third parties. It emphasizes the impact of ex-post opportunism on ex-ante investment incentives, formalizes the hold-up problem arising from specific investments, and discusses the optimal transfer of residual control rights (Grossman and Hart, 1986); and 3) incentive theory, assuming rational agents but asymmetric information, formalizes the problems of adverse selection and moral hazard and discusses optimal contract design to overcome principal-agent problems (Laffont and Martimort, 2002).

There is a growing body of empirical literature investigating the determinants of contract duration and contractual terms. Masten (1999) provides a first categorization of studies analyzing contracting structures. Whereas the early literature focusing on the natural gas sector is based on the US market; Hirschhausen and Neumann (2008) provide the first study using international trade data. Our contribution to the literature is the first empirical assessment focusing on long-term liquefied natural gas supply contracts. In contrast to traditional pipeline infrastructures; there is no locational specificity of investments resulting from technical characteristics since trades between varying players theoretically are feasible. We discuss the determination of optimal contract length as a trade-off between the minimization of transaction costs due to repeated bilateral bargaining and the risk of being bound in an inflexible agreement in uncertain environments. Furthermore, this study adds to the theoretical discussion an analysis of different dimensions of transaction frequency and their impact on governance choice.

Building a simultaneous equation model to account for the endogeneity of a right-hand side variable, we empirically test propositions i) on the above mentioned trade-off with long-term contracts securing durable investments but forgoing some flexibility, and ii) on the influence of transaction frequency (within the relationship as well as between the trading partners) on contract duration. Estimation results using a unique dataset including information of LNG supply contracts from the beginning of the industry until today show that the presence of high asset specificity results in longer contracts, confirming the predictions of transaction cost economics whereas the need for flexibility in today's 'second generation' LNG market supports shorter-term agreements. When firms have experience in bilateral trading, contract duration decreases. In addition, countries heavily reliant on natural gas imports via LNG are often willing to forgo some flexibility in favor of supply security. Contracts dedicated to competitive downstream markets on average are shorter than those concluded with customers in non-liberalized importing countries.

2 Literature Review

Most empirical studies testing transaction cost economics' propositions analyze the make-or-buy decision; there is still a relatively small body of literature explaining contract duration or other contractual provisions. Nevertheless, existing empirical papers offer broad support for the proposition that economic actors choose organizational form and contract terms that promote efficient adaptation and minimize transaction costs.

Several empirical studies, most of which are based on a transaction cost framework, investigate contract duration and environmental characteristics. Pirrong's (1993) analysis on contracting practices in bulk shipping markets investigates differences in exogenous factors such as market structure or vessel specialization in order to explain the diversity of existing governance forms. Whereas spot contracts are chosen in the absence of any bilateral dependency relationship; forward contracts are employed when significant temporal specificity is observed. In a specialized shipping market where both temporal and contractual specificities are present, long-term contracts or vertical integration are the transaction cost economizing organizational forms. Using data on trading relationships between input suppliers and engineering firms, Lyons (1994) shows that the probability of using formal contracts increases with the vulnerability to opportunistic behavior whereas it decreases with the complexity of the transaction.

Empirical work on long-term contracts in the energy sector started during the 1980s. Joskow's path-breaking work (1985, 1987) investigating the relationship between specific investments and contract duration in the US coal industry shows that contracting parties make longer commitments when site specific, physical asset specific or dedicated investments occur. Using a sample of 277 supply contracts between coal producers and electric utilities, Joskow estimates different models, accounting for nonlinear relationships between endogenous and exogenous variables, the truncated nature of the sample, alternative measures of asset specificity as well as the endogeneity of the annual contracted volume.

Whereas Joskow (1987) focuses mainly on the benefits of contracting, Saussier (1999) provides an empirical study based on the European coal industry discussing the trade-off between both, the costs and benefits of contracting. Using a dataset containing all 70 contracts for the transportation and unloading of coal to Électricité de France's power plants which have been concluded between 1977 and 1997, he confirms that contract duration reflects the desire to minimize transaction costs. Whereas duration increases with the level of appropriable quasi rents at stake in the transaction, it decreases with the level of uncertainty. These results are also robust to a second model in which he accounts for the endogeneity of specific investments. Saussier (2000) adds to the discussion a new dimension via testing the influence of transaction parameters on the level of completeness of French coal supply contracts, accounting again for the endogeneity of asset specificity. Analyzing a sample of 29 contracts signed between 1977 and 1997 he shows that the completeness of contracts increases with the level of physical-, site-, dedicated-, and human asset specificity and decreases with the level of uncertainty.

Kerkvliet and Shogren (2001), too, confirm transaction cost economics by empirically investigating 89 coal contracts concluded between producers in the US Powder River Basin and utilities from 1972 to 1984. They find a positive relationship between physically specific investments and contract duration and show that contract duration decreases with rising trading and market experience. However, for their measure of dedicated asset specificity they find counterintuitive results.

Ellman (2006) extends the basic transaction cost economics model by formalizing the contracting costs associated with multiple investments (i.e., initial specific investment and adaptation investment). In cases where the so called side-compatibility[2] is low, long-term contracts preventing hold-up of quasi rents generated by the initial specific investment may induce hold-up of adaptation investments. Contracts therefore should be shorter under low side-compatibility when at the same time it is important to motivate adaptation investments. Hence, Ellman is able to explain Kerkvliet and Shogren's (2001) counterintuitive result of dedicated asset specificity leading to shorter contracts: dedication lowers side-compatibility and thereby is raising the costs of long-term contracting because in the case an adaptation investment will be necessary, there will be less potential trading partners.

A number of studies investigating the natural gas sector discuss contractual relations in different institutional settings: Mulherin (1986) shows that specific investments in the US natural gas industry historically have been protected by the use of complex long-term forms of organization. Whereas prior to the 1930s vertical integration from production over transportation to distribution has been common, governmental regulation (i.e., the Public Utility Holding Act 1935 and the Natural Gas Act 1938) led to long-term contracts being the predominant governance form with pipeline companies buying from producers and reselling to distributors. Exclusive dealing and take-or-pay provisions served as a mean to protect quasi rents at stake and prevent opportunistic behavior by the non-investing parties.

[2] Side-compatibility refers to the possibility that adaptation investments are organized with a third contracting partner parallel to the initial contract. Side-trading obviously will be most effective and least expensive when adaptation and basic trade are least related.

Hubbard and Weiner (1986) analyze long-term natural gas supply contracts between producers and pipelines following the phased deregulation of wellhead prices in the US and derive a theoretical model on the determination of take-or-pay provisions. They show that wellhead price ceilings favor long-term contracts which include non-price contract provisions such as take-or-pay clauses which increase the producers' total compensation. The authors can corroborate these predictions by empirical evidence from a sample of 470 contracts concluded between producers and pipelines after 1978 (i.e., after the passage of the Natural Gas Policy Act which constituted different classes of price ceilings according to natural gas well characteristics).

Crocker and Masten (1988) discuss and test the impact of regulatory actions on contract duration. Using a dataset of 280 contracts between US natural gas producers and their customers concluded between 1960 and 1981 they confirm the trade-off between the costs of repeated bargaining in the presence of relationship-specific investments and the hazard of being bound to an inflexible long-term agreement. They furthermore show theoretically as well as empirically that distortions in performance incentives raise the costs of long-term agreements and therefore shorten contract duration. In the presence of binding price ceilings, buyers are unable to compete for scarce resources with higher prices and will instead attempt to attract sellers by offering more favorable non-price contract terms. In a later paper Masten and Crocker (1991) investigate the choice of alternative price adaptation clauses in US natural gas supply contracts. Whereas the presence of uncertainty should favor renegotiation, the presence of high quasi rents at stake should favor redetermination clauses based on pricing formulas which reduce the frequency of negotiations and therewith the hazard of opportunistic haggling.

Doane and Spulber (1994) argue that regulatory reforms in the US natural gas market promoting open access to transportation infrastructures have reduced the specificity of investments since bilateral dependencies between sellers and buyers decreased which in turn resulted in a lower hold-up risk and a substitution of long-term contracts in favor of short-term and spot trade.

Neuhoff and Hirschhausen (2005) discuss the role of long-term natural gas contracts in markets undergoing liberalization. First, they argue that long-term contracts diminish in importance with increasing downstream competition. Second, they develop a theoretical model built upon the industrial organization literature showing that both producers and consumers benefit from lower prices and a higher market volume if long-run demand elasticity is significantly higher than short-run elasticity.

Hirschhausen and Neumann (2008) provide an empirical analysis of the changing contract structure in international natural gas trading. Using a dataset of 311 long-term natural gas supply contracts including pipeline as well as LNG deliveries, they find that contract duration decreases as market structure evolves to more competitive regimes and provide further empirical support for transaction cost economics showing that investments linked to specific infrastructures increase contract duration by an average of three years. They also find that market entrants tend to sign shorter contracts confirming the hypothesis that long-term agreements are mainly relevant during the early stages of industry development when large scale infrastructure investments have to be realized and the number of potential trading partners is limited.

Whereas the early literature focusing on the natural gas sector is based on the US market; Hirschhausen and Neumann (2008) provide the first study using international trade data. Our contribution to the literature is the first empirical assessment focusing on long-term liquefied natural gas supply contracts. In contrast to traditional pipeline infrastructures there is no locational specificity of investments resulting from technical characteristics since trades between varying players theoretically are feasible. The market structure has changed dramatically during the past decade; the survival of incumbents as well as new entrants strongly depends on their ability to act economically; strategic decisions (of private sector players) are driven by cost minimization. The heterogeneity of transactions in terms of varying levels of relationship-specific investments and external uncertainty should be matched by diversity in forms of governance (varying levels of vertical integration; varying characteristics and duration of supply contracts, etc.). For these reasons, the data are particularly well-suited to test transaction cost theory's propositions. We discuss the determination of the optimal contract length as a trade-off between the minimization of transaction costs due to repeated bilateral bargaining and the risk of being bound by an inflexible agreement in uncertain environments. Furthermore, this study adds to the theoretical discussion an analysis of different dimensions of transaction frequency and their impact on governance choice.

3 Theoretical Background

3.1 Optimal contract duration – a trade-off

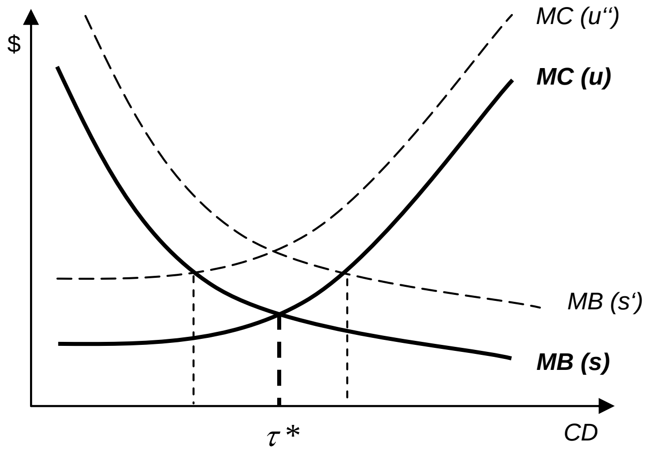
The trade-off between contracting costs and flexibility is discussed in theory and investigated in a number of empirical papers (e.g., Gray, 1978; Crocker and Masten, 1988; Klein, 1989; Klein et al. 1990; Heide and John, 1990). On the one hand, transaction cost economics predicts that investments in idiosyncratic assets result in ex-post bilateral dependency and lead to a lock-in situation where the investor faces the hazard of post-contractual opportunism and strategic bargaining by the counterparty. In such settings longer-term agreements attenuate those costs by stipulating the terms of trade over the life of the contract. On the other hand, contract duration is limited due to uncertainty about the future and the hazard of being bound by an agreement that may no longer reflect market realities (e.g., demand levels, input and output prices, changes in the institutional environment, technological innovations); obviously, spelling out every contingency is costly or even impossible. Hence, the trade-off lies in choosing "terms that maintain incentives for efficient adaptation while minimizing the need for costly adjudication and enforcement" (Crocker and Masten, 1988, p. 328).

The optimal level of contract duration $\tau *$ corresponds to a situation where the marginal costs and the marginal benefits of contracting are equal. The costs of being bound by the contract are determined mainly by the level of uncertainty and will increase with duration. Uncertainty about the future of the environment is higher for more distant time horizons; parameters that are fixed in the short-term become variable in the long-term; stipulated terms may be inefficient in later periods. Marginal costs increase with uncertainty and contract duration. Hence, the principal costs as against a shorter contract can be traced back to ex-ante information costs and potential ex-post maladaptation and renegotiation costs. It has to be noted that the presence of uncertainty also rises the costs of bargaining (i.e., spot trade); however, the costs of contracting increase to a greater extent since the party must account for all (known) possible contingencies.

The benefits of avoiding repeated negotiation are chiefly determined by the level of idiosyncratic investments dedicated to the trading relationship. Longer-term agreements support the willingness of the party to take actions whose values are conditional upon the counterparty's post-contractual behavior; longer contracts reduce the exposure to opportunistic behavior by the non-investing contractor by defining the distribution of rents ex-ante. Furthermore, the costs of the repeated bargaining of shorter trading agreements can be reduced. Marginal benefits decrease with every additional period covered by the contract.

Figure 1 illustrates the optimization problem. An increase in the level of uncertainty (u'' > u) will result in an upward shift of the marginal cost curve; an increase in the level of asset specificity (s' > s) will result in an upward shift of the marginal benefits curve.

Figure 1: Optimization problem



Source: Own depiction

We can formalize the discussion above by the following optimization problem: $\max_{\tau} G(\tau)$ with $G(\tau) = B(\tau) - C(\tau)$ with G being the net gains in transaction costs which equal the difference between the benefits of contracting B and the costs of contracting C (both, ex-ante as well as ex-post). The first order condition yields:

$$G^{'}(\tau) = MB(\tau) - MC(\tau) = 0$$
$$MB(\tau *) = MC(\tau *) \qquad (1)$$

with optimal contract duration determined by the setting where marginal benefits equal marginal costs. Since it is difficult to observe and measure contracting costs, we construct a reduced form model where the marginal cost and marginal benefits of contracting are related to observable contracting attributes:

$$MB(\tau *) = MB(\tau, s, \nu) = \alpha_0 + \alpha_1 \tau + \alpha_2 s + \nu$$
$$MC(\tau *) = MC(\tau, u, \omega) = \beta_0 + \beta_1 \tau + \beta_2 u + \omega \qquad (2)$$

with τ being the length of the agreement, s the level of specific assets dedicated to the trading relationship, u the level of uncertainty and ν and ω further explaining attributes such as unobserved heterogeneity between the parties or environmental characteristics. Substituting (2) into (1) and rearranging yields the reduced form

$$\tau^* = \gamma_0 + \gamma_1 s - \gamma_2 u + \varepsilon \qquad (3)$$

$$\text{with } \gamma_0 = \frac{\alpha_0 - \beta_0}{\beta_1 - \alpha_1}, \gamma_1 = \frac{\alpha_2}{\beta_1 - \alpha_1}, \gamma_2 = \frac{\beta_2}{\beta_1 - \alpha_1}, \varepsilon = \frac{\nu - \omega}{\beta_1 - \alpha_1}$$

with optimal contract duration on the left side of the equation and contracting attributes on the right. From the discussion above the following propositions are derived:

Proposition 1a: Contract duration should increase with the level of investments in idiosyncratic assets to avoid repeated bilateral bargaining and mitigate the vulnerability to ex-post hold-up.

Proposition 1b: Higher environmental uncertainty should reduce contract duration to minimize the risk of being bound by a long-term commitment that no longer reflects market realities.

3.2 The impact of transaction frequency

Transaction cost theory argues that transaction costs increase with the frequency of the transaction within the trading relationship due to the repeated hazard of opportunistic behavior and potential strategic renegotiation. This will yield in increased incentives to organize the transaction under stronger internal control. An alternative, complementary explanation for a high frequency resulting in more firm-like governance structures is the greater potential for internal specialization and for exploiting scale economies (see e.g., Williamson, 1985). Transaction costs imposed by specific assets make more hierarchical organizational forms more appealing; however, a specialized governance mechanism involves significant setup as well as bureaucratic costs. Hence, the net benefits from avoiding post-contractual hold-up as compared to the fixed costs of a more hierarchical governance form increase with transaction frequency. We am only aware of a small number of empirical studies testing transaction cost economics predictions and including transaction frequency as explanatory variable (such as Anderson and Schmittlein, 1984).

However, another perspective looks at the number of settlements in which similar transactions by the same parties occur. First, faithful partners may be rewarded and opportunistic behaviors punished in such long-term relationships. Second, there may be a decrease in transaction costs due to learning processes, established routines, enhanced efficiency of communication, and reputational effects (see e.g., Milgrom and Roberts, 1992; Langlois, 1992), all of which reduce the need for formal mechanisms to enforce bilateral agreements. Transaction frequency therefore should result in shorter contracts. Garvey (1995) develops a model investigating the effect of reputation on governance choice in settings where non-contractible investments occur. He finds that integration is favored for one-shot games whereas more hybrid structures like joint ventures are preferred in repeated games. He argues further that reputational considerations have an effect on both the parties' surplus and the optimal choice of asset ownership, supporting less hierarchical governance modes.

I argue that these two perspectives on transaction frequency complement rather than compete one another. With increasing 'within frequency' the costs of contracting will rise due to the repeated hazard of opportunistic bargaining; with increasing 'between frequency' the costs of contracting will fall due to lower ex-ante as well as ex-post transaction costs. Therefore, the above developed model is expanded by including two frequency measures: *fw* indicating the frequency of the transaction <u>within</u> the relationship and *fb* indicating the historical frequency of transactions <u>between</u> the same trading partners expecting a positive (respectively negative) relationship with contract duration:

$$\tau^* = \gamma_0 + \gamma_1 s - \gamma_2 u + \gamma_3 fw - \gamma_4 fb + \varepsilon \qquad (4)$$

The following propositions are derived:

<u>Proposition 2a:</u> Contract duration should increase with the level of frequency of the transactions within the trading relationship to avoid the repeated hazard of post-contractual opportunism by the non-investing party.

<u>Proposition 2b:</u> Contract duration should decrease with the frequency of transactions between the same trading partners due to learning and reputational effects.

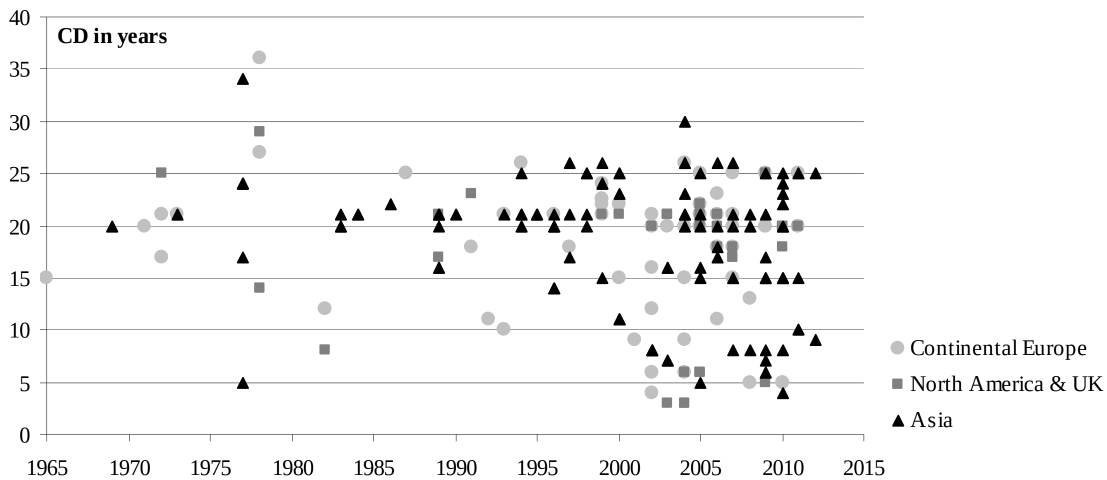
4 Data and Methodology

4.1 Data

The global dataset covering long-term agreements from the beginning of the industry until today has been compiled from various publicly available information such as periodical reports, newsletters, and industry journals. It includes contracting partners, annual and total contracted volumes, the year of contract signature, the start date of deliveries and contract duration. Both, contracts currently in place or agreed for with the start of delivery during the coming years and contracts that already have been terminated are incorporated. Therefore, this study does not suffer from a truncated dependent variable as discussed in several other empirical papers investigating the determinants of contract duration (e.g., Joskow, 1987; Crocker and Masten, 1988; Masten and Crocker, 1991). After talking to industry experts it can be assumed that the dataset covers at least 80% of all ever existing long-term LNG supply contracts.

Omitting observations with implausible data as well as contracts with a duration of less than three years (since these have the character of short-term agreements in the LNG industry), the sample consists of 261 LNG supply contracts, of which 105 correspond to Atlantic Basin trade and 156 to Asia-Pacific deliveries. Figure 2 illustrates the contract duration of all LNG supply contracts included in the estimation sample. Contract duration of these agreements varies between three and 36 years and is typically in the range of 15 to 30 years in the early decades of the industry. In the last decade there has been an increase in the number of agreements with less than 20 years and even less than ten years duration. Average contract length for agreements starting delivery prior to the year 2000 is 20.5 years in the sample; for contracts starting delivery from 2000 on it is 16.5 years.[3]

Figure 2: Contract duration and start of deliveries of LTCs included in the sample



[3] Differentiating between importing regions, average contract duration in Continental Europe has been 20.6 years (16.9 years), in the more competitive natural gas markets of North America and the UK 19.7 years (16 years), and in Asia 20.5 years (16.9 years) before and from the year 2000 on respectively based on this dataset.

The unit of analysis for studying the determinants of contract duration is an LNG supply contract concluded between an upstream seller (company or consortium) and a downstream buyer. Transactions are defined as cargo deliveries of LNG. The endogenous variable is contract duration in years. For the purpose of this study we assume a sample of contracts that holds constant other contract provisions, such as price adaptation or renegotiation clauses. Unfortunately, the existence and utilization of such provisions is held confidentially by the trading partners and cannot be accounted for in this analysis.

4.2 Explanatory variables

Asset specificity. The benefits of writing a long-term contract should be positively related to the vulnerability of the trading partners to ex-post opportunistic behavior by the counterparty. Asset specificity varies across the transactions in the industry; in this study it refers to the degree to which an LNG import terminal is not redeployable. The characteristic of a seller's market accompanied by restructuring and liberalization of downstream natural gas (and electricity) markets results in downstream asset specificity. A player investing in regasification capacity without having secured supplies and access to midstream shipping is caught in a lock-in situation. LNG sellers profit from significant bargaining power since importers compete globally for supplies; furthermore, competitive downstream markets provide easy access to numerous buyers. To quantify the level of idiosyncrasy (i.e., relationship specific investments) the ratio to which the contract exploits the nominal capacity of the import terminal (<u>RCAPSHARE</u>) is used. A buyer relying on a single supplier for a large volume of deliveries will have difficulties to replace these supplies if they are terminated suddenly in an illiquid market such as the LNG market, where only very limited free capacities (upstream supplies as well as midstream ships) are available.[4]

Uncertainty. Uncertainty is a broad concept; Klein (1989) distinguishes between complexity and unpredictability; Williamson (1985, p. 57) states that "disturbances… are not all of a kind. Different origins are usefully distinguished." This study focuses on external uncertainty components measuring environmental dynamism (i.e., price uncertainty, political instability in the exporting country, and general environmental uncertainty). The standard deviation of the West Texas Intermediate crude oil spot prices (<u>STDEVOIL</u>) in the year before contract signature, calculated based on daily data, is employed as a measure of price uncertainty. Oil prices traditionally influence natural gas prices via oil-linkage in pricing formulas; even though oil-linkage is substituted step by step in favor to gas indexes that reflect gas-to-gas competition, this variable still continues to be an adequate measure of natural gas price volatility.

[4] We observe dedicated assets since traditionally, investments in upstream, midstream, or downstream capacities are safeguarded by ex-ante contracting on a significant part of the nominal export and import capacities. Physical asset specificity is related to the importance of a specific supplier to an import facility. Other types of specificity are less relevant for the unit of analysis in this study.

A second variable reflects political uncertainty in the exporting country (UNC). It is based on the POLCON index developed by Henisz (2000). As the OECD (2007, p. 28) highlights, "long-term contracts do not guarantee supply;" governments may change institutions such as legal rules; parties may renegotiate contractual provisions ex-post. Henisz' index measures the degree of constraints on policy change in a country averaged for five-year periods since 1960. Various studies have shown the suitability of this index for measuring political uncertainty in transaction cost economic studies. We adjust the POLCON index so that a high value expresses high uncertainty and a low value low uncertainty; hence, the proxy variable UNC is defined as (1-POLCON).[5]

Finally, a third variable to account for a firm's need for flexibility is added. Whereas the early industry relied on inflexible, well predictable, bilateral buyer-seller relations, the industry today is characterized by significant changes and a specific unpredictability about the future: formerly regional markets become linked, new players (i.e., countries and firms) enter the industry, liquid trading hubs gain in importance, numerous companies invest in a portfolio of export and import positions to be able to benefit from arbitrage potentials. Therefore, flexibility is of prime importance. Empirical research provides evidence that we can distinguish the 'infant' (1960s to 1990s) from the 'mature' (from 2000s on) industry (Ruester and Neumann, 2009). A dummy variable indicating LNG supply contracts that became operational after 1999 (D2000) is used expecting a negative relationship with contract duration.

Transaction frequency within the relationship. To measure the frequency of transactions within the trading relationship (i.e., within the LNG supply contract) the annual contracted volume (VOL) is employed. Under the assumption that contracts are fulfilled according to their specifications and with respect to the fact that the standard size of LNG vessels ranges from 130,000 to 145,000 m^3, the annual contracted volume provides a good indicator for the frequency of shipments within the contract.

Transaction frequency between the trading parties. Three alternative variables indicating the historical trading experience between the same trading partners are defined under the assumption that repeated negotiation of LNG supply contracts reduces ex-ante as well as ex-post contracting costs. Theory argues that transaction costs diminish due to learning processes; contracting parties gain information about each others behavior; reputational aspects reduce the hazard of post-contractual opportunistic behavior. Firstly, a count index indicating the cumulative number of LNG trade relationships between supplier and buyer (BILEXP1) is defined. Thus, if the parties negotiate a contract for the first time the variable will be one; if we observe a second contract between the same parties it will be two, and so on. Secondly, we use a similar count index indicating the cumulative number of years of bilateral LNG trade (BILEXP2). And finally, a dummy variable equaling one if the contract represents a

[5] Henisz (2000) reports POLCON indexes until the period 1990-1994. For observations after 1994 we use the most recently reported value which is an appropriate assumption, since the index is very stable over the reported period.

contract renewal (RENEW) instead of the first trade relationship between the same upstream and downstream players is included.

Control variables. To account for varying supply structures, the buyer country's LNG share in total imports (LNGSHARE) is included as a control variable. While countries like the US can import natural gas via pipeline and LNG plays only a minor role in total gas supplies, other countries like South Korea or Japan rely heavily upon LNG imports. The higher the share of LNG in total imports the higher should be the duration of supply contracts. Furthermore, we define a dummy variable indicating contracts dedicated to competitive downstream markets (COMP) assuming that only the markets in the US and the UK can be regarded as liquid and competitive natural gas markets. This variable equals one if the contract became operational in periods of unbundled transportation infrastructures (i.e., from 1992 on for the US and from 1997 on for the UK), since unbundling of the monopolistic element of the value added chain is an essential precondition for non-discriminatory access to infrastructures and free market entry.

Instrumental variables. To account for the endogeneity of a right-hand side variable (i.e., contracted volume) and conduct two-stage estimation of simultaneous equations, instrumental variables have to be included. Therefore, the level of self-sufficiency of the importing country (ratio of domestic natural gas production over total consumption, SELFSUFF), the nominal capacity of the import terminal (CAP), and the number of import terminals in the respective country in the year LNG deliveries under the respective contract began (TERMINALS) are defined as instruments. The correlation matrix (Table 2) supports the choice of these variables, since they weakly correlate with contract duration and more with the annual contracted volume. For an alternative model accounting additionally for the endogeneity of the level of relationship-specific assets a dummy variable indicating value chains which operate in the Atlantic Basin (ATLANTIC) is included.

For a survey of all exogenous variables as well as their descriptive statistics see Table 1. More than half of the contracts of the dataset (60%) started delivery from 2000 on, mirroring the expanding international LNG trade during the last decade. The contracts account for very small shares of the import terminal capacities (0.2%; deliveries from Australia to Japanese customers) as well as for a share of up to 100% (deliveries from Nigeria to Italy). The political uncertainty index of the exporting countries ranges between zero and one with a mean of 0.62; the standard deviation of the WTI crude oil spot price in the year before contract signature varies strongly between 0.87 and 12.85 for recently concluded contracts. Annual contracted volume is between 0.03 (deliveries from Australia to Japan) and 6.75 bcm/a (planned deliveries from Iran to India). The negotiating parties in most cases bargained for the first time; however, bilateral experience for single players shows values of up to nine (Gaz de France and Algerian Sonatrach) and we observe previous trading experiences of up to 31 years. 13% of the contracts in the database represent renewals of expired agreements. The dataset involves both highly self-sufficient (e.g., US or UK) and LNG import-dependent (e.g., Japan or South

Korea) countries. In 12% of the observations, deliveries are dedicated to competitive downstream markets. The nominal capacity of the import facilities varies between 0.21 (Nippon's Kagoshima terminal) and 75 bcm/a (Tepco's import portfolio in Japan). The number of import terminals per country in the year of the start of deliveries lies between one (e.g., Belgium, Greece, Turkey) and 29 (Japan).

Table 1: Explanatory variables and summary statistics

Characteristic	Proxy	Unit	Denotation	Exp. Sign	Mean	Std. Dev.	Min	Max	N
Propositions 1a and 1b									
Relationship specificity	Ratio to which the contract exploits the nominal capacity of the import terminal	%	RCAPSHARE	+	0.214	0.245	0.002	1	261
External uncertainty and need for flexibility	Political instability in the supplying country		UNC	-	0.622	0.387	0	1	261
	Standard deviation of WTI crude oil spot price in the year before contract signature		STDEVOIL	-	3.778	2.733	0.874	12.853	224
	Start-up of deliveries after 1999	Dummy	D2000	-	0.598	0.491	0	1	261
Propositions 2a and 2b									
Within frequency	Annual contracted volume	bcm/a	VOL	+	1.779	1.496	0.03	6.75	261
Between frequency	Cumulative number of contracts negotiated between the two parties	Count	BILEXP1	-	1.678	1.239	1	9	261
	Cumulative number of years of trading relationship between the two parties	Count	BILEXP2	-	5.755	8.151	1	31	261
	Contract representing a contract renewal	Dummy	RENEW	-	0.134	0.341	0	1	261
Control variables									
Dependence on LNG imports	LNG share in total natural gas imports	%	LNGSHARE	+	0.718	0.376	0.03	1	261
Downstream competition	Contract dedicated to competitive downstream market (i.e., US from 1992; UK from 1997)	Dummy	COMP	-	0.126	0.333	0	1	261
Instruments									
Self-sufficiency import country	Domestic production / total consumption	%	SELFSUFF		0.202	0.367	0	1	261
Import terminal capacity	Nominal capacity of regasification terminal	bcm/a	CAP		18.076	18.164	0.21	75	261
Number of import terminals	Number of import terminals in import country	Count	TERMINALS		10.126	9.635	1	29	261
Atlantic Basin value chain	Contract destined to Atlantic Basin customers	Year	ATLANTIC		0.411	0.493	0	1	261

Table 2: Correlation matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CD	1	1														
RCAPSHARE	2	0.223	1													
UNC	3	-0.037	0.159	1												
STDEVOIL	4	-0.208	-0.007	0.003	1											
D2000	5	-0.265	0.088	0.090	0.369	1										
VOL	6	0.227	0.556	0.133	0.032	0.132	1									
BILEXP1	7	-0.269	-0.258	0.066	0.107	0.011	-0.139	1								
BILEXP2	8	-0.263	-0.302	0.028	0.061	-0.039	-0.090	0.844	1							
RENEW	9	-0.321	-0.175	0.060	0.067	-0.010	0.014	0.660	0.775	1						
LNGSHARE	10	0.119	-0.368	-0.273	-0.052	-0.182	-0.209	0.111	0.288	0.138	1					
COMP	11	-0.183	0.212	0.012	0.016	0.247	0.076	-0.185	-0.229	-0.179	-0.594	1				
SELFSUFF	12	-0.008	0.540	0.046	0.163	0.238	0.301	-0.257	-0.314	-0.191	-0.553	0.670	1			
CAP	13	-0.066	-0.469	-0.107	0.036	-0.003	0.079	0.088	0.246	0.149	0.375	-0.235	-0.370	1		
TERMINALS	14	-0.020	-0.392	-0.264	-0.057	-0.057	-0.349	0.218	0.376	0.224	0.642	-0.274	-0.449	0.213	1	
ATLANTIC	15	-0.071	0.174	0.298	0.001	0.196	0.126	-0.098	-0.280	-0.134	-0.834	0.472	0.287	-0.272	-0.661	1

4.3 Methodology

To test the above derived propositions, the following estimation model with contract duration as the endogenous variable is defined:

$$\begin{aligned} CD_i &= \phi_0 + \phi_1 RCAPSHARE_i + \phi_2 UNC_i + \phi_3 STDEVOIL_i + \phi_4 D2000 \\ &+ \phi_5 VOL_i + \phi_6 BETWFREQ_i + \phi_7 LNGSHARE_i + \phi_8 COMP_i + \varsigma_i \end{aligned} \tag{6-6}$$

where *i* indexes contracts and the error term ς_i is assumed to be i.i.d. Three models – each including only one of the alternative measures of the frequency of transactions between the same trading partners (BETWFREQ in Equation 6-6) at a time in order to avoid multicollinearity problems with: a) ln(BILEXP1), b) ln(BILEXP2), and c) RENEW – are estimated. Based on a first regression analysis including BILEXP1 and BILEXP2 in linear as well as quadratic form a nonlinear relationship between each of these variables and CD was found; therefore, the logged values are included into the estimation model.

However, contract duration and contracted volume are determined simultaneously when an LNG seller and buyer agree for a supply arrangement. Therefore, the model is estimated applying two-stage least squares (2SLS) with

$$\begin{aligned} VOL_i &= \theta_0 + \theta_1 RCAPSHARE_i + \theta_2 UNC_i + \theta_3 STDEVOIL_i + \theta_4 D2000 \\ &+ \theta_5 BETWFREQ_i + \theta_6 LNGSHARE_i + \theta_7 COMP_i + \theta_8 SELFSUFF_i \\ &+ \theta_9 CAP_i + \theta_{10} TERMINALS_i + \xi_i \end{aligned} \tag{6-7}$$

as the second equation in the system with ξ_i again assumed to be i.i.d. Estimation results are verified using the generalized method of moments (GMM) procedure.[6]

5 Estimation Results and Interpretation

Tables 3 to 6 present estimation results of the simultaneous equation system. Three models (i.e., A, B, and C) are estimated including one of the above defined measures of historical transaction frequency between the same trading partners; each model furthermore is estimated in two versions including STDEVOIL (Tables 3 and 4) and not including this variable respectively (Tables 5 and 6) to benefit from the whole dataset. 2SLS and GMM lead to very similar results. Propositions 1a, 1b and 2b can

[6] GMM is a robust estimator; no information on the exact distribution of the disturbances is required. In this study the estimation is based on the assumption that the error terms are uncorrelated with the set of instrumental variables. Via the GMM procedure, parameter estimates are chosen such that the orthogonality conditions are satisfied.

be confirmed empirically; estimation results are robust to alternative model specifications. The p-values of F-statistics (all < 1%) show that the null hypotheses of all slope coefficients equaling zero must be rejected for all estimations. Adjusted (respectively centered) R^2 of 2SLS (GMM) for the equations explaining contract duration is between 0.21 and 0.27 (0.23 and 0.30).

The transaction cost prediction of Proposition 1a is confirmed for the variable indicating the ratio to which the contract exploits the nominal capacity of the import terminal (RCAPSHARE). The more important the respective contract to the import terminal and therefore the higher asset specificity, the longer the contract's duration in order to mitigate the hazard of ex-post hold-up. Buyers relying strongly on one supplier prefer longer-term contracts.[7] In addition, since the level of the coefficient is one of the highest of all exogenous variables it supports the theory's prediction that asset specificity is the strongest determinant of transaction costs.

The coefficient of the measure of political instability (UNC), testing for Proposition 1b, lacks any statistical significance.[8] This type of uncertainty does not appear to be the relevant dimension of uncertainty for the unit of analysis in this study and has no impact on the choice of contract duration. Joint ventures of private oil and gas majors with national companies as well as the in many cases very high dependence of exporting countries on revenues from oil and natural gas deliveries may mitigate the hazard of opportunistic behavior of upstream states. The variable indicating price uncertainty (STDEVOIL) shows the expected sign and is statistically significant for the 2SLS models; hence, contract duration appears to decrease with the risk of being bound by an agreement that no longer reflects the actual market situation with respect to the price level, which determines the profitability of the capital-intensive LNG value chain.

The variable controlling for the need for flexibility as measured by the start-up date of the contract (D2000) indicates as expected that contract duration has decreased over time. Whereas in the 'first generation' LNG market inflexible bilateral long-term supply agreements typically lasted 20 to 30 years, the 'second generation' market is characterized by a considerable expansion of capacities (e.g., worldwide regasification capacities doubled from 2000 on), changing trading conditions due to restructuring processes in downstream markets favoring competition, and trading places gaining in liquidity. Market liquidity promotes the use of flexible trades that helps parties to benefit from arbitrage potentials in the global gas market.

Proposition 2a refers to the impact of transaction frequency within the relationship. No statistical significance of the coefficient of the annual contracted volume (VOL), indicating the number of transactions (i.e., cargo deliveries) within the trading relationship, was found for the models

[7] This result goes in line with the findings of Lyons (1994) who shows a positive relationship between vulnerability to ex-post opportunism and the choice of more hierarchical governance modes with vulnerability measured as the share of output of a component supplier dedicated to the customer firm.

[8] Regressions using alternative measures of political instability in the exporting country (i.e., the International Country Risk Guide reported by the PRS Group as well as the Political and Economic Risk Report prepared by Aon Corporation) led to similar results.

accounting for the endogeneity of the variable.[9] An alternative estimation testing for a non-linear impact of the contracted volume, as has been found for example in Joskow (1987), does not change the presented result. Real-world LNG contracts contain numerous clauses that specify potential adaptations to changing environmental conditions. Unfortunately for research purposes, most agreements are confidential, so we are not able to account for the impact of provisions such as pricing or volume flexibility clauses that would be very valuable to empirical analyses.

Empirical results provide broad support for Proposition 2b; the estimation coefficients of all three variables (ln(BILEXP1), ln(BILEXP2), RENEW) have the expected negative signs and are highly statistically significant; LNG supply contracts decrease in contract duration as bilateral trading experience between the contracting parties (i.e., historical transaction frequency between the trading partners) increases. For contracts representing the renewal of a matured agreement, duration will be more than five years shorter. This can be explained by a decrease in contracting costs; LNG supplier and buyer gain information about each others' characteristics with every negotiation process, economies of communication develop, reputational effects may diminish the hazard of opportunistic behavior, and the partners benefit from a body of informal institutions that evolve over repeated bargaining.

The statistically significant control variables also provide interesting findings. Countries with a greater dependence on imports in the form of LNG (LNGSHARE) tend to negotiate longer agreements and forgo some flexibility in favor of supply security. Even in the present economic downturn it is expected that new importers with demand growth well above average like China and India will further tighten global supply. Committing to one supplier decreases the risk that the supplier may seek another destination market with more attractive provisions when a shorter-term contract ends. Furthermore, deliveries to a competitive downstream market (COMP) are realized via contracts with about 2.5 to three years shorter duration, confirming the findings of Hirschhausen and Neumann (2008) analyzing a dataset including pipeline as well as LNG contracts. Competition favors diversification of suppliers, supply sources, and supply routes and hence is conducive to supply security; long-term contracts lose in importance.

Tables 4 and 6 show the estimation results of the first-stage regression (Equation 6-6) which explains annual contracted volume adding a set of instrumental variables. For econometric reasons all system exogenous variables must be included in this regression, even though their explanatory power is very low. The level of self-sufficiency (SELFSUFF) in natural gas supply of the importing country has no major impact on the contracted volume. The higher the nominal capacity (CAP) of the import terminal the higher will be the contracted volume. There is a negative relationship between the number of

[9] In contrast, a positive and significant impact of VOL on CD is found in the simple OLS model. This shows that ignoring the endogeneity of right-hand-side variables can produce misleading estimation results.

import facilities (TERMINALS) in the buying country and the annual contracted volume. This result, for example, reflects the situation in Japan, where numerous (also small scale) terminals near all major demand centers substitute for the nonexistent gas transmission network, whereas countries such as Belgium receive all deliveries via a single import facility.

Table 3: Estimation results explaining CD including STDEVOIL

Specification	**OLS** (VOL as exogenous variable)			**2SLS** (VOL as endogenous variable)			**System GMM** (VOL as endogenous variable)		
	Model A	Model B	Model C	Model A	Model B	Model C	Model A	Model B	Model C
CONSTANT	18.98 *** (1.60)	18.67 *** (1.58)	18.45 *** (1.52)	19.59 *** (1.68)	19.17 *** (1.66)	19.05 *** (1.60)	19.69 *** (1.53)	19.29 *** (1.51)	18.99 *** (1.54)
RCAPSHARE	3.52 * (1.85)	3.24 * (1.85)	3.29 * (1.77)	5.69 ** (2.51)	5.18 ** (2.54)	5.64 ** (2.44)	5.64 ** (2.37)	5.02 ** (2.38)	5.50 ** (2.30)
UNC	-0.36 (0.97)	-0.37 (0.97)	-0.23 (0.94)	-0.29 (0.98)	-0.32 (0.98)	-0.18 (0.95)	-0.41 (1.00)	-0.50 (0.99)	-0.35 (0.93)
STDEVOIL	-0.24 * (0.14)	-0.25 * (0.14)	-0.23 * (0.13)	-0.24 * (0.14)	-0.25 * (0.14)	-0.24 * (0.14)	-0.22 (0.16)	-0.23 (0.16)	-0.22 (0.15)
D2000	-2.67 *** (0.86)	-2.81 *** (0.86)	-2.70 *** (0.83)	-2.47 *** (0.89)	-2.63 *** (0.88)	-2.49 *** (0.86)	-2.45 *** (0.75)	-2.63 *** (0.74)	-2.42 *** (0.74)
VOL	0.72 ** (0.29)	0.80 *** (0.29)	0.92 *** (0.28)	0.05 (0.59)	0.22 (0.59)	0.22 (0.57)	0.08 (0.57)	0.28 (0.56)	0.28 (0.56)
ln(BILEXP1)	-2.77 *** (0.70)			-2.77 *** (0.71)			-2.83 *** (0.68)		
ln(BILEXP2)		-1.23 *** (0.29)			-1.19 *** (0.30)			-1.23 *** (0.29)	
RENEW			-5.63 *** (0.97)			-5.33 *** (1.01)			-5.53 *** (0.85)
LNGSHARE	1.76 (1.27)	2.41 * (1.28)	1.83 (1.23)	1.68 (1.29)	2.32 * (1.30)	1.73 (1.25)	1.57 (1.15)	2.19 * (1.14)	1.70 (1.18)
COMP	-2.70 ** (1.30)	-2.35 * (1.29)	-2.85 ** (1.25)	-2.93 ** (1.33)	-2.54 * (1.31)	-3.05 ** (1.28)	-3.14 ** (1.37)	-2.75 ** (1.36)	-3.20 ** (1.41)
Adjusted R^2	0.234	0.239	0.288	0.214	0.225	0.267			
Centered R^2							0.243	0.255	0.296
N	224	224	224	224	224	224	224	224	224

*** Statistically significant at a 1%-level; ** statistically significant at a 5%-level; * statistically significant at a 10%-level. All levels of statistical significance are based on two-tailed test statistics. Corrected standard errors in parentheses.

Table 4: Estimation results 1st stage explaining VOL including STDEVOIL

Specification	2SLS			System GMM		
	Model A	Model B	Model C	Model A	Model B	Model C
CONSTANT	0.38 (0.33)	0.38 (0.33)	0.38 (0.32)	0.38 (0.31)	0.38 (0.31)	0.38 (0.30)
RCAPSHARE	4.04 *** (0.39)	4.05 *** (0.39)	4.04 *** (0.39)	4.04 *** (0.41)	4.05 *** (0.41)	4.04 *** (0.41)
UNC	0.05 (0.20)	0.04 (0.20)	0.02 (0.20)	0.05 (0.17)	0.04 (0.17)	0.02 (0.17)
STDEVOIL	-0.02 (0.03)	-0.02 (0.03)	-0.02 (0.03)	-0.02 (0.03)	-0.02 (0.03)	-0.02 (0.03)
D2000	0.24 (0.18)	0.25 (0.18)	0.24 (0.18)	0.24 (0.19)	0.25 (0.19)	0.24 (0.18)
ln(BILEXP1)	0.11 (0.15)			0.11 (0.13)		
ln(BILEXP2)		0.08 (0.06)			0.08 (0.06)	
RENEW			0.46 ** (0.21)			0.46 (0.22)
LNGSHARE	-0.09 (0.32)	-0.10 (0.32)	-0.04 (0.32)	-0.09 (0.34)	-0.10 (0.34)	-0.04 (0.34)
COMP	-0.29 (0.32)	-0.29 (0.33)	-0.23 (0.33)	-0.29 (0.29)	-0.29 (0.29)	-0.23 (0.30)
SELFSUFF	0.23 (0.33)	0.23 (0.33)	0.21 (0.33)	0.23 (0.31)	0.23 (0.31)	0.21 (0.32)
CAP	0.03 *** (0.004)	0.03 *** (0.004)	0.03 *** (0.005)	0.03 *** (0.01)	0.03 *** (0.01)	0.03 *** (0.01)
TERMINALS	-0.02 ** (0.01)	-0.03 ** (0.01)	-0.03 ** (0.01)	-0.02 ** (0.01)	-0.03 ** (0.01)	-0.03 ** (0.01)
Adjusted R^2	0.466	0.469	0.477			
Centered R^2				0.490	0.493	0.500
N	224	224	224	224	224	224

*** Statistically significant at a 1%-level; ** statistically significant at a 5%-level; * statistically significant at a 10%-level. All levels of statistical significance are based on two-tailed test statistics. Corrected standard errors in parentheses.

.Table 5: Estimation results explaining CD excluding STDEVOIL

Specification	**OLS** (VOL as exogenous variable)			**2SLS** (VOL as endogenous variable)			**System GMM** (VOL as endogenous variable)		
	Model A	Model B	Model C	Model A	Model B	Model C	Model A	Model B	Model C
CONSTANT	17.73 *** (1.45)	17.39 *** (1.44)	17.16 *** (1.39)	18.49 *** (1.54)	18.05 *** (1.53)	17.89 *** (1.49)	18.44 *** (1.49)	17.97 *** (1.46)	17.66 *** (1.49)
RCAPSHARE	3.53 ** (1.73)	3.28 * (1.74)	3.27 * (1.68)	6.18 ** (2.42)	5.69 ** (2.44)	5.97 ** (2.39)	6.12 *** (2.28)	5.52 ** (2.29)	5.87 *** (2.25)
UNC	0.28 (0.90)	0.18 (0.90)	0.21 (0.88)	0.31 (0.92)	0.20 (0.91)	0.23 (0.89)	0.26 (0.92)	0.10 (0.91)	0.16 (0.87)
D2000	-3.02 *** (0.71)	-3.06 *** (0.71)	-2.84 *** (0.69)	-2.87 *** (0.72)	-2.94 *** (0.72)	-2.72 *** (0.71)	-2.87 *** (0.65)	-2.94 *** (0.65)	-2.66 *** (0.65)
VOL	0.67 ** (0.27)	0.72 *** (0.27)	0.82 *** (0.26)	-0.10 (0.56)	0.03 (0.56)	0.04 (0.54)	-0.07 (0.53)	0.11 (0.53)	0.12 (0.53)
ln(BILEXP1)	-2.92 *** (0.66)			-2.90 *** (0.67)			-2.92 *** (0.65)		
ln(BILEXP2)		-1.24 *** (0.28)			-1.20 *** (0.28)			-1.22 *** (0.28)	
RENEW			-5.61 *** (0.98)			-5.32 *** (1.00)			-5.43 *** (0.89)
LNGSHARE	2.11 * (1.16)	2.64 ** (1.16)	2.17 * (1.13)	2.07 * (1.18)	2.59 ** (1.18)	2.13 * (1.15)	2.11 * (1.13)	2.67 ** (1.12)	2.30 ** (1.15)
COMP	-2.36 * (1.27)	-2.03 (1.26)	-2.45 ** (1.23)	-2.61 ** (1.30)	-2.24 * (1.28)	-2.65 ** (1.26)	-2.57 * (1.40)	-2.14 (1.39)	-2.57 * (1.42)
Adjusted R^2	0.236	0.236	0.272	0.211	0.216	0.247			
Centered R^2							0.234	0.241	0.271
N	261	261	261	261	261	261	261	261	261

*** Statistically significant at a 1%-level; ** statistically significant at a 5%-level; * statistically significant at a 10%-level. All levels of statistical significance are based on two-tailed test statistics. Corrected standard errors in parentheses.

Table 6: Estimation results 1st stage explaining VOL excluding STDEVOIL

Specification	2SLS			System GMM		
	Model A	Model B	Model C	Model A	Model B	Model C
CONSTANT	0.44	0.45	0.45	0.44	0.45	0.45
	(0.31)	(0.31)	(0.31)	(0.28)	(0.28)	(0.28)
RCAPSHARE	4.29 ***	4.29 ***	4.29 ***	4.29 ***	4.29 ***	4.29 ***
	(0.36)	(0.36)	(0.35)	(0.36)	(0.36)	(0.36)
UNC	-0.03	-0.03	-0.04	-0.03	-0.03	-0.04
	(0.19)	(0.19)	(0.19)	(0.17)	(0.17)	(0.17)
D2000	0.11	0.12	0.10	0.11	0.12	0.10
	(0.15)	(0.15)	(0.15)	(0.16)	(0.16)	(0.16)
ln(BILEXP1)	0.12			0.12		
	(0.14)			(0.13)		
ln(BILEXP2)		0.07			0.07	
		(0.06)			(0.06)	
RENEW			0.43 **			0.43 **
			(0.21)			(0.22)
LNGSHARE	0.02	0.01	0.05	0.02	0.01	0.05
	(0.29)	(0.06)	(0.28)	(0.29)	(0.29)	(0.29)
COMP	-0.11	-0.11	-0.06	-0.11	-0.11	-0.06
	(0.29)	(0.30)	(0.30)	(0.25)	(0.25)	(0.25)
SELFSUFF	-0.03	-0.04	-0.06	-0.03	-0.04	-0.06
	(0.29)	(0.29)	(0.29)	(0.25)	(0.25)	(0.25)
CAP	0.04 ***	0.03 ***	0.03 ***	0.04 ***	0.03 ***	0.03 ***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
TERMINALS	-0.03 ***	-0.03 ***	-0.03 ***	-0.03 ***	-0.03 ***	-0.03 ***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Adjusted R^2	0.455	0.456	0.462			
Centered R^2				0.473	0.475	0.481
N	261	261	261	261	261	261

*** Statistically significant at a 1%-level; ** statistically significant at a 5%-level; * statistically significant at a 10%-level. All levels of statistical significance are based on two-tailed test statistics. Corrected standard errors in parentheses.

However, theory argues that the level of specific investments is itself a decision variable (Masten, 1996, p. 60). Therefore, we run an additional regression model explaining in a first step the variable indicating relationship-specific investments in the LNG industry (RCAPSHARE) by the set of all exogenous variables and an additional instrument (ATLANTIC). The predicted values of asset specificity are included into the 2SLS model. Estimation results are listed in Tables 7 and 8 and reconfirm the above findings; however, the coefficient of the level of specific investments loses in statistical significance.

Table 7: Estimation results RCAPSHARE endogenized using 2SLS including STDEVOIL[10]

Specification	1st stage (Dep. var.: VOL)			2nd stage (Dep. var.: CD)		
	Model A	Model B	Model C	Model A	Model B	Model C
CONSTANT	0.59 (0.80)	0.61 (0.78)	0.57 (0.79)	19.97 *** (2.05)	19.52 *** (1.98)	19.33 *** (1.89)
RCAPSHARE_hat	3.29 (2.53)	3.20 (2.51)	3.33 (2.60)	4.81 (3.02)	4.25 (3.04)	4.88 * (2.88)
UNC	0.09 (0.27)	0.08 (0.27)	0.05 (0.27)	-0.23 (1.02)	-0.27 (1.01)	-0.15 (0.98)
STDEVOIL	-0.02 (0.04)	-0.02 (0.04)	-0.02 (0.04)	-0.24 (0.15)	-0.25 * (0.14)	-0.24 * (0.14)
D2000	0.25 (0.22)	0.27 (0.22)	0.26 (0.22)	-2.44 *** (0.92)	-2.62 *** (0.90)	-2.48 *** (0.88)
VOL				0.02 (0.66)	0.21 (0.64)	0.22 (0.62)
ln(BILEXP1)	0.07 (0.23)			-2.89 *** (0.78)		
ln(BILEXP2)		0.06 (0.09)			-1.24 *** (0.32)	
RENEW			0.44 (0.27)			-5.40 *** (1.04)
LNGSHARE	-0.11 (0.39)	-0.11 (0.39)	-0.05 (0.39)	1.48 (1.43)	2.14 (1.41)	1.56 (1.37)
COMP	-0.45 (0.65)	-0.47 (0.64)	-0.38 (0.66)	-2.96 ** (1.37)	-2.56 * (1.34)	-3.06 ** (1.31)
SELFSUFF	0.50 (0.97)	0.54 (0.99)	0.47 (1.03)			
CAP	0.03 *** (0.01)	0.03 *** (0.01)	0.03 *** (0.01)			
TERMINALS	-0.03 * (0.01)	-0.03 * (0.01)	-0.03 * (0.01)			
Adjusted R²	0.457	0.211	0.218	0.176	0.195	0.232
N	224	224	224	224	224	224

*** Statistically significant at a 1%-level; ** statistically significant at a 5%-level; * statistically significant at a 10%-level. All levels of statistical significance are based on two-tailed test statistics. Corrected standard errors in parentheses.

[10] Estimation results of the model explaining RCAPSHARE using the set of exogenous variables as well as the additional instrument ATLANTIC is available from the author upon request. Using the method of GMM, we could verify the above presented results.

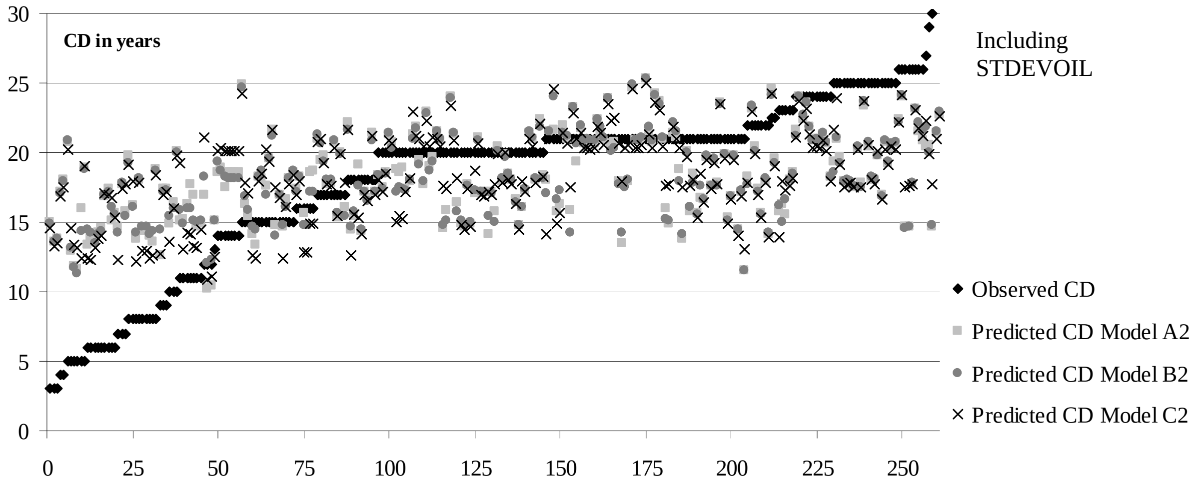
Table 8: Estimation results RCAPSHARE endogenized using 2SLS excluding STDEVOIL

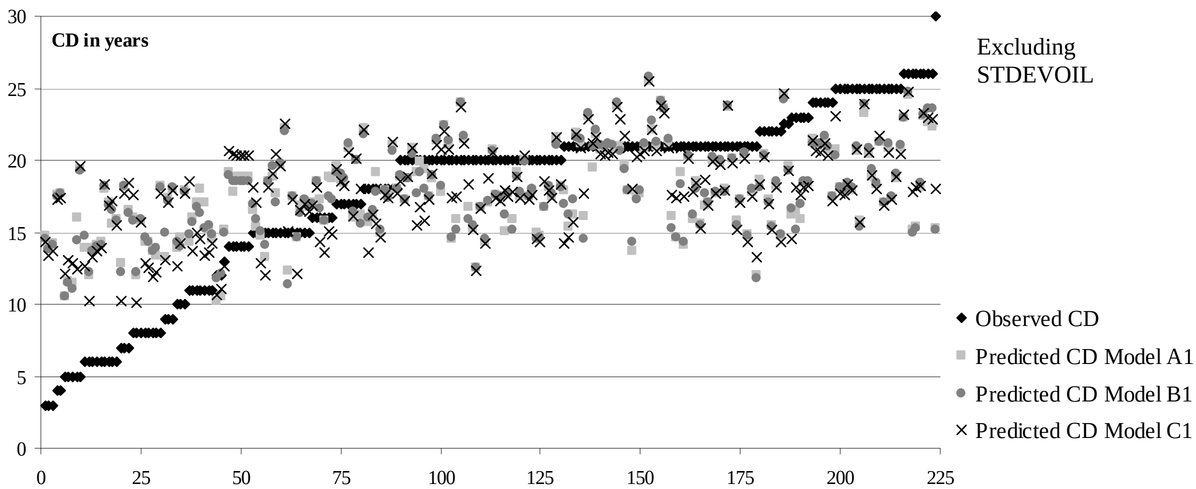
Specification	1st stage (Dep. var.: VOL)			2nd stage (Dep. var.: CD)		
	Model A	Model B	Model C	Model A	Model B	Model C
CONSTANT	0.31	0.35	0.34	19.67 ***	19.19 ***	18.73 ***
	(0.83)	(0.78)	(0.78)	(2.11)	(2.04)	(1.92)
RCAPSHARE_hat	4.81 *	4.67 *	4.78 *	4.41	4.20	4.95 (2.97) *
	(2.91)	(2.82)	(2.88)	(3.10)	(3.12)	
UNC	-0.06	-0.05	-0.07	0.52	0.41	0.38 (0.96)
	(0.29)	(0.28)	(0.28)	(0.99)	(0.98)	
D2000	0.10	0.11	0.09	-2.82 ***	-2.89 ***	-2.69 ***
	(0.20)	(0.19)	(0.20)	(0.77)	(0.76)	(0.74)
VOL				-0.44	-0.28	-0.20
				(0.68)	(0.67)	(0.64)
ln(BILEXP1)	0.15			-3.15 ***		
	(0.22)			(0.76)		
ln(BILEXP2)		0.08			-1.30 ***	
		(0.09)			(0.32)	
RENEW			0.45			-5.42 ***
			(0.28)			(1.07)
LNGSHARE	0.01	0.004	0.04	1.58	2.21	1.76 (1.31)
	(0.36)	(0.36)	(0.36)	(1.37)	(1.34)	
COMP	-0.04	-0.06	0.004	-2.74 **	-2.33 *	-2.71 **
	(0.52)	(0.50)	(0.51)	(1.38)	(1.35)	(1.32)
SELFSUFF	-0.17	-0.14	-0.19			
	(0.83)	(0.82)	(0.85)			
CAP	0.04 ***	0.04 ***	0.04 ***			
	(0.01)	(0.01)	(0.01)			
TERMINALS	-0.03 *	-0.03 **	-0.03 *			
	(0.02)	(0.01)	(0.02)			
Adjusted R^2	0.152	0.152	0.155	0.118	0.136	0.172
N	261	261	261	261	261	261

*** Statistically significant at a 1%-level; ** statistically significant at a 5%-level; * statistically significant at a 10%-level. All levels of statistical significance are based on two-tailed test statistics. Corrected standard errors in parentheses.

Predicted values of contract duration are plotted in Figure 3. As can be seen, they typically are in the range between 12 and 25 years, with significant deviations from the observed contract duration for data points with very low (and respectively very high) levels of the dependent variable. Error terms do not follow a random scatter but rather depend on the observed contract duration. Short agreements covering less than ten years as well as very long-term agreements covering more than 25 years cannot be explained by the model. Non-observable factors – not included in the estimation system – therefore seem to have an important impact on contract design. On the one hand, it can be assumed that contract provisions such as price adaptation clauses, rules governing regular renegotiations or actions in the case of force majeure, play a very important role in real world long-term contracts. As Saussier (2000) highlights, the level of completeness of a contract is itself a decision variable and contracts may be left explicitly incomplete in order to safe on transaction costs. On the other hand, exporters as well as importers in general contract for a portfolio of supply agreements, where large scale contracts may be accompanied by more flexible shorter-term agreements and different kinds of risks can actively be hedged.

Figure 3: Predicted values CD using 2SLS





6 Summary and Conclusions

This paper provides an empirical assessment of LNG supply contracts in order to determine optimal duration. Testable hypotheses are derived from theoretical approaches on contracting; the trade-off between contracting costs due to repeated bilateral bargaining versus the need for flexibility in uncertain environments is discussed. Furthermore, we add to the theoretical discussion an analysis of different dimensions of transaction frequency and their impact on governance choice.

Estimation results of a model of simultaneous equations show that the presence of high dedicated asset specificity in LNG contracts results in longer contract duration, which confirms the predictions of transaction cost economics. We observe, however, that the increasing need for flexibility in today's ‘second generation’ LNG industry reduces contract duration, as does the presence of a high price uncertainty. Concerning transaction frequency one has to distinguish between a ‘within’ perspective (i.e., transaction cost economics view) and a ‘between’ perspective (i.e., organizational learning and reputational effects view); firms experienced in bilateral trading generally are able to negotiate shorter contracts. Countries that rely heavily on LNG imports are often willing to forgo some flexibility in favor of supply security. Deliveries to competitive downstream markets take place under shorter-term agreements.

Unfortunately, not all uncertainty variables produce significant results. However, numerous empirical studies investigating the effect of environmental uncertainty on governance choice present non-significant and even ambiguous results (e.g., Crocker and Masten, 1988; Klein et al. 1990, Heide and John, 1990; Masten and Crocker, 1991; Zaheer and Venkatraman, 1995), which is also confirmed in Zaheer and Venkatraman (1995). As Klein (1989, p. 256) states: “It appears that uncertainty is a too broad concept and that different facets of it lead to both a desire for flexibility and a motivation to reduce transaction costs.” He argues further that the effect depends on the dimension of uncertainty and shows that whereas unpredictability should have a negative impact on vertical control; complexity should have a positive impact. Therefore, it is suggested that empirical studies should split external uncertainty into its components, investigate the opposing effects and determine which dimensions of uncertainty are relevant for the respective transaction.

In addition, contractual provisions (such as price adaptation clauses) – which unfortunately are confidential and cannot be incorporated in this analysis – are an important measure to react to changing environmental conditions and to decrease the inflexibility of long-term agreements. Masten and Crocker (1991, p. 5) point out that “where uncertainty about what will constitute optimal behavior at the time of performance is great, it may be better to leave aspects of that performance open to negotiation rather than to constrain parties to specific but potentially inappropriate actions.” The main objective is to define contract terms that encourage rent-increasing adjustments but at the same time discourage rent-dissipating efforts to redistribute existing surpluses by opportunistic behavior. It is commonly known, that price adaptation clauses typically are included in long-term LNG supply contracts; the recent move towards more volume flexibility (see IEA, 2004, pp. 111 ff.), the drop of destination clauses as well as the increasing importance of free-on-board rather than cost-insurance-freight/delivered-ex-ship contracts further reduce the risk of being bound by an inflexible agreement not reflecting market realities.

Future empirical work should address several issues. First, researchers need to identify better proxies of theoretical constructs (such as transaction costs, asset specificity, uncertainty, transaction frequency, etc.) that will improve empirical testing. If it would be possible to find a valid proxy for transaction costs, models in the structural form as defined in Equation (6-2) could be estimated and one could draw conclusions on the impact of transaction cost variables and other exogenous factors on costs and benefits of contracting for one more period. Second, the concept of uncertainty should be discussed with respect to various dimensions as argued above. Third, although empirical studies should account for the simultaneous choice of contract provisions like contract duration or the level of completeness of contracts, there are huge challenges due to very limited data availability.

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