Long-term Contracts and Asset Specificity Revisited

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Long-Term Contracts and Asset Specificity Revisited – An Empirical Analysis of Producer-Importer Relations in the Natural Gas Industry

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Abstract

In this paper, we analyze structural changes in long-term contracts in the international trade of natural gas. Using a unique data set of 262 long-term contracts between natural gas producers and importers, we estimate the impact of different institutional, structural and technical variables on the duration of contracts. We find that contract duration decreases as the market structure of the industry develops to more competitive regimes. Our main finding is that contracts that are linked to an asset specific investment are on average four years longer than those who are not.

Keywords: asset specificity, econometric analysis, long-term contracts, natural gas

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1 Introduction

Long-term contracts are back on the research and the policy agenda. The issue of long-term contracts as an intermediate organizational form somewhere in between vertical integration and short-term, market-based trading in itself is a regular topic in industrial economics and contract theory. Yet empirical work on the determinants of long-term contracts evolved mainly during the 1980s (e.g. Joskow, 1987) in the wake of liberalization and globalization of commodity markets (such as oil, natural gas, coal, non-ferrous metals, steel, etc.). This debate, which had somewhat abated in the 1990s, is now back in full swing, driven by theoretical developments in institutional and contract theory, but also by increasing concerns about reduced security of supply and skyrocketing short-term prices of these commodities, the most drastic being the unexpected surge in oil prices.

The interpretation of long-term contracts also depends to a certain degree on subjective assessments, and sometimes on pure interests: thus, adherents of market competition are generally less enthusiastic about the (re-)emergence of long-term contracts, as these may reduce the scope for short-term competition. On the other hand, industry and a large part of policymakers defend the (often collusive) nature of long-term contracts with its positive impact on investment decisions. Competition authorities therefore have a difficult time when assessing the total impact of long-term contracts on social welfare.

This paper provides an empirical assessment of the changing nature of long-term contracts in a commodity sector that has undergone drastic structural changes during the last decades and upon which little empirical research exists: natural gas. Natural gas is not only a rapidly expanding global business, due to the environmental-friendly and flexible uses it offers, but is also an under-researched sector since the mid- and late 1980s. The paper analyzes the development of long-term contracts in liberalizing natural gas markets world-wide, with a particular focus on the determinants of the duration of contracts under changing technical, economic, and institutional conditions. Our hypothesis, derived from theoretical work and more recent empirical analysis, is that the move from a monopolistic industry to more competitive market structures implies that long-term contracts loose some of their importance, and that they are likely to play a considerable role (only) when large-scale, asset-specific investment decisions are at stake.

The paper is structured in the following way: the next section provides a comprehensive review of the literature on long-term contracts in the natural gas and other sectors, both from a theoretical and an empirical perspective. Section 3 describes the structural changes ongoing in the natural gas industry, from a technical, an institutional, and an economic perspective. From there, we derive the main hypotheses to be tested in Section 4 ("Data, Model Specification and Results"). Based on a unique dataset of more than 300 long-term natural gas contracts, we test the impact of structural and institutional variables on the duration of these contracts empirically. Amongst other things, we find that contract duration decreases significantly as natural gas markets become more competitive, and that the volume of yearly contracted natural gas is positively correlated with contract length. Our main result is that contracts related to a significant asset-specific investment are on average several years longer than those where less significant investment issues are at stake. The last section concludes.

2 Literature on Long-Term Contracts

The main arguments for extensive bilateral contractual arrangements are based on transaction cost economics and its assumptions. It has been widely recognized that long-term contracts are a way of minimizing transaction costs for two parties engaging in a commitment involving significant specific assets, but where full vertical integration is not feasible. Long-term contracts including requirement clauses, price indexation, liquidated damages, arbitration and other provisions have been identified as a means to overcome the "hold-up" problem without vertical integration. The hold-up problem is likely to arise when transaction-specific investments are required (Klein et. al (1978)). Indeed, asset-specific investments and uncertainty are the main contributing factors to a high level of transaction costs as defined by Williamson (1975, 1985), all of which explain requirements of alternative institutional arrangements as opposed to "simple" contracting (Williamson, 1983). As a theoretical response to transaction cost economics, the concept of incomplete contracts has been developed (Grossmann and Hart (1986), Hart and Moore (1988)). Both concepts are based on the assumption of opportunistic behavior by the agents whose rationality is bounded. However, as pointed out by Saussier (2000), the main difference of these concepts is the role of contracts: whereas in the incomplete contracting framework contracts minimize ex ante investments distortions, in the setting of transaction cost economics they provide sufficient investment incentives and inexpensive ex post renegotiation.

Research since Coase's (1937) seminal paper on the nature of the firm has brought forward many amendments to economics, but all contributors so far agree upon the fact that minimizing transaction costs depends on the degree of asset specificity, the level of uncertainty, and frequency of the transactions at stake. Two parties wanting to engage in a supplier-buyer relationship have instruments of institutional arrangements available spanning from anonymous spot trading via long term contracting to vertical integration. As noted by Furubotn and Richter (1997), the lack of a consistent theoretical framework has led to the development of a variety of methodologically related approaches which are partially overlapping, complementing and extending, but also differentiating one another.

Contractual arrangements have been the center of attention in a variety of analyses and based on different research applications ranging from traditional topics such as R&D cooperation (Oerlemans and Meeus, 2001) to less conventional applications such as the winegrape industry (Goodhue, 2003). Long-term contracts in the energy sector have served early on to provide empirical evidence of transaction cost theory: thus, Joskow (1987, 1988) shows that the duration of contracts in the American coal industry is positively related to the level of asset-specificity. Crocker and Masten (1985) and Masten and Crocker (1988) were the first to test empirically the influence of different regulatory regimes in the US natural gas sector. They examine a sample of 245 American natural gas contracts with detailed information on prices, quantities and take-or-pay provisions[3] provided by the Energy Information Agency, and determine changing regulatory environment and liberalization efforts as the main parameters of these contracts. Furthermore, the authors argue that take-or-pay provisions inherent in traditional contracts provide a sufficient mechanism to avoid breach and thus expensive renegotiation of contracts. Mulherin (1986) shows that governmental regulation in the US

[3] Long-term take-or-pay contracts link sellers and buyers into a bilateral monopoly for a long period, during which both parties have strictly defined obligations. Purchasers are required to pay for a pre-specified minimum quantity of gas whether or not they actually take the gas, and producers are required to deliver this quantity (Masten, 1988).

(mainly the Public Utility Holding Company Act of 1935 and the Natural Gas Act of 1936) led to an increasing use of long-term contracts and take-or-pay provisions, and to price adjustments reducing the hold-up problem. Hubbard and Weiner (1986) analyze take-or-pay provisions of long-term gas supply contracts following deregulation of wellhead prices in the US. The sample of 884 natural gas contracts, collected by the Energy Information Administration in 1982, signed after the 1978 Natural Gas Policy Act, reveals minor effects in mean take-or-pay requirements; this result is in line with MacAvoy's (1962) observations. Doane and Spulber (1994) argue that open access to the transportation system reduces the potential for a bilateral monopoly between pipeline owners and field producers and the related contractual hold-up problem; thus, transaction costs associated with assuring contractual performances will be reduced.

The process of liberalization and market integration currently on the way in continental Europe with the ambition to create a functioning internal market for electricity and natural gas mimics developments implemented some 20 years ago in the US and some 10 years ago in the UK. Thus, the developments in these two countries serve as a benchmark for the developments to expect in continental Europe. Empirical evidence on the changing nature of long-term contracts in the US and the UK suggests an inverse relation between gas sector liberalization and contract length. In both countries, long-term contracts between gas producers and wholesale buyers have lost "market share" although long-term contracts do not entirely disappear with market liberalization. Average contract length has shortened significantly (from 20-25 years down to approximately 8-15 years, IEA, 2004, 110).

In the US, the share of natural gas supplies through long-term contracts was reduced from almost 100% to below 50%. Until 1991, the average contract volume fell from 1.27 billion cubic meters per year (bcm/a) to 0.24 bcm/a (IEA, 1998). However, as natural gas demand picked up again in the late 1990s, industry found itself suddenly deprived of (moderately priced) natural gas supplies. Hence, in the year 2000 (and, notably, before the Californian energy crisis), prices rose significantly, and have remained high until today. It is expected that natural gas prices will remain high, whereas most large consumers are currently attempting to (re-)conclude long-term contracts, both for pipeline gas and for liquefied natural gas (LNG). In the UK, one observes a similar trend: a price drop in the first years after liberalization. Today, about 85% of natural gas delivered at the beach is covered by long-term contracts (IEA, 2004, 110). The most recent contracts contain a price indexation to the UK spot gas market, and no more take-or-pay obligation. A liquid spot market has developed.

The first quantitative analysis of developments in European long-term gas supply was provided by Neumann and Hirschhausen (2004). It was based on a dataset of long-term contracts concluded by European importers since 1985. The authors show that the length of take-or-pay contracts for natural gas supply to Europe has significantly decreased over the past two decades, which supposedly is driven in large part by the move towards liberalization in the European Union. The results do not suggest the disappearance of long-term contracts for European gas supply; rather they put emphasis on required structural changes of these contracts adapting to a more competitive environment. In a theoretical paper, Neuhoff and Hirschhausen (2005) take the analysis a step further by accounting for different short-run and long-run demand elasticities. The analysis shows that for long-run demand elasticity significantly higher than short-run elasticities, producers prefer institutional arrangements allowing for long-term contracting.

Last but politically not least, the most recent energy sector inquiry carried out by the European Commission's Directorate General for Competition (EC, 2005b) identifies main barriers in the development of a truly competitive internal market for electricity and natural gas. The survey is based on a set of 242 long-term contracts and disparages the very long duration of these. Furthermore, it is criticized that the lack of use of flexibility inherent in those contracts as well as resulting vertical foreclosure within the value chain benefits incumbents of the market for natural gas.

3 Technical, Institutional and Economic Changes in the Natural Gas Industry

The first decade of this century has witnessed an unprecedented surge of commodity prices, and a revival of the debate on the virtues and inconveniences of long-term contracts. We have identified the natural gas sector as particularly representative for these trends, and upon which little research has been carried out recently. The current upsurge in oil prices associated with an awkward geopolitical situation in the Middle East, the revival of nuclear power and the increasing awareness of inevitable changes in climate policies have placed natural gas back on the policy and research agenda. During the last 25 years, natural gas markets world-wide went through significant structural changes, in technical, institutional and economic terms. As in other network industries, the natural gas industry has witnessed attempts to create competitive markets, the breaking up of monopolistic, vertically integrated structures, and the introduction of sector-specific regulation (see Dixon and Easaw (2001) for the UK, and Joskow (2005) for a survey of general lessons from de- and reregulation). This section describes some of the structural changes going on in the industry that we will quantify and which should yield testable hypotheses for the empirical part of the paper.

3.1 Decreasing capital intensity (in particular in the LNG chain)

Natural gas production is generally carried out in places remote from demand centers. Transportation can take place in pipelines or by ship in the form of liquefied natural gas (LNG).[4] As transportation technology improves and economies of scale are reaped upstream, mid-stream and downstream, the capital intensity of the natural gas value-added chain has significantly diminished over the past decades. This is particularly the case for LNG, but it also holds for traditional pipeline technology. In the LNG chain, investment costs per unit of output (here: million British thermal units, MBtu), has decreased from well above $4.50/MBtu in the early 1990s, to about $3/MBtu today (in 2004 US$). Figure 1 shows the composition of these costs, the reduction of which has different sources:

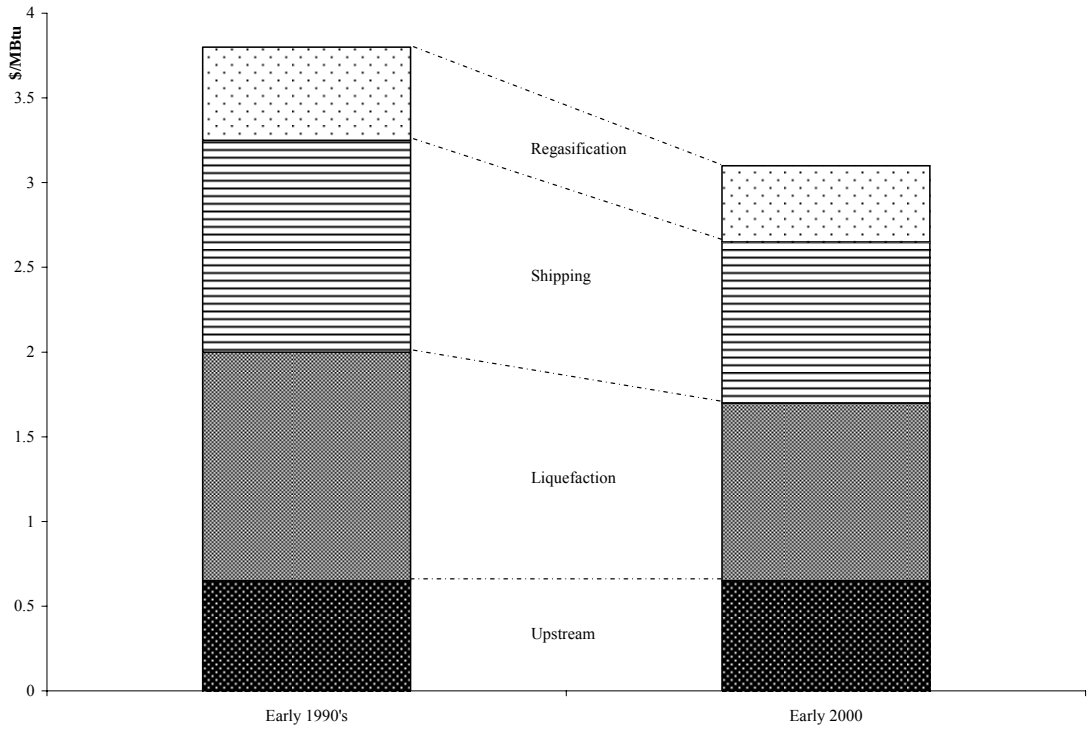
- Liquefaction is carried out in larger units than before. The standard size of a train was about 1 million tons per year (mtpa) at the upsurge of LNG business and has now reached a capacity of 3.5 to 4 mtpa; plans for 7.8 mtpa trains exist in Qatar;
- likewise, shipping is carried out in larger LNG-vessels (140.000 to 145.000 cubic meters (cm) today, 40.000 cm 15 years ago, 25.000 cm 40 years ago) that use more efficient motors; costs for construction of tankers in Asia have dropped from $250 million to $170 million for a standard 135.000 cm ship since some ten years ago (IEA, 2004);

[4] For a non-technical survey of the natural gas industry, see IEA (1998).

- downstream, regasification also benefits from scale economies mainly for storage (according to IEA (2004) tanks with storage capacity of 200.000 cm are the current optimal size) and using different technologies.

Decreasing investment intensity leads to lower risks in the industry, and should thus have a negative effect on contract duration.

Figure 1: Decreasing capital intensity of LNG



Source: Jensen (2004), IEA (2004), EIA (2003)

3.2 Diminishing asset specificity of investment

Distinct from lower capital costs is the issue of the changing nature of the asset specificity itself. In the "old days" of the emerging natural gas industry, the emergence of international natural gas trade between large producers (such as Canada or Russia) and consumers (such as the US and Western Europe) required investments in the upstream natural gas fields, pipeline infrastructure, and a downstream distribution network. These investments were often project specific, leading to high asset specificity and, subsequently the well known issues of quasi-rent negotiations, which were often resolved by the use of long-term contracts.

Since these days, market structures up-, mid-, and downstream have changed potentially, leading to a reduction of asset specificity:

- Upstream, contracts are no longer field-specific, but related to the overall natural gas exports of a country or a producer. Thus, investments are no longer contract-specific, i.e. a given field can be used to serve a variety of contracts. These developments are mirrored in the abatement of the destination clause in European contracts. The development of a large number of trading

companies also diminishes asset specificity, since the loss of having to move from the first-best match to the second-best match (i.e. another trader) is no longer large[5];

- midstream, a lot of the necessary long-distance pipeline connections have been established. Thus, new projects require "only" a low portion of capacity expansion, either via an increasing number of compressor stations, or an additional trunk line. This investment is no longer highly asset specific;
- similarly, the downstream infrastructure for natural gas distribution is now established in most places, so that no large investments from scratch are required any longer; extensions are only gradual.

The decreasing asset specificity of natural gas trade related investment implies a reduced reliance on long-term contracts to resolve potential hold-up conflicts. In our view, this would suggest - ceteris paribus- lower contract duration over time.

3.3 Development of spot markets

The development of spot markets changes the nature of an entire industry, comparable to the development of the world oil markets after the establishment of spot markets in the 1970s. A similar development is currently under way in international natural gas trade, where different trading centers have emerged. Experience shows that spot markets for natural gas are most likely to develop at locations where several sources of supply and demand interconnect, often including landing facilities for LNG. Examples are the Henry Hub (USA), Zeebrugge (Belgium), or NBP (UK). Determining factors for the success of trading places are participation of traders and the institutional framework surrounding the business. Liberalized markets generate spare quantities unsold under long-term contracts, and an increasing number of players trading at short notice. Furthermore, a sound regulatory system ensuring planning viability for industry and efficient use of the pipeline network are required. Finally, regulated third party access to the network is requested. Market places require suppliers and buyers willing to trade at prices set defined by supply and demand. Existing and newly signed long-term contracts will have to undergo significant changes in order to provide additional quantities of natural gas to be traded at spot markets. There is now ample evidence that the spot markets are becoming more liquid in Europe as well. Trade at Zeebrugge in Belgium, at the Title Transfer Facility in the Netherlands and at other continental European trading places is increasing, thus following the developments at the NBP and therefore reducing uncertainty in short term trade to a certain extent. The standardization of products and introduction of financial instruments such as options and forward futures provide appropriate tools for managing price risks in a "new" environment. In addition, one observes increasing integration of the spot prices on either side of the Atlantic (NBP and Henry Hub), pointing to even trans-Atlantic markets.

Uncertainty in natural gas trade is diminishing with the rapid development of spot markets and with increasing liquidity on these markets. As a proxy, one can use the share of short-term LNG trade in international natural gas trade, which has grown steadily over the last two decades (up to 11% in

[5] The changing nature of LNG trade towards more spot and short-term trade without signing long-term agreements before investing in regasification terminals (Hartley and Brito (2002)) clearly point towards a lower asset specificity of these projects.

2004, see Jensen (2005)). Thus, with an increasing share of spot trading we should observe a reduction in long-term contract duration.

3.4 Increased number of market participants

Liberalization and the opening up of the natural gas industry have also favoured market entry. Thus, one observes an increasing number of market participants in several segments of the value chain:

- Upstream, the number of natural gas producers and exporters has increased during the last decade. Countries like Nigeria, Trinidad, Libya and Egypt, and even Australia have joined the incumbents such as Russia; thus competition upstream has increased;
- downstream, at the level of wholesale trading, one also observes a move away from monopolistic structures, a variety of market entrants such as multi-utility companies and power plants are engaging in the market. This is particularly the case in Europe after liberalization set in the late 1990s. [6]

Realized cost reductions, especially in the LNG business, have mainly attracted global oil players integrating downstream. In a growing natural gas market, characterized by more flexibility in contract duration, volumes, and alternative re-selling of received LNG the number of market participants increases substantially. New entrants, mainly electricity companies aim at a direct supply of natural gas thus benefiting from more supply security in times of increasing demand.

Using a traditional microeconomic search model, Hartley and Brito (2002) have shown that an increasing number of market participants in natural gas trade leads to more short-term trade, as compared to the old regime of bilateral monopolies. Along these lines, we expect that the increasing number of natural gas producers and wholesale traders enhances contracting opportunities other than long-term contracts and leads to a reduction in contract duration.

3.5 Implications for the empirical tests

Formally, the changing nature of contracts in international natural gas trade can be explained by a changing level of transaction costs triggering changes in the institutional organization of the sector. According to standard theory, transaction costs are expected to increase with growing asset specificity and uncertainty, and to decrease with the frequency of transactions (Williamson, 1985). The developments as outlined above should therefore contribute significantly to the reduction of transaction costs. This in turn reduces the need for "traditional" long-term contracts. Summarizing, the following reasons and their potential impact on transaction costs have been identified as the main structural changes currently taking place (in parentheses the expected sign of the coefficient):

- increasing spot trade on liquid markets, thus reduced frequency of transactions with one partner (-)
- reduction of uncertainty (due to growing demand, institutional framework) (-)
- decreasing asset specificity (-)

In the following section, we provide a quantitative analysis of relations in natural gas contracts.

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[6] The number of players differs significantly in European member states. Whereas only 40% of available gas is controlled by the largest company in Spain this share amounts to 91% in France (European Commission, 2005a). Developments have mainly taken place in Southern Europe (Spain, Italy) where this market share has come down from 75% to more acceptable levels.

4 Data, Model Specification, and Results

4.1 Data

Empirical research in international natural gas trade is heavily restricted due to data availability. Different to the US, where a list of signed contracts and respective information on price provisions, take obligations and several adjustment parameters as of 1981 was available, there seems to be no better secret kept in Europe than the structure of natural gas trade. The data used is in this analysis has been collected from several publicly available sources and verified through expert interviews. Detailed information is available on the date of contract signature, and for a large share on the starting and ending date of deliveries and contracted volumes (annual or total). This paper analyzes a total of 262 long-term contracts signed since 1980. [7] Table 1 provides the summary characteristics of these contracts.

Table 1: Summary statistics

		All				Europe			
	Observations	262				135			
Variable	**Description**	**Mean**	**Min.**	**Max.**	**Std. Dev.**	**Mean**	**Min.**	**Max.**	**Std. Dev.**
CD	Contract duration (years)	19.28	2	39	6.68	18.96	2	39	8.17
YVol	Yearly contracted volume (bcm)	2.29	0.03	16	2.42	2.81	0.15	16	2.79
Spot	Share of total LNG spot trade	4.10	0	11.5	3.73	3.71	0	11.5	3.53
Project	Contract signed to dedicated project: Dummy	D=1: 101 observations				D=1: 36 observations			
Trad	Contract signed by importing incumbent: Dummy	D=1: 99 observations				D=1: 38 observations			
D1980-1989	Contract signed 1980-1989: Dummy	D=1: 54 observations				D=1: 29 observations			
D1990-1998	Contract signed 1990-1998: Dummy	D=1: 104 observations				D=1: 55 observations			
D1999-2005	Contract signed 1999-2005: Dummy	D=1: 104 observations				D=1: 51 observations			

In the empirical analysis that follows, we make a distinction between contracts struck worldwide, and those regarding only European importers. While the dataset covers natural gas contracts worldwide, the dataset provides particularly accurate information on European imports, as it includes 23 contracts with Russia, 42 with Norway, 10 with Algeria, and 11 and 9 with the UK and the Netherlands respectively.[8] The analysis covers all EU-25 Member States, candidate countries and Switzerland. European LNG importing contracts include a variety of imports to the main consuming countries such as France, Spain, Belgium, Portugal and Italy.[9] A large share of the sample set including all contracts is represented by trade in the Asian-Pacific region.[10]

[7] We have no information about price settings in these long-term contracts whereas it seems to be common knowledge that those are indexed to the substitute fuel oil through a variety of formulas. Recently signed contracts link the price for natural gas in these contracts to power pool prices, natural gas spot market prices or mixtures of these.

[8] According to experts 10 to 12 long-term contracts a year are signed in Europe. Deliveries covered by these European importing contracts cover over 8 tcm including all contracts with deliveries to commence.

[9] The trading branch of a market entrant, Electricité de France, added the shortest pipeline importing contract when signing an agreement with Statoil of Norway to deliver 0.9 bcm for two years to France in 2003. The contracts with the longest

4.2 Methodology and Model Specification

We are interested in the duration of signed long-term contracts (CD) and ask how the changing institutional framework, the maturity of energy markets and overall market developments effect contract duration. Expectations for a number of drivers for contract duration are listed below. Besides the theoretical industrial organization framework that we apply, the hypotheses are also rooted in extensive interviews with industry experts. The following variables are introduced:

- As natural gas producers regularly argue that long-term contracts are required to ensure reasonable long-term rents in order to cover up-front investments, we expect a positive relation between annual contracted volumes (YVol) and contract duration;
- spot markets provide a relatively efficient mechanism with regard to transaction costs, whereas bilateral contracts implicate higher transaction costs than financial instruments traded on market places. Therefore, we include the share of LNG spot trade in total traded volumes of liquefied natural gas (SPOT) in the respective year into our analysis expecting a negative relation with the dependent variable[11];
- the variable of major interest is called PROJECT and defined as a dummy variable. It will take the value of one if the signed contract is dedicated to a specific greenfield project (such as the exploration of the Troll fields in Norway, the construction of a Interconnector pipeline, or a capacity extension at an LNG terminal exhibiting a high level of asset specificity;
- major contributions to competition are expected to be made by new market entrants. This might either be electricity producers, oil companies, or new gas companies aiming at minimizing the costs of negotiating, enhancing and controlling agreements. Therefore, the dummy variable TRAD for "traditional" market participants is defined in order to distinguish the market incumbent from entrants;
- in Europe, a number of efforts has been undertaken to introduce competition to the markets for electricity and natural gas. We therefore introduce different dummy variables that characterize different time periods with different underlying structural characteristics. A first dummy variable (D1980-1989) identifies all long-term contracts that have been signed in the traditional monopolistic setting. The first move towards a changing market environment was made with the adaptation of the Directives of price transparency[12] and transit[13] during the early 1990ies and reached its first punch line in 1998, when the First Natural Gas Directive 1998/30/EC came into effect (D1990-1998). Since then, a "new world" has emerged, which we capture by a third dummy variable (D1999-2005). The year 2005 also corresponds to the implementation of the Second Natural Gas Directive (so-called "Acceleration Directive"), that tries to address remaining

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duration originate in deals between traditional monopolistic importing and exporting companies, i.e. Ruhrgas and Gazprom, and the Troll contracts of 1986.

[10] In particular, the dependency on LNG imports mainly from Malaysia, Indonesia and Australia has been neatly documented. Prices for natural gas imports in Asia are known to be linked to the JCC (Japanese Crude Cocktail, the average of Japanese crude import prices) and signed for long time periods. Recent developments indicate the willingness to introduce more competitive trading. However, this is only expected to be implemented when the Asian electricity sectors have been liberalized.

[11] There are no precise figures on European spot trade relative to all natural gas traded available.

[12] Council Directive 90/377/EC of 29 June 1990 (OJ L 185, 17.7.1990).

[13] Council Directive 91/296/EEC of 31 May 1991 (OJ L 147, 12.6.1991).

barriers to a competitive internal market. We expect a significant negative influence of European legislation on contract duration;

- the difference in observations in the samples (European and all contracts) is mainly represented by Asian LNG importing countries. Hence, the Asian market (characterized by traditional structures) could bias the results towards longer contract durations. Allowing for this difference and a possible impact on our estimation results we introduce a dummy variable ASIA with an expected positive estimation coefficient.[14]

Using a similar approach as Joskow (1987), we estimate three specifications of our model, allowing explanatory and dependent variables to enter in levels as well as log-levels.[15] The specifications are defined as follows:

$$CD_i = c + \beta_1 Yvol_i + \beta_2 Dummy(1990-1998) + \beta_3 Dummy(1999-2005) + \beta_4 \text{Pr}oject + \beta_5 Trad + \beta_6 LNGDummy + \beta_7 Spot + \varepsilon_i \quad (1)$$

$$CD_i = c + \beta_1 \log(Yvol_i) + \beta_2 Dummy(1990-1998) + \beta_3 Dummy(1999-2005) + \beta_4 \text{Pr}oject + \beta_5 Trad + \beta_6 LNGDummy + \beta_7 \log(Spot) + \varepsilon_i \quad (2)$$

$$\log(CD_i) = c + \beta_1 (Yvol_i) + \beta_2 Dummy(1990-1998) + \beta_3 Dummy(1999-2005) + \beta_4 \text{Pr}oject + \beta_5 Trad + \beta_6 LNGDummy + \beta_7 \log(Spot) + \varepsilon_i \quad (3)$$

If we assume standard properties of error terms in equations (1) to (3), ordinary least squares (OLS) will provide best linear unbiased estimates. However, as pointed out by Sykuta (2005) and Masten and Saussier (2002) in an analysis of recent empirical work in new institutional economics, we might encounter a number of challenges implying that standard OLS produces a regression that is a biased estimate of the true slope. In the case of contracts, there are three limitations in using OLS techniques: First, values of the variable duration are limited to a lower bound of zero, thus effecting the distribution of error terms. Second, results may be biased due to over-presentation of longer-term agreements (see Masten and Saussier, 2002, and Maddala 1983). This can be taking account of when using maximum likelihood estimation techniques as done by Joskow (1987) and Crocker and Masten (1988). Finally, heteroskedasticity may arise due to long-term contracts usually occurring in clusters at discrete intervals of five or ten years, compared to short and spot-term trading.
The following section provides OLS for equation (1) and maximum likelihood estimation results assuming a logistic distribution of the error term for all specifications with regard to European contracts on the one hand, and all agreements on the other hand.

[14] Note that we will run two separate estimations of which only the second including all contracts will include the ASIA dummy.

[15] Joskow (1987) expects a diminishing effect of quantity as these increase and a nonlinear relationship between the variables.

4.3 Estimation results

We apply a truncated regression model implementing the Gauss-Newton algorithm for general least squares problem[16] to identify optimal parameters θ of the objective function F(θ). The truncation point of the dependent variable CD is defined as one year since we regard other contracts to be traded on spot markets. The observation period of contracts signed for natural gas imports covers the time period from 1980 until 2005. Results of estimation specifications considering the sample of European contracts only are presented in Table 2.

All the estimated coefficients confirm our anticipation at highly significance levels of 1% and 5%. Over time, contract duration has decreased compared to the basis time period 1980 until 1989 and higher annually contracted volumes lead to longer contract duration. The main hypothesis of a positive relation between asset specificity and contract duration is confirmed at a 1% significance level in all but one specification. Contracts that have been tied to the development of infrastructure are on average more than 5 years longer than others.[17] This indicates the similarity to developments in the US where mature infrastructure and market environment have led to shorter average contract durations. Since the transportation type of natural gas does not significantly impact contract duration, we conclude that the development towards importing LNG has not yet reached maturity. Therefore, the argument of investment incentives remains the driving force for the use of long-term contracts in European imports of natural gas.

Table 2: Estimation results for Europe

	OLS		ML	
Specification	(1)	(1)	(2)	(3)
C	**20.90*** **	**21.18*** **	13.15	2.54
	(0.0000)	(0.0000)	(0.9913)	(0.9995)
YVOL	**0.95*** **	**0.98*** **	**3.12*** **	**0.22*** **
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
D1990-1998	**-5.08*** **	**-5.97*** **	3.84	0.16
	(0.0055)	(0.0012)	(0.9975)	(1.0000)
D1999-2005	**-9.21*** **	**-9.99***	-0.99	-0.21
	(0.0050)	(0.0504)	(0.9993)	(1.0000)
PROJECT	**5.34*** **	**5.97*** **	**3.97*** **	**0.28** **
	(0.0001)	(0.0000)	(0.0020)	(0.0115)
TRAD	-1.01	-0.48	-0.37	-0.04
	(0.4472)	(0.7539)	(0.7714)	(0.7125)
LNGDUMMY	0.96	0.99	1.08	0.13
	(0.4228)	(0.5159)	(0.4043)	(0.1888)
SPOT	-0.14	-0.17	-0.44	-0.02
	(0.6939)	(0.7738)	(0.7298)	(0.8760)
R^2		0.429	0.388	0.343
Adj. R^2		0.393	0.338	0.289

Reported are estimated coefficients and p-values.

***, **,* indicate significance at 1%, 5%, and 10% level

[16] Often referred to as Berndt-Hall-Hall-Hausman optimization algorithm.

[17] Since the third representation allows both regressor and regressand to enter the specification in loglevels, the estimated coefficients prevail on a much lower level.

In analogy to the European sample we proceed with our investigation of all contracts. The results are similar and presented in Table 3. The estimated coefficients reveal the predicted signs at high significance levels. The variable of main interest, PROJECT, confirms the importance of asset specificity on contract duration: specific investment projects lead to an average reduction of contract duration of more than two years. Somewhat surprising, the share of LNG spot trade in global LNG trade does not exhibit significant coefficients. This might be explained by the lack of precise data availability concerning the share of spot trading of pipeline and LNG movements. However, an increasing number of market participants on the exporting as well as on the importing side might have contributed to decreasing costs of searching contracting partners. Hence, duration of contracts was shorter for importers not being a market incumbent. The extension of the data set by a number of Asian LNG importing contracts has not led to a bias towards longer more extensive contract duration. However, changes in the institutional and legislative framework have endorsed decreasing contract duration. Contracts signed during the first restructuring phase of the natural gas industry in Europe and since are on average 3 to 9 years, respectively shorter than those signed in the "old world".[18]

Table 3: Estimation results for all contracts

	OLS		ML	
Specification	(1)	(1)	(2)	(3)
C	**19.66*** **	**19.10*** **	**17.15*** **	**2.79*** **
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
YVOL	**0.84*** **	**0.84*** **	**2.09*** **	**0.12*** **
	(0.0000)	(0.0000)	(0.0000)	(0.0001)
D1990-1998	**-3.85*** **	**-3.36*** **	-0.53	-0.03
	(0.0010)	(0.0050)	(0.9040)	(0.9124)
D1999-2005	**-9.43*** **	**-9.36*** **	-4.83	-0.29
	(0.0006)	(0.0009)	(0.3672)	(0.4324)
PROJECT	**3.06*** **	**2.53*** **	**2.77*** **	**0.16*** **
	(0.0001)	(0.0018)	(0.0017)	(0.0134)
TRAD	**-2.05*** **	**-1.66** **	-1.09	-0.06
	(0.100)	(0.0478)	(0.2171)	(0.2796)
LNGDUMMY	0.99	1.22	1.94	**0.14***
	(0.3547)	(0.3031)	(0.1023)	(0.0716)
SPOT	0.46	**0.54***	0.74	0.05
	(0.1278)	(0.0919)	(0.4718)	(0.5293)
ASIA	0.11	0.09	1.57	0.08
	(0.9123)	(0.9294)	(0.1719)	(0.3086)
R^2		0.257	0.217	0.199
Adj. R^2		0.231	0.181	0.163

Reported are estimated coefficients and p-values.
***, **,* indicate significance at 1%, 5%, and 10% level

5 Conclusion

In this paper, we have revisited the theory of long-term contracts, and added recent empirical analysis on contracts in the natural gas sector. In fact, energy markets remain a fruitful field of industrial

[18] Robustness of our results is not affected by the including the dummy variables pre and post 1999. Only the variable SPOT gains significance with an estimated coefficient of -0.93 and a p-value of 0.000 respectively.

economic analysis. Indeed, deregulation of North American natural gas markets has triggered extensive research in industrial organization on contract structures. Today, most of the natural gas on the US-American and British markets is sold under short – and medium-term contracts, spot trade at a diversity of market places has reached a mature level, spot markets are liquid and financial instruments with some forward depth have evolved. Similar to these events, European markets are today, 20 years later, undergoing significant changes. Breaking up of monopolistic market structures, introduction of regulated third party access to infrastructure, decreasing indigenous production, and the growing importance of LNG in the supply mix cause increasing spot activities, entrance of new market participants, and multi-sourcing of supplies.

We have analyzed the development of long-term supply contracts during these structural changes. Long-term contracts are generally considered as an instrument to overcome the hold-up problem albeit assuring efficient investments in infrastructure. However, with a growing maturity of the existing transporting infrastructure and increasing competition, theory predicts a diminishing importance of long-term contracts on investment incentives. Using an extensive database of 262 contracts, we show that contract duration is diminishing over time, and is positively related to annually contracted volumes. Contracts that have been signed in combination with exploration of new resources or building of new infrastructure are on average five years longer in duration in Europe and almost three years for all contracts. Further research should be targeted at extending the analysis and at introducing, e.g., a differentiation of contract types, or investment types (e.g. greenfield, extensions, etc.). A further differentiation between LNG and pipeline contracts might also be introduced. The analysis in this paper needs also to be counterchecked by empirical results from other commodity industries.

References

Coase, Ronald (1937) The Nature of the Firm, *Economica*, **4**, 386-405.

Crocker, Keith J., and Scott E. Masten (1988) Mitigating Contractual Hazards: Unilateral Options and Contract Length, *RAND Journal of Economics*, **19(3)**, 327-343.

Dixon, Huw, and Joshy Easaw (2001) Strategic Response to Regulatory Policies: What Lessons can be Learned from the U.K. Contract Gas Market?, *Review of Industrial Organization*, **18(4)**, 379-396.

Doane, Michael J., and Daniel F. Spulber (1994) Open Access and the Evolution of the US Spot Market for Natural Gas, *Journal of Law and Economics*, **37(2)**, 477-517.

European Commission (2005a) Annual Report on the Implementation of the Gas and Electricity Internal Market, Technical Annexes, European Commission COM(2004)863.

--- (2005b) Energy Sector Inquiry – Issue Paper, European Commission Competition DG, Version 15 November 2005.

Furubotn, Eirik G., and Rudolf Richter (1997) *Institutions and Economic Theory: The Contribution of the New Institutional Economics*. Ann Arbor: University of Michigan Press

Goodhue, Rachael E., Dale M. Heien, Hyunok Lee, and Daniel A. Summer (2003) Contracts and Quality in the California Winegrape Industry, *Review of Industrial Organization*, **23(3-4)**, 267-282.

Grossman Sanford J., and Oliver D. Hart (1986) The Cost and Benefit of Ownership: A Theory of Lateral and Vertical Integration, *Journal of Political Economy*, **94**, 691-719.

Hart, Oliver D., and John Moore (1988) Incomplete Contracts and Renegotiation, *Econometrica*, **56**, 755-785.

Hartley, Peter R., and Dagobert L. Brito (2002) New Energy Technologies in the Natural Gas Sectors. Houston, Texas, The James A. Baker III Institute for Public Policy.

Hubbard, R. Glenn, and Robert J. Weiner (1986) Regulation and Long-Term Contracting in US Natural Gas Markets, *Journal of Industrial Economics*, **25(1)**, 71-79

International Energy Agency (1998) *Natural Gas Pricing in Competitive Markets.* Paris, OECD.

--- (2004) *Security of Gas Supply in Open Markets – LNG and Power at a Turning Point*. Paris, OECD.

--- (2005) *Natural Gas Information 2004*. Paris, OECD.

Jensen, James T. (2005) Introduction to Global and Pacific RIM LNG Markets. Presented at California Energy Commission Workshop on LNG Access Issues and Security of Supply, Sacramento, July 1, 2005.

Joskow, Paul L. (1985) Vertical Integration and Long-term Contracts: The Case of Coal Burning Electric Generation Plants, *Journal of Law, Economics and Organization*, **1(1)**, 33-80.

--- (1987) Asset Specificity and the Structure of Vertical Relationships, *Journal of Law, Economics, and Organization*, **4(1)**, 95-177.

--- (2005) Regulation and Deregulation after 25 Years: Lessons Learned for Research in Industrial Organization, *Review of Industrial Organization*, **26(2)**, 169-193.

Klein, Benjamin, Robert G. Crawford, and Armen A. Alchian (1978) Vertical Integration, Appropriate Rents, and the Competitive Contracting Process, *Journal of Law and Economics*, **28(2)**, 297-326.

Mabro, Robert, and Ian Wybrew-Bond (eds.) (1999) *Gas to Europe: The Strategies of Four Major Suppliers*. Oxford: University Press.

MacAvoy, Paul W. (1962) *Price Formation in Natural Gas Fields: A Study of Competition, Monopsony, and Regulation*. Yale University Press, New Haven.

Maddala, G.S. (1983) *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge: University Press.

Masten, Scott E. (1988) Minimum Bill Contracts: Theory and Policy, *The Journal of Industrial Economics*, **37(1)**, 85-97.

Masten, Scott E., and Keith J. Crocker (1985) Efficient Adaptation in Long-Term Contracts: Take-or-Pay Provisions for Natural Gas, *American Economic Review*, **75(5)**, 1093-1093.

Masten, Scott E. and Stéphane Saussier (2002) Econometrics of Contracts: An Assessment of Developments in the Empirical Literature on Contracting, in: Eric Brousseau and Jean-Michel Glachant eds., *The Economics of Contracts. Theories and Applications*. Cambridge: University Press.

Mulherin, J.Harold (1986) Complexity in Long-Term Contracts: An Analysis of Natural Gas Contract Provisions, *Journal of Law, Economics and Organization*, **2(1)**, 105-117.

Neuhoff, Karsten, and Christian von Hirschhausen (2005) Long-term Contracts for Gas Imports – A Theoretical Perspective, Cambridge, CMI Working Paper.

Neumann, Anne, and Christian von Hirschhausen (2004) Less Long Term Gas to Europe? A Quantitative Analysis of European Long Term Gas-Supply Contracts, *Zeitschrift für Energiewirtschaft*, **28(3)**, 175-182.

Neumann, Anne, Boriss Siliverstovs, and Christian von Hirschhausen (forthcoming): Convergence of European Spot Market Prices for Natural Gas? A Real-Time Analysis of Market Integration Using the Kalman Filter, *Applied Economics Letters*.

Oerlemans, Leon A.G., and Marius T.H. Meeus (2001) R&D Cooperation in a Transaction Cost Perspective, *Review of Industrial Organization*, **18(1)**, 77-90.

Saussier, Stéphane (2000) When Incomplete Contract Theory Meets Transaction Cost Economics: A Test on Contractual Choice, in Claude Menard ed., *Institutions, Contracts and Organizations*. Cheltenham: Edward Elgar.

Sykuta, Michael E. (2005) New Institutional Econometrics: The Case of Contracting and Organization Research, New Institutional Economics Working Papers.

Williamson, Oliver E. (1975) *Markets and Hierarchies*. New York: Free Press.

--- (1983) Credible Commitments: Using Hostages to Support Exchange, *American Economic Review*, **73(4)**, 519-540.

--- (1985) *The Economic Institutions of Capitalism - Firms, Market, Relational Contracting*. New York: Free Press.