Economics of the LNG Value Chain and Corporate Strategies
An Empirical Analysis of the Determinants of Vertical Integration

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Abstract
This paper analyzes corporate strategies in the emerging global market for liquefied natural gas (LNG). In particular, we provide an empirical analysis of the determinants driving companies towards increasing vertical integration leading to an industry in which a small number of large and powerful players are active. Our hypothesis of high transaction costs along the LNG value chain inducing a higher degree of vertical integration is tested by implementing Ordered Response Models. To explain determinants of vertical integration in the LNG industry we derive proxy variables by using explicit project data on 85 LNG (importing and exporting) projects worldwide. The transaction cost attributes asset specificity, uncertainty and frequency are measured. Additionally, we include industry and firm characteristics into the analysis. Our results show that players active in LNG export projects are characterized by a higher degree of vertical integration than those situated on the importing side of the value chain. The extent of investments in specific assets has a positive impact on the degree of vertical integration. The extent of vertical integration has increased significantly with start up dates of projects since 2002. Private companies' degree of vertical integration exceeds the degree of vertical integration of state-owned entities. Players tend to be more integrated with rising firm size and frequency of transactions in the LNG industry. We show that for value chains situated in the Atlantic Basin (in contrast to the Pacific Basin), and there especially for value chains connecting to European instead of North American import markets, the degree of vertical integration is higher.

Keywords: liquefied natural gas, vertical integration, LNG value chain, corporate strategies
JEL-Codes: D23, L22, L95

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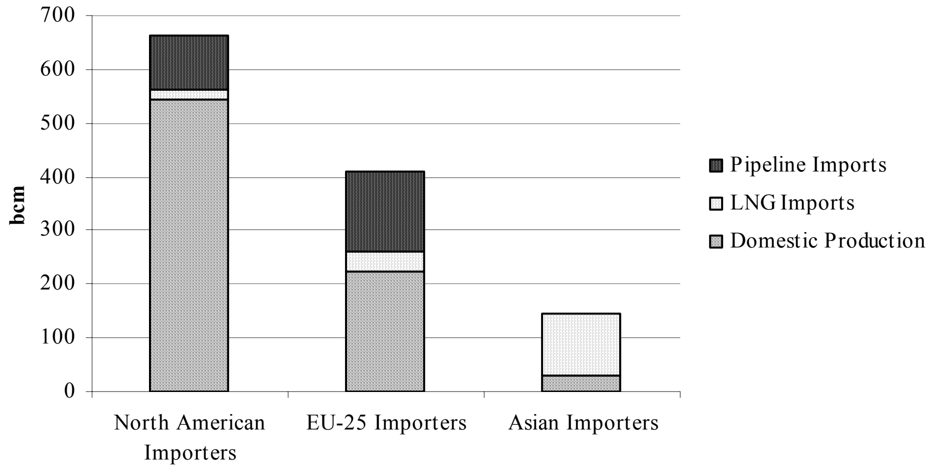
1 Introduction

This paper analyzes corporate strategies in the emerging global market for liquefied natural gas (LNG). In particular, an empirical analysis of the determinants pushing companies towards vertical integration, a trend recently observed, is provided. The dataset was developed using detailed information on 85 LNG projects – both export and import – worldwide. The main hypothesis is that increasing transaction costs along the LNG value chain induce a higher degree of vertical integration. This hypothesis is tested based on ordered probit estimation.

Transporting natural gas via LNG in tankers over oceans has been around for 40 years, but it is only now that it increasingly gains in importance. However, natural gas transportation is more capital intense than oil or coal shipping since the fuel has a lower density and therefore a lower energy content per volume unit. Prices between different geographic locations may differ substantially. Break even of pipeline and LNG transport is achieved at about 3,000 km (Jensen, 2004).Varying pre-conditions and development of LNG trade in the Atlantic and the Pacific Basins continue to affect import volumes, pricing systems, and contract terms. During the 1980s and early 1990s, in the Atlantic Basin indigenous natural gas supplies and imports via pipeline were sufficient to cover demand; therefore, LNG capacities grew relatively slowly. Even today, LNG has to compete with domestic supplies and pipeline imports. In contrast, natural gas importers in the Pacific Basin like Japan, South Korea or Taiwan do not have large (or even no) domestic supply and no pipeline sources and are therefore strongly dependent on LNG imports. For this reason, the countries are willing to pay for security of supply. Hence, LNG prices have historically been higher in Japan than in the Atlantic Basin. Figure 1 depicts structural differences of natural gas supply situations in the three LNG importing regions:

Figure 1: Supply structure of different natural gas importing regions (2004)



Source: BP (2006)

The past five years have seen the development from an *"infant"* towards a *"maturing"* LNG industry. Even if LNG technologies enabled transport over longer distances, transport remained expensive and markets therefore regional in nature. Most of the infrastructure along LNG value chains remained under state control; private or foreign companies were hardly involved and markets were not competitive. Inflexible bilateral long-term contracts with take-or-pay and destination clauses between the LNG export project as seller and national energy companies as buyers secured infrastructure investments on the one hand and security of supply on the other hand. These contracts were signed before any investment took place. A crucial element, ship ownership, was traditionally embedded in these contracts. Transportation capacity has thus been dedicated to special import and export projects and routes.

Fostered by increasing natural gas demand, investments in LNG infrastructure grew rapidly during the 1990s. Liquefied natural gas turned from being an expensive and only regionally traded fuel to a globally traded source of energy with rapidly diminishing cost. Over-design has been reduced and benefits from large economies of scale in liquefaction due to the shift from steam-driven to gas-turbine-driven compressors and increasing size of gas turbines are realized. The first liquefaction trains had a capacity of 1.1 mtpa (Arzew in Algeria), today trains with a capacity of around 4 mtpa are common, and the construction of units with 7.8 mtpa is planned.[2] Shipyards gain experience in tanker constructions and an increasing number of shipyards is capable to construct LNG vessels thus enhancing competition. The construction of larger ships lowers average transport costs per unit and makes deliveries over longer distances more economic. On the importing side of the value chain, economies of scale especially due to larger but fewer storage tanks were achieved.

LNG plays an increasing role in the energy supply of all major coastal countries such as the United States, the UK, Spain, South Korea, India or China. The Middle East, accounting for more than 40% of worldwide proven natural gas reserves, is expected to become the largest LNG exporting region and is currently evolving to a swing producer; deliveries to European as well as Asian markets are feasible without a significant difference in (transportation) cost. For a survey of the globalizing LNG market see Jensen (2004).

Changes in the institutional framework have moved away from monopolistic structures opening up for competition thus stipulating fundamental changes in the organizational behavior of market participants. Increasing competition, mirrored by functioning spot markets, a gain in contract flexibility and increasing international trade, put traditional players under pressure. Recent years have been characterized by integration and strategic partnerships becoming a common corporate behavior in the industry. Global oil and natural gas producing companies as well as original distributors heavily engage in all stages of the value chain of LNG production. Export projects, a long time dominated by state-owned entities, are increasingly developed by private oil and gas companies. Former (European) monopolists of

[2] E.g Qatargas II and III in Qatar. Economies of scale of two 4 mtpa trains reduce liquefaction cost of an 8 mtpa green-field project with four 2 mtpa units by nearly 30%; a further increase to one 7.5 mtpa unit leads to an additional cost reduction by another 20% (Jensen, 2003).

natural gas are facing their traditional markets challenged by the intrusion of oil and gas majors integrating downstream into import markets. Vertical integration in response to market deregulation features several drivers: upstream producers aiming to benefit from downstream margins, ownership of transportation capacities to exploit arbitraging possibilities, and distribution and power companies moving upstream to ensure margins and security of supply in times of increasing demand. Several publications (e.g. Cornot-Gandolphe (2005), Iniss (2004)) focus on activities in LNG trade in the Atlantic Basin and indicate that coexistence of long- and short-term trading activities is increasingly accompanied by vertical integration in the LNG industry.

However, vertical integration, strategic partnerships and mergers lead to an industry in which a small number of large and powerful players are active. Jensen (2004) argues that in the developing global LNG market *"super majors"* will play an important role. Vertical integration along the whole value chain limits competition at the horizontal level thus counteracting liberalization efforts in downstream markets.

A large number of empirical case studies examine firms' motivation to choose alternative institutions of governance and determinants of vertical integration in different industries, such as Monteverde and Teece (1982), Masten (1984), and Klein (1988) focusing on make-or-buy decisions in the manufacturing sector. Our contribution is placed in the continuation of this literature analyzing the determinants of vertical integration in the LNG industry from the perspective of transaction cost economics. The main hypothesis of increasing transaction costs along the LNG value chain (mainly due to increasing asset specificity and uncertainty) leading to a higher degree of vertical integration is tested applying ordered response models. Main findings are consistent with theory: we show that investments in specific infrastructure have a positive impact on the likelihood of vertical integration; with rising firm size and increasing frequency of transactions in the LNG industry players tend to be more integrated;

private companies' degree of vertical integration exceeds the degree of vertical integration of state-owned entities. Furthermore, our analysis shows that for value chains situated in the Atlantic Basin (in contrast to the Pacific Basin), and there especially for value chains connecting to European instead of North American import markets, the degree of vertical integration is higher. The extent of vertical integration has increased significantly with project start up dates from 2002.

The remainder of this paper is organized as follows: Section 2 provides an overview on existing theoretical and empirical literature analyzing determinants of vertical integration. Section 3 derives testable hypothesis, summarizes used data and introduces the econometric methodology. We present and interpret results in Section 4 before concluding in Section 5.

2 Related Literature

In order to empirically test the hypothesis of increasing transaction costs inducing a higher degree of vertical integration we can follow two main streams of literature. Since there exists no uniform theory of vertical integration as pointed out by Joskow (2005) we will identify different motivations of firms to prefer the internal form of organization as opposed to others.

Transaction cost economics finds its origin in Coase's theory of the firm (1937) and has been developed further by contributions from Williamson (1971, 1983, etc.), and Klein, Crawford and Alchian (1978). Asset specificity, uncertainty, and frequency of transactions are the main drivers influencing the extent of arising transaction costs. The hold-up problem – arising from a high level of relationship-specific investments in uncertain environments with players characterized by bounded rationality – results in costly ex post bargaining, inefficient ex-ante investment levels and decreasing efficiency. Organizing transactions within the own hierarchy avoids these problems by internalizing arising quasi rents in the firm.

Following the more formal property rights approach, incentives to integrate vertically are generated by the advantage of possessing residual rights of control over assets in cases where specific investments have to be realized. According to Grossman and Hart (1986), defining ownership as the possession of these residual rights, bargaining power over ex post distribution of surplus inhibits positive investment incentives. Vertical integration is worthwhile if it is too costly to list all specific rights in a contract and if one party's investment decision is of major importance.

Several other approaches from industrial organization conclude that market imperfections such as the existence of market power, barriers to entry, price discrimination, and asymmetric information are possible drivers for vertical integration. However, vertical integration is not only an answer to market power but potentially creates market power by gaining control over different stages of a value chain (Joskow,2005).

Analyses investigating a firm's motivation to choose alternative institutions of governance in different industries have a long-standing history. A large number of empirical case studies, such as Klein (1988), Monteverde and Teece (1982), and Masten (1984), examine firms' motivations to integrate vertically rather than to choose market exchange.[3] Klein (2004) provides an in-depth overview of empirical studies on the choice of organizational structures distinguishing between qualitative case studies, quantitative studies focusing on a single industry and cross sectional studies. Whereas empirical analysis in its early stages typically focused on the manufacturing sector and the impact of investments in specific physical assets on corporate behavior, later work also discusses the importance of human assets and extends the analysis to numerous industries. A rise in the prominence of a transaction cost approach of vertical integration was observed during the 1980s. First empirical work based on the property rights theory followed about 15 years later (e.g. Baker et al., 2004). We place

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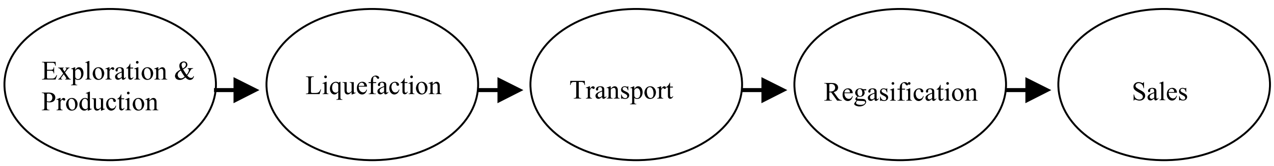
[3] All mentioned case studies explain vertical integration by institutional factors represented by proxy variables for transaction costs, industry or other exogenous characteristics.

ourselves in the continuation of this literature by analyzing the determinants of vertical integration in the LNG industry from the perspective of transaction cost economics. Our hypothesis is that increasing transaction costs along the LNG value chain (mainly due to increasing asset specificity and uncertainty) lead to a higher degree of vertical integration.

3 Data, Variables, and Methodology

Figure 2 depicts the LNG value chain with field development forming the first stage. Following exploration and production (stage 1) natural gas is transported per pipelines to the liquefaction facilities and cooled down to –160°C under atmospheric pressure (stage 2), thus becoming liquid and shrinking to about 1/600 of its volume. This liquefied natural gas is loaded into specially constructed vessels, containing complex cooling systems which are essential to keep the gas liquid. The LNG is transported by ship to its destination countries (stage 3);[4] where through a heating process the gas is converted to its original state of aggregation (stage 4). Finally, natural gas is fed into the pipeline grid and sold to marketers, distributors or directly to power producers (stage 5).

Figure 2: The LNG Value Chain



Investment costs within the five stages vary significantly with the largest share required by the liquefaction project. Exploration and production account for 15-20% of the total costs of

[4] Transportation infrastructure is a substantial element linking exporting and importing projects. As opposed to oil tankers, vessels for LNG transport remain dedicated assets to certain routes booked under extensive long term contracts. However, an increasing number of vessels for uncommitted trade are in the order books of shipyards thereby reducing dedicated asset specificity.

the LNG value chain; liquefaction for 30-45%; shipping for 10-30%; and regasification for 15-25%. Exact figures depend on different driving factors such as the distance, or the traded volumes (EIA, 2003).

We have compiled a dataset on the LNG industry from various publicly available information and expert interviews. It comprises detailed information on capacities, ownership structures, investment costs, financing structures and expansion plans of liquefaction and regasification projects and data on the LNG tanker world fleet and vessels currently in the order books of shipyards. Negotiated contracts have been analyzed concerning contracting partners, supplying facilities, volumes, and contract duration. Our sample includes 271 observations which are comprised by identifying actual value chains out of 60 importing and 25 exporting LNG projects.[5] The degree of vertical integration is defined by

$$VI_i = \begin{cases} 1 & \qquad n = 1 \\ 2 & \qquad n = 2 \\ 3 \qquad \text{if} & \qquad n = 3 \\ 4 & \qquad n = 4 \\ 5 & \qquad n = 5 \end{cases}$$

where VI indicates the degree of vertical integration, i is the number of the observation and n the number of successive stages in which the player has ownership rights along the actual value chain. The variable is a discrete measure distributed on an ordinal scale.

The degree of vertical integration in a transaction cost framework is influenced by three main dimensions: asset specificity, uncertainty, and frequency of transactions.[6] Proxy variables testing the hypothesis of increasing transaction costs (due to higher asset specificity and

[5] For all existing regasification and liquefaction plants worldwide as well as projects being under construction or planned to be operational before 2010.

[6] Some authors introduce additional attributes like complexity or measurability of the transactions. Since complexity or measurability are characteristics applicable to the whole industry, not varying between diverse LNG value chains, they are not included into this analysis.

environmental uncertainty) leading to a higher degree of vertical integration are defined. Furthermore, several industry- and firm characteristics are employed as control variables.

Liquefaction projects require investments in much more specific infrastructure than regasification facilities. Located near natural gas fields to avoid high pre-export transportation costs they are highly site specific. Furthermore, a liquefaction terminal lacks redeployability. Not used in its original intention to liquefy natural gas its value decreases nearly to zero (physical asset specificity). Additionally, investment costs are twice as high as those of comparable regasification terminals and asset specificity decreases with deregulation of network industries (Dahl and Matson, 1998). Third party access to import infrastructure enhances redeployability. As in different other empirical studies (e.g. Masten, 1984) a dummy variable indicating export projects (DX) allows for this higher degree of asset specificity.

Inhomogeneous distribution of natural gas in often political critical regions is introduced into the analysis by including a political country risk index (RISK).[7] The index ranks countries on a seven-level ordinal scale. Following transaction cost theory we expect that with higher investments in specific infrastructure and increasing uncertainty the degree of vertical integration increases.

The frequency of a player's activities in the LNG industry is measured by cumulating regasification and liquefaction capacities owned worldwide by this company (CAPOWN). We argue that a firm owning more LNG (export or import) capacities can benefit from economies of scale and therefore tends to integrate stronger than new entrants. Other empirical studies (e.g. Simoens et al., 1999) provide evidence of frequency being positively correlated with the likelihood of integration.

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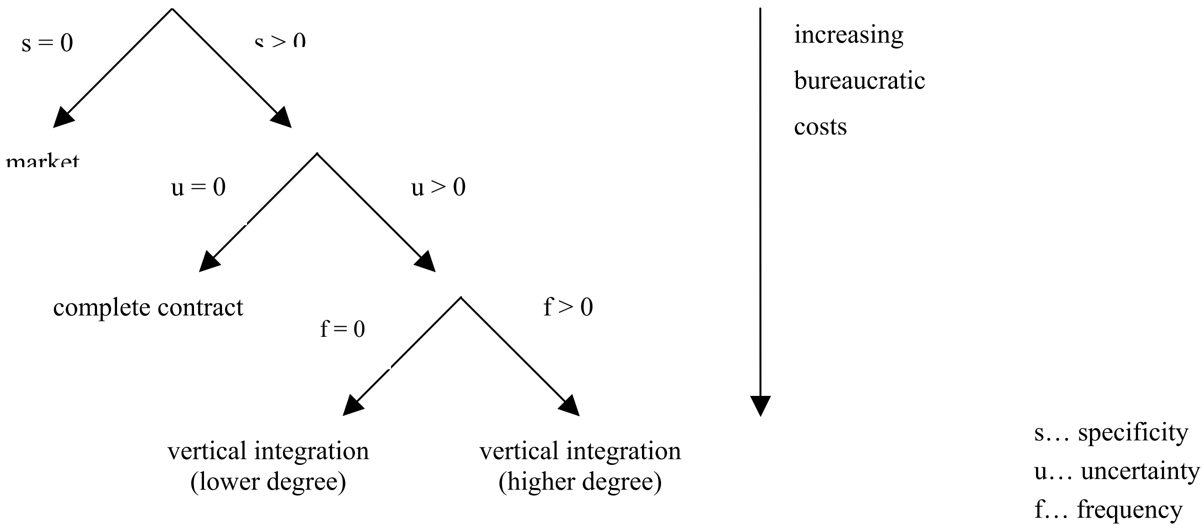
[7] As reported by Coface Country Rankings (2005).
For example, guerilla activities of Aceh separatists in Western Sumatra (Indonesia) have led to a temporary shutdown of the Arun liquefaction facility in 2001.

Figure 3: Choice of an Organizational Structure Dependent on Transaction Attributes



Source: Own illustration following Williamson (2006)

Figure 3 describes the relationship between the above described transaction cost determinants of vertical integration and the expected firm's choice of an organizational structure. Transaction cost economics predicts that asset specificity is the strongest determinant of vertical integration. For exchange relationships not involving any investment in specific assets, theory shows that trade on a spot market is the most efficient solution. Markets become inefficient as bilateral dependencies – resulting from investments in specialized assets – arise. Specific investments in environments without any uncertainty can be secured through complete long-term contracts. In contrast, the existence of uncertainty results in vertical integration being more efficient than long-term contracts. Frequency of transactions in the industry, defined as experience leading to the availability of specific knowledge, staff, and economies of scale, is assumed to have a positive impact on the degree of vertical integration. However, the more integrated a firm, the higher are additional bureaucracy costs occurred through internal organization. This leads to a trade-off between costs and benefits of integration.

First success of efforts of introducing competition into the natural gas industry (not only within Europe) since the late 1990s is evident. Monopolistic market structures have been (partially) broken up allowing new players to enter the market. Works of Ohanian (1994), Lieberman (1991), or Rosés (2005) indicate that market concentration as a measurement of transaction costs resulting from a small number bargaining problem has a significant positive influence on the degree of vertical integration. Following this argumentation the Herfindahl-Hirschman Index for the importing market (<u>HHI</u>) is included as independent variable. It is argued that the higher the persistent HHI in a country the fewer the number of alternative LNG buyers, thus the higher transaction costs resulting from small number bargaining and therefore the higher the degree of vertical integration to avoid these costs.

International LNG trade has only picked up since the late 1990s. We introduce a dummy variable (<u>D2002</u>) identifying project start up dates before 2002, hence, allowing for structural changes in the LNG industry. This enables the examination of the impact of a changing market environment due to the liberalization of Continental European natural gas markets on corporate behavior.

A dummy variable (<u>ATLANTIC</u>) is used to allow for differences in corporate strategies resulting from regional factors, varying between Atlantic markets (deliveries to Europe and North America), where natural gas hubs are evolving and Pacific (Asian) markets where importers are strongly dependent on LNG imports. For the analysis of a sub-sample including value chains situated in the Atlantic Basin only, an additional dummy indicates value chains connecting to European instead of North American import markets (<u>EUR</u>) to investigate if there are significant differences between the European market and the competitive U.S. market.

Two additional variables accounting for differences in firm characteristic are included. The dummy (<u>ST</u>) separates state-owned entities from private firms. The value of firms’ assets in million US$ (ASSETS) is used as a proxy for firm size, expecting that larger firms tend to be more integrated since balance sheets enable the financing of integration. Other papers show a positive influence of firm size, often expressed by the assets value, on the likelihood or degree of vertical integration (e.g. Anderson et al., 1984, Ohanian, 1994).

Table 1 summarizes explanatory variables and the expected influence on the degree of vertical integration.

Table 1: Exogenous Variables

Characteristic	**Proxy**	**Denotation**	**Exp. Sign**
Asset specificity	Dummy export project (high specificity)	DX	+
Uncertainty of a project	Political country risk (ranked on ordinal scale)	RISK	+
Transaction frequency	Firm's participation in projects (standardized)	CAPOWN	+
Small number bargaining	Market concentration index (HHI)	HHI	+
Industry characteristics	Dummy start up before 2002 Dummy value chain situated in Atlantic Basin Dummy value chain connecting Europe	D2002 ATLANTIC EUR	-
Firm characteristics	Dummy state-owned entity Firm size (assets in million US$, standardized)	ST ASSETS	- +

Table 2 provides descriptive statistics of the original whole world dataset (before standardization of the variables measuring firm size and transaction frequency).[8] An average degree of vertical integration of all observations included into the analysis of 2.58 implies that companies are integrated on average along two or three stages of the value chain. The mean Herfindahl-Hirschman Index of 0.64 indicates very high concentration of suppliers in natural gas importing countries which is characteristic for the whole industry. Player's firm size

[8] Since the variables measuring frequency and firm size have a high variance in comparison to all other variables, they are standardized to be normally distributed and to have the mean of zero and a standard deviation of one for the regression.

varies significantly, ranging from US \$151mn (Spanish EVE) and US \$279bn (Japanese Nippon Oil Corporation).[9] Only roughly 40% of the dataset includes projects which started operation between 1964 and 2001. This is a sound representation of the booming capacity construction period starting in the 21st century. About 45% of the dataset include oil and gas majors as players, 38% original distributors and 17% others. In 36% of all projects state-owned entities are involved.

Table 2: Descriptive Statistics Original Data

	VI	DX	RISK	CAPOWN	HHI	D2002	ATLANTIC	ST	ASSETS
Mean	2.58	0.52	0.32	13.6	0.64	0.43	0.60	0.36	68,769
Median	2	1	0.17	12.3	0.55	0	1	0	60,000
Maximum	5	1	1	54.5	1	1	1	1	279,177
Minimum	1	0	0	0.15	0	1	0	0	151
Std. Dev.	1.06	0.50	0.31	10.86	0.30	0.49	0.49	0.47	62,596
Observations	271	271	271	271	271	271	271	271	271

Having defined the degree of vertical integration as a discrete measure distributed on an ordinal scale we apply an ordered probit model.[10] For the analysis of the world dataset the degree of vertical integration is explained by different exogenous variables as presented below:

$$VI_{World,i} = \alpha + \beta_1 DX + \beta_2 CAPOWN + \beta_3 RISK + \beta_4 HHI + \beta_5 D2002 + \beta_6 ST$$
$$+ \beta_7 ATLANTIC + \beta_8 ASSETS + u_i$$

[9] An average value for assets (US \$ 60,000) is assumed for state-owned entities if data was not available.

[10] For ordered response models the dependent variable is modeled by considering a latent variable that depends on certain exogenous variables. One distinguishes between ordered logit and ordered probit models, dependent on whether the error term is distributed logistically or normally. For this analysis, an ordered probit model is employed. Estimation is based on a maximum likelihood procedure with the likelihood function (iterative process).

and for the analysis of the sub-set including only value chains situated in the Atlantic Basin the degree of vertical integration is explained by:

$$VI_{Atlantic,i} = \alpha + \beta_1 DX + \beta_2 CAPOWN + \beta_3 RISK + \beta_4 HHI + \beta_5 D2002 + \beta_6 ST$$
$$+ \beta_7 ASSETS + \beta_8 EUR + u_i$$

where *VI* is the degree of vertical integration along an actual value chain *i,* α and β_n are parameters, *u* the error term expected to follow a normal distribution and the other variables defined as explained in the preceding section.

4 Estimation Results

Estimation results based on the whole world dataset generated by using an iterative solution process are provided in Table 3:[11]

Table 3: Estimation Results Projects Worldwide

	Coefficient	Std. Error	z-Statistic	Prob.
DX	0.525	0.171	3.073	**0.0021**
RISK	-0.086	0.248	-0.347	0.7289
CAPOWN	0.395	0.078	5.059	**0.0000**
HHI	0.694	0.273	2.542	**0.0110**
D2002	-0.535	0.145	-3.691	**0.0002**
ST	-0.384	0.171	-2.252	**0.0243**
ASSETS	0.134	0.086	1.565	0.1176
ATLANTIC	0.346	0.159	2.172	**0.0299**

[11] The LR-Statistic with a value of 89.96 (p-value: 0.000) shows, that the null hypothesis of all slope coefficients being equal to zero has to be rejected.

As transaction cost theory predicts, estimation results show that there exists a positive relationship between the degree of vertical integration and the extent of a project's asset specificity at a 5% significance level. Players coming from the upstream side of the value chain tend to be more integrated than original downstream players. Investing at the upstream end of the value chain, players face a higher level of asset specificity. Furthermore, uncertainty and political risk in exporting (often developing) countries exceed those of importing projects in consuming regions. Companies aim to benefit from downstream margins and to control transportation capacities in order to exploit arbitraging possibilities.

Even though uncertainty itself does not lead to vertical integration (Williamson, 1971), its presence intensifies the impact of specific investments on firms' motivations to organize transactions within the own hierarchy since (long-term) contracts would be unavoidably incomplete. The employed variable indicating uncertainty – political country risk – is not statistically significant; hence, unable to measure the inability to predict all contingencies likely to occur due to changes in the industry and trading environment ex ante.

With increasing frequency of transactions in the LNG industry, measured through the cumulated capacity owned by a player, the degree of integration increases significantly at a 1% level. We argue that this is a result from increasing experience on the one hand and the possibility to benefit from economies of scale on the other hand. Firms already participating in a number of LNG (export and/or import) projects are endued with specialized human capital (like a business unit LNG) and have mature relationships to trading partners. The effort of entering an additional project or an additional stage of the value chain is lower for those firms than for new entrants into the business.

Market concentration in the importing country (HHI) as proxy for small number bargaining transaction costs exhibits a highly significant positive impact on our dependent variable.

Hence, our expectation of higher market concentration and the resulting small number bargaining problem, inducing a higher degree of vertical integration is confirmed.

The hypothesis of an increasing degree of vertical integration since the introduction of structural changes and the rapid capacity extension and new built facilities since 2002 can not be rejected. As a result from deregulation and liberalization, firms adapt to the changing investment environment. Risks inherent in the capital intensive LNG industry are internalized by the strategic repositioning and reshaping of companies. Size matters when it comes to the increased capability of financing an integration and entering new stages of the value chain which traditionally were not considered core competences. Firm size, measured through the asset value, has a positive and significant impact on the degree of vertical integration. Furthermore, private companies' degree of vertical integration exceeds the degree of vertical integration of state-owned entities. The coefficient of the dummy variable state-owned entity (ST) has the expected sign and is significant at a 5% level. Private companies face partly higher risks – with no or little influence on political decisions and not benefiting from state capital – and in general follow a different business strategy.

Finally, we show that players are much more integrated along value chains situated in the Atlantic Basin. In contrast to the Asian LNG industry, where in most cases state-owned entities control LNG facilities, private companies participate intensively in European and North American import projects as well as in Atlantic Basin export projects.

The expectation-prediction Table 3 compares the number of actual observations in each category with the number of observations that should be classified into these categories since their probability for the corresponding response is maximal. Hence, it can be observed that for 176 observations the level of vertical integration should be two, whereas only 114 observations actually take on this value leading to a negative error of 62. Overall, more observations than predicted are classed into the outer categories. Hence, firms are more likely to choose a polar structure (non-integration or high vertical integration) rather than a medium degree of vertical integration.

Table 4: Expectation-Prediction Table Ordered Response Model (World Dataset)

Value	Count	N° of observations with max prob.	Error
1	32	0	32
2	114	176	-62
3	82	90	-8
4	21	0	21
5	22	5	17

Focusing on the LNG business in the Atlantic Basin provides similar results. Table 5 summarizes the estimation results for a detailed Atlantic Basin analysis. Coefficients exhibit the expected signs, but statistical significance decreases since the number of datasets is reduced from 271 to 162. Adding an additional dummy variable indicating regasification projects situated in Europe, it becomes obvious that for value chains connecting to European instead of North American import markets, the degree of vertical integration is higher on average. This is an interesting issue since the liberalization process in North America has started during the 1980s, about 15 years before it was initiated in Continental Europe. It may be hypothesized that players in the U.S. may not need to integrate to secure their supply and the amortization of investments. The market seems to work well, companies face increasing natural gas demand, reacting with huge investments in natural gas infrastructure and new players entering the market. It can be speculated that in Continental Europe competition will also enhance the emergence of independent non-integrated companies in about ten years.

Table 5: Estimation Results Atlantic Basin

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.702	0.441	-1.592	0.1114
DX	0.593	0.435	1.365	0.1723
RISK	1.702	0.582	2.924	**0.0035**
CAPOWN	0.586	0.151	3.880	**0.0001**
HHI	-0.264	0.491	-0.538	0.5907
D2002	-0.113	0.284	-0.398	0.6908
ST	-0.825	0.328	-2.513	**0.0120**
ASSETS	0.487	0.210	2.316	**0.0205**
EUR	0.994	0.455	2.185	**0.0289**

Figure 5 summarizes the influence of transaction cost determinants and certain project and firm characteristics on the degree of vertical integration:

Figure 4: Influence on the Degree of Vertical Integration

Positive:

- Player originally situated on export side of the value chain and having to invest in highly specific infrastructure
- High frequency of player's activities in the LNG industry
- High market concentration of natural gas suppliers in the importing country
- Large firm size
- Value chain in the Atlantic Basin
- Value chain connecting to European instead of North American markets

Negative:

- Start up value chain before 2002 (in the "infant LNG industry")
- State-owned entity instead of private company

Beside these main results we find that exporting and importing players control the mid-stream stage transportation to a similar extent: both, oil and gas majors as well as original distributors, have chartered vessels under long-term contracts and possess or have ordered own ships. Controlling transport capacity is the key to trade more flexible and to benefit from various export and import positions and price difference between different regions. Order books of international shipyards include a large number of ordered vessels of which a certain number will be owned by major players of the industry, not dedicated to neither project nor transport route.

5 Conclusions

The past five years have seen the development from an *"infant"* towards a *"maturing"* LNG industry. Increasing natural gas demand and the ongoing process of liberalization and deregulation in Continental Europe lead to fundamental changes in corporate behavior. Global oil and natural gas majors as well as original distributors engage in all stages of the LNG value chain, new players enter the market. Today's industry is characterized by more flexible long-term contracts accompanied by short-term agreements, and companies integrating vertically to internalize risk factors resulting from investments in capital intensive LNG infrastructures.

The continuing growth of LNG short-term trade accompanied by an increasing flexibility inherent in contracts enhances reshaping of the industry. In addition, players order non-dedicated vessels thereby creating uncommitted transport capacities which will be the key to exploit arbitraging profits from price differences between regions.

We use a transaction cost economics approach to empirically analyze determinants of vertical integration in the (liquefied) natural gas industry. Vertical integration and strategic partnerships become a common form of organization to face changing market conditions. This is evident for private companies which tend to be more integrated than state-owned entities. We show that players active in LNG export projects are characterized by a higher degree of vertical integration than those situated on the importing side of the value chain. The extent of vertical integration has increased significantly with project start up dates from 2002 on. With rising firm size and frequency of transactions in the LNG industry players tend to be more integrated. Furthermore, we have shown that for value chains situated in the Atlantic Basin (in contrast to the Pacific Basin), and there especially for value chains connecting to European instead of North American import markets, the degree of vertical integration is higher.

The natural gas industry develops to an industry dominated by global super majors benefiting from a certain market power as well as from the financial strength to finance integration, mergers and large investments. The high degree of vertical integration in the LNG industry is limiting horizontal competition, thus counteracting liberalization efforts currently under way in Continental Europe. Since we can show that for LNG value chains connecting to the competitive U.S. import market the degree of vertical integration is significantly lower (new independent non-integrated players enter the stage) we argue that with the proceeding of the liberalization process in Continental Europe the level of competition will increase and enhance the emergence of independent non-integrated companies also in European markets in about ten years.

The *"LNG rush"* forecasted during the early years of this decade has already brought an increase in regasification capacity of about 40% since 2000 (from 35.6 mtpa in 1999 to 49.8 mtpa at the end of 2005). A large number of additional terminals or existing facilities' expansions are approved or already under construction, and will increase LNG import capacity many-fold over the next five years. Countries currently not engaging in the LNG industry actually think about the LNG option. Discussions are under way about terminals at Wilhelmshaven (Germany), Gdansk (Poland), or Krk (Croatia).

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