Vertical Structures in the Global Liquefied Natural Gas Market: Empirical Analyses Based on Recent Developments in Transaction Cost Economics

Dissertation

zur Erlangung des akademischen Grades

Doctor rerum politicarum (Dr. rer. pol.)

vorgelegt an der

Fakultät Wirtschaftswissenschaften
der Technischen Universität Dresden
im Januar 2010

von

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verteidigt am 25. Juni 2010

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Acknowledgements

I am especially grateful to my supervisor, Prof. Christian von Hirschhausen, for giving me the opportunity to work on this dissertation at the Chair of Energy Economics and Public Sector Management at Dresden University of Technology, for his collaboration, helpful comments and suggestions, and for having been thrown in at the deep end several times. The last years have been full of great experiences and new knowledge does not confine itself only to transaction cost economics and the economics of natural gas markets.

I would like to thank Prof. Stéphane Saussier, from whom I learned much about theories of the firm and empirical work and who always was available for comprehensive discussions. Furthermore, I had the great opportunity to discuss my work with Oliver Williamson, Jackson Nickerson, Scott Masten, and Jean-Michel Glachant at the European School on New Institutional Economics in Cargèse. They helped me a lot to understand the manner of thinking of institutional economists and gave me various inspirations on how to improve and continue my work.

I thank Jeff Makholm, Manfred Hafner and David Nissen for their very helpful insights into (liquefied) natural gas markets. Special thanks go to Jan Abrell, Anne Neumann, Hannes Weigt, and my other colleagues for giving me a broader view on network industries and economic theory. Special thanks also go to my family for always supporting me in what I do and for their steady interest in my work. Finally, I thank Philipp for his encouragement, particularly during the last months of this dissertation; he did not cease to assure me that things would work out all right.

Abstract

During the last decade, the global liquefied natural gas (LNG) market altered substantially. Significant investments have been realized, traded volumes increased and contracting structures gained in flexibility. Various governance forms co-exist, including the poles of spot market transactions and vertical integration as well as numerous hybrid forms such as long-term contracts, joint ventures, and strategic partnerships. This dissertation empirically investigates, based on transaction cost economics and recent extensions thereof, which motivations drive companies towards the choice of hierarchical governance forms. First, the likelihood of vertical integration and the impact of inter-organizational trust as a shift parameter accounting for differences in the institutional environment are analyzed. Estimation results confirm transaction cost economics by showing that relationship-specific investments in an uncertain environment drive LNG companies to invest in successive stages along the value chain. Furthermore, the presence of inter-organizational trust increases the likelihood of less hierarchical governance modes. Second, alternative theories of the firm are linked in order to explain the menu of strategic positions recently observed in this dynamic market. Estimation results support the positioning-economizing perspective of the firm. The three strategic choices of target market position, resource profile, and organizational structure are interdependent. Third, the determinants 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 is discussed. Estimation results show that the presence of high asset specificity results in longer contracts whereas the need for flexibility in today's LNG market supports shorter 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.

JEL Codes: D23, L22, L95

Keywords: Transaction cost economics, shift parameter framework, positioning-economizing perspective, vertical integration, long-term contract, contract duration, liquefied natural gas

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List of Abbreviations

2SLS	two-stage least squares
AIC	Akaike information criterion
bbl	barrel
bcm	billion cubic meters
bcm/a	billion cubic meters per year
BIC	Bayesian information criterion
BP	British Petroleum
bn	billion
cif	cost, insurance, and freight included
des	delivered ex-ship
E&P	exploration and production
EA	econometric analyses
EIA	Energy Information Administration
FERC	Federal Energy Regulatory Commission
fb	frequency of transactions between the same trading partners
fob	free-on-board
fw	frequency of transactions within the relationship
GC	governance costs
GIIGNL	Groupe International des Importateurs de Gaz Naturel Liquéfié
GMM	generalized method of moments
GW	gigawatt
H	hierarchy
IEA	International Energy Agency
IV	instrumental variable
kg	kilogram
l	liquefaction capacity
L	hybrid governance modes
LNG	liquefied natural gas
M	market
m^3	cubic meter
MARAD	Maritime Administration
MB	marginal benefits
MBTU	million British thermal units
MC	marginal costs
MENA	Middle East and North Africa
MJ	megajoule

mn	million
mtpa	million tons per year
N	number of observations
NBP	National Balancing Point
NI	non-integration
NIE	New Institutional Economics
NOC	national oil and gas company
OECD	Organization for Economic Co-operation and Development
OLS	ordinary least squares
PC	production costs
Pr	probability
r	regasification capacity
s	asset specificity
Std. dev.	standard deviation
t	trust
TAC	transaction costs
TWh	terra Watt hours
u	uncertainty
UK	United Kingdom
US	United States
USD	US Dollar
VI	vertical integration
WTI	West Texas Intermediate

1 Introduction

"[T]he problem of economic organization is properly posed not as markets *or* hierarchies, but rather as markets *and* hierarchies."
Williamson (2002, p. 175)

When I was a student in industrial engineering at Dresden University of Technology, I had the great opportunity to work together with Prof. Christian von Hirschhausen since 2004. After a first excursion into the field of investments in nuclear energy in Eastern Europe during my time as a research assistant, we soon discovered the global liquefied natural gas market to be an interesting field of research. In fact, this became the starting point for more than four years of exciting and fruitful work that included a diploma thesis, workshops, summer schools, conference presentations, and finally, this dissertation. In the summer of 2006, I presented the first ideas of my diploma thesis at the European School on New Institutional Economics. When Prof. Oliver Williamson asked me a question, I did not understand anything. My limited language skills and his American accent might have been one reason, but my very limited knowledge on New Institutional Economics doubtlessly did not support any comprehension. However, after two more years of work and three resubmissions, I succeeded in publishing a first paper which strongly motivated me to continue; and when Prof. Williamson finally was awarded the Nobel Prize in Economics last year, my colleagues and I gladly clinked classes of champagne.

1.1 The issue

The technology of natural gas liquefaction and shipping enables inter-regional gas trade linking the formerly isolated markets of North America, Europe-Eurasia, and Asia-Pacific. The past decade has seen the global market for liquefied natural gas (LNG) undergoing substantial developments. Driven by growing natural gas demand and declining investment costs for LNG export and import facilities until the mid-2000s, large-scale infrastructure investments have been realized along the whole value chain. Export capacities increased from 108 million tons per year (mtpa) at the end of 1999 to 229 mtpa in 2009 (+112%), import capacities increased from 251 to 462 mtpa (+84%) during the same period and the number of operating LNG vessels augmented from 106 to 337 (+218%). New players, countries as well as companies, entered the market. International trade nearly doubled in volume.

During the early years of the industry, most of the world's LNG export infrastructure remained under state control and private or foreign companies were involved only with minority shares. Inflexible bilateral long-term supply agreements with take-or-pay and destination clauses secured the capital-intensive investments on the one hand and reliable supplies for import-dependent buyers on the other. Ship ownership typically was embedded in these contracts. In today's LNG market, new flexibility in

trading patters comes from changes in the structure of long-term contracts. Average contract duration and contracted volume are decreasing, take-or-pay requirements are relaxed, options for additional cargoes are included in recent contracts, and destination clauses are eliminated enabling the diversion of deliveries. These long-term contracts are increasingly accompanied by short-term agreements and spot transactions balancing supply and demand in the short- to medium-term. Whereas only 3.8% of total LNG trade took place under short-term contracts in 1999, this share increased to 20% in 2007 (Cornot-Gandolphe, 2005; Jensen, 2009b). The first export projects without having sold total volume based on long-term contracts are moving forward.

LNG suppliers increasingly follow a strategy of forward integration from the upstream to the downstream sector. Concluding for a sales-and-purchase agreement with the own marketing affiliate and investing at the same time in LNG import capacities, leads to the players controlling successive stages of the value chain. Some companies invest in an entire portfolio of LNG export, shipping, and import positions, enabling them to conduct flexible trades and to benefit from regional price differences. For example, Exxon Mobil in partnership with Qatar Petroleum controls export capacities in Qatar, has a fleet of 27 ships, and invested in importing capacities on both sides of the Atlantic (i.e., UK and US). Furthermore, traditional natural gas distributors started to participate in LNG export ventures and also electricity companies, forming part of the extended value chain including gas-fired power production, entered the market and integrate backward from the downstream to the upstream sector. In contrast, some new entrants invested in non-integrated LNG import terminals operating them as so called tolling facilities, selling the service of unloading, regasification, and storage to third parties, or speculating for short-term deliveries.

The occurrence of such a menu of governance forms including vertical and horizontal integration, joint ventures and strategic partnerships, long- and short-term contracts, and spot transactions in one and the same industry is very interesting from a New Institutional Economics (NIE) point of view. In addition, we observe varying strategies of different companies which are active in similar stages of the value chain, and one and the same company choosing different positions along alternative value chains. Therefore, this thesis addresses vertical structures in the global LNG market and investigates what drives companies towards vertical integration and which external factors determine optimal contract duration of long-term supply agreements.

1.2 Approach

The origins of transaction cost economics go back to Ronald Coase's seminal article on the nature of the firm. When Coase (1937) asked why there are firms, he could not find an answer in price theory but rather argued that there must be some cost of using the price mechanism and that firms are likely to emerge when contracting becomes too expensive. However, with every transaction organized within a firm, additional bureaucratic costs arise and the entrepreneur's capabilities of making the best use of production factors decreases, limiting firm size. More than three decades later, the field of NIE

established. Williamson (1975, 1985) operationalized transaction cost economics discussing the determinants of (ex-post) transaction costs and contractual difficulties.

Economic actors are assumed to be characterized by bounded rationality and may behave opportunistically in the sense of "self-interest seeking with guile" (Williamson, 1985, p. 47). In a world in which uncertainty about the future state of nature is present, long-term contracts will remain incomplete not accounting for all possible contingencies. As long as there is functioning competition among trading partners, incomplete contracts are unproblematic. However, ex-post bilateral dependencies, as do result from investments in relationship-specific assets, encourage ex-post hold-up by the non-investing party and provide economic incentives to internalize quasi-rents into the own hierarchy.

Transaction cost economics is a comparative analysis studying governance structures under the target of economizing exchange relationships with respect to the sum of both production and transaction costs. Transactions, which differ in their attributes, have to be aligned with governance structures, which differ in their costs and competencies, in a discriminating way. Internal organization will be the efficient mode of organization only in the presence of both substantial relationship-specific investments and environmental uncertainty where the hazard of post-contractual opportunistic behavior by the counterparty would otherwise result in ex-ante under-investment and decreasing overall efficiency. Asset specificity without uncertainty allows for the conclusion of complete contingent claim contracts. Uncertainty without asset specificity can be dealt with in exchanges on competitive markets.

Transaction cost economics became prominent during the 1980s. At first glance, this approach seems to be an empirical success story with about 900 applications. However, the existing body of empirical literature suffers from a number of shortcomings. Several studies are not fully consistent with propositions developed within the framework of transaction cost economics. Often, imperfect proxies for key variables have to be employed. Numerous studies ignore the endogeneity of right-hand-side variables. Finally, most econometric tests are based on reduced form models and therefore cannot test for the theory's propositions directly. While empirical evidence demonstrates that firms choose governance consistent with transaction cost predictions, the performance implications of governance choice are less well explored.

In recent years, researchers have continued to develop and improve transaction cost economics. Whereas research on the institutional environment and the institutions of governance have developed in disjunct ways for a long time, Williamson (1991b) introduces the shift parameter framework which investigates how the optimal choice of governance changes in response to dynamics in the institutional environment. Changes in exogenous parameters will shift the relative costs of alternative governance structures and, therefore, will have an impact on the optimal alignment of transactions and institutional arrangements. Nickerson (1997) develops the positioning-economizing perspective arguing that decisions regarding market position, resource investments, and governance mode are interdependent

and determined simultaneously. A target market position is supported by a resource profile that in turn determines the organizational choice of a firm. In addition, a number of authors came up with an increasing interest in relational (i.e., implicit or self-enforcing) institutional arrangements arguing that transaction cost economics may overstate the desirability of complex long-term contracts and vertical integration in exchange settings where a substantial hold-up potential is present.

This thesis picks up several of the above discussed limitations of existing empirical work. It tests transaction cost economics' predictions and recent developments thereof using data on the global liquefied natural gas market. First, the impact of inter-organizational trust as a shift parameter on the choice of governance mode is investigated. Second, an empirical test of the positioning-economizing perspective is provided. Third, optimal contract duration of long-term LNG supply contracts is analyzed accounting for the trade-off between contracting costs and flexibility. Both contract duration and contracted volume thereby are considered as endogenous variables.

1.3 Structure of the thesis

Chapter 2 provides an introduction to New Institutional Economics and discusses the role of transaction cost economics within this field of research. The theory is delineated from other theories of the firm. The development of empirical contributions related to transaction cost economics' predictions is summarized and limitations of the existing body of empirical literature are discussed before recent developments in transaction cost economics are introduced.

Chapter 3 is devoted to dynamics in the global LNG market. After a technical introduction to the LNG value chain, the historical development of capacities and the role of LNG with respect to a globalization of natural gas markets are reviewed. Regional prospects for investments in LNG export and import capacities until 2015 are provided. Finally, vertical structures in the industry are discussed. Long-term contracts are decreasing in duration and inflexible clauses are relaxed. Short-term and spot transactions gain in importance. Joint ventures, forward, backward, and horizontal integration seem to be promising strategies in this industry.

Chapter 4 contributes an empirical analysis that examines the effect of both transaction characteristics and the institutional environment on the choice of governance in the global LNG industry. Using a dataset of 237 corporate-specific value chains, inter-organizational trust is introduced as a shift parameter. First, following transaction cost economics, it is hypothesized that specific investments under uncertainty provide incentives to integrate vertically. Second, it is argued that inter-organizational trust changes the relative costs of vertical integration and non-integration and supports less hierarchical governance modes. These economic relationships are tested i) based on a probit model to explain the binary choice between vertical integration into midstream shipping and non-integration and ii) based on an ordered probit model to explain the degree of vertical integration (i.e., non-integration versus integration from upstream or downstream into midstream shipping versus integration along the whole value chain). Estimation results provide broad support for transaction cost

economics by showing that relationship-specific investments in an uncertain environment drive LNG companies to invest in successive stages along the value chain. The presence of inter-organizational trust increases the likelihood of less hierarchical governance modes. The consideration of a shift parameter further enhances the explanatory power of the model supporting the need for empirical studies accounting for both transaction cost variables as well as variables capturing dynamics in the institutional environment.

Chapter 5 investigates corporate strategies in the emerging global market for LNG linking alternative theories of the firm in order to explain the menu of strategic positions recently observed in this dynamic market. In the first step, three alternative target market positions are defined, each supported by an underlying resource profile. In the second step, determinants that move companies towards vertical integration are investigated using the dataset of 237 corporate-specific value chains. Estimation results of a two-step decision making process confirm the positioning-economizing perspective of the firm. The three strategic choices of target market position, resource profile, and organizational structure are interdependent. It is shown that national oil and gas companies rely on less idiosyncratic assets than companies following a flexibility strategy, i.e., investing in a portfolio of export and import positions, and that companies following a flexibility strategy rely on less idiosyncratic assets than chain optimizers, i.e., companies investing along a single value chain. Transaction cost economics predictions are confirmed, too. Idiosyncratic investments in uncertain environments have a positive impact on the likelihood of vertical integration.

Chapter 6 analyses the determinants of contract duration in order to investigate the impact of market structure on optimal governance choice. Contract duration thereby is determined based on 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 an analysis of different dimensions of transaction frequency and their impact on governance choice to the theoretical discussion. Propositions are tested using a unique dataset including information on 261 LNG supply contracts from the beginning of the industry until today. Estimation results of a simultaneous equation model accounting for the endogeneity of the contracted volume show that the presence of high asset specificity results in longer contracts whereas the need for flexibility in today's LNG market supports shorter 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.

Chapter 7 provides conclusions and a critical assessment of the analyses carried out. Topics for future theoretical and empirical research are identified.

2 Recent Developments in Transaction Cost Economics

2.1 Transaction cost economics in the framework of New Institutional Economics

2.1.1 Introduction to New Institutional Economics

New Institutional Economics[1] is still a young theory. Having its origins in the seminal article of Ronald Coase (1937) on 'The Nature of the Firm' (see Section 2.2 for a more detailed discussion), it developed not before the 1970s and 1980s. Major works have been contributed by Ronald Coase, Douglass North, and Oliver Williamson amongst others (see e.g., Ménard and Shirley, 2005). NIE is an interdisciplinary approach combining research from the fields of economics, law, social and political sciences, organization theory, and strategic management; it "is all but an isolated and closed paradigm" (Ménard, 2004, p. xv). The literature focuses on institutions and on how institutions interact with organizational arrangements.

Traditional neoclassical economics differs from NIE in various respects. Firms typically are treated as production functions transforming inputs into outputs, taking the available technologies as given. Market prices contain all relevant information. Individuals are assumed to have perfect information and to be super-rational (i.e., do not have any problems with memory usage and can formulate and solve problems of high complexity). Transactions are realized instantaneously and without any transaction costs. Disputes are disregarded because of the presumed efficacy of court adjudication. Given technology, input prices and the demand function, the firm is able to maximize its profits. A firm's size and product range are explained in terms of production costs. Economies of scale imply larger firms; economies of scope support multi-product corporations.

However, "[w]hat economists usually mean by 'the theory of the firm' is the theory of production, not the theory of the firm as a legal entity" (Klein, 1999, p. 463). Neoclassical economics provides little insight into the boundaries of the firm and alternative organizational forms cannot be explained. Cost subadditivity implies that a certain output can be produced more efficiently when it is produced within one single production plant. Absent any transaction costs, two independent firms could agree for sharing the same facility and jointly produce the efficient level of output. However, whether the firms will integrate depends on the cost of writing and enforcing contracts, i.e., ex-ante and ex-post transaction costs, not only on the production technology.

NIE assumes that individuals suffer from bounded rationality and that the environment may be characterized by uncertainty about the future state of nature. The firm is understood as an institution created by economic actors in order to reduce risk and transaction costs. Firms are not regarded as black boxes but as possessing an internal structure. NIE went beyond the "conception of the firm-as-

[1] The term 'New Institutional Economics' has been introduced by Williamson (1975, p. 1). Like the 'old' institutional economics, NIE is interested in social, economic, and political institutions, but social phenomena such as corporate culture "[are taken] as explananda, not the explanans" (Klein, 1999, p. 457). Furthermore, NIE does not abandon neoclassical economics. Rather it investigates new questions such as why economic institutions emerge in the way they do.

production function (which is a technological construction) to consider the firm as a governance structure (which is an organizational construction) in which internal structure has economic purpose and effect" (Williamson, 2000, p. 602) Thus, "organizational variety is not disregarded but located centrally on the research agenda [of NIE]" (Williamson, 1986, p. 172).

Davis and North (1971, pp. 6 f.) define the institutional environment as "the set of fundamental political, social, and legal ground rules that establishes the basis for production, exchange and distribution." These rules guide individuals' behavior and can be both formal, explicit rules (such as property rights or laws) and informal, implicit rules (such as norms, customs or social and religious conventions). They further define an institutional arrangement as "an arrangement between economic units that governs the ways in which these units can cooperate and/or compete".[2] It may be formal or informal, temporary or long-lived.

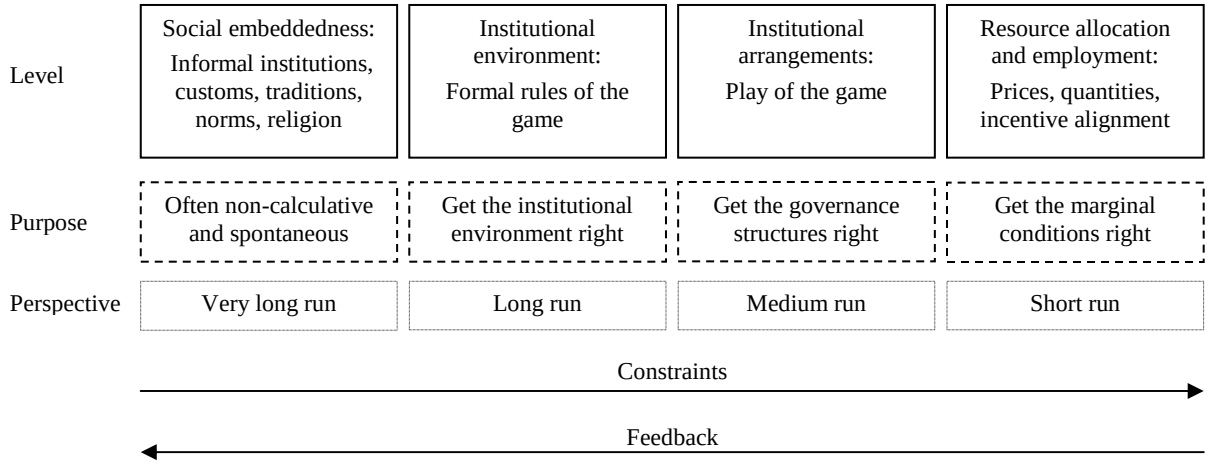
Williamson (2000) proposes to consider four levels of social analysis, corresponding to different time perspectives (see Figure 1): The first level represents *social embeddedness* (i.e., customs, traditions, religion, norms, etc.). These institutions tend to change very slowly and are taken as given by most institutional economists. Nevertheless, they contribute to shaping the institutional environment in defining rules and supporting the organization of transactions. The second level describes the *institutional environment* containing formal rules. Level three is referred to as the *institutional arrangements* (i.e., governance modes) embedded in the existing institutional environment as well as in traditions and norms shaping the behavior of transactors. These institutions may be changed periodically in order to reorganize transactions in a production and transaction cost economizing way. Finally, the last level focuses on *short-term resource allocation and employment* (i.e., neoclassical economics' object of investigation) with the firm typically being described as a production function. Adjustments concerning prices, supply and demand levels occur continuously. Within this framework, first levels impose constraints on the levels immediately following; lower levels in turn give feedback to the higher ones. NIE in general is concerned with levels two and three.

One can summarize that NIE investigates how institutions emerge and operate, how they shape the arrangements that support exchange relationships and production processes, as well as how these arrangements act in turn to change the institutional environment. Klein (1999, pp. 461 ff.) concludes that "development is seen as a response to the evolution of institutions that support social and commercial relationships. Economic growth thus depends on the degree to which the potential hazards of trade (shirking, opportunism and the like) can be controlled by institutions, which reduce

[2] Institutional arrangements "must … be designed to accomplish at least one of the following goals: to provide a structure within which its members can cooperate to obtain some added income that is not available outside that structure; or to provide a mechanism that can effect a change in laws or property rights designed to alter the permissible ways that individuals (or groups) can legally compete" (Davis and North, 1971, p. 7).
Ménard (1995) builds on these definitions and further delineates and defines the fundamental concepts of 'institutions' and 'governance structures' (i.e., markets and organizations) with the last being embedded in the institutional environment.

information costs, encourage capital formation and capital mobility, allow risks to be priced and shared and otherwise facilitate cooperation. […] Economic development, then, is institutional development."

Figure 1: Williamson's four levels of social analysis



Source: Own depiction based on Williamson (2000) and Ménard (2004)

2.1.2 Alternative theories of the firm

Two alternative streams of research are distinguished within the field of NIE. One stream focuses on institutional arrangements ('micro level'), the other deals with the institutional environment in which institutions are embedded ('macro level'). Whereas the former is especially interested in the trade-off among governance modes and provides some insights on the internal structure of institutions such as firms or contractual agreements, the latter investigates the role of laws and formal rules on economic development and growth as well as on transaction costs of exchange relationships. Major contributions on the micro level come amongst others from Oliver Williamson, Paul Joskow, Benjamin Klein, Scott Masten, and Stéphane Saussier; on the macro level Douglass North is one of the most influential authors. The focus of this thesis lies on (empirical) literature on the optimal choice of vertical organizational structures. Therefore, the next section provides an overview on alternative theories investigating firms' boundary choices which have developed during the last decades under the umbrella of NIE.

The starting point of a theory explaining vertical integration goes back to Adam Smith, who argued in the 18th century that the division of labor is limited by the extent of the market (Smith, 1776). According to Stigler's (1951) life cycle theory of the firm, emerging industries are characterized by a small size with the market not being able to supply input, technologies or specialized skills. With the expansion of the industry, tasks can be turned over to specialists. Declining industries in contrast, will again favor vertical integration with the surviving firm re-appropriating functions. However, this approach is incomplete as only one cost component (the cost of production) is considered. Competing theoretical frameworks within the field of NIE – despite their differing underlying assumptions – are

all based on a common starting point: in the absence of any transaction costs, contractual choices, organizations, and institutions are of no interest and the way property rights are distributed in an economy does not impact the way this economy uses scarce resources (Coase Theorem). In contrast, the below introduced approaches explicitly allow for non-zero transaction costs.

(1) Transaction cost economics (see e.g. Williamson, 1975, 1985, 1993b; Klein et al., 1978) hypothesizes that the optimal choice of governance depends on the relative costs of alternative institutional arrangements which in turn depend on the characteristics of the transaction at stake. Economic actors are assumed to be characterized by bounded rationality and may behave opportunistically. In a world in which uncertainty about the future state of nature is present, contracts will remain incomplete and do not account for all possible contingencies. This distinguishes transaction cost economics from neoclassical economics, where contracts are assumed to be complete, probability distributions of all possible future events are known and all relevant future external conditions can be considered ex-ante in the contracting stage.

As long as there is functioning competition among trading partners, incomplete contracts are unproblematic. However, ex-post bilateral dependencies, as do result from investments in relationship-specific assets, will generate ex-post exchange hazards (e.g., maladaptation, opportunistic renegotiations). For a discussion of the hold-up problem and optimal alignment of different kinds of transactions to alternative governance structures see Section 2.2.

(2) The property rights theory developed at a time when transaction cost economics had already been confirmed empirically (see e.g., Grossman and Hart, 1986; Hart and Moore, 1990). The reason why ownership and property rights become important is the incompleteness of contracts. Grossman and Hart (1986, p. 691) describe two types of contractual rights: Contractible specific rights and non-contractible residual rights of control which are not verifiable by any third party. A firm is limited by the assets over which is has control.[3] The central proposition of the property rights approach argues that it is optimal to allow one party to purchase the asset when it is too costly to list all specific rights in a contract and that the party which is mainly responsible for the return of the asset should own it in order to be endued with the residual control rights. Implications for the real world following Grossman and Hart (1986), Hart and Moore (1990), Hart (1995), and Salanié (1997) can be summarized as follows: i) highly complementary assets should be under joint ownership whereas independent assets should be separately owned; ii) employees doing simple routine jobs will not have control rights since their ownership of residual rights would not increase the firm's revenue; iii) control over non-human assets leads to control over human assets.

Even though both approaches have a similar point of interest (i.e., the make-or-buy decision), the property rights theory differs from transaction cost economics in its underlying assumptions. It assumes that economic actors are rational without any cognitive limitations, that the environment is

[3] Grossman and Hart (1986) do not distinguish between ownership and control. Employees are treated in the same way as outside contractors if the firm provides all tools and other assets used by the contractor.

characterized by risk about the future state of nature and that there is symmetric information between contracting partners but asymmetric information with third parties. Hence, actions and investments of the parties are observable, but not verifiable. Whereas transaction cost economics understands ex-post haggling over quasi-rents as the principal source of inefficiency, the property rights theory assumes efficient bargaining ex-post but non-contractible specific investments and investment distortions ex-ante. Furthermore, property rights models typically distinguish between upstream and downstream integration whereas transaction cost economics investigates only whether successive stages of a value chain should be unified. See Williamson (2000, p. 606) and Saussier and Yvrande-Billon (2007, pp. 100 ff.) for further details.

Whinston (2001) discusses whether empirical literature confirming transaction cost economics does deliver any evidence for the property rights theory. Predictions of the two approaches differ substantially. To formulate testable hypothesis for the second, numerous information about the trading environment, in general not documented in transaction cost analysis, are necessary. Therefore, existing empirical studies in general do not provide evidence for both approaches due to the lack of information, mainly on the extent of non-contractible investments.

(3) On the roots of incentive theory a third stream of literature has established, based on the assumption of asymmetric information between the contracting parties (see e.g., Laffont and Martimort, 2002). Within this approach, the firm itself is not the unit of analysis, but rather the collection of contracts between owners and managers, managers and employees, the firm and its customers and suppliers, or a regulator and the firm. The firm is understood as "nexus of a set of contracting relationships" (Klein, 1999, p. 466) with the central question being the optimal design of ex-ante incentive compatible contracts suited to mitigate agency costs in the face of potential adverse selection and moral hazard. The boundary of the firm here is not the focal subject of attention. This is criticized by Williamson (1991b, p. 274), who argues that "to regard the corporation only as a nexus of contracts misses much of what is truly distinctive about this mode of governance."

(4) From an alternative perspective, numerous articles discuss the boundaries of the firm with respect to its resources and capabilities. The resource-based view (see e.g., Barney, 1991) has especially contributed to the field of strategic management. Competitive advantage is supposed to stem from the possession of unique factors of production and valuable, difficult-to-imitate, difficult-to-transfer resources. A firm's specific resources may include organizational capabilities and routines, managerial skills, technological and reputational capital. A value chain of production can be broken down into various activities. Some activities may be similar in that they draw on the same firm capabilities; others may be complementary in that they are connected within the value chain. Richardson (1972, p. 895) argues in an early paper that "[w]here activities are both similar and complementary they could be coordinated by direction within an individual business." Dissimilarity of activities is supposed to make integration costly. Asset specificity is primarily regarded as a form of human assets embedded in firm-specific routines. Accordingly, the resource-based view hypothesizes that increased asset

specificity enhances the governance efficiency of internal organization rather than decreasing the efficiency of market exchange.

(5) Other theoretical approaches have concluded that market imperfections such as the existence of market power, barriers to entry, or price discrimination favor vertical integration. See Joskow (2005) for a detailed summary.

2.2 Transaction cost economics: A static concept

Transaction cost economics is a comparative analysis studying governance structures under the target of economizing economic exchanges with respect to the sum of both production and transaction costs. Organizational forms are never examined separately but always in relation to alternatives. The transaction, defined as "occur[ing] when a good or service is traded across a technologically separable interface", is the basic unit of analysis of transaction cost economics (Williamson, 1993b, p. 16). The following paragraphs provide an overview on the theory's underlying assumptions, the relevance of transaction costs in exchange relationships and the optimal alignment of transactions which differ in their attributes to governance modes that differ in their costs and competencies.

2.2.1 The concept of transaction costs: From Coase (1937) to Williamson (1975, 1985)

"There was nothing inevitable about my writing The Nature of the Firm. It came about as a series of accidents" Ronald Coase stated in 1988, three years before he was awarded the Nobel Prize in Economics. In fact, Coase, who chose to study economics only because of little interest in mathematics and a lack of knowledge in Latin, made one of the most important contributions to New Institutional Economics.

Coase (1937) criticizes the simplified view of an economy assumed by most researchers until the first half of the 20th century. The economic system was understood to work by itself without any central control and supply and demand being coordinated by a price mechanism, i.e., an automatic, totally elastic and immediately adaptive process. In traditional price theory there were no costs but production and transportation costs. So when Coase asked "his brilliant naive question" (Langlois et al., 2002, p. xii) why there are firms, he could not find an answer in price theory. He was the first economist, thinking about costs that accompany exchange relationships on markets arguing that the neoclassical picture would be incomplete and not able to explain two basic questions, namely the existence of firms and the determinants of firm size.

The first central statement of his article is that the "main reason why it is profitable to establish a firm would seem to be that there is a cost of using the price mechanism" (Coase, 1937, p. 389). These include the costs of discovering relevant prices and negotiating and concluding contracts. Hence, firms are likely to emerge when contracting becomes too expensive. Coase defines the firm based on the concept of authority as a coordinating device. Whereas on a market agents decide on their exchange relationships based on relative prices, in a firm the employer decides on the employees' activities.

But what determines the optimal size of the firm with size defined as the number of transactions organized internally? Coase (1937, p. 393) asks: "Why, if by organizing one can eliminate certain costs and in fact reduce the cost of production, are there any market transactions at all? Why is not all production carried by one big firm?" He specifies two reasons. First, additional internal costs arise with every transaction organized within a firm; second, the entrepreneur's capability of making the best use of production factors decreases. All innovations improving management efficiency tend to increase firm size since internal organization and coordination costs are reduced. A firm will tend to expand until the cost of organizing an extra transaction within the own hierarchy equals the cost of carrying out the same transaction on the market or the cost of organizing it within another firm.

About 30 years Coase's work attracted little attention, but with the development of NIE during the 1970s it became one of the most cited articles. However, Coase (1937) does not discuss the sources of transaction costs and contractual difficulties. Williamson (1975, 1985) operationalized transaction cost economics focusing on the economic actors' behavioral characteristics on the one hand and on transaction attributes on the other. Ménard (2004, xxi) points out that "[Williamson] opens the door to a systematic analysis of alternative modes of governance" in establishing the relationship between the sources of contractual hazards and their impact on the choice of institutional arrangements. His work has been widely cited during the last three decades (Foss and Klein, 2009) and has a substantial impact on recent theoretical developments based on transaction cost economics as well as on a huge body of empirical literature.

Williamson (1975, pp. 20 ff.) develops a framework of organizational failure in market exchanges softening step by step neoclassical economics' assumptions on behavioral and environmental characteristics (see Figure 2):

Behavioral assumptions: Economic individuals are characterized by bounded rationality; they are "intendedly rational, but only limited so" (Simon, 1961, xxiv).[4] Bounded rationality involves limited cognitive competences such as neurophysiologic limits (impossibility to receive, store, retrieve, and process all information without any error) and language limits (individuals are not able to articulate their knowledge and information clearly to be perfectly understood by others). See Selten (1990) for a discussion on the development of the concept of bounded rationality.

Second, economic actors may behave opportunistically guided by considerations of self-interest and making strategic decisions in a way to achieve an individual advantage (e.g., by lying, cheating, or calculated distorted disclosure of information). Two types of opportunistic behavior are distinguished: i) deviations from joint-surplus maximizing within the terms of an existing agreement and ii) enforcement of renegotiations and modification of contractual terms in the case unexpected changes in market conditions evolve (hold-up). Woolthuis et al. (2005, p. 814) distinguish between a passive form

[4] Williamson (1986, pp. 173 f.) later distinguishes between three levels of rationality: i) strong rationality (i.e., postulated in neoclassical economics with firms being reduced to production functions, consumers being characterized by utility functions, institutions taken as given), ii) semistrong rationality (i.e., bounded rationality), and iii) weak rationality (i.e., organic rationality relevant within evolutionary approaches).

of opportunism (lack of dedication in performing to the best of one's own competences) and an active form (self-interest seeking with guile as referred to within transaction cost economics).

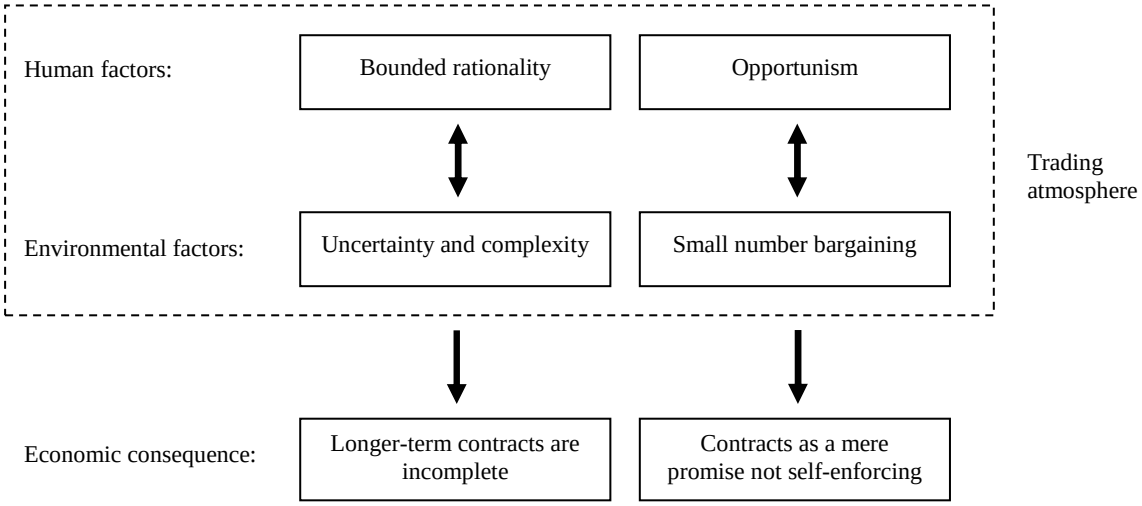
Transaction attributes: There are several exchange hazards that necessitate contractual safeguards. The institutional environment may be characterized by uncertainty about the future state of nature including amongst others price and demand levels, technological innovations, or legal instabilities. An increase in uncertainty can originate from two sources: more disturbances occur and/or disturbances become more consequential (Williamson, 1991b, p. 291). Within exchange relationships, the most relevant form of uncertainty is behavioral uncertainty which arises from the difficulty in predicting actions of the counterparty considering the potential for opportunistic behavior.

The presence of relationship-specific assets transforms an exchange relationship from ex-ante competition where the identity of the trading partners is irrelevant to an ex-post bilateral dependency where the identity of the exchange partner is of critical importance. Williamson (1986, pp. 184 ff.) calls this 'fundamental transformation'. The frequency of transactions will have an impact on the recovery of investments in relationship-specific assets (Williamson, 1985, pp. 60 f.). Asset specificity thereby refers to "durable investments that are undertaken in support of particular transactions, the opportunity cost […] is much lower in best alternative uses or by alternative users should the original transaction be prematurely terminated" (Williamson, 1985, p. 55). The excess value of an asset over its salvage value is termed 'quasi-rent'. Six types of specific assets are distinguished:

- Site specificity: Immobile assets are placed in close proximity in order to minimize transportation or time costs or to benefit from complementarity advantages (e.g., the liquefaction plant has to be close to natural gas fields whereas crude oil economically can be transported to refineries in downstream countries);
- Physical asset specificity: Assets involving design characteristics specific to the transaction having a lower value in alternative uses (e.g., regasification facilities of the first generation were designed to receive natural gas from a specific supplier characterized by a certain quality);
- Dedicated assets: Investments in assets dedicated to a certain trading partner that otherwise would not be made; they are not redeployable due to a limited size of the market for these assets (e.g., LNG vessels in the early years of the industry were ordered once a long-term sales and purchase contract was signed and were dedicated to specific trade routes between an export and an import project);
- Human asset specificity: Human capital evolving due to learning of individuals and team building (e.g., only a small number of engineering firms is capable of constructing LNG terminals);
- Intangible assets: Intangible capital such as a brand name (e.g., McDonald's); and
- Temporal specificity (added to the discussion by Klein et al., 1978, p. 301): The threat of a delay in production or delivery may be an effective bargaining device (e.g., newspaper publishers generally own presses whereas book publishers in general do not).

In a static market, free of any uncertainty, bounded rationality is irrelevant and an analysis of transaction costs uninteresting. All contingencies can be specified ex-ante in a complete contingent claims contract.[5] Bounded rationality will become relevant under environmental uncertainty and complexity which makes periodical contract adaptations necessary. Writing a complete long-term contract is too costly or not feasible anymore since it is not possible to specify all contingencies ex-ante. However, the presence of incomplete contracts per se would be unproblematic as long as economic individuals are benevolent. Since this cannot be presumed for the 'homo oeconomicus', the hazard of ex-post opportunistic behavior persists. As long as the exchange can be carried out on a functioning competitive market, economic agents will have no incentive to deviate from joint-surplus maximizing behavior. However, in situations where only a small number of potential trading partners are available on the market – which is the case once specific investments are realized – contracting on the market will result in high ex-post transaction costs.

Figure 2: Organizational failure framework



Source: Own depiction

Transaction costs have been described as the "costs of running the economic system" (Arrow, 1969, p. 48) or the "equivalent of friction in physical systems" (Williamson, 1985, p. 19). One distinguishes ex-ante costs (e.g., discovering potential trading partners and relevant prices, negotiating and writing contracts) from ex-post costs (e.g., costs from maladaptation, renegotiation, monitoring, and breach of contract). The focus of transaction cost economics typically is on ex-post transaction costs which become especially relevant under long-term contracting and might exceed ex-ante costs by far.

Summarizing, economic individuals within the framework of transaction cost economics are cognitively less competent due to bounded rationality but motivationally more complex due to

[5] 'Complete contingent claims contracts' can be specified if everything is observable to everyone and if the observable information is also verifiable by third parties. One talks about 'complete contracts' if there are information asymmetries (world of agency theory) and of 'incomplete contracts' if neither everything is observable to all parties nor the observable is fully verifiable.

opportunism in the sense of self-interest seeking with guile than are those presumed within neoclassical economics. Therefore, it is essential to "[o]rganize transactions so as to economize on bounded rationality while simultaneously safeguarding them against the hazards of opportunism" (Williamson, 1986, p. 177). Williamson (1971, p. 112) picks up Coase's (1937) discussion asking: "if the costs of operating in competitive markets are zero […] why integrate?" Transaction cost economics understands the firm as being more than a simple efficiency instrument in the sense of economies of scale and/or scope or technical complementarities. The firm possesses coordinating potential. Substituting market exchange by internal organization is efficient in the presence of market failures (see also Williamson, 1975, pp. 20-40). Transaction cost economics tries to explain how trading partners choose, from a set of feasible institutional arrangements, the governance form that protects relationship-specific investments at least costs. The following paragraph discusses this so-called discriminating alignment.

2.2.2 Discriminating alignment

Given that long-term contracts are unavoidably incomplete due to bounded rationality and that contracts as mere promise are not self-enforcing due to opportunism, the question is, which transactions should be organized under which governance modes. NIE focuses on a comparative institutional analysis. Thereby, the difference between rather than the absolute magnitude of transaction costs matters.

Two pole governance structures, market and hierarchy with a continuum of hybrid forms in between, are distinguished.[6] Anonymous spot markets have an advantage over central planning in situations where the price reflects all relevant information. Firms get to specialize in doing what they do best and innovation is generated by numerous sources. The opposite pole of governance is vertical integration in the form of backward integration into the supply of inputs or forward integration into marketing and distribution. Internal organization of successive stages of the value chain is the optimal governance choice where relationship-specific investments under uncertainty are required. Between the two poles hybrid forms of governance (e.g., long-term contracts, joint ventures, or partial ownership arrangements) are settled. Since an economically enforceable long-term contract is the primary alternative to vertical integration in order to avoid opportunistic behavior, some economists regard these two organizational structures with indifference. However, Klein et al. (1978, p. 302), as other transaction cost economists, criticize this simplified view as having "defined [the] extremely difficult question [of optimal governance choice] away by calling a long-term contract a form of vertical integration."

As already revealed by Hayek (1945, p. 523), "economic problems arise always and only in consequence of change." Williamson (1991b) understands adaptation to unexpected circumstances as the central economic problem. Thereby, he distinguishes between inconsequential disturbances

[6] Other authors use alternative terms such as buy, ally, and make (e.g., Gulati and Nickerson, 2008). 'Internal organization' and 'firm' are used as synonyms for 'hierarchy' in this thesis.

(adjustment costs would exceed the efficiency gain), consequential disturbances to which contractual agreements are adaptable (for example via price adaptation provisions), and highly consequential disturbances (providing incentives for ex-post opportunism departing from the original spirit of the contract).

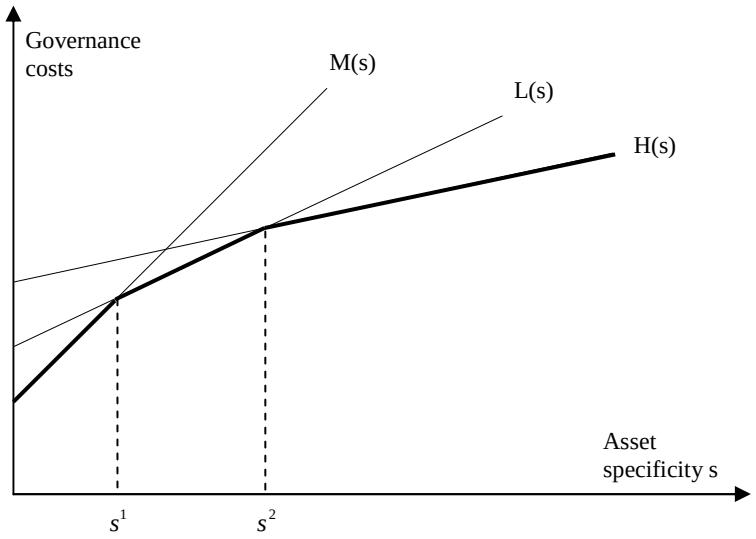
Governance structures differ in their capacity to respond to exogenous disturbances. Whereas Hayek (1945) proposes that the price system is a more efficient mechanism for communicating information and inducing change as compared to central planning, Barnard (1938) highlights adaptation within the organization. Williamson (1991b) picks up both opinions arguing that the two authors refer to adaptations of different kinds. There is autonomous adaptation (i.e., the neoclassical economics' ideal) on the one hand and coordinated adaptation (i.e., required within long-term bilateral exchange relationships) on the other.

The central hypotheses of transaction cost economics originate from the discriminating alignment hypothesis according to which "transactions that differ in their attributes, are aligned with governance structures, which differ in their costs and competencies, in a discriminating (mainly transaction cost economizing) way" (Williamson, 1991b, p. 277). The level of investments in relationship-specific assets thereby is the most important dimension.

Governance costs for market organization (M) or internal organization (H) increase with the level of investments in specific assets (s). Since internal organization involves higher bureaucratic costs as well as lower internal incentives (changes in an agent's effort have little or no immediate effect on his compensation assuming a fixed-wage schedule), the intercept of a hierarchy's governance cost curve is higher than that of market organization with $M(0) < H(0)$. Whereas the market supports autonomous adaptation to unpredictable events, internal organization supports coordinated adaptation which becomes relevant in the presence of bilateral dependency (i.e., relationship-specific investments). Hence, the slopes of the cost curves are characterized by $dM(s)/ds > dH(s)/ds > 0$. Hybrid governance forms (L) are located between market and hierarchy with respect to incentives, adaptability, and bureaucratic costs with $M(0) < L(0) < H(0)$ and $dM(s)/ds > dL(s)/ds > dH(s)/ds$. The choice of the optimal (i.e., transaction cost economizing) governance form implies operating on the envelope and using the market for $s < s^1$, hybrid governance modes for $s^1 < s < s^2$ and internal organization otherwise (see Figure 3).

A variety of alternative governance modes for similar transactions is most likely to be observed where the governance form matters least, i.e., for levels of asset specificity near the threshold values. In contrast, where one governance form has large cost advantages over the others, the superior alternative will tend to dominate. In the short run, misalignment may occur, though in the long run, a firm's governance choice given transaction attributes converges to equilibrium.

Figure 3: Discriminating alignment



Source: Own depiction

Table 1 summarizes the attributes of alternative governance modes with respect to incentive intensity, administrative controls and adaptation. The gains from coordinated adaptation for internal organization in the presence of bilateral dependency relationships come at a cost. Decreased incentives and an increase in agency costs (i.e., inter-organizational opportunism) with an increasing size of the firm are accompanied by increased bureaucratic costs. Therefore, "[v]ertical and lateral integration are usefully thought of as organization forms of last resort, to be employed when all else fails" (Williamson, 1991, p. 279). Internal organization will be the efficient mode of organization only in the presence of both substantial relationship-specific investments and environmental uncertainty where the hazard of post-contractual opportunistic behavior by the counterparty would otherwise result in ex-ante under-investment and decreasing overall efficiency. Asset specificity without uncertainty allows for the conclusion of complete contingent claim contracts; uncertainty without asset specificity can be dealt with in exchanges on competitive markets.

Table 1: Attributes of alternative governance modes

Attribute	Market	Hybrid	Hierarchy
Incentive intensity	Strong	Semi-strong	Weak
Administrative controls	Weak	Semi-strong	Strong
Autonomous adaptation	Strong	Semi-strong	Weak
Coordinated adaptation	Weak	Semi-strong	Strong

Source: Own depiction based on Williamson (1991b, p. 281)

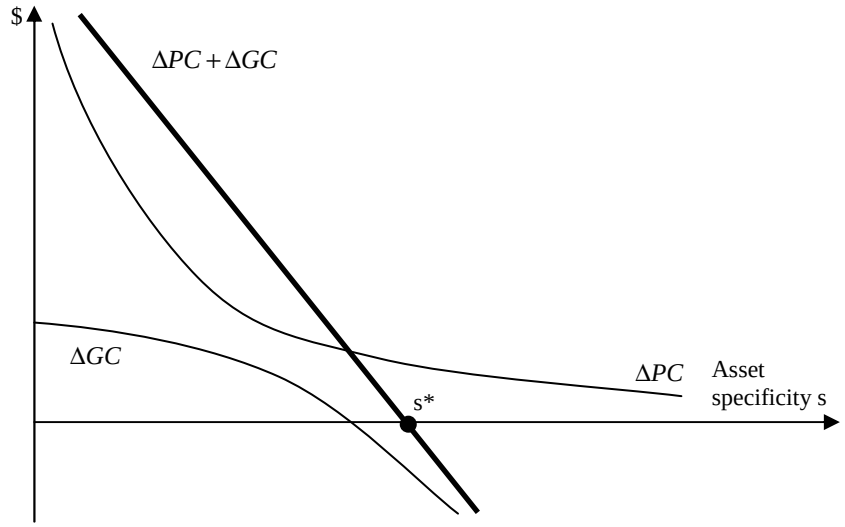
It has to be pointed out again that the objective of firms is to economize on the sum of both transaction *and* production costs as is illustrated in Figure 4. Assuming a constant output level, the difference in governance costs between internal organization and market exchange depending on the level of

specific investments s is defined as $\Delta GC(s) = GC_H(s) - GC_M(s)$. If economies of scale and scope are assumed to be negligible, the decision to integrate successive stages of the value chain will depend solely on the difference in governance costs. Internal organization will be the preferred governance form when asset specificity is high, i.e., when ex-post bilateral dependency arises and coordinated adaptations become necessary.

However, markets are often able to realize economies of scale and/or scope by aggregating the demands of various customers. Hence, production cost differences have to be taken into account. The production cost difference between internal and market procurement of a given output is defined as $\Delta PC(s) = PC_H(s) - PC_M(s)$. This difference will always be positive and decreases with s. For generic transactions, the penalty of internal procurement is large due to forgone scale economies and higher internal organization costs. With an increasing level of investments in specific assets, the potential of economies of outside supply in aggregating demands decreases and $\Delta PC(s)$ converges to zero.

The minimization of $\Delta GC(s) + \Delta PC(s)$ reveals a threshold value of the level of specific investments s^*. Economies of aggregation favor market procurement over a wider range of asset specificity than would be observed if production cost economies were absent. Since the market always has an advantage over the firm in production cost respects, vertical integration will never be economically reasonable for production cost reasons alone.

Figure 4: Comparative production and governance costs



Source: Own depiction following Williamson (1985, p. 93)

The investment in specific assets and the additional costs of hierarchical governance forms will be easier to recover for transactions of a recurrent kind (Williamson, 1985, p. 60). Therefore, the frequency of transactions is understood as the third critical dimension determining investment behavior and governance choice. A firm will be better able to realize economies of scale as its own requirements of the respective product or service become larger. For a higher transaction frequency

$\Delta PC(s)$ will fall with $\Delta GC(s)$ remaining unchanged. The critical value of s^* will move to the left. Hence, larger firms are predicted to be more integrated than smaller firms.

2.3 Transaction cost economics: An empirical success story?

"[T]heory without evidence is, in the end, just speculation" (Masten, 2002, p. 428). Transaction cost economics often has been referred to as an "empirical success story" (e.g., Williamson, 2002, p. 182). Several literature reviews highlight the increasing number of corroborative empirical papers. About 900 studies, including published articles, working papers and book chapters, test propositions derived from transaction cost economics. Most of them seem to be consistent with the theory's predictions; investments in relationship-specific assets are identified as the main driver of more hierarchical governance structures. The following section summarizes the historical development of empirical contributions related to the optimal governance choice and discusses critically, whether the existing body of literature provides conclusive support for transaction cost economics.

2.3.1 Review on empirical literature

Empirical studies investigating a firm's motivation to choose among alternative governance modes have a long-standing history. One can distinguish between quantitative analyses (i.e., based on econometrics) and qualitative studies (i.e., case studies), cross-sectional and panel data, papers investigating the make-or-buy decision and papers interested in the choice of contractual provisions. This review cannot present all existing empirical work in the transaction cost economics tradition, but rather summarizes the development of alternative classes of empirical contributions during the last three decades and introduces some seminal papers.

The first generation of empirical tests based on a transaction cost framework appeared already during the early 1980s. At this time, the authors focused on backward integration in manufacturing sectors with most studies using data on US-based companies. Monteverde and Teece (1982a) describe the phenomenon of 'quasi vertical integration', where a downstream firm owns specialized tools that are used in the upstream production stage. Motivations for integration are flexibility on the one hand (if the supplier's production is interrupted, tools can be moved to another supplier) and avoiding post-contractual opportunistic behavior on the other. Estimation results from a linear probability model using data on 28 input components of a US car company show that the likelihood of integration increases with the level of quasi-rents at stake. Masten (1984) analyzes input procurement in the US aerospace industry using a dataset of 1,887 components. He shows that the probability of backward integration is higher for complex and highly specialized inputs and that the hazards from incomplete contracting in complex environments increase in the presence of component design specificity. Further contributions include amongst others Klein et al. (1978), Monteverde and Teece (1982b), Walker and Weber (1984), and Klein (1988).

The second generation of studies investigates forward integration into marketing and distribution of products from the manufacturing sector. Anderson and Schmittlein (1984), focusing on vertical

structures in the US electronic component industry, analyze the corporate choice between employing a sales person (corresponding to market exchange) and direct employee sales people (corresponding to integration). Estimation results from a logit model show that the presence of asset specificity, the difficulty in evaluating performance, and company size have a positive influence on the likelihood of integration. John and Weitz (1988) analyze forward integration into the distribution stage of industrial good manufacturers. Distribution channels are classified into direct channels (company employees) and indirect channels (independent resellers). The authors show that the likelihood of integration increases with the level of specific assets and environmental uncertainty. Further contributions include Klein (1989).

Whereas this early literature mainly focused on the manufacturing sector, later studies also analyze vertical integration in other industries. These are for example studies on the make-or-buy decision in the rail freight sector (Palay, 1984), in the Canadian forest industry (Globerman and Schwindt, 1986), in the aluminum and tin industries (Hennart, 1988), in naval shipbuilding (Masten et al., 1991), in the chemical sector (Lieberman, 1991), in bulk shipping markets (Pirrong, 1993), in the pulp and paper industry (Ohanian, 1994), in the poultry, egg, and broiler industries (Martinez 1999, 2002), in information services (Poppo and Zenger, 1998; 2002; Aubert et al., 2004), in the Spanish cotton industry (Rosés, 2005), in sugar production (Sartorius and Kirsten, 2005), or in the global natural gas market (Ruester and Neumann, 2009).

Another group of empirical studies is interested in the choice of contractual provisions. This literature started with qualitative discussions of contracting structures in the mid-1980s. Mulherin (1986) shows that specific investments in the US natural gas industry historically have been protected by the use of complex forms of organization. Whereas prior to the 1930s vertical integration from production over transportation to distribution has been common, governmental regulation 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. 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 which increase the producers' total compensation.

A quite substantive body of empirical literature aims to explain the determinants of contract duration. Joskow's (1987) seminal work 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. 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 70 contracts for the transportation and unloading of coal to Electricité de France's power plants, 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. Further contributions include Crocker and Masten (1988), Kerkvliet and Shrogren (2001), Hirschhausen and Neumann (2008), and Ruester (2009a).

Other studies explore the optimal determination of alternative contractual provisions. 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 support redetermination clauses based on pricing formulas which reduce the frequency of negotiations and therewith the hazard of opportunistic haggling. Saussier (2000) adds a new dimension to the discussion, testing the influence of transaction parameters on the level of completeness of French coal supply contracts, accounting for the endogeneity of asset specificity. Analyzing a sample of 29 contracts 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.

Recent papers pick up the aspect of relational governance in the form of implicit, unwritten contractual agreements. Using data on outsourcing relationships in information services, Poppo and Zenger (2002) show empirically that formal contracts and relational governance function as complements and both have a positive impact on exchange performance. The complementarity of contractual and relational governance is also confirmed by Zheng et al. (2008). Further contributions include Liu et al. (2008), Nagaoka et al. (2008), and Desrieux et al. (2009).

Other literature – which is not discussed in detail here – also focuses on other hybrid governance forms such as inter-firm alliances (e.g., Oxley, 1999), franchise contracts (e.g., Bercovitz, 2004), or joint ventures (e.g., Richards and Yang, 2007). However, as Gulati and Nickerson (2008, p. 690) point out, there are only few empirical studies addressing this expanded set of governance modes. Table 2 illustrates the historical development of different generations of empirical literature as discussed above. Table 3 and 4 in the Appendix provide a summary on selected empirical papers testing transaction cost economics' propositions. Literature reviews are also provided by Klein (2004) and Macher and Richman (2006).

Table 2: Development of empirical literature

Period	> 1975	> 1980	> 1985	> 1990	> 1995	> 2000	> 2005
Make-or-buy decision	Backward integration in manufacturing sector *(e.g., Klein et al, 1978; Monteverde and Teece, 1982a and b; Masten 1984)*						
		Forward integration in manufacturing sector *(e.g., Anderson and Schmittlein, 1984; John and Weitz, 1988)*					
			Back-/forward integration in non-manufacturing industries *(e.g., Globerman et al., 1986; Lieberman, 1991; Ohanian, 1994)*				
Contractual provisions			Qualitative discussion of contracting structure *(e.g., Mulherin, 1986; Hubbert and Weiner, 1986)*				
			Econometric analyses (EA) explaining contract duration *(e.g., Joskow, 1987; Crocker and Masten, 1988; Lyons, 1994)*				
				EA explaining other contractual provisions *(e.g., Masten and Crocker, 1991)*			
						EA explaining contractual completeness *(e.g., Saussier, 2000)*	
						EA investigating relational governance *(e.g., Poppo/Zenger, 2002)*	

Source: Own depiction

2.3.2 Limitations of existing empirical literature

At first glance, transaction cost economics in fact seems to be an empirical success story. However, the existing body of empirical literature suffers from a number of shortcomings: i) a part of the studies is not fully consistent with propositions developed within transaction cost theory; ii) in some cases, imperfect proxies for key variables are employed; iii) the endogeneity of right-hand side variables often is ignored; and iv) most analyses are based on reduced form models and therefore cannot test for the theory's propositions directly.

2.3.2.1 Inconsistency with hypotheses derived from transaction cost theory

As is also highlighted in Carter and Hodgson (2006), only few empirical studies provide unambiguous support for the hypotheses derived from transaction cost theory. Most of the studies do not test for all three transaction attributes, i.e., relationship-specific investments, uncertainty, and frequency of transactions. This is also mirrored by the above presented sample of empirical papers; most of those focus on asset specificity and uncertainty, ignoring the frequency of transactions within the exchange relationship. Furthermore, few studies explore the interaction effects among transaction cost variables and other potentially relevant factors (e.g., specific investments in the presence of uncertainty). Also

contractual provisions such as contracted volume, contract duration, and price adaptation clauses are chosen simultaneously and can be expected to interact with one another.

Whereas empirical findings generally provide broad support for the positive relationship between specific investments and the likelihood of more hierarchical governance forms, this is not always the case for other transaction attributes. Anderson and Schmittlein (1984), for example, testing the impact of transaction frequency on forward integration do not find any support for the predicted positive impact. Macher and Richman (2008, p. 7) justifiably claim that a "greater theoretical and empirical treatment of frequency is […] required."

In addition, 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; Heide and John, 1990; Masten and Crocker, 1991). Klein et al. (1990, p. 206) argue that their study "raises more questions than it answers" finding a positive impact of uncertainty in the form of volatility in environmental conditions and a negative impact of uncertainty in the form of diversity in uncertainty sources on vertical integration. Klein (1989) argues that the effect of uncertainty depends on its dimension. He shows that whereas unpredictability has a negative impact on vertical control, complexity has a positive impact. Therefore, future 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.

2.3.2.2 Measurement difficulties

Of the transaction attributes that have been examined empirically, the level of relationship-specific investments is argued to be the most important determinant of governance choice (see e.g., Klein, 1999; Macher and Richman, 2008). However, this variable at the same time is argued to be the most difficult to measure. Proxy variables in general are constructed using secondary data sources and, therefore, are often only very rough approximations of the respective theoretical construct. Typical proxies include the level of investment costs (physical asset specificity, e.g., Lieberman 1991), worker-specific knowledge (human asset specificity, e.g., Monteverde and Teece, 1982b), the complexity of components (physical asset specificity, e.g., Masten, 1984), locational proximity of exchange partners (site specificity, e.g., Joskow 1987), quantities dedicated to the trading partner (dedicated asset specificity, e.g., Saussier, 1999), the percentage of input capacity satisfied by the counterpart (dedicated asset specificity, e.g., Kerkvliet and Shrogren, 2001), or a ranking of the importance of having an input on schedule (temporal specificity, e.g., Masten et al., 1991). Often, these right-hand-side variables are constructed based on ordinal – and even binary – rankings which limit the comparability of the variables across studies.

Environmental uncertainty is generally referred to unanticipated changes in circumstances surrounding an exchange. Among the proxy variables employed are the volatility of prices indicating price uncertainty (e.g., Masten and Crocker, 1991), time dummies indicating more or less uncertain periods (e.g., Saussier, 1999), rankings of uncertainty concerning future demand (e.g., Athias and Saussier,

2007), rankings of general environmental uncertainty (e.g., John and Weitz, 1988), rankings of technological requirements' unpredictability (e.g., Heide and John, 1990), or rankings evaluating the exchange partner's performance indicating behavioral uncertainty (e.g., Anderson and Schmittlein, 1984). As discussed above, empirical evidence for the impact of different dimensions of uncertainty on optimal governance choice is mixed.

Furthermore, a number of studies obtain data from the contracting parties themselves using surveys and interviews with key informants.[7] On the one hand, this has the advantage that the researchers can specify survey questions in a way measuring the variables of interest for their analyses which otherwise generally are not publicly available (e.g., specificity of an investment, exchange performance, reliability of the exchange partner, etc.). On the other hand, however, this has the disadvantage that the received information may be based on the respondents' subjective beliefs rather than on objective valuations. In addition, the quality of survey data may suffer from the respondents' difficulties in understanding the question: Masten (1996, pp. 48 f.), for example, argues that the difference between asset specificity (i.e., non-redeployability) and specialized assets (e.g., equipment that only can produce a single product) often is not clear and underline this presumption reporting very low correlations between two respondents' evaluations of the level of asset specificity of input component in naval shipbuilding.

2.3.2.3 Endogeneity of right-hand-side variables

Variables affecting governance choice and contractual design often are themselves endogenous variables. This applies amongst others for the level of specific investments, the contracted volume in long-term supply agreements, or contractual completeness. These variables are chosen simultaneously with and dependent on the governance form. However, "[t]he binding constraint here is not technique but data availability" (Masten and Saussier, 2000, p. 232). Instrumental variables are difficult to identify and researchers often lack access to written contracts so that they have no information on contractual provisions such as price adaptation or renegotiation clauses.

Therefore, endogeneity is a serious problem in econometric studies testing theories of the firm.[8] Even though some authors account for this issue (e.g., Saussier 1999, 2000), there is a huge body of empirical literature ignoring the endogeneity of right-hand-side variables. Hamilton and Nickerson (2003, p. 53) found that "of the 421 empirical papers published in the Strategic Management Journal

[7] Among empirical studies using survey data are Anderson and Schmittlein (1984), Walker and Weber (1984), John and Weitz (1988), Klein (1989), Masten et al. (1991), Lyons (1994, 1995), Zaheer and Venkatraman (1995), Zaheer et al. (1998), Saussier (1999), Poppo and Zenger (2002), Gulati and Nickerson (2008), and Gulati and Sytch (2008).

[8] Endogeneity of a right-hand-side variable occurs when the respective regressor is not orthogonal to the error term, i.e., $Cov(x, u) \neq 0$. Simple one-stage estimation procedures such as ordinary least squares will lead to biased estimates; two-stage instrumental variables estimation is required. For further details on econometric procedures see the empirical applications in Chapters 5 and 6.

(out of 601) between January, 1990, and December, 2001, […] only 27 papers […] explicitly econometrically correct for potential endogeneity concerns."

2.3.2.4 Tests based on reduced form models

Since an efficient outcome would be achieved under any governance form in the absence of any transaction costs, an explanation of the existence of alternative institutional arrangements must turn on a comparison of the costs of governing the transaction under alternative modes of organization. One can formalize Coase's (1937) discussion as

$$G^* = \begin{cases} G^A & \text{if } C^A < C^B \\ G^B & \text{if } C^A \geq C^B \end{cases} \tag{2-1}$$

where G^* represents the chosen governance form; G^A and G^B indicate alternative modes of organization (such as spot market versus internal organization) and C^A and C^B are the costs of governing the transaction under the corresponding organizational alternatives. However, it is very difficult or even impossible to measure (ex-post) transaction costs. Furthermore, transaction costs only can be observed for actually chosen governance forms but not for the alternative. Williamson's (1975, 1985) major contribution to the theoretical discussion was the identification of transaction attributes that influence the transaction costs of alternative organizational arrangements, which can be formalized as $C^A = f(X, e^A)$ and $C^B = f(X, e^B)$ with

$$\begin{aligned} C^A &= \alpha X + e^A \\ C^B &= \beta X + e^B \end{aligned} \tag{2-2}$$

assuming linear relationships. X represents a vector of observable transaction attributes, α and β are vectors of parameters, and e^A and e^B capture unobserved factors such as omitted variables, decision maker misperceptions about the true values of transaction costs, and measurement errors. Even though transaction costs themselves are not observable, testable propositions can be derived by analyzing how transaction attributes affect the relative costs of institutional alternatives. The probability of observing governance mode G^A equals

$$\Pr\left(G^* = G^A\right) = \Pr\left(C^A < C^B\right) = \Pr\left(e^A - e^B < (\beta - \alpha)X\right) \tag{2-3}$$

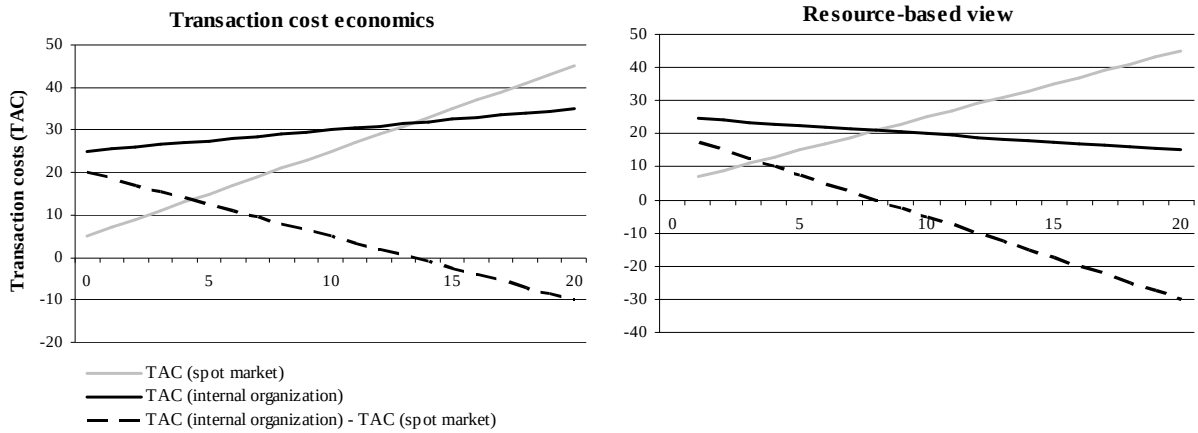
The impact of exogenous variables X on optimal governance choice then depends on the sign of $(\beta - \alpha)$. According to Williamson's transaction cost economics, the likelihood of more hierarchical governance modes will increase with the quasi-rents at stake (i.e., the level of relationship-specific

investments), with the level of uncertainty and complexity of the transaction, and with transaction frequency.

First generation empirical tests predict exactly this differential effect by applying discrete choice models such as probit or logit specifications with the chosen governance form (typically make versus buy) defined as a binary dependent variable (e.g., Monteverde and Teece, 1982b; Masten, 1984; Lieberman, 1991) and transaction attributes as well as a number of control variables as explanatory variables. Later studies also extend these models to multinomial settings (e.g., Masten and Crocker, 1991) or parameterize the governance form as a continuous variable, such as the degree of vertical integration (e.g., Ohanian, 1994; Rosés, 2005). However, estimation results of such reduced form models cannot say anything about the respective signs of the single coefficients but calculate coefficients in the form of $(\beta - \alpha)/\sigma$ with σ being the standard deviation of the difference of the error terms e^A and e^B. This variance negatively correlates with the quality of the decision maker's perceptions. The less precise the manager's evaluation of the performance of alternative governance modes, the higher will be σ and the lower will be the estimated effect of an exogenous attribute on the probability of choosing a particular governance mode.

The estimation of differential effects implies that a significant number of studies can be reinterpreted in terms of other theories of the firm. However, alternative approaches not always predict complementary but in some cases also rival propositions on the impact of exogenous factors on governance choice. This shall be illustrated comparing theoretical discussions coming from transaction cost economics with those deduced from the resource-based view of the firm. Whereas both approaches predict increasing transaction costs on the market under increasing asset specificity, transaction cost economics hypothesizes that transaction costs within the firm increase, too, even though to a lower extend – whereas the resource-based view argues that transaction costs of internal organization decrease with specific human assets (see Figure 5).

Figure 5: Rival propositions on the impact of asset specificity on transaction costs



Source: Own depiction

According to the resource-based view, increased human asset specificity may generate shared language, knowledge, and routines that enhance the efficiency of coordination (see Poppo and Zenger, 1998, pp. 853 f.). Alternatively, skilled workers may require less monitoring (Masten et al. 2001, p. 19). Hence, we should test for ($\beta - \alpha$) > 0 with ($\beta > \alpha > 0$) to test for transaction cost economics and for ($\beta - \alpha$) > 0 with ($\beta > 0$) and ($\alpha < 0$) to test for the resource-based view. Estimating only the differential effect does not allow for differentiating between these rival hypotheses.

Similar reduced form tests are conducted in order to investigate the optimal duration of long-term agreements. Starting with the discrete choice problem developed above, exchange partners will choose to contract if the expected gains from doing so exceed the expected gains from organizing the transaction in another way: $G^* = G^C$ if $V^C > V^0$ with V^C and V^0 measuring the net gains from contracting and not contracting respectively. The choice of optimal contract duration can be understood as a series of discrete choices in which the exchange partners decide whether or not to contract for an additional period. This can be formalized as

$$\max_{\tau} \; V^C(\tau) + V^0(T - \tau) \tag{2-4}$$

with τ indicating contract duration, T indicating the potential duration of the exchange relationship, $V^C(\tau)$ representing the cumulative value of exchange under the contract, and $V^0(T - \tau)$ being the value of trade in periods not covered by the contract. The first order condition yields optimal contract duration τ^* with $V^{C\prime}(\tau^*) = V^{0\prime}(\tau^*)$. Since the costs (i.e., the hazard of being bound in an agreement not reflecting market realities) and benefits (i.e., avoiding repeated negotiations) of contracting for an additional period are not observable, the value of exchange under contracting and respectively not contracting are related to observable transaction attributes X with $V^{C\prime} = f(\tau, X, e^C)$ and $V^{0\prime} = f(\tau, X, e^0)$. Assuming linear relationships:

$$\begin{aligned} V^{C\prime} &= \alpha_0 + \alpha_1 \tau + \alpha_2 X + e^C \\ V^{0\prime} &= \beta_0 + \beta_1 \tau + \beta_2 X + e^0 \end{aligned} \tag{2-5}$$

with the error terms capturing unobserved factors. From Equation (2-5) one can derive the optimal contract duration being determined by

$$\tau^* = \gamma_0 + \gamma_1 X + v \tag{2-6}$$

$$\text{with } \gamma_0 = (\beta_0 - \alpha_0)/(\alpha_1 - \beta_1),\ \gamma_1 = (\beta_2 - \alpha_2)/(\alpha_1 - \beta_1), \text{ and } v = (e^0 - e^C)/(\alpha_1 - \beta_1)$$

Existing empirical literature generally predicts these differential effects instead of testing for the structural form propositions derived from theory.

2.4 Recent trends in transaction cost economics

Even though "there is considerable support for many of the central tenets of [transaction cost economics]" (Macher and Richman, 2008, p. i), researchers have continued to develop and improve the theory. The following paragraphs introduce recent trends in the theoretical discussion as well as in empirical testing.

2.4.1 From a static to a dynamic concept

Transaction cost economics in its basic form is a static concept taking the institutional environment as given. This has been a major point of criticism in the New Institutional Economics literature. In 1991, Oliver Williamson therefore introduced the so called shift parameter framework, an extension of the transaction cost economics model investigating how the optimal choice of governance changes in response to dynamics in the institutional environment. Changes in exogenous parameters will shift the relative costs of alternative governance structures and therefore, will have an impact on the optimal alignment of transactions to institutional arrangements. Shift parameters shall be used to indicate institutional differences between alternative market settings (such as developed versus developing countries) and will influence the predictions about transaction costs and governance choice in each environment. Hence, the influences of both transaction characteristics and the institutional environment on governance choice are analyzed (Williamson, 1991b).

Empirical work testing Williamson's shift parameter framework is rather scarce. Oxley (1999) analyzes the impact of intellectual property protection on the structure of inter-firm technology transfer alliances linking US and non-US firms. Henisz and Williamson (1999) investigate the concept of shift parameters for national and multinational firms focusing on the impact of weak (respectively strong) property rights and on the stability of contract law on governance choice (e.g., partnership between the foreign and a host-country firm). Gulati and Nickerson (2008) discuss the impact of inter-organizational trust on governance choice and the performance of exchange relationships in the US auto industry. For a formalization of the shift parameter framework and an application to the global liquefied natural gas market see Chapter 4.

2.4.2 Linking alternative theories of the firm

As early as in the mid-1980s, Williamson (1986, p. 200) argued that "[t]ransaction cost economics is […] in need of refinement. […] it needs to be joined with other approaches to the study of economic process. I am confident that developments of both kinds will be forthcoming and that the evolving theory of economic organization will be deepened as a consequence." In recent years, several authors have started to develop theoretical approaches combining alternative theories of the firm. The general consensus is that "managers are well advised to adopt a multidisciplinary approach to strategy to ensure their firms' survival" (Silverman et al., 1997, p. 31).

To link transaction cost economics with the field of strategic management has first been proposed by Day and Klein (1987) who discuss the determinants of inter-firm cooperations along value chains from

both a market failure and a strategic management approach. Rumelt et al. (1991, p. 14) highlight "[transaction cost economics'] affinity with strategic management." Both approaches are interested in organizational structures and institutional details such as particular contract provisions.

The so called positioning-economizing perspective finally has been introduced by Nickerson (1997). He develops an extension of the basic transaction cost model transforming Williamson's theory from an 'economizing theory of organization' that focuses on the discriminative alignment of transactions to institutional arrangements into an 'economizing theory of strategy'. Nickerson argues that decisions regarding market position, resource investments, and governance mode are interdependent and are determined simultaneously. A target market position is supported by a resource profile that in turn determines the organizational choice of a firm. Ghosh and John (1999) develop a similar model starting with traditional transaction cost economics linking transaction attributes to governance modes and then add positioning (i.e., the target market position) as well as resources (i.e., scarce and imperfectly mobile skills, assets, or capabilities). According to this approach, two firms in the same market may choose varying governance forms in order to align these to the respective external and internal conditions depending on their strategy.

Empirical literature testing hypotheses derived from the positioning-economizing perspective is very rare. The first application has been provided by Nickerson et al. (2001) analyzing the international courier and small packages service in Japan. For a formalization of the positioning-economizing perspective and an application to the global liquefied natural gas market see Chapter 5.

2.4.3 Structural form tests: The two-stage Heckman model

The majority of empirical tests is based on reduced-form models where the probability of observing a certain governance form depends on transaction attributes (i.e., asset specificity, uncertainty, transaction frequency). Such studies, however, "establish correlations, not causal relations" (Klein, 2004, p. 25); they provide no basis to test for structural relations derived from alternative theories of the firm and leave open the question what the costs of misalignment are. Since in some cases rival explanations for certain correlations between exogenous variables and the governance form would be viable (e.g., transaction cost economics versus resource-based view), there is an obvious need for tests that can discriminate between alternative interpretations. In order to conduct stronger tests of transaction cost propositions, measures of transaction costs or other performance indicators are needed.

There is an extensive literature finding mixed results for the relationship between measures of firm performance and governance choice. However, these studies simply regress a performance measure π on an indicator of the governance form G and a vector of exogenous variables X with $\pi_i = \alpha G_i + \beta X_i + e_i$ and interpret the estimated parameter α as the contribution of governance choice to performance (Masten, 2002). But they fail to account for the fact that managers make strategic decisions, such as the organizational structure, not randomly but rather decide based on the expectations on how their choices affect future performance and self-select into the strategy where they expect a competitive

advantage. Therefore, this literature ends up answering the question: 'What is the difference in the performance of firms that adopt a certain governance form and of those adopting an alternative institutional arrangement?' In contrast, from a transaction cost perspective, the crucial question that should be addressed is: 'What *would have been* the performance level if the transactor had chosen the alternative governance form?'

The Heckman model is a two-stage estimation in which results from a first regression explaining the selection decision (e.g., governance choice) are used to control for selection bias in the structural form performance equations. Suppose a simple model with a set of strategies (e.g., make versus buy) $G = (G^0, G^1)$ and the corresponding performance outcomes $\pi = (\pi^0, \pi^1)$. Transaction cost economics is interested in the difference between the performance under the chosen governance form and the performance under the alternative, namely what Hamilton and Nickerson (2003, p. 60) call the 'strategy effect' $\pi_i^1 - \pi_i^0$. The question is, what would have been the performance outcome under the alternative, not chosen, governance form, $E(\pi^0 \mid S^1)$ and $E(\pi^1 \mid S^0)$, respectively.

Governance choice is modeled as a continuous latent variable G^* and depends on the expected performance difference $\pi_i^1 - \pi_i^0$, on exogenous variables Z affecting governance choice but not the performance outcome, and on some unobserved factors v:

$$G_i^* = \gamma\left(\pi_i^1 - \pi_i^0\right) + \delta Z_i + v_i \quad \text{with } G_i = 1 \text{ if } G_i^* > 0 \text{ and zero otherwise.} \tag{2-7}$$

The parameter γ measures the extent to which the impact of strategy on performance itself affects strategy choice. Since we only observe the performance outcome under the chosen alternative, we have to substitute the performance levels using $\pi_i^1 = \beta^1 X_i + e_i^1$ and $\pi_i^0 = \beta^0 X_i + e_i^0$ and get the reduced form model

$$G_i^* = \beta X_i + \delta Z_i + w_i \quad \text{with } w_i = \gamma\left(e_i^1 - e_i^0\right) + v_i \text{ and } \beta = \gamma\left(\beta^1 - \beta^0\right). \tag{2-8}$$

Heckman (1979) showed that under the assumptions that e^1, e^0 and v are jointly normally distributed and that unobservables for π_i^1 are uncorrelated with unobservables for π_i^0 that

$$\begin{aligned} E\left(e_i^1 \middle| G^1\right) &= E\left(e_i^1 \middle| G^* > 0\right) = -\sigma_u^1 \phi\left[X_i\beta + Z_i\delta\right] / \Phi\left[X_i\beta + Z_i\delta\right] = -\sigma_u^1 \lambda_i^1 \\ E\left(e_i^0 \middle| G^0\right) &= E\left(e_i^0 \middle| G^* \le 0\right) = \sigma_u^0 \phi\left[X_i\beta + Z_i\delta\right] / \Phi\left[X_i\beta + Z_i\delta\right] = \sigma_u^0 \lambda_i^0 \end{aligned} \tag{2-9}$$

with ϕ being the normal density function, Φ being the cumulative normal distribution, λ being referred to as the inverse Mills ratios, and the parameter values β and δ estimated from Equation (2-8). The sample-selection corrected performance equations then can be estimated using ordinary least squares

(OLS), including the inverse Mills ratios as an additional regressor. The inclusion of the inverse Mills ratios leads to expected values of the error terms equaling zero by construction; OLS estimation will deliver unbiased estimates for the parameters of

$$\begin{aligned}\pi_i^1 &= \beta^1 X_i - \sigma_u^1 \phi\left[X_i\hat{\beta} + Z_i\hat{\delta}\right] / \Phi\left[X_i\hat{\beta} + Z_i\hat{\delta}\right] + e_i^1 \\ \pi_i^0 &= \beta^0 X_i + \sigma_u^0 \phi\left[X_i\hat{\beta} + Z_i\hat{\delta}\right] / \left(1 - \Phi\left[X_i\hat{\beta} + Z_i\hat{\delta}\right]\right) + e_i^0\end{aligned} \tag{2-10}$$

As discussed in Hamilton and Nickerson (2003, pp. 64 ff.), the parameter estimates of the inverse Mills ratios in fact have an interesting interpretation. The expected performance outcome for firms having adopted G^1 is given by $E\left(\pi_i^1 \middle| G^1\right) = \beta^1 X_i - \sigma_u^1 \lambda_i^1$. Since the inverse Mills ratio always has a positive value, $\sigma_u^1 < 0$ implies that $E\left(\pi_i^1 \middle| G^1\right) > \beta^1 X_i$ and that a positive selection into the strategy occurs; i.e., firms having chosen G^1 actually have performance outcomes above average under this strategy selection. Similarly, $\sigma_u^0 > 0$ implies that $E\left(\pi_i^0 \middle| G^0\right) > \beta^0 X_i$ and indicates a positive selection of firms into G^0. Summarizing, if we observe both $\sigma_u^1 < 0$ and $\sigma_u^0 > 0$, we have a situation of competitive advantage. Each firm has chosen the strategy where it maximizes its expected performance. When $\sigma_u^1 = \sigma_u^0 = 0$ strategy choice is exogenous.

The estimated parameters from Equation (2-10) furthermore can be used to construct the strategy effects and calculate the gain in performance realized by having chosen a certain governance form (G^1 for the first equation or G^0 for the second equation) instead of the alternative (G^0 or G^1, respectively):

$$\begin{aligned}E\left(\pi^1 - \pi^0 \middle| G^1, X_i\right) &= X_i\left(\beta^1 - \beta^0\right) + \left(-\sigma_u^1 + \sigma_u^0\right)\lambda^1 \\ E\left(\pi^1 - \pi^0 \middle| G^0, X_i\right) &= X_i\left(\beta^1 - \beta^0\right) + \left(\sigma_u^1 - \sigma_u^0\right)\lambda^0\end{aligned} \tag{2-11}$$

For an extension of the two-stage Heckman model to situations in which numerous alternative strategies (e.g., make versus long-term contract versus buy) are possible, see Hamilton and Nickerson (2003, pp. 68 ff.).

There is only a small number of studies that test transaction cost economics' predictions based on structural form equations and that therefore can explicate the costs associated with failing to align transactions and governance forms in a transaction cost economizing way and test for hypotheses derived from rival theories of the firm, but "[w]e would like to know how much we lose by going from the best to the next best" (Joskow, 1991, p. 81).

Masten et al. (1991) investigate organizational choice in the US naval shipbuilding industry. Using survey data, they are able to construct a measure of the governance costs of internal organization (i.e., the number of hours devoted by the management to planning, directing, and supervising a particular component or process times the average hourly wage rate). The authors provide dollar estimates of

transaction costs based on a two-stage Heckman model and show that organizational misalignment would lead to substantial cost increases of 175% if the internally made items in the sample would have been subcontracted and of 72% if subcontracted items would have been produced within the respective firm. This implicates that changes in legal rules that favor one governance form can have significant efficiency implications. For the first-stage estimation Masten et al. confirm transaction cost theory's predictions showing that internal organization is more likely the higher temporal and human asset specificity are. They find a non-monotonic effect of complexity on the probability of vertical integration; the deficiencies of contracting seem to exceed the administrative costs of internal organization only for very complex components. Labor intensity has a positive and engineering intensity a negative effect on the integration decision. For the second-stage estimation, they furthermore show that contrary to transaction cost economics' predictions, an increase in human asset specificity will *decrease* the costs of internal organization suggesting that it is less costly to manage employees with more specific skills.

Developing a model of comparative institutional performance, Poppo and Zenger (1998) examine the make-or-buy decision in information services and test alternative theories of the firm (e.g., transaction cost theory, resource-based view, agency theory). Using survey data, they measure overall exchange performance (considering production and transaction costs) via proxy variables that rank the satisfaction with overall costs, the quality of the output, and the responsiveness to problems or inquiries. The first-stage estimation results show that the presence of firm-specific assets encourages internal procurement whereas outsourcing of a service is more likely if extensive technological skills are required. The second-stage equations indicate that asset specificity has a negative effect on firm performance under outsourcing but no significant effect on performance of internal organization. Measurement difficulty has a negative impact on the overall costs. Furthermore, uncertainty seems to have no effect on boundary choice in the information services industry. Summarizing, this paper provides broad support for transaction cost economics and refutes rival hypotheses concerning the impact of asset specificity on the performance under integration derived from the resource-based view of the firm.

Leiblein et al. (2002) analyze firms' decision to outsource production in the global semiconductor industry and quantify the impact of governance choice on technological performance (measured as a function of transistor density). In the first step, they show that firms tend to internalize production when ex-ante small number bargaining with potential suppliers is severe. Furthermore, confirming transaction cost economics, they find that outsourcing is less likely when firms have to invest in specific assets under high demand uncertainty. Estimation results of the second stage support the assumption that firms self-select into the strategy where they expect a higher performance. Deviation from the optimal governance mode with respect to the attributes of the transaction will have a negative impact on performance. Average expected performance would decrease by about 45% if firms that

internalized production would rely on outsourcing; expected performance for observations showing outsourcing would decrease by about 30% if those would be integrated.

Sampson (2004) examines the costs of misaligned governance in the context of R&D alliances in the telecommunications equipment industry. Thereby, she distinguishes between excessive contracting hazards in an alliance not safeguarding ex-post opportunism and excessive bureaucracy in an alliance providing too much hierarchical structures. She shows that firms choose a more hierarchical governance mode when alliance activities are more complex (specification and monitoring are expected to be difficult) and when only weak external protections for intellectual property are available. Furthermore, she finds support for transaction cost economics' structural form hypotheses. If the alliance form is selected according to the theory's propositions, firm performance (measured via firm patents for a specified period after the alliance) improves substantially. Misalignment will decrease performance by more than 60%. Interestingly, misalignment costs occur inhomogenously; governance misalignments imposing excessive bureaucracy reduce performance more than misalignments imposing excessive contracting hazards.

Ruester and Zschille (2009) investigate the impact of governance structure on firm performance using a database of German water supply companies. Based on a first OLS model, they find that private sector participation as opposed to pure public service provision is accompanied with higher retail prices. Controlling for scale economies as well as technical and structural characteristics, a representative household on average pays 18.40 € per year more if water is supplied under private sector participation. Estimation results of a two-stage Heckman model indicate, however, that governance choice seems to be an exogenous variable from the supplier's perspective. In fact, outsourcing decisions are taken by local public authorities and need not always be driven by economical but also by political considerations.

2.4.4 Relational contracting

During the past decade, researchers came up with an increasing interest in relational institutional arrangements since traditional transaction cost economics may overstate the desirability of complex long-term contracts and vertical integration in exchange settings where a substantial hold-up potential is present. Close relationships between exchange partners allow to enact relational contracts and to obtain first best outcomes that would not be achievable through explicit contracts alone.

Relational (or implicit) contracts are informal agreements between two parties – within the firm (between employer and employee) or between firms (vertically or horizontally) – which are not enforceable by any third party such as a court. They circumvent the limitations of formal contracting in helping to respond to unforeseen contingencies or inducing a supplier to provide informally agreed optimal product or service quality when transaction attributes are not verifiable ex-post. Exchange partners may choose to rely on a less complete contract in order to avoid contractual rigidities, leaving

out certain elements of intended performance unspecified and enforcing these terms instead by a private enforcement mechanism. [9]

Since relational contracts are not verifiable ex-post, they have to be self-enforcing; the value of the future relationship must be sufficiently large that neither party wishes to renege. Mechanisms through which relational governance attenuates exchange hazards can be both economic (monetary cost-benefit calculus) and sociological (based on social norms and developed social ties). Exchange partners compare the short-term gain with the long-term disadvantages of breaching the contract, including the future loss due to the termination of the relationship plus the potential damage in reputation. The self-enforcing range measures the extent to which market conditions can change without providing one of the parties an incentive to hold-up the other, but where the parties will perform in a way consistent with the mutually understood contractual intent (Klein, 1996). Relational contracting increasingly is becoming the subject of study in theoretical and applied literature. The following paragraphs introduce a number of selected exemplary contributions.

Focusing on a setting where actions are unobservable (moral hazard) and outcomes are observable but not verifiable (non-contractibility), Baker et al. (2002) develop repeated-game models investigating why and how relational contracts within firms differ from those between firms. Amongst others, they formally show that vertical integration is an efficient response to widely varying supply prices since integration reduces the incentives to renegotiate contract terms in such settings.

Poppo and Zenger (2002) focus on relational governance in the form of relational norms such as trust between the exchange partners and point out that contractual enforcement within relational contracts occurs through social processes that promote norms of flexibility (facilitating adaptation to unforeseen events), solidarity (facilitating problem solving), and information sharing (facilitating both problem solving and adaptation). Using survey data on outsourcing relationships in information services, they find that formal contracts and relational governance function as complements. Well-specified contracts may support more cooperative exchange relationships at the same time that relational governance may help to overcome the limitations of incomplete contracts in the sense that there exists a bilateral commitment to 'keep-on-with-it' also for situations where market conditions change unexpectedly. Second, the authors show that both relational governance and contractual complexity deliver higher levels of satisfaction with exchange performance. The complementarity of contractual and relational

[9] An illustrative example of a rigid contract resulting in unexpected ex-post hold-up is the Fisher Body / General Motors case study often cited in transaction cost literature: In 1919, General Motors signed a contract with its supplier Fisher Body over the delivery of closed metal automobile bodies. Fisher Body had to make a relationship-specific investment in stamping machines which resulted in a significant hazard that General Motors could hold-up Fisher Body, once the investment was realized. Therefore, the exchange partners concluded a long-term contract including a ten-year exclusive dealing clause and setting the price equal to Fisher Body's variable costs plus 17.6%. However, the demand for automobiles increased enormously and the altered environmental conditions permitted the supplier to hold-up its customer. Fisher Body took advantage of the contract and rejected to invest in cost-decreasing technologies or to locate its production facilities closer to General Motors' assembly plant. General Motors could not switch to an alternative supplier because the company had agreed to purchase bodies exclusively from Fisher Body. As this case illustrates, once an agreement is formalized in a written contract, it cannot cheaply be breached if unanticipated changes occur in the market.

governance is also confirmed by Zheng et al. (2008) discussing two case studies of long-term arrangements in the form of public-private partnerships.

Liu et al. (2008) study the role of contractual and relational mechanisms in manufacturer-distributor relationships in the Chinese household appliance industry. Estimation results of a multivariate regression show that written contracts and relational governance in the form of mutual norms and trust are complements in that opportunism is restrained more effectively and exchange performance is improved when both mechanisms operate simultaneously. However, they do not account for the impact of relational norms on the *degree* of contractual complexity but only regard whether any contract is used to govern the relationship. Chapter 4 of this thesis adds to this discussion an empirical study investigating the impact of inter-organizational trust on the choice of more or less hierarchical governance modes.

Nagaoka et al. (2008) assess the determinants of governance choice extending the traditional decision between make and buy introducing as a third choice the procurement from an affiliated supplier. This typically Japanese type of strategic alliance, also called keiretsu, is a form of relational contracting. Using survey data on Japanese car manufacturers and their component supply, the authors find that an increasing level of design specificity of a component makes keiretsu sourcing preferred to market procurement, but does not significantly affect the probability of vertical integration over keiretsu. This result suggests that relational contracting can effectively mitigate the hold-up risk associated with specific investments.

Gil and Marion (2009) examine the impact of relationships between contractors and subcontractors in the Californian highway construction market on bidding, auction participation, and subcontractor choice. Amongst others, they show that a bigger stock of past relationships between the same exchange partners results in lower bids (i.e., indicating lower coordination costs) and that a higher number of potential future interactions results in lower bids, too (i.e., indicating a higher value of continuing the exchange relationship). Furthermore, past relationships seem to have only a negligible impact in the absence of any self-enforcement mechanism of future business.

Desrieux et al. (2009) seek to explain why local public authorities tend to bundle the provision of alternative services to private operators instead of contracting every service separately. In a first step, the authors develop a model based on the incomplete contracts literature. A public authority decides to contract out the management of two services whose uncontractible investments (i.e., innovative efforts) have different impacts on social benefit (for one service, a cost reducing innovation will have an adverse effect on service quality). The key question is whether the choice to bundle the two services to one private operator has a consequence on relational mechanisms (i.e., non-verifiable informal dealings in the form of promises about supplementary money transfer). The model shows that in a static framework, the presence of relational governance as well as the decision to bundle services are irrelevant. However, in a repeated game framework, bundling can force the private operator to respect informal dealings; immediate gains from breaching the contract are traded-off against future

costs. The model is tested using data on the French water sector. Consistent with the predictions, the authors find that if the provision of water and waste water services is under the responsibility of the same private operator, water prices are lower (having controlled for possible scale and scope economies). Based on their theoretical model, they argue that bundling should help sustaining relational contracts and provides incentives for the contracting parties to improve efficiency.

2.5 Summary and conclusions

Under the assumption that economic individuals are characterized by bounded rationality and might behave opportunistically, once relationship-specific investments have been realized, transaction cost economics aims to align transactions that differ in their attributes to governance modes that differ in their costs and competencies in an optimal way. Developed during the 1970s and 1980s, transaction cost economics motivated a huge body of empirical literature. The studies typically seem to confirm the theory's predictions; investments in relationship-specific assets are identified as the main driver of more hierarchical organizational forms. However, existing empirical literature suffers from a number of limitations. Not all analyses are entirely consistent with the theory's propositions, regularly, imperfect proxies for key variables are employed, the endogeneity of right-hand-side variables often is ignored, and most analyses are based on reduced form tests.

Several theoretical advancements have been proposed in recent years. Williamson (1991b) introduces the shift parameter framework investigating how the optimal choice of governance changes in response to dynamics in the institutional environment. Nickerson (1997) develops the positioning-economizing perspective linking transaction cost economics with the strategic management literature. Structural form tests employing two-stage Heckman models account for the self-selection of managers into a certain strategy (i.e., organizational form) and succeed in testing for rival propositions on the relationship between exogenous variables and exchange performance derived from alternative theories of the firm (e.g., Poppo and Zenger, 1998). Furthermore, researchers increasingly are interested in relational institutional arrangements (e.g., Gil and Marion, 2009).

Chapters 4 to 6 of this thesis pick up several of the above discussed limitations of existing empirical work testing for transaction cost economics' predictions and recent developments thereof using data on the global LNG market. First, the impact of inter-organizational trust as a shift parameter on the choice of more hierarchical governance modes is investigated. Second, an empirical test of the positioning-economizing perspective is provided. Third, optimal contract duration of long-term LNG supply contracts is analyzed accounting for the trade-off between contracting costs and flexibility. Contract duration as well as contracted volume thereby are considered as endogenous variables.

2.6 Appendix

Table 3: Selected empirical studies testing transaction cost economics: Make or buy

Authors/Year	Sector/Unit of analysis	Method	Dependent variables	Main independent variables	Main findings
Klein et al. (1978)	US auto sector (Fisher Body and GM), petroleum industry	Qualitative discussion	Vertical integration along successive stages of the value chain	Hold-up potential by exchange partner	Vertical integration is more likely when hold-up potential (i.e., quasi-rents from firm-specific investments) is large.
Globerman (1980)	Technology-intensive industries (focus on telecommunication, defense, IT)	Qualitative discussion	Backward integration into research and development	Uncertainty, complexity, transaction-specific investments	The more complex, uncertain, and specialized the innovation, the more complex will be the governance structure. Competitive bidding only feasible when technology transfer is amenable to fairly precise performance and feature specifications.
Monteverde and Teece (1982a)	US auto sector	Linear probability model	Vertical quasi integration (downstream firm owns specialized tools used in upstream production)	Asset specificity	Positive relationship between appropriable quasi-rents and the occurrence of quasi integration.
Monteverde and Teece (1982b)	US auto sector	Probit model	Backward integration into component supply	Human assets	Engineering effort is positively related to appropriable quasi-rent. The higher the appropriable quasi-rent, the greater the likelihood of vertical integration.
Masten (1984)	US aerospace industry	Probit model	Internal versus external procurement of supplies	Design and site specificity, complexity of item	Probability of internal procurement is higher for complex and highly specialized inputs. Hazard of incomplete contract in complex environments is greater when specific designs are involved.
Walker and Weber (1984)*	US auto sector	Multiple-indicator structural equation model (unweighted least squares)	Backward integration into supply of simple components	Volume and technological uncertainty, specificity, supplier production cost advantage	The higher the supplier production cost advantage the more likely is external procurement; the competitiveness of supplier market increases production cost advantage of suppliers over buyers. Volume uncertainty increases the likelihood of integration.
Palay (1984)*	Rail freight industry	Qualitative discussion and some statistics	Vertical structures between rail freight carriers and their shippers	Asset specificity	As investment characteristics become more transaction-specific, the associated institutional structure becomes increasingly unique to the parties and transactions it supports.

Authors/Year	Sector/Unit of analysis	Method	Dependent variables	Main independent variables	Main findings
Anderson and Schmittlein (1984)*	US electronic component industry	Logit model	Forward integration into marketing	Specificity, uncertainty (environmental unpre-dictability, difficulty of evaluating performance)	Asset specificity, the difficulty in evaluating performance, and company size all have a positive influence on the likelihood of forward integration.
Joskow (1985)	US coal-burning power plants	Qualitative discussion	Vertical structure between coal supplier and power plant (i.e., spot market, vertical integration, or long-term contract)	Specificity (site, physical asset, dedicated), uncertainty and complexity	Empirical results consistent with transaction cost economics; e.g. vertical integration or very long and complex long-term contracts are used for mine-mouth plants.
Globerman and Schwindt (1986)	Canadian forest products	Qualitative discussion	Backward integration of forest product companies into ownership of timber rights	Dedicated asset specificity	Transactional considerations, particularly asset specificity, prove to be robust empirical determinants of governance structures.
Klein (1988)	US auto sector (Fisher Body and GM)	Qualitative discussion	Backward integration of General Motors into the supply of car bodies	Hold-up potential by exchange partner	Vertical integration will be used when hold-up potential (i.e., quasi-rents from firm-specific investments) is large.
Hennart (1988)	Aluminum and tin industries	Qualitative discussion	Upstream vertical integration	Number of actual or potential parties at each stage, level of quasi-rents, uncertainty	Scale economies, barriers to entry, higher transportation costs, and greater asset specificity explain a higher degree of upstream integration.
John and Weitz (1988)*	Industrial good manufacturers	Multiple regression and multinomial logit models	Forward integration into distribution	Specificity, environmental and behavioral uncertainty	The higher the level of specific assets and the higher the level of uncertainty, the higher the likelihood of forward integration.
Klein (1989)*	Canadian exporting firms	Multiple regression	Degree of vertical control exerted by a firm in its export channel	Specificity, uncertainty (complexity/dynamism), transaction frequency	The higher asset specificity, frequency, and uncertainty (i.e., complexity) the higher will be the degree of vertical control. Uncertainty (i.e., dynamism) has a negative effect.
Lieberman (1991)	US chemical sector	Logit model	Backward integration	Specificity, supplier concentration, demand variability measures	The likelihood of integration increases with asset specificity. Backward integration to avoid variability in the input market that is independent of fluctuations in own downstream market (assuring stable supplies).

Authors/Year	Sector/Unit of analysis	Method	Dependent variables	Main independent variables	Main findings
Masten, Meehan, Snyder (1991)*	Naval shipbuilding sector	Two-stage self selection model	Backward integration into input component supply	Specificity (physical, human, temporal), complexity, similarity of the transactions	Temporal and human asset specificity have a positive impact on the likelihood of vertical integration. Non-monotonic effect of complexity (for simple components increases in complexity make it less likely that production is internalized; for more complex components positive impact). Integration is more likely for more labor-intensive and less engineering-intensive activities. Contrary to expectations, human asset specificity has a negative impact on transaction costs suggesting that workers with more specific skills are less costly to manage.
Pirrong (1993)	Bulk shipping markets	Qualitative discussion	Contracting practices and vertical integration	Differences in exogenous factors (e.g., market structure, vessel specialization)	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 observed.
Ohanian (1994)	US pulp and paper industry 1900-1940	Logit and tobit models	Likelihood and degree of vertical integration of pulp and paper production	Market concentration, controls such as firm size	With rising small number bargaining problem and higher investments in specific assets the likelihood for as well as the level of vertical integration increase.
Lyons (1995)*	UK mechanical engineering, motor vehicle, electronics, and metal processing industries	Logit models	Backward integration into input procurement	Specificity (specialized equipment necessary for input production), economies of scale and scope	The probability of buying-in specialised inputs is higher if the production technology is non-specific, but only if there are economies of scale or scope. The effect of economies of scale and scope is much reduced in the presence of specific assets.
Poppo and Zenger (1998)*	Information services	Two-stage Heckman model	Outsourcing (dummy, percentage)	Asset specificity, measurement difficulty, technological uncertainty, economies of scale	1st stage probit: The presence of firm-specific assets encourages internalization whereas outsourcing more likely if extensive skills are required. 2nd stage: Asset specificity has a negative effect on market performance and no clear effect on firm performance; measurement difficulty has a negative impact on overall costs.
Martinez (1999)	US pork and broiler industry	Qualitative discussion	Contracting practices and vertical integration	Transaction cost variables	Observed vertical structures in the pork and broiler industry are consistent with transaction cost economics' predictions.

Authors/Year	Sector/Unit of analysis	Method	Dependent variables	Main independent variables	Main findings
Simoens and Scott (1999)	UK primary care sector	Qualitative discussion and literature review	Vertical and horizontal integration	Transaction cost variables	Economic and non-economic theories of integration are relevant and applicable to explain integration in primary care.
Gonzalez et al. (1999)	Spanish construction industry	OLS, fixed effects panel data approach	Subcontracting	Specificity, uncertainty, geographical dispersion, output variety, technological specialization	As specificity is higher, firms tend to subcontract less. The opposite happens when output heterogeneity and the use of intangible assets and capabilities increase. Neither temporary shortage of capacity nor geographical dispersion of activities seem to affect the extent of subcontracting. Proxies for uncertainty do not show any clear effect.
Fan (2000)	Petrochemical industry	Multivariate regression	Vertical integration (input self-sufficiency ratio)	Specificity, price uncertainty	Input price uncertainty in the 1970s positively affected the extent of backward integration. This positive reaction of vertical integration to price uncertainty mainly occurs in transactions subject to asset specificity.
Vernimmen et al. (2000)	Belgian agriculture sector	Probit model	Outsourcing of administration	Complexity, uncertainty, transaction frequency	The complexity of the task and uncertainty regarding the outcome have a high impact on the decision to outsource. Larger firms tend to outsource more administration.
Martinez (2002)	US poultry, egg, and pork industries	Qualitative discussion	Contracting practices and vertical integration	Transaction cost variables	Observed vertical structures are consistent with transaction cost economics' predictions.
Leiblein et al. (2002)	Global semiconductor industry	Two-stage Heckman models	Outsourcing of production, technological performance	Ex-ante number of suppliers, asset specificity, uncertainty of product demand	1st stage: Firms tend to internalize production when ex-ante small number bargaining with potential suppliers is severe. Outsourcing is less likely when the firms have to invest in specific assets under high demand uncertainty. 2nd stage: Firms self-select into the strategy where they expect a higher performance.
Aubert et al. (2004)*	IT outsourcing	Partial least squares	Level of outsourcing	Asset specificity, uncertainty, required business and technical skills	Uncertainty is the major deterrent to outsourcing, while the level of technical skills is the most important reason to outsource. Business skills do not seem to play a significant role; asset specificity showed inconsistent effects.
Sampson (2004)	R&D alliances in the international telecommunications equipment industry	Two-stage Heckman model	Alliance type (pooling contract vs. equity joint venture), firm innovative performance	Contracting difficulties, alliance characteristics, strength of intellectual property regime	Misaligned governance dampens firm performance.

Authors/Year	Sector/Unit of analysis	Method	Dependent variables	Main independent variables	Main findings
Rosés (2005)	Spanish cotton industry 1720-1860	Logit and tobit models	Likelihood and degree of vertical integration of cotton spinning and weaving production	Market concentration, asset specificity, firm size	The likelihood as well as the level of vertical integration increase with higher specificity and a higher small numbers bargaining problem.
Acemoglu et al. (2005)	Numerous industries worldwide	OLS	Degree of vertical integration	Contracting costs, credit market development, barriers to entry	Firms are more integrated in countries with greater contracting costs, greater credit market imperfections, and greater barriers to entry. Countries with worse contracting institutions and greater credit market imperfections are more concentrated in industries that are typically characterized by strong vertical integration.
Sartorius and Kirsten (2005)*	Southern African sugar production	Case study	Outsourcing of sugarcane production to small-scale farmers	Transaction frequency, asset specificity, uncertainty	Sugarcane production should not be outsourced but rather co-ordinated by a more relational structure such as a strategic alliance.
Makholm (2006)	US natural gas industry	Qualitative discussion	Vertical integration between pipelines, production, and distribution	Asset specificity, regulatory actions	Until 1935, no federal regulation and a high degree of vertical integration – consistent with transaction cost economics due to the high level of asset specificity. After 1935, vertical separation of pipelines and long-term take-or-pay contracts between producers and pipelines with pipelines re-selling the gas to distributors. Since 1985, functioning market for pipeline capacity with well defined property rights and transparency over prices.
Spekle et al. (2007)	Auditing activities in Dutch companies	OLS	Proportion of outsourcing of auditing activities	Specificity, frequency, environmental and behavioral uncertainty	Firm-specific knowledge and frequency (influenced e.g. by firm size) positively influence internal auditing. Uncertainty has no impact on the outsourcing decision.
Gil (2007)	Spanish movie industry	OLS, two-stage least squares	Share of vertically integrated companies	Renegotiation frequency, movie release in the US, Spanish origin of the movie	Movies renegotiated ex-post more often are more likely to be distributed by integrated distributors. Hence, integrated distributors specialize in movies that are contractually more complex and use their own theaters more often for those of their movies that are contractually more complex.
Bigelow and Argyres (2008)	US auto industry 1917-1933	Probit models	Make or buy of the engine for each of its models	Specificity, number of suppliers, firm's industry experience	Asset specificity associated with an engine was associated with a greater likelihood that the engine would be produced internally.

Authors/Year	Sector/Unit of analysis	Method	Dependent variables	Main independent variables	Main findings
Nagaoka et al. (2008)*	Japanese automobile manufacturers	Multinomial logit	Choice between vertical integration, relational contracting (keiretsu) or market sourcing	Design specificity, interdependency in design of this and other components, testability of quality	An increasing level of design specificity of a component makes keiretsu sourcing preferred to market procurement, but does not significantly affect the probability of vertical integration over keiretsu. The interdependency of components has a positive impact on the likelihood that more hierarchical governance forms are chosen.
Fernández-Olmos et al. (2008)	Spanish wine industry	Ordered logit models	Market versus hybrid versus hierarchy	Physical and dedicated asset specificity, behavioral and environ-mental uncertainty, firm size, product quality	The probability of vertical integration increases with asset specificity and uncertainty. Wineries that produce high-quality wines are more likely to vertically integrate.

*… based on survey data

Table 4: Selected empirical studies testing transaction cost economics: Contractual provisions

Authors/Year	Sector/Unit of analysis	Method	Dependent variables	Main independent variables	Main findings
Mulherin (1986)	US natural gas industry	Qualitative discussion	Development of vertical structures 1920s to mid-20th century	Vulnerability to opportunistic behavior	Potential for opportunistic behavior created by specialized assets has induced the use of complex, long-term contracts.
Hubbert and Weiner (1986)	US natural gas industry	Qualitative discussion with some descriptive statistics	Contractual structure	Phased deregulation of wellhead prices in the US	Derive a theoretical model on the determination of take-or-pay provisions. Wellhead price ceilings favor long-term contracts which include non-price contract provisions such as take-or-pay clauses increasing the producers' total compensation.
Joskow (1987)	US coal industry	OLS and maximum-likelihood models	Contract duration	Site, physical asset, and dedicated specificity	Contracting parties make longer commitments when specific, investments occur.
Crocker and Masten (1988)	US natural gas sector	Tobit model, OLS, two-stage least squares	Take-or-pay percentage, contract duration	Uncertainty, number of potential traders to capture quasi-rent, regulatory actions	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. Show theoretically and empirically that distortions in performance incentives raise the costs of long-term agreements and therefore shorten contract duration.
Masten and Crocker (1991)	US natural gas sector	Probit and multinomial probit models	Processes by which parties adjust prices in long-term contracts (renegotiation vs. redetermination)	Specificity, price uncertainty	No significant results for transaction cost variables. With increasing contract duration, the probability of adopting renegotiations increases as expected; negative relationship between price and quantity flexibility as expected.
Lyons (1994)*	UK engineering firm	Probit model	Formal contract	Vulnerability to opportunistic behavior, complexity	The probability of using formal contracts increases with the vulnerability to opportunistic behavior whereas it decreases with the complexity of the transaction.
Saussier (1999)**	Electricité de France's coal supply	OLS, two-stage least squares	Contract duration	Specificity (physical, site, dedicated, human assets), uncertainty	Whereas contract duration increases with the level of appropriable quasi-rents at stake, it decreases with the level of uncertainty.
Saussier (2000)**	Electricité de France's coal supply	OLS, ordered probit, and two-stage models	Contractual completeness	Specificity (physical, site, dedicated, human assets), uncertainty	Whereas contractual completeness increases with the level of appropriable quasi-rents at stake, it decreases with the level of uncertainty.

Authors/Year	Sector/Unit of analysis	Method	Dependent variables	Main independent variables	Main findings
Kerkvliet and Shrogren (2001)	US coal supply contracts to power plants in Powder River Basin	OLS	Contract duration	Specificity (physical, site, dedicated assets), trading and market experience	Positive relationship between physically specific investments and contract duration but counterintuitive result for impact of dedicated asset specificity. Duration decreases with rising trading and market experience.
Poppo and Zenger (2002)*	Information services	Three-stage least squares model correcting for self-selection into outsourcing	Contractual complexity and relational governance, exchange performance	Exchange performance , relational governance index, contractual complexity, asset specificity, measurement difficulty, technological change	Increases in the level of relational governance are associated with greater levels of contractual complexity. Both relational governance and contractual complexity deliver higher levels of satisfaction with exchange performance.
López-Bayon and González-Diaz (2004)*	Spanish electronics industry	Logit and multinomial logit models	Contract duration of subcontracting agreements	Product specificity, technological and demand uncertainty	Probability of signing an indefinite duration contract is related positively to the specificity of the activity and negatively to the uncertainty regarding future demand and to the degree of formalization of the contract. Indefinite duration contracts (working as relational contracts) improve flexibility for adjusting the relationship to the changing environment.
Zylbersztajn and Lazzarini (2005)	Technology licensing contracts between seed companies and a governmental R&D organization in Brazil	Hazard rate models	Contract survival	Quasi-rents, monitoring costs, past performance, environmental stability	Rates of contract termination decrease with the level of quasi-rents at stake, decrease as a function of past satisfactory outcomes, increase with the extent of disturbances affecting the technology's demand, and increase over time.
Brickley et al (2006)	Franchise contracts	OLS and ordered probit models	Contract duration, change in contract duration	Total investments, training requirements, contract renewal restrictions	Contract duration increases with the franchisee's physical and human capital investments, recontracting costs, and the franchisor's experience in franchising (argued to be negatively related to uncertainty about optimal contract provisions).
Athias and Saussier (2007)**	International infrastructure concession contracts	Ordered logit and two-stage ordered logit models	Contractual rigidity	Uncertainty (future demand, costs, difficult to predict future), reputation	Develop a model combining property rights theory and TCE. The higher demand uncertainty, the more flexible the toll adjustment provisions will be. Reputation has a negative effect on the level of rigidity.

Authors/Year	Sector/Unit of analysis	Method	Dependent variables	Main independent variables	Main findings
Liu et al. (2008)*	Chinese household appliance industry	Multivariate regression	Relationship between formal and relational contracts	Specific investments, relational norms, trust, exchange performance	Contracts are more effective in restraining opportunism while relational mechanisms are more powerful in improving performance. Written contracts and relational governance in the form of mutual norms and trust are complements.
Hirschhausen and Neumann (2008)	World natural gas market	OLS	Contract duration	Specificity, market restructuring	Contract duration decreases as the market structure evolves to more competitive regimes. Investments linked to specific infrastructures increase contract duration by an average of three years.
Ruester (2009)	World liquefied natural gas market	Two-stage least squares, GMM	Contract duration, annual contracted volume	Specificity, uncertainty, transaction frequency	The higher asset the longer is contract duration. On the contrary, 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. Countries with a greater dependence on imports in the form of LNG tend to negotiate longer agreements. Deliveries to competitive downstream markets are realized via contracts with about 2.5 to three years shorter duration.
Kozhevnikova and Lange (2009)	US coal industry	Tobit model	Contract duration	Asset specificity, contractual complete-ness, regulatory reforms	Larger quantities and spatial closeness of plants and mines lead to longer contracts. Contract completeness has no impact on the duration once it is controlled for endogeneity. The railroad reform, which decreased transportation costs, had a negative effect on contract duration.

* … based on survey data
** … authors had access to complete contracts

3 Dynamics in the Liquefied Natural Gas Industry

3.1 Introduction

Natural gas accounts for about 24% of world primary energy supply. It is mainly employed for power production, for industrial uses as well as for heating and cooking in the residential sector. In 2008, 27% of the total production of 3,018 billion cubic meters (bcm) have been traded internationally. LNG thereby accounted for 28% (227 bcm) of the exported gas (BP, 2009). The International Energy Agency (IEA) forecasts that natural gas will play a key role in the global energy picture also in the future, even though the pace of demand growth will critically depend on climate policy actions. In the IEA reference scenario, global gas demand increases by an average of 1.5% per year until 2030 with the power sector remaining the largest driver of gas demand (IEA, 2009b, p. 365).[10] LNG is expected to continue to gain in importance since it enables the transportation of natural gas over long distances and often becomes the fuel of choice in cases where pipeline sources are limited (e.g., Japan or Portugal) and where supply sources and trade routes shall be diversified (e.g., Spain or Greece).

During the last decade, the LNG industry altered substantially. Traded volumes increased by an annual average of 7% from 2000 on. New players entered the market and new trading patterns evolved. On the one hand, vertical and horizontal integration have become more common with oil and gas majors investing in a portfolio of LNG export, transport, and import capacities which enables flexible trades. On the other hand, new business models of non-integration emerged. Long-term contracts with a duration of more than 20 years co-exist with short-term agreements. Recent developments of unconventional gas resources change the global supply picture. The current economic crisis entails short-term overcapacities in the global LNG export market and supports the development of a buyers' market at least for the mid-term future. The survival of incumbents and new entrants strongly depends on their ability to operate economically.

The heterogeneity of transactions in terms of varying levels of relationship-specific investments, external uncertainty, downstream competition, and dependence on natural gas imports in the form of LNG of buying countries should be matched by a diversity in governance forms such as varying levels of vertical integration and varying characteristics and durations of supply contracts. For these reasons, the LNG industry seems to be particularly well-suited to test propositions derived from transaction cost economics. This chapter provides an overview on dynamics in the LNG industry from a technical and an economic perspective as well as with respect to corporate behavior and qualitatively discusses observed vertical structures before Chapters 4 to 6 conduct econometric tests based on transaction cost economics and recent developments thereof.

[10] This increase in natural gas demand is fostered by environmental motivations. Natural gas entails lower specific CO_2 emissions as compared to coal or oil. Improvements in the technology of combined cycle gas turbine power plants furthermore allow for natural gas being employed for mid- and base-load electricity generation. The average yearly increase in world demand for the period from 1990 to 2008 was 2.4%. See Figure 19 in the Appendix for an illustration of the development of world natural gas demand.

3.2 The LNG industry

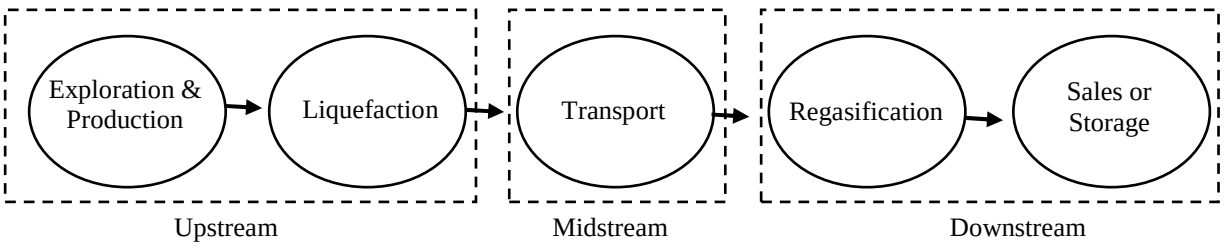
3.2.1 LNG value chain

Prior to the development of the LNG technology, the transportation of natural gas was limited to destinations that could be served by pipeline. The liquefaction of natural gas enables transport over long distances as well as between regions where the construction of pipelines is not feasible due to difficult geographic conditions. Whereas transportation of natural gas in the form of LNG requires very capital-intensive upfront investments, variable costs increase less with shipping distance than for pipelines. Break-even of offshore pipeline and LNG transport is achieved at about 2,500 km (Jensen, 2009b, p. 7).

Figure 6 depicts the five stages of the LNG value chain. Following exploration and production (stage 1), the raw feed gas is transported via pipeline to liquefaction facilities. After removing impurities and separating heavier hydrocarbons, it is cooled to minus 160°C under atmospheric pressure in so called liquefaction trains and shrinks to about 1/600 of its volume (stage 2). This energy-intensive process consumes about 12% of the incoming gas. The liquefied gas is transported to the destination country using tankers equipped with a complex insulation system essential to keep the gas liquid during shipment (stage 3). Gas boiling-off throughout the journey (0.15% of the cargo volume per day) can be used to fuel the ship. Upon arrival, tankers are off-loaded to terminals that reconvert the LNG to its original state of aggregation via heat exchangers where again up to 1% of the incoming gas is used as a fuel (stage 4). Finally, the gas is fed into the destination country's pipeline grid, traded and sold to marketers, distributors, or power producers, or stored for future demand (stage 5).

To investigate the LNG industry from an economic perspective, the five stages of the value chain should be considered together. In general, the structure of export and import projects is largely predetermined by exogenous factors and therefore lies beyond the control of individual players. Exploration and production of natural gas are directly linked to the liquefaction projects whose ownership structures in many cases are determined by national oil and gas companies. On the downstream end, national infrastructure, marketing, and distribution systems are often in place before import terminal construction. Therefore, this analysis concentrates on the three successive stages of upstream, midstream, and downstream activities.

Figure 6: LNG value chain



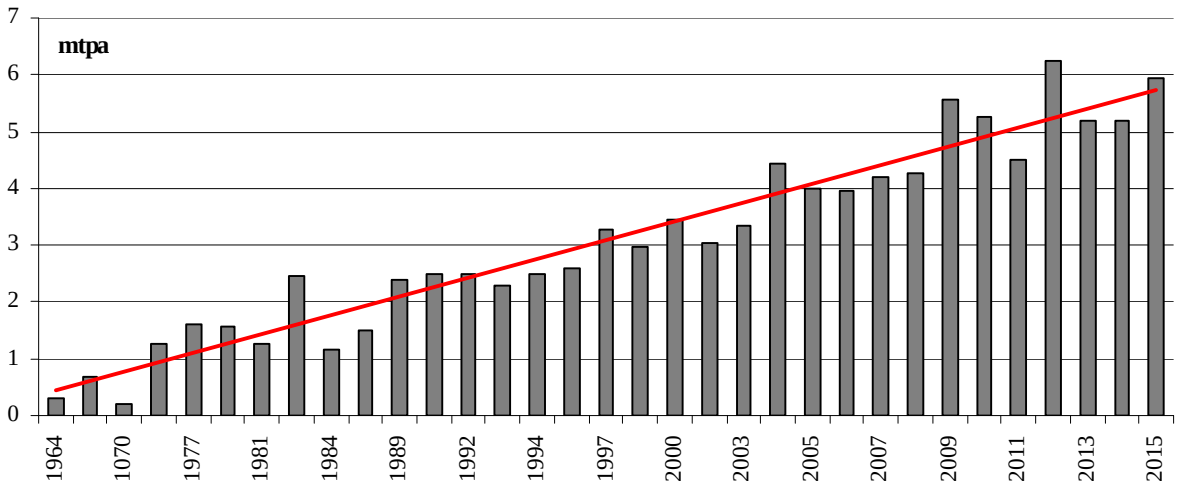
Source: Own depiction

Transportation infrastructure is a substantial element linking exporting and importing projects. In contrast to oil shipping, vessels for LNG transport are very capital-intensive and therefore traditionally have been dedicated assets for specific routes booked under extensive long-term contracts. However, an increasing number of vessels for uncommitted trade are now in the order books of shipyards and will reduce dedicated asset specificity.

Investment costs within the five stages vary significantly. Exploration and production including gas processing and transportation from the field to the liquefaction facility account for 15-20% of the total costs of the LNG value chain; liquefaction including gas treatment, cooling, loading and storage for 30-45%; shipping for 10-30%; and regasification including unloading and storage for 15-25% (EIA, 2003, p. 42). Exact figures depend on the distance, traded volumes, and local conditions such as construction costs.

During the period from the mid-1990s to about 2003, costs along the whole value chain were declining (see e.g., EIA, 2003; Cornot-Gandolphe, 2005; Energy Charter Secretariat, 2008) which supported the rapid expansion of the LNG sector and a general enthusiasm with respect to future growth potentials. This was mainly driven by technological advances and the realization of economies of scale in liquefaction, shipping, and storage. Fuel efficiency in liquefaction and regasification could be improved using higher-efficiency gas turbines. Overcapacities and redundancies have been reduced. Whereas the first liquefaction trains (Arzew in Algeria) had a capacity of 0.3 mtpa, today, trains with a capacity of 4 mtpa are common and Qatar recently completed its first 'mega-trains' including 7.8 mtpa units. See Figure 7 for an illustration of the development of average liquefaction train size. Economies of scale of two 4 mtpa trains reduce liquefaction cost of an 8 mtpa greenfield project with four 2 mtpa units by nearly 30%. An increase to one 7.8 mtpa unit leads to an additional 20% cost reduction (Jensen, 2003, p. 31). Average investment costs fell from about 550 USD/mtpa in the early years of the industry to 350 USD/mtpa in the 1980s, 250 USD/mtpa in the late 1990s, and 200 USD/mtpa in the early 2000s (Cornot-Gandolphe, 2005, p. 8).

Figure 7: Development of average liquefaction train size by start-up year



Source: Own depiction

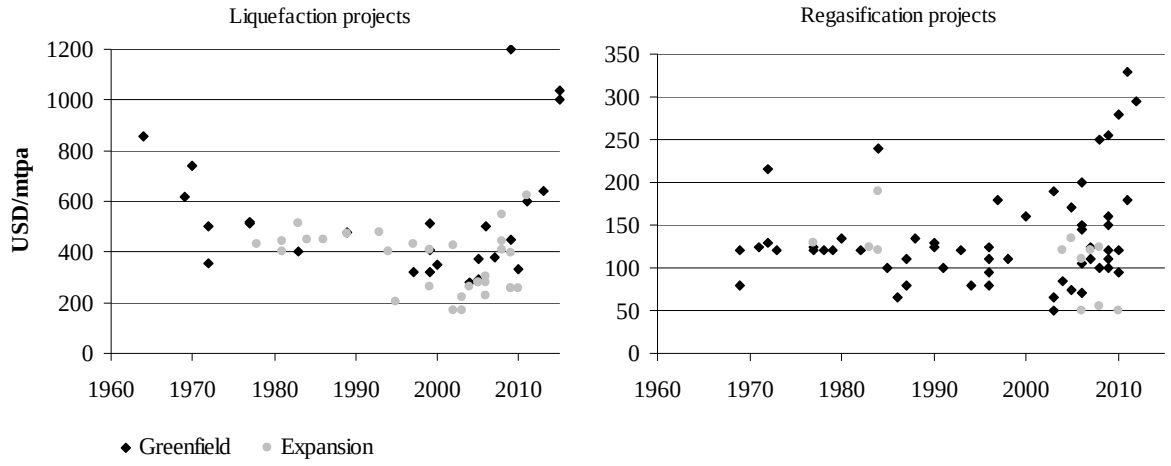
Tanker financing and construction schedules have benefited from new manufacturing techniques and more shipyards that can build LNG vessels. Typical vessel size today is in the range of 120,000 to 180,000 cubic meters (m^3). Building costs for standard LNG tankers have decreased from about 280 million USD in the mid-1980s to 155 million USD in the early 2000s (EIA, 2003, p. 42). In November 2007, the first super-size tankers with a capacity above 210,000 m^3 have been delivered (see Figure 20 in the Appendix). These ships benefit from lower average transport costs; however, there are restrictions concerning potential destination facilities since only a number of ports can handle these vessels. Small-size LNG carriers are employed in Japan, where intra-country LNG transport compensates for the lack of a nationwide transmission system.

In the mid-2000s, the trend of falling costs reversed due to rising raw material prices (such as steel or nickel – a critical component for cryogenic storage tanks and piping) and the large demand for LNG facility construction. There are only four companies contracting for engineering, procurement and construction of LNG plants and the contractor market has become increasingly tight during the last years, when significant investments along the LNG value chain have been realized. The number of liquefaction trains simultaneously under construction increased from an average of eight during the 1990s to twelve in the early 2000s and to 16 for the period from 2005 to 2008 (IEA, 2009b, p. 451). Table 5 provides a summary of cost estimates over time. The initial decrease and following re-increase in recent years are also mirrored by the dataset used for empirical tests in this thesis (see Figure 8).

Table 5: Development of costs along the LNG value chain

	Cost of service early 1990s [USD/MBTU]	Cost of service early 2000s [USD/MBTU]	Capex as of 2006 [bn USD]	Cost of service as of 2006 [USD/MBTU]	Capex as of 2009 [bn USD]	Cost of service as of 2009 [USD/MBTU]
Source	Cornot-Gandolphe (2005):		Jensen (2006):		Jensen (2009b):	
Trade route	Deliveries from Middle East to Europe		Two 4 mtpa trains, Nigeria to US Gulf coast		Two 4 mtpa trains, Nigeria to US Gulf coast	
E&P	0.5-0.8	0.5-0.8	1.6	0.80	3.0	1.00
Liquefaction	1.3-1.4	1.0-1.1	1.6	0.94	4.3	2.15
Shipping	1.2-1.3	0.9-1.0	2.0	0.99	2.1	1.23
Regasification	0.5-0.6	0.4-0.5	0.6	0.38	1.1	0.70
Total	**3.5-4.1**	**2.8-3.4**	**5.8**	**3.11**	**10.5**	**5.08**

Figure 8: Development of per unit costs of liquefaction and regasification projects



Source: Own depiction

A number of projects have suffered from cost overruns and construction delays during the last years: e.g., for Indonesia's 7.6 mtpa Tangguh project, an 18-month delay in the final investment decision led to a cost increase from 1.4 to 1.8 billion USD. The Russian Sakhalin II and Norway's Snovhit projects have experienced huge cost overruns which might partially be caused by the Arctic environment. Snovhit furthermore suffered from technical failures and ran at only 55% of nominal capacity from its commissioning in 2007 and was shut down again in 2008 for an additional maintenance. Cost overruns and delays also have been reported for Yemen LNG and the large-scale trains at Qatargas IV and V (all still under construction).

3.2.2 Development of the LNG industry

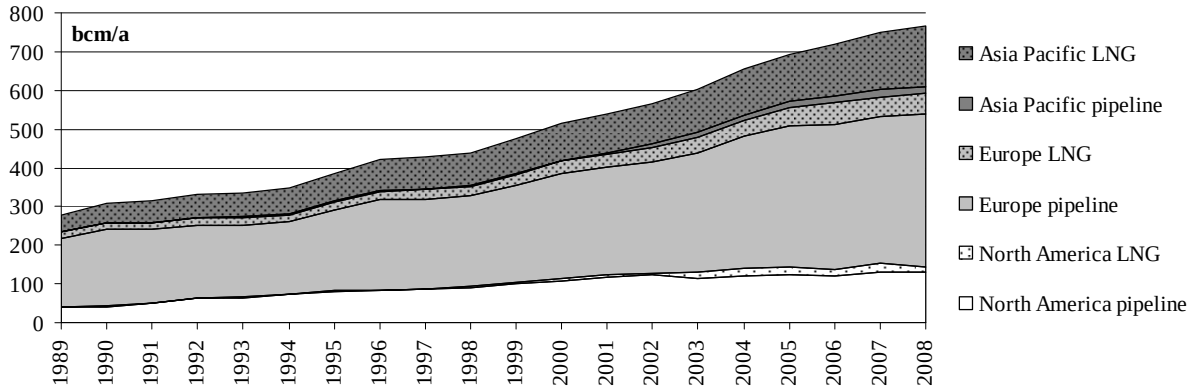
Converting natural gas to LNG for transportation by tanker has been utilized for more than 40 years, but the industry achieved a remarkable level of global trade only recently. Since 1964, the technology of natural gas liquefaction enables commercial transport in tankers with the first deliveries having been dedicated from Algeria to the UK.[11] Transport remained expensive and natural gas markets stayed regional in nature until the 1990s.

The North American market including the US, Canada and Mexico traditionally has been highly self-sufficient with substantial domestic production in all three countries and some intra-regional pipeline trade. The US opened its first LNG receiving terminal in 1971 to import additional volumes from Algeria. However, due to a surplus in domestic supplies in the mid-1980s two of the four import terminals (i.e., Elba Island and Cove Point) have been mothballed in 1985 and contracts with the Algerian Sonatrach were terminated before their official end. In Europe, indigenous natural gas supplies and imports via pipeline were available to meet demand and LNG capacities grew relatively slowly. Spain opened its first LNG import terminal in 1969, Italy and France followed in 1971 and

[11] The UK imported LNG from 1964 to 1982. With the growing natural gas production in the North Sea, however, imports had been stopped, the UK became a net exporter of natural gas and the regasification facility at Canvey Island was dismantled.

1972, respectively. In contrast, traditional Pacific Basin natural gas importers such as Japan, South Korea or Taiwan lack domestic supplies and are beyond the reach of any pipeline sources. They are highly dependent on imports in the form of LNG and dominated the LNG industry during its first decades (see Figure 9).

Figure 9: Development of natural gas imports of the world's major importing regions



Source: Own depiction based on data from BP Statistical Reviews of World Energy (1990-2009)

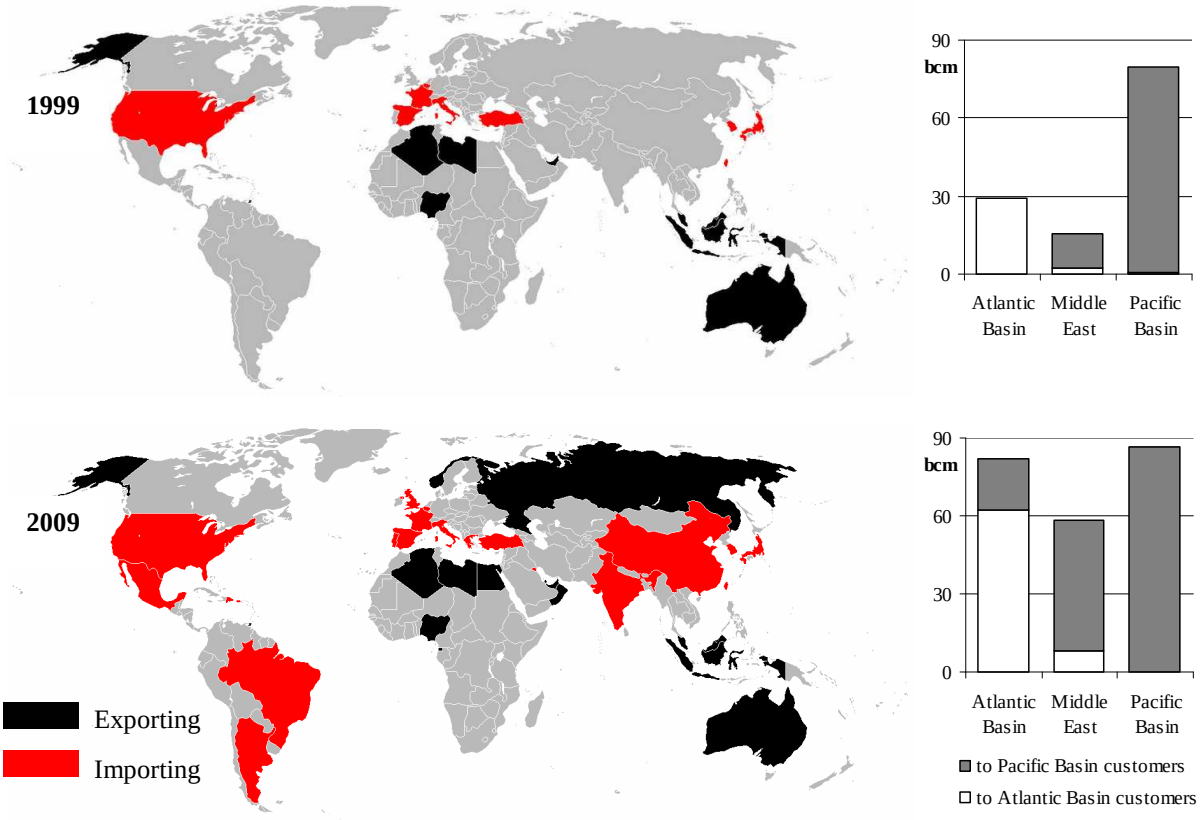
During this early stage, most of the world's LNG export infrastructure remained under state control and private or foreign companies were involved only with minority shares. Inflexible bilateral long-term contracts with take-or-pay and destination clauses secured the capital-intensive infrastructure investments and reliable supplies for import-dependent buyers (see Section 3.4 for a detailed discussion of the development of contracting structures in the global LNG market).

Nissen (2004) calls these early trading structures 'project-utility chain model' where the export project (typically a joint venture between a national oil and gas company (NOC) and a private oil and gas major) functions as the seller and a monopoly franchised utility or a merchant trader as the buyer. Downstream competition in most importing countries was not encouraged; e.g., buyers in South Korea and Taiwan were state entities, the Japanese natural gas sector was highly regulated without any foreign participation and Japanese utilities controlling all imports; and also in European countries such as France for example, a state-owned monopoly was responsible for all imports and natural gas transmission. Capacities along the whole value chain, including shipping, have been bilaterally committed and each supply project was linked by technical and commercial design to a specific market.

Since the 1990s, investments in LNG infrastructure grew rapidly as worldwide natural gas demand increased significantly, leading to substantial economies of scale throughout the value chain. New entrants include Turkey (1994), Greece (2000), Portugal (2003), India (2004), China, and Mexico (both 2006). The UK re-emerged as an LNG importer in 2005 to substitute for declining domestic production. Significant expansions and new investments have been realized in Spain and the US re-opened its mothballed terminals since domestic supply sources no longer appeared adequate to support the expected increase in demand. South American countries received their first LNG in mid-2008.

Industry experts agree that the LNG industry has altered substantially during the last decade (Iniss, 2004, p. 9; Jensen, 2004, pp. 7 ff.). Regasification capacities increased from 251 mtpa in 1999 to 462 mtpa at the end of 2009 (+84%), liquefaction capacities from 108 to 229 mtpa (+112%) during the same period and the number of operating LNG vessels augmented from 106 to 337 (+218%). Atlantic Basin LNG trade gained in importance. After nearly 20 years without any export capacity extensions, Trinidad/Tobago and Nigeria opened their first liquefaction trains in 1999, Egypt followed in 2005 and Equatorial Guinea and Norway in 2008 and 2009, respectively. The Middle East, accounting for more than 40% of worldwide proven natural gas reserves, is becoming the largest regional exporter of LNG. With Qatar and Oman, two additional suppliers started deliveries in 1997 and 2000. The region is currently evolving to a swing producer. Deliveries to European and Asian markets and even to North America are feasible without a significant difference in transportation cost.[12] Jensen (2007a, p. 29) even argues that Qatar, the largest LNG exporter since 2005, may become the "Henry Hub of global LNG pricing".

Figure 10: Countries participating in LNG trade and inter-regional trade volumes 1999 vs. 2009[13]



Source: Own depiction based on data from BP Statistical Reviews of World Energy (2000, 2009)

[12] Shipping costs for deliveries from North Africa account for about 0.35 USD/MBTU (to Europe), 0.95 USD/MBTU (to the US Gulf coast), and 1.8 USD/MBTU (to Japan). For deliveries from the Middle East they are in the range of 0.8, 1.0, and 1.4 USD/MBTU, respectively (Razavi, 2009, p. 14).

[13] The figure of traded volumes in 2009 uses trade data of 2008. However, due to the economic crisis and its negative impact on natural gas demand, no increase in traded volumes is expected for 2009 (IEA, 2009b, p. 48).

In today's LNG market, new flexibility in trading patterns comes from i) changes in the structure of long-term contracts, ii) a small but growing short-term market, and iii) a trend of suppliers towards self-contracting with their own downstream marketing affiliates. Changing contract terms have taken several forms: average contract duration as well as contracted volume are decreasing, take-or-pay requirements are reduced, destination clauses are eliminated and buyers increasingly conclude for free-on-board agreements enabling cargo diversions. Long-term contracts are accompanied by flexible short-term agreements as well as vertical integration and strategic partnerships. Today, spot and short-term trade account for about 20% of total LNG trade. Arbitrage trade in the Atlantic Basin is increasingly linking North American and European markets. The first liquefaction projects without having sold total volume based on long-term contracts are moving forward.

Changes in the institutional framework, i.e., the move from monopolistic structures to competition,[14] in turn demand fundamental changes in the organizational behavior of market participants. More competition, mirrored by evolving spot markets, a gain in contract flexibility, and increasing international trade, exposes traditional players to greater pressure. Global mergers and acquisitions, integration, and strategic partnerships have become routine today and the LNG industry is dominated by a small number of large players. Global oil and natural gas producers and distributors are frequently engaged in all stages of the LNG value chain. In addition, export projects are increasingly financed and developed by private (and foreign) interests. Former downstream monopolists of natural gas are finding their traditional markets challenged by the intrusion of oil and gas majors integrating into import markets. Vertical integration in response to market deregulation features drivers including upstream producers aiming to benefit from downstream margins and from ownership of transportation capacities to exploit arbitraging possibilities. Distribution and power companies move upstream to ensure margins and supply security. See Section 3.4 for a discussion of vertical structures in the LNG industry.

3.2.3 Globalization of the natural gas market

The technology of natural gas liquefaction enables inter-regional gas trade linking the historically isolated markets of North America, Europe-Eurasia and Asia-Pacific. Even though regional trading patterns prevailed a long time, today's natural gas market can be regarded as a global market in the sense that price signals are transmitted from one region to another. However, the (liquefied) natural gas market is different from global commodity markets such as the oil industry. Highly capital-intensive infrastructures make it economically difficult to hold permanent spare capacity and instead support the conclusion of long-term sales and purchase agreements. Together with high cost of

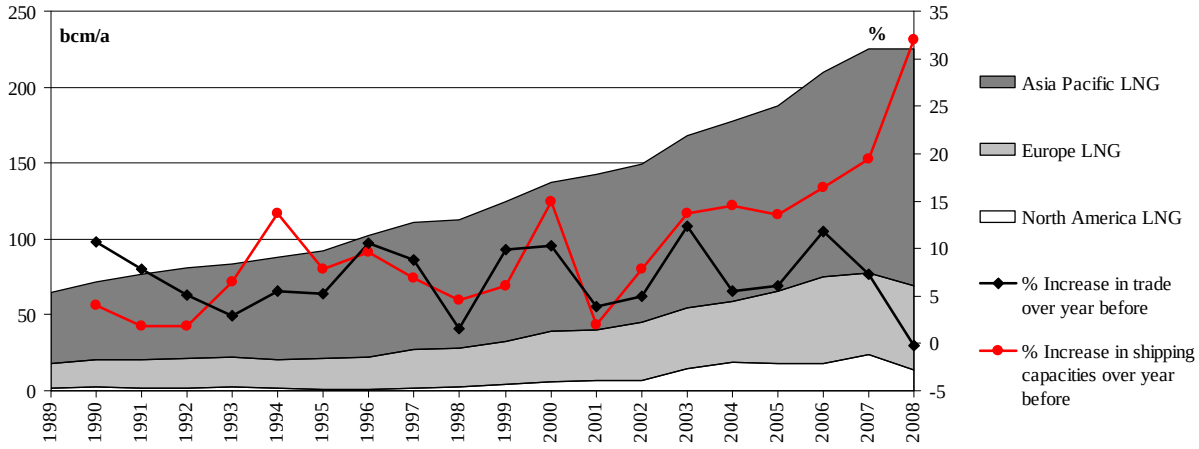
[14] The US natural gas industry, where restructuring already started in 1978 with the Natural Gas Policy Act deregulating wellhead prices, is a functioning and highly competitive market. See Makholm (2006; 2007) and Hirschhausen (2006, pp. 4 f.) for an overview on regulatory actions implementing vertical unbundling and competition in production and marketing. The UK followed with the privatization of British Gas in 1986 and vertical unbundling in the 1990s. In Continental Europe, the liberalization process did not start before the late 1990s with the EU directives 98/30/EC and 2003/55/EC. In Japan, deregulation of natural and electricity sectors started only recently.

transportation and a lack of liquid trading hubs and fully competitive downstream markets these conditions prevented the establishment of a global natural gas price.

However, recent developments towards more flexibility within contracts and trades support the globalization of the natural gas market. The volume of uncommitted capacities along the value chain increases. The first export projects without having sold their total volume based on long-term contracts are constructed (e.g., Oman LNG, Malysian Tiga LNG, Russian Sakhalin II, expansion trains of Australia's North West Shelf Venture). Project delays of downstream regasification plants or a surplus in capacity during ramp-up periods can be used to conduct short-term deliveries (e.g., in 2002, LNG shipments from Oman and Abu Dhabi which had been destined for India's Dabhol import terminal suffering from construction delays were sold on the short-term market).

A long time, shipping has been seen as the critical bottleneck motivating oil and gas majors and export and import consortia to order a large number of vessels. As a result, the number of LNG ships has augmented significantly. Whereas in 1999, virtually all ships had been dedicated to specific trade routes, the share of uncommitted capacity increased to 14% in 2009 (49 of the 337 ships with a total capacity of 6.9 million m³; see Figure 21 in the Appendix for an illustration of the development of shipping capacities). Free transport capacities are also available due to recent delays in the start-up of liquefaction projects. In addition, the current economic crisis reinforces this imbalance between LNG production and transportation capacities at least in the mid-term future. Whereas LNG trade ceased growing in 2008, the number of LNG ships still increased by 32% from 2007 to 2008; another 35 ships are currently in the shipyards' order books (see Figure 11). It is likely that this surplus will support the future expansion of the short-term and spot market. LNG vessels also could be employed as temporary floating storage and sellers thereby could take advantage of short-term and seasonal price differences.

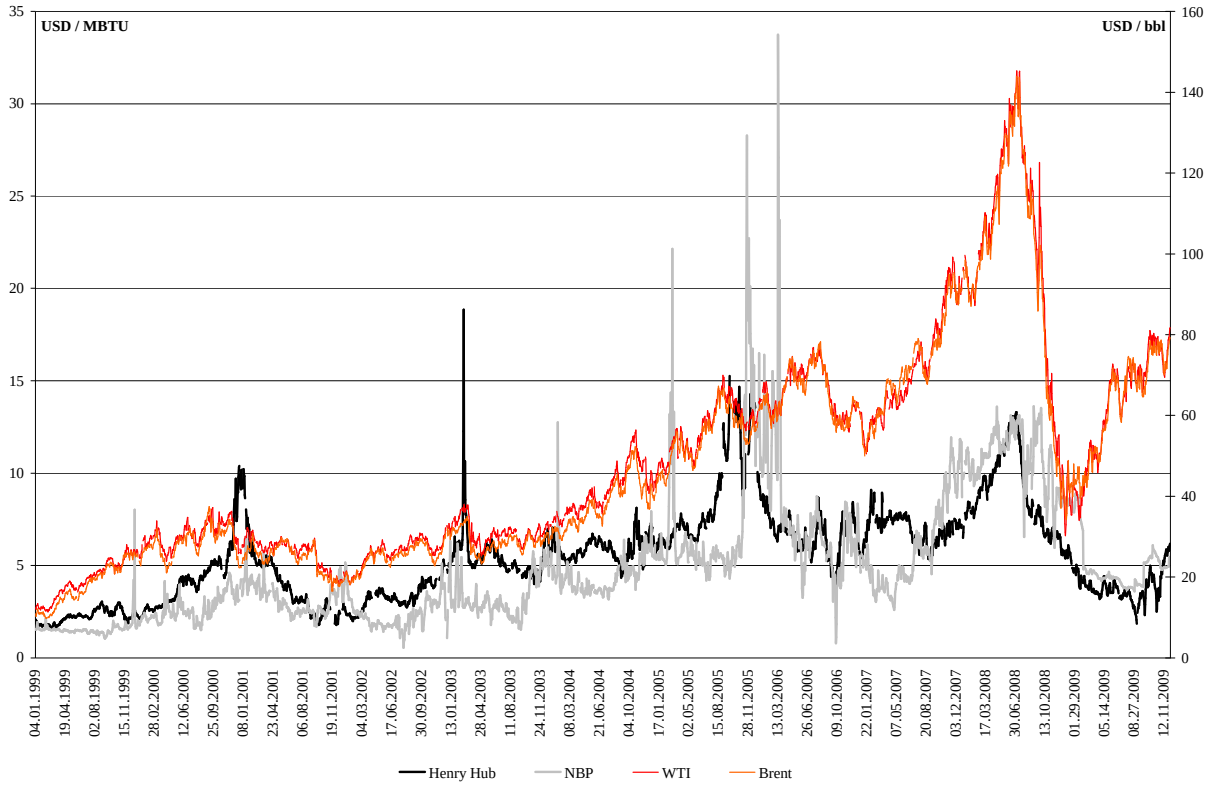
Figure 11: Development of LNG trade and shipping capacities



Source: Own depiction based on data from http://www.shipbuildinghistory.com and BP Statistical Reviews of World Energy

Figure 12 shows the historical natural gas and crude oil spot prices observed on both sides of the Atlantic. Whereas oil prices (i.e., the US West Texas Intermediate (WTI) and North Sea Brent) move quite parallel reflecting a global oil price, natural gas prices (i.e., US Henry Hub and UK National Balancing Point (NBP)) clearly diverge. To a major part, they reflect region-specific, instead of global, supply-demand conditions. Using spot data for the US, the UK and Continental Europe from 1999 to 2008, Neumann (2009) confirms the non-convergence of international natural gas prices. However, she shows that formerly regionally isolated markets are becoming more integrated and that convergence is higher for winter months when markets are tight and natural gas spot prices tend to be more volatile, supporting the redirection of LNG spot cargoes.

Figure 12: Development of crude oil and natural gas prices



Source: Own depiction based on data from the EIA and ICIS Heren

Tight supply situations in Asian importing countries regularly mirror in high prices for short-term deliveries, too, despite the absence of liquid natural gas markets and import prices being determined based on oil price indexed pricing formulas within long-term contracts. The short-term price differences between regions provide economic incentives to redirect flexible cargoes and to deliver additional spot volumes to higher value markets. In the period from 2000 to 2001, for example, the US faced higher price levels than Continental Europe which led to cargoes being redirected from Europe to North America. A similar price relationship and trade pattern was observed in 2003. During the winter of 2005/2006, a severe competition for LNG spot cargoes within the Atlantic Basin and sharp price spikes occurred. In North America, hurricanes Katrina and Rita severely affected production; in

the UK, the transition from a net exporter to a net importer created additional import demand; Spain suffered from poor hydro conditions raising the demand for gas-fired power generation; and demand in Continental Europe was high due to a cold winter. In early 2008, cold weather pushed Japanese power consumption to record levels at the same time when a major share of the country's nuclear capacity was offline. Tokyo Electric Power shut down its 8.2 GW Kashiwazaki-Kariwa power plant after an earthquake in July 2007. Hence, natural gas demand from the power sector increased substantially which mirrored in prices of up to 19 USD/MBTU paid for LNG spot cargoes at a time when average import prices were in the range of 9 USD/MBTU. In April 2008, China bought an LNG spot cargo at 14 USD/MBTU. Similar prices have been paid for other spot shipments in spring 2008. RWE contracted for the delivery of eight cargoes to be delivered to the UK from December 2009 to January 2010. Due to recent price increases in the US, however, these volumes will be redirected towards the North American market.

Theoretical and empirical studies of arbitrage trade in the LNG industry are rare. Hayek (2007) simulates the value of the option to conduct flexible LNG trades developing a mean-reverting model to represent the stochastic evolution of gas prices in regional markets and the resulting price spreads. Obviously, larger price differences will be observed for a low correlation between regional prices. Zhuravleva (2009) provides a qualitative discussion of different arbitrage models (i.e., initial seller-arbitrageur, initial buyer-arbitrageur, and independent trader-arbitrageur). Section 3.4.2 of this thesis discusses alternative corporate strategies in today's LNG industry amongst others with respect to a player's motivation to benefit from systematic investments in infrastructure along successive stages of the LNG value chain.

3.3 Prospects for liquefied natural gas

Evaluating the future development of LNG export and import capacities is a very difficult task due to a number of reasons: i) during the last decade, natural gas (and/or LNG) demand augmented rapidly in countries such as China, India, or Spain, but also in historically self-sufficient countries such as the UK or Indonesia. The recent economic crisis, however, yields a stagnation (and even reversion) of regional demand growth at least for a shorter-term perspective and has fostered the development from a sellers' to a buyers' market. The exploration of unconventional natural gas sources such as shale gas in North America may have an impact on the domestic supply of different countries; ii) oil and natural gas prices experienced a sharp increase during 2007 and the first half of 2008, followed by a rapid price decrease. The demand for LNG is inherently sensitive to natural gas price volatility and small changes in the supply-demand balance alter incentives to invest in its capital-intensive infrastructures; iii) the future treatment of greenhouse gas emissions will also have an impact on the economics of natural gas as a fuel competing with coal and oil on the one hand as well as with renewable and nuclear energy sources on the other.

This is supported by Jensen (2007b, p. 10), who argues that "[i]n this environment, it is unlikely that any forecast – no matter how well done – will get it right." The following paragraph therefore focuses on the prospects of investments in LNG export and import capacities in the mid-term future up to 2015. A dataset including all LNG facilities (i.e., operating, under construction, planned, and proposed) has been built up using data from various publicly information such as periodical reports, newsletters, industry journals, and company websites. It includes information on nominal liquefaction, regasification, and storage capacities, ownership structures, capital investments, supply sources, customer portfolios, concluded contracts as well as the LNG world fleet. The number of projects reported publicly substantially exceeds the number of projects that are likely to be commercialized; therefore, it is necessary to judge which projects are likely to go forward and when. Based on these data as well as an objective evaluation of the technically feasible and from an economic point of view reasonable realization of the projects, forecasts for capacity development have been generated. These are compared to evaluations of future LNG demand made by industry experts and international energy agencies.

3.3.1 Prospects for LNG exporters

The early LNG industry was dominated by Pacific Basin trade with supplies coming from Alaska (start-up 1969), Brunei (1972), Indonesia (1977), Malaysia (1983), and Australia (1989). In the Atlantic Basin, Algeria (1964) and Libya (1970) were early exporters and the United Arab Emirate started deliveries from the Middle East to Asian customers in 1977. At the end of 2009, there are 226 mtpa of liquefaction capacity, of which 35% are located in the Atlantic Basin, 42% in the Pacific Basin and 23% in the Middle East (see Table 6 in the Appendix). In 2008, Qatar was the largest exporter supplying a total of 39.7 bcm of LNG to both European and Asian customers. Together with Malaysia (29.4 bcm), Indonesia (26.8 bcm), Algeria (21.8 bcm), Nigeria (20.5 bcm), Australia (20.2 bcm), and Trinidad/Tobago (17.4 bcm), these seven countries accounted for 78% of total LNG exports (BP, 2009).

For the near term, significant expansions will be added especially within the Middle East, a region where more than 40% of world natural gas reserves are located.[15] Major expansions are under way in Qatar and an additional greenfield project is expected to start operation in Yemen in 2010. Qatar announced to observe the behavior of the production from the North Field before making commitments about further expansions; therefore, additional export capacities beside those already under construction are not expected for the mid-term. In the Atlantic Basin, capacities will be expanded in Algeria and Libya. In Norway a small-scale LNG project for intra-regional trade is under construction and Angola is likely to enter the stage as an additional supplier. Nigeria in the longer-term has the potential to provide additional exports; domestic consumption is low and still much gas is flared during oil production. In the Pacific Basin, neither Brunei nor Malaysia are expected to expand

[15] A substantial share of the Middle East's natural gas reserves are situated within the world's largest natural gas field (i.e., Qatar's North Field and Iran's South Pars form one single geological field).

their liquefaction capacity. The Alaska venture will reach the end of its economic life in the mid-term. Peru is expected to open its first LNG terminal in 2010. Works on Australia's Pluto venture already started in 2007 and also the Gorgon venture is likely to be developed until 2015.

In recent years, the evolving competition between growing domestic demand and exports in traditional supply countries such as Algeria or Libya has become increasingly discussed.[16] In the absence of new gas developments, export availability will be reduced (IEA, 2009a). For example, Egypt faced continuously increasing domestic natural gas consumption over the last 20 years with an average yearly demand increase of 11% from 1998 to 2008. The government decided to prioritize the home market and introduced a moratorium on new export projects in 2008. In Iran, domestic consumption increased by an average of 8.7% during the last decade. Large volumes of produced natural gas are re-injected into oil fields in order to maintain oil production at economic levels.

Indonesia is a country showing substantial dynamics. After twenty-five years enjoying the position as a reliable supplier of LNG, the country has become a source of supply uncertainty. LNG exports peaked in 1999 at a level of 38.8 bcm and declined to 26.9 bcm in 2008. The reasons are diverse. First, domestic demand increases due to the government's efforts to reduce oil consumption via slowly reducing subsidies on domestic oil use. Second, the Arun natural gas field, which began production in 1978, is aging and production declines. Furthermore, domestic natural gas consumption is prioritized; certain volumes are delivered to a fertilizer and a pulp company. The LNG plant is already partially shut down and is expected to stop exports during the next decade. From the Bontang field, some natural gas is diverted to the domestic industry, too.

Hence, the country was not able to fulfill its long-term supply contracts. According to Global Insight, ten cargoes destined for Taiwan had to be cancelled in late 2004; the Oil and Gas Journal reported in 2007 that Indonesia already had failed to deliver 72 cargoes of LNG (4.1 mtpa) to Japanese customers. In 2007, 0.23 mtpa of scheduled LNG cargoes to South Korea had been dropped. Pertamina, the state-owned oil and gas company, negotiates with LNG buyers over the further proceeding (i.e., whether the export volume will be reduced or whether some cargoes might be rescheduled or replaced by swap arrangements). The company furthermore has purchased volumes on the spot market to fulfill its delivery commitments. Some of its older contracts with Taiwan and South Korea will expire in the coming years and Pertamina already has indicated that it will not renew these contracts at their original levels. The new Tangguh liquefaction plant which started operation in early 2009 will temporarily absorb the decline in the country's exports. However, industry experts agree that any exports from the

[16] Razavi (2009) discusses natural gas pricing policies in MENA countries (holding almost half of global gas reserves) where gas prices are set by the governments, often substantially below its economic cost which in turn results in a wasteful use of gas, the deployment of inefficient technologies, and a huge burden on government budgets. For example, the Egyptian government buys the gas from producers at a price of 2.65 USD/MBTU and sells it in the domestic market at an average price of 1.19 USD/MBTU resulting in a subsidy of about 7 bn USD/a. The Iranian government provides gas to the national power utility at 0.1 USD/MBTU, to the industrial sector at 0.6 USD/MBTU and to residential/commercial customers at 0.45 USD/MBTU. Similar estimates for actual price levels and much higher market values for numerous countries are provided by EIA (2009b, p. 525).

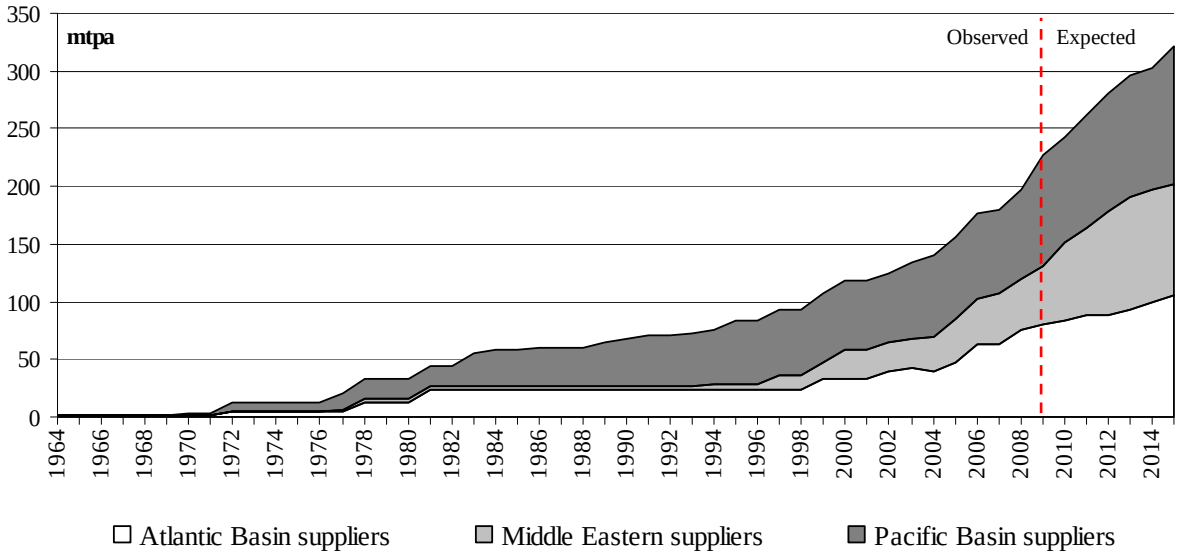
Donggi field, as had been proposed for the mid-term future, are very unlikely due to the high domestic demand as well as lower gas reserves confirmed as expected.

Another interesting development in Indonesia is that the country announced to study the potential of LNG *import* facilities. A pipeline network covering Sumatra and Java connects the main demand centers Java and Bali and with the predominant supply sources Natuna Island and southern Sumatra. Other supply regions such as Kalimantan and Papua are not connected to the pipeline system and LNG import terminals are considered in eastern and western Java as well as in northern Sumatra.

Taking the above discussed developments into account, world liquefaction capacity being operational in 2015 is forecasted to be 322 mtpa, with the Atlantic Basin accounting for 33%, the Pacific Basin for 37% and the Middle East augmenting its share to 30% of the installed capacities (see Figure 13). In the short-run, the current economic crisis will have a negative effect on LNG demand and on the ability to finance infrastructures along the value chain. However, the normal lag in liquefaction plant construction (on site works take about four years) makes it difficult for suppliers to respond quickly to demand variations. The delayed supply response to an earlier demand growth will start operation until 2015 and will create a surplus in supply in the mid-term future.

These forecasts go in line with the LNG demand projections developed by Jensen (2009b, p. 58) expecting between 270 and 325 bcm in 2015. Also the Energy Information Administration (EIA) in its recent World Energy Outlook projects global LNG trade to be in the range of 300 bcm in 2015 (EIA, 2009b, p. 439) with prospects for installed liquefaction capacity at a level of 295 mtpa.

Figure 13: Development of liquefaction capacities



Source: Own depiction

3.3.2 Prospects for LNG importers

The first LNG import facilities started operation in the UK (1964), Japan and Spain (both 1969), Italy and the US (both 1971), France (1965), and South Korea (1986). Whereas capacities in Europe and North America grew slowly or even were mothballed (i.e., UK and US) during the first decades of the

industry, Pacific Basin countries, rapidly invested in additional projects. Since 2000, however, Atlantic Basin countries experience substantially higher annual growth rates with an average of 16.4% (versus 2.3% for Asian importers). This renewed interest in LNG had a number of reasons including decreasing production from conventional natural gas fields in the US and the North Sea (the UK has become a net importer of natural gas in 2006), increasing employment of gas-fired combined cycle gas turbine power plants (e.g., gas-fired generation increased from 19 TWh in 1999 to 93 TWh in 2007 in Spain), and efforts to diversify supply sources.

At the end of 2009, there are 450 mtpa of regasification capacity, of which 41% are located in the Atlantic Basin, 58% in the Pacific Basin and 1% in the Middle East (see Table 7 in the Appendix). In 2008, Japan was the largest importer receiving a total of 92.1 bcm of LNG (41% of world LNG trade). Together with South Korea (36.6 bcm), Spain (28.7 bcm), France (12.6 bcm), and Taiwan (12.1 bcm), these five countries accounted for 80% of total LNG imports (BP, 2009). In the coming five years, significant expansions are expected especially within Asian emerging countries. Moderate expansions are projected for European countries whereas North America currently faces a supply-overhang due to the development of substantial unconventional natural gas sources. Figure 22 in the Appendix classifies LNG import countries according to their dependence on natural gas imports in the form of LNG and the level of proposed new capacities.

3.3.2.1 North America

With 812 bcm of natural gas production and a consumption of 824 bcm in 2008, North America accounts for a major share of the total world natural gas industry. Thereby, the US represents the world's largest consumer (657 bcm) and the second largest producer (582 bcm). Domestic production was rather sufficient to satisfy demand during the last decades and LNG historically could not compete with cheap domestic production. It accounted for less than 1% of North American gas consumption in 1999 and was mainly used for peak-load energy needs with LNG import facilities restricted to the area of the US. Intra-regional trade included pipeline deliveries from Canada to the US as well as some minor volumes from the US to Mexico.

The EIA forecasts in its latest Annual Energy Outlook that natural gas demand in the US is expected to decline in the short-run until 2011 and will continue to grow afterwards with an average annual growth rate of 0.2% for the period from 2007 to 2030 (EIA, 2009b, p. 109). The major consuming regions are the states of Louisiana and Texas in the South (high consumption originating from the industrial and electricity sectors), the Midwest and the Northeast (mainly for heating purposes). The share of electricity generated by gas-fired power plants increased from 15% in 1999 to 22% in 2007. This equals average annual growth rates of 6.2% since 1999. In comparison, growth rates for coal, nuclear, fuel oil, and hydroelectric generation have been less than 1% over the same period (EIA, 2009c, p. 11). However, the future demand for natural gas is mainly influenced by future climate policy actions and the economics of natural gas with respect to relative costs of alternative fuels (Ruester and Neumann, 2008, pp. 3162 f.).

Major producing regions are Texas, Louisiana, offshore fields in the Gulf of Mexico, and Alaska. Production in the Rocky Mountains has increased steadily since 1998. The construction of new transmission capacity to consumption centers in the Northeast and Midwest and the expansion of existing pipelines to Southern California underline the importance of the mid-central region as a domestic supply source. In 2008, nearly one fifth of total US production came from unconventional sources; 55.6 bcm of coal-bed methane (mainly from Wyoming, Colorado and New Mexico) and 57.2 bcm of shale gas (mainly from Texas) were extracted. [17]

The year 2000 saw a renaissance of interest in imports in the form of LNG. Conventional natural gas production reached a peak in 2001 at the same time that demand was projected to continue to increase and forecasts claimed that US natural gas production would be unable to meet growing demand (e.g., EIA, 2004, p. 91). With the opening of the LNG export terminal in Trinidad/Tobago, furthermore, a supply source close to the North American market was emerging. Potential investors for LNG for a long time believed the biggest struggle for realizing new capacities would be to get the regulator's (i.e., FERC or MARAD) approval. FERC, however, sought to create an investor-friendly environment and even deviated from its initial view where LNG import capacity should be treated the same way as pipeline capacity. With the 'Hackberry Decision' in 2002, it terminated open access requirements to regasification facilities. This led to a rapid boost in project proposals. At present, there are 25 approved projects (including greenfield investments and expansions) in total North America.

All four LNG import terminals which have been built during the 1970s and early 1980s have revisited operation and even have undergone substantial expansions (see Ruester and Neumann, 2008, pp. 3163 f.). Gulf Gateway LNG, an offshore facility in the Gulf of Mexico operated by Excelerate, is the first new-built terminal since more than two decades and started operation in 2005. Four additional terminals came on stream recently (i.e., Freeport Texas, Sabine Pass Louisiana, and Northeast Gateway offshore Boston all commissioned in 2008; Cameron LNG Louisiana received its first shipment in July 2009). Mexico opened its Energia Costa Azul import facility in May 2008; total capacity is dedicated for re-exports via the 140-mile Baja North pipeline to California and Arizona.

It becomes apparent that all new-build and advanced proposed projects are either located in the Gulf of Mexico or feed into the US pipeline system (see Figure 14). Since September 11, 2001, the public has grown more aware of risks to national security. Chemical plants and existing and planned nuclear and LNG facilities have come under intense scrutiny. Receiving terminals on both the Atlantic and Pacific coast face a strong resistance from the local population ('not-in-my-backyard' attitude).

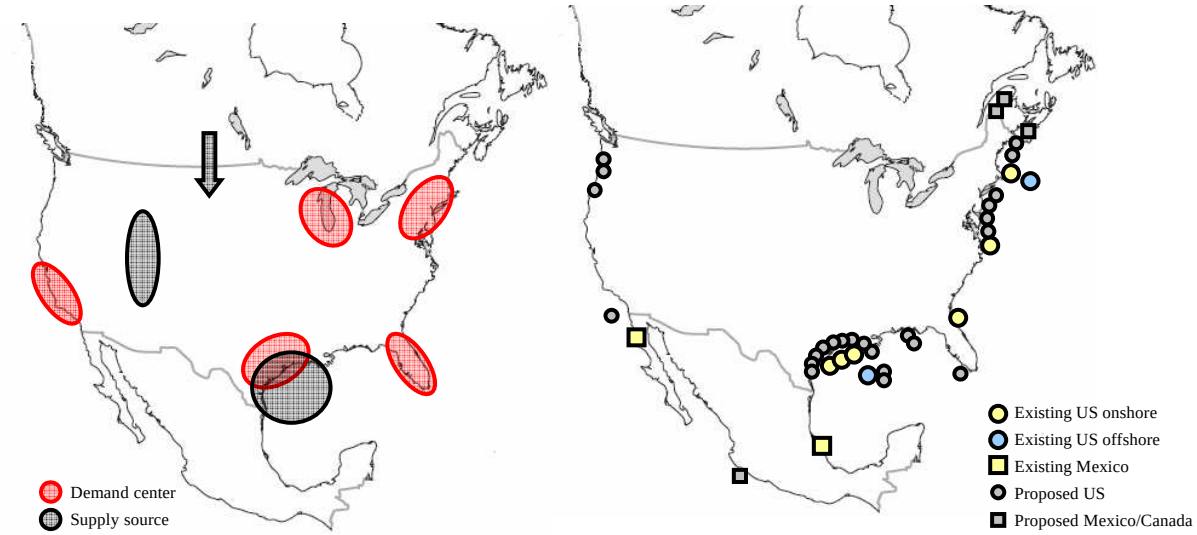
The long-standing history of natural gas production in Texas and Louisiana has proved beneficial for all participants: local governments and population are familiar with the approval process, several large

[17] 'Unconventional gas' is found in difficult-to-access geological formations with the rocks being hardly permeable and natural gas only flowing with great difficulty. The three main sources include gas shale, tight sands, and coal-bed methane.

customers are nearby, and major pipelines are connecting to the Midwest and northeastern US.[18] At present, the pipelines are reserved 100% by firm customers, but there are two issues of interest: the feasibility of expansions and declining domestic production from conventional sources. Volumes in the form of imported LNG could make up such shortfalls. Beside the already completed projects, two further facilities are under construction.

It is difficult to assess the probability of success for individual US projects outside the Gulf of Mexico (see also Jensen, 2004; Frisch et al., 2005). Developers regularly delay or cancel proposed projects. In California and Massachusetts, for example, both states with an increasing natural gas demand, proponents face strong public resistance. Thus, investors look elsewhere. Mexico has already opened an import terminal dedicated to supply the southwestern US; another project is proposed. Canada's Atlantic provinces deliver natural gas produced offshore near Sable Island to the northeastern US since 1999. The Canaport LNG terminal currently under construction is expected to start operation in 2010. Two further projects are under consideration.

Figure 14: North American LNG import potential



Source: Own depiction

New LNG must compete with existing facilities and expansions both within the US and in other importing regions. A barrier to entry during the first half of the 2000s was the lack of available upstream deliveries. Excelerate Energy's Gulf Gateway import facility, for example, received only nine cargoes during its first year of operation. In contrast to market entrants, incumbent oil and natural gas majors therefore currently simultaneously construct liquefaction capacities to correspond with regasification capacities.

However, nothing has altered the North American natural gas market and its appetite for LNG as severe as the discovery and development of significant unconventional gas sources. Within a couple of

[18] E.g., The Transco-, Texas Eastern-, and Tennessee Gas pipelines extend to the Northeast. Trunkline Gas Company and Mississippi River Transmission supply power producers and industrial users in the Midwest.

years, the supply-demand balance has changed from one of continuous production declines to one of an upcoming surplus. Rising natural gas prices since 2001, easy financing and technological innovations (i.e., horizontal drilling and hydraulic fracturing) encouraged companies to invest in wells. Amongst others, large deposits were explored with the Barnett Shale and Eagle Ford plays (both in Texas) and the Haynesville Shale (Louisiana). The Potential Gas Committee states in its 2008 assessment report that the US alone might possess a total resource base of 51,200 bcm which would increase the static reserves-to-production ratio from about ten to 90 years. In Canadian British Columbia, the Horn River Shale Basin is estimated to comprise about 14,000 bcm. A pipeline to the coast and a liquefaction terminal are under consideration.

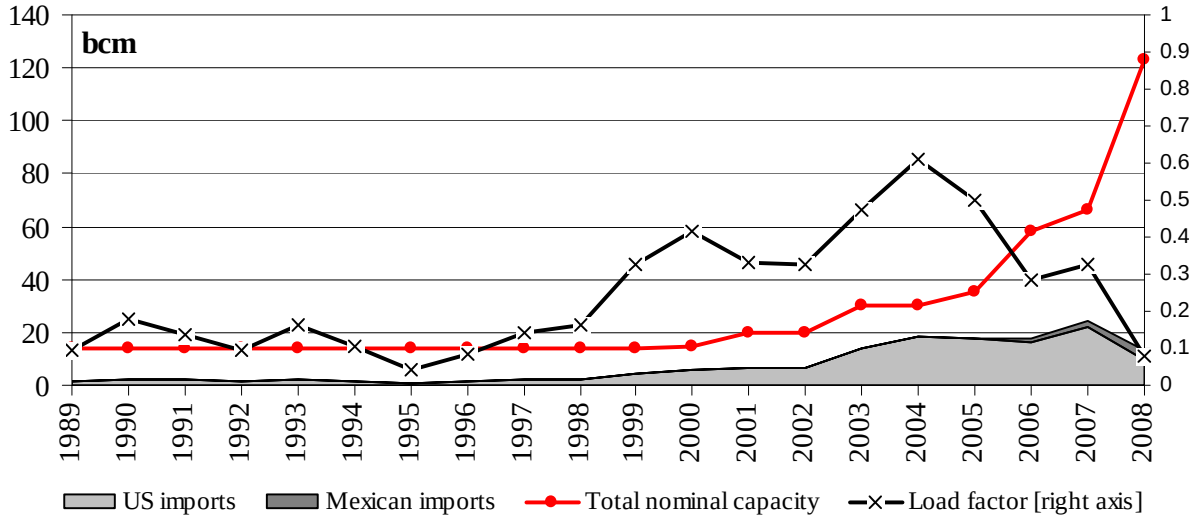
The substantial rise in unconventional gas production reversed the historical decline in US gas output reducing demand for LNG. In the early 2000s, researchers still saw North America as a major player in the future LNG market (see e.g., Chabrelie, 2003, p. 5; CIEP, 2003, p. 114). The EIA regularly adapted its annual energy production and consumption forecasts. In 1999, most domestic production was expected from conventional natural gas with unconventional sources projected to account for not more than 200 bcm in 2020 and LNG imports were forecasted to remain at marginal levels. The 2004 outlook five years later predicted unconventional production to increase to 255 bcm and LNG imports to rise to 140 bcm in 2025. In its latest outlook, future unconventional natural gas production has been adjusted further upwards (340 bcm in 2025 and 400 bcm in 2030) whereas the prospects for LNG imports with 30 bcm in 2030 are less enthusiastic (see Table 8 in the Appendix).

The future potential for natural gas production from unconventional sources, however, will mainly be determined by the level of natural gas prices and the development of production costs. Each shale play has its individual geological characteristics; no general statement on the cost structure can be made. Dar (2009) quotes the break-even price at 3.88 USD/MBTU (Eagle Ford), 3.74 USD/MBTU (Marcellus), 4.49 USD/MBTU (Haynesville), and 5.18 USD/MBTU (Barnett). This goes in line with Jensen (2009b) arguing that much shale gas could be developed at natural gas price levels of 4 USD/MBTU. Berman (2009), in contrast, argues that only half of the Barnett Shale wells would be economic at prices of 10 USD/MBTU and expects a drop in drilling activities as a response to the lower prices since mid-2008. Whether current production levels can be maintained at prices below 5 USD/MBTU is one of the major uncertainties for the mid-term future.

As a consequence of the increased domestic production, needs for imports declined. For the short-term, this trend is further amplified by the recent demand downturn due to the economic crisis (IEA, 2009a). US LNG imports dropped in 2008 to 9.9 bcm from 21.8 bcm in 2007. Import terminal operators suffered from idle regasification capacities. The load factor of total North American LNG import capacity fell from 61% in 2004 to 8% in 2008 (see Figure 15). It is very likely that beside the completion of projects already under construction, no significant investments in LNG capacities will be realized in the mid-term future. Some LNG terminal operators even have already sought permission from FERC to add *export* equipment to their facilities. Since North America was expected to be a

major growth market for LNG, this development has a severe impact on the future global LNG demand.

Figure 15: Development of North American LNG imports and nominal import capacity



Source: Own depiction

3.3.2.2 South America

South America has emerged as an LNG importing region in mid-2008 with the commissioning of Argentina's Bahia Blanca offshore terminal operated by Excelerate Energy in June and Brazil's Port Pecem offshore facility operated by state-owned Petrobras in July. An additional project is already under construction offshore Rio de Janeiro and is expected to start operation in 2010. South American natural gas demand is expected to increase above world average from 127 bcm in 2007 to 229 bcm in 2030 with an average annual growth rate of 2.6% (IEA, 2009b, p. 366).

Further proposals for regasification facilities include one project each in Argentina and Uruguay and two projects each in Brazil and Chile. For the mid-term outlook, it is very likely that no substantial investments will be realized since most countries are endued with some natural gas reserves and intra-regional pipeline trade (e.g., from Bolivia to Brazil or Argentina) could be expanded. For Chile, a country without large natural gas resources, the construction of one small-scale facility until 2015 seems probable. In 2004 and 2005, Argentina reduced its deliveries to the country in order to ease its own domestic gas shortages which raised concerns about energy security.

3.3.2.3 Europe

After a short-term decrease in natural gas demand as a consequence of the world economic crisis, the long-term upward path is projected to continue from 2010 on. The IEA forecasts an increase from 544 bcm in 2007 to 651 bcm in 2030 in the reference scenario (IEA, 2009b, p. 366) with the demand growth mainly being driven by the power sector. Modern combined-cycle gas turbine power plants

benefit from lower up-front investment costs and shorter construction times than alternative mid- and base-load technologies, greenhouse gas emissions are significantly lower than for other fossil fuels, and gas-fired capacity is a suitable complement to renewable energy sources since its flexible operation is able to absorb supply fluctuations.

On the supply side, overall OECD Europe's production is expected to decline from 294 bcm in 2007 to 222 bcm in 2030, even though Norway will raise output during the coming decade increasing its production from the Ormen Lange and Snovhit fields. The Netherlands' Groningen field and UK's Continental Shelf are reaching maturity. The exploration of unconventional gas sources is still in its infancy. Shale gas resources are estimated to be in the range of 14,000 bcm but will only play a minor role on a local scale, given that public resistance in the densely populated areas can be overcome (Schulz and Horsfield, 2009). Hence, overall import needs are forecasted to move up from 250 bcm in 2007 to 428 bcm in 2030 (IEA, 2009b, p. 478).

The future composition of foreign supplies will depend on a number of factors including the comparative supply costs and natural gas availability of alternative sources, upstream investment risks and midstream transit risks of alternative supply routes, and the countries' policies with respect to diversification. Industry experts agree that increased import needs are likely to be met through additional pipeline supplies from Europe's traditional suppliers (i.e., Russia, Algeria, and Norway), new supplies from the Caspian region and potentially from the Middle East, and additional LNG imports. Thereby, Russia will experience higher supply costs in the long-term since production from its Yamburg, Urengoy and Medvezhye fields will decline and new, more expensive fields (e.g., Shtokman, Yamal Peninsular) have to be developed, which in turn improves the competitiveness of alternative supplies. Figure 23 in the Appendix provides an overview on supply costs of potential natural gas sources for both pipeline as well as LNG.

Nominal European LNG import capacities augmented from 36 mtpa in 1999 to 91 mtpa at the end of 2009 with Spain accounting for about one third of the capacity increase. The country has always been highly dependent on natural gas imports receiving the first LNG deliveries in 1986. Pipeline deliveries are restricted to supplies from Algeria via Morocco and some minor volumes from Norway via France. In order to meet rapidly increasing demand and to diversify supply sources, Spain expanded its existing LNG receiving terminals and three new facilities came on stream since 2003. A seventh terminal currently is under construction.

Greece and Portugal entered the industry in 2000 and 2003, respectively. For both countries no expansions are planned for the mid-term future. Italy, in contrast, will become a more important destination for LNG imports in the next years; two terminals are under construction; numerous additional projects are proposed. The commissioning of about three import terminals until 2015 seems likely and will decrease Italy's reliance on Algerian and Russian natural gas imports. Further capacity additions are expected for France, Croatia (functioning as a transit country for deliveries to Central

Europe), and the Netherlands. Proposed projects in other countries such as Albania, the Canary Islands, Germany, Ireland, or Poland are not likely to be realized until 2015.

The decline in the UK's domestic production has provided incentives to invest in LNG infrastructure. Three regasification facilities started operation during the last four years and additional capacities are under construction. Imports in the form of LNG add to supply security on the one hand and may enable the country to function as a European hub and re-export volumes via the Interconnector and BBL pipelines to the Continent if local price differences support this.

3.3.2.4 Asia Pacific

Within the Asia Pacific region, one has to distinguish between traditional LNG importers (Japan, South Korea, and Taiwan) and newcomers (China and India). The somewhat isolated and more developed economies in northeast Asia lack substantial energy resources and have started to use LNG and nuclear energy in order to minimize their dependence on imported oil. Natural gas consumption is forecasted to increase only moderately during the coming two decades supporting only minor investments in new LNG import capacities. Two facilities will come on stream in Japan until 2015; one new import terminal is expected for Taiwan.

The emerging economies of China and India, on the contrary, are the critical uncertainty factor within the global LNG market. Historically, the two countries have mainly used domestic coal to satisfy their energy needs. However, natural gas is increasingly becoming an important component of their primary energy mixes. The IEA forecasts an increase in natural gas consumption from 73 (39) bcm in 2007 to 242 and 132 bcm in 2030 for China and India, respectively (IEA, 2009b, p. 366), representing annual growth rates of 5.3 and 5.4%, much above world average of 1.5%.

The Chinese natural gas market has been expanding rapidly in recent years, particularly after the completion of the West-East pipeline in 2004. The government aims to expand the share of gas-fired power generation from currently 1% to about 10% in 2020 (IEA, 2009a, p. 123). Production growth cannot keep up with demand growth although new supplies from the Sichuan Province are expected to come on line in the short-term. The country could be dependent on imports for more than 30% of its consumption in 2030. These are likely to be met by pipeline imports from Turkmenistan via Kazakhstan and LNG (EIA, 2009a, p. 44). Three LNG import terminals are in operation with the Guangdong terminal (start-up in 2006) and the Fujian and Shanghai facilities commissioned in 2009. Two additional facilities are under construction, 14 terminals are proposed.

In India, natural gas plays a small role in the total energy mix, but demand has been growing rapidly, too. Much of the country's current production originates from more mature fields that are beginning to decline and India is projected to be dependent on imports for more than 30% in 2030 (EIA, 2009a, p. 44). Some new domestic production will come from the Krishna Godavari Basin. Pipelines supplying natural gas from the Middle East, Central Asia, or Myanmar have been discussed in the past; however, their realization is very unlikely in the near future. With the Dahej and Hazira facilities,

two LNG import terminals are operating since 2004 and 2005. One additional terminal is already under construction, seven projects have been proposed.

For both countries, however, it is very difficult to evaluate how many projects finally will be realized and when. Unconventional gas resources are supposed to be present in China (e.g., South China, Zhungaer, Tuha, Qadam, and East China Basins) as well as in India (e.g., Gondwana and Gambay Basins) and could reduce the needs for natural gas imports. Their scope and recoverability have not yet been explored. Furthermore, cheap abundant coal reserves could affect the optimistic growth forecasts for LNG imports. Obviously, Asian emerging economies represent a substantial challenge in a carbon-constrained world given the large share of coal in their energy supply portfolios and the high growth rates in energy demand.

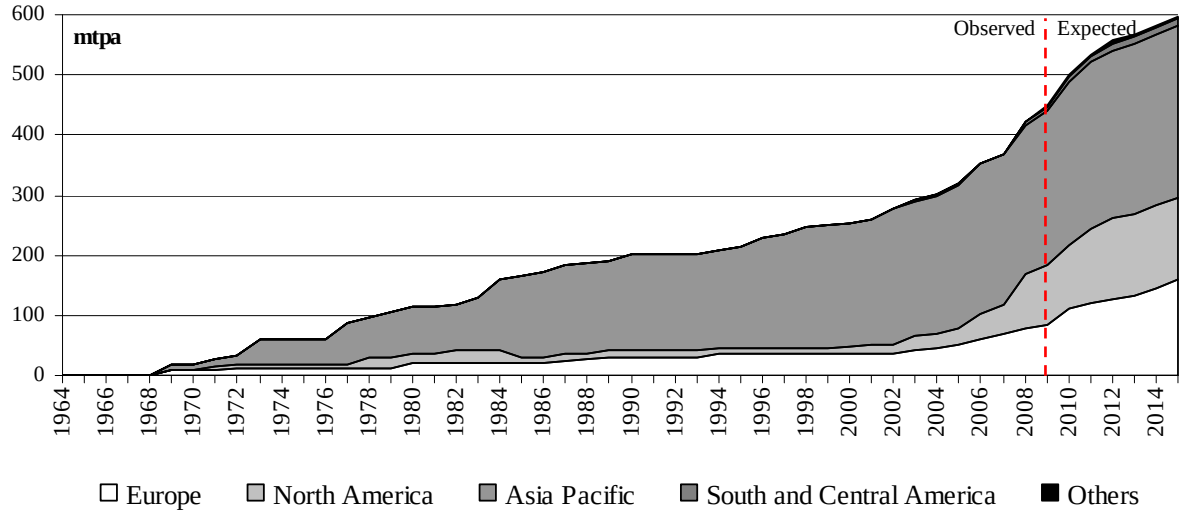
Using a model of the world natural gas market, Huppmann et al. (2009) investigate the impact of a strong demand increase in China and India on global trade patterns. Whereas domestic production levels in the two countries would increase only slightly under this positive demand scenario, imports gain in importance. Regasified volumes in 2030 would increase by 860% for China and by 450% for India as compared to the reference case. Intra-regional pipelines are constructed from Kazakhstan (2015) and Russia (2020) to China as well as from Pakistan (2020) to India, with expansions in later periods. LNG deliveries from the Middle East to Europe and North America decrease by 20% and 47% respectively; exports to Asia increase by 40% and price levels raise. This mirrors that the future development of the supply-demand balance in these emerging economies will have a substantial impact on the global (liquefied) natural gas market.

Two further countries will enter the LNG market until 2015. Singapore is constructing an import terminal in order to secure natural gas supplies. LNG shall complement the current pipeline imports from Indonesia and Malaysia which are used to generate 80% of the country’s electricity supply. Gas demand also is expected to rise due to the substitution of oil-fired power plants for new-built gas-fired capacities as well as the construction of new petrochemical plants. Thailand is constructing an import terminal in order to diversify supply sources. Domestic production is declining and pipeline imports are restricted to deliveries from Myanmar.

3.3.2.5 Summary

Taking the above discussed developments into account, world regasification capacity being operational in 2015 is forecasted to be 596 mtpa, with Europe accounting for 27%, North America (including Mexico) for 23%, Asia for 48%, and South and Central America for 2% of the installed capacities (see Figure 16).

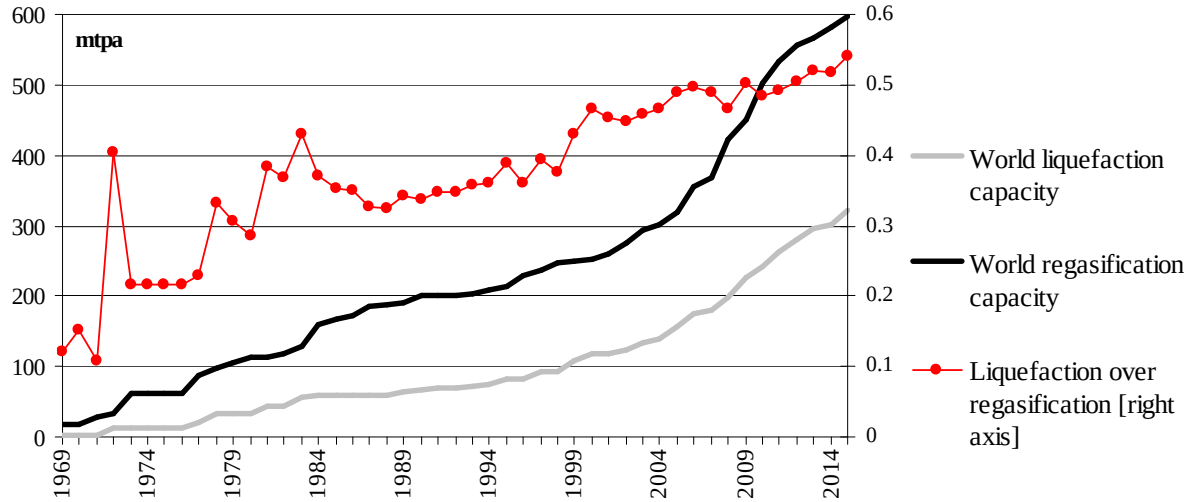
Figure 16: Development of regasification capacities



Source: Own depiction

World regasification capacity is outstripping liquefaction capacity; the ratio of total import over total export capacity approached about 0.5 during the last decades (see Figure 17). To a certain extent this is a natural development since LNG in some countries is a major source of seasonal supply. Korea Gas Corporation for example has a twenty-year long-term supply contract with Yemen LNG over the delivery of 2 million tons of LNG per year; 50% of the annual contracted volume thereby is taken off during the winter months. Other import terminals are run mainly based on short-term and spot deliveries in order to exploit favorable supply-demand situations (e.g., India's Hazira terminal operated by Shell and Total; Excelerate Energy's import facilities in the US, the UK, Argentina, and Kuwait). Moreover, a regasification facility is the cheapest part of the value chain and some players invest in an import terminal in order to enter a new market.

Figure 17: World liquefaction versus regasification capacities



Source: Own depiction

3.4 Vertical structures in the LNG industry

The development of the global LNG market from an infant towards a mature industry has been accompanied by far reaching dynamics in vertical structures within the industry. The following subsections discuss the changing role of traditional long-term contracts and the increasing relevance of short-term and spot trade. A number of oil and gas majors follows a strategy of vertical and horizontal integration investing in a portfolio of export, shipping, and import capacities at the same time that other companies choose a strategy of non-integration operating LNG terminals as 'tolling facilities'. The occurrence of such a menu of governance forms in one and the same industry is very interesting from a New Institutional Economics point of view.

3.4.1 The changing role of long-term contracts

Investments in LNG infrastructure, especially in upstream exploration, production, and liquefaction, are very capital-intensive. Therefore, financing traditionally required the conclusion of long-term sales and purchase contracts before the construction process was initiated (Jensen, 2009a, p. 7). Sellers typically have been state-owned oil and gas majors (e.g., Algerian Sonatrach, Indonesian Pertamina, Malaysian Petronas) and for a minor share joint ventures of private companies (i.e., US' Philipps and Marathon) or of private and state companies (e.g., Brunei Coldgas, a partnership between the state of Brunei, Shell, and Mitsubishi). Buyers typically have been downstream state-controlled utilities (e.g., Gaz de France, Japanese Tokyo Gas and Osaka Gas, Korea Gas Corporation, Turkish Botas, or Spanish Enagas).

The traditional contract was a rigid take-or-pay contract in which the buyer accepted to take-off a certain minimum level in the range of 90% of the nominal contracted quantities (CIEP, 2003, p. 12). The seller in turn accepted a price escalator related to some measure of competing energy prices. Hence, the buyer took the volume risk whereas the price risk was transferred to the seller. Restrictions in destination limited arbitrage trades.

Within the three importing regions, alternative contracting patterns and pricing structures established. Prices for LNG thereby are set either by price competition with domestic gas (mainly US, UK) or by the operation of pricing formulas. When the first LNG contracts were negotiated with Japanese buyers in the 1960s, Japanese power generation was heavily dependent on fuel oil. Pricing clauses therefore tied the price escalation to the Japanese Customs Clearing price, an index of Japanese crude oil import prices. This pricing scheme later was adopted for other Asian contracts, too. In the mid-1990s, the oil-linkage of LNG prices in Asian contracts was softened. So-called 'S-curve' formulas guarantee the interest of the seller if the price of the benchmark crude oil index drops below a certain threshold and protects the buyer from oil prices rising above a certain ceiling.[19] Asian importers traditionally were willing to pay a price premium of about 1 USD/MBTU as compared to LNG buyers in Europe and

[19] The first 'S-curve' formula was applied within a contract concluded between the Australian North West Shelf venture and Japanese customers in 1994. The floor price was set at 16.95 USD/bbl and the ceiling price at 26.95 USD/bbl (Chabrelie, 2003, p. 7).

North America reflecting their concerns about supply security (EIA, 2003, p. 35; IEA, 2009b, p. 521; see also Figure 24 in the Appendix). Continental European pricing structures were effectively originated by the Netherlands' pricing policies for domestic natural gas produced from the Groningen field since 1962. The natural gas price was indexed to light and heavy fuel oil. This pattern later was also adopted for export contracts. More recent (liquefied) natural gas contracts include also prices of other relevant energy sources such as coal, natural gas or electricity (see Figure 25 in the Appendix). The improvement of gas-to-gas competition and increasing liquidity in natural gas hubs should support the establishment of gas market indicators. In contrast, North America and the UK today are characterized by a functioning gas-to-gas competition with long- and mid-term contracts being to a large extent tied to gas market indicators.[20]

As the LNG industry has expanded during the past decade, terms of long-term supply contracts started to change and trade became more flexible. Average contract duration as well as contracted volumes are decreasing in both Atlantic and Pacific Basin markets (see e.g., Hirschhausen and Neumann, 2008; Ruester, 2009a). Destination clauses are eliminated (Energy Charter Secretariat, 2008, pp. 56 f.). Take-or-pay requirements are relaxed and options for additional cargoes are included in recent contracts, e.g., in a recent contract between Korea Gas Corporation and Qatar's Rasgas venture (Chabrelie, 2003, p. 6). Whereas deliveries in the early years of the industry typically have been ex-ship sales, free-on-board (fob) agreements are becoming more common (Eng, 2006; Nissen, 2007b). For fob contracts, the buyer takes ownership of the cargo once it is loaded and has complete flexibility over a potential redirection or resale. For example, Korea Gas Corporation traditionally procured LNG ex-ship but enlarged its tanker fleet recently and now concludes for fob contracts. In 2007, Equatorial Guinea sold its entire LNG output on an fob basis to BG. In 2008, a re-loading facility was inaugurated at the Zeebrugge import terminal. Once a cargo is discharged to the storage tanks, the LNG belongs to the importing company and re-export is feasible without violating the contract. Cargoes sourced originally from Qatar already have been delivered to South Korea, India, Portugal and Spain.

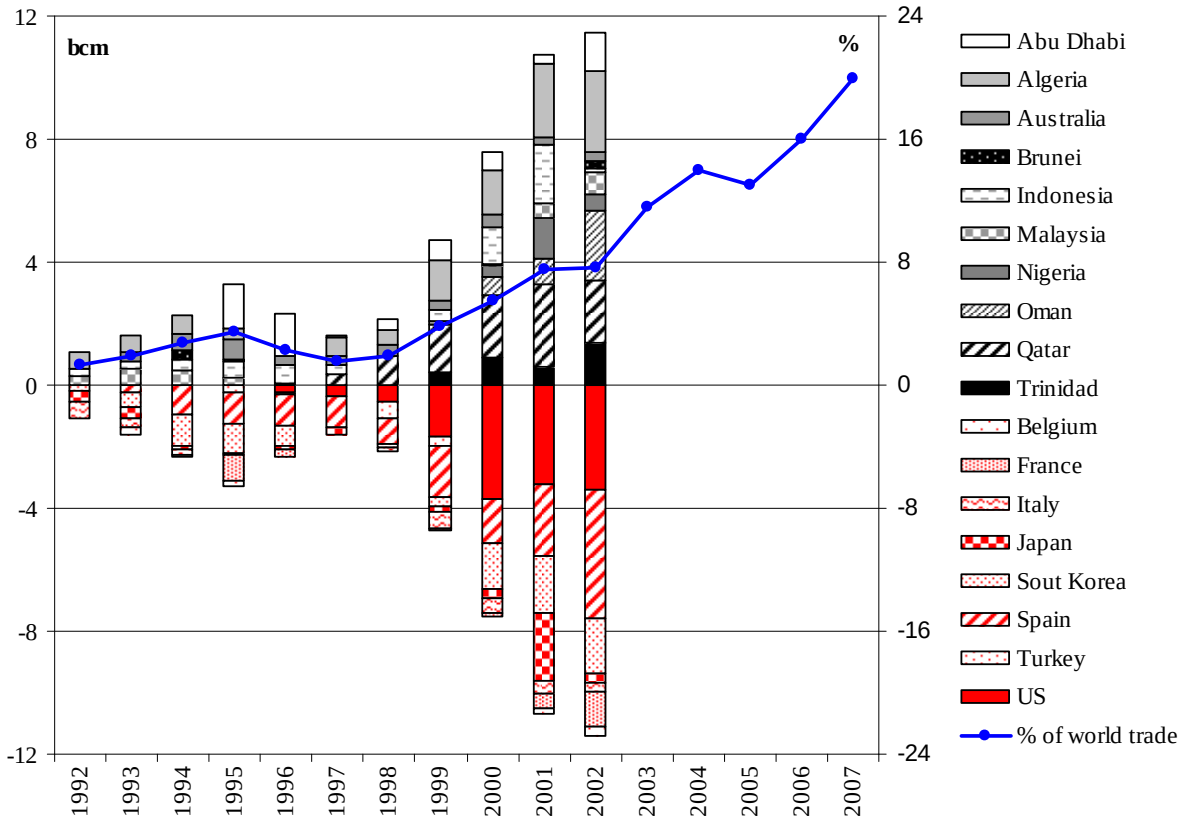
Contract flexibility has also been a major target of buyers when renegotiating existing contracts. The Japanese importers Tokyo Gas and Tokyo Electric Power for example have renegotiated a Malaysian contract to supply a part of the volume fob rather than ex-ship enabling the buyers to resale some cargoes. According to Zhuravleva (2009), it is also becoming common practice to divert contractually committed LNG volumes to third markets given a mutual agreement of both seller and buyer. This increased contract flexibility is supportive to supply security (see also Makholm, 2007, p. 32) since it permits adaptations to short-term changes in the supply-demand balance. The netback value will determine the most attractive market in those cases where LNG shippers are free in the choice of destination.

[20] Suppliers adopt their contracts according to the common pricing structures in the import market; e.g., Qatar links the price for LNG deliveries to crude oil prices in Japan, to fuel oil prices in Continental Europe, and to natural gas spot prices (Henry Hub and NBP) in the US and the UK (Dorigoni and Portatadino, 2008, p. 3372).

Long-term supply contracts allowing the financing of new infrastructures are increasingly accompanied by short-term agreements (less than 3 years) and spot transactions balancing supply and demand in the short- to medium-term. For example, a consortium of Japanese buyers signed contracts with Malaysia to buy 0.68 mtpa for a period of 20 years and an additional 0.34 mtpa for a single year beginning in April 2004. The short-term component is updated annually. This combination of short- and long-term provisions provides much higher volume flexibility than conventional take-or-pay contracts.

The short-term market established not before the 1990s with the first arbitrage trades and swap agreements appearing in the early 2000s (Energy Charter Secretariat, 2008, pp. 57 ff.). Electricité de France (holding 3.3 mtpa at Zeebrugge and 0.7 mtpa at Montoir) has signed a swap agreement with the US-based Dow (3.75 mtpa at Freeport) offering each party a slot of 1 bcm per month of import capacity at the other company's import terminals.[21] The additional margin is shared among Electricité de France, Dow and the supplying company. A similar trans-Atlantic swap agreement involves Suez and ConocoPhilipps. Major short-term and spot volumes today are supplied by Qatar, Algeria, and Oman; main buyers have been the US, Spain and South Korea (see Figure 18).

Figure 18: Development of short-term and spot trade



Source: Own depiction based on data from EIA (2003), Cornot-Gandolphe (2005), Jensen (2009b)

[21] Electricité de France's supply for Zeebrugge from Qatar's Rasgas project is interruptible at the supplier's option, which explains why many of its Zeebrugge slots are not used.

However, there may be technical and economic constraints limiting arbitrage activities. First, free capacities have to be available along the value chain including liquefaction plants (sellers may utilize volumes during the ramp-up period of a contract), shipping and storage at the downstream regasification plants. Second, gas quality differs by natural gas source (see Table 9 in the Appendix) and import facilities constructed during the early years of the industry have been designed to receive LNG of a certain composition. However, it is technically feasible to endow import terminals with natural gas adaptation equipment allowing for a decrease (i.e., nitrogen injection; mainly necessary in the UK and the US) or increase (i.e., propane injection; mainly Asian importers) of natural gas quality in order to meet grid requirements. Third, during the loading and shipping period, typically between four days (e.g., Trinidad/Tobago to the US Gulf Coast) and two weeks (e.g., Qatar to Japan), spot prices in the destination country may change.

For the near-term future, the outlook for spot LNG trade is quite modest and will critically depend on how quickly the global economy recovers from the current recession. Many buyers that have been active in spot- and short-term trade currently can meet their gas requirements by their long-term contracts and some even have to demand downward adjustments in volume flexibility due to weak consumption levels (IEA, 2009b, p. 529). For the longer term, the outlook is more optimistic. LNG exporters increasingly dispose of uncommitted liquefaction capacities. The overhang in regasification capacities facilitates downstream market access for non-incumbents and the increasing liquidity of European trading hubs enhances price transparency.

3.4.2 Recent trends towards vertical and horizontal integration

After the analysis of contracting practices for the supply of LNG, the following discussion addresses corporate structures in the sense of vertical and horizontal integration (and non-integration) within the LNG industry. The role of private and state-owned oil and gas companies, partnerships, and organizational forms with respect to the operation of LNG facilities are investigated.

Joint ventures always have been a common form of organization within the LNG industry for two main reasons. First, the large investment costs associated with upstream exploration, production and liquefaction ventures makes it difficult for one single company to develop and finance the project on its own. Joint ventures are set up in order to share the risks and financial burden. Partnerships between private oil and gas companies have formed: e.g., for Alaska LNG (ConocoPhillips and Marathon) or for the North West Shelf Venture in Australia (BHP Billiton, BP, Chevron, Mitsubishi/Mitsui, Shell, and Woodside Energy). Second, a joint venture with the incumbent NOC is likely (e.g., Abu Dhabi, Egypt, Indonesia, Nigeria, Russia or Qatar). On the one hand, NOCs seek to retain control over natural gas reserves; on the other hand, private majors contribute to the partnership technological knowledge and marketing channels. In summary, 15% of the existing nominal liquefaction capacities are owned and operated by joint ventures between private majors, the majority of 76% is controlled by partnerships between NOCs and private partners, and the remaining 9% of the capacities are operated by NOCs without any third party (i.e., Algeria, Libya).

Forward integration from the upstream to the downstream sector is a governance form which has become characteristic for the industry with players controlling capacities along successive stages of the value chain. Upstream producers aim to benefit from downstream margins. One recent phenomenon is the increasing employment of self-contracting. Thereby, the seller concludes for a sales-and-purchase agreement with its own marketing affiliate as has been realized at Qatar's Qatargas and Rasgas liquefaction projects (Exxon Mobil, Qatar Petroleum, and Total), in Trinidad/Tobago (BP, Repsol, and BG), or Norway (Statoil and Gaz de France). In Nigeria, the first three trains of the Bonny Island venture were dedicated to traditional long-term take-or-pay contracts concluded between the venture and European buyers. For trains 4 and 5 in contrast, Shell and Total (holding equity shares in the liquefaction plant) self-contracted certain volumes. In total, eleven companies have self-contracted for about 1,660 bcm of LNG over the period from 2009 to 2025 (IEA, 2009b, p. 527).

In one version of this commercial business model, the LNG export project is operated as a tolling facility selling the services of liquefaction, storage, and loading to the LNG merchant (see also Nissen, 2004; 2006) and natural gas producers rather than the venture become the sellers of natural gas. This structure has been adopted for example in Egypt where the BG Group and BP act as merchant traders at the Idku plant and the Spanish Union Fenosa at the Damietta facility. Alternatively, the venture's project partners buy the LNG from the project.

The unbundling of transportation assets and services from rigid export-import project relationships is a major precondition for flexible trade and the control of non-committed shipping capacities has become of strategic value in today's LNG market. Private players have invested in a significant number of vessels during the last decade: Shell controls 30 carriers through joint ventures and direct ownership. Exxon Mobil and Qatar Petroleum have a fleet of 27 ships. The BG Group owns eight vessels and recently ordered another four ships. Several other companies entered the midstream shipping stage during the 2000s (e.g., BP, Gaz de France, and Osaka Gas). As already discussed above, the number of uncommitted ships has increased from approximately zero before 2000 to 49 in 2009 (of a total of 337 ships representing 14% of total shipping capacity).

Self-contracting accompanied with investments in a portfolio of upstream and downstream positions and uncommitted ships enables the players to decide where to send LNG cargoes on a shorter-term basis and to take advantage of favorable price conditions. Three case studies shall demonstrate the successful employment of this strategy: Shell disposes of LNG export positions in Australia, Brunei, Malaysia, Nigeria, Oman, and Russia at the same time that the company holds capacity rights at import terminals in India and Mexico. It will continue its expansion within the industry and participate in projects proposed for France, Italy, and Brazil. Similarly, Total has built up a portfolio of export positions in all three exporting regions and import positions in India, Mexico, and France. Exxon Mobil and Qatar Petroleum entered a partnership in the late 1990s. In order to mitigate supply costs given the long distance from the Middle East to consuming centers, they constructed the largest liquefaction facilities (7.8 mtpa trains) and ordered the largest vessels (>210,000 m^3) ever, thus

realizing substantial economies of scale. At the same time, the partners secured capacity rights at import terminals on both sides of the Atlantic (South Hook in the UK, Rovigo in Italy and Golden Pass in the US).

Backward integration from the downstream to the upstream sector is observed, too. Traditional natural gas distributors increasingly participate in LNG export ventures, motivated mainly by supply security considerations: Gaz de France holds shares in Egypt's Idku project and Norway's Snovhit LNG; Union Fenosa participates in Oman's expansion train; and Tokyo Gas in Australia's Darwin project. Also electricity companies, forming part of the extended value chain including natural gas-fired power production, enter the stage. Whereas Spain's first LNG terminals were operated by Enagas, traditional electricity companies (Union Fenosa, Endesa, and Iberdrola) are now the dominant investors. AES Corporation, the operator of a 319 MW gas-fired power plant in the Dominican Republic also owns and operates the country's LNG import terminal. Electricité de France proposed a regasification facility in the Netherlands. Some Japanese power producers even integrate further upstream: Tokyo Electric Power holds a share in Australia's Darwin project and Kansai Electric will participate in the Pluto venture. Hunger (2003) and Newbery (2007) provide theoretical analyses of the ongoing convergence of the natural gas and electricity sectors.

In contrast to these integrated players, there are also some new entrants into downstream LNG markets which follow a strategy of non-integration: With the upcoming enthusiasm for LNG needs within North America in the early 2000s, Cheniere Energy entered the market and applied for the construction of four onshore LNG import facilities at the Gulf coast which should be operated as tolling facilities. The Freeport LNG and Sabine Pass projects were commissioned in 2008. However, as discussed above, the US' supply-demand balance altered throughout the last years. With the development of substantial unconventional resources, increased domestic production is outstripping higher cost LNG supplies. Thus, the two terminals suffer from low utilization rates. Plans to build the additional facilities are dormant at the moment and it is very unlikely that these projects will be realized in the next decade. In fact, recent developments have resulted in liquidity problems for the company and Cheniere had to lay off more than half of its 360 employees in April 2009.

Another entrant is Excelerate Energy, founded in 1999. In 2008, the German RWE acquired a 50% stake in the company. Excelerate employs an innovative technology of offshore, onboard regasification. Five import facilities have been already been built with the Gulf Gateway (start-up 2005) and Northeast Gateway (2008) in the US, Teesside GasPort in the UK (2007), Bahía Blanca GasPort in Argentina and Mina Al-Ahmadi GasPort in Kuwait (both 2008). An additional facility is proposed for Germany offshore Wilhelmshaven. However, industry experts report that only minor deliveries took place up to today through these facilities. The non-integrated players still have to prove to be successful in an industry, which a long time has been a sellers' market without major uncommitted export capacities, and in which also in the longer-term future, once, the economic crisis is overcome, importers are expected to continue to compete for global supplies.

3.5 Summary and conclusions

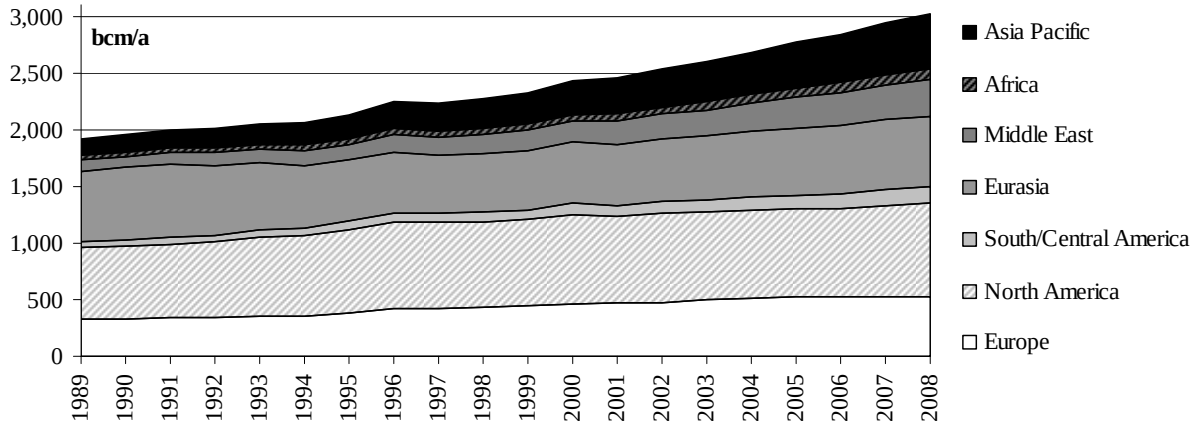
This chapter has discussed recent dynamics in the global LNG market, which developed from an infant towards a mature industry during the last decade. Capacities along all stages of the value chain more than doubled since 2000 and numerous players, countries as well as companies, entered the market. Long-term contracts gained in flexibility and are increasingly accompanied by short-term trades. Whereas the early industry typically was characterized by ex-ship take-or-pay contracts concluded between the upstream project and downstream utilities with the import terminal being part of the integrated value chain, today, explicit destination flexibility regularly is requested. LNG players increasingly invest in a portfolio of import positions and uncommitted shipping capacities enabling flexible trade. Some new import terminals are operated as merchant terminals, receiving spot cargoes and lacking any long-term supply contracts (e.g., India's Hazira facility), others are operated as tolling facilities, with the owner selling unloading, storage, and regasification services (e.g., UK's Grain LNG).

The coming five years will see expansions in export and import capacities even though the recent decrease in global energy demand, falling cash flows, and a tight credit market have led to a drop in investments in large-scale energy projects. Long lead times in the construction of LNG facilities result in a delayed supply response to the demand growth observed during the past five years and numerous projects which currently are under construction will start operation until 2015 creating an oversupply in the market for the short-term. On the supply side, the Middle East will become a major exporting region and amplifies the globalization of the natural gas market delivering LNG to both Atlantic and Pacific Basin customers. On the demand side, emerging economies in Asia represent a major source of uncertainty concerning future LNG demand and competition for global supplies. For the longer-term, the development of LNG depends on several factors such as natural gas' relative competitiveness compared to coal in power generation, environmental policies, or the exploration and cost structure of unconventional natural gas sources.

Various governance forms co-exist in the LNG industry, including the poles of spot market transactions and vertical integration as well as numerous hybrid forms such as long- and short-term contracts, joint ventures and strategic partnerships. Frequently, the same company chooses different governance modes along alternative value chains. Furthermore, different companies follow varying strategies even though they traditionally operate in similar stages of the value chain. These observations represent a suitable base for empirical studies investigating firms' motivations to choose alternative organizational structures. Therefore, the following chapters empirically investigate, based on transaction cost economics and recent extensions thereof, i) the likelihood of vertical integration and the impact of inter-organizational trust on the choice of more or less hierarchical governance modes; ii) the relationship between strategic positioning in the market, relationship-specific investments, and governance form, iii) and the choice of optimal contract duration of long-term supply contracts.

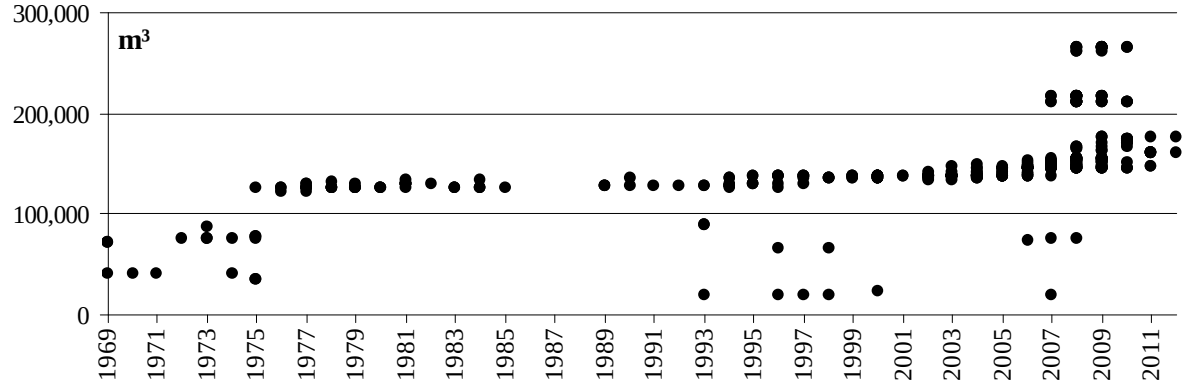
3.6 Appendix

Figure 19: Development of world natural gas consumption



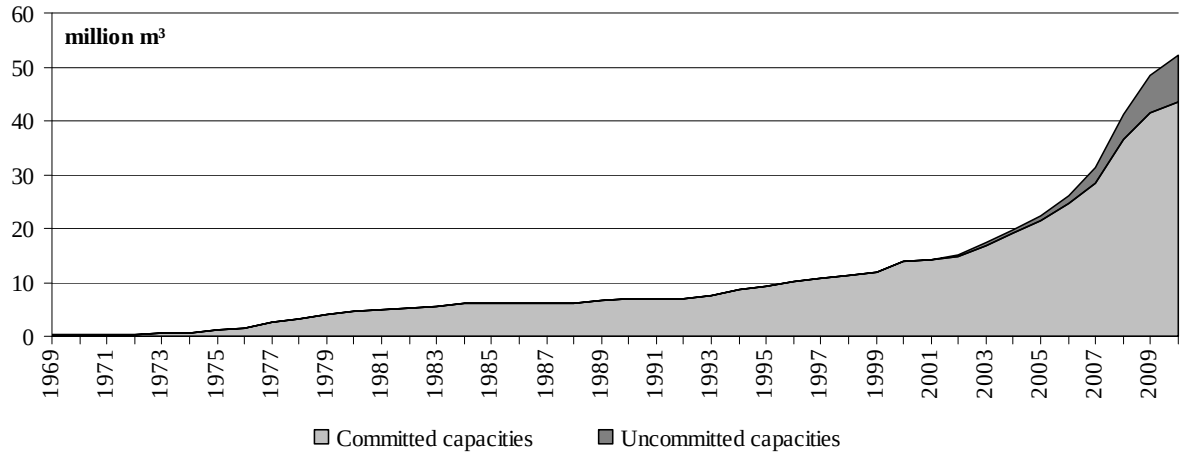
Source: Own depiction based on data from BP Statistical Reviews of World Energy

Figure 20: Development of vessel capacity by start-up year



Source: Own depiction based on data from http://www.shipbuildinghistory.com

Figure 21: Development of shipping capacities



Source: Own depiction based on data from http://www.shipbuildinghistory.com

Table 6: Existing and proposed liquefaction facilities as of 2009

Country	Existing sites	Nominal capacity [mtpa]	Under construc-tion	Nominal capacity [mtpa]	Proposed	Nominal capacity [mtpa]
Atlantic Basin						
Algeria	2	20.2	1	4.5	-	-
Angola	-	-	1	5.2	-	-
Egypt	2	16.2	-	-	-	-
Equatorial Guinea	1	3.7	-	-	exp.	4.4
Libya	1	0.6	-	-	exp.	3.2
Nigeria	1	20.3	-	-	3	40
Norway	1	4.3	1	0.3	-	-
Trinidad/Tobago	1	14.8	-	-	exp.	3
Venezuela	-	-	-	-	1	4.7
Total	***9***	***80.1***	***3***	***10***	***4***	***55.3***
Pacific Basin						
Australia	2	19	1	4.3	5	37.5
Brunei	1	7.2	-	-	-	-
Indonesia	3	35.1	-	-	2	4
Malaysia	1	22.7	-	-	-	-
Peru	-	-	1	7	-	-
Russia	1	9.6	-	-	1	7.5
US	1	1.4	-	-	-	-
Total	***9***	***95***	***2***	***11.3***	***8***	***49***
Middle East						
Abu Dhabi	1	4.8	-	-	-	-
Iran	-	-	-	-	3	28.8
Oman	1	10.7	-	-	-	-
Qatar	2	35.7	exp.	31.2	exp.	7.8
Yemen	-	-	1	6.7	-	-
Total	***4***	***51.2***	***1***	***37.9***	***3***	***36.6***
Total	**22**	**226.3**	**6**	**59.2**	**15**	**140.9**

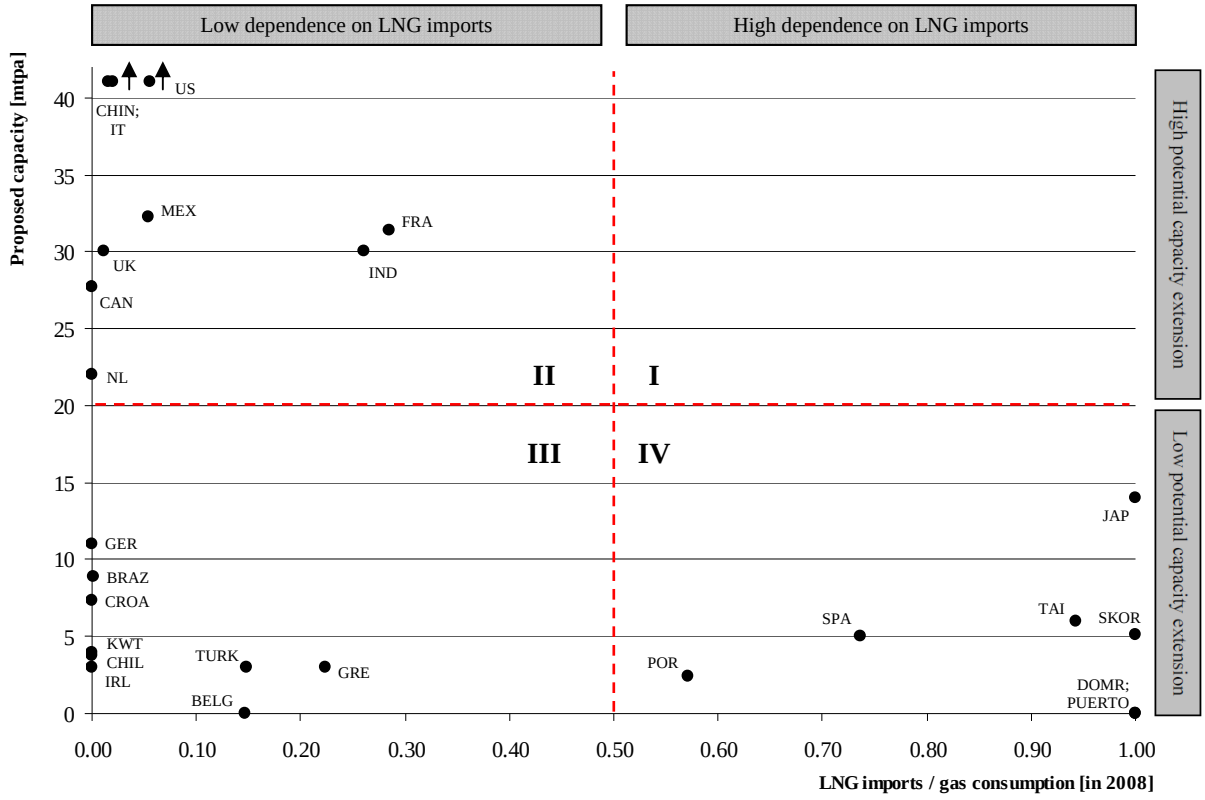
Source: Own depiction based on data from various publicly available sources

Table 7: Existing and proposed regasification facilities as of 2009

Country	Existing sites	Nominal capacity [mtpa]	Under construc-tion	Nominal capacity [mtpa]	Proposed	Nominal capacity [mtpa]
Atlantic Basin						
Argentina	1	2.2	-	-	-	-
Belgium	1	6.3	-	-	-	-
Brazil	1	1.6	1	3.7	2	3.6
Canada	-	-	1	3.6	5	24.1
Canaries	-	-	-	-	1	1.3
Croatia	-	-	-	-	1	7.3
Dominican Republic	1	2	-	-	-	-
France	2	10.7	1	6.1	4	19.3
Germany	-	-	-	-	2	11
Greece	1	3.3	-	-	-	-
Ireland	-	-	-	-	1	3
Israel	-	-	-	-	1	2.9
Italy	1	2.6	3	21.3	13	75
Jamaica	-	-	-	-	1	1.1
Mexico	1	3.6	-	-	-	-
Netherlands	-	-	-	-	4	24.7
Portugal	1	4	-	-	-	-
Puerto Rico	1	0.7	-	-	-	-
Spain	6	33.5	1	5	-	-
Turkey	1	4.6	-	-	1	~ 3
UK	3	20	1	4.5	3	15.7
Uruguay	-	-	-	-	1	2.6
US	8	88.7	3	29.6	25	~ 51
Total	***29***	***183.8***	***11***	***73.8***	***65***	***194.6***
Pacific Basin						
Chile	-	-	-	-	2	4
China	3	9.3	2	6	12	45
El Salvador	-	-	-	-	1	0.8
Hong Kong	-	-	-	-	1	3
India	2	8.6	1	5	7	22.5
Indonesia	-	-	-	-	4	9
Japan	23	176.3	1	3.7	5	~ 10
Mexico	1	7	1	3.8	4	20.9
Philippines	-	-	-	-	2	2.4
Singapore	-	-	1	3	-	-
South Korea	4	53.6	-	-	1	5
Taiwan	1	7.4	1	3	1	3
Thailand	-	-	1	5	-	-
Total	***34***	***262.2***	***8***	***29.5***	***40***	***115.6***
Middle East						
Dubai	-	-	-	-	1	3
Kuwait	1	3.8	-	-	-	-
Pakistan	-	-	1	3	-	-
Total	***1***	***3.8***	***1***	***3***	***1***	***3***
Total	**63**	**449.8**	**20**	**106.3**	**105**	**310.2**

Source: Own depiction based on data from various publicly available sources

Figure 22: Import country matrix

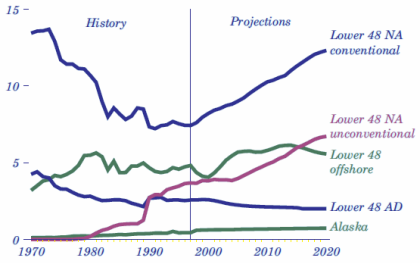
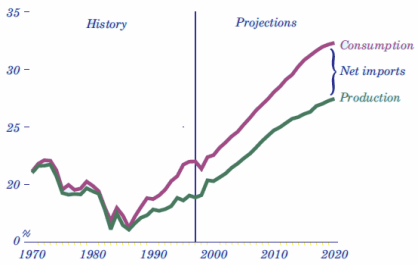
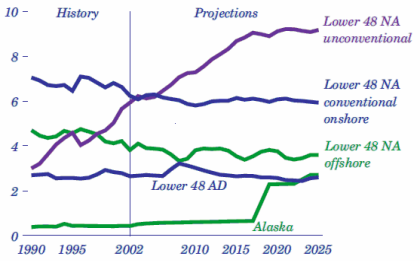
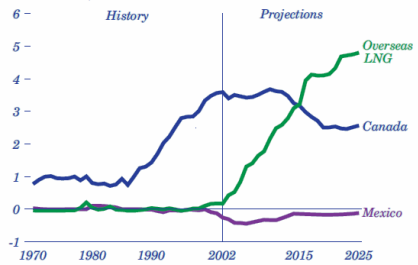
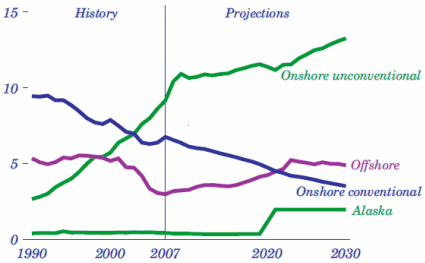
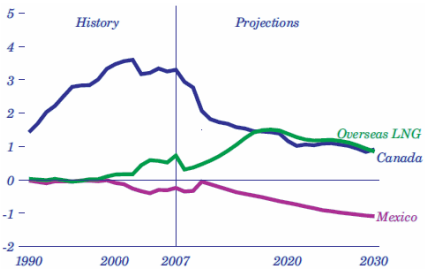


Source: Own depiction

Figure 22 classifies LNG import countries according to their dependence on natural gas imports in the form of LNG and the level of proposed new capacities (irrespective of the probability of realization of these capacities). Quadrant I thereby indicates countries with a high dependence on LNG imports and a high level of proposed new capacities which would indicate a low level of short-term physical supply security. No country is situated within this area. In contrast, there are many players within Quadrant II, characterized by numerous project proposals, too, but a low dependence on imports. These markets are expected to grow (e.g., China, India).[22] Diversification of energy sources and natural gas supply routes is one motivation to expand LNG capacities (e.g., France, Italy). Other countries have to come up against decreasing domestic production (e.g., UK, Netherlands) or plan to expand re-exported volumes (e.g., Mexico, Canada, UK). Quadrant III mainly represents (potential) new entrants into the LNG market (e.g., Brazil, Kuwait) and small players in the market (e.g., Greece, Turkey, Belgium). Quadrant IV includes mature markets with a high dependence on LNG imports where significant investments have been realized in the past (e.g., Japan, Spain).

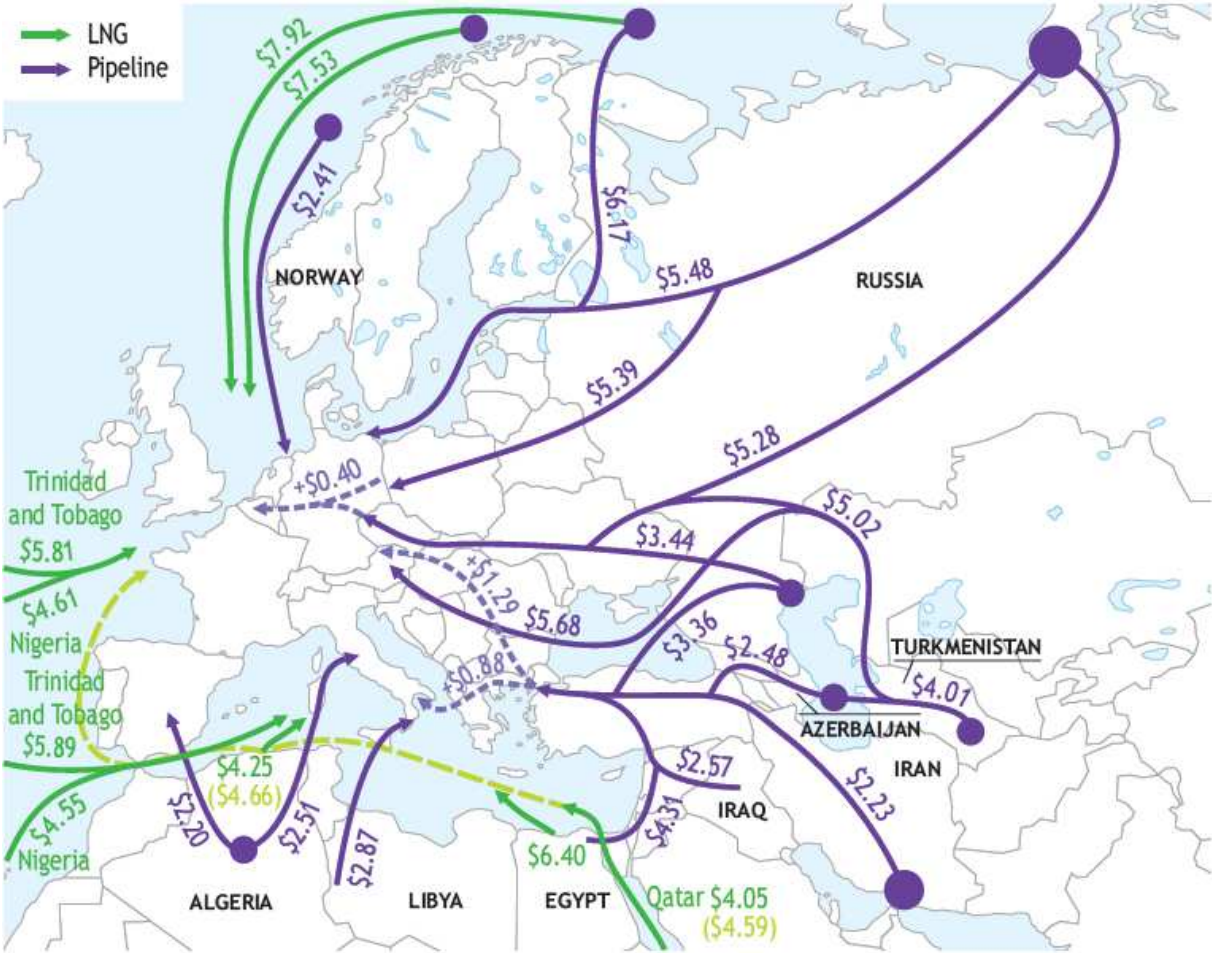
[22] The US represents an exemption due to the recent change in the domestic supply-demand balance. Projects proposed during the last decade not being under construction yet are very unlikely to be realized in the near- to mid-term.

Table 8: EIA Annual Energy Outlook projections over time (reference case)

Year of publication	Supply sources	Net imports	Average annual increase in demand (%)
1999 (p. 71)	 - Most production expected from conventional sources - Unconventional: ~7 tcf in 2020 (200 bcm)	 - Most imports from Canada - LNG not expected to grow on a significant scale	1% for the period 1999-2020
2004 (pp. 90-91)	 - Most production expected from unconventional sources - Unconventional: ~9 tcf in 2025 (255 bcm)	 - LNG expected to gain in importance with ~5 tcf in 2025 (140 bcm)	1.4% for the period 2002-2025
2009 (pp. 77-78)	 - Significant potential of unconventional sources forecasted - Unconventional: ~12 tcf in 2025 (340 bcm) and ~14 tcf in 2030 (400 bcm)	 - LNG prospects corrected downwards with ~1 tcf in 2030 (28 bcm)	0.2% for the period 2007-2030 (decline in the short-run for 2008-2011)

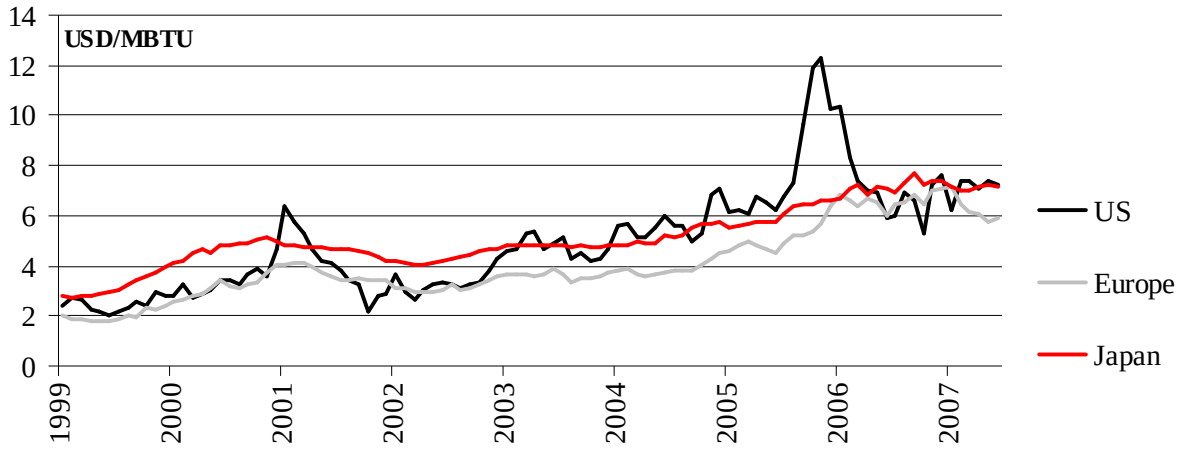
Source: Own depiction based on EIA (1999, 2004, 2009b)

Figure 23: Supply costs for potential sources of gas delivered to Europe (USD/MBTU)



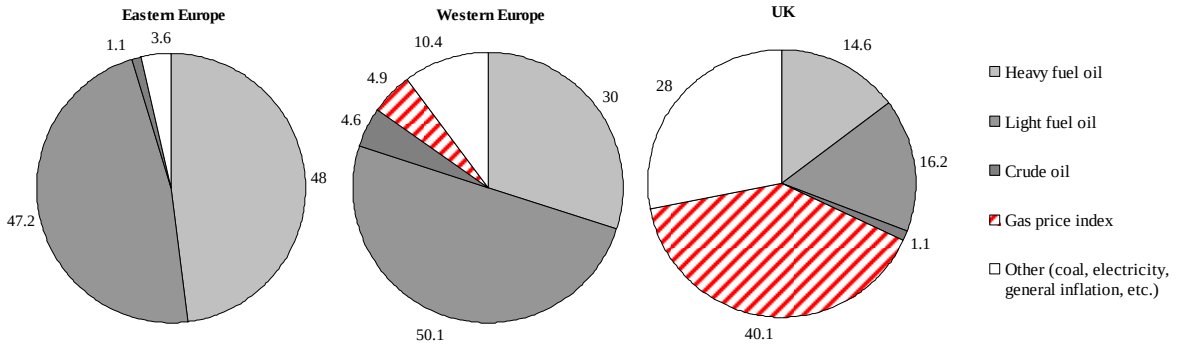
Source: IEA (2009b, p. 482)

Figure 24: Average LNG import prices (monthly data)



Source: Own depiction based on data from IEA Energy Prices and Taxes

Figure 25: Oil-linkage in long-term natural gas contracts



Source: Own depiction based on data from Stern (2007, pp. 9 f.)

Table 9: LNG characteristics

Origin	Nitrogen %	Methane %	Ethane %	Propane %	C4+ %	LNG density kg/m³	Gross calorific value MJ/m³ [gas]
Algeria-Arzew	0.6	88.0	9.0	2.0	0.5	464	44.1
Algeria-Beth. 1	1.2	87.6	8.4	2.1	0.7	469	44.0
Algeria-Beth. 2	0.9	91.4	7.2	0.5	0.0	451	42.1
Algeria-Skikda	1.0	91.2	7.0	0.7	0.1	453	42.2
Egypt-Damietta	0.08	97.7	1.8	0.2	0.2	427	40.8
Egypt-Idku	0.0	97.2	2.3	0.3	0.2	430	41.0
Equat. Guinea	0.0	93.4	6.5	0.0	0.0	439	42.0
Libya	0.7	81.6	13.4	3.7	0.7	485	46.6
Nigeria	0.1	91.3	4.6	2.6	1.4	458	44.2
Norway	0.8	91.8	5.7	1.3	0.4	451	40.1
Trinidad/Tobago	0.0	96.8	2.7	0.3	0.1	432	41.0
Abu Dhabi	0.3	84.8	13.2	1.6	0.1	467	44.9
Oman	0.4	87.9	7.3	2.9	1.6	470	45.3
Qatar	0.4	90.1	6.2	2.3	1.0	460	44.0
US-Alaska	0.2	99.7	0.1	0.0	0.0	423	39.9
Australia	0.1	87.4	8.3	3.4	0.8	467	45.3
Brunei	0.1	90.6	5.0	2.9	1.5	461	44.6
Indonesia-Arun	0.2	90.7	6.2	2.0	1.0	457	43.9
Indonesia-Badak	0.0	91.2	5.5	2.4	0.9	456	43.9
Malaysia	0.3	90.3	5.3	3.1	1.1	461	44.3

Source: GIIGNL (2008, p. 8)

4 Inter-organizational Trust as a Shift Parameter in the Extended Transaction Cost Framework

4.1 Introduction

Even though the huge body of empirical literature testing transaction cost economics' predictions has increased the understanding of post-contractual hold-up, transaction cost economics in its basic form is a static concept taking the institutional environment as given. This has been a major point of criticism and motivated Oliver Williamson to introduce an extension of the transaction cost economics model. The shift parameter framework investigates how the optimal choice of governance changes in response to dynamics in the institutional environment. Changes in exogenous parameters (such as the stability of property rights, improvements in contract law, reputational effects in networks, or varying levels of uncertainty) will shift the relative costs of alternative governance structures. The impact of both transaction characteristics and the institutional environment on governance choice are analyzed (Williamson, 1991b).

Transaction cost economics discusses post-contractual hazards under the assumption that the investing party faces an opportunistic counterpart with formal contractual arrangements and internal organization being the only possible safeguards against ex-post expropriation of quasi-rents. However, inter-organizational trust, a concept intensively studied in social sciences and psychology, can attenuate the incentives to behave opportunistically. Immediate gains from opportunism must be traded off against future costs since unreliable behavior would be punished with respect to future exchange relationships. The presence of inter-organizational trust should enhance information exchange, support conflict resolution, and decrease transaction costs. Thus, trust reduces the need for hierarchical controls and should favor the choice of less hierarchical (i.e., more relational) governance modes.

The following study contributes to the empirical literature an analysis that examines the effect of both transaction characteristics and the institutional environment on the choice of governance in the global LNG industry where vertical integration and strategic partnerships have become a common organizational form at the same time that short-term trade is continuously increasing in volume. Using a dataset of 237 corporate-specific value chains, I introduce inter-organizational trust as a shift parameter. First, following transaction cost economics, it is hypothesized that specific investments under uncertainty provide incentives to integrate vertically. Second, it is argued that inter-organizational trust changes the relative costs of vertical integration and non-integration and supports less hierarchical governance modes.

These economic relationships are tested i) based on a probit model to explain the binary choice between vertical integration into midstream shipping and non-integration and ii) based on an ordered probit model to explain the degree of vertical integration (i.e., non-integration versus integration from upstream or downstream into midstream shipping versus integration along the whole value chain).

Estimation results provide broad support for transaction cost economics by showing that relationship-specific investments in an uncertain environment drive LNG companies to invest in successive stages along the value chain. The presence of inter-organizational trust increases the likelihood of less hierarchical governance modes. The consideration of a shift parameter further enhances the explanatory power of the model supporting the need for empirical studies accounting for both transaction cost variables as well as variables capturing dynamics in the institutional environment.[23]

4.2 Literature review

Empirical literature testing the shift parameter framework is rather scarce. The first application is Oxley (1999) who investigates the impact of intellectual property protection on the structure of inter-firm technology transfer alliances linking US and non-US firms. Finding support for transaction cost economics' hypotheses she shows that more hierarchical alliances (i.e., equity joint venture instead of a contractual alliance) are more likely in the presence of weak intellectual property protection. A strong protection of intellectual property is achieved only when property rights are easy to establish, interpreted broadly and strictly enforced. Weak protection will result in an increased appropriability hazard and support the choice of more hierarchical governance modes.

Henisz and Williamson (1999) discuss the concept of shift parameters for national and multinational firms focusing on the impact of weak (respectively strong) property rights and on the stability of contract law on governance choice (e.g., partnership between the foreign and a host-country firm). They argue that within a single country, the choice is mainly determined by the attributes of the transaction. Comparing corporate behavior over time or across countries, a higher credibility of the institutional environment (i.e., secure property rights, stable contract law) will support complex transactions and governance forms. High political hazards should support partnering of multinational firms with host-country entities.

Gulati and Nickerson (2008) analyze the impact of inter-organizational trust as a shift parameter on governance choice and the performance of exchange relationships in the US auto industry using a survey of component buyers at Ford Motor Company and Chrysler Corporation. Estimation results of a three-stage switching regression model[24] support transaction cost theory's predictions. Further, the authors' hypotheses of exogenous trust enhancing performance both directly and indirectly are confirmed. On the one hand, an increase in inter-organizational trust directly enhances firm performance; on the other hand, it shifts the likelihood of organizational choice from hierarchy to the market (i.e., a more expensive mode of governance is substituted by a less expensive one) and hence indirectly enhances firm performance, too.

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[23] This chapter builds on Ruester (2009b).

[24] In the first stage regression, inter-organizational trust is explained as a function of exchange attributes and a number of antecedents of pre-existing trust; the second stage explains governance choice (i.e., buy, ally, and make) as a function of transaction attributes and the predicted level of trust; the third stage switching regression explains exchange performance as a function of governance choice, transaction attributes, and the predicted level of trust.

4.3 Theoretical background

The following paragraph discusses the concept of inter-organizational trust and its relation to inter-personal trust. It is assessed whether relational and formal contracts should be regarded as complements or substitutes. After a formalization of the shift parameter framework, industry-specific propositions are derived.

4.3.1 Inter-personal and inter-organizational trust

The past decade has shown increased interest in investigating the sources and consequences of trust in economic exchanges. Recent literature encompasses research in the fields of social psychology, organizational theory, strategic management, business history, and economics. Gulati and Sytch (2008) provide a detailed literature review, Gulati and Nickerson (2008, p. 690) a survey of empirical studies showing that trust is an important element of market exchanges.

Traditional transaction cost economics argues that exchange relationships involving non-redeployable investments create ex-post bilateral dependency and vulnerability to opportunistic behavior, trust does not yield a reliable safeguard unlike formal modes of governance. On the contrary, trust is understood as an important mean to mitigate relational risks in the social science literature which argues that economic players may not always behave opportunistically. There is an emerging view that in the governance of exchange relationships non-economic, social factors complement economic ones (see e.g., Zaheer and Venkatraman, 1995).[25] Woolthuis et al. (2005, p. 816) argue that "…the assumption that actors have an intrinsic tendency to keep promises is as true as their likelihood to behave opportunistically."

A narrow definition is called for when delineating the concept of trust from traditional economic terms. Zaheer et al. (1998, p. 143) define trust as "the expectation that an actor (1) can be relied on to fulfill obligations, (2) will behave in a predictable manner, and (3) will act and negotiate fairly when the possibility for opportunism is present." In other words, trust is based on reliability, predictability, and fairness. Similar definitions appear in Woolthuis et al. (2005, p. 816), Gulati and Sytch (2008, p. 167), and Gulati and Nickerson (2008, p. 689).

Dispositional trust reflecting expectations about the trustworthiness of others in general is distinguished from relational trust which is based on experience and interaction with a particular exchange partner (Zaheer et al., 1998; Gulati and Sytch, 2008).[26] The focus of the following discussion will be on the latter. Williamson (1993a) distinguishes calculative trust (i.e., refers to a rational form of trust built upon reputation and can be understood in terms of risk), personal trust (i.e., altruistic behavior not depending on calculations of self-interest but being motivated by benevolence), and institutional trust (i.e., derives from social and organizational embeddedness). Partly in line with this

[25] Zaheer and Venkatraman (1995, p. 374) discussing the complementarity of social and economic factors claim that "the significant social component in economic action is generally ignored in economic explanations of exchange activity, and is frequently consigned to the error term or to 'noise'."

[26] Woolthuis et al. (2005) discuss 'competence trust' and 'intentional trust' which correspond to dispositional and relational trust respectively.

last classification, Gulati and Nickerson (2005) discuss exogenous trust (i.e., arising out of past interactions) as opposed to endogenous trust (i.e., intrinsic to the governance mode). Organizational arrangements may reduce the likelihood of opportunistic behavior since they provide a basis for trust by creating incentives, providing administrative controls and a means for solving disputes.

Trust in its relational form can be understood as an endogenous variable being determined by the history of prior interactions between trading partners as well as by their evaluation of the future value of the relationship. For example, potential partners can jointly adjust the incentives to make trustworthy behavior an economically preferable option, select firms which engage in non-opportunistic behavior, etc. Trust increases due to learning about the partner and his likely behavior as well as due to improved coordination processes among firms. Contracts furthermore are self-enforcing if the present value of continuing the relationship exceeds the value of deviating from the implicit contractual terms. Fehr (2009) provides a literature review on recent research addressing the presence of inter-personal trust and its formation.

A trust relationship becomes particularly valuable in situations characterized by risk and (behavioral) uncertainty. Higher levels of trust are related to reduced negotiation costs, less severe conflicts and easier problem solving, superior information sharing, and high levels of cooperation. Negotiations are less costly in the presence of trust because agreements are reached more quickly and easily. Trust mitigates information asymmetries by allowing more open sharing of information. When unforeseen contingencies arise, high trust facilitates the development of a common understanding about the contingencies and how they might be resolved. The presence of trust reduces transaction costs by reducing or eliminating opportunism. Indeed, a number of papers find that trust in inter-firm exchanges can be a source of competitive advantage. Gulati and Nickerson (2005) discuss the central role of exogenous inter-organizational trust in both directly enhancing exchange performance and indirectly enhancing performance by supporting the use of less hierarchical (i.e., less costly) governance.

Whereas the early literature focused on inter-personal trust (relationships between individuals such as boundary spanners who handle and manage inter-organizational exchange), later studies explicitly delineate inter-organizational trust (relationships between entities). Zaheer et al. (1998, p. 141) point out that “a fundamental challenge in conceptualizing the role of trust in economic exchange is extending an inherently individual-level phenomenon to the organizational level of analysis. Not clearly specifying how trust translates from the individual to the organizational level leads to theoretical confusion about who is trusting whom.”

Gulati and Sytch (2008, p. 171) argue that there are at least two mechanisms that contribute to the development of inter-organizational trust from the history of interaction between individuals representing their entities (i.e., organizational boundary spanners). First, emerging interpersonal trust between boundary spanners is likely to transform with time into organizational trust as the initially informal inter-personal commitments between individuals become routinized and institutionalized at

the organizational level. Second, the history of interaction between organizational boundary spanners can foster inter-organizational trust directly as those individuals are viewed first and foremost as occupants of constrained organizational roles. Interaction between boundary spanners will reflect not just an inter-personal connection, but also an institutionalized role relationship. Zaheer et al. (1998, p. 144) argue similarly that the connection between inter-personal and inter-organizational trust is based on institutionalizing processes. Over time, repeated ties between two firms evolve into deeper, more stable cooperative arrangements. Informal commitments made by individual boundary spanners become established as organizational structures and routines. Using data on exchange relationships between electrical equipment manufacturers and their component suppliers the authors confirm empirically the high correlation between inter-personal and inter-organizational trust as well as the negative impact of inter-organizational trust on the transaction costs of inter-firm exchange.

4.3.2 Trust versus formal contracts: Complements or substitutes?

Empirical evidence about the relationship between trust and formal contracts is mixed (Poppo and Zenger, 2002, pp. 711 ff.; Woolthuis et al., 2005, pp. 813 ff.). Gulati and Nickerson (2008) argue that trust and formal governance modes (i.e., hybrid modes as well as vertical integration) act simultaneously as both substitutes and complements.

Trust can be understood as a substitute for formal contracts. If trust exists when firms enter an exchange relationship, it mitigates some of the contracting hazards associated with the exchange relationship which in turn results in a higher exchange performance since formal governance is substituted by less formal (i.e., less expensive) organizational forms. On the other hand, trust can also be understood as a complement for formal contracts reducing ex-ante and ex-post transaction costs and facilitating joint problem solving in cases where unexpected contingencies arise. Hence, exchange performance will be superior when trust operates with formal contracts regardless of the chosen governance structure.[27]

Poppo and Zenger (2002) find empirical evidence for the complementarity of formal contracts and relational governance in the outsourcing of information services with both organizational forms having a positive impact on exchange performance. Woolthuis et al. (2005) investigate the relationship of trust and formal contracts based on case study analyses focusing on collaborative innovations involving complex transactions, environmental uncertainty, and relationship-specific investments. Trust can successfully substitute for contracts (i.e., a very incomplete contract is accompanied by high inter-organizational trust which results in a successful relationship), or trust and formal contracts may be complements in the sense that trust is understood as a precondition for contract negotiations. Gulati and Nickerson (2008) confirm empirically the simultaneity of trust inducing a substitution effect on

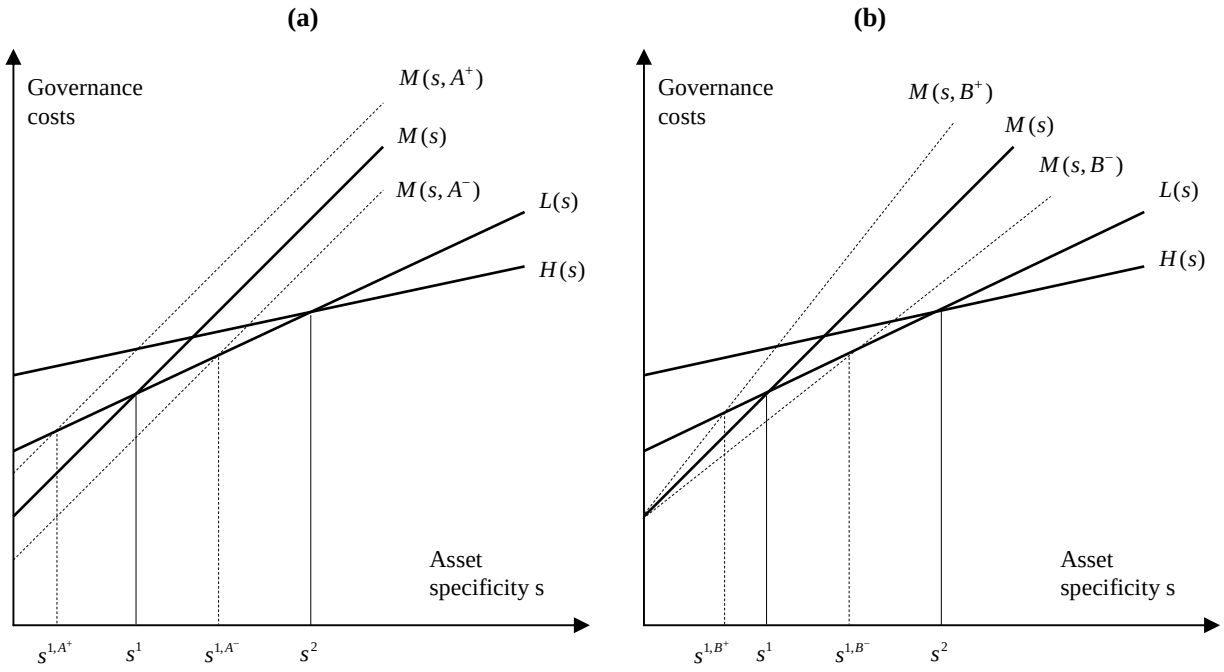
[27] The complementarity view in some cases is also interpreted as trust being a precondition for negotiating a complex contract. Pre-existing trust may be necessary for the parties to be willing to invest in the relationship. An alternative view comes from social science. Contracts may also signal distrust and the active use of a contract may evoke conflict.

the optimal choice of governance mode and the complementarity effect of trust lowering the governance costs of all modes of organization whenever exchange hazards are present. They furthermore find that exchange relationships involving inter-organizational trust are more successful than those strongly exposed to opportunistic behavior.

4.3.3 Formalization of the shift parameter framework

As discussed in Section 2.2, transaction cost economics studies economic organizations from a comparative point of view. The choice of the optimal governance mode is determined based on an economization of the sum of transaction and production costs. The purpose of this chapter is to consider how the equilibrium of optimal governance choice will change in response to disturbances in the institutional environment. Changes in exogenous parameters, or shift parameters, will have a disproportional impact on the costs of different modes of organization. They may shift the cost curves via changes in the intercepts and/or slopes and may be relevant for one or more of the alternative modes of governance. Figure 26a illustrates the impact of a shift parameter raising (A^+) or decreasing (A^-) the intercept of the governance costs of market exchange; Figure 26b illustrates the impact of a shift parameter raising (B^+) or decreasing (B^-) its slope (i.e., the effect depends on the level of specific investments). These dynamics move the critical values of asset specificity determining the optimal governance choice.

Figure 26: Shift parameter with an impact on a governance cost curve's intercept (a) and slope (b)



Source: Own depiction

In analyzing the optimal governance of technology transfer alliances, Oxley (1999) hypothesizes that weaker intellectual property protection increases the costs of contracting relative to the costs of equity joint ventures. The intercept of the contracting cost curve increases which results in a shift of the

critical level of appropriability hazards to the left-hand side. More hierarchical governance becomes more likely. Henisz and Williamson (1999) discuss the impact of property rights and contract law on governance choice. Since vertical integration supports internal conflict settlement, changes in contract law will influence only market exchange and hybrid governance modes. A change in contract law that improves the quality of enforcement will therefore reduce the governance costs of market and hybrid contracting as compared to hierarchy. The intercepts of their governance cost curves decrease; less hierarchical governance modes become more likely. Williamson (1991b) discusses property rights protection as a possible shift parameter. The fear of expropriation by the government and/or expropriation by rivals, suppliers, or customers distorts ex-ante incentives to invest and motivates ex-post safeguards via protective (hierarchical) governance structures. The governance cost curves for market exchange and hybrid modes will shift upwards with decreasing stability of property rights. Further, he argues that improved reputation in a network will attenuate incentives to behave opportunistically since the immediate gains from opportunistic behavior must be traded-off against future costs. The governance cost curves for market and hybrid governance forms will decrease favoring less hierarchical governance modes. See Figure 29 to 32 in the Appendix for graphical illustrations of these applications of the shift parameter framework.

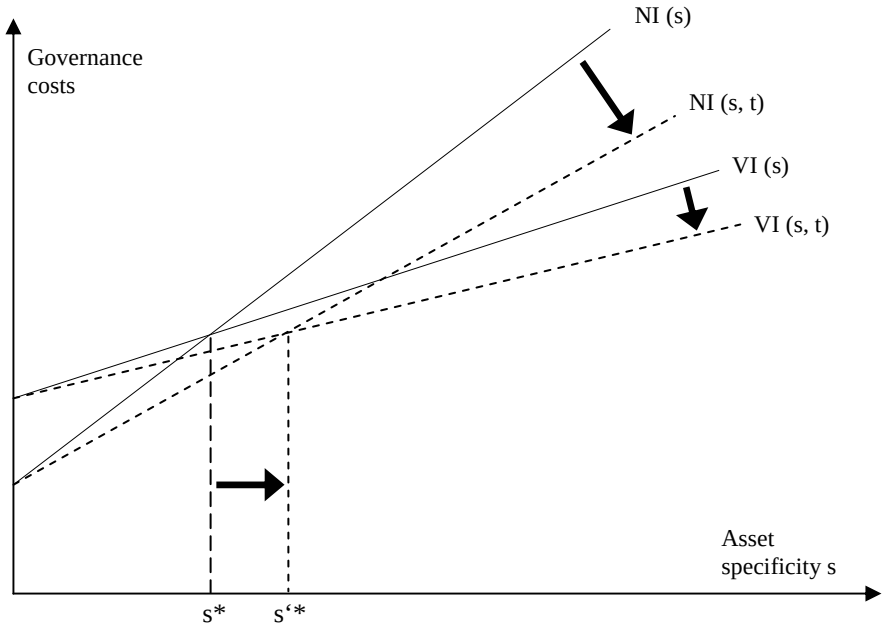
The following discussion focuses on inter-organizational trust as a shift parameter, in particular, trust engendered by past interactions between the same trading partners. As discussed above, prior empirical work finds that the presence of inter-organizational trust reduces transaction costs in the sense of lowering (re-)negotiation costs, facilitating adaptation, information exchange and joint problem-solving. In the presence of relationship-specific investments, inter-organizational trust will decrease the probability and/or extent of post-contractual opportunistic behavior by the non-investing party; exchange partners are more likely to avoid disputes or to resolve them quickly.

Looking at market exchange, trust will have no effect on the governance cost curve when exchange hazards are absent, but otherwise will shift the curve downward. The impact of trust on the governance costs of hybrid modes of organization is similar. However, the decrease will be less significant than for market exchange since complex contracting may limit the effectiveness of trust and may even dissipate it. Finally, trust is important in hierarchical exchanges as well. Internal disputes between divisions should arise less frequently, and should they occur, they will more often be resolved by the partners themselves without recourse to other authorities. The decrease in governance costs will be lower than for hybrid modes since high levels of bureaucracy and administrative controls limit the ability of exchange partners to make adaptations and agreements independently.

In summary, pre-existing inter-organizational trust should enhance exchange performance independent of the chosen organizational structure with this effect being the higher the less hierarchical the respective governance mode. More formal governance modes will be substituted by less formal ones. As the level of specific investments deepens, the cost of opportunistic behavior as well as the benefits from mechanisms that reduce the likelihood of such behavior will increase.

Figure 27 illustrates Williamson's shift parameter framework applied to the binary decision about whether to integrate vertically (*VI*), or to use less hierarchical governance modes (non-integration, or *NI*). In the absence of pre-existing trust, the choice of the optimal (transaction cost economizing) governance form implies using non-integration for $s < s^*$ and internal organization otherwise. The presence of inter-organizational trust t will decrease the probability and extent of post-contractual opportunistic behavior and reduce governance costs in the presence of asset specific investments: $NI(0, t) = NI(0)$ and $VI(0, t) = VI(0)$ and the slope of the governance cost curves flatten with $\partial NI(s, t)/\partial t < \partial VI(s, t)/\partial t < 0$ for all $s > 0$ if $t > 0$. The critical value of asset specificity shifts from s^* to s'^* with $s^* < s'^*$. The likelihood of organizing a transaction within the own hierarchy therefore should decrease with an increase in the level of inter-organizational trust.

Figure 27: Inter-organizational trust as a shift parameter



Source: Own depiction

4.3.4 Industry-specific propositions

As discussed in Section 3.2, we distinguish upstream, midstream, and downstream activities in the LNG industry. Firms may specialize in one, two, or all three of these segments. First, a number of players integrate along several stages of the value chain (e.g., the BG Group will control the whole value chain for deliveries from Idku/Egypt to Brindisi/Italy which is expected to start operation in 2010; GdF Suez owns a fleet of LNG vessels used to transport natural gas amongst other from Algeria to France). Second, there are companies investing in a portfolio of export and import positions, thereby focusing a strategy of both vertical and horizontal integration (e.g., Exxon Mobil has interests in liquefaction facilities in Qatar as well as in Indonesia and holds import capacities in South Hook/UK and Rovigo/Italy and recently started investments in Golden Pass/US). Strategic

partnerships and joint ventures here play an important role. Third, a number of new non-integrated players have entered the LNG market during the last decade (e.g., Cheniere, Excelerate Energy). However, we also observe varying strategies of different companies which are active in similar stages of the value chain, and one and the same company choosing different positions along alternative value chains.

The definition of asset specificity in the LNG industry is not straightforward. According to Nissen (2007a, p. 5), asset specificity is "a property of the transportation links, created by the terms of physical and commercial access [to shipping capacities]." In particular, the midstream element of the value chain is of crucial importance in an industry with a relatively illiquid shipping market. Post-contractual opportunism by the counterparty may be hazardous for parties without shipping control, in other words, ex-ship/cif buyers and fob sellers.[28] However, the natural gas market traditionally has been a sellers' market. The accompanying restructuring and liberalization of downstream natural gas (and electricity) markets results in downstream physical asset specificity. A player investing in regasification capacity without having secured supplies and access to midstream shipping might be caught in a lock-in situation. LNG sellers profit from significant bargaining power since importers competed globally for natural gas supplies. Furthermore, competitive downstream markets facilitate their access to numerous buyers.

According to the transaction cost approach, idiosyncratic assets in uncertain environments lead to the hazard of post-contractual opportunistic behavior by the counterparty which in turn results in ex-ante under-investment and decreasing overall efficiency. Organizing transactions within a firm's own hierarchy will avoid ex-post appropriation of quasi-rents. Based on transaction cost economics' discriminating alignment hypothesis, the first proposition is derived:

> *Proposition 1: The higher the share of idiosyncratic (downstream) assets in the portfolio of an LNG firm in an uncertain environment, the higher will be the probability of vertical integration along the LNG value chain.*

As discussed above, prior empirical work has found that the presence of inter-organizational trust reduces transaction costs. In the presence of relationship-specific investments, inter-organizational trust will decrease the probability and/or extent of post-contractual opportunistic behavior by the non-investing party; governance costs (i.e., transaction costs) are reduced and overall exchange performance increases. Since governance costs change disproportionally between governance modes, less hierarchical modes become more attractive, leading to the second proposition:

[28] Free-on-board (fob): title transfer at the loading port with the buyer being responsible for shipping; cost-insurance-freight (cif): title transfer during voyage with the seller being responsible for shipping; delivered ex-ship (des): title transfer at the unloading port with the seller responsible for shipping.

Proposition 2: An increase in the level of trust between upstream and downstream players in the LNG industry will favor less hierarchical modes of governance.

It is assumed that the observed governance modes represent efficient choices and that potential misalignment will result in a re-positioning or in the company ceasing its activities in the industry due to entrepreneurial failure. Since transaction-specific performance data (i.e., performance related to activities along the LNG value chain) are not publicly available, a possible third proposition hypothesizing that the presence of trust will increase exchange performance independent of the chosen organizational structure cannot be tested.

The next section describes the econometric model developed to analyze the propositions. In the first step, the determinants that drive players towards vertical integration are investigated; in the second step estimation results for a static transaction cost model are compared to those of a model that includes trust as a dynamic factor characterizing the institutional environment.

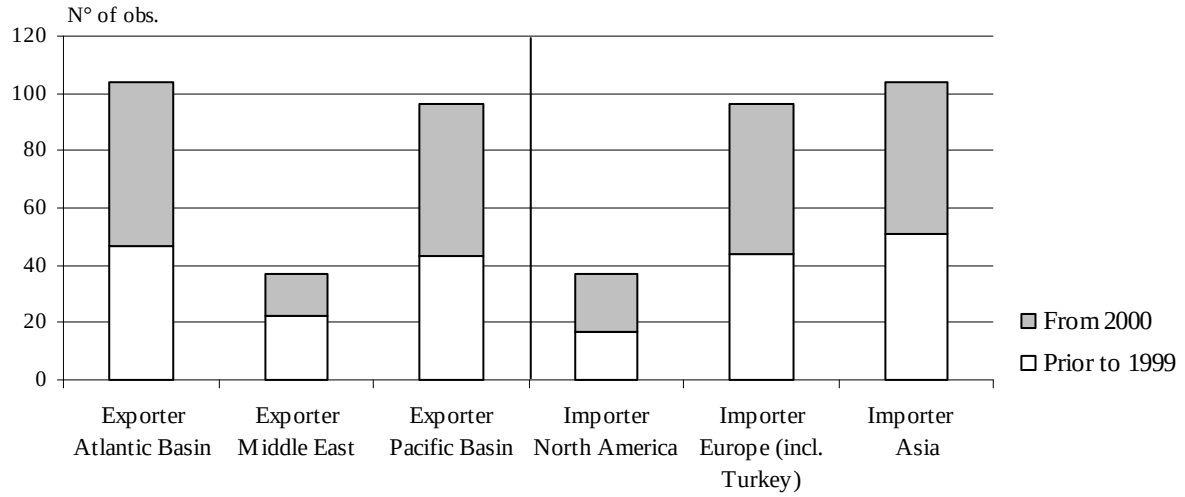
4.4 Data and methodology

4.4.1 Data

The global dataset encompasses corporate investment behavior along LNG value chains from the beginning of the industry until today. It was compiled from various publicly available sources such as company websites, industry reports, newsletters, and journals, etc., and complemented with interviews with industry experts. The dataset includes export and import capacities, ownership structures, investment costs, financing structures, and expansion plans for liquefaction and regasification projects, data on the global tanker fleet, including vessels currently listed in shipyard order books, and analyses of contracting partners, contracted volumes, and contractual durations.

Using the dataset's 66 import and 23 export projects (including all of the existing regasification and liquefaction plants worldwide and projects under construction and expected to be operational up to 2012), existing value chains (historical, actual, and planned for the near-term) are identified in a first step. In a second step, individual companies' activities throughout the chains are analyzed. The sample consists of 237 corporate-specific value chains, 131 of which are situated in the Atlantic Basin and 106 correspond to Asia-Pacific trade. Figure 28 summarizes the observations in the sample by export and import region. The large share (~ 50%) of identified value chains having started operation from 2000 on indicates the growing importance of natural gas trade in the form of LNG.

Figure 28: Number of observed corporate-specific value chains by export and import region



Source: Own depiction

The unit of analysis for studying the determinants of vertical integration is a corporate-specific value chain. Two alternative measures for integration are specified. First, a binary variable indicating vertical integration from upstream or downstream into midstream shipping is defined. Both, equity relationships and long-term charter contracts are classified as vertical integration. Even though NIE considers long-term contracts as a hybrid form of governance, it is appropriate to classify long-term charter agreements for LNG vessels as vertical integration since the ships traditionally have been dedicated to specific companies and transport routes over their whole lifetime. The dependent variable $\underline{VI}^1$ is a discrete measure taking the value of one if we observe vertical integration of the player along the value chain *i*, and zero otherwise:

$$VI_i^1 = \begin{cases} 1 & \text{if vertical integration} \\ 0 & \text{otherwise} \end{cases}$$

In 134 of the 237 observations vertical integration of the respective player into midstream shipping is observed. Second, the degree of vertical integration (i.e., no vertical integration versus vertical integration from upstream or downstream into midstream shipping versus vertical integration along the entire value chain) is defined as $\underline{VI}^2$:

$$VI_i^2 = \begin{cases} 2 & \text{if vertical integration along upstream, midstream and downstream} \\ 1 & \text{if vertical integration from upstream or downstream into midstream shipping} \\ 0 & \text{otherwise} \end{cases}$$

In 103 of the observations there is no integration, in 85 cases integration into midstream shipping takes place, and in 49 cases companies control the entire value chain.

4.4.2 Explanatory variables

Transaction cost variables. Proposition 1 refers to the impact of idiosyncratic assets and uncertainty on the likelihood of vertical integration. Transaction cost economics predicts that asset specificity is the strongest determinant of integrating successive stages of the value chain into the corporation's own hierarchy. Theory shows that the most efficient solution is trade on a short-term market for exchange relationships not involving any investment in specific assets. Markets become inefficient as bilateral dependencies arise. Specific investments in environments without uncertainty can be secured through long-term contracts. In contrast, the existence of uncertainty results in vertical integration being more efficient. The relative extent of idiosyncratic assets of a player (SPEC) is defined as the ratio of regasification capacity over the sum of regasification and liquefaction capacity the player controls in the start-up year of value chain *i* with $SPEC_i = r_{i,\,year} / (r_{i,\,year} + l_{i,\,year})$. The variable increases with the share of regasification capacities in a firm's LNG portfolio, mirroring the lock-in situation of a player investing downstream in a sellers' market. It is continuously distributed between zero and one, including these boundaries.

Due to the high capital-intensity of infrastructure investments and uncertainties about the scope of natural gas fields and price developments, investors generally face different risks. In addition, natural gas fields are often located in politically unstable regions.[29] Several risks can be hedged via diversification (e.g., upstream exploration success), price adaptation and renegotiation clauses or other measures (price and quantity risks). Therefore, the political risk associated with upstream investments is evaluated as the main driver of uncertainty. The variable for political uncertainty (UNC) is based on the so-called POLCON-index developed by Henisz (2000). This index measures the degree of constraints on policy change in a country averaged for five-year periods since 1960.[30] Various studies have shown that this measure is a suitable index for political uncertainty testing transaction cost economics' hypotheses. I adjust the POLCON-index so that a high (low) value expresses high (low) uncertainty; UNC is defined as (1 – POLCON) with $UNC_i \in [0, 1]$.

To account for transaction cost economics' proposition that relationship-specific investments in the presence of uncertainty drive companies to the internalization of quasi-rents, an interaction term (SPEC · UNC) is included.

Shift parameters: As discussed above, Williamson (1991b) proposes as one potential shift parameter reputational effects discussed in the context of social networks; Gulati and Nickerson (2005) employ a measure of exogenous trust based on an assessment of the opinion of the buyer about its supplier compared to the best alternative partner. Gulati and Sytch (2008) point out that the history of prior interaction is the most important factor determining inter-organization trust. Gulati and Nickerson

[29] For example, the guerrilla activities of Aceh separatists in Western Sumatra (Indonesia) caused a temporary shutdown of the Arun liquefaction facility in 2001.

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

(2008) employ variables measuring the length of historical exchange; Oxley (1999) quantifies the number of prior alliances between the trading partners. For this study, three proxy variables indicating inter-organizational trust are defined.

Prior interactions between the same trading partners thereby are expected to improve exchange productivity via diminishing coordination and contracting costs. Furthermore, the potential of future interactions deters exchange partners from engaging in opportunistic behavior; short-term gains from a deviation of implicit contractual terms have to be traded-off against long-term disadvantages. Investments in inter-organizational trust (or reputation) represent relationship-specific investments being sunk in nature. The termination of an existing trade relationship will imply an increase in exchange costs (i.e., additional costs for searching a new exchange partner and higher contracting costs due to a lack in historical bilateral trading experience).

TRUST1 is a count index of the years of inter-country LNG trade before the initiation of the respective value chain indicating the stock of prior interactions between two trading partners. On a country level, we very often observe the same players active in LNG exportation and/or importation (e.g., Sonatrach is the only exporter in Algeria; Gaz de France is the main importer in France), which justifies the choice of this variable as a measure of trust resulting from past inter-country (and respectively inter-company) trading experiences. TRUST2 indicates whether the value chain is an expansion project of an already pre-existing value chain. For example, ENI is vertically integrated along the value chain for LNG deliveries from Nigeria's Bonny Island facility train 3 to the Sines import terminal in Portugal where deliveries started in 2003. Three years later, the company entered a value chain representing an expansion of this existing value chain including Bonny Island's trains 4 and 5. TRUST3 indicates whether trading partners already operate along value chains between the same countries since one might argue that due to the limited number of firms active in the industry, the same trading partners with a high probability will meet again.

Control variables. To account for changes in corporate strategies over time a dummy variable indicating value chains that came into operation after 1999 (D2000) is included. It is expected that players will encounter a changing environment given the industry's rapid expansion and maturation since the end of the 1990s and that they must select or adapt strategies to maintain or gain competitive advantages as discussed above.

Several dummy variables are used to control for differences in corporate strategies resulting from regional factors that vary between the Atlantic Basin market (deliveries to Europe and North America) where LNG trading hubs already exist or are developing, and Asia-Pacific trade where buyers depend strongly on LNG imports. EXPAB indicates exporters situated in the Atlantic Basin; EXPPB indicates exporters situated in the Pacific Basin; suppliers delivering LNG from the Middle East to Europe, North America, or Asia (EXPME) are the default category.

CAPOWN accounts for a company's market share in the industry, calculated as the ratio of the accumulated liquefaction and regasification capacities controlled (owned or contracted) by a global

player over the sum of worldwide liquefaction and regasification capacities in operation at the end of the respective start-up year of the value chain: $(r_{i,\ year} + l_{i,\ year}) / (r_{total,\ year} + l_{total,\ year})$. Companies controlling significant LNG capacities may be able to benefit from arbitrage possibilities which in turn increases the motivation to integrate into midstream shipping, especially when downstream regasification assets account for a significant share in the portfolio.

Empirical research on the make-or-buy decision building on transaction cost economics often includes the size of the transaction or of the exchange partners as a control variable (e.g., Zaheer and Venkatraman, 1995; Rosés, 2005; Gulati and Nickerson, 2008; Fernández-Olmos et al., 2008). The player's assets value (ASSETS) is a proxy variable for firm size and financial strength. A positive relation between vertical integration and ASSETS is expected since companies endued with a strong capital basis face lower barriers to entry in terms of funding capital-intensive LNG projects.

Finally, the dummy variable STATE identifies state-owned entities, thus allowing for differences in corporate strategies due to a different ownership structure.

For a survey of all explanatory variables as well as their descriptive statistics see Table 10. Slightly more than half (53%) of the analyzed corporate-specific value chains in the dataset began operations after 1999, mirroring this decade's expanding international LNG trade. Asset specificity of the respective company's LNG portfolio ranges between zero (no specificity of the investments since the portfolio is dominated by upstream capacities; e.g., National Gas Company Trinidad and Tobago) and one (very high specificity since the portfolio is dominated by downstream positions; e.g., Korea Gas Corporation) with a mean of 0.48. The political uncertainty index of the exporting country lies between 0.13 and one with a mean of 0.62. The history of LNG trade between two countries differs widely, whereas some value chains represent the first exchange relationships and other value chains cover bilateral trading experience of up to 37 years. In 37% of all observations the value chains represent expansion projects; 22% represent trading partners already operating along value chains between the same countries. Broken out by region, 44% of the observations represent value chains originating from Atlantic Basin exporters, 40% represent Pacific Basin exporters' deliveries and 16% involve Middle Eastern suppliers. Players control between 0.1% (Union Fenosa in 2000) and 30.3% (Osaka Gas in 1972) of worldwide liquefaction and regasification capacities during the observation period. Corporate size ranges from USD 358mn (Italian Enel) to USD 279bn (Japanese Nippon Oil Corporation).[31] Finally, 33% of the observed value chains include state-owned entities.

[31] If no data was available the firm's assets value was set to USD 10 bn (i.e., Pertamina, National Libyan Oil Company, and EGPC).

Table 10: Explanatory variables and summary statistics

Characteristic	Proxy	Unit	Denotation	Exp. sign	Mean	Std. dev.	Min	Max	N
Proposition 1 (transaction cost variables)									
Asset specificity	Share of downstream capacities in the player's LNG portfolio	%	SPEC	+	0.479	0.446	0	1	237
External uncertainty	Political instability in the supplying country		UNC		0.616	0.379	0.13	1	237
Proposition 2 (shift parameters)									
Inter-organizational trust	Years of previous inter-country LNG trade	Count	TRUST1	-	5.283	8.583	0	37	237
	Value chain covering an expansion project of an already existing value chain	Dummy	TRUST2	-	0.367	0.483	0	1	237
	Firm already active along a value chain between the same export and import countries	Dummy	TRUST3	-	0.219	0.415	0	1	237
Control variables									
Change in industry structure	Start-up of the value chain after 1999	Dummy	D2000		0.527	0.500	0	1	237
Export region	Exporter in the Atlantic Basin	Dummy	EXPAB		0.439	0.497	0	1	237
	Exporter in the Pacific Basin	Dummy	EXPPB		0.405	0.492	0	1	237
	Exporter in the Middle East	Dummy	EXPME		0.156	0.364	0	1	237
Market share in the LNG industry	Capacity controlled by the player (% of total existing export and import capacity)	%	CAPOWN		0.040	0.052	0	1	237
Financial resources	Company size measured by the assets value	bn USD	ASSETS		63.476	63.628	0.358	195.265	237
Company type	Company being state-owned	Dummy	STATE		0.380	0.486	0	1	237

Table 11: Correlation matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
VI[1]	1	1													
VI[2]	2	0.882	1												
SPEC	3	0.159	0.103	1											
UNC	4	-0.205	-0.151	-0.224	1										
TRUST1	5	-0.140	-0.185	0.042	0.104	1									
TRUST2	6	-0.092	-0.105	0.040	0.053	0.634	1								
TRUST2	7	-0.008	0.011	-0.141	0.055	0.467	0.654	1							
D2000	8	0.176	0.336	0.011	-0.068	0.011	-0.033	-0.029	1						
EXPAB	9	-0.065	0.067	-0.059	0.330	-0.142	-0.038	0.024	0.173	1					
EXPPB	10	0.030	-0.113	0.202	-0.230	0.288	0.138	0.103	-0.286	-0.730	1				
EXPME	11	0.049	0.067	-0.192	-0.140	-0.195	-0.135	-0.172	0.151	-0.380	-0.355	1			
CAPOWN	12	0.120	-0.001	0.222	0.004	0.014	0.053	0.090	-0.329	-0.100	0.237	-0.184	1		
STATE	13	-0.051	-0.119	-0.180	0.242	-0.103	-0.001	0.152	-0.148	0.097	-0.150	0.071	0.115	1	
ASSETS	14	0.197	0.225	-0.365	-0.115	-0.041	-0.066	0.006	0.063	-0.141	0.033	0.148	-0.098	-0.491	1

4.4.3 Methodology

In the first step, the probability of observing vertical integration into midstream shipping is explained with the dependent variable representing a binary choice. Binary choice models (see e.g. Greene, 2002, pp. 665 ff., Maddala, 2001, 317 ff.) are a class of qualitative response models. They express the occurrence of an event or the choice between two alternatives (i.e., governance choice in this study), with the probabilities

$$\begin{aligned} \Pr(Y=1|X) &= F(X\beta) \\ \Pr(Y=0|X) &= 1-F(X\beta) \end{aligned} \tag{4-1}$$

where X is the (1 x K) vector of exogenous variables j with $j \in \{1,2,\ldots,K\}$ and β the vector of parameters reflecting the impact of changes in X on the probability. The expected value of the endogenous variable equals $E(Y) = 1 \cdot F(X\beta) + 0 \cdot (1 - F(X\beta)) = F(X\beta)$. The objective is to estimate the effect of exogenous factors on the probability of observing the outcome ($Y = 1$).

To estimate regression models with a dichotomous left-hand-side variable, several methods exist. The simplest model is the linear probability model, assuming that the probability of the dependent variable taking the value of one is a linear function of X with $\Pr(Y = 1 \mid X) = F(X\beta) = X\beta$. One can show that $Y = E(Y) + (Y - E(Y)) = \Pr(Y = 1 \mid X) + (Y - E(Y)) = X\beta + \varepsilon$. The marginal effect of x_j on the probability $\Pr(Y = 1 \mid X)$ equals the estimated coefficient β_j. However, since the explained variable takes only the values of zero or one, the error term will be heteroscedastic and depends on β.[32] Predicted probabilities may lie outside the [0,1] range and coefficient estimates are very sensitive to extreme realizations of exogenous variables.

Nonlinear probability models are alternative estimation methodologies avoiding the problem of out-of-range probabilities. $F(\cdot)$ is assumed to be a symmetric cumulative distribution function such that

$$\lim_{X\beta \to +\infty} \Pr(Y=1|X) = 1 \quad \text{and} \quad \lim_{X\beta \to -\infty} \Pr(Y=1|X) = 0 \tag{4-2}$$

The value of the binary outcome is considered to be specified by an unobservable index function $Y^* = X\beta + \varepsilon$ where

$$Y = \begin{cases} 1 & \text{if} \quad Y^* \geq 0 \quad \text{with} \quad \Pr(\varepsilon \geq -X\beta) = F(X\beta) \\ 0 & \text{if} \quad Y^* < 0 \quad \text{with} \quad \Pr(\varepsilon < -X\beta) = 1 - F(X\beta) \end{cases} \tag{4-3}$$

[32] The error term will take the values of $(1 - X\beta)$ and $(-X\beta)$ with the respective probabilities $(X\beta)$ and $(1 - X\beta)$. Therefore, $E(\varepsilon^2) = (1 - X\beta)^2 \cdot X\beta + (-X\beta)^2 \cdot (1 - X\beta) = (1 - X\beta) \cdot X\beta$; observations with a probability of observing the outcome close to one or zero have a low variance, whereas for probabilities near 0.5 the variance is high.

Parameters are estimated using the method of maximum likelihood with each observation *i* being treated as a single draw from a Bernoulli distribution. Since all observations are independent with the success probability $\Pr(Y = 1 \mid X) = F(X\beta)$, the likelihood function is given by

$$L = \Pr\left(Y_1 = y_1, Y_2 = y_2, ..., Y_n = y_n \middle| X_i\right) = \prod_{y_i=0} \left(1 - F\left(X_i\beta\right)\right) \prod_{y_i=1} F\left(X_i\beta\right)$$
$$= \prod_{i=1}^{n} \left(F\left(X_i\beta\right)\right)^{y_i} \left(1 - F\left(X_i\beta\right)\right)^{1-y_i} \tag{4-4}$$

Taking natural logarithms, one gets

$$\ln L = \sum_{i=1}^{n} \left[y_i \ln F\left(X_i\beta\right) + \left(1 - y_i\right) \ln\left(1 - F\left(X_i\beta\right)\right)\right] \tag{4-5}$$

with the first order conditions

$$\frac{\partial \ln L}{\partial \beta} = \sum_{i=1}^{n} \left[\frac{y_i f_i}{F_i} + \left(1 - y_i\right) \frac{-f_i}{\left(1 - F_i\right)}\right] x_i = 0 \tag{4-6}$$

where f_i is the density function. Marginal effects are calculated by $\gamma = \partial \Pr / \partial x_j = \partial F(X\beta) / \partial x_j = F'\beta = f\beta$. In this study, a probit model is employed. The dependent variable is specified as an unobserved latent variable VI^{1*}. It is assumed that $VI^{1*} = X\alpha + \varepsilon$ where X is a (1 x K) vector of exogenous variables representing asset specificity, uncertainty and further independent and heterogeneous factors, α is a (K x 1) vector of coefficients, and ε is an error term with the cumulative density function $F(\varepsilon)$. We will observe $VI^1 = 1$ if $VI^{1*} > 0$ and $VI^1 = 0$ otherwise. Thus, the probability of observing vertical integration $\Pr(VI^1 = 1)$ equals $\Pr(\varepsilon > -X\alpha) = 1 - F(-X\alpha) = F(X\alpha)$. The probit model assumes $F(\cdot)$ to be standard normal. Hence,

$$\Pr\left(VI^1 = 1\right) = \int_{-\infty}^{\alpha X_i} \phi(t)\, dt = \Phi\left(X\alpha\right) \tag{4-7}$$

with the log-likelihood function

$$\ln L = \sum_{i=1}^{N} \left[y_i \ln \Phi\left(X\alpha\right) + \left(1 - y_i\right) \ln\left(1 - \Phi\left(X\alpha\right)\right)\right] \tag{4-8}$$

The level of specific investments is treated as an exogenous variable. An interaction term combining specificity and uncertainty is included to account for the impact of specific investments under uncertainty on optimal governance choice. To check for a non-linear impact of firm size on the integration decision, the asset's value is included in both linear and quadratic form into the estimation model:

$$VI_i^1 = \alpha_0 + \alpha_1 SPEC_i + \alpha_2 UNC_i + \alpha_3 (SPEC_i \cdot UNC_i) + \alpha_4 EXPAB_i + \alpha_5 EXPPB_i + \alpha_6 D2000_i + \alpha_7 CAPOWN_i + \alpha_8 STATE_i + \alpha_9 ASSETS_i + \alpha_{10} (ASSETS_i)^2 + \varepsilon_i \quad (4\text{-}9)$$

where i indexes a corporate-specific value chain and ε_i is the error term. In the second step, inter-organizational trust as a shift parameter is added. Three models – each including only one of the alternative measures of trust to avoid multicollinearity problems with are estimated.[33] In order to test for diminishing returns to history in the formation of trust, TRUST1 is included in both linear and quadratic form. One would not expect exchange partners that already have transacted for a twenty years to have twice as much trust as those who have transacted for only one decade.

$$VI_i^1 = \beta_0 + \beta_1 SPEC_i + \beta_2 UNC_i + \beta_3 (SPEC_i \cdot UNC_i) + \beta_4 EXPAB_i + \beta_5 EXPPB_i + \beta_6 D2000_i + \beta_7 CAPOWN_i + \beta_8 STATE_i + \beta_9 ASSETS_i + \beta_{10} (ASSETS_i)^2 + \beta_{11} TRUST1_i + \beta_{12} (TRUST1_i)^2 + v_{1i} \quad (4\text{-}10a)$$

$$VI_i^1 = \beta_0 + \beta_1 SPEC_i + \beta_2 UNC_i + \beta_3 (SPEC_i \cdot UNC_i) + \beta_4 EXPAB_i + \beta_5 EXPPB_i + \beta_6 D2000_i + \beta_7 CAPOWN_i + \beta_8 STATE_i + \beta_9 ASSETS_i + \beta_{10} (ASSETS_i)^2 + \beta_{11} TRUST2_i + v_{2i} \quad (4\text{-}10b)$$

$$VI_i^1 = \beta_0 + \beta_1 SPEC_i + \beta_2 UNC_i + \beta_3 (SPEC_i \cdot UNC_i) + \beta_4 EXPAB_i + \beta_5 EXPPB_i + \beta_6 D2000_i + \beta_7 CAPOWN_i + \beta_8 STATE_i + \beta_9 ASSETS_i + \beta_{10} (ASSETS_i)^2 + \beta_{11} TRUST3_i + v_{3i} \quad (4\text{-}10c)$$

In order to differentiate between different degrees of vertical integration, a second class of models following a similar specification is estimated. The variable VI^2 shows discrete values (i.e., zero, one, or two). Since these outcomes represent a ranking of values on an ordinal scale, ordinary least squares is not the suitable methodology. The difference between an outcome of two and one would be treated the same as the difference between one and zero. Therefore, an ordered probit model is employed

[33] A regression including all three variables at the same time confirms the results presented below but does not significantly improve the overall explanatory power of the model.

(Greene, 2002, pp. 736 ff.). Similarly to the probit model, the ordered probit model is based on a latent regression with $VI^{2*} = X\alpha + \varepsilon$. With respect to actual governance mode choice, we observe

$$\begin{aligned}
&VI_i^2 = 0 \quad \text{if } VI_i^{2*} \le \mu_1 \quad \text{with } \Pr\left(VI_i^2 = 0 \middle| X\right) = \Phi\left(\mu_1 - \alpha X_i\right) \\
&VI_i^2 = 1 \quad \text{if } \mu_1 < VI_i^{2*} \le \mu_2 \quad \text{with } \Pr\left(VI_i^2 = 1 \middle| X\right) = \Phi\left(\mu_2 - \alpha X_i\right) - \Phi\left(\mu_1 - \alpha X_i\right) \\
&VI_i^2 = 2 \quad \text{if } \mu_2 < VI_i^{2*} \quad \text{with } \Pr\left(VI_i^2 = 2 \middle| X\right) = 1 - \Phi\left(\mu_2 - \alpha X_i\right)
\end{aligned} \tag{4-11}$$

where μ_1 and μ_2 are referred to as break points (i.e., unknown parameters to be estimated with the vector of coefficients). The log-likelihood function is given by

$$\ln L = \sum_{i=1}^{N} \sum_{j=1}^{M} \left[\ln \Pr\left(y_i = j \middle| X\right) \cdot 1\left(y_i = j\right)\right] \tag{4-12}$$

with the probabilities as defined in (4-11). The following equations excluding and including alternative shift parameters are estimated:

$$\begin{aligned}
VI_i^2 = {} & \alpha_0 + \alpha_1 SPEC_i + \alpha_2 UNC_i + \alpha_3 \left(SPEC_i \cdot UNC_i\right) + \alpha_4 EXPAB_i + \alpha_5 EXPPB_i \\
& + \alpha_6 D2000_i + \alpha_7 CAPOWN_i + \alpha_8 STATE_i + \alpha_9 ASSETS_i + \alpha_{10} \left(ASSETS_i\right)^2 + \varepsilon_i
\end{aligned} \tag{4-13}$$

$$\begin{aligned}
VI_i^2 = {} & \beta_0 + \beta_1 SPEC_i + \beta_2 UNC_i + \beta_3 \left(SPEC_i \cdot UNC_i\right) + \beta_4 EXPAB_i + \beta_5 EXPPB_i \\
& + \beta_6 D2000_i + \beta_7 CAPOWN_i + \beta_8 STATE_i + \beta_9 ASSETS_i + \beta_{10} \left(ASSETS_i\right)^2 \\
& + \beta_{11} TRUST1_i + \beta_{12} \left(TRUST1_i\right)^2 + v_{1i}
\end{aligned} \tag{4-14a}$$

$$\begin{aligned}
VI_i^2 = {} & \beta_0 + \beta_1 SPEC_i + \beta_2 UNC_i + \beta_3 \left(SPEC_i \cdot UNC_i\right) + \beta_4 EXPAB_i + \beta_5 EXPPB_i \\
& + \beta_6 D2000_i + \beta_7 CAPOWN_i + \beta_8 STATE_i + \beta_9 ASSETS_i + \beta_{10} \left(ASSETS_i\right)^2 \\
& + \beta_{11} TRUST2_i + v_{2i}
\end{aligned} \tag{4-14b}$$

$$\begin{aligned}
VI_i^2 = {} & \beta_0 + \beta_1 SPEC_i + \beta_2 UNC_i + \beta_3 \left(SPEC_i \cdot UNC_i\right) + \beta_4 EXPAB_i + \beta_5 EXPPB_i \\
& + \beta_6 D2000_i + \beta_7 CAPOWN_i + \beta_8 STATE_i + \beta_9 ASSETS_i + \beta_{10} \left(ASSETS_i\right)^2 \\
& + \beta_{11} TRUST3_i + v_{3i}
\end{aligned} \tag{4-14c}$$

4.5 Estimation results and interpretation

The following paragraphs present estimation results of the probit and ordered probit models explaining the likelihood and respectively degree of vertical integration in the global LNG industry.

4.5.1 Probit model

Table 12 displays estimation results of nested models explaining governance choice based on a probit model with i) Model 1 including only transaction cost variables, ii) Model 2 including furthermore variables controlling for differences between exporting regions as well as changes in corporate behavior over time, iii) Model 3 including additionally company characteristics, and finally, iv) Models 4 to 6 accounting for alternative shift parameters.[34]

Both industry-specific propositions can be confirmed empirically. Estimation results are robust with respect to alternative model specifications. The log-likelihood values as well as different information criteria (i.e., Akaike and Bayesian information criteria) indicate that Model 4 which includes transaction cost variables, all above defined control variables, and TRUST1 as a shift parameter has the best explanatory power.

Contrary to transaction cost economics' predictions, specific investments (SPEC) appear to decrease the likelihood of vertical integration into midstream transportation for Models 1 and 2; the coefficient for the remaining four models is not significant. Uncertainty (UNC) is negatively related to the integration decision which goes in line with Williamson (1971).[35] However, as theory hypothesizes, investments in relationship-specific assets in the presence of uncertainty result in a strong motivation to avoid the appropriability hazards under market organization and to internalize the transaction instead. The coefficients of the interaction term are positive and highly statistically significant for all specifications. This finding reflects recent efforts of traditional buyers to increasingly integrate upstream (e.g., Kyushu Electric and Tokyo Electric established a shipping company in 2005 which owns and operates LNG vessels).

Model 2 including control variables for the export region provides only a slight improvement in explanatory power compared to Model 1. The variables EXPAB and EXPPB have no significant impact on the decision to integrate vertically and there appears to be no difference in corporate strategies between value chains in the Atlantic Basin which are dedicated to more or less competitive downstream markets, value chains in the Pacific Basin market where countries typically strongly rely upon natural gas imports in the form of LNG, and value chains from the swing producer region of the Middle East. An alternative regression accounting for the importing region (deliveries dedicated to Atlantic Basin customers instead of to Pacific Basin customers) does not reveal any regional differences, too.

D2000, the variable controlling for the start-up date of the value chain, indicates that vertical integration is becoming more common, which reflects global players' efforts to establish a portfolio of export and import positions and shipping capacities to exploit arbitrage potentials. An alternative

[34] Probit estimation is preferred to the logit model (assuming a logistic instead of a normal distribution of the error term) since the first shows slightly better goodness-of-fit indicators (i.e., Pseudo R^2, log-likelihood values, AIC, BIC). Estimation results are similar for both estimation procedures.

[35] A regression using an alternative measure 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) produces similar results.

model specification including the start-up date of the value chain delivers a similar result. Testing for breakpoints in corporate behavior over time, the dummy variable indicating value chains which became operational after 1999 shows the highest significance. Access to flexible transport capacities (e.g., via integration into midstream shipping) is the key to a successful employment of this strategy. Rapid industrial expansion when accompanied by a restructuring process prompts firms to internalize risks inherent in the capital-intensive industry via strategic repositioning and reshaping.

Model 3 which adds variables accounting for corporate specific characteristics shows an improvement of the Pseudo R^2 to 0.212. Players controlling a larger share of world LNG regasification and liquefaction capacities (CAPOWN) show a higher likelihood of vertical integration. This can be explained by a higher motivation to integrate into midstream shipping to benefit from the portfolio of upstream and downstream positions.

The value of assets positively relates to the likelihood of vertical integration (with a non-linear impact as shown by the negative sign of the variable in its quadratic form). This indicates that larger firms have the financial capabilities necessary to invest in numerous capital-intensive export and/or import and shipping capacities.

Finally, the variable STATE is significant, too. In contrast to private firms, state-owned entities tend to prefer vertical integration as opposed to less hierarchical governance modes. Upstream NOCs aim to benefit from downstream margins, several state-owned distribution and power companies moved upstream to ensure margins and supply security.

The type and scope of the transaction explain much of the variation in governance modes. Dynamics in the institutional environment, however, also play an important role. The last three model specifications include shift parameters indicating inter-organizational trust. As expected, the presence of trust supports less hierarchical governance. Estimated coefficients of the three variables, TRUST1, TRUST2, and TRUST3, show the expected negative sign, although only TRUST1 is statistically significant. The impact of trust decreases with its nominal level as is indicated by the positive sign of the coefficient of the variable in its quadratic form.

Table 12: Estimation results probit model

Specification	Proposition 1 Transaction cost and control variables			Proposition 2 Trust as a shift parameter included		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
CONSTANT	0.986 *** (0.269)	0.730 ** (0.328)	-0.942 * (0.485)	-0.802 (0.500)	-0.878 * (0.489)	-0.943 * (0.485)
SPEC	-0.779 ** (0.368)	-0.802 ** (0.375)	-0.317 (0.459)	-0.398 (0.471)	-0.333 (0.461)	-0.317 (0.458)
UNC	-1.492 *** (0.341)	-1.474 *** (0.359)	-1.579 *** (0.390)	-1.589 *** (0.401)	-1.579 *** (0.391)	-1.579 *** (0.390)
(SPEC*UNC)	1.847 *** (0.521)	1.906 *** (0.524)	2.022 *** (0.580)	2.083 *** (0.596)	2.051 *** (0.586)	2.020 *** (0.583)
EXPAB		-0.058 (0.263)	-0.001 (0.279)	0.013 (0.281)	-0.019 (0.279)	-0.001 (0.283)
EXPPB		0.017 (0.270)	0.043 (0.292)	0.332 (0.316)	0.085 (0.295)	0.046 (0.298)
D2000		0.482 *** (0.181)	0.712 *** (0.204)	0.747 *** (0.209)	0.728 *** (0.205)	0.712 *** (0.204)
CAPOWN			5.476 ** (2.244)	6.025 ** (2.500)	5.809 ** (2.343)	5.486 ** (2.258)
STATE			0.846 *** (0.261)	0.826 *** (0.270)	0.837 *** (0.263)	0.848 *** (0.264)
ASSETS			0.021 *** (0.006)	0.019 *** (0.006)	0.020 *** (0.006)	0.021 *** (0.006)
$(ASSETS)^2$			-0.0001 ** (0.000)	-0.0001 * (0.000)	-0.0001 * (0.000)	-0.0001 ** (0.000)
TRUST1				-0.083 *** (0.032)		
$(TRUST1)^2$				0.002 ** (0.001)		
TRUST2					-0.246 (0.194)	
TRUST3						-0.010 (0.242)
Pseudo R^2	0.080	0.104	0.212	0.239	0.217	0.212
Log-likelihood	-149.23	-145.46	-127.78	-123.50	-126.97	-127.78
AIC	306.47	304.91	277.56	272.99	277.95	279.56
BIC	320.34	329.19	315.71	318.08	319.56	321.18
N	237	237	237	237	237	237

*** Statistically significant at a 1%-level; ** statistically significant at a 5%-level; * statistically significant at a 10%-level; standard errors in parentheses. All levels of statistical significance are based on two-sided test statistics. The calculation of the goodness-of-fit indicators is explained in the Appendix. Marginal effects are reported in Table 16 in the Appendix.

Model 4, the specification with the best explanatory power, predicts the correct parameter value of the binary endogenous variable indicating vertical integration for 177 of the observations (75%). Differentiating between value chains in which we observe internal organization and those where we do not, the predictive power is better for the first with 83% and 64% correct predictions respectively (Table 13).

Table 13: Predictive power probit model (Model 4)

VI^1_hat = k and VI = k	177 observations (75%)
VI^1_hat = 1 and VI = 1	111 observations (83%)
VI^1_hat = 0 and VI = 0	66 observations (64%)

4.5.2 Ordered probit model

Table 14 displays estimation results of nested models explaining the *degree* of vertical integration based on an ordered probit model with again i) Model 1 including only transaction cost variables, ii) Model 2 including furthermore variables controlling for differences between exporting regions as well as changes in corporate behavior over time, iii) Model 3 including company characteristics, and finally, iv) Models 4 to 6 accounting for alternative shift parameters.

The log-likelihood values and different information criteria indicate again that Model 4, which includes transaction cost variables, the control variables defined above, and TRUST1 as a shift parameter, is the best suited model.

Both industry-specific propositions can be confirmed empirically. Estimation results are robust with respect to alternative model specifications and are consistent with those found in the probit model discussed above. Specific investments in the presence of uncertainty lead to a strong motivation to integrate vertically; the presence of inter-organizational trust reduces the need for hierarchical controls and supports the choice of a lower degree of vertical integration. Significant control variables also provide some interesting findings. Vertical integration along the whole value chain has become more common reflecting the players' attempts to invest in a portfolio of LNG capacities both upstream and downstream and to exploit arbitrage potentials. State-owned companies tend to be more integrated than private players; e.g., Qatar Petroleum is endued with significant export capacities, a fleet of 27 ships (together with its partner Exxon Mobil), and recent downstream investments permitting market access to the UK or Italy for example. Firm size has as expected a positive and decreasing effect on the degree of vertical integration.

Table 14: Estimation results ordered probit model

Specification	Proposition 1 Transaction cost and control variables			Proposition 2 Trust as a shift parameter included		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
SPEC	-0.624 ** (0.316)	-0.722 ** (0.324)	-0.284 (0.387)	-0.388 (0.392)	-0.324 (0.389)	-0.280 (0.388)
UNC	-1.122 *** (0.301)	-1.317 *** (0.323)	-1.272 *** (0.345)	-1.268 *** (0.352)	-1.289 *** (0.347)	-1.269 *** (0.345)
(SPEC*UNC)	1.408 *** (0.453)	1.676 *** (0.464)	1.630 *** (0.494)	1.775 *** (0.502)	1.694 *** (0.497)	1.629 *** (0.493)
EXPAB		0.078 (0.232)	0.104 (0.241)	0.129 (0.242)	0.126 (0.242)	0.098 (0.245)
EXPPB		-0.141 (0.234)	-0.219 (0.243)	0.029 (0.257)	-0.147 (0.246)	-0.227 (0.249)
D2000		0.781 *** (0.162)	0.892 *** (0.176)	0.975 *** (0.181)	0.919 *** (0.178)	0.889 *** (0.177)
CAPOWN			3.113 * (1.672)	3.068 * (1.700)	3.231 * (1.685)	3.095 * (1.675)
STATE			0.497 ** (0.212)	0.456 ** (0.215)	0.492 ** (0.212)	0.492 ** (0.215)
ASSETS			0.018 *** (0.005)	0.017 *** (0.005)	0.017 *** (0.005)	0.018 *** (0.005)
$(ASSETS)^2$			-0.0001 ** (0.000)	-0.0001 ** (0.000)	-0.0001 ** (0.000)	-0.0001 ** (0.000)
TRUST1				-0.060 ** (0.026)		
$(TRUST1)^2$				0.001 (0.001)		
TRUST2					-0.243 (0.166)	
TRUST3						0.031 (0.200)
Breakpoint 1	-0.787	-0.518	0.740	0.634	0.665	0.737
Breakpoint 2	0.235	0.598	1.950	1.876	1.881	1.948
Pseudo R^2	0.034	0.095	0.151	0.172	0.155	0.151
Log-likelihood	-241.72	-226.38	-212.54	-207.30	-211.46	-212.53
AIC	493.44	468.76	449.08	442.60	448.92	451.06
BIC	510.78	496.51	490.70	491.15	494.01	496.14
N	237	237	237	237	237	237

*** Statistically significant at a 1%-level; ** statistically significant at a 5%-level; * statistically significant at a 10%-level; standard errors in parentheses. All levels of statistical significance are based on two-sided test statistics. Marginal effects are reported in Table 17 in the Appendix.

The specified model predicts the correct parameter value of the endogenous variable indicating the degree of vertical integration for 133 of the observations (56%). Differentiating between value chains in which we observe no internal organization, vertical integration into midstream shipping from upstream or downstream, and vertical integration along the whole value chain, the predictive power is 63%, 47%, and 60%, respectively (Table 15).

Table 15: Predictive power ordered probit model (Model 4)

VI^2_hat = k and VI = k	133 of 237 observations (56%)
VI^2_hat = 0 and VI = 0	69 of 110 observations (63%)
VI^2_hat = 1 and VI = 1	43 of 92 observations (47%)
VI^2_hat = 2 and VI = 2	21 of 35 observations (60%)

4.6 Summary and conclusions

This study provides empirical evidence for Williamson's (1991b) shift parameter framework. The presence of inter-organizational trust shifts the governance cost curves for alternative modes of organization disproportionally. It can be shown that pre-existing trust increases the likelihood of less hierarchical governance forms. Hence, the discussion of an optimal alignment of transactions, differing in their attributes, with appropriate governance structures should take into account both parameters on the transaction level (e.g., specificity of investments, uncertainty) and parameters accounting for dynamics in the institutional environment (i.e., shift parameters).

The 'LNG rush' forecasted during the early years of this decade has increased regasification capacity by almost 80% compared to 1999 levels. Increasing worldwide demand (even though recent projections are less enthusiastic due to the economic recession that began in 2007) and the ongoing process of deregulation in downstream markets have brought fundamental changes in corporate behavior. Many firms are already investing in regionally diversified LNG portfolios and integrate vertically to internalize risk factors resulting from investments in capital-intensive infrastructures. Control of transport capacities is a key factor in order to benefit from cross-trade opportunities.

Using probit and ordered probit models, the determinants of vertical integration are analyzed. Empirical results confirm the industry-specific propositions and support classical transaction cost economics as well as the relevance of shift parameters. The models show that relationship-specific investments in the presence of uncertainty favor hierarchical modes of governance to safeguard quasi-rents and avoid the hazard of post-contractual opportunism. However, pre-existing inter-organizational trust as determined by the historical relationship between the exchange partners mitigates the need for formal controls and favors less hierarchical structures. Trust can also provide a strong, relational safeguard against opportunism; as Williamson (1993a, p. 482) highlights, "breach of contract is sometimes efficient, even in a commercial contract that is supported by perfect safeguards. By

contrast, betrayal of a personal trust can never be efficient. Betrayal is demoralizing." Summarizing, a complete understanding of governance choice requires that both transaction characteristics and the institutional environment are considered. The current scarcity of empirical literature testing the shift parameter framework suggests fruitful avenues of research into alternative shift parameters.

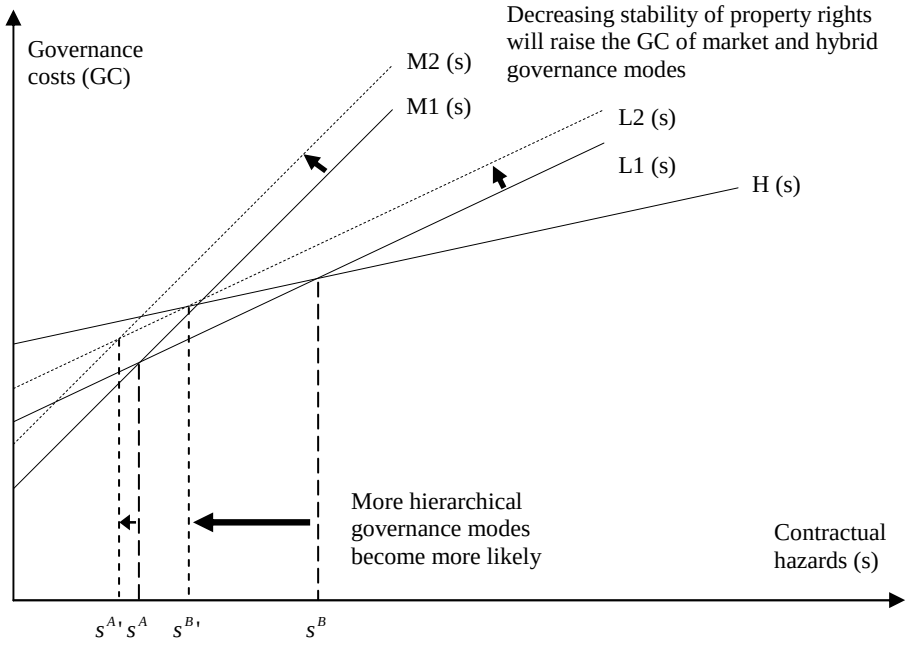
This study has some limitations. First, pre-existing inter-organizational trust should be regarded as an endogenous variable being determined by prior experiences between the exchange partners (see also Fehr, 2009). As Gulati and Sytch (2008, p. 166) point out, empirical studies "have focused primarily on the consequences and not the antecedents of trust." Therefore, two-stage regression models that explain the level of trust in a first step would substantially improve the analysis. However, it is difficult to measure inter-organizational trust; all studies explaining trust rely on survey data in which the measure of trust derives from indirect questions to be answered by key informants. Second, this study tests only reduced form equations since transaction costs cannot be measured. Should performance data on transaction levels become publicly available, researchers could investigate the direct impact of trust on the performance of alternative governance costs. Third, the ability to distinguish between pre-existing trust and emerging trust, that is, the relationship that develops during an exchange and/or over time is critical. Panel data including a measure of actual trust levels would greatly enhance our understanding of the relationship between inter-organizational trust and choice of governance.

4.7 Appendix

Illustrations of alternative shift parameter applications

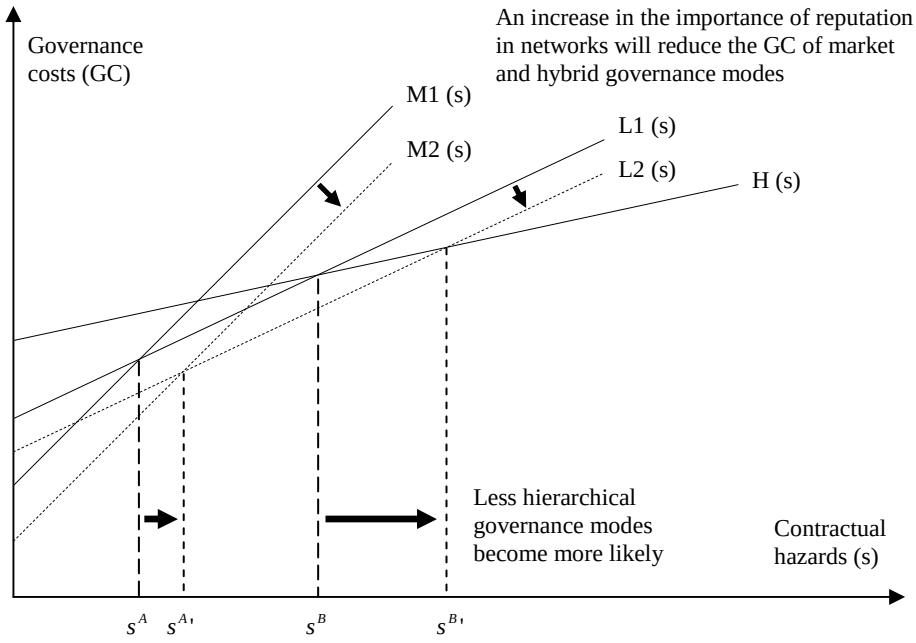
The following figures provide illustrations of alternative shift parameter applications including Williamson (1991b), Oxley (1999), and Henisz and Williamson (1999).

Figure 29: Shift parameter framework (stability of property rights) in Williamson (1991b)



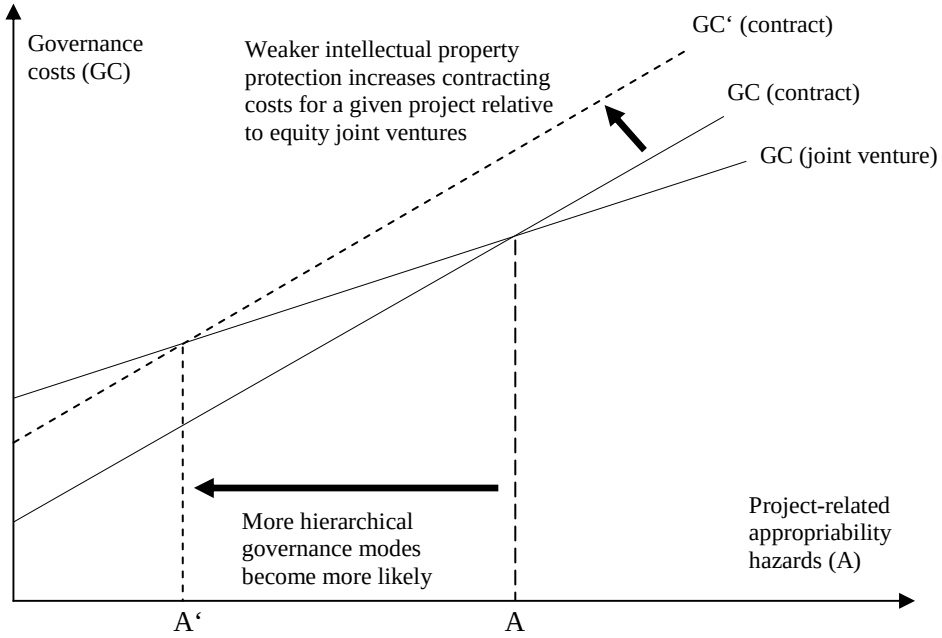
Source: Own depiction

Figure 30: Shift parameter framework (increased reputation) in Williamson (1991b)



Source: Own depiction

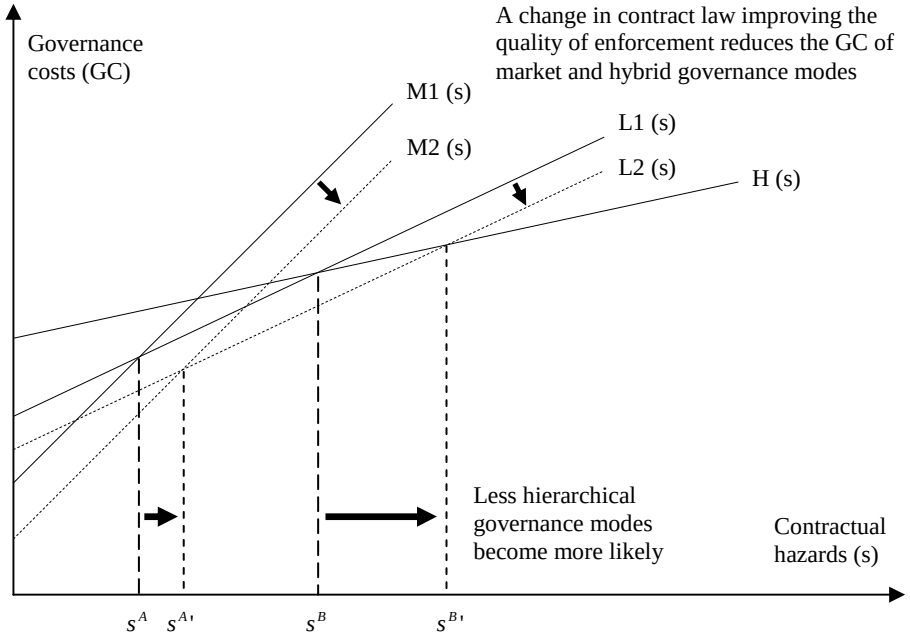
Figure 31: Shift parameter framework in Oxley (1999)



Source: Own depiction following Oxley (1999)

→ Even though the governance costs associated with equity joint ventures are also likely to rise, they will do so at a lower extent. The change in relative governance costs is the relevant factor.

Figure 32: Shift parameter framework in Henisz and Williamson (1999)



Source: Own depiction following Henisz and Williamson (1999)

→ This downward shift of the governance cost curves of market and hybrid organization can also be interpreted as an improvement in the intellectual property rights, thereby supporting greater inter-firm contracting.

Goodness-of-fit indicators

In order to evaluate the goodness-of-fit of alternative model specifications, different information criteria have been proposed. In this thesis, the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) are calculated in Chapters 4 and 5. Under the condition that the models to be compared use the same underlying dataset and that the dependent variable is equal over all specifications, the model with the smallest information criteria represents the best suited specification. Thereby, information criteria trade-off fit (measured via the log-likelihood value) and complexity of the model (measured via the number of exogenous variables). AIC and BIC are defined as:

$$\begin{aligned} AIC &= -2 \cdot (\ln L) + 2 \cdot (k) \\ BIC &= -2 \cdot (\ln L) + \ln(N) \cdot k \end{aligned} \qquad \text{(A4-1)}$$

with (ln L) being the value of the log-likelihood function, k the number of parameters to be estimated, and N the number of observations. The first part of the formulas represents the model fit. The larger this value, the worse the model is suited to explain the dependent variable. The second part represents a penalty term increasing with the number of regressors. Hence, the risk of biased estimates due to omitted exogenous variables is traded-off against the increasing variance of the error term with every additional regressor (i.e., with the loss of degrees of freedom).

Another goodness-of-fit indicator is the likelihood ratio index (or Pseudo R^2), defined as

$$LRI = 1 - \frac{\ln L}{\ln L_0} \qquad \text{(A4-2)}$$

with (ln L) being the maximized value of the log-likelihood function and (ln L_0) being the log-likelihood value of restricted model assuming that all slope coefficients are equal to zero. The index ranges between zero and one. Even though the nominal values have no natural interpretation (Greene, 2002, p. 683), an increase in the *LRI* will indicate an improvement in the fit of the model.

Marginal effects

Table 16 reports marginal effects of the alternative probit model specifications. The estimated coefficients from the probit model are difficult to interpret because they measure the change in the latent variable VI^{1*} associated with a change in one of the exogenous variables. More useful are marginal effects which are calculated via $\partial \Pr(VI = 1 \mid x)/\partial x = f(x'\alpha)\alpha = \phi(x'\alpha)\alpha$ (see e.g., Greene, 2002, pp. 667 f.). Hence, the marginal effects vary with the values of the exogenous variables. For a right-hand-side dummy variable, the marginal effect is determined calculating the difference in probabilities for the dummy equaling one versus the dummy equaling zero, all other variables hold at their means.

An infinitesimal change of transaction cost variables (i.e., asset specificity, uncertainty, and the interaction term) has a stronger impact on the probability of observing vertical integration than the presence of inter-organizational trust. It is furthermore interesting to note, that for value chains which began operation from 2000 on, the probability that we observe vertical integration of the respective player is more than 25% higher than for the early decades of the industry (e.g., 28.6% for Model 4).

Table 16: Marginal effects probit model

Specification	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
SPEC	-0.307	-0.316	-0.124	-0.155	-0.130	-0.124
UNC	-0.587	-0.580	-0.616	-0.619	-0.616	-0.616
(SPEC*UNC)	0.726	0.750	0.788	0.811	0.800	0.787
EXPAB		-0.020	-0.001	0.005	0.007	0.000
EXPPB		0.007	-0.017	0.128	0.033	0.018
D2000		0.188	0.273	0.286	0.279	0.273
CAPOWN			2.134	2.346	2.265	2.139
STATE			0.313	0.305	0.310	0.313
ASSETS			0.008	0.008	0.008	0.008
$(ASSETS)^2$			-0.000	-0.000	-0.000	-0.000
TRUST1				-0.032		
$(TRUST1)^2$				0.001		
TRUST2					-0.096	
TRUST3						-0.004

The marginal effects of an ordered probit model with an endogenous variable having one of the values {0, 1, 2} are calculated as $\partial \Pr(VI = 0 \mid x)/\partial x = -\phi(\mu_1 - x'\alpha)\alpha$; $\partial \Pr(VI = 1 \mid x)/\partial x = [\phi(\mu_1 - x'\alpha) - \phi(\mu_2 - x'\alpha)]\alpha$; and $\partial \Pr(VI = 2 \mid x)/\partial x = \phi(\mu_2 - x'\alpha)\alpha$. The marginal effects sum to zero, which follows from the requirement that the probabilities sum to one. For a right-hand-side dummy variable, the

marginal effect is determined by calculating the difference in probabilities for the dummy equaling one versus the dummy equaling zero, all other variables hold at their means.

Table 17: Marginal effects ordered probit model

Specification		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
SPEC	$VI^2 = 0$	0.246	0.283	0.111	0.152	0.126	0.110
	$VI^2 = 1$	-0.074	-0.097	-0.043	-0.063	-0.050	-0.043
	$VI^2 = 2$	-0.172	-0.176	-0.068	-0.089	-0.076	-0.067
UNC	$VI^2 = 0$	0.442	0.517	0.498	0.497	0.505	0.497
	$VI^2 = 1$	-0.133	-0.177	-0.194	-0.205	-0.200	-0.194
	$VI^2 = 2$	-0.308	-0.339	-0.303	-0.292	-0.305	-0.303
(SPEC*UNC)	$VI^2 = 0$	-0.555	-0.658	-0.638	-0.695	-0.663	-0.637
	$VI^2 = 1$	0.168	0.226	0.249	0.288	0.263	0.248
	$VI^2 = 2$	0.387	0.432	0.389	0.407	0.400	0.489
EXPAB	$VI^2 = 0$		-0.030	-0.041	-0.051	-0.049	-0.038
	$VI^2 = 1$		0.010	0.016	0.021	0.019	0.015
	$VI^2 = 2$		0.020	0.025	0.030	0.030	0.023
EXPPB	$VI^2 = 0$		0.055	0.086	-0.011	0.068	0.089
	$VI^2 = 1$		-0.020	-0.035	0.005	-0.028	-0.036
	$VI^2 = 2$		-0.035	-0.051	0.006	-0.040	-0.053
D2000	$VI^2 = 0$		-0.300	-0.340	-0.369	-0.349	-0.338
	$VI^2 = 1$		0.103	0.132	0.151	0.137	0.131
	$VI^2 = 2$		0.197	0.208	0.218	0.212	0.207
CAPOWN	$VI^2 = 0$			-1.218	-1.202	-1.266	-1.211
	$VI^2 = 1$			0.476	0.497	0.502	0.472
	$VI^2 = 2$			0.743	0.705	0.764	0.739
STATE	$VI^2 = 0$			-0.190	-0.175	-0.188	-0.188
	$VI^2 = 1$			0.064	0.064	0.065	0.064
	$VI^2 = 2$			0.126	0.111	0.123	0.128
ASSETS	$VI^2 = 0$			-0.007	-0.007	-0.007	-0.007
	$VI^2 = 1$			0.003	0.003	0.003	0.003
	$VI^2 = 2$			0.004	0.004	0.004	0.004
$(ASSETS)^2$	$VI^2 = 0$			0.000	0.000	0.000	0.000
	$VI^2 = 1$			-0.000	-0.000	-0.000	-0.000
	$VI^2 = 2$			-0.000	-0.000	-0.000	-0.000
TRUST1	$VI^2 = 0$				0.023		
	$VI^2 = 1$				-0.010		
	$VI^2 = 2$				-0.013		
$(TRUST1)^2$	$VI^2 = 0$				-0.0004		
	$VI^2 = 1$				0.0001		
	$VI^2 = 2$				0.0003		
TRUST2	$VI^2 = 0$					0.096	
	$VI^2 = 1$					-0.040	
	$VI^2 = 2$					-0.056	
TRUST3	$VI^2 = 0$						-0.012
	$VI^2 = 1$						0.005
	$VI^2 = 2$						0.007

5 Linking Transaction Cost Economics and Strategic Management

5.1 Introduction

In recent years, theories drawing upon institutional economics (i.e., Williamson's transaction cost economics) and the strategic management literature (i.e., Porter's strategic positioning framework and the resource-based view of the firm) have evolved to exploit the strengths of both disciplines. The key issue is to determine why different firms within the same industry choose to adopt varying strategies. Empirical work provides strong support for transaction cost economics, but "generally does not explore how the make or buy decision for a single transaction fits into a firm's overall strategy" (Nickerson, 1997, p. 3). In addition, empirical testing for alternative theories of the firm is rather scarce.

This study contributes to the literature an empirical analysis of corporate strategies in the emerging global market for liquefied natural gas linking alternative theories of the firm in order to explain the menu of strategic positions recently observed in this dynamic market. Based on a unique dataset including all LNG exporting and importing projects as well as the LNG fleet worldwide, 237 corporate-specific value chains are identified. In the first step, three alternative target market positions are defined, each supported by an underlying resource profile. In the second step, determinants that move companies towards vertical integration are investigated. Industry-specific propositions are tested by employing a two-step decision making process.

Estimation results provide broad support for the so-called positioning-economizing perspective of the firm; the three strategic choices of target market position, resource profile, and organizational structure are interdependent. It can be shown that national oil and gas companies rely on less idiosyncratic assets than companies following a flexibility strategy (i.e., investing in a portfolio of export and import positions) and that companies following a flexibility strategy rely on less idiosyncratic assets than chain optimizers (i.e., investing along a single value chain). Second, transaction cost economics predictions can be confirmed. Idiosyncratic investments in uncertain environments have a positive impact on the likelihood of vertical integration.[36]

5.2 Literature review

5.2.1 Transaction cost economics versus strategic management

Theoretical literature provides a number of approaches explaining corporate behavior. All theories of the firm have their origin in the seminal article of Ronald Coase published in 1937 explaining the emergence of firms by the presence of costs evolving by using the price mechanism and the boundaries of the firm by the presence of costs of internal organization. One can distinguish two streams of literature discussing organizational structures. Whereas economic approaches are mainly

[36] This chapter is an update of Ruester and Neumann (2009).

concerned with the performance of markets in the allocation and coordination of resources, strategic management approaches focus on the coordination and resource allocation inside the firm. Rumelt et al. (1991) provide a discussion on the relationship between economics and strategic management. They compare the historical development of both disciplines and illuminate the contributions of one discipline to the other. See Langlois et al. (2002) for an extensive survey of articles discussing alternative theories of the firm.

As discussed in Chapter 2, transaction cost economics identifies asset specificity, environmental uncertainty, and the frequency of transactions as the most significant factors influencing transaction costs. The hold-up problem arising from a high level of relationship-specific investments in an uncertain environment with players characterized by bounded rationality results in costly ex-post bargaining, ex-ante under-investment, and decreasing efficiency. Organizing transactions within a corporation's own hierarchy by internalizing the subsequent quasi-rents avoids these problems.

Concurrently to traditional economic approaches, the strategic management literature has also investigated corporate strategies and organizational forms, with 'strategy' understood as a firm's selection of a certain position in the market and activities that fit with the firm's position and with each other, both chosen to achieve a competitive advantage.[37] However, no one ideal position along the value added chain exists for all companies because customers and markets differ. Porter (1979) develops a model of five competitive forces (i.e., threats from substitute products, threats from new entrants, power of suppliers, power of customers, and competition within the industry itself) and their impact on corporate strategy. The goal of a competitive strategy is to find a position in the industry where the company can best defend itself against these competitive forces or can influence them in its favor (Teece, 1984).

According to the strategic positioning framework, there are cost-based and differentiation-based positions. Porter (1996, p. 62) discusses 'operational effectiveness' (performing similar activities better than rivals perform them) and 'strategic positioning' (performing different activities from rivals or performing similar activities in different ways).[38] He further argues that for companies to survive, they must be both flexible and able to respond to structural changes within their industry. A company can outperform rivals only if it can establish a stable competitive advantage.

The resource-based view of the firm focuses on rents derived from unique and imperfectly imitable or substitutable resources. Differences in firm performance are assumed to signal differences in resource endowments. Organizational resources (such as managerial ability, firm-specific language, routines, knowledge transfer capabilities) are distinguished from technological resources (such as physical assets, innovations protected by patents, technological competences) and reputational resources (such

[37] Porter (1996) defines strategic positions (the variety of the company's products and services based on customer needs and customer accessibility), activities (functions that create, produce, and deliver products or services) and fit (consistency between each activity and the overall strategy as well as reinforcement).

[38] In other work it is often referred to differentiation, cost leadership, and cost focus (e.g. Porter, 1985; Nickerson et al., 2001).

as consumer trust, brands, established networks, reputational capital). Competitive advantage and superior performance are derived from developing, deploying, and protecting these resources.

Similar to Porter's strategic positioning framework, the capabilities view is a dynamic concept in which firms need to match resources and capabilities to changes in the environment if they wish to attain optimum performance.[39] The capabilities view suggests that the choice of internalization of activities into the firm's own hierarchy is determined, at least in part, by the relative strengths of internal and external capabilities (Langlois, 1992) with capabilities being defined as the knowledge, experience and skills of the firm. Some activities may be similar (i.e., draw on the same general capabilities) others may be complementary (i.e., connected along the value chain). Where activities are both, similar and complementary, internal organization will be a suitable governance form. Dissimilarity in turn will make integration costly. Opportunities for growth from a diversification of activities are thus limited (see also Teece and Pisano, 1994). Some authors have explicitly examined the relationship between relative capabilities and the choice of a governance mode (e.g. Argyres, 1996).

Williamson (1991a) already discusses that transaction cost economics can make several contributions to the field of strategic management. He distinguishes two branches of strategy: strategizing (mainly in the sense of exercising market power) and economizing (adapting efficiently to changing environmental conditions and aligning transactions which differ in their attributes to appropriate governance modes that differ in their competences). Whereas the market is superior for autonomous adaptations, internal organization should be favored in cases where coordinated adaptations are necessary. Whereas the strategy view highlights the from a firm's perspective advantageous consequences of integration (such as enhanced bargaining power), transaction cost economics explicitly considers both, costs (such as high bureaucratic costs) and benefits. Williamson therefore argues that "… firms that mindlessly integrate weaken themselves in relation to nonintegrated rivals" (p. 83) and concludes that in the long run "…the best strategy is to organize and operate efficiently" (p. 75).

5.2.2 Recent trends toward a synthesis of competing theories

Empirical work provides strong support for transaction cost economics, but "generally does not explore how the make or buy decision for a single transaction fits into a firm's overall strategy" (Nickerson, 1997, p. 3). In recent years, several authors have developed theoretical approaches combining economics and strategic management literature. Whereas the economic literature analyzes

[39] Winter (2003, p. 991) founds the concept of organizational capabilities on the broader concept of organizational routine: "An organizational capability is a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization's management a set of decision options for producing significant outputs of a particular type." He further distinguishes ordinary capabilities (i.e., permitting a firm to operate in the short-term) and dynamic capabilities (i.e., capabilities necessary to extend, modify and create ordinary capabilities).

markets in which various firms are active, the strategic management literature examines the behavior and the performance of individual firms without any implications for the industry as a whole.

In an early paper, Day and Klein (1987) discuss the determinants of cooperations between firms along value chains from two perspectives, a market failure approach (i.e., transaction cost economics) and a strategic management approach. Whereas the market failure perspective focuses on the formation of vertical cooperations as a mean to safeguard firms against opportunistic behavior by the counterparty in cases where bilateral dependencies evolve, strategic behavior is largely ignored. The level of ex-ante competition is taken as given, whereas the strategic perspective focuses on competitive and anticompetitive strategies. Day and Klein argue that the creation of relationship-specific assets may be a key ingredient of a competitive strategy (e.g., in the case of product differentiation). They conclude that "… to fully appreciate vertical linkages, one must understand both the effect of competitive markets on strategy formulation and the effect of market failure on strategy realization. To ignore either element is to miss the adaptive nature of competitive strategy and cooperative behavior" (p. 62). They suggest that future research should combine strategic management and transaction cost economics.

Nickerson (1997) develops an extension of the basic transaction cost economics framework in order to transform Williamson's theory from an 'economizing theory of organization' focusing on the discriminative alignment of transactions to governance forms into an 'economizing theory of strategy'. Pointing out that "a firm's strategy is more than a collection of independent transactions" and that the activities a firm chooses to undertake must somehow be related and reinforcing (p. 2), he combines strategic management and transaction cost economics to the so called 'positioning-economizing perspective' and argues that decisions regarding market position, resource investments, and governance mode are interdependent. A target market position is supported by a resource profile that in turn determines the organizational choice of a firm. See Section 5.3 for a more detailed discussion of this theory.[40]

Building on Day and Klein (1987) and Nickerson (1997), Ghosh and John (1999) develop a similar model. Their 'governance value analysis' starts with Williamson's model linking transaction attributes to governance modes and then adds positioning (i.e., the target market position) as well as resources (i.e., scarce and imperfectly mobile skills, assets, or capabilities). Strategic positioning will determine the level of investments in specific assets, the level of adaptation needs, as well as ex-post measurement problems. Hence, two firms in the same market may choose varying governance forms in order to align these to the respective conditions depending on their strategy.

[40] Rumelt et al. (1991) already argue that strategic decisions, such as the products and services offered as well as the scope of activities integrated into the firm and the appropriate organizational structure, must be reinforcing, hence, are not independent. Nelson (1991, p. 69) likewise argues that "… to be successful in a world that requires that firms innovate and change, a firm must have a coherent strategy that enables it to decide what new ventures to go into and what to stay out of. And it needs a structure, in the sense of mode of organization and governance, that guides and supports the building and sustaining of the core capabilities needed to carry out that strategy effectively. "

Empirical literature testing for alternative theories or their combination is still rare. Building on Nickerson (1997) and Ghosh and John (1999), Nickerson et al. (2001) link Porter's strategic positioning framework and the transaction cost approach with an application to the international courier and small package service in Japan in order to overcome the weaknesses of both approaches, since "Porter (1996) fails to call upon Williamson's insights to inform whether activities should be organized internally or outsourced, and Williamson (1991[a]) claims that managers are well advised to concentrate on economizing instead of on positioning" (p. 252). Using a dataset 995 parcels shipped from Japan to 160 destination cities in 42 countries they test industry-specific predictions relating market position to resource investments, the resource profile to organizational form and the resource profile/organization pairings to firm performance (i.e., delivery speed). Estimation results of the three-stage, reduced form, endogenous self-selection model provide broad support for all propositions and confirm that decisions on a firm's market position, resource profile and organizational choice are interrelated in ways predicted by the positioning-economizing perspective. The authors conclude that the heterogeneity in corporate strategies reflects the reality of firms being endowed with different feasible resource profile/organization pairings.

Poppo and Zenger (1998) investigate make-or-buy decisions in information services testing alternative theories of the firm (e.g., transaction cost theory, resource-based view, agency theory). These approaches offer alternative – in some cases complementary and in other cases contradictory – explanations of corporate behavior. By developing a model of comparative institutional performance rather than the traditional reduced-form institutional choice model, they test for various theory-specific hypotheses. The authors conclude that in order to improve the theory of the firm, competing approaches must be integrated.

This chapter provides an empirical study of the determinants of vertical integration in the global LNG industry, accounting for the endogeneity of investments in specific assets. The analysis is based on the positioning-economizing approach. First, following Porter, three strategic target market positions in this industry are identified: chain optimization versus a flexibility strategy versus national oil and gas companies. Each target market position is supported by an underlying resource profile characterized by a certain level of idiosyncrasy. Second, following transaction cost economics, it is argued that specific investments under uncertainty provide incentives to integrate vertically. These economic relationships are tested empirically based on a two-step procedure.

5.3 Theoretical background

5.3.1 Positioning-economizing perspective

Assuming that all firms in one industry face the same environmental conditions and the same level of transaction attributes, transaction cost economics would predict that all firms choose identical governance forms. However, this is not the case in the real world. In the LNG industry for example,

we observe vertical integration but at the same time also non-integrated players as well as various forms of hybrid governance.

Transaction cost economics has made several contributions to strategic management; the central problem of make-or-buy has been applied to numerous other problems such as lateral integration, joint ventures, employment relations, etc. See Williamson (1991a) and Nickerson (1997) for more detailed discussions. However, several authors call for a combination of both approaches; Nickerson et al. (2001, p. 251) argue that "… if followed in isolation, each theory can lead to inferior performance". The positioning-economizing perspective provides a framework which is able to explain this diversity of governance forms.[41] Whereas the unit of analysis in transaction cost economics is the single transaction, its ability to explain corporate strategies on a firm-level is underdeveloped. Therefore, the unit of analysis in the positioning-economizing perspective is the firm-level strategy (i.e., the combination of all transactions).

Nickerson (1997) argues that the decisions regarding targeting a specific set of consumers, choosing a production technology, making specific investments or not to support the customer transaction, and selecting a governance mode are interdependent. He defines the 'strategy four-tuple' as $\{A, k^p, k^m, \gamma\}$ where A represents the vector of product attributes including features and quality, k^p represents a vector of production technologies p and the corresponding level of specific investments, k^m is the vector of the nature and level of specific investments m in the consumer transaction and γ represents the governance mode. In the following discussions k^p and k^m are jointly referred to as resource investments. The firm's optimal strategy is the four-tuple that generates the greatest net receipts. Hence, successful strategic behavior requires taking into consideration various aspects (i.e., demand conditions and competitive market structure, production costs as well as transaction costs). A formalization of the four-tuple choice problem is provided in the Appendix.

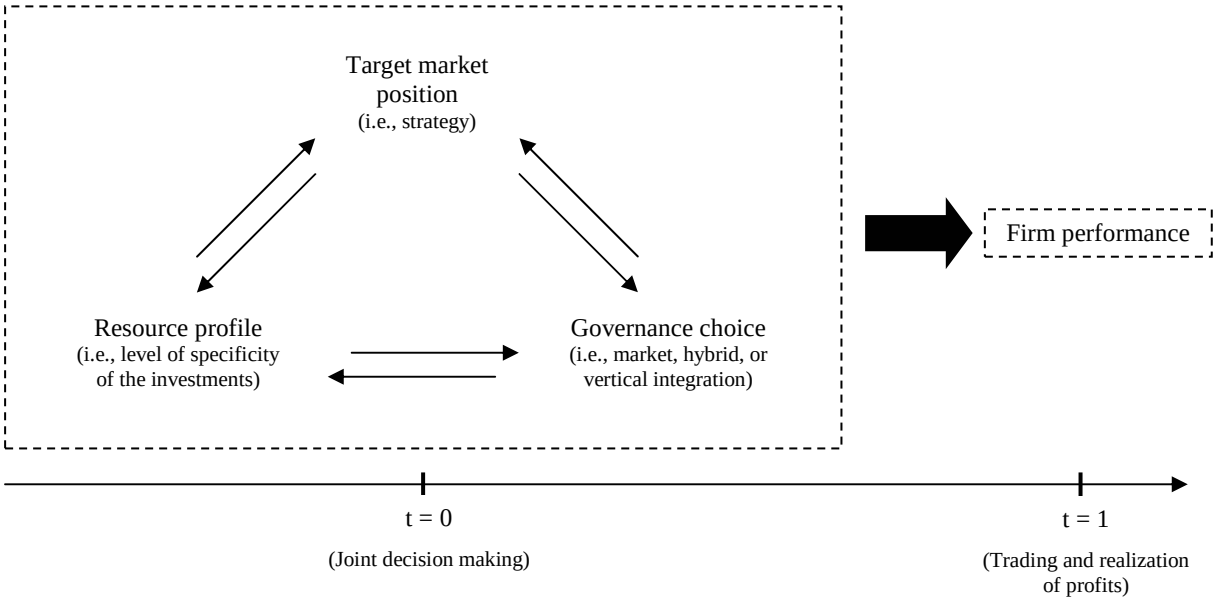
Figure 33 illustrates the positioning-economizing perspective. A target market position (i.e., products and services a firm desires to serve to a specific group of consumers) is supported by an underlying resource profile (defined as the set and type of resources and capabilities employed in the vertical chain). These resources are of a certain kind (i.e., degree of idiosyncrasy) which in turn determines the optimal governance mode. The decisions on target market position, resource investments and governance mode are made jointly in t = 0. In the next period, trading takes place and profit are realized. Firms will prefer the strategy with the greatest profitability; "combinations that are not reinforcing are not feasible in the long-run" (Nickerson et al., 2001, p. 271). Heterogeneity in firm strategies reflects that firms occupy different feasible resource profile/organization pairings.

Hence, three related questions have to be answered: Which resource profiles support different target market positions? Which governance forms economize on transaction and production costs given the

[41] The term 'positioning-economizing perspective' has been introduced by Nickerson et al. (2001). Nickerson (1997) talks about an 'economizing theory of strategy' based on a four-tuple analysis. Ghosh and John (1999) talk about a 'governance value analyses'.

resource profile? Which impact has the resource profile/organization pairing on product and service attributes (i.e., performance)?

Figure 33: Positioning-economizing perspective



Source: Own depiction

Nickerson et al. (2001) make an important contribution to this literature responding to three challenges present when combining alternative theories of the firm. First, they show that the assumptions underlying both approaches are not inconsistent since they focus on unrelated factors. Transaction cost economics makes two behavioral assumptions with economic actors being characterized by bounded rationality and opportunism. In the strategic positioning framework, no behavioral assumptions (in the sense of bounded rationality) are made. Furthermore, it is explicitly assumed that consumers are heterogeneous and that not one single strategy optimally serves all customers. Second, they point out that both theories have a consistent unit of analysis – the value chain and transactions (unbundled value chain), respectively. Third, they offer a methodology of operationalization of the model (i.e., a three-step estimation procedure).

5.3.2 Industry-specific propositions

This section introduces alternative corporate strategies observed in the global LNG market and develops industry-specific propositions. To investigate the LNG industry from an economic as well as from a strategic perspective, it is distinguished between upstream activities (exploration, production, and liquefaction), midstream shipping, and downstream regasification and marketing. Companies may be specialized in one, two, or even all three of these segments. However, we also observe varying strategies of different companies which are active in similar stages of the value chain, and one and the same company choosing different positions along alternative value chains. Strategic positioning is understood as performing different activities from rivals' or performing similar activities in different

ways. From Porter's strategic positioning framework, three possible target market positions taken by LNG firms can be identified:

- Flexibility strategy: Players following a flexibility strategy (e.g. BG Group, Exxon Mobil) are investing in a portfolio of LNG export and import capacities on both sides of the Atlantic or even in the Atlantic and Pacific Basins, enabling benefits from arbitraging possibilities. The control of midstream transportation capacities is a key factor required for flexible trade.
- Chain optimizers are typically active in one import country (e.g. Gaz de France, Korea Gas Corporation), contracting or integrating along the associated value chain in order to secure supplies.
- National oil and gas companies (NOCs) are upstream state-owned, traditionally producing, companies (e.g. Sonatrach in Algeria) with the main objective of generating state revenues.

Each target market position is supported by an underlying resource profile. However, as already discussed in Section 4.4, the definition of asset specificity in the LNG industry is not straightforward. A company investing in downstream capacity without having secured supplies and access to midstream shipping is caught in a lock-in situation. LNG sellers traditionally profited from significant bargaining power since importers competed globally for natural gas supplies. Competitive downstream markets facilitate their access to numerous buyers.
Whereas NOCs typically invest in the upstream sector and may integrate downstream, chain optimizers hold downstream positions contracting or integrating upstream along the associated value chain in order to secure supplies. Employing a flexibility strategy leads players to invest in a portfolio of upstream and downstream capacities. Hence:

> *Proposition 1: National oil and gas companies rely on less idiosyncratic assets than companies following a flexibility strategy; companies following a flexibility strategy rely on less idiosyncratic assets than chain optimizers.*

According to transaction cost economics, idiosyncratic assets in uncertain environments lead to the hazard of ex-post opportunistic behavior by the counterparty. Organizing transactions within a firm's own hierarchy will avoid these costs. Asset specificity furthermore is argued to be the strongest determinant of vertical integration. Hence:

> *Proposition 2: Given the presence of environmental uncertainty, a higher share of idiosyncratic (downstream) assets in the portfolio of an LNG firm will increase the probability of vertical integration along the LNG value chain.*

For this study, it is assumed that the observed governance modes represent efficient choices and that potential misalignment will result in a re-positioning or in the company ceasing its activities in the industry due to entrepreneurial failure. Unfortunately, transaction-specific performance data (i.e., performance related to activities along the LNG value chain) are not publicly available. Therefore, a possible third proposition – as proposed theoretically in the positioning-economizing perspective – relating feasible resource profile/organization pairings to firm performance cannot be tested.

An econometric model analyzing the above described two-part decision-making process is developed below. In the first step, it is examined how players choose a resource profile supporting their target market position. In the second step, the determinants that drive players towards vertical integration are investigated.

5.4 Data and methodology

5.4.1 Data

This study is based on the same dataset as the analysis carried out in Chapter 4. The unit of analysis for studying the determinants of vertical integration is again the corporate-specific value chain with vertical integration from upstream or downstream into midstream shipping as the main endogenous variable. The dependent variable VI is a discrete measure taking the value of one if we observe vertical integration of the player along value chain *i*, and zero otherwise. In 135 of the 237 observations we observe vertical integration into midstream shipping:

$$VI_i = \begin{cases} 0 & \text{if no vertical integration into midstream shipping} \\ 1 & \text{if vertical integration} \end{cases}$$

5.4.2 Explanatory variables

Corporate strategies. Proposition 1 describes the relationship between a target market position and the resource profile (i.e., the level of idiosyncrasy of a player's LNG assets). Dummy variables indicating chain optimizers (CHAIN) and national oil and gas companies (NOC) are used as exogenous variables. The flexibility strategy (FLEX) is the omitted position. The allocation of the companies active in the LNG industry to one of the three target market positions was accomplished based on an evaluation of their activities and was verified in interviews with natural gas market experts. Proposition 1 indicates a positive (respectively negative) relationship between the level of specific investments and CHAIN (respectively NOC).

Transaction cost variables. Proposition 2 refers to the impact of idiosyncratic assets and uncertainty on the likelihood of vertical integration. Transaction cost economics predicts that asset specificity is the strongest determinant of integrating successive stages of the value chain into the corporation's own hierarchy. The relative extent of idiosyncratic assets of a player (SPEC) is defined as the ratio of

regasification capacity over the sum of regasification and liquefaction capacity the player controls in the start-up year of the value chain with $SPEC_i = r_{i, year} / (r_{i, year} + l_{i, year})$. The variable increases with the share of regasification capacities in a firm's LNG portfolio, mirroring the lock-in situation of a player investing downstream in a sellers' market. It is continuously distributed between zero and one, including these boundaries.

Due to the high capital-intensity of infrastructure investments and uncertainties about the scope of natural gas fields and price developments, investors generally face different risks. In addition, natural gas fields are often located in politically unstable regions. As discussed in Chapter 4, several risks can be hedged and the political risk associated with upstream investments is evaluated as the main driver of uncertainty. The variable for political uncertainty (UNC), based on the so-called POLCON-index developed by Henisz (2000), is defined as (1 – POLCON) with $UNC_i \in [0, 1]$.

Control variables. To account for changes in corporate strategies over time a dummy variable indicating value chains that came into operation after 1999 (D2000) is included. It is expected that players will encounter a changing environment given the industry's rapid expansion and maturation since the end of the 1990s and that they must select or adapt strategies to maintain or gain competitive advantages as discussed above.

Several dummy variables are used to control for differences in corporate strategies resulting from regional factors that vary between the Atlantic Basin market (deliveries to Europe and North America) where LNG trading hubs already exist or are developing, and Asia-Pacific trade where buyers depend strongly on LNG imports. EXPAB indicates exporters situated in the Atlantic Basin, EXPPB indicates exporters situated in the Pacific Basin, suppliers delivering LNG from the Middle East to either Europe, North America, or Asia (EXPME) are the default category.

CAPOWN accounts for a company's market share in the industry, calculated as the ratio of the accumulated liquefaction and regasification capacities controlled (owned or contracted) by a global player over the sum of worldwide liquefaction and regasification capacities in operation at the end of the respective start-up year of the value chain: $(r_{i, year} + l_{i, year}) / (r_{total, year} + l_{total, year})$. Companies controlling significant LNG capacities may be able to benefit from arbitrage possibilities which in turn increases the motivation to integrate into midstream shipping, especially when downstream regasification assets account for a significant share in the portfolio.

The player's assets value (ASSETS) is used as a proxy variable for firm size and financial strength. A positive relation between the probability of vertical integration and ASSETS is expected since companies endued with a strong capital basis face lower barriers to entry in terms of funding capital-intensive LNG projects.

Finally, the dummy variable STATE identifies state-owned entities, thus allowing for differences in corporate strategies due to a different ownership structure.

For a survey of all explanatory variables as well as their descriptive statistics see Table 18. More than half of the analyzed corporate-specific value chains (53%) began operation after 1999. In 34% of all

cases we observe companies following a flexibility strategy, in 44% chain optimizers and in 22% NOCs. Asset specificity of the respective company's LNG portfolio ranges between zero (i.e., no specificity of the investments since the portfolio is dominated by upstream capacities; e.g., National Gas Company Trinidad/Tobago) and one (i.e., high specificity since the portfolio is dominated by downstream positions; e.g., Korea Gas Corporation) with a mean of 0.48. The political uncertainty index of the exporting country lies between 0.13 and one. Broken up on a regional level, 44% of the observations represent value chains originating from Atlantic Basin exporters, 40% represent Pacific Basin exporters' deliveries and in 16% Middle Eastern suppliers are involved. Players control between 0.1% (Union Fenosa in 2000) and 30.3% (Osaka Gas in 1972) of worldwide LNG capacities during the observation period. Corporate size ranges from USD 358mn (Italian Enel) to USD 279bn (Japanese Nippon Oil Corp.). Finally, 33% of the observed value chains include state-owned entities.

Table 18: Explanatory variables and summary statistics

Characteristic	Proxy	Unit	Denotation	Exp. sign	Mean	Std. dev.	Min	Max	N
Proposition 1 (dependent variable: SPEC)									
Strategy 1: Flexibility	Company following a flexibility strategy investing in a portfolio of export and import positions	Dummy	FLEX		0.342	0.475	0	1	237
Strategy 2: Chain optimizer	Company following a chain optimizing strategy investing along single value chains	Dummy	CHAIN	+	0.439	0.497	0	1	237
Strategy 3: NOC	National oil and gas company	Dummy	NOC	-	0.219	0.415	0	1	237
Proposition 2 (dependent variable: VI)									
Asset specificity	Share of downstream capacities in the player's LNG portfolio	%	SPEC	+	0.479	0.446	0	1	237
External uncertainty	Political instability in the supplying country		UNC		0.616	0.379	0.13	1	237
Control variables									
Change in industry structure	Start-up of the value chain after 1999	Dummy	D2000		0.527	0.500	0	1	237
Export region	Exporter in the Atlantic Basin	Dummy	EXPAB		0.439	0.497	0	1	237
	Exporter in the Pacific Basin	Dummy	EXPPB		0.405	0.492	0	1	237
	Exporter in the Middle East	Dummy	EXPME		0.156	0.364	0	1	237
Market share in the LNG industry	Capacity controlled by the player (% of total existing export and import capacity)	%	CAPOWN		0.040	0.052	0	1	237
Financial resources	Company size measured by the assets value	bn USD	ASSETS		63.476	63.628	0.358	195.265	237
Company type	Company being state-owned	Dummy	STATE		0.380	0.486	0	1	237

Table 19: Correlation matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13
VI	1	1												
FLEX	2	0.213	1											
CHAIN	3	0.082	-0.637	1										
NOC	4	-0.342	-0.382	-0.469	1									
SPEC	5	0.169	-0.299	0.758	-0.565	1								
UNC	6	-0.213	-0.176	-0.096	0.318	-0.224	1							
D2000	7	0.167	0.148	-0.032	-0.131	0.011	-0.068	1						
EXPAB	8	-0.073	-0.010	-0.165	0.209	-0.059	0.330	0.173	1					
EXPPB	9	0.040	-0.160	0.292	-0.168	0.202	-0-230	-0.286	-0.730	1				
EXPME	10	0.032	0.219	-0.153	-0.065	-0.177	-0.150	0.137	-0.386	-0.337	1			
CAPOWN	11	0.124	-0.270	0.183	0.090	0.222	0.004	-0.329	-0.100	0.237	-0.189	1		
ASSETS	12	0.190	0.691	-0.417	-0.292	-0.365	-0.115	0.063	-0.141	0.033	0.140	-0.098	1	
STATE	13	-0.057	-0.454	-0.114	0.657	-0.180	0.242	-0.148	0.097	-0.150	0.061	0.115	-0.491	1

5.4.3 Methodology

To test the above derived propositions, an estimation model with both vertical integration as well as the level of specific investments as endogenous variables is defined. The first stage of the regression investigates the relationship between a target market position and the level of idiosyncratic assets, the second stage analyzes the impact of the firm's resource profile (with respect to the level of idiosyncrasy) on the likelihood of vertical integration

Since the above developed theoretical discussion is built on a set of relationships with two endogenous variables, one has to deal with simultaneous equations (Greene, 2002, pp. 74 ff. and 378 ff.; Maddala, 2001, pp. 343 ff.). Two-stage estimation procedures using instrumental variables (IV) are required. An independent OLS estimation of the single equations would lead to inconsistent estimators (i.e., simultaneous equation bias) since the endogenous variables are correlated with the disturbances. Suppose a population model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_K x_K + \varepsilon \tag{5-1}$$

with $E(\varepsilon) = 0$ and $Cov(x_j, \varepsilon) = 0 \ \forall \ j \in (1 \ldots (k-1))$. The right-hand-side variable x_k is an endogenously determined variable. Hence, the error distribution cannot be considered independent of the regressor's distribution with $E(\varepsilon \mid x_k) \neq 0$; the regressor is correlated with the error term: $Cov(x_k, \varepsilon) \neq 0$. The idea is to find a set of instruments Z which is correlated with x_k, but orthogonal to the error term. Hence, $Cov(Z, x_k) \neq 0$ and $Cov(Z, \varepsilon) = 0$. However, the identification of suitable instruments is a very challenging task. Greene (2002, p. 80) highlights that "[u]nfortunately, there usually is not much choice in the selection of instrumental variables. The choice of Z is often ad hoc. There is a bit of a dilemma in this result. It would seem to suggest that the best choices of instruments are variables that are highly correlated with X. But the more highly correlated a variable is with the problematic columns of X, the less defensible the claim that these same variables are *uncorrelated* with the disturbances."

Consistent estimates of the parameters can be constructed by using these assumed relationships between Z, x_k and ε. In the two-stage least squares (2SLS) model, x_k is regressed on all system exogenous variables as well as on the vector Z in the first stage. The fitted values are used as instrument for y in the second stage:

$$\begin{aligned} x_k &= \delta_0 + \delta_1 x_1 + \delta_2 x_2 + ... + \delta_{k-1} x_{k-1} + \theta_1 z_1 + \theta_2 z_2 + ... + \theta_m z_m + v \\ y &= \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_K \hat{x}_K + \varepsilon \end{aligned} \tag{5-2}$$

Following Proposition 1 that refers to the strategic positioning framework, it has been hypothesized that each target market position is supported by an underlying resource profile. To check for a non-linear impact of firm size on the integration decision, the asset's value is included both in linear and in quadratic form into the estimation model:

$$SPEC_i = \alpha_0 + \alpha_1 CHAIN_i + \alpha_2 NOC_i + \alpha_3 UNC_i + \alpha_4 D2000_i + \alpha_5 EXPAB_i + \alpha_6 EXPPB_i + \alpha_7 CAPOWN_i + \alpha_8 ASSETS_i + \alpha_9 (ASSETS_i)^2 + \alpha_{10} STATE_i + v_i \quad (5\text{-}3)$$

where the error term v_i is expected to follow a normal distribution. For econometric reasons, all control variables used in Equation (5-4) are also included in Equation (5-3). In the second step, based on the transaction cost approach, the impact of specific investments on a firm's choice of governance form is analyzed. Following Proposition 2, it is expected that idiosyncratic assets relate positively to the likelihood of vertical integration:

$$VI_i = \beta_0 + \beta_1 SPEC_i + \beta_2 UNC_i + \beta_3 D2000_i + \beta_4 EXPAB_i + \beta_5 EXPPB_i + \beta_6 CAPOWN_i + \beta_7 ASSETS_i + \beta_8 (ASSETS_i)^2 + \beta_9 STATE_i + \varepsilon_i \quad (5\text{-}4)$$

where the error term ε_i is assumed to follow a normal distribution. Having defined the dependent variable as a binary variable, a two-stage probit estimation model with an endogenous right-hand side variable (i.e., SPEC) is applied. Similarly to the more general two-stage least squares procedure, the observed values of the first-stage dependent variable (estimated using OLS) are replaced by their predicted values. Equation (5-4) is then specified as a probit model. See Section 4.4.3 for a technical summary on probit estimation.

5.5 Estimation results and interpretation

Table 20 provides estimation results of three models with Model 1 including only the main explanatory variables (i.e., target market positions as well as the level of specific investments), Model 2 including furthermore the transaction cost variable controlling for external uncertainty as well as control variables indicating the start-up of the value chain and the exporting region, and finally, Model 3 including all above defined exogenous variables. Both industry-specific propositions are confirmed empirically. Estimation results are robust with respect to the alternative model specifications. The log-likelihood values as well as different information criteria (i.e., AIC, BIC) indicate that the least parsimonious Model 3 has the best explanatory power.

Estimation results provide broad support for Proposition 1. As expected, the estimation coefficient of the variable indicating chain optimizers (CHAIN) has a positive sign and the estimation coefficient of the variable indicating NOCs has a negative sign (both statistically significant at a 1% level for all models). Hence, it can be confirmed that national oil and gas companies rely on less idiosyncratic assets than companies following a flexibility strategy, and the last rely on less idiosyncratic assets than chain optimizers.

The results of the second-stage estimation provide support for the transaction cost economics' prediction. Asset specificity (SPEC) shows the expected positive sign and is highly significant. Hence, the more idiosyncratic (downstream) assets a company has in its portfolio of LNG export and import

positions, the higher will be the likelihood of vertical integration along single value chains. The players secure their supplies by investing in midstream shipping and in some cases also in downstream production and liquefaction. This goes in line with the recent move towards more flexibility in long-term LNG supply contracts; destination clauses often are eliminated and we observe an increasing importance of fob rather than des/cif contracts, leaving the control of midstream transportation with the buyers.

Even though theory argues that the level of specific investments is itself a decision variable (see also Masten, 1999), an augmented Durbin-Wu-Hausman test as suggested by Davidson and MacKinnon (1993) has been applied to explicitly test for the endogeneity of the variable SPEC. In the case that the regressor and the error term are uncorrelated both estimators (i.e., OLS and two-stage estimator) will yield consistent estimates, with the two-stage estimator being less efficient. The test statistic applied to Model 3 yields a chi-squared value of 16.5 significant at a 1% level. The null hypothesis of specificity being an exogenous variable can be rejected. This justifies the use of an instrumental variable estimation procedure (i.e., two-stage probit model with an endogenous regressor), since a simple probit regression of Equation (5-4) without accounting for the endogeneity of SPEC would lead to biased estimates. For a more detailed description of the calculation of this test statistic see the Appendix.

The presence of external uncertainty (UNC), in terms of political instability of the exporting country, seems to have a negative impact on the integration decision.[42] However, theory predicts that its presence intensifies the impact of specific investments. Interestingly, the level of specific investments decreases with increasing uncertainty (statistically significant at a 1% level). This indicates that companies increasingly safeguard investments in downstream assets by respective upstream investments the higher the political instability of the exporting country and hence, the higher the hazard of ex-post opportunistic (or unforeseeable) behavior by national agencies or companies.

Statistically significant control variables provide several interesting findings. The variable controlling for the start-up date of the value chain (D2000) indicates that vertical integration has become a more common organizational mode throughout the industry. This reflects global players' efforts to establish a portfolio of export and import positions in order to benefit from arbitrage potentials. We observe that access to flexible transport capacities is the key to a successful employment of this strategy. Rapid industrial expansion accompanied by a restructuring process prompts firms to internalize risks inherent in the capital-intensive industry via strategic repositioning and reshaping.

The variables EXPAB and EXPPB have no significant impact on the decision to integrate vertically and there appears to be no difference in corporate strategies between value chains in the Atlantic Basin which are dedicated to more or less competitive downstream markets, value chains in the Pacific Basin market where countries typically strongly rely upon natural gas imports in the form of LNG, and value

[42] 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.

chains from the swing producer region of the Middle East. An alternative regression accounting for the importing region (deliveries dedicated to Atlantic Basin customers instead of to Pacific Basin customers) does not reveal any regional differences, too.

Players controlling a larger share of world LNG (regasification and liquefaction) capacities (CAPOWN) show a higher extent of investments in specific assets. However, no significant influence on the likelihood of vertical integration could be found.

For the variable measuring a firm's financial strength (ASSETS) it can be shown that investments in specific assets decrease with a higher assets value. A possible explanation is that most capital-intensive investments are required upstream (exploration, production, and liquefaction). In contrast, the value of assets is positively related to the likelihood of vertical integration (with a non-linear impact), an indication that larger firms have the financial capabilities necessary to invest in numerous capital-intensive LNG (export and/or import and shipping) facilities.

In contrast to private firms, state-owned entities (STATE) tend to invest in assets with a higher level of idiosyncrasy; the share of regasification capacities in their LNG portfolios is larger on average. This can be explained by the fact that in the first decades of the LNG industry, mainly national natural gas companies and distributors invested in LNG import capacities, even though we observe the move to privatization (e.g. Gaz de France, ENI). Furthermore, the likelihood of vertical integration is on average also higher for state-owned entities.

Table 20: Estimation results

Specification	Proposition 1 - Dependent variable: SPEC First stage regression			Proposition 2 - Dependent variable: VI Second stage regression		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
CONSTANT	0.306 *** (0.032)	0.282 *** (0.258)	0.555 *** (0.071)	-0.144 (0.140)	0.123 (0.294)	-2.285 *** (0.452)
CHAIN	0.551 *** (0.042)	0.556 *** (0.042)	0.233 *** (0.047)			
NOC	-0.314 *** (0.051)	-0.296 *** (0.051)	-0.648 *** (0.059)			
SPEC				0.670 *** (0.234)	0.544 ** (0.254)	1.917 *** (0.307)
UNC		-0.151 *** (0.050)	-0.112 *** (0.043)		-0.505 ** (0.248)	-0.392 (0.262)
D2000		-0.021 (0.036)	0.034 (0.043)		0.412 ** (0.178)	0.482 ** (0.197)
EXPAB		0.196 *** (0.052)	0.185 *** (0.047)		-0.175 (0.263)	-0.129 (0.272)
EXPPB		0.089 * (0.054)	0.121 ** (0.049)		-0.089 (0.271)	-0.124 (0.280)
CAPOWN			1.649 *** (0.316)			1.985 (2.154)
ASSETS			-0.004 *** (0.001)			0.026 *** (0.006)
$(ASSETS)^2$			0.000 * (0.000)			-0.0001 ** (0.000)
STATE			0.055 *** (0.046)			1.220 *** (0.265)
Log-likelihood				-184.37	-167.84	-107.53
AIC				382.73	365.68	261.05
BIC				407.01	417.70	340.82
N	237	237	237	237	237	237

*** 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.

5.6 Summary and conclusions

This study provides empirical evidence for combining alternative theories of the firm. Recent theoretical literature argues that economic and strategic management approaches should be linked in order to explain companies' behavior in dynamic markets and the emergence of different corporate strategies in one and the same industry (see e.g., Nickerson and Bigelow, 2008). The study builds on recent theoretical developments which propose the so-called positioning-economizing perspective linking Williamson's transaction cost approach and Porter's strategic positioning framework.

During the early years of this decade worldwide regasification capacity has increased significantly, even though recent projections are less enthusiastic with regard to the world financial crisis and the resulting global demand decrease. Rapidly increasing worldwide demand in the past and the ongoing

process of deregulation in downstream markets have brought fundamental changes in corporate behavior; many companies are investing in regionally diversified LNG portfolios and integrating vertically to internalize risk factors resulting from investments in capital-intensive infrastructures. The control of transport capacities is a key factor in order to benefit from cross-trade opportunities.

Based on a two-step decision-making process, two propositions on corporate strategies in the LNG industry are tested. First, based on the strategic positioning framework, three possible target market positions are identified: chain optimization (investments in infrastructure along a single value chain) versus a flexibility strategy (investments in a portfolio of LNG export and import positions) versus national oil and gas companies. Empirical results confirm the industry-specific predictions and support the positioning-economizing approach hypothesis of an interrelation between the three strategic choices of target market position, resource profile, and organizational structure. It can be shown that NOCs rely on less idiosyncratic assets than companies following a flexibility strategy and that those companies following a flexibility strategy rely on less idiosyncratic assets than chain optimizers. Second, based on transaction cost economics the determinants of vertical integration are investigated. Estimation results confirm the theory's predictions and show that idiosyncratic investments in uncertain environments lead to a motivation to organize transactions within a firm's own hierarchy.

As Porter (1996, p. 78) argues, "a company may have to change its strategy if there are major structural changes in its industry." Hence, strategic positioning is not a static concept but rather requires dynamic adaptations. He further points out that "most commonly, new positions open up because of change" (p. 65). Market entrants may be more flexible in adopting an innovative strategy since they – unlike incumbents – do not have to consider already realized investments. A number of new players have entered the LNG market during the last decade. For example, Cheniere Energy has invested in two regasification terminals in the US gulf coast, two further projects are planned. Excelerate Energy operates offshore on-board regasification facilities in several countries. However, a sustainable success of these non-integrated, downstream business models still has to be demonstrated in the future.

5.7 Appendix

Formalization of the positioning-economizing perspective

Nickerson (1997, pp. 34 ff.) provides a first formalization of the four-tuple choice problem. Consider two vertically related transactions T(*i*) for product markets *i* with *i* = {1, 2}. T(1) is referred to as the transaction between the firm and the consumers; T(2) is referred to as the transaction between the firm and its own suppliers.

Consumer preferences are heterogeneously distributed along dimensions A(*j*) with *j* being finite. It is further assumed that the firm can invest in specific assets k(1) in T(1) at a per unit cost λ and that these investments will shift demand. Firm revenue then is a function of k(1), the distribution of A(*j*) and the produced quantity *X*.

It is also assumed that the firm chooses a production technology which may range in its characteristic between generic and highly specific. The choice of this technology represents the choice of the level of asset specificity k(2) in T(2) at a per unit cost ω. Production costs then are a function of the produced quantity *X*, the levels of specific investments k(1) and k(2) and the distribution of A(*j*).

T(2) can be organized within the own hierarchy (H) or on the market (M). We define γ = {H, M} with governance costs being a function of the exchange conditions in T(1) and T(2). Then the profit equation for the observed firm becomes:

$$\pi(X, A, k(1), k(2), \gamma) = R(X, k(1), A(j)) - C(X, k(1), k(2), A(j)) - G^{\gamma}(k(1), k(2)) - \varpi \cdot k(2) - \lambda \cdot k(1) \quad \text{(A-1)}$$

where A can be understood as the targeted customer group (i.e., strategic market position), k(*i*) are the levels of specific investments and γ represents the chosen governance mode. For a given customer type, these parameters are chosen such that profit is maximized. The four-tuple {A, k(1), k(2), γ} will be a feasible strategy if profits are greater than or equal to zero:

$$\max_{k(1),k(2),\gamma} \pi(A, X, k(1), k(2), \gamma) \text{ s.t. } \pi(\cdot) \geq 0 \quad \text{(A-2)}$$

Developing implications from this model requires explicit information on production costs, revenues and governance costs under alternative forms of organization. The above specified model is dedicated to a simplified case with only two transactions. Complexity of the decision analysis will increase when multiple investments and multiple supply transactions are considered. Furthermore, exchange conditions for customer and supply transactions may be multi-dimensional when a combination of different types of specific investments occurs.

Augmented Durbin-Wu-Hausman test

When there is a reasonable suspicion that one of the regressors is not orthogonal to the error term ε (i.e., a right-hand-side variable is endogenous and $Cov(x_i, \varepsilon) \neq 0$), an endogeneity test should be carried out. In the case that the regressor and the error term are uncorrelated ($Cov(x_i, \varepsilon) = 0$) both estimators, the ordinary least squares (OLS) and the two-stage IV estimator, will yield consistent estimates. However, the IV estimator will be less efficient.[43] If endogeneity is present, IV estimation is mandatory since other estimation procedures will deliver biased parameter values.

The Durbin-Wu-Hausman test involves estimating the model via both OLS and IV approaches and comparing the resulting coefficient vectors. For a more detailed description see e.g. Baum et al. (2003). Under the null-hypothesis, OLS and IV will deliver consistent estimates with the OLS estimator being more efficient. Under the alternative, only an IV procedure will deliver consistent estimates. Hence, the rejection of the null hypothesis provides evidence of the endogeneity of the right-hand-side variable.

Davidson and MacKinnon (1993) suggest an augmented Durbin-Wu-Hausman test. In a first step, the endogenous variable is regressed on all system exogenous variables. In a second step, the residuals of this first regression are included into an augmented regression investigating the main functional relationship. Hence, for Model 3 specified in this chapter, the following steps have been carried out:

$$\begin{aligned} SPEC_i &= \alpha_0 + \alpha_1 CHAIN_i + \alpha_2 NOC_i + \alpha_3 UNC_i + \alpha_4 D2000_i + \alpha_5 EXPAB_i \\ &+ \alpha_6 EXPPB_i + \alpha_7 CAPOWN_i + \alpha_8 ASSETS_i + \alpha_9 (ASSETS_i)^2 + \alpha_{10} STATE_i + \varepsilon_i \end{aligned} \quad \text{(A-3)}$$

where the error term ε_i is assumed to follow a normal distribution. The residuals (RES_SPEC) are calculated and included into the probit model explaining the likelihood of vertical integration:

$$\begin{aligned} VI_i &= \beta_0 + \beta_1 SPEC_i + \beta_2 UNC_i + \beta_3 D2000_i + \beta_4 EXPAB_i + \beta_5 EXPPB_i \\ &+ \beta_6 CAPOWN_i + \beta_7 ASSETS_i + \beta_8 (ASSETS_i)^2 + \beta_9 STATE_i \\ &+ \beta_{10} RES\_SPEC_i + u_i \end{aligned} \quad \text{(A-4)}$$

The test statistic investigating whether the residual's parameter is different from zero yields a chi-squared value of 16.5 (significant at a 1% level). The null hypothesis of specificity being an exogenous variable can be rejected supporting the use of two-stage instrumental variable estimation procedures.

[43] An estimator is *consistent* if it converges in probability to the true parameter value: $\text{plim}(\hat{\beta}) = \beta$. An estimator is asymptotically *efficient* if it converges faster than other consistent estimators: $\text{var}(\hat{\beta}^A) < \text{var}(\hat{\beta}^B)$.

6 Optimal Contract Duration of Long-term LNG Supply Contracts: A Trade-off

6.1 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 USD 140/bbl range in summer 2008 and liquefied natural gas (LNG) spot cargoes delivered to Japan were above USD 19/MBTU in January 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, they „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 the liquidity on secondary markets.

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 NOC and a private partner and a downstream importer. Contract duration of these agreements typically was 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.

As discussed above, the structure of long-term contracts has changed. Contract duration as well as annual contracted volume is 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 (cif/des) towards contracts in which title transfer occurs at the loading port (fob). Under an fob contract, buyers have the possibility to manage variations in demand more flexible via cargo re-direction and to benefit from resell options.

This chapter 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. As discussed in Chapter 3, there are several dynamic factors currently affecting the global market for natural gas: realization of large-scale infrastructure investments (LNG as well as pipelines), new market entrants, 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: i) transaction cost economics, assuming bounded rationality of economic actors, 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); ii) 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 iii) 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. The following study contributes to the literature 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. I 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 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.

Building a simultaneous equation model to account for the endogeneity of a right-hand side variable, I 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.

6.2 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 (1987) seminal work 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 Electricité 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 a new dimension to the discussion 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[44] 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.

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

[44] 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.

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 by 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.

6.3 Theoretical background

6.3.1 Optimal contract duration: A trade-off

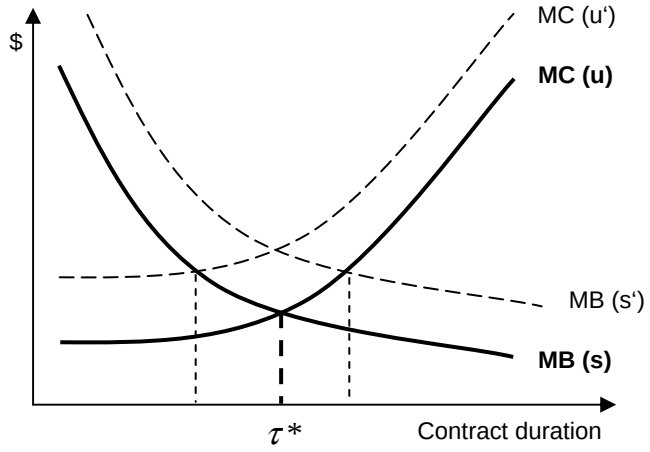
The trade-off between contracting costs and flexibility is discussed in theory and investigated in a number of empirical papers (e.g., Gray, 1978; Crocker and Masten, 1988; Klein, 1989; Klein et al. 1990; Heide and John, 1990). On the one hand, transaction cost economics predicts that investments in 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 τ^* corresponds to a situation where the marginal costs and 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 cost of bargaining (i.e., spot trade). However, the cost 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 cost of the repeated bargaining of shorter trading agreements can be reduced. Marginal benefits decrease with every additional period covered by the contract.

Figure 34 illustrates the optimization problem. An increase in the level of uncertainty (u' > u) will result in an upward shift of the marginal cost curve (MC); an increase in the level of asset specificity (s' > s) will result in an upward shift of the marginal benefits curve (MB).

Figure 34: Optimization problem



Source: Own depiction

We can formalize the discussion above by the following optimization problem: $\max_{\tau \geq 0} G(\tau)$ 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:

$$\begin{aligned} G'(\tau) &= MB(\tau) - MC(\tau) = 0 \\ MB(\tau^*) &= MC(\tau^*) \end{aligned} \tag{6-1}$$

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

$$\begin{aligned} MB(\tau^*) &= MB(\tau, s, v) = \alpha_0 + \alpha_1 \tau + \alpha_2 s + v \\ MC(\tau^*) &= MC(\tau, u, \omega) = \beta_0 + \beta_1 \tau + \beta_2 u + \omega \end{aligned} \tag{6-2}$$

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 *v* and ω further explaining attributes such as unobserved heterogeneity between the parties or environmental characteristics. Substituting (6-2) into (6-1) and rearranging yields the reduced form

$$\tau^* = \gamma_0 + \gamma_1 s - \gamma_2 u + \varepsilon \tag{6-3}$$

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

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 increases with the level of investments in idiosyncratic assets in order to avoid repeated bilateral bargaining and mitigate the vulnerability to ex-post hold-up.

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

6.3.2 The impact of transaction frequency

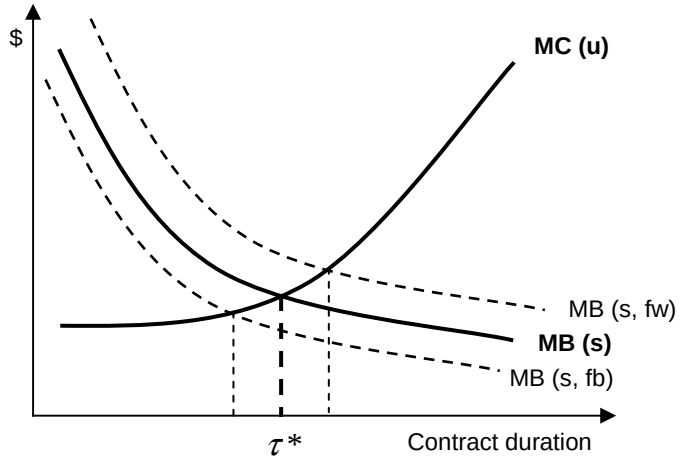
Transaction cost theory argues that transaction costs increase with the frequency of the transaction within the trading relationship due to the repeated hazard of opportunistic behavior and potential strategic renegotiation. This will increase incentives to organize the transaction under stronger internal 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 exploitation of 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. I 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).

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 (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 benefits of contracting will rise due to the repeated

hazard of opportunistic bargaining; with increasing 'between frequency' the benefits of contracting will fall due to lower ex-ante as well as ex-post transaction costs (see Figure 35).

Figure 35: Extended optimization problem including transaction frequency



Source: Own depiction

The above developed model is expanded by including two frequency measures: *fw* indicating the frequency of the transaction within the relationship and *fb* indicating the historical frequency of transactions between the same trading partners expecting a positive (respectively negative) relationship with contract duration:

$$\tau^* = \gamma_0 + \gamma_1 s - \gamma_2 u + \gamma_3 fw - \gamma_4 fb + \varepsilon \qquad (6\text{-}4)$$

The following propositions are derived:

> *Proposition 2a: Contract duration increases with the level of frequency of the transactions within the trading relationship in order to avoid the repeated hazard of post-contractual opportunism by the non-investing party.*
>
> *Proposition 2b: Contract duration decreases with the frequency of transactions between the same trading partners due to learning and reputational effects.*

6.4 Data and methodology

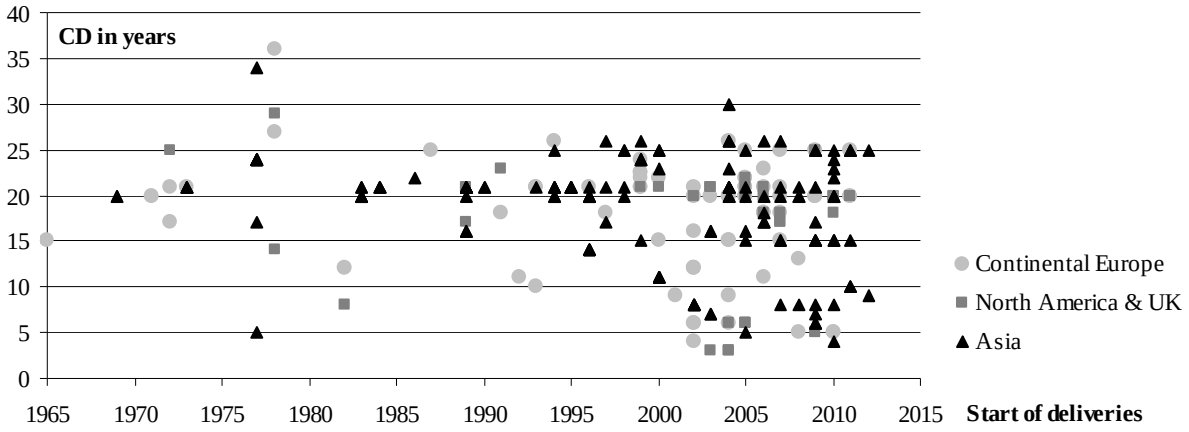
6.4.1 Data

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 including 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 36 illustrates the 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. During the past 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.[45]

Figure 36: Contract duration and start of deliveries of contracts included in the sample



Source: Own depiction

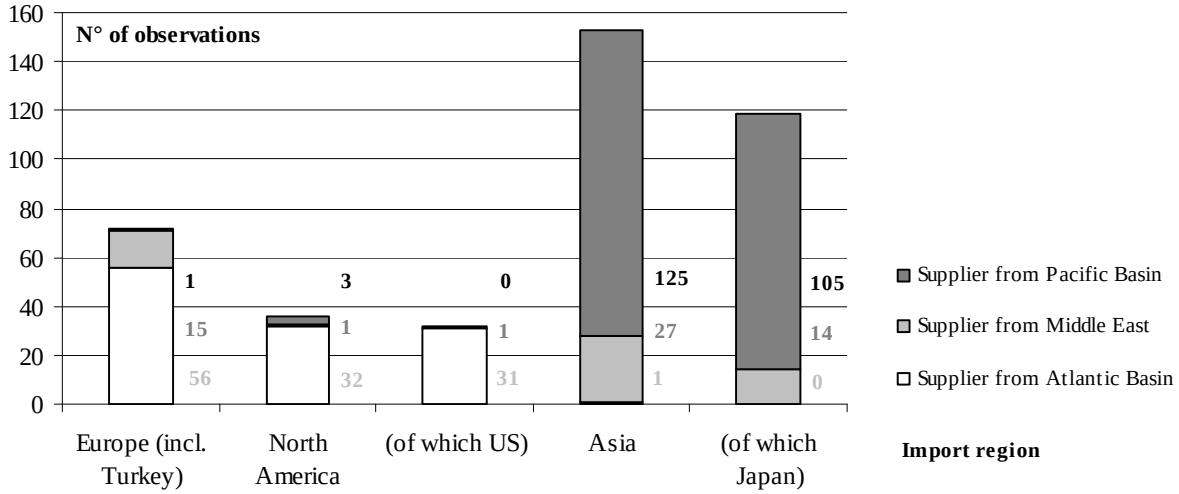
The unit of analysis for studying the determinants of contract duration is an LNG supply contract concluded between an upstream seller (company or consortium) and a downstream buyer. Transactions are defined as cargo deliveries of LNG. The endogenous variable is contract duration in years. For the purpose of this study I assume a sample of contracts that holds constant other contract provisions, such as price adaptation or renegotiation clauses. Unfortunately, the existence and

[45] 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.

utilization of such provisions is held confidentially by the trading partners and cannot be accounted for in this analysis.

Figure 37 summarizes the distribution of regional trade patterns in the dataset and mirrors that the Middle East increasingly functions as a swing supplier. Whereas Atlantic Basin exporters typically deliver LNG to European and North American customers, the Pacific Basin exporters deliver mainly to Asia with some minor volumes being dedicated to the North American west coast (i.e., Mexico). Middle Eastern exporters conclude long-term supply contracts with importers from different regions. For example, the Qatargas I project delivers 5.4 bcm of LNG per year to Chubu Electric in Japan over a period of 25 years and at the same time additional volumes under mid-term agreements to France. Oman LNG has contracted 0.9 bcm/a to Osaka Gas for 25 years and at the same time 2.2 bcm/a to the Spanish Union Fenosa for 21 years.

Figure 37: Distribution of regional trade patterns in the dataset



Source: Own depiction

6.4.2 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 sellers' 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 (RCAPSHARE) 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.

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 WTI crude oil spot prices (STDEVOIL) 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.

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. For the reasons discussed in Chapter 4, UNC is defined as (1 – POLCON) with $UNC_i \in [0, 1]$.

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 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. 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. First, 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. Second, I 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 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, I 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. These variables should not have a systematic impact on contract duration, but one would expect that they are related to the annual contracted volume. In order to tests for the instruments' independence from the error term, the Sargan and Hansen-J-statistics are calculated for the 2SLS and GMM models, respectively. Thereby, a rejection of the null hypotheses would imply that the instruments are not satisfying the orthogonality conditions required for their employment. See Baum et al. (2003, pp. 16 ff.) for further technical details.

For a survey of all exogenous variables as well as their descriptive statistics see Table 21. 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 21: 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

Table 22: Correlation matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
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

6.4.3 Methodology

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

$$CD_i = \phi_0 + \phi_1 RCAPSHARE_i + \phi_2 UNC_i + \phi_3 STDEVOIL_i + \phi_4 D2000_i + \phi_5 VOL_i + \phi_6 BETWFREQ_i + \phi_7 LNGSHARE_i + \phi_8 COMP_i + \varsigma_i \quad (6\text{-}6)$$

where *i* indexes contracts and the error term ζ_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.

However, contract duration and contracted volume are determined simultaneously when an LNG seller and buyer agree for a supply arrangement, both represent endogenous variables. The error distributions cannot be considered independent of these regressors' distributions. Therefore, the model is estimated applying two-stage least squares. As already discussed in Section 5.4.3, the right-hand-side endogenous variable (VOL) is regressed on all system exogenous variables as well as on the vector of instrumental variables in the first stage. The fitted values are used as instrument in the second stage. Therefore,

$$VOL_i = \theta_0 + \theta_1 RCAPSHARE_i + \theta_2 UNC_i + \theta_3 STDEVOIL_i + \theta_4 D2000_i + \theta_5 BETWFREQ_i + \theta_6 LNGSHARE_i + \theta_7 COMP_i + \theta_8 SELFSUFF_i + \theta_9 CAP_i + \theta_{10} TERMINALS_i + \xi_i \quad (6\text{-}7)$$

is defined 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. If the error terms are heteroscedastic, the two-stage IV estimator will be consistent but inefficient. GMM is a robust estimator when facing heteroscedasticity of unknown form; 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. For further technical details see Greene (2002, pp. 525 ff.). However, the GMM estimator can have poor small sample properties (Baum et al. 2003, p. 11). Therefore, a Pagan-Hall test investigating the presence of some form of heteroscedasticity is recommended.

6.5 Estimation results and interpretation

The following paragraph presents 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 (Table 23) and not including this variable respectively (Table 25 in the Appendix) in order to benefit from the whole dataset. 2SLS and GMM lead to very similar results. The Pagan-Hall test statistics support the use of GMM estimation; the null hypothesis of the disturbances being homoscedastic has to be rejected for all model specifications.

Propositions 1a, 1b and 2b can 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 (0.24 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.[46] 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. 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. 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. 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, 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.

[46] 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.

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 accounting for the endogeneity of the variable. 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. 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 I am 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.

Table 23: 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)
Pagan-Hall				31.595 (0.000)	32.772 (0.000)	35.156 (0.000)			
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 24 shows the estimation results of the first-stage regression 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 Sargan and Hansen-J statistics for all three models are calculated in order to test whether the instruments are uncorrelated with the error terms. The null hypotheses of the instruments satisfying orthogonality conditions cannot be rejected for any specification, supporting the choice of these instruments.

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 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 24: Estimation results 1st stage explaining VOL including STDEVOIL

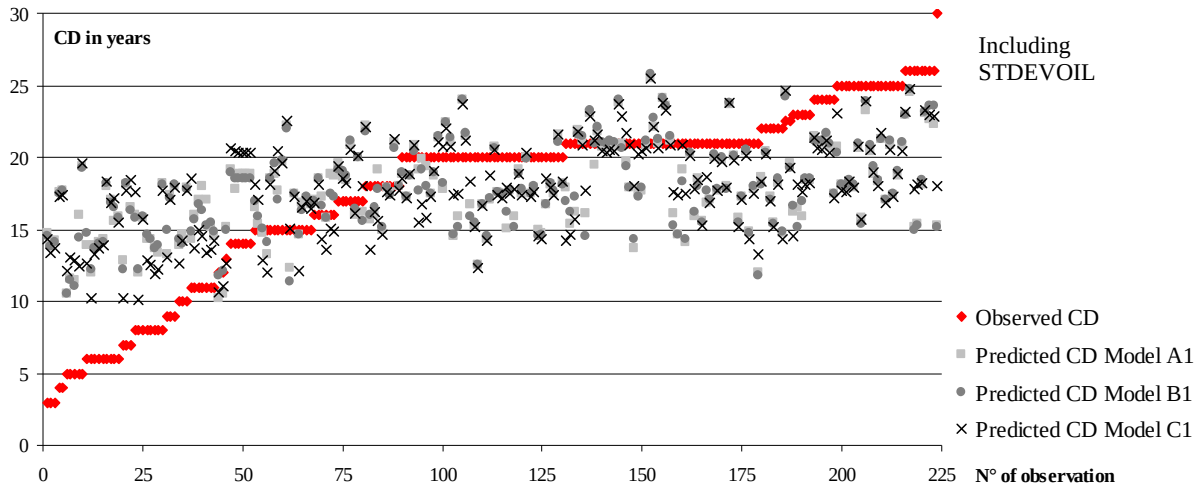
Specification	2SLS			System GMM		
	Model A	Model B	Model C	Model A	Model B	Model C
CONSTANT	0.38	0.38	0.38	0.38	0.38	0.38
	(0.33)	(0.33)	(0.32)	(0.31)	(0.31)	(0.30)
RCAPSHARE	4.04 ***	4.05 ***	4.04 ***	4.04 ***	4.05 ***	4.04 ***
	(0.39)	(0.39)	(0.39)	(0.41)	(0.41)	(0.41)
UNC	0.05	0.04	0.02	0.05	0.04	0.02
	(0.20)	(0.20)	(0.20)	(0.17)	(0.17)	(0.17)
STDEVOIL	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
D2000	0.24	0.25	0.24	0.24	0.25	0.24
	(0.18)	(0.18)	(0.18)	(0.19)	(0.19)	(0.18)
ln(BILEXP1)	0.11			0.11		
	(0.15)			(0.13)		
ln(BILEXP2)		0.08			0.08	
		(0.06)			(0.06)	
RENEW			0.46 **			0.46
			(0.21)			(0.22)
LNGSHARE	-0.09	-0.10	-0.04	-0.09	-0.10	-0.04
	(0.32)	(0.32)	(0.32)	(0.34)	(0.34)	(0.34)
COMP	-0.29	-0.29	-0.23	-0.29	-0.29	-0.23
	(0.32)	(0.33)	(0.33)	(0.29)	(0.29)	(0.30)
SELFSUFF	0.23	0.23	0.21	0.23	0.23	0.21
	(0.33)	(0.33)	(0.33)	(0.31)	(0.31)	(0.32)
CAP	0.03 ***	0.03 ***	0.03 ***	0.03 ***	0.03 ***	0.03 ***
	(0.004)	(0.004)	(0.005)	(0.01)	(0.01)	(0.01)
TERMINALS	-0.02 **	-0.03 **	-0.03 **	-0.02 **	-0.03 **	-0.03 **
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Sargan stat.	0.770	1.249	1.718			
	(0.68)	(0.54)	(0.42)			
Hansen-J stat.				0.846	1.361	1.592
				(0.66)	(0.51)	(0.45)
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.

Predicted values of contract duration are plotted in Figure 38. As can be seen, they typically are in the range between ten and 25 years, with significant deviations from the observed contract duration for data points with very low and 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 38: Predicted values CD using 2SLS including STDEVOIL



6.6 Summary and conclusions

This chapter 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, I 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. 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). 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, the drop of destination clauses as well as the increasing importance of fob rather than cif/des 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.

6.7 Appendix

The following tables and figure present estimation results for the whole sample excluding the variable STDEVOIL for which only 224 out of 261 observations are available. OLS, 2SLS, and GMM estimations produce qualitatively similar results.

Table 25: 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)
Pagan-Hall				21.303 (0.011)	22.181 (0.008)	25.665 (0.002)			
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

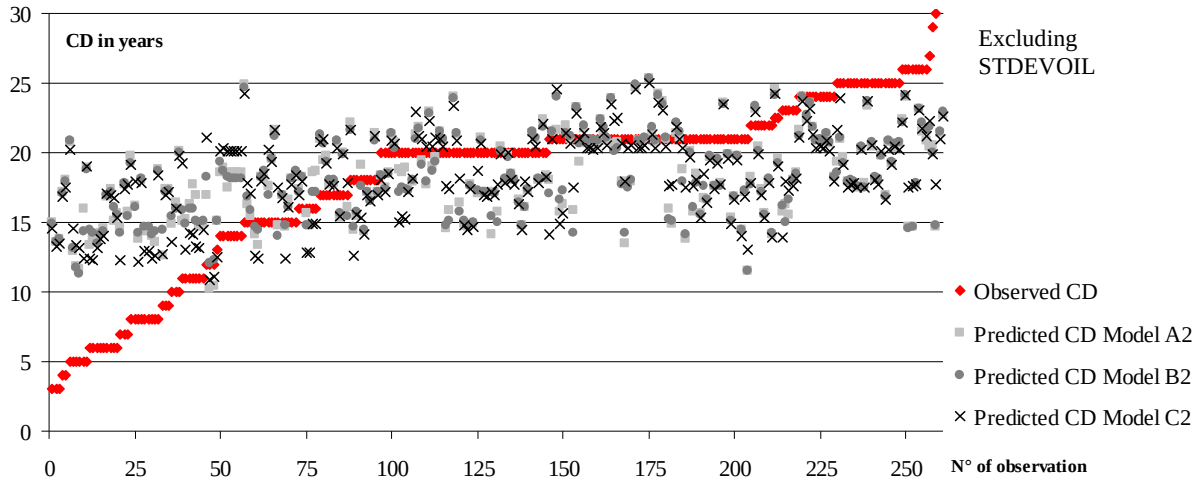
*** Statistically significant at a 1%-level; ** statistically significant at a 5%-level; * statistically significant at a 10%-level. All levels of statistical significance are based on two-tailed test statistics. Corrected standard errors in parentheses.

Table 26: 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 (0.31)	0.45 (0.31)	0.45 (0.31)	0.44 (0.28)	0.45 (0.28)	0.45 (0.28)
RCAPSHARE	4.29 *** (0.36)	4.29 *** (0.36)	4.29 *** (0.35)	4.29 *** (0.36)	4.29 *** (0.36)	4.29 *** (0.36)
UNC	-0.03 (0.19)	-0.03 (0.19)	-0.04 (0.19)	-0.03 (0.17)	-0.03 (0.17)	-0.04 (0.17)
D2000	0.11 (0.15)	0.12 (0.15)	0.10 (0.15)	0.11 (0.16)	0.12 (0.16)	0.10 (0.16)
ln(BILEXP1)	0.12 (0.14)			0.12 (0.13)		
ln(BILEXP2)		0.07 (0.06)			0.07 (0.06)	
RENEW			0.43 ** (0.21)			0.43 ** (0.22)
LNGSHARE	0.02 (0.29)	0.01 (0.06)	0.05 (0.28)	0.02 (0.29)	0.01 (0.29)	0.05 (0.29)
COMP	-0.11 (0.29)	-0.11 (0.30)	-0.06 (0.30)	-0.11 (0.25)	-0.11 (0.25)	-0.06 (0.25)
SELFSUFF	-0.03 (0.29)	-0.04 (0.29)	-0.06 (0.29)	-0.03 (0.25)	-0.04 (0.25)	-0.06 (0.25)
CAP	0.04 *** (0.00)	0.03 *** (0.00)	0.03 *** (0.00)	0.04 *** (0.01)	0.03 *** (0.01)	0.03 *** (0.01)
TERMINALS	-0.03 *** (0.01)	-0.03 *** (0.01)	-0.03 *** (0.01)	-0.03 *** (0.01)	-0.03 *** (0.01)	-0.03 *** (0.01)
Sargan stat.	0.200 (0.90)	0.743 (0.69)	0.899 (0.64)			
Hansen-J stat.				0.192 (091)	0.777 (0.67)	0.796 (0.67)
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.

Figure 39: Predicted values CD using 2SLS excluding STDEVOIL



7 Conclusions

This thesis investigates vertical structures in the global market for liquefied natural gas, an industry which is changing both in quantity and quality. Natural gas hubs gain in liquidity. Long- and short-term contracts co-exist. On the one hand, joint ventures, strategic partnerships, and vertical and horizontal integration become common practice and enable arbitrage trades and the realization of swap agreements; on the other hand, some new entrants invest in non-integrated commercial LNG import facilities.

The market structure has changed substantially during the past decade. The survival of incumbents and 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, external uncertainty, downstream competition, or dependence on natural gas imports in the form of LNG of natural gas importing countries 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 LNG industry is particularly well-suited to test transaction cost economics' propositions.

Based on transaction cost economics and recent developments thereof, it is analyzed which motivations drive companies towards vertical integration along successive stages of the value chain and which external factors determine optimal contract duration of long-term supply agreements. First, the impact of inter-organizational trust as a shift parameter on the choice of more hierarchical governance modes is investigated. Second, an empirical test of the positioning-economizing perspective, linking transaction cost economics and strategic positioning, is provided. Third, optimal contract duration of long-term LNG supply contracts is analyzed accounting for the trade-off between contracting costs and flexibility in uncertain environments with both contract duration and contracted volume being considered as endogenous variables.

These analyses have some limitations: i) pre-existing inter-organizational trust should be treated as an endogenous variable determined by prior experiences between the exchange partners. A two-stage regression model explaining the level of trust in a first step would improve the analysis; ii) since no performance data on the transaction-level are available, it is not possible to test for the direct impact of the presence of inter-organizational trust on exchange performance; iii) similarly, transaction-specific performance data would allow to relate feasible resource-profile/organization pairings to firm performance and to estimate structural form instead of reduced form models as is suggested within the positioning-economizing perspective; and finally, iv) contractual provisions such as price adaptation clauses or volume flexibilities are an important measure to react to changing environmental conditions. However, these are confidential information. Nevertheless, the recent move towards more volume flexibility, the drop of destination clauses, and the increasing importance of fob rather than cif/des contracts reduce the risk of being bound by an inflexible agreement not reflecting market realities.

Even though transaction cost economics often is referred to be an empirical success story with about 900 empirical contributions providing considerable support for its central propositions, “the field continues to offer many opportunities to plant, grow, and harvest new and value-creating research” (Nickerson and Bigelow, 2008, p. 208). In recent years, transaction cost economics has become more interdisciplinary. Researchers increasingly combine predictions derived from transaction cost economics with those from other theoretical perspectives such as strategic management or the resource-based view of the firm.

Future empirical work should address several issues: i) more precise proxies for theoretical constructs such as transaction costs, asset specificity, uncertainty, or transaction frequency will improve empirical testing. If researchers succeed in measuring governance costs, structural form models can be estimated allowing for the confrontation of propositions derived from rival theories of the firm and to evaluate the costs associated with failing to align transactions and governance forms; ii) as discussed above, the concept of uncertainty should be considered with respect to a variety of dimensions and a more intensive theoretical and empirical treatment of transaction frequency is required; iii) more empirical tests investigating governance choice in a more comprehensive way are desirable (e.g., studies analyzing the trichotomous choice between market, hybrids, and hierarchy, or studies investigating a set of alternative hybrid governance forms such as different forms of joint ventures and inter-firm alliances); iv) analyses going beyond the single transaction as the unit of analysis but instead regarding constellations of interdependent transactions would improve the understanding of overall firm strategy; and finally, v) accounting for the simultaneous choice of contract provisions such as contract duration and the level of completeness would provide important insights on their interactions. For this purpose, case studies are a suitable tool. Even though often criticized because of a lack of generality, case studies are able to focus on institutional and transactional details and provide, as a complement to econometric tests, a richer perspective.

Summarizing, transaction cost economics, assuming bounded rationality of economic actors and discussing the ex-post hold-up problem, once relationship-specific investments have been realized, is an appropriate approach to analyze firm boundaries and the choice of alternative governance forms. A number of empirical studies reveal that boundary choice matters and that misalignment increases governance costs (e.g., Masten et al., 1991; Leiblein et al., 2002). However, also motivations other than efficiency such as strategic reasons, the establishment of a portfolio of activities, or market foreclosure might drive company behavior.

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