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The role of LNG in the energy transition

Impact on the logistics chain in Europe

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Summary

This paper studies the developments in the worldwide trade of Liquefied Natural Gas (LNG) and the impact this development has on the logistics network in Europe. Data on the worldwide trade is retrieved from the databases of the International Energy Agency and a Fixed Effects model is used to measure the effect of population, GDP, prices for energy and government policy on the demand for LNG. In line with the expectations, the effects of population, GDP and price of substitutes were positive of nature, whereas prices for natural gas and LNG had a negative effect on the demand for LNG. Government policy represented by greenhouse gas emissions had mixed effects, which could only partially be explained. The observed increase of trade in LNG over the last decades has resulted in an increase in the LNG handling capacity in Europe. The number of receiving terminals in Europe has risen and will continue to rise over the next five years. The capacity of the LNG terminals is concentrated in the Mediterranean Sea area, which can be explained by (1) the closeness to the countries of origin and (2) the lack of an extensive pipeline network in Spain and Portugal. Ports that want to attract LNG terminals should therefore focus on the hinterland infrastructure (pipeline network) and the rising demand for LNG from the maritime and road transport sectors.

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1. Introduction

“Europe places bets on natural gas to secure energy future” is the title of an article published in The Guardian on 16 February 2016 after the announcement by the European Commission of its new energy strategy. According to this strategy, Europe’s energy supply will rely heavily on natural gas for the next two decades (Harvey, 2016). The main reasons for this development are the increased focus on reducing greenhouse gas emissions by governments and increasing energy efficiency.

This chapter first sketches the background of the thesis subject, introducing the role of LNG in the energy market and the important role European ports play in the supply of gas to the European hinterland. The following paragraph discusses the research approach, stating the research questions and the sub questions to be answered. The chapter ends with a brief overview of the structure of this paper.

1.1. Background

Worldwide energy demand is expected to rise by an average of 1.0% over the next 25 years, with the share of natural gas rising from 21% today to 24% in 2040 (with an average annual growth of 1.5%). The continuous debate on sustainability and clean energy has led to an increased focus on the importance of natural gas. As a result, natural gas has over the past decades increasingly become an important energy source due to its lower greenhouse gas emissions than the conventional fossil fuels, such as coal and oil. It is expected that in the years up to 2050 natural gas will form an important part of the transition from the conventional fossil fuels (i.e. coal and oil) to renewable energy sources (e.g. wind and solar) (IEA, 2016a).

Traditionally, natural gas was supplied from the gas producing areas to the gas consuming areas through pipelines. However, the supply of gas by pipelines contains a few flaws, one being the permanent fixture of the pipelines and another being the physical limitations of pipelines (such as the 100m depth limitation) (Keyaerts et al., 2011). Liquefied Natural Gas[1] (LNG) is much more flexible, due to its liquid form. LNG can therefore by transported in cryogenic tankers by trucks, ships and trains, both over land and over sea. As undeveloped gas reserves are mostly located in remote areas, far away from developed countries, it becomes clear that LNG already plays and

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[1] Liquefied Natural Gas (LNG) is natural gas which is cooled down to a temperature of -161 ^{0}C at which point it is condensed to a liquid. LNG is colourless, odourless, non-corrosive and non-toxic (PwC, 2006).

will continue to play a major role in the supply of natural gas from these producing areas to the demand markets (Kumar et al., 2011a).

The increasing distance between the production locations of LNG and the demand markets has resulted in a redesign of the supply chain for natural gas, as transportation via pipelines has become more and more difficult. This discrepancy between production and consumption results in an increase in trade of LNG and therefore leading to a growing importance of the logistics market. Part of the redesign of the supply chain includes liquefaction and re-gasification terminals, so that natural gas can be transported in cryogenic tankers from and to certain locations. The global liquefaction capacity build-out has increased from 155 Million Metric Tonnes per Annum (mtpa) in 2005 to 295 mtpa in 2015, averaging an annual growth of 6%, showing the increased importance of LNG as a source for energy (IGU, 2016).

The transition from the conventional fossil fuels to LNG will have a significant impact on ports that now rely heavily on the throughput of oil or oil products, such as the port of Rotterdam. In order to throughput LNG, specialised terminals need to be build and a revision of the strategy of ports towards LNG might therefore be needed.

The objective of this thesis therefore is to first assess the development of the trade in LNG in the last decade, including an analysis of the supply and demand markets. Secondly, it will review the impact of the trade on the supply chain and the logistics market in particular with a strong focus on the role and position of European ports and the port distribution.

1.2. Research approach

In order to tackle this problem, the following research question is formulated: *"How has the trade in LNG developed globally since 2001 and what is the impact on (oil dependent) ports in Europe?"* This question can be split up into two main components: the development of the worldwide trade in LNG and the position of European ports towards LNG. Several sub questions are therefore stated below.

First off, this study will discuss the principles around LNG that are relevant for the research. The sub questions that will be answered are:

- What is LNG and how is it different from traditional natural gas?
- How are the LNG supply chains structured and who are the active and relevant players?

In order to complete this section, this study will use academic literature, consultancy and agency reports on the energy, natural gas and LNG market.

The second part focuses on the development of the worldwide trade in LNG both from the supply (production) and demand (consumption) perspectives. A quantitative research lies at the basis of this analysis and therefore the following sub questions are formulated:

- How has the LNG production capacity increased since 2001 and what is the forecast?
- What caused the rising demand for LNG since 2001 and how will it develop?

The method used for this analysis will be a multiple linear regression model with the LNG demand growth as dependent variable and explanatory variables, such as the price of LNG and substitutes, increased awareness of sustainability and main driver of LNG demand: economic growth.

The third part of this research discusses the position of European ports and the role that they play in the supply of natural gas to the European hinterland, leading to the following sub questions:

- What is the demand forecast of LNG in the European region?
- What are the current and planned LNG terminals?
- What are port location factors for LNG and consequently convenient locations for new LNG terminals?

Data on LNG terminals and port throughput will be used to sketch the picture of the handling of LNG in Europe and port location factors (from academic literature) will be used and where possible extended in order to assess the most convenient locations for new LNG terminals.

1.3. Structure

Chapter 2 will elaborate on the fundamentals of natural gas and LNG and their roles in the energy market. Furthermore, a literature review on LNG supply chains and global LNG trade is presented. Chapter 3 will zoom in on the trade development of LNG from both a demand and a supply perspective and is based on a quantitative research. Following, in chapter 4 the impact on the position of European (oil dependent) ports is assessed. Finally, chapter 5 will contain the general conclusion and answer to the research question.

2. Natural gas and LNG – the worldwide structure

In most regions of the world natural gas has been the fastest growing energy source in the energy mix over the past two decades, due to on the one hand its lower greenhouse gas emissions compared to the traditional fossil fuels (oil and coal) and on the other hand the higher conversion efficiency in power generation (Mokhatab, 2014). Investments in natural gas are expected to grow to its availability and versatility. The world's demand will continue to be supplied by natural gas production in Russia, Qatar, China and the US. However, due to the rising level of investments in LNG, other markets, such as Canada and Australia, are and will be playing an important role in the supply of natural gas (Leather et al., 2013).

The first paragraph describes the growing importance of natural gas in the energy fuel mix and the developing position of LNG in the natural gas market. The following paragraph focuses on the different supply chains that currently exist in the LNG market, first explaining the traditional supply chain, followed by the offshore supply chain. The last paragraph of this chapter considers the development of the global trade in LNG and reviews the literature on this subject. Also, several hypotheses are formulated who will be studied in the following chapters.

2.1. Position of natural gas and LNG in the energy market

As of today, only 20% of the world population lives in countries that are part of the Organisation for Economic Co-operation and Development (OECD), consuming approximately half of the worldwide energy. However, with the rapidly increasing world population (from 7.5 billion today to 9-10 billion by the end of the century) and rising living standards in emerging economies, the energy demand is expected to grow. Environmental awareness leads to a change in policy settings and requires an *energy transition*: a shift from high-carbon fuels to lower-carbon fuels and renewables (Shell, 2016). This paragraph firstly discusses the role natural gas plays in this energy transition, followed by the driver of natural gas supply: LNG.

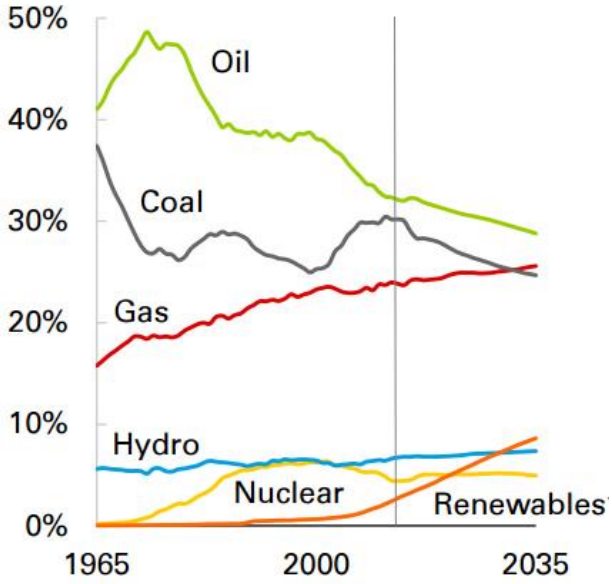
2.1.1. Position of natural gas in the energy market

Coal and oil have traditionally been the main primary sources for fulfilling energy demand. Since the industrial revolution in the 18th and 19th century, there has been a steep rise in the demand for coal and oil, leading to a decline in the reserves of these fossil fuels. Increasing exploration and production costs led to rising prices in the last century. Furthermore, the rising awareness for the environment questions the use of fossil fuels. This resulted in a shift of the energy mix to lower-carbon fuels. Burning natural gas produces 45% less CO_2 than burning coal and 25% less than burning oil[2] and is therefore seen as a cleaner fossil fuel.

Gas is therefore set to be the fastest growing fossil fuel, driven by production increases and changing environment policies. Growth in the demand for coal and oil are expected to slow down, as a result of the rebalancing of the Chinese economy. Furthermore, renewables are on the rise and since the Climate Conference in Paris in 2015 will become an increasingly important supply of energy. Figure 2.1 portrays the development of the position of the different energy sources in the fuel mix since 1965 up to 2015 and forecasts up to 2035. As can be seen, natural gas is the fastest growing fossil fuel, with an expected average growth rate of 1.8% (BP, 2016).

In the World Energy Outlook 2016 by the International Environment Agency, the expected growth in worldwide gas consumption up to 2040 is driven mainly by power generation and the industry sector, both accounting for 35% of total expected growth. The share of natural gas use in buildings will fall from 22% now to 20% in 2040, whereas the share of transport will rise to 5% in 2040 (IEA, 2016a).

Figure 2.1: Fuel mix development up to 2015 and forecast to 2035 (BP, 2016).



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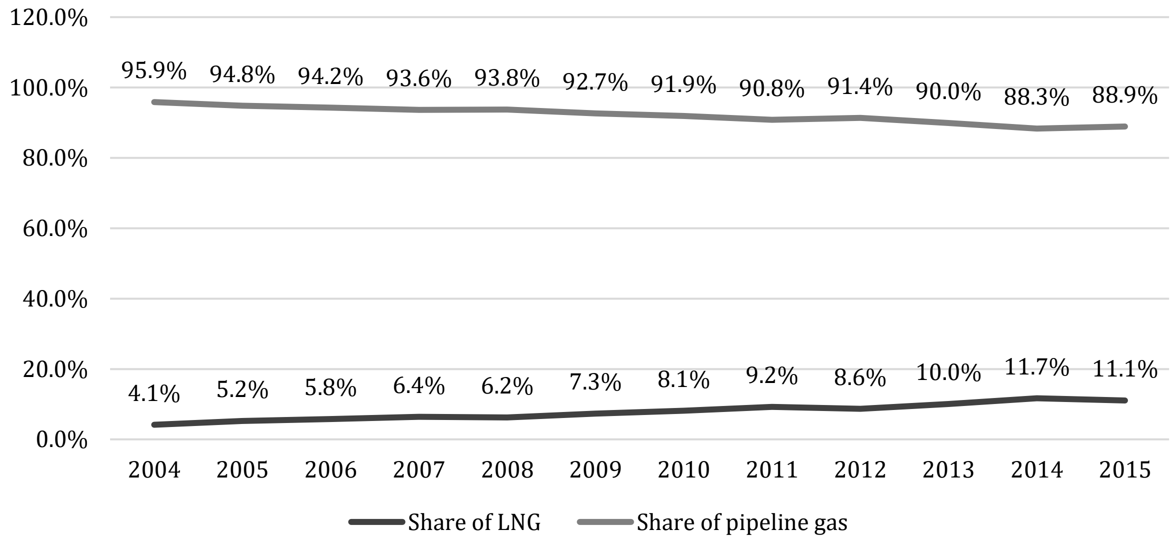
[2] EIA (2016). How much carbon dioxide is produced when different fuels are burned? Retrieved from https://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11.

2.1.2. Position of LNG in the market for natural gas

Natural gas has proven to be a reliable, safe and economical energy source over the past century. Pipelines were ideal when natural gas was found in large reservoirs in accessible locations. However, past decades have shown that newly discovered gas fields are found at remote locations, which cannot easily be connected to a pipeline infrastructure. As more and more remote gas reserves are being discovered, attention has shifted to the fields that previously were considered too technically difficult or not economically viable to develop. The past three decades have shown that LNG is a successful solution to transport the natural gas from its production location to the demand regions (Mokhatab, 2014).

Traditionally, natural gas was transported using pipelines and this method is still applied when there are large gas reservoirs available. However, over the last decades, the composition of trade in natural gas has changed significantly. Figure 2.2 shows the development of the share of LNG and the share of pipeline gas since 2004 in the exports of natural gas. As can be seen, the share of LNG in the trade of natural gas has been increasing rapidly, from 4.1% in 2004 to 11.1% in 2015 (IEA, 2016). Expectations by oil and gas companies are that LNG trade will grow significantly, even surpassing the pipeline gas by 2035. This coincides with a shift in the regional distribution of trade, as the US is expected to become a net exporter, due to its large reserves of shale gas, whereas Europe and China will rely more heavily on natural gas imports (BP, 2016).

Figure 2.2: Composition of natural gas exports (IEA, 2016b).



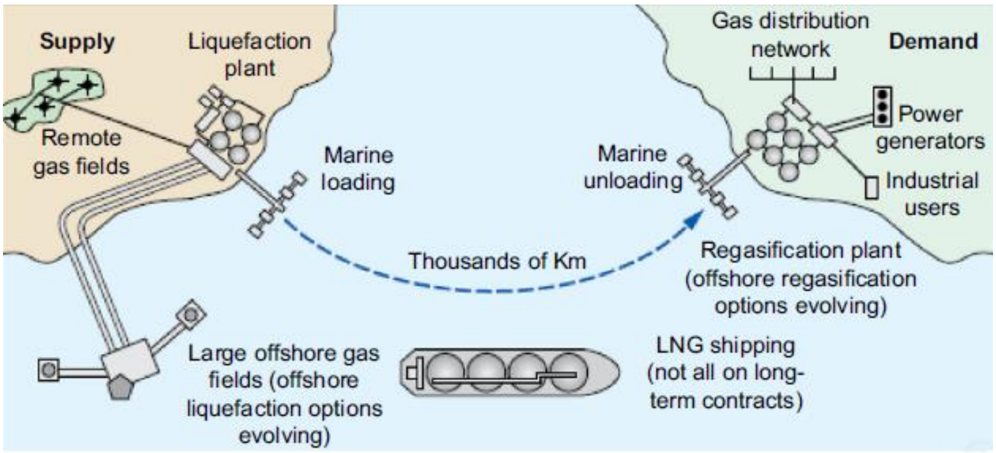
2.2. LNG supply chains

Energy companies, transportation providers, storage companies and governments all are part of the supply chain for LNG. In order to get the LNG from the country of origin (supply) to the end user (demand), an integrated and extensive supply chain is needed, with many different facilities linked to each other. In principle, two different types of supply chains can be distinguished, one being the traditional LNG supply chain and the other being the FPSO LNG supply chain. In the traditional supply chain LNG is retrieved from gas fields that are located inland, whereas in the FPSO supply chain gas is recovered from offshore gas fields by and processed on Floating Production, Storage and Offloading (FPSO) units (Mokhatab, 2014). This paragraph will zoom in on both supply chains, starting with the traditional supply chain and ending with the FPSO supply chain.

2.2.1. Traditional LNG supply chain

The traditional LNG supply chain can be divided into four main activities: gas exploration, liquefaction, transportation and regasification. Over the past decades, technology improvements in each of these stages have contributed to cost savings and hence to an increase in the competitiveness of LNG (Wang & Notteboom, 2011). The key elements of a traditional LNG supply chain are displayed in figure 2.3.

Figure 2.3: Stages of a traditional LNG supply chain (Mokhatab & Purewal, 2006).



The first stage of the supply chain is formed by the gas fields from which natural gas is extracted. From the onshore or off-shore gas fields, the natural gas is transported by pipelines to the liquefaction plant, where the gas is processed and LNG is produced. Normally, before it is liquefied, natural gas is routed through a Natural Gas Liquid (NGL) recovery unit. The NGL components that are recovered from the natural gas, are valuable and can be sold separately to the market. After this process, the remaining lean gas[3] is liquefied, resulting in the product LNG.

The next stage in the traditional supply chain is the storage of LNG and transport to the customer demand regions. Transportation of LNG from the liquefaction plant to the regasification facilities can be performed by different transport modes, which for LNG are primarily ship and truck. Specialised ships are used for the transport of LNG, with tanks that are double-hulled and insulated. The tanks are designed to keep the cargo at a cryogenic temperature of around -169 ^{0}C during transport. Figure 2.4 portrays a LNG carrier with the typical spherical tanks containing the product. Carriers are used for the transportation overseas to customers that are located close to the coast. However, if customers of LNG are situated in an area that cannot be reached by ship, trucks are the only viable option. A typical LNG truck (as displayed in figure 2.5) also contains a cryogenic tank (Mokhatab, 2014).

Figure 2.4: A Shell LNG carrier (Shell, 2017[4]).

Figure 2.5: A typical LNG truck (Shell, 2017[2]).

Once the LNG has reached the demand region, it is offloaded to a regasification plant. At the receiving terminal, the LNG is, through the regasification process, transformed back to natural gas, which is then pumped through the already existing gas distribution network (e.g. pipeline network) to power generators or other end users. The regasification plants can be either offshore or onshore. Offshore units that are gaining in importance are Floating Storage and Regasification Units (FSRU) with five being completed in 2014 and four in 2015 (IGU, 2016). The natural gas is transported to the mainland via subsea pipelines. At onshore terminals, carriers are unloaded using ship pumps, after which it is stored and regasified (Mokhatab, 2014).

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[3] Lean gas is residual gas, mainly methane and ethane, which remains after the heavier hydrocarbons haven been extracted. The liquefaction of lean gas results in LNG.

[4] Royal Dutch Shell (2017). LNG carrier and truck. Retrieved from http://www.shell.nl/klanten/commercialfuels/liquefied-natural-gas.html.

Just like oil projects, LNG projects have a high capital intensity. Costs of large projects can rise to several billion dollars. In achieving cost reductions, economies of scale play an important role. In a typical LNG project, the gas production accounts for 15-20% of the total cost, the liquefaction plant for 30-45%, transportation for 10-30% and storage and regasification for 15-25% (Wang & Notteboom, 2011). As a result, extensive research has been done on minimising the total cost in the different stages of the LNG supply chain.

Reducing unit cost of the liquefaction plant cannot only be achieved by increasing the capacity of the processing train, but also by constructing an additional train. Adding a second processing train to the site can reduce the unit cost by 20-30% (Cornot-Gandolphe, 2005). Özelkan et al. (2008) were the first to look at the design of the LNG receiving terminal and its impact on profitability of LNG projects. Cost reductions in the transportation stage focus on the routes (optimal) and the size of LNG carriers (economies of scale versus flexibility). Kumar et al. (2011a) state that the fall in tanker prices over the last decade have led to the wider reach of the transportation of LNG. Gkonis & Psaraftis (2009) have a game theoretic approach, examining the optimal level of transportation capacity supplied to a certain trade route.

2.2.2. Offshore LNG supply chain

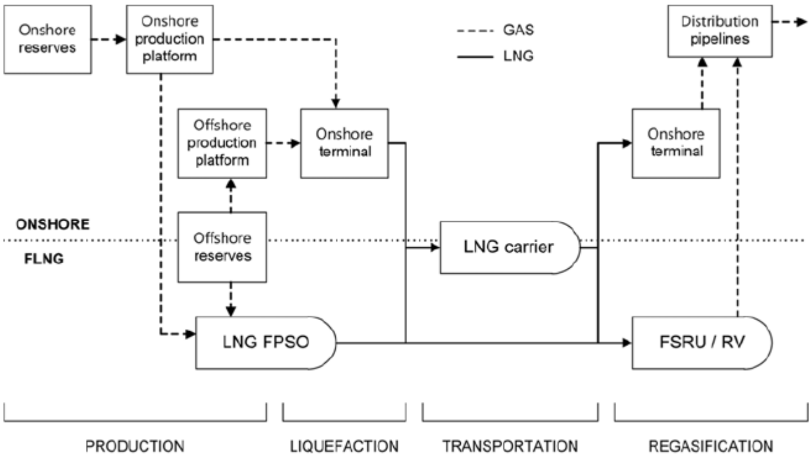
The nuclear accident of Fukushima in March 2011 sent a shockwave through Japan and the rest of the world with regards to the energy security. Not only were nuclear reactors shut down in Japan, the accident resulted in the loss of public acceptability of nuclear power. The accident resulted in an increase in investments in LNG as the main replacement fuel for nuclear power (Hayashi & Hughes, 2013). As onshore gas fields have become scarcer over the years, there has been more exploration into offshore gas fields to meet the rising demand in the major consuming markets. Traditionally, as seen in the previous paragraph, gas produced offshore is transported back to onshore facilities via pipelines, where the sour gas is further processed into LNG and rest products. However, a revolution of the LNG supply chain has taken place at the beginning of this decade (Mokhatab, 2014).

In 2011, oil and gas company Royal Dutch Shell took the final investment decision (FID) for a Floating Production, Storage and Offloading (FPSO) unit specifically designed for the production of LNG (FLNG) (Kavanagh, 2013). FPSOs are already used in the production of oil and now Shell has initiated the potential market for FLNGs. Shell's Prelude, the first FLNG, is expected to be operational somewhere in 2017 or early 2018[5]. FPSOs or FLNG differ from traditional facilities as all processing takes place offshore on a floating facility. The activities exploration, production, processing and liquefaction of LNG are performed on a floating facility (displayed in figure 2.6).

The difference between the supply chains for LNG and FLNG therefore only exists in the first two stages of the LNG supply chain. After liquefaction of the natural gas, the LNG is offloaded onto a LNG carrier described in the previous paragraph. The remaining stages in the supply chain are then completed as in the traditional supply chain (Won et al., 2014). A visual presentation of both supply chains is pictured in figure 2.7. As of 2015, seven FLNG projects are being constructed, with the largest being Prelude with an expected production capacity of 3.6 million tonnes per annum (mtpa) of LNG (Shell, 2017).

Figure 2.6: Shell's Prelude FLNG (Shell, 2017[6]).

Figure 2.7: Traditional versus FLNG supply chain (Won et al., 2014).



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[5] LNG World News. (2016, April 14). Shell's Prelude to start production in 2017? Retrieved from https://www.lngworldnews.com/shells-prelude-flng-to-start-production-in-2017/.

[6] Royal Dutch Shell (2017). Prelude FLNG. Retrieved from http://www.shell.com/about-us/major-projects/prelude-flng/a-revolution-in-natural-gas-production.html.

2.3. A review of global LNG trade

LNG can be seen as a global commodity, as it can be delivered to meet demand all over the world. Wood (2012) states that the main drivers behind LNG consuming countries developing their LNG supply chains are "concerns over energy supplies, higher natural gas prices, rising gas import demand, and requirements for clean, low-emissions, flexible energy supplies". Oil and gas companies invest heavily in monetizing their remote natural gas reserves as a result of technological improvements that have led to cost reductions in the production of LNG. A shift in the strategy of integrated oil companies can be observed, moving from capital investments in oil to investments in natural gas as they expect (Reuters, 2016; Crooks, 2013).

The shift towards LNG can be explained by rising natural gas prices and falling LNG production costs (see paragraph 2.2.1), making the LNG business more attractive and more profitable for oil and gas companies (Maxwell & Zhu, 2011). The higher gas prices have provided producers with more incentive to increase the supplied quantity of LNG, leading to a great enlargement of the LNG industry.

The use of LNG in different sectors is increasing rapidly around the world. The two main sectors in which LNG is used as feedstock are transportation and electricity production (Kumar et al., 2011b). In road transportation it is used in heavy duty trucks, buses and waste collection trucks as an alternative to oil products. Shell recently opened its fifth LNG gas station for trucks in The Netherlands[7] and is planning to expand the network to the rest of Europe. In addition, LNG is planned to be used as fuel in seagoing ships[8]. The use of LNG is not only limited to the transport sector, but is also used in power generation. Using LNG as feedstock in the process of producing electricity improves the atmospheric environment and significantly reduces CO_2 emissions (Okamura et al., 2007).

2.3.1. Drivers for LNG demand

In order to study the development of the trade in LNG, it is essential to gain a better understanding of the drivers behind this increase in trade. Extensive research has been done on both the supply and demand side of the trade balance. This paragraph provides a literature review of the drivers of the rise in worldwide (and regional) LNG demand and states the hypotheses that will be researched in chapter 3 of this paper.

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[7] Shell (2016, July 12). Shell breidt LNG tankstation network uit. Retrieved from http://www.shell.nl/media/2016-media-releases/shell-expands-lng-filling-station-network.html.

[8] Financieel Dagblad (2016, October 3). Shell gaat LNG leveren aan grootste cruiseschepen. Retrieved from https://fd.nl/ondernemen/1169909/shell-gaat-lng-leveren-aan-grootste-cruiseschepen.

Maxwell & Zhu (2011) and the EIA (2014) analysed the market for LNG in the United States. The demand for LNG is driven by the economic and population growth that increase the residential and industrial demand for heating, cooling and electric power as well as production of industrial goods that use natural gas. In the US, power generation and industrial demand account for around 60% of total gas consumption. The following hypotheses are therefore formulated:

> ***Hypothesis 1****: Economic (GDP) and population growth have a positive effect on the demand for LNG.*

Next to the economic drivers, several other factors influencing LNG demand exist. Kumar et al. (2011a) discuss the role of government policies in the development of the LNG industry. Two main aspects can be distinguished. First, policies on liberalisation of the gas and power markets have an impact. Secondly, government policy on the protection of the environment plays an important role on the demand for LNG. Commitments from governments to reducing greenhouse gas emissions under the Kyoto Protocol (1997) or the Paris Agreement (2015) are difficult to achieve without moving from traditional fossil fuels coal and oil to natural gas, as the market for renewables is still underdeveloped. To illustrate, since the beginning of this century China has been developing measures to establish a sustainable balance between economic growth and protecting the environment. Shi et al. (2010) show that LNG is an important strategy in achieving this goal.

> ***Hypothesis 2****: Government policies aimed to reduce greenhouse gas emissions stimulate the demand for LNG.*

In addition, the prices for natural gas and alternative fuels have an impact on the demand for LNG. Contrary to oil and coal prices, natural gas is mostly imported through long-term contract prices and very limited through spot market prices. However, the contracts are renegotiated at scheduled times (every three years) and therefore prices stated in these contracts do have a medium-term impact on the demand for natural gas (Dorigoni et al., 2010).

Hypothesis 3a*: LNG market prices and demand for LNG are negatively related.*
Hypothesis 3b*: Alternative fuel prices (oil and coal) and demand for LNG are positively related.*

2.4. Role and competitive position of sea ports in the LNG supply chain

Sea ports form and will continue to form an integrated part of the supply chain for many goods, amongst which LNG, as was shown in paragraph 2.2. In seaports, or close to seaports, goods are loaded and offloaded, after which these goods after transported to the hinterland, so that they can reach the end customers in an efficient and effective way. The same holds for LNG, which needs to be offloaded and regasified once it is shipped from the source country to the destination region. The ideal location for the regasification process to happen is close to hinterland connections, such as already existing pipeline networks and other transportation methods for natural gas in either liquid or gaseous form. Seaports often have a large variety of connections with the hinterland by barge, rail, pipeline or road. LNG import terminals are therefore frequently located in seaports, as they form a perfect location for further distribution of LNG. However, the process of constructing LNG terminals comes with certain considerations. Ports compete for different *port products*: the transport product, the logistics product and the manufacturing product. These port products will be discussed in the following section. For each of these products, different Unique Selling Points (USP) exist and they form an important tool in choosing a certain port over another as the offloading location for commodities, including LNG. Therefore, the second section of this paragraph will elaborate on the USPs of the port products.

2.4.1. Port products

In seaports, there is a large variety of services that are offered, ranging from offloading to packaging and manufacturing. All these services can be grouped into three different sets, so-called *port products*. According to De Langen *et al.* (2012), the activities in seaports can be divided into three port products, which are:

1. The *transport product* or cargo handling product. The most important service that is offered in this group is the loading and offloading of ships. This product forms the core product of the activities that are performed in a sea port.
2. The *logistics product*. Activities included in this product are the storage and processing of goods before they are loaded or after they are offloaded.
3. The port *manufacturing product*. Sites inside port boundaries on which goods are produced or manufactured.

The activities in these port products are highly different and therefore different sorts of companies are active in each of these groups. As a result of the different port users, the port selection criteria are also different for the abovementioned sets. When looking specifically at the function of sea ports in the supply chain for LNG, all three port products play an important role. First, LNG is loaded or offloaded in the sea port, entailing the transport product of the port.

Secondly, LNG is stored in the port before it is transported further to the end customers. The logistics product of the port is therefore also present in the LNG supply chain. However, before LNG is transported it is often regasified in LNG import terminals, so that it can be transferred by pipeline or truck to the destination region. This regasification process can be seen as a part of the port manufacturing product. Thus, all three functions of a sea port are represented in the LNG supply chain and the decision for selecting a certain port therefore needs extensive consideration (De Langen *et al.* 2012).

The selection criteria or USPs for the *transport product*, the *logistics product* and the *manufacturing product* will be discussed in the following paragraph.

2.4.2. Competitive analysis of ports and corresponding USPs

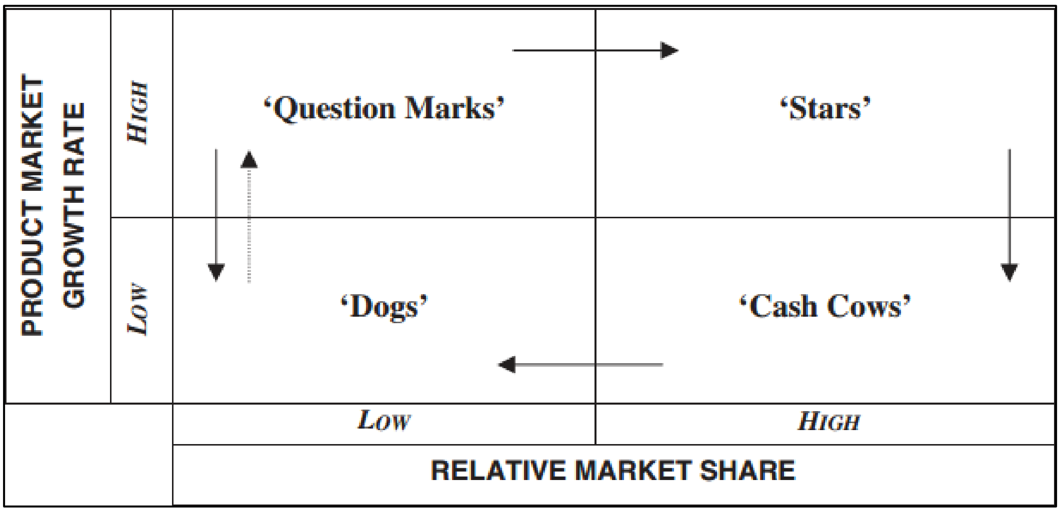
In order to analyse the competitiveness of certain ports, several tools are available. According to De Langen *et al.* (2012) the most suiting tools for analysing port competitiveness are the Product Portfolion Analysis (PPA) and the Shift Share Analysis. This research will use some aspects from the PPA to identify the development of the competitive position of ports in Europe for LNG. The PPA consists of several different parts, of which the *growth matrix* is the most suitable for port analysis (Dyson, 1990). The growth matrix displays a visual representation of the development of the growth for certain actors (can be commodities, ports, etc.), including the average annual growth rate and the market share of the commodity.

The matrix can be composed on different levels. Level 1 focuses on the growth and market share of an entire sea port compared to other sea ports (in a specific range). Level 2 on the other hand zooms in on the types of cargo that go through a specific port and level 3 analyses one type of cargo and how different ports handle this commodity. The analysis can be represented visually in de Boston Consulting Group (BCG) matrix which is displayed in figure 2.8. The x-axis shows the relative market share of the actor, whereas the y-axis shows the average annual growth rate of the actor. Four categories in the matrix can be observed. ‘Question Marks’ can be seen as units that need important investments, as they have a high growth rate, but need to increase their market share. ‘Stars’ are often referred to as success stories, as they have both a high market share and growth rate. ‘Cash Cows’ on the other hand desperately need investments in order to maintain their high market share. Finally, ‘Dogs’ are doomed to fail, as they have a low market share and a low growth rate (Dibb *et al.*, 1991).

In chapter 4, the PPA will be used to analyse the development of LNG in sea ports in Europe and which ports hold a competitive position according to throughput data. This will be done on level

2 and 3 bases, so that both the competitiveness of LNG within ports can be observed, as well as the competitive position of ports in the handling of LNG.

Figure 2.8: Boston Consulting Matrix (Dibb *et al.*, 1991).



Although an analysis of the throughput can contribute in analysing the competitive position of ports, it does not show the causes of the differences in this competitiveness. In order to analyse these differences, the strengths and weakness of sea ports for handling certain cargo groups can be observed by several USPs. These USPs can be seen as selection criteria for companies to establish a presence in a particular sea port. Not only do the three different port products as mentioned in section 2.4.1 have varying USPs, the priority of USPs also differs for commodities. Table 2.1 contains an overview of the USPs for the three port products and originates from De Langen *et al.* (2012), who have combined findings from scientific articles.

Not all USPs have the same level of importance for all cargo types. In general, six different cargo types can be distinguished: dry bulk (including coal and ores), liquid bulk (including crude oil), neo-bulk (including fruit and vehicles), containers, general cargo and roll-on/roll-off. Chapter 4 will zoom in on the USPs that are relevant for the handling of LNG.

Table 2.1: Potential USPs for the transport, logistics and manufacturing products (De Langen *et al.*, 2012).

Transport product	**Logistics product**	**Manufacturing product**
Draft and maritime accessibility	Central location in consumer markets	Presence of customers and suppliers
Favourable location in maritime networks	Road accessibility	Quality of hinterland infrastructure, including pipelines
Favourable location close to origins and destination of cargo flows	Multimodal hinterland transport services	Presence of raw materials and utilities
Hinterland infrastructure	Proximity airport	Presence of qualified labour
Services to hinterland markets	Cluster of logistics activities	Effective innovation system
Safety and security in port	Quality labour market	Advantages of industrial ecology
Quality of shipping services	Price and quality transport firms	Availability of sites
Availability of sites	Land availability and costs	Environmental regulations and licence to operate
Organisation of the labour market	Embeddedness firms in global supply chains	Availability of sustainable resources and sources of energy
Price and quality TOCs	Responsive government	
Intra port competition	Quality of life region	
Presence of cargo generating firms in port	Reputation and effective marketing	
Good ICT infrastructure		
Presence of maritime services		
Quality innovation system		
Brand name, reputation and networks		

3. The drivers behind the worldwide trade in LNG

In the previous chapter the fundamentals of the market for natural gas and LNG were covered. It was stated that the importance of LNG is growing in the supply of natural gas as alternative to oil and coal. LNG trade volumes have more than quadrupled since the early nineties, driven by a much larger number of importing countries. Seventeen countries exported LNG in 2015, with a strong concentration in the Asia-Pacific, Middle Eastern and African regions. The largest demand growth in 2015 came from Europe, followed by Africa and the Middle East. A large decline in the demand from the Asia-Pacific region was observed in 2015, due to weaker electricity demand (because of slowing economic growth), the return of nuclear plants in Japan and South Korea and increased competition from competing fuels (IGU, 2016).

The hypotheses formulated in paragraph 2.3 mention several factors that have an impact on the demand for LNG: economic and population growth, changing government policies and fuel prices. This chapter analyses the impact of these variables on the demand for LNG. The first paragraph covers the data used and describes observations that can be done after the data analysis. In order to analyse the relations between the dependent and explanatory variables, the linear regression model that is used is explained in the following paragraph, including assumptions that were made. The final paragraph of this chapter focuses on the results.

3.1. Data analysis

This section describes the origin of the data and provides a descriptive overview of the data, including (remarkable) observations. First, data on the imports of LNG are depicted, followed by the data analysis of the explanatory variables.

Several institutions report on the trade development of LNG. Worldwide organisations who publish statistics and report on the trade in natural gas and LNG in specific include the International Gas Union (IGU) and the International Energy Agency (IEA). The U.S. Energy Information Administration also performs research on a global level, but with a strong focus on the North American region. In Europe, the European Commission keeps track of the trade in natural gas and LNG, storing the data in its online database, Eurostat. Gas Infrastructure Europe (GIE) focuses on the infrastructure aspect of the trade, including publications of LNG terminals in Europe. GIE data will be discussed in more detail in the following chapter.

For this study, data on the exports and imports of natural gas and LNG are retrieved from the IEA through the OECD iLibrary. The data sets are part of the *IEA Natural Gas Information Statistics* which are used for the annual report on natural gas by the IEA. This data set collection contains four separate databases, of which two contain data on OECD countries and two contain data on a global level. The former consist of (1) data for the supply and consumption of natural gas and (2) export data by destination for natural gas (separated in pipeline gas and LNG). The latter consist of (3) natural gas statistics on a global level and (4) imports of natural gas (separated in pipeline gas and LNG) by origin (OECD, 2017).

For this research, data from the fourth collection is used. The dependent variable 'demand for LNG' is in this study equal to the import of LNG by the specific country or region. Imports in this data collection are "imports of gas by ultimate origin for use in the country" (IEA, 2016). This entails that the imports of LNG are equal to the demand for LNG in the country and therefore re-export of LNG is excluded. In order to analyse the development of the demand for LNG, a sufficient data selection is needed. As demand on regional level is of importance, the following regions are retrieved from the database: Africa, Asia (excluding China), Middle East, China (region), Non-OECD Americas, Non-OECD Europe/Eurasia, OECD Americas, OECD Asia Oceania, OECD Europe and World[9]. Besides these regions, countries from the G20 are added, being Argentina, Brazil, Canada, China, France, India, Italy, Japan, Mexico, Turkey, United Kingdom and the United States. Australia, Germany, Indonesia, Russia, Saudi Arabia and South Africa are omitted as they do not import LNG.

Figure 3.1 shows the development of the LNG imports for the regions mentioned above. As can be seen, the total world imports of LNG have increased significantly in the period 2001-2015. Asia and Europe/Eurasia are the leaders in the LNG imports, with Asia accounting for over 71% of the global LNG imports in 2015. 2008 shows a remarkable drop in the trend of growing LNG imports. In all regions, the import either dropped or slowed down. This can be explained by the shale gas revolution in the US. A sudden drop in shale gas prices resulted in a strong increase in the demand for shale gas from the US. This resulted in a pressured market for LNG, which only recovered two years after the revolution (Stevens, 2010). A second drop takes place in 2012, caused by rapidly increasing prices for oil and gas, which as a result led to decreasing demand for natural gas and LNG. The market for LNG recovered in 2013 and 2014, followed by a small decrease in 2015, driven by slowing demand for energy from the Asian region (China in particular).

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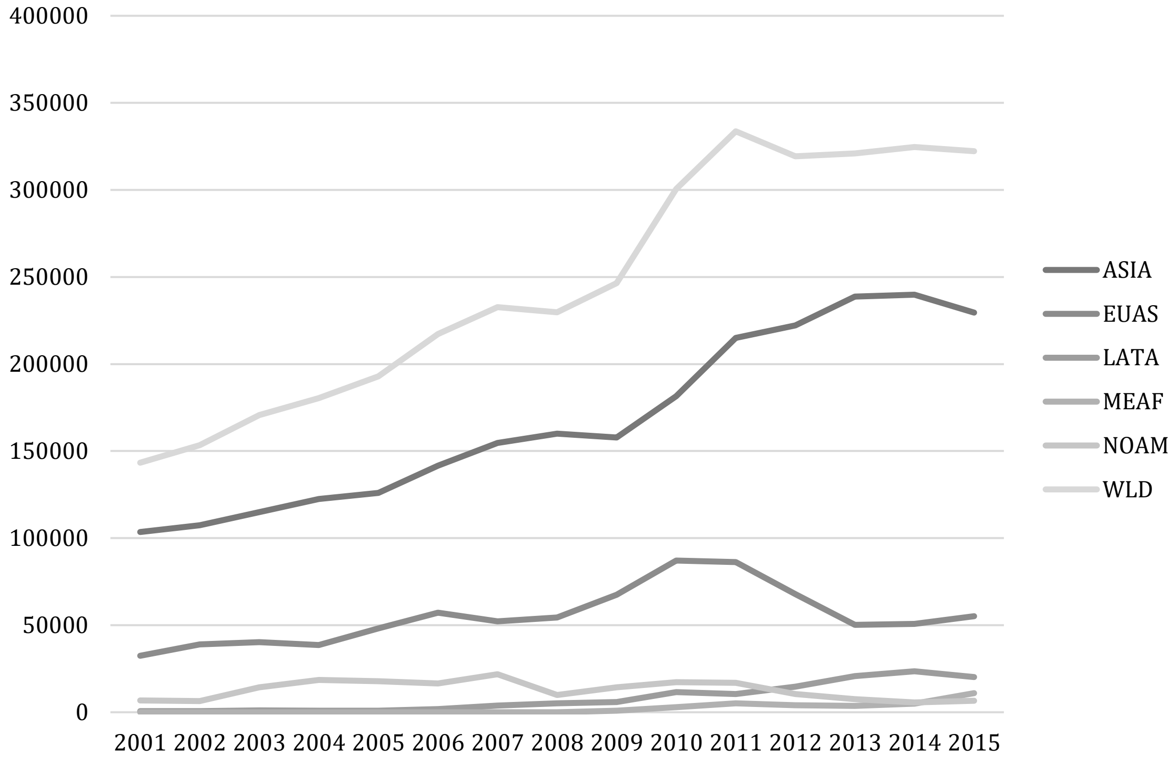
[9] An overview of the countries included in these regions can be found in Chapter 3 of the Natural Gas Information report by the IEA (IEA, 2016b).

Figure 3.1: Development of LNG imports per region from 2001 – 2015.



The independent variables in this research are the Gross Domestic Product (GDP), the population, the prices of substitutes (crude oil and coal), the prices of natural gas and LNG and the greenhouse gas (GHG) emissions.

Data on the GDP and the population is retrieved from the statistical database of the World Bank (World DataBank). The database 'World Development Indicators' contains global data on several macroeconomic indicators. For this study, GDP and population are represented by the indicators 'GDP at market prices (contstant 2010 US$)' and 'Population, total'. Data for the same (G20) countries is retrieved from this database for both variables. The World Bank uses a different classification for the regions, leading to the following regions being retrieved from the database: East Asia and Pacific, Europe and Central Asia, Latin America & the Carribean, Middle East and North Africa, North America, South Asia and Sub-Saharan Africa[10]. South Korea is excluded, as there is no data available on GDP (World Bank, 2017b).

As the regions for the OECD and the World Bank data do not match, a revision of the regions is necessary. For the purpose of performing a reliable analysis, the data is split into six separate

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[10] An overview of the countries included in these regions can be found on the website of the World Bank (World Bank, 2017a).

regions: Asia (ASIA), Latin America (LATA), Middle East & Africa (MEAF), Europe/Eurasia (EUAS), North America (NOAM) and World (WLD). Thus, this study comprises 18 different observations, including 6 regions and 12 separate countries. In the LNG import data Mexico was included in the North America region as opposed to the World Bank data on population and GDP, in which Mexico was included in the Latin America region. Therefore, the data set is adjusted, so that Mexico is now included in the Latin America region for all variables.

Next to GDP and population, the prices of substitutes and natural gas are included in this study. The historical data (2001-2015) is retrieved from 'Global Economic Monitor (GEM) Commodities' database by the World Bank. Prices (nominal) included are coal (Australia, Colombia and South Africa), crude oil (average, Brent, WTI and Dubai) and natural gas (LNG Japan, Europe and US) (World Bank, 2017c).

A final independent variable can be found in the emissions of greenhouse gases. The World Bank provides data on the emissions of all greenhouse gases (CO_2, methane, nitrous oxide, other greenhouse gases (HFC, PFC and SF6)) in the database 'World Development Indicators' (World Bank, 2017b). Data for CO_2 is available up to 2013; methane, other greenhouse gases and total greenhouse gas emissions up to 2012; and for nitrous oxide up to 2008. In order to assess the impact of environmental policy by governments, the emissions of CO_2, methane and all greenhouse gases are included in the analysis. Missing values for 2013-2015 are extrapolated using the FORECAST.ETS function in Microsoft Excel, which predicts future values on existing historical values by using an Exponential Smoothing algorithm[11].

3.2. Methodology

In order to explain the development of the demand for LNG three different methods are considered, which are the ordinary least squares (OLS), random effects (RE) and fixed effects (FE). The data used to estimate the models are classified as panel data, since the data have an individual dimension (country/region) and a time dimension (year). Normally in panel data the errors are positively serially correlated across time, because the individual country-specific component remains the same over time (Garcia-Gomez, 2014). This will violate the assumption of OLS of no serial correlation. Therefore, the fixed effects and random effects models are considered since these models estimate an OLS model on deviations from individual means. Due to this, the country-specific constant disappears from the model. However, the standard OLS

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[11] Microsoft Office (2017). FORECAST.ETS function. Retrieved at February 18, 2017 from Office Support: https://support.office.com/en-us/article/FORECAST-ETS-function-15389b8b-677e-4fbd-bd95-21d464333f41.

method can be used when pooled time series is performed. In this way, the model will take into account the standard errors that are not valid in a normal OLS regression due to serial correlation. This is the reason that both models are estimated. Note that this pooled OLS model only holds in case the country-specific constant does not correlate with the explanatory variables (Garcia-Gomez, 2014). After running the regressions with the three different models a choice can be made. The relationship that is estimated in both models is shown in the equation below (1):

$$\begin{aligned} D_{LNG} &= \beta_0 + \beta_1 * population + \beta_2 * GDP + \beta_3 * crudeav + \beta_4 * ngus \\ &+ \beta_5 * ngeur + \beta_6 * lngjap + \beta_7 * co2emi + \beta_8 * methemi + \varepsilon \end{aligned} \tag{1}$$

The equation can be explained as follows. Under the assumption that the imports of LNG are equal to the demand for LNG in a certain region/country, it can be observed that D_{LNG} is the estimated demand for LNG in this particular region/country. This demand is estimated in this study by the population (*population*), GDP (*GDP*), prices of substitutes (crudeav), prices of natural gas (*ngus,, lngjap*) and GHG emissions (*co2emi, methemi*). After performing the regression with all variables, it is observed that the model is not optimal when all variables are included (see table 1 in the appendix). After excluding several variables, the most optimal model is presented in equation 1. A comparison between the pooled OLS, Random Effects and Fixed Effects regressions of this equation is discussed in the following paragraph (3.3.). The results presented in the following paragraph will be used to reject or accept the hypotheses that are formulated in section 2.3.1.

Table 3.1 below presents an overview of all variables that are part of the data set with a short description and their unit of measurement.

Table 3.1: Overview of used variables in final model.

Parameter	Description
D_{LNG}	Demand for LNG in metric tonnes per annum
population	Total population of region/country
GDP	Gross Domestic Product at market prices in US dollars
crudeav	Nominal average spot price of crude oil in US dollar per barrel
ngus	Nominal price of natural gas in US in US dollar per million BTU (British Thermal Unit)
lngjap	Nominal price of LNG in Japan in US dollar per million BTU (British Thermal Unit)
co2emi	CO_2 emissions in kilotons
methemi	Emissions of methane in kilotons of CO_2 equivalent

3.3. Results

Table 3.2 shows the values of the coefficients and the related significance of the three models that are considered: the pooled OLS model with cluster-robust standard errors, random effects model and fixed effects model. Although the R-squared can be taken as a measure for goodness-of-fit for the individual models, they cannot be compared, as the different panel data models maximise different variations (within, between and overall) (Woolridge, 2014). The value of R-squared in the OLS regression model is equal to 82.02%, which means that the model explains a large part of the total observed variance. The goodness-of-fit of the random effects model can be measured by the overall R-squared (74.74%), whereas for the fixed effects model this is the within R-squared (84.19%). All models have a relative high R-squared, which means that a large part of the measured variance can be explained by the models. Comparing the coefficients of the three models however, it can be observed that nearly all coefficients in the pooled OLS model are insignificant at a 5% significance level, opposed to the random effects and fixed effects models. This could be explained by omitted variable bias and therefore the OLS model is excluded in further analysis. The random effects model assumes there is no correlation between the explanatory variables and all unobserved, time-constant factors. However, if the fixed effects model is estimated, the following value is of importance: corr(u_i, Xb) = -0.9485. This means that there is a strong correlation between the explanatory variables and the unobserved, time-constant factors, leading to the conclusion that the best fit for this study is the fixed effects model. All analysis in the remainder of this research is therefore performed using the fixed effects model.

Table 3.2: Coefficients and P-values of three regression models. Dependent variable is demand for LNG.

	Model					
	OLS		RE		FE	
Variables	Coef.	P-value	Coef.	P-value	Coef.	P-value
Constant	-7611.189	0.230	-13473.72	0.122	-50459.09	0.000
population	0.0000633	0.064	0.0000328	0.001	0.0000725	0.000
GDP	2.30E-09	0.303	3.83E-09	0.000	3.19E-09	0.000
crudeav	195.833	0.157	263.5419	0.003	262.4372	0.001
ngus	-1372.469	0.048	-1538.163	0.001	-1481.895	0.001
lngjap	24.49729	0.976	-1366.498	0.026	-1521.275	0.008
co2emi	0.0034509	0.532	0.012435	0.000	0.0093104	0.000
methemi	-0.0561018	0.180	-0.0655965	0.000	-0.0460932	0.000

As can be observed from table 3.2, all included variables are significant at a 1% significance level. The coefficients can be interpreted according to the following example: an increase in the population in the region by a thousand leads to an increase in the demand for LNG by 0.0725 metric tonnes. However, more important are the relationship between the explanatory variables and the dependent variable D_{LNG}. The fixed effects model shows positive relationships for the variables *population, GDP, crudeav* and *co2emi* and negative relationships for *ngus, lngjap* and *methemi*. As expected, an increase in population and GDP have a positive effect on the demand for LNG, as these two variables are the main driver behind the demand for energy. An increase in the price for crude oil leads, according to expectations, to an increase in the demand for LNG, due to cross-price elasticity.

The negative relationship between the price of natural gas in the United States and the demand for LNG can be explained by the fact that LNG forms a part of the total demand for natural gas, which means that if the spot price of natural gas in the US rises, demand for natural gas and as a result LNG drops. The same argument holds for the price of LNG in Japan, as a rising price leads to a drop in demand for LNG.

Finally, the values of the coefficients for greenhouse gas emissions can be explained as follows. Higher emissions of CO_2 mean higher imports for LNG, which explains the positive relationship. The sign for emissions of methane however cannot be explained. Natural gas mainly consists of methane (CH_4) and during the production, processing, storage, transmission and distribution of natural gas some methane is emitted to the atmosphere. Natural gas and other petroleum systems account for 33% of the total methane emissions in the US, being the largest source. Thus, there should be a positive relationship between the methane emission and the LNG imports (EPA, 2017). However, the model shows a negative relationship between the two variables. Therefore, further research into greenhouse gas emissions and especially the effect of methane emissions is needed to identify the reason for this discrepancy.

4. Impact of LNG trade on European ports

The development of trade in LNG over the last years that was shown in the previous chapter has an impact on the current logistics chain, as the supply chain for LNG as energy source differs from the traditional energy sources (i.e. oil and coal). An overview of the supply chain for LNG as presented in section 2.2 shows the change in the function of sea ports as compared to the handling of oil and coal. After LNG carriers have delivered the product to a receiving terminal, the LNG is regasified in or close to the port area. As a result, the *manufacturing product* of a sea port gains in importance due to the rise in demand for LNG (Mokhatab, 2014).

This chapter zooms in on the import of and demand for LNG in Europe and the impact of the increasing demand for LNG on the competitive position of sea ports. The first paragraph discusses the development of the demand for LNG in Europe over the 2001-2015 time range and the countries of origin. The following paragraph focuses on the development of the regasification capacity in Europe, which is of importance when looking at the competitive position of sea ports in the future. Paragraph 3 zooms in on the specifics of the competitiveness of sea ports in the LNG market in Europe, both on a quantitative and qualitative basis.

4.1. LNG demand in Europe

LNG imports for European countries are being recorded by the European Commission and the International Energy Agency (IEA). In order to establish continuity in this report, the same data from the IEA as in the previous chapter is used, now concentrated on the European countries. When analysing the European countries that import LNG, it can be observed that only 11 countries import LNG, being Belgium, France, Greece, Italy, Lithuania, Netherlands (NL), Poland, Portugal, Spain, Turkey and the United Kingdom (UK). Therefore, in the remainder of this chapter 'Europe' will refer to these countries only.

Table 4.2 on page 26 displays the imports of LNG reported by all European countries by country of origin. Depending on the year, between 97 and 99% of the LNG imports originate from Norway, Russia, Algeria, Egypt, Libya, Nigeria, Trinidad and Tobago, Peru, Oman, Qatar and Yemen.

Several observations can be made from the data presented in the table. Firstly, the total LNG imports have increased significantly over the 2001-2015 time range. A rapid increase from 2001 to 2011 can be observed, followed by a large drop in the years 2012 and 2013. This steep decrease can be explained by the rising prices for energy commodities, including natural gas and LNG. The imports recovered in 2014 and even more in 2015 as a result of the sudden drop in energy prices

(2015 oil price crisis). A second observation is the shift from imports from Algeria in the first decade of this century to Qatar in the second decade. As of 2015, Qatar is the primary country of origin for the European imports of LNG, followed by Algeria and Nigeria.

Table 4.3 on the following page shows the imports of LNG by European country and the originating countries in 2015 (the most recent year with data). The United Kingdom and Spain are market leaders in Europe concerning the import of LNG, together covering nearly 50% of all European imports. Comparing the origins of the UK and Spain, it can be observed that the UK imports nearly all of its LNG from Qatar, whereas Spain imports from several other countries (next to Qatar), including Algeria, Nigeria and Trinidad and Tobago. European countries no longer import LNG from Egypt, which was caused by shutdowns for feedstock loss. Libya no longer exports LNG and Yemen's export decline is caused by political instability that led to closures of the plants throughout 2015, resulting in limited export capacity (IGU, 2016).

Next to the historic development of the demand for LNG, it is important to analyse the future development of LNG imports or LNG demand. In chapter 3 a statistical model was developed in order to observe the relationship between the dependent and explanatory variables. The outcomes of this model are used to forecast the demand for LNG in the European Union up to 2021. As Turkey forms an important player in the imports of LNG in Europe, data for Turkey is added to the European Union data. In the remainder of this paragraph Europe will include the European Union and Turkey.

In order to achieve this goal, forecasted values for the variables as in equation (2) are gathered from several sources. First, data on the population for Europe are retrieved from the 'Population Estimates and Projections' database by the World Bank. GDP data is retrieved from the International Monetary Fund (IMF), which provides GDP growth forecasts per region against constant prices. The GDP value for 2015 is used as base year, after which each year is projected using the growth factor provided by the IMF. Projections for the commodity prices (oil, natural gas and LNG prices) are provided by the World Bank in its 'Commodities Price Forecast', released on January 24, 2017. Finally, the OECD provides forecasts for greenhouse gas emissions (CO_2 and methane) in its 'OECD Environmental Outlook to 2050' from 2012.

$$\begin{aligned} D_{LNG} &= \beta_0 + \beta_1 * population + \beta_2 * GDP + \beta_3 * crudeav + \beta_4 * ngus \\ &\beta_5 * lngjap + \beta_6 * co2emi + \beta_7 * methemi + \varepsilon \end{aligned} \tag{2}$$

Table 4.1: Forecasted demand for LNG in European Union + Turkey from 2016-2021.

Variable	Coefficient	2016	2017	2018	2019	2020	2021
constant	-50459.09	-50459.09	-50459.09	-50459.09	-50459.09	-50459.09	-50459.09
population	7.25E-05	5.90E+08	5.91E+08	5.92E+08	5.93E+08	5.94E+08	5.95E+08
GDP	3.19E-09	1.92E+13	1.95E+13	1.99E+13	2.02E+13	2.06E+13	2.10E+13
crudeav	262.44	42.81	55.00	60.00	61.46	62.95	64.47
ngus	-1481.90	2.49	3.00	3.50	3.61	3.71	3.83
lngjap	-1521.28	6.90	7.25	7.43	7.62	7.81	8.00
co2emi	0.01	39131.74	39611.75	40073.22	40507.64	40937.47	41501.73
methemi	-0.05	8632.15	8763.64	8898.59	9037.04	9179.06	9267.40
lngimport		50432	53510	55047	56225	57422	58623

The forecasted values for the demand for LNG in Europe are presented in table 4.1. As can be seen, there is a deviation from the forecasted values and the observed values in previous years. This can be explained by the fact that the model is built on world data and differences between regions may occur. However, one main observation can be made, which is that the demand for LNG in Europe is expected to increase over the next five years.

Table 4.2: LNG imports reported by European countries in million cubic metres by country of origin for the period 2001-2015.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Algeria	22452	26935	27335	20409	22709	22337	20279	18635	20705	18708	15745	14270	14262	15505	13585
Egypt	0	0	0	0	4929	8047	5425	5654	6816	4572	3895	1788	644	0	0
Libya	825	634	754	694	952	697	783	545	758	579	86	0	0	0	0
Nigeria	6700	6752	9127	11394	11601	14814	15784	14266	8648	15211	15636	12471	6816	5839	7745
Norway	0	0	0	0	0	0	0	1108	2097	3426	2671	3065	2367	2746	3411
Oman	1005	1126	577	1324	1772	818	323	171	1421	341	171	0	171	163	86
Peru	0	0	0	0	0	0	0	0	0	81	85	2421	1503	1243	960
Qatar	681	2184	1997	3977	4859	5788	6881	7900	18337	34834	39973	27717	21499	21764	26776
Russia	0	0	0	0	0	0	0	0	0	3	3	5	6	12	29
Trinidad and Tobago	609	475	34	0	751	4075	2620	5610	7402	5142	3576	2781	2360	2817	2220
Yemen	0	0	0	0	0	0	0	0	0	167	1078	0	98	0	0
Other	153	904	484	756	594	631	167	604	1280	4048	3394	3405	422	710	264
Total	32425	39010	40308	38554	48167	57207	52262	54493	67464	87112	86313	67923	50148	50799	55076

Table 4.3: LNG imports by European country in million cubic metres by country of origin for 2015.

	Belgium	France	Greece	Italy	Lithuania	NL	Poland	Portugal	Spain	Turkey	UK	Total
Algeria	0	4647	371	0	0	133	0	177	3867	3916	474	13585
Egypt	0	0	0	0	0	0	0	0	0	0	0	0
Libya	0	0	0	0	0	0	0	0	0	0	0	0
Nigeria	0	1326	80	0	0	219	0	904	3752	1420	44	7745
Norway	0	0	150	0	441	1845	0	84	711	180	0	3411
Oman	0	0	0	0	0	0	0	0	86	0	0	86
Peru	0	0	0	0	0	0	0	0	960	0	0	960
Qatar	2524	531	0	5893	0	0	126	236	3040	1708	12718	26776
Russia	0	0	0	0	0	0	29	0	0	0	0	29
Trinidad and Tobago	0	0	0	49	0	263	0	93	1134	166	515	2220
Yemen	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	5	0	0	259	0	264
Total	2524	6504	601	5942	441	2460	160	1494	13550	7649	13751	55076

4.2. Existing and planned regasification terminals in Europe

Data on the gas infrastructure network is gathered and structured by Gas Infrastructure Europe (GIE), which is an association that represents the interest of the infrastructure industry in the natural gas business. LNG terminal operators are amongst others a member of this association. Apart from collecting data on natural gas, it provides a comprehensive overview of the LNG terminals in Europe, both existing as under construction. Data is collected from its members (GIE, 2017). GIE provides a map and dataset on a yearly basis giving an overview of all terminals and their location, start-up date, send-out and storage capacity and other terminal characteristics.

As of December 2016, 29 LNG import terminals were active in Europe, with a total handling capacity of 222 billion cubic metres per year. Figure 4.1 shows the development of the LNG handling capacity in Europe since the first terminal became operational in 1969, in Barcelona, Spain. From the beginning this terminal is owned and operated by Enagas, which is the owner and operator of Spain's gas grid since 1962. The non-existence of pipeline connections with other countries and limited gas reserves required for a different solution to securing supply of natural gas to Spain. Therefore, Enagas constructed the first regasification plant in Barcelona, ensuring a security in supply to Spanish households.

As can clearly be seen from the chart, the capacity for the regasification of LNG has risen significantly over the years. Start-up year 2009 shows a steep increase, due to the opening of the South Hook LNG terminal in Milford Haven, which is currently the largest European LNG terminal in operation. As mentioned in paragraph 2.2, different types of LNG import terminals exist. Nearly all terminals are still large onshore terminals. However, of the last six terminals that became operational, three were offshore (FSRUs). This coincides with the global trend of the shift from large onshore LNG regasification terminals to floating offshore units. Technological advances make it possible to build FSRUs which have the advantage that they partly bypass the need for large-scale import infrastructure (IEA, 2016a). Looking at the terminals that are under construction and planned, this observed trend is reinforced. Of all 33 LNG import terminals that have a start-up date in 2017 or later, 11 are offshore, either as FSRUs or other floating regasification units.

Figure 4.1: Cumulative nominal annual capacity of European LNG import terminals (in billion cubic metres).

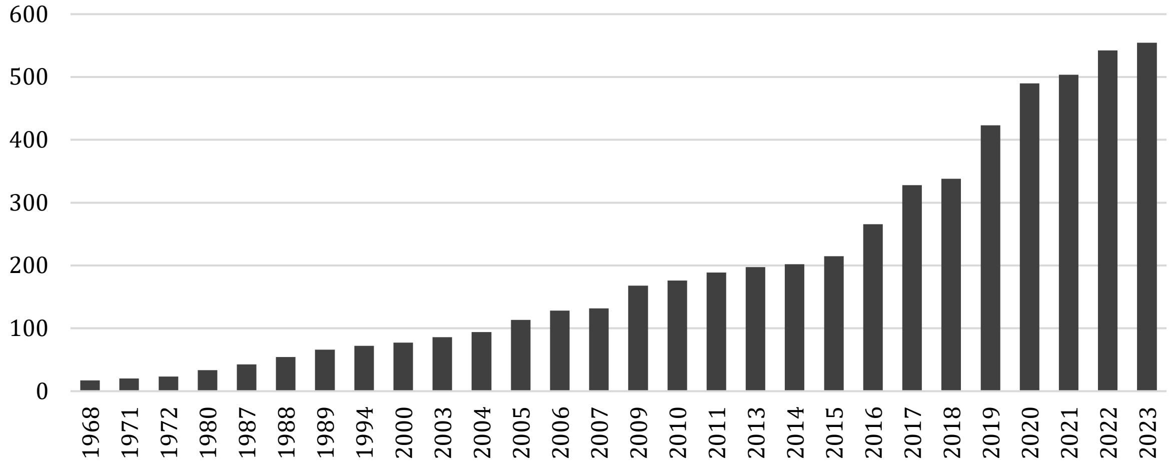

Figure 4.1 not only shows the historic development of the European regasification capacity, but also includes data for the period 2016-2023. These data include terminals that have become operational in 2006, terminals that are currently under construction or are planned for the future. As can be seen, the total capacity of all European LNG regasification terminals is expected to double by 2023 from 2016 to 554 billion cubic metres per year. In the previous paragraph it was observed that the demand for LNG slowed down over the last years and only recovered in 2015. However, the planned increase of the regasification capacity can be explained by the time the Final Investment Decisions (FID) of the terminals was taken. As constructing these terminals is a CAPEX [12] intensive process, many of these decisions were made before the demand slowdown in 2012. This therefore partly explains the expected increase in capacity over the next years.

A remarkable observation lies in the location of LNG terminals. Where large European ports are concentrated in the Hamburg-Le Havre range when looking at the throughput of dry bulk, liquid bulk and containers (on a throughput basis), few LNG terminals exist in this traditional European port range. The first LNG terminal in the Hamburg-Le Havre range that became operational was the Zeebrugge terminal in Belgium (1987) which was expanded in 2016. Additionally, terminals were constructed in Rotterdam, The Netherlands (2011, expanded in 2016) and Dunkerque, France (2016). The concentration of LNG terminals in ports located in the Mediterranean Sea is much higher, with ten LNG terminals currently in operation. This image is reinforced if the under construction and planned terminals are taken into account. Table 4.4 shows the distribution of

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[12] CAPEX and OPEX are part of the terminology in the construction industry, and more specifically in the oil & gas industry. CAPEX stands for Capital Expenditure, which includes the upfront investments. OPEX stands for Operational Expenditure which covers the costs that come with operating the facility that is constructed (IGU, 2016).

LNG terminals across the Mediterranean Sea, Atlantic Ocean, North Sea and Baltic Sea. The distribution clearly shows (1) a strong concentration in the Mediterranean Sea area, both currently as planned, (2) a future increase in Baltic Sea region and (3) lagging investments in the North Sea area.

Table 4.4: Number of LNG import terminals per region.

	Operational	Under construction + planned	Total
Mediterranean Sea + Black Sea	11	18	29
Atlantic Ocean	8	2	10
North Sea	5	1	6
Baltic Sea	4	13	17

Combining the findings from the previous paragraph with the allocation of the LNG terminals according to GIE, several conclusions can be drawn. First of all, a large portion (around 70%) of the LNG imports originates from countries (i.e. Qatar and Algeria) that are positioned closest to sea ports in the Mediterranean Sea. As a result, investments in LNG import terminals are higher in ports in this region than others.

Secondly, a rise in the construction of LNG import terminals in the Baltic Sea region can be observed. Reasons for the construction of LNG terminals in the Baltic Sea region are mainly focussed on "ensuring a diversified, reliable and secure supply of LNG and natural gas to Eastern Europe" (Gulf Times, 2015). Due to conflicts between Russia and Ukraine, the security of natural gas supply to Europe have been put at risk. As of January 2006, Russia cut off the natural gas supplies to Ukraine. Many countries in the European Union get their gas through the Ukrainian pipeline network (Dweck, Meyer & Wochner, 2007). As a result, the construction of LNG terminals has become a priority for especially countries that are relying on natural gas from Russia. LNG import terminal projects are backed by the European Union as it helps to meet its security supply objectives (Intellinews, 2016).

When looking at the development of the actual demand versus the nominal capacity of the regasification terminals, a large overcapacity can be observed. Figure 4.1 shows a capacity of over 200 billion cubic metres of regasification capacity in 2015, whereas total European imports are only good for 55 billion cubic metres of LNG (table 4.2). When looking at the forecasted values, it is expected that the demand for LNG will continue to grow in the following years. However, it can be concluded that the increase in capacity significantly outgrows the demand for LNG up to 2021.

4.3. Competitiveness of European ports for LNG

As can be seen from the previous two paragraphs, a strong case can be made for the importance of the proximity to the origin of LNG as a USP for sea ports. The investments in terminals in ports that are close to the country of production of LNG are significantly higher than those that are not in the proximity of the country of origin. However, when looking at quantitative data on the LNG imports through ports in Europe, some observations that could contradict these investments can be made. Figure 4.2 presents the Port Portfolio Analysis Level 3, as discussed in chapter 2. It displays the position of ports with regard to the throughput of LNG in the period 2001-2015. Data is retrieved from Eurostat's database 'Gross weight of goods transported to/from main ports' with detailed quarterly data on the port throughput per country.

As can be seen, Rotterdam, Sines and London are considered to be Question Marks, which will require serious investments to increase their market share in the LNG import market in Europe. Especially Rotterdam and Sines perform well, with high annual growth rates. Milford Haven is amongst the Stars, with a high market share and high annual growth, which can be explained by the fact that it is the largest terminal in Europe as of 2015 and functions as a hub for reloading (see below). Finally, Barcelona and Marseille are Cash Cows, as the throughput of LNG respectively declines or is very low, but have a high market share.

Boon (2014) writes on the development of the competitive position of Marseille in the supply of energy in the second half of the twentieth century. In the transition from coal to oil, Rotterdam is considered to have gained a better competitive position than Marseille. However, figure 4.2 shows that Marseille has a better position with regards to the transition from oil to natural gas. It is too early to draw a conclusion, but Marseille currently shows a more favourable position in the market for LNG than Rotterdam.

Remarkably, ports in the Mediterranean Sea have a low growth rate, which may be explained by the high number of terminals that are active in that region (see table 4.2). Besides, the LNG terminal is Barcelona is the oldest terminal in Europe, which may explain the steady growth rate as compared to the other, newer terminals.

Figure 4.2: Port Portfolio Analysis Level 3 for LNG in period 2001-2015.

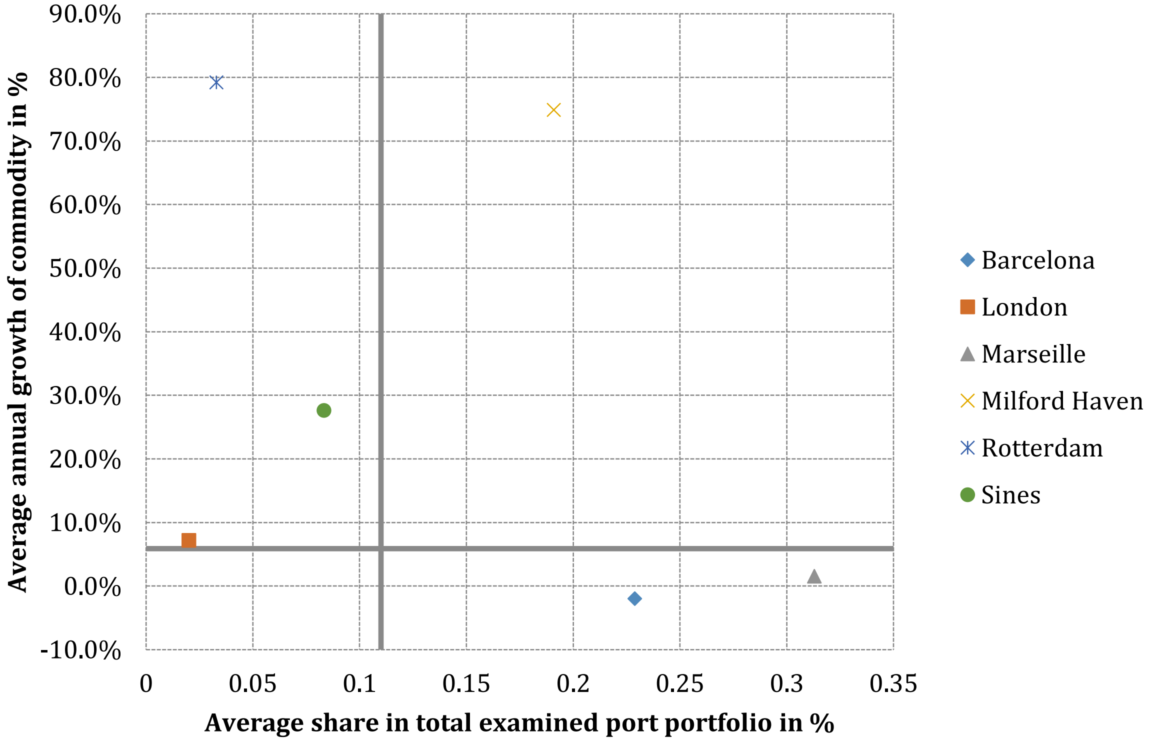

Table 4.5 on the following page shows the assessment of the importance of various USPs. LNG can be placed in the segment 'Liquid bulk'. However, several adaptations can be made to this assessment after abovementioned conclusions.

First of all, the draft and maritime access is of lesser importance, as LNG carrier have a smaller draft than other liquid bulk carriers, such as oil tankers. An average LNG carrier has a draft of 12 metres versus 15-20 metres for crude oil tankers (Hughes, 2004).

Secondly, the USP 'Favourable location close to origins and destinations of cargo flows' is more important, as was shown in the previous paragraphs. This can be explained by the fact that LNG is transported through pipelines once it is regasified. Transportation through pipelines is significantly faster than transportation overseas, which can explain the want to limit the maritime distance of LNG transport. Overseas LNG transportation forms around 15-30% of the total cost of an LNG project (Mokhatab, 2014). This is a substantial share and it is therefore a potential cause for LNG terminals to be constructed close to the country of origin.

Besides a short distance between the country of origin and the importing port, the distance between the port and the destination of LNG is important. Many of the existing and planned terminals are focussed on supplying the region in which they are constructed (next paragraph discussed the hinterland infrastructure). However, several LNG import terminals have contracts for re-export of LNG to other regions[13], such as the LNG terminal in Zeebrugge, Belgium (De Krant van West-Vlaanderen, 2014). This terminal re-exports LNG to Scandinavian countries. Besides the Zeebrugge terminal, other terminals are active in the *reloading* market. The market for reloading in Europe as of 2015 is dominated by Spain (60% of worldwide reloading capacity), Belgium (18%), France (7%) and the Netherlands (6%) (Business Monitor International, 2015).

The hinterland infrastructure is a third important factor in the port selection process. The existence and extensiveness of the pipeline network differs significantly throughout Europe. Networks in Spain and the United Kingdom are less developed than in countries like Germany, France, Italy and the Netherlands (see figure 1 in appendix 7.2). The need for LNG terminals is therefore higher in these countries in order to cope with supply constraints, as opposed to countries with extensive pipeline connections. Regasification projects in these countries are driven more by diversification of energy sources and the encouragement of supply competition (Dweck, Meyer & Wochner, 2007).

Finally, the safety and security in the port is of high importance, due to the highly dangerous process of transforming LNG to natural gas.

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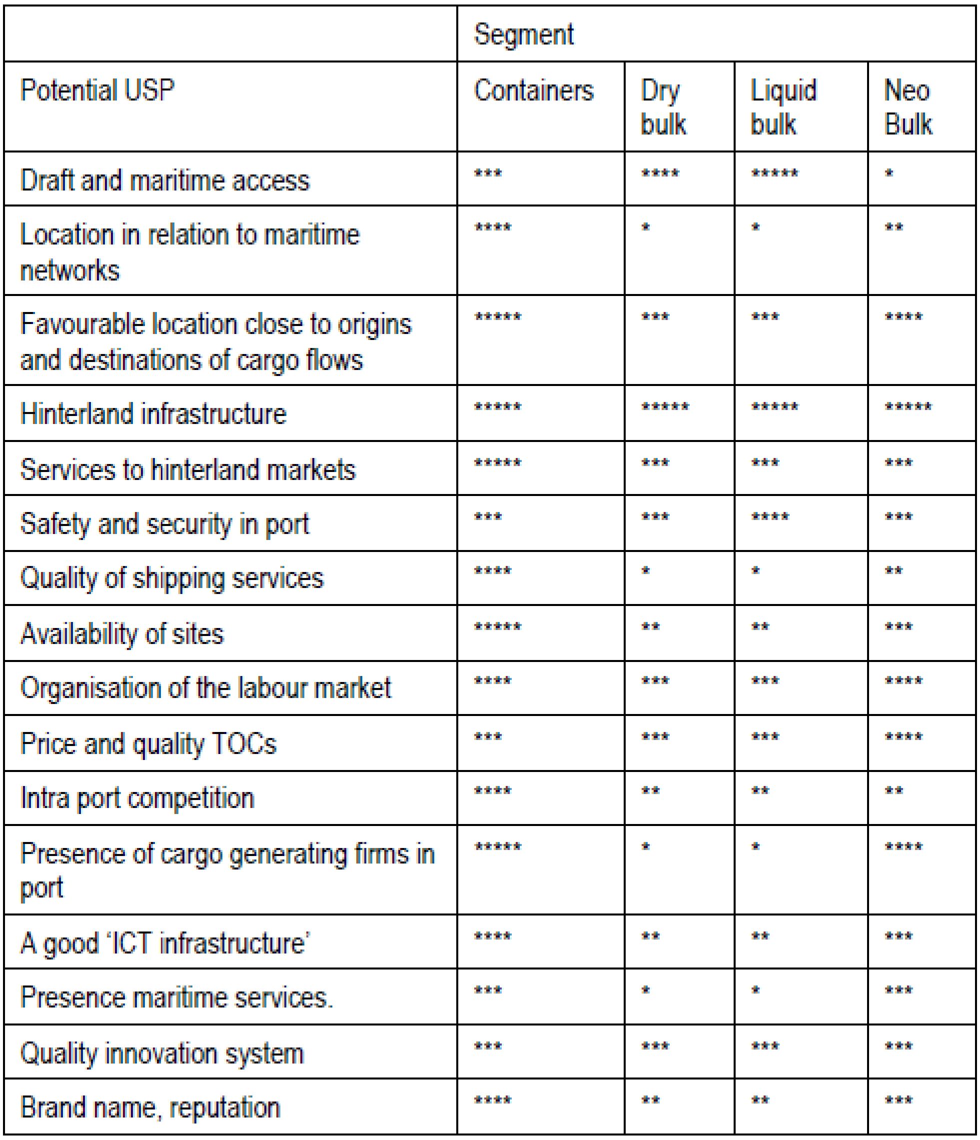
[13] The process in which LNG is offloaded, stored in the terminal and afterwards re-exported to terminals in other regions is called *reloading*. In this process the LNG is not regasified and does not reach the national gas grid.

Table 4.5: Assessment of the importance of the various USPs for some important commodities in the Hamburg-Le Havre range (De Langen *et al.*, 2012).



	Segment			
Potential USP	Containers	Dry bulk	Liquid bulk	Neo Bulk
Draft and maritime access	***	****	*****	*
Location in relation to maritime networks	****	*	*	**
Favourable location close to origins and destinations of cargo flows	*****	***	***	****
Hinterland infrastructure	*****	*****	*****	*****
Services to hinterland markets	*****	***	***	***
Safety and security in port	***	***	****	***
Quality of shipping services	****	*	*	**
Availability of sites	*****	**	**	***
Organisation of the labour market	****	***	***	****
Price and quality TOCs	***	***	***	****
Intra port competition	****	**	**	**
Presence of cargo generating firms in port	*****	*	*	****
A good ‘ICT infrastructure’	****	**	**	***
Presence maritime services.	***	*	*	***
Quality innovation system	***	***	***	***
Brand name, reputation	****	**	**	***

5. Discussion and conclusions

This research focussed on the demand for LNG on a global level and on a European level. An extensive quantitative analysis was used to identify drivers behind the demand for LNG, followed by the implications of the LNG demand development on the European logistics chain. In this chapter several limitations will be discussed and recommendations for future research on this subject will be given. Furthermore, it will answer (sub) questions and the stated hypotheses will be either accepted or rejected. Finally, an answer to the main research questions will be given.

5.1. Limitations and recommendations for further research

The demand for LNG in this research was interpreted using the imports of LNG in a certain region or country. This assumption may have had a strong impact on the results of this study, as it is not guaranteed that these two variables are equal. Imports of LNG can be higher than the demand for LNG, as the LNG that enters the country can be stored for later use or for trading purposes. Therefore, this assumption may be seen as a limitation to this research.

A second limitation lies in the sample size. As the research was focused on a regional level rather than a country level, limited observations were used in order to perform this study. Although several countries were added to the sample size, it does not provide ideal results, as was observed during the forecasts that were performed in chapter 4. Supplementary countries as control groups might have helped increase the reliability of the results.

An additional limitation can be found in the greenhouse gas emissions as proxy for the government policy. As government policy is difficult to be quantified, the greenhouse gas emissions were used as an indirect proxy for the country's/region's policy. A deeper research into the energy policies and as a result different variables may add value to this study. However, results from this research can still be interpreted reliably.

Further research that can contribute to the study of location criteria for LNG receiving terminals is the analysis of the transportation component of LNG projects. Although some research has been performed on the ocean segment of LNG transportation, there is limited research available on the inland transportation of LNG. Therefore, a quantitative and/or qualitative analysis of the ocean and inland component of the transportation cost for LNG can contribute to answering the question whether LNG terminals locate close to the country of origin as a result of cheaper transportation through pipelines versus transportation overseas.

5.2. Conclusions

In chapter 2, it was observed that technological improvements significantly impact the way natural gas is supplied to end customers. LNG has gained an important position in the natural gas supply market. As natural gas is a cleaner (less CO_2 emissions) burning fossil fuel than oil and coal, it has gained an increased focus from governments, resulting in higher investments from oil and gas majors such as Shell and BP. LNG plays a key role in fulfilling the increasing demand for LNG as the natural gas reserves that are being discovered are often located in remote locations, making it difficult to construct pipeline infrastructure in order to supply the demand regions. LNG has proven to be a reliable and economic solution to this problem. However, the rise of LNG has resulted in disruptions in supply chains as compared to traditional supply chains for oil, coal and natural gas in gaseous form. A worldwide rise in demand is accompanied by an increase in LNG import terminals over the last decades. These terminals form an integrated part of the supply chain, as the regasification often takes place at these terminals. For the next decades, the main function of LNG will be the generation of power and will therefore be regasified and pumped into the existing gas network, as opposed to being used as fuel for sea and road transport. However, the latter will increase in importance as investments in LNG driven vessels and road trucks are growing. As the market for LNG grows, technological improvements, such as floating processing units (either for liquefaction or regasification), ensure a reduction in costs, making the LNG market even more attractive for suppliers of energy.

Chapter 3 showed the increase in demand of LNG since the beginning of this century. Several factors proved to drive this increase in demand. The hypotheses formulated in the second chapter can all be (partially) accepted. The first hypothesis can be accepted, as a growing population and GDP have a positive impact on the demand for LNG. Hypothesis 2 can be partially accepted, as a limited relation between the greenhouse gas emissions and the demand for LNG was observed. As mentioned in the limitations, further research into this hypothesis is necessary for a clear conclusion. The final hypothesis can also be accepted partially. It was expected that the prices for natural gas and LNG and the demand for LNG were negatively related (hypothesis 3a). This was partially proven by the model in chapter 3. US natural gas and LNG Japan prices proved to have a significant negative effect on the demand for LNG, as opposed to EU natural gas prices, which did not show a significant relationship. Alternative fuel prices (oil and coal) were expected to have a positive relationship with the demand for LNG (hypothesis 3b). Only the average crude oil price proved to have a significant relationship with the demand for LNG. Coal prices and other crude oil prices (WTI and Brent) were not significant.

The focussed research on Europe that was performed in chapter 4 showed that LNG demand is expected to grow over the next years, after several years of slowing growth or even decline. However, the market is expected to recover and grow substantially. This is confirmed by the LNG import terminals that are either under construction or planned to be constructed for the coming years. A strong concentration of terminals in ports in the Mediterranean Sea was observed, which could be explained by the closeness to the countries of origin (Qatar and Algeria are currently the main suppliers of LNG to Europe). With the planned number of regasification terminals, it can be expected that the current overcapacity will persist and even increase. As a result, ports that are focussed on acquiring LNG terminals into their area might need to revise their strategy. They should at least take into account the different port selection criteria that are important for locating LNG terminals. An extensive hinterland infrastructure in the form of a pipeline network and reloading possibilities are key in the location selection process for LNG terminals.

In order to conclude this study, the main research question should be answered. The following question was formulated in the first chapter: *"How has the trade in LNG developed globally since 2001 and what is the impact on (oil dependent) ports in Europe?"* As was mentioned often in this study, the demand for LNG has increased significantly since 2001, due to the increased awareness for sustainable economic growth and the present remote locations of natural gas fields. Large investments by oil and gas majors show the increased importance that natural gas and thus LNG will have in the next decades and as a result LNG trade will reach higher levels. This will impact the current logistics chain as few LNG terminals still exist and competition between European (and globally) ports will impact the allocation of these terminals. It seems that ports in the Mediterranean Sea have an advantage due to their location close to the countries that produce LNG. Ports in other regions should therefore focus on other USPs, such as reloading possibilities or a good connection to the hinterland via pipelines. Finally, a rising demand from the road and maritime transport industry may play an important role in the location process of LNG terminals.

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7. Appendices

7.1. Stata output

Table 1: Fixed effects regression with all variables included.

```
Fixed-effects (within) regression               Number of obs      =       270
Group variable: nr                              Number of groups   =        18

R-sq:                                           Obs per group:
     within  = 0.8477                                         min =         15
     between = 0.8144                                         avg =       15.0
     overall = 0.7872                                         max =         15

                                                F(15,237)          =     87.96
corr(u_i, Xb)  = -0.9576                        Prob > F           =    0.0000

------------------------------------------------------------------------------
   lngimport |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     crudeav |  -482.2374   941.9909    -0.51   0.609    -2337.982    1373.507
  crudebrent |  -7.272546   917.8149    -0.01   0.994     -1815.39    1800.845
  crudedubai |   739.1729   1229.194     0.60   0.548    -1682.368    3160.714
    crudewti |          0  (omitted)
     coalaus |  -133.7799   349.6353    -0.38   0.702    -822.5699      555.01
     coalcol |  -194.3491   333.2676    -0.58   0.560    -850.8942    462.1961
      coalsa |   380.2406   608.4602     0.62   0.533    -818.4407    1578.922
        ngus |   -286.257   1026.122    -0.28   0.781    -2307.741    1735.227
       ngeur |  -904.3971   954.2649    -0.95   0.344    -2784.322    975.5277
      lngjap |  -1343.288   765.6889    -1.75   0.081    -2851.714    165.1373
  population |   .0000753   .0000176     4.28   0.000     .0000407      .00011
         gdp |   3.31e-09   9.74e-10     3.40   0.001     1.39e-09    5.23e-09
   gdpcapita |  -.5689973   .6597596    -0.86   0.389     -1.86874    .7307451
      co2emi |   .0063354   .0019247     3.29   0.001     .0025438    .0101271
     methemi |  -.0488477   .0123462    -3.96   0.000      -.07317   -.0245255
      ghgemi |   .0027268   .0014958     1.82   0.070    -.0002201    .0056736
       _cons |  -46690.17   19336.36    -2.41   0.017    -84783.26   -8597.076
-------------+----------------------------------------------------------------
     sigma_u |  109969.03
     sigma_e |  8607.7436
         rho |  .99391045   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(17, 237) = 153.69                   Prob > F = 0.0000
```

Table 2: OLS regression with limited variables included.

```
Linear regression                               Number of obs     =        270
                                                F(6, 17)          =          .
                                                Prob > F          =          .
                                                R-squared         =     0.8202
                                                Root MSE          =      29711

                                   (Std. Err. adjusted for 18 clusters in nr)
------------------------------------------------------------------------------
             |               Robust
   lngimport |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  population |   .0000633   .0000319     1.98   0.064    -3.99e-06    .0001305
         gdp |   2.30e-09   2.17e-09     1.06   0.303    -2.27e-09    6.87e-09
     crudeav |    195.833   132.3523     1.48   0.157    -83.40593    475.0719
        ngus |  -1372.469   644.3424    -2.13   0.048    -2731.913   -13.02538
      lngjap |   24.49729    818.819     0.03   0.976     -1703.06    1752.054
      co2emi |   .0034059   .0053385     0.64   0.532    -.0078574    .0146692
     methemi |  -.0561018   .0400812    -1.40   0.180    -.1406658    .0284622
       _cons |  -7611.189   6116.582    -1.24   0.230    -20516.05     5293.67
------------------------------------------------------------------------------
```

Table 3: Random Effects regression with limited variables included.

```
Random-effects GLS regression                   Number of obs     =        270
Group variable: nr                              Number of groups  =         18

R-sq:                                           Obs per group:
     within  = 0.8300                                         min =         15
     between = 0.7495                                         avg =       15.0
     overall = 0.7474                                         max =         15

                                                Wald chi2(6)      =          .
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =          .

------------------------------------------------------------------------------
   lngimport |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  population |   .0000328     .00001     3.28   0.001     .0000132    .0000525
         gdp |   3.83e-09   6.92e-10     5.54   0.000     2.47e-09    5.19e-09
     crudeav |   263.5419    88.1177     2.99   0.003     90.83444    436.2495
        ngus |  -1538.163   480.5593    -3.20   0.001    -2480.042    -596.284
      lngjap |  -1366.498   614.9056    -2.22   0.026    -2571.691   -161.3049
      co2emi |    .012435   .0013501     9.21   0.000     .0097889     .015081
     methemi |  -.0655965   .0114873    -5.71   0.000    -.0881112   -.0430819
       _cons |  -13473.72   8713.773    -1.55   0.122    -30552.41    3604.957
-------------+----------------------------------------------------------------
     sigma_u |  28888.903
     sigma_e |  8625.7451
         rho |  .91814549   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

7.2. Figures

Figure 1: Gas pipeline networks in France and Spain (GIE, 2017).