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Abstract

The main objective in this thesis is to investigate how various factors are influencing investments in the US natural gas industry. The thesis puts a special emphasis on the "Shale Gas Revolution" that struck the US natural gas market in 2006/2007 and how it has affected investments in natural gas. The yearly growth rate in shale gas production from 2007-2013 was 31 %. The analysis is based on data from the period 1990-2013. The thesis gives an overview of the US natural gas market and its participants, competition and price formation. Different methods are applied in the analysis. Investment theory and the Net Present Value (NPV) formula are used as a framework to identify and describe important variables and how they have developed in the period 1990-2013. Based on this, the thesis shows how the variables influences the Net Present Value of a natural gas project and thereby the willingness to invest in the natural gas industry. Two linear regression models are applied in the analysis. The objective of the first model is to test whether the shale gas revolution has influenced the investment pattern in the natural gas industry. The objective of the second model is to quantify and explain how various economic variables are linked together and how they influence the investments in natural gas in the US.

The findings are as follows: The empirical analysis confirms that the investments in natural gas industry are positively correlated with; growth in the US- economy (represented by Gross Domestic Product), demand for gas, the price of gas, technological development and proven reserves. The analysis also shows that the shale gas revolution has had a significantly positive effect on investments since its occurrence in 2006/2007. The price of oil has also a strong positive effect on investments, but as the price of oil and the price of gas became more delinked following the shale revolution and the financial crisis in 2009, it is reasonable to assume a weaker correlation between the price of oil and investments in natural gas after 2009. I also find that the shale gas revolution has had a significantly positive impact on investments since its occurrence in 2006/2007. The regression model also indicates that the investments are negatively correlated with the cost of capital, represented by the interest rate on the 10- year US Treasury bond.

Preface

This thesis is written as a finalization of my Master´s Degree in Industrial Economics at the University of Stavanger. It has been a challenging but exiting task, and I have learned a lot in the process.

I would like to thank my supervisor Roy Endrè Dahl for the time and effort he has spend on my thesis. He has been a valuable source of guidance and support throughout my work and I greatly appreciate his help.

I would also like to thank friends and family for their help and involvement in my work. It is highly appreciated.

Stavanger, June 2015

Pål Holmefjord Lorentzen

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Chapter 1 - Motivation and Background

The US natural gas market has seen some extraordinary development during the last decade. Technological advancements have allowed for a large-scale extraction of natural gas from unconventional resources such as shale rock. In 2006 this development culminated in the phenomenon that later has been referred to as the US "Shale Gas Revolution". In 2000, shale gas accounted for 1.6 % of US domestic production of natural gas. In 2005, the number had risen to 4.1 % and by 2013 shale gas accounted for astonishing 40.4 % of the domestic production (Sieminski, 2014).

A necessary ingredient for such a phenomenon to occur in the private sector is the expectation of a high return on investment, or at least the expectation of a *future* high return on investment. An anticipation of future high profit within the natural gas sector should, according to theory of rational expectations, lead to an increase in investments today. Numbers derived from the US Bureau of Economic Analysis (see figure 19) show that investments in private fixed assets in the US oil and gas industry experienced sharp growth during the previous decade. An interesting question to ask is which market related factors have been the catalysts for the observed significant increase in investments? This dissertation aims to answer this question.

1.1 Scope Of the Thesis

The objective of this thesis is to investigate the relationship between investments in natural gas and various potentially influencing variables by using a descriptive statistical analysis and a linear regression model. The descriptive analysis is performed using the Net Present Value formula as a conceptual framework for analyzing how the variables might affect investments. The linear regression model uses an OLS estimator to determine the relationship between investments and the potentially influencing variables and how they hinge together. The thesis will also investigate how the shale revolution has affected investments.

The remaining part of the thesis is structured in the following way: I end this section by looking into the motivation behind the thesis and a short presentation of previous work. The next section presents a brief history of natural gas´s role in the global energy market and in the US energy market. Chapter 3 discusses the Shale Gas Revolution with focus on technology, why it happened in the US, how applicable it is to replicate in the EU and controversy associated with the extraction- process. Chapter 4 shows the global natural gas market and why it differs from the oil market. I then examine the US natural gas market and describe some of the important participants, types of trading and how the price of natural gas is determined in the market. Chapter 5 provides the reader with information on the data used in the analysis. In chapter 6 and 7 the descriptive analysis and the regression model is presented, respectively. Chapter 8 discusses the results of the analysis and chapter 9 concludes.

1.2 Motivation Behind the Thesis

In light of the relatively recent happenings in the US natural gas market and the effects of the shale gas revolution it is interesting to examine which influencing factors are affecting investments in natural gas. It is valuable to have an understanding of this from an investor's perspective as he/she will have a greater understanding of which factors are most likely to influence gas projects Net Present Value. An investor can then monitor these variables more closely in order to make more qualified judgments regarding whether or not to invest in a natural gas project. For large oil companies, investing in unconventional sources such as shale rock have been important in recent years to diversify their portfolio.

It is also valuable to investigate this from a societal perspective. One of the most debated topics in the world today is the global warming and CO_2- emission debate. The US is the second largest emitter of CO_2 in the world and their choice of fuel and energy sources within its various economic sectors will have huge implications for their overall emission of CO_2. Natural Gas is the "cleanest" of the fossil fuels and has been introduced by many as a way of transition to a low- emission society. An investigation of how influencing variables are linked together and how they affect investments in natural gas will provide the decision makers and politicians with valuable input if they are to facilitate a substitution to natural gas from for example coal.

There is an ongoing debate in several other countries around the world on whether or not to exploit their own shale gas/oil resources. The US shale revolution is the best case study available and looking into which factors has influenced investments will provide valuable information to decision makers on how to facilitate for shale activity elsewhere.

Although being a relatively recent phenomenon there has already been extensive research on the effect of the Shale gas revolution, both domestically in the US and how the new industry has affected the global energy markets. However, there is a lack of research on the main factors that are influencing the willingness to invest in natural gas. This is a topic that needs to be investigated further.

1.3 Previous Work

An article that has investigated the effects of the shale revolution is "Macroeconomic Impacts of LNG Exports from the United States" published in the Economics of Energy & Environmental Policy journal (Baron, Bernstein, Montgomery, & Tuladhar, 2015) (Baron, Bernstein, Montgomery, Tuladhar, 2015). The paper aims to investigate if natural gas exports from the US are in the public's interest. Under various US LNG export scenarios (based on EIA´s *Annual Energy Outlook 2013)*, the economic consequences are estimated. They find that exports of LNG did not in any scenario cause the price of gas in the US to become linked to world oil prices, and in all of the scenarios analyzed would the US gain economic benefits from exporting LNG.

Another interesting article published in the same journal tells the story of how the technology that enabled the shale revolution was developed by Mitchell Energy Company during the 1980´s, 1990´s and the 2000´s (Wang & Krupnick, 2015). The article highlights important governmental policies during the 1970´s that stimulated research into techniques that could allow for extraction of gas from unconventional sources.

Chapter 2- Natural Gas

2.1 Natural Gas

Natural gas is a fossil fuel that is formed when buried plants, gases and animals are exposed to intense heat and pressure over thousands of years. It is a nonrenewable energy source and together with coal and oil, the most important fossil fuels. Natural gas consists of a mixture of hydrocarbons, meaning that it is made up of compounds of hydrogen and carbon. The most common hydrocarbon in natural gas is methane. Natural gas is found in reservoirs beneath the surface of the earth and is often located in association with oil (Natural Gas.org, 2013). Since the gas is trapped within large layers of rock, thereby preventing the gas from escaping to the surface, drilling is needed to release the gas.

The first natural gas extraction on an industrial level started at Fredonia, New York (US) in 1821 (US Department of Energy, 2013). Since then, the natural gas industry has grown to become one of the largest energy sources in the world. In 2013 it accounted for 23,7% of the worlds primary energy consumption, only beaten by coal and oil (British Petroleum, 2014). Figure 1 shows the worlds primary energy consumption by fuel.

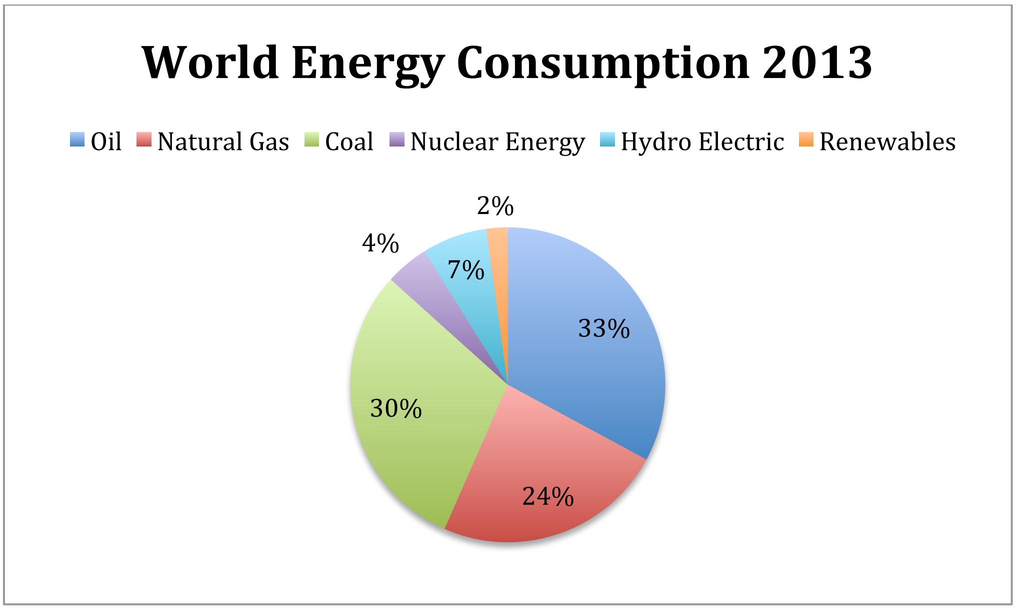

Figure 1: World Energy Consumption 2013. Source (British Petroleum, 2014)

It is expected that demand for natural gas will grow by 1,9 % annually up until 2035, led by demand from Asia (British Petroleum, 2015). Around half of the demand will be met by rising conventional gas production, mainly from Russia and the Middle East, while the rest will be met by an increase in shale gas production. In the same report they predict that the increase in demand will lead to higher levels of LNG transport and possibly create a more global gas market with more similar price levels.

2.2 Natural Gas in the US

In the US natural gas has historically been, and still is, a major source of energy. In 2013 natural gas contributed 27 % of the primary energy consumption in the US (U.S Energy Information Administration, 2014). Crude oil is the largest contributor with 36 % and coal is the third largest with 19 %. The US pipeline system is an integrated transmission and distribution grid that can deliver gas to nearly any location in the country, creating a highly efficient market with many suppliers and consumers. Figure 2 shows a graphic illustration of the extensive pipeline grid in the US (EIA).

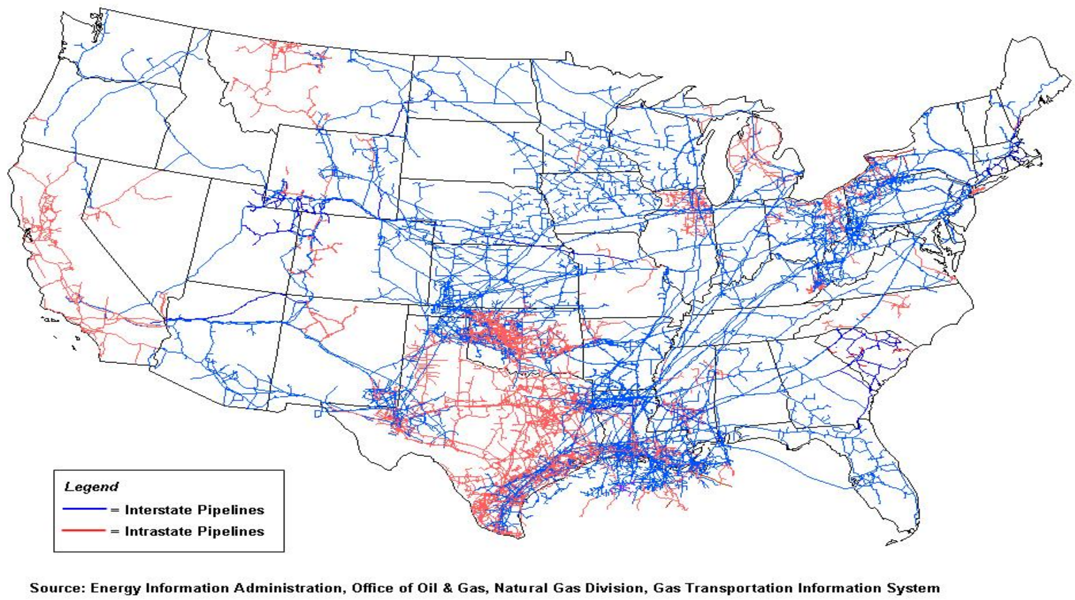

Figure 2: US Pipeline grid (Source: EIA)

As a result of large capital investments and new technology the US has experienced a substantial increase in its domestic production of crude oil and gas in recent years. They are on their way to become self- sufficient of oil supply and in BP´s "Energy Outlook 2035" it is estimated that the US will become a net exporter of crude oil by 2031 if the ban on export is removed. However, as of 2015 the domestic production of natural gas compared to the US consumption of natural gas is much larger than that of crude oil. The US is less dependent of import of natural gas than it is dependent on crude oil imports.

Only in 2013 natural gas imports to the US declined by 14 %, and forecasts shows that the US is expected to become a net exporter of natural gas before 2020 (U.S Energy Information Administration, 2014, 2014).

Table 1 shows the main industry sectors where natural gas is used as a source of energy. It also shows in which sectors coal and oil are primarily used. From the table below we can see that the consumption of the US natural gas resource is quite evenly spread between residential & commercial, industrial and electric power. The transportation sector is a relatively minor consumer of natural gas. It also shows the versatility of natural gas. Unlike coal and oil, which are primarily used in electricity generation and transportation respectively, natural gas is a major energy source in several sectors. It also tells us that the different fuels have somewhat different markets. Oil is directed towards transportation, while coal towards production of electricity.

	Residential & Commercial	Industrial	Electric Power	Transportation	Total
Natural Gas	32 %	34 %	31 %	3 %	100 %
Coal	<1%	9 %	91 %		100 %
Oil	4 %	24 %	1 %	71 %	100 %

Table 1: Natural gas consumption by sector. Source: EIA

Table 1 also provides information about the primary competitors producers of natural gas have in the different sectors, and what kind of fuels they have the biggest possibility of substituting.

Within the industrial sector natural gas is used for a variety of applications. It is used for waste treatment and incineration, preheating of metals, drying and dehumidification, glass melting, food processing and fueling industrial boilers. It is also used as a raw material for the manufacturing of a number of chemicals and products. Within the residential and commercial sector its primary use is heating, cooling and cooking (Naturalgas.org, 2013). In electricity generation natural gas is used in gas turbines. The technological development within the gas turbine field has been huge, especially with the introduction of the high- efficiency Natural Gas Combined Cycle (NGCC), which can generate electricity at a lower cost than coal- fired generators (U.S Energy Information Administration, 2014).

In BP´s “Energy Outlook 2035” it is estimated that natural gas will have an increasingly important role in the US energy- mix in the future. With rising domestic production, BP predicts that natural gas will replace oil as the number one energy source in the US by 2028, accounting for 38 % of the country´s energy consumption (British Petroleum, 2015).

Chapter 3- The US Shale Gas Revolution

As mentioned at the end of the previous chapter, British Petroleum expects natural gas to become the biggest primary energy source in the US in the future. The reason for the prediction is rooted in a phenomenon that took place midway in the last decade, referred to as the *Shale Gas Revolution.*

Figure 3 show that the US has experienced a significant growth in the domestic production of natural gas in recent years. The blue area in the figure represents the total extraction of natural gas in the US. The red area is natural gas extracted from shale rock. The connections between increased production from shale rocks, and overall increase in domestic production since 2006/2007 is quite evident.

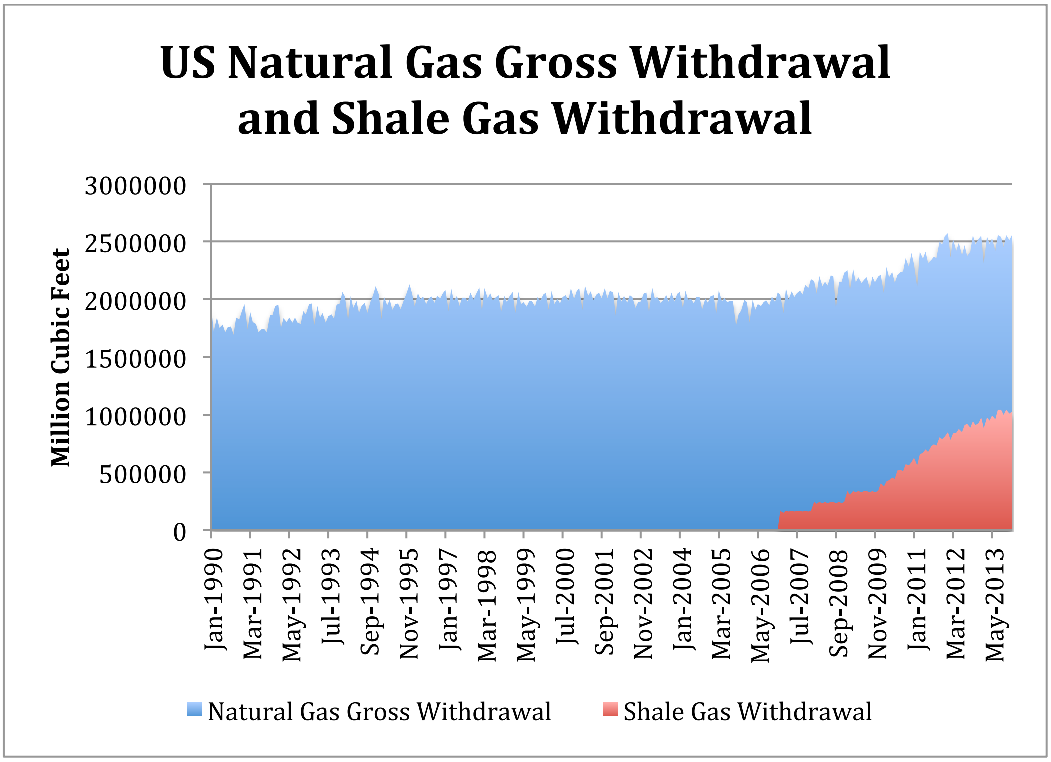

Figure 3: US Natural Gas Gross Withdrawal and US Shale Gas Withdrawal. Source: EIA

New technology has allowed the US to take advantage of their huge reserves of shale gas, causing a large positive shift in the supply of natural gas. As economic theory states, a shift in the supply side of a commodity will cause a drop in prices, all else being equal. This is what happened in the US after the shale gas revolution started. At Henry Hub, the average natural gas spot price per million Btu was 8.86 $ in 2008. In 2013 the price had dropped to a yearly average of 3.73 $ per MBtu (U.S Energy Information Administration, 2015). To illustrate the large change in the US gas market compared to other gas markets the spot prices for Henry Hub (US) and National Balancing Point (UK) is presented in figure 4. It is interesting to see how the spread between the two has changed dramatically following the shale gas revolution in the US and the global financial crisis in 2009. The shale revolution has clearly been a *regional* phenomenon so far.

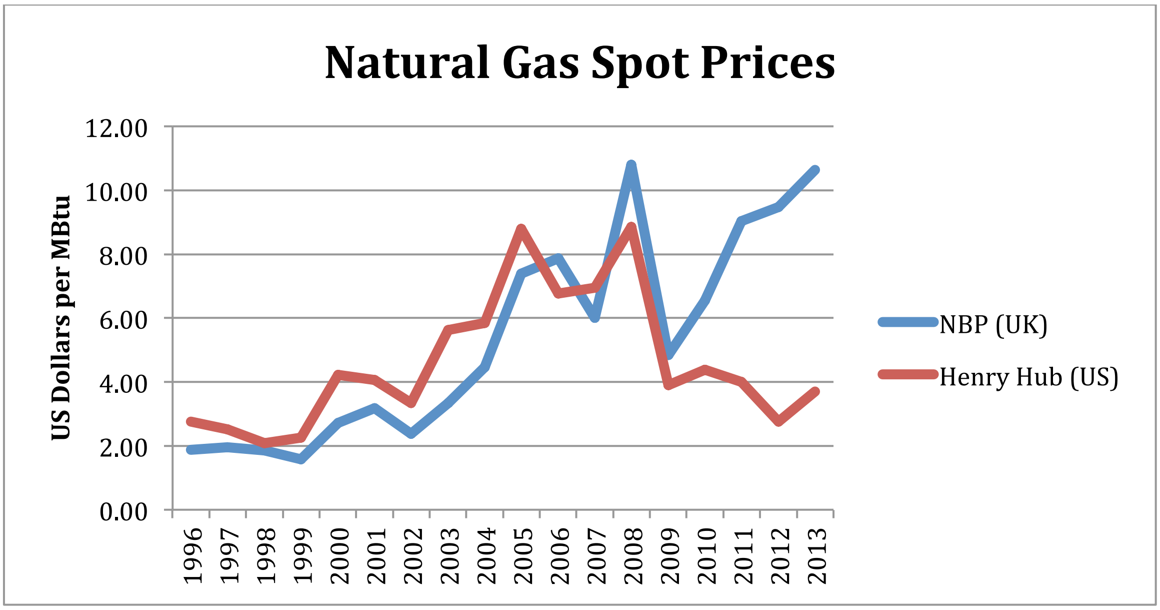

Figure 4: Natural Gas Spot Prices NBP and Henry Hub. Source: (British Petroleum, 2014)

The increased supply of natural gas and the drop in natural gas prices have affected the energy mix in the US. The introduction of cheap natural gas has led to an exploration of new areas of application for natural gas. As an example, natural gas has replaced coal as fuel in many electric power plants. Within the transportation sector oil has traditionally been immune from price competition because of the lack of alternatives. Shale gas has sparked interest for the utilization of natural gas as a substitute for oil- refined products such as gasoline and diesel. Warren Buffet´s BNSF railways is already testing the use of natural gas instead of diesel in its US trains (Makan Ajay, Financial Times, 2013), and several car manufacturers in the US are testing out gas- fired engines for freight trucks.

In a report from McKinsley & Company in 2013 shale gas extraction is viewed as the industry having the biggest possibility of increasing GDP growth in the US (Mckinsley & Company, 2013). The report estimates that shale gas can contribute as much as $690 billion annually and create up to 1,7 million jobs across the economy by 2020. Many argue that without the shale gas revolution and the hundred of thousands of jobs it has created the US economy would have slipped back into recession. Having access to a cheap energy source gives the US a major competitive advantage compared to China and Europe where the price of natural gas is significantly higher. It is without doubt that the shale gas revolution has had a major impact on the geopolitical capital of the US in terms of energy independence.

3.1 Shale Gas Technology

Shale gas is found in shale formations, or *plays,* where the natural gas is trapped within large unconnected pores and natural fractures. Natural gas resources are usually divided between *conventional* resources and *unconventional* resources. The easiest explanation for the distinction between the two is that unconventional gas sources require further processing after the initial well has been drilled before the gas can flow to the surface. In a conventional well the gas flows naturally after the well has been drilled. Shale gas is referred to as *unconventional* gas because drilling is simply not enough to generate a commercial gas flow. The techniques that have allowed for unconventional gas extraction are mainly *horizontal drilling*, *hydraulic fracturing* (commonly referred to as *fracking) and three- dimensional seismic imaging* (Wang & Krupnick, 2015). Fracking is a process where water, sand and chemicals are pumped into the horizontal borehole of the well at a high pressure. The high- pressure fluid that is pumped in is supposed to fracture the shale rocks, allowing the gas to be released from inside the shale´s pores. Neither horizontal drilling nor hydraulic fracturing are new technologies. Horizontal drilling was developed in the 1930s and the first well was fracked in 1947 in the US (Stevens, 2010). In addition to hydraulic fracturing and horizontal drilling, 3- D Seismic imaging has since its early commercialization in the 1980s transformed the oil and gas industry by providing literally a clearer picture of structures and properties of subsurface rocks. It has been an important tool in making the shale revolution a reality. Another technology that has been important in optimizing how shale gas wells are hydraulically stimulated is Microscopic Fracturing Mapping, developed in the early 2000s. Figure 5 shows a graphic presentation of the process of opening up the shale rocks and extracting the gas.

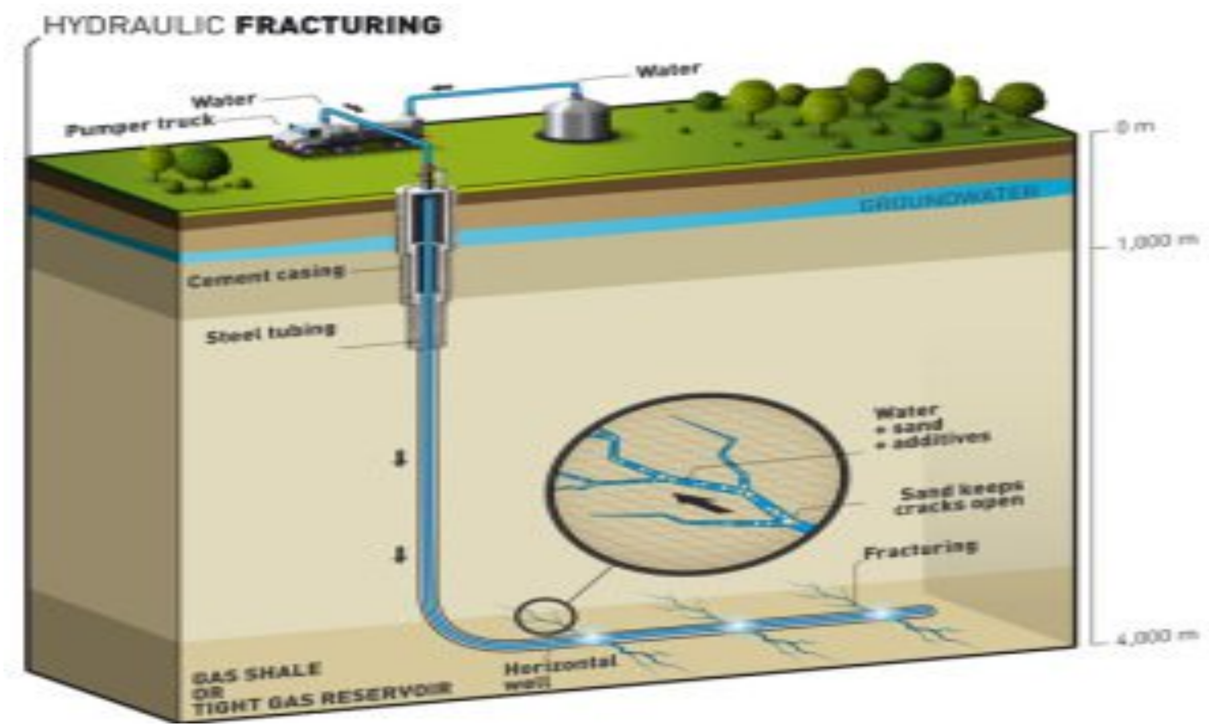

Figure 5: Horizontal drilling and Fracking illustration. Source: (Breaking Energy, 2013)

3.2 Why did the Shale Gas Revolution happen in the US?

The US is not the only country in the world with large reserves of shale gas. Countries like China and Argentina have even larger reserves of technically recoverable shale gas than the US and they are certainly aware of its existence. It is therefor interesting to ask why the shale gas revolution happened in the US and not elsewhere in the world?

Researchers point on three factors that have been important to enable the US to extract its large shale gas resources:

- A massive resource base
- A decade of high and ricing prices for both oil and gas
- A competitive environment, allowing for entrepreneurs to be willing to take the risk to connect the other two.

The first two is true for many countries around the globe. It is the third one that separates the US from the rest of the world.

In an article by Robert Hefner, CEO of GHK Companies, he points on several factors that were crucial for the development of the shale gas revolution in the US (Hefner, 2014). It begins with the United States unique legal framework, which states that the landowner has not just the right to the resources on the surface of his property, but also everything below it- in theory all the way to the center of the earth. This gives the landowners an incentive to lease its land to any company wanting to drill and explore the ground, as he will get a share of the potential profit. This is unlike most other countries in the world, where the resources below ground are strictly controlled or owned by the state.

This unique legal framework has laid the foundation for a true innovative competition among companies trying to survive. The US has over 6000 independents oil & gas companies and just as many independent service companies, each being forced to become more effective and innovative in order to stay ahead of the competition. This has spawned an enormous wave of innovation within drilling technique and gas extraction with the results that productivity has been maximized, costs have been continuously cut and well completion time is less than half from where they began.

In addition to the legal framework, government policies throughout the decades prior to the shale revolution were highly contributory to its emergence. In the 1960´s and 70´s price ceilings on interstate gas were set at levels below market equilibrium price in the US. This encouraged demand but discouraged production. Eventually this led to gas shortage, which again led to the passing of the Natural Gas Policy Act of 1978. The act removed price ceilings and provided incentive pricing to encourage development of new natural gas sources. In addition to tax credits and incentive pricings, several R&D projects were initiated during the 1970´s. This was a reaction to the 1973 oil embargo and the following "energy crisis". Energy security became an important political topic, and research into the possibility of extracting from unconventional sources was started.

3.3 Prospects of Shale Gas development in the EU

The shale gas revolution in the US has triggered a discussion on whether this phenomenon can be replicated elsewhere. In recent years Europe has seen trends and developments that are in favor of shale gas development (Chyong & Reiner, 2015).

- Energy prices have been rising steadily and the energy debate is becoming more and more of a political battlefield. Energy security is already a hot topic in the EU.
- The European industry is lacking competiveness compared to the US, not just because of the financial difficulties in the EU, but also because of relatively higher energy prices. Many industrial producers would definitely welcome a cheap energy source.
- The conflict in Ukraine is breeding uncertainty with regards to supply of natural gas from Russia.
- Because natural gas has replaced coal in power plants in the US, cheap coal is now being exported to Europe, replacing gas in European power plants. This has increased CO_2 emissions in several EU states. Considering the ambitious climate targets of the EU, increasing the number of coal- fired plants is not in alignment with the plan to reach emission goals.

In addition, several European countries such as Poland, Germany, Hungary, Romania and the northwest of England have significant shale gas resources and the reasons mentioned above are the most important arguments to why Europe should develop these resources. The question, however, is whether or not it is feasible to replicate the US success story. There are several fundamental differences between Europe and the US when looking at the necessary factors needed for large- scale extraction of shale gas.

Beginning with the geology, it is less promising in Europe than it is in the US. The general differences are that the gas deposits are found deeper in the ground and the deposits are smaller. In addition, the shale plays[1] are more fragmented and contains more clay, a property that is not favorable for hydraulic fracturing.

A major challenge to develop Europe's shale resources is gaining public acceptance. In a Eurobarometer survey in 2013 (TNS Political & Social, 2013) less than one in ten EU citizens saw unconventional fossil fuel such as shale gas as a priority in the EU energy mix for the next 30 years. The skepticism is mainly caused by environmental concerns (more on controversy surrounding shale gas in chapter 3.4). In contrast to the US, a large part of Europe has historically seen less onshore activity related to oil and gas. This lack of familiarity for EU citizens towards oil and gas activity further accelerates their will against proposals related to shale gas exploration. In addition to the skepticism from the public the much higher population density in Europe compared to the US is also a problem.

Another important difference between the EU and the US is regarding the unique legal framework in the US, described in section 3.2. In Europe the *state* has the right to natural resources beneath the ground and not the landowner. This eliminates the potential for compensation to the landowner for leasing out his land and for the disturbances that comes with gas extraction (noise, truck traffick, etc). Because of the lack of compensation, the landowners and others being affected would naturally oppose shale activity on their land.

Chyong and Reiner (Chyong & Reiner, 2015) argues that Europe is also missing the highly competitive, liberalized gas transportation market that the US has, and they view it as a necessary ingredient for creating an effective and liquid gas market. Because of

[1] Play is used in the oil and gas industry to refer to a geographical area that has been targeted for exploration due to favorable geoseismic properties.

the high uncertainty regarding depletion time and well productivity of shale gas wells, producers of shale gas would avoid selling gas through long term contracts and rather deliver gas directly to a trading hub or sign short term contracts with buyers to lower the risk. Because of this preference a liquid market is not just important for pricing but also for hedging. Compared with Europe´s most liquid trading hub, UK´s NBP, Henry Hub in the US is at least six times more liquid.

The arguments above clearly show that there are some major obstacles laying ahead for those wishing to exploit Europe's shale- resources. Whether or not these can be conquered depends largely on the public´s perception on how shale activity can damage the local environment.

3.4 Shale Gas Controversy

Although natural gas is the cleanest of the fossil fuels in terms of CO_2 emissions, there is quite a lot of controversy around shale gas extraction. It is an issue that has received a lot of attention by the press and media in recent years and has been the root cause of many conflicts between several stakeholders.

A report made by The Pacific Institute in 2012 points at the most important concerns regarding shale gas activity (Cooley & Donnelly, 2012). The report is based on interviews with several stakeholders, ranging from representatives from state and agencies, academia, industry, environmental groups and community based organizations across the US.

Much of this concern has to do with how the shale gas is extracted and especially the hydraulic fracturing process. Countries like Bulgaria and France have banned fracking and in Germany and the Netherlands there is a moratorium on fracking. Hydraulic fracturing is a process where water, sand and chemicals are pumped into the horizontal borehole of the well at high pressure. This high- pressure fluid is supposed to fracture the shale rocks, allowing the gas to be released from inside the shale´s pores.

This process utilizes a relatively large amount of water for each well, depending on the amount of times the process must be repeated. Estimates by the US Environmental

Protection Agency suggest that on average somewhere between 2.3 and 3.8 million gallons of water is needed for each well. Translated into the metric system, this would be equivalent to 8.7 and 14.4 million liters of water. Much criticism has been directed towards this water consumption and it has been claimed that fracking is stealing reserves from drinking water or sources meant for agriculture, leading to water shortage. It is important to be aware of the fact that this is highly dependent on the location of the gas well. In dry areas where little water is available and water is a scarce resource, then yes, water used for hydraulic fracturing may likely pose a threat to other water consumers. In areas where water is abundant, then the water consumption for fracking will most likely not pose a threat.

Another issue that there has been raised concern about is the possibility of ground water contamination because of the chemicals in the fluid used for hydraulic fracturing. Although the shale formations are usually located far below the underground sources of drinking water, the risk of chemicals and natural gas entering these sources are present. If the well bore is not properly sealed and cased this may pose a threat. Even though there are quite strong regulations for how a well bore must be sealed, accidents might still occur. Most of the debate around drinking water contamination has to do with reports of methane entering the groundwater sources. Although methane is not known to affect the quality of the drinking water, the danger is that it can be released from the water into the atmosphere where it can cause explosions or fires. On New Years day 2009, a residential drinking water facility in Dimock, Pennsylvania, exploded without warning. Further investigation showed that methane- fumes that had been accumulating in the well caused the explosion (The Times- Tribune, 2009). Although there were not established any direct link between the explosion and the shale gas activity in the area, the incident literally sparked the national media coverage of the shale gas debate.

After the process of hydraulic fracturing is completed the pressure inside the well is released and some of the injected fluid will then return to the surface. This fluid is then called wastewater and might return to the surface anywhere from a few hours up to a few weeks after the pressure is released. The wastewater coming out of the well can contain a mixture of brine, toxic metals and radioactivity, representing a substantial threat to nearby sources of drinking water if not taken care of properly. Ideally, the wastewater should be recycled and used over again, eliminating the need for wastewater disposal. This is done to some extent, but in most cases the wastewater is disposed. One of the solutions that have been used is to deposit the water in wells beneath the earth surface. Again, the risk of contaminating ground water is present.

There have also been studies showing a link between increasing numbers of earthquakes in areas of shale gas activity. When water is injected into the earths crust it increases the natural tension that already exists. If the injection happens in an area that already have a natural weakness in the structure of the crust, the structure might shift, thereby triggering an earthquake.

The reasons mentioned above are the most common arguments from anti- shale activists and opponents of shale related activity. The concerns addressed are definitely relevant and caution must be taken when performing the processes related to shale gas/oil extraction. Common for many of the problems that might occur is that they are highly dependent on local circumstances. Ground water contamination and water consumption related to fracking are not nearly as relevant in low- populated areas as in high- populated areas. Due to several reasons there might be large variations in the seriousness of the potential problems from place to place. The description of the production process shows that the extraction of shale gas is likely to generate negative environmental effects, which normally are not included in the company´s calculation of the net present value of the project. Some of these environmental effects could be irreversible in the meaning that the environmental damages cannot be repaired. Below is a summary of the most common concerns (table 2).

Activity	Concerns	Possible Consequences
Hydraulic Fracturing related to Shale Gas Activity	Leakage from Well	Ground Water Contamination caused by Fracturing Fluid and Methane Leakages
Hydraulic Fracturing related to Shale Gas Activity	Consumption of Water	Shortage of water used for agriculture, drinking water, etc
Waste Water Disposal	Leakage from disposal- well	Ground water contamination (Brine, toxic metals and radioactivity
Injection of Water	Earthquakes	Human injury/death and destruction of property
Hydraulic Fracturing related to Shale Gas Activity	Methane leakage into ground water	Explosions

Table 2: Most common concerns related to Shale Gas activity

Chapter 4- Gas Markets

Natural gas is a commodity that is being used all over the world in a variety of applications and it is becoming increasingly important as a primary energy supplier. As of 2014 natural gas provided 24 % of the worlds primary energy, only beaten by coal and oil. Since this thesis is investigating factors that influence investments in natural gas in the US, it is therefore useful to understand what kind of market the natural gas market is, and try to identifying market forces and pricing models. I will start with a short description of why gas markets differs from oil markets. Then, I continue with an introduction of the global natural gas market before I take a more thorough look at the US natural gas market.

4.1 Why gas markets are different from oil markets

Today's gas markets differ from oil markets in several ways. Unlike the oil market, gas is much more of a regional market because of what is referred to as the "tyranny of distance"- problem. Gas is a high- volume, low -value commodity, meaning that there are high costs related to the transportation of gas. Therefore, to rationalize moving natural gas from one market place to another, the price differentials between these market regions must be large enough to offset the costs (Stevens, 2010).

Another important difference between gas and oil is the security of supply to markets. It is far easier to replace lost oil supply than gas because of the much higher flexibility of trade and transport of oil. Finding alternative sources of gas are for many countries very hard. The end of a pipeline is the end of a pipeline. Another difference with regards to transportation is that since pipeline/transmission grids are natural monopolies they must either be in public ownership or heavily regulated if privately owned. This has traditionally meant that gas markets have experienced a higher level of state involvement than the oil market (Stevens, 2010).

In many parts of the world, gas trade is performed under long- termed contracts and not in a spot market like the one where oil is traded. There are often large capital expenditures related to gas projects; high fixed costs and relatively low variable costs. For the operator, who must carry these costs, it is most economically efficient to spread the high fixed costs over as big a volume as possible, meaning running at full capacity. The best way to achieve this is through long- term contracts with the buyer.[2]

4.2 Global Natural Gas Supply and Demand

Natural gas reserves around the world have increased steadily the last 25 years. As shown in figure 6 natural gas reserves in 1990 was around 4000 trillion cubic feet while in 2014 it had increased to roughly 7000 trillion cubic feet (U.S Energy Inforormation Administration, 2015). To set the number from 2014 in context, it is sufficient to meet 55 years of global production. The largest reserves are located in the Middle East, Africa and Eurasia. In 2013, the US accounted for all of the net growth in world reserves, due to new additions of reserves from shale plays.

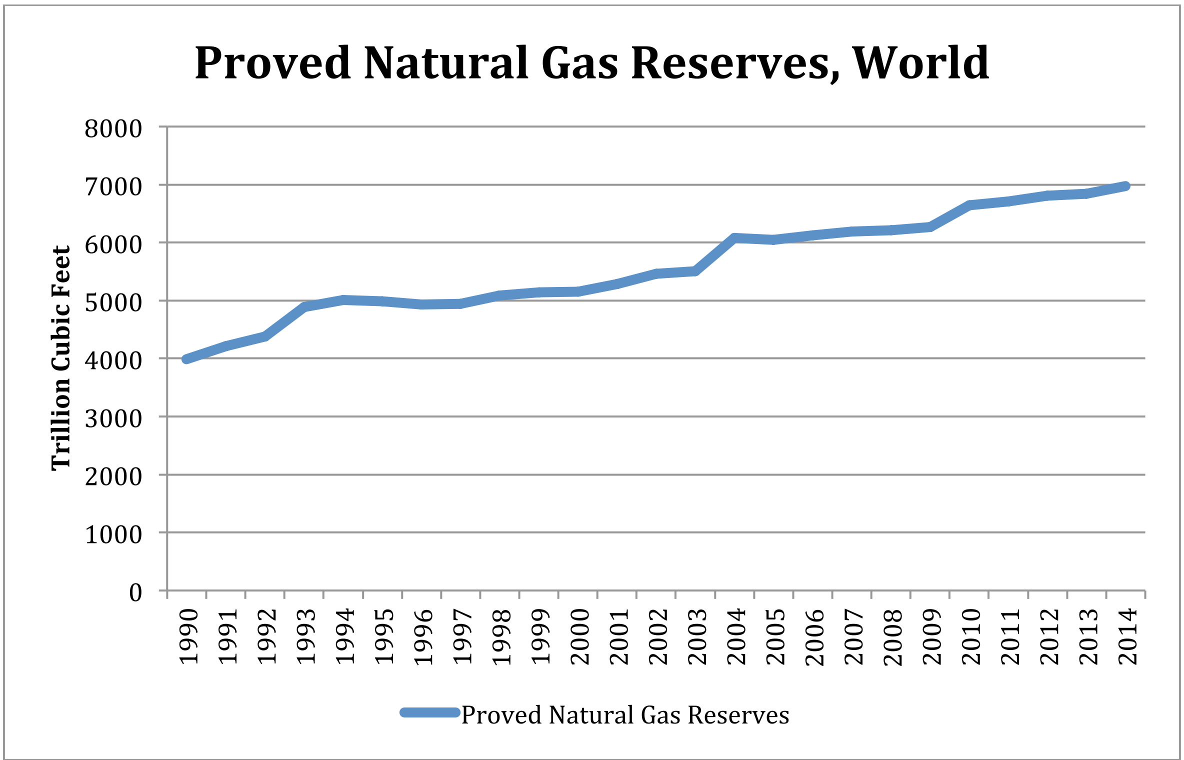

Figure 6: Proved Natural Gas Reserves, World. Source: EIA

However, there is little correlation between level of reserves and level of production within a country and the relationship between them is complicated (Leidos Inc., 2014). This might seem somewhat contradictory, but one explanation might be that there are differences between countries in regulations for booking reserves and incentives to prove up reserves. There are also other factors influencing whether or not a country can exploit their natural resources. Infrastructure is an important one. To be able to move

[2] That is unless the market is an extremely efficient one, in economic terms.

the gas from seller to buyer large capital expenditures are needed. In other words it is not sufficient to have large reserves, you also need capital in order to extract the gas. Producers also need someone to deliver the gas to, and in many cases the buyer is located in another country. It often takes time to obtain the approvals needed for gas export/imports. The important point here is that even though a country might have large reserves, there are several other factors influencing whether or not these resources can be exploited commercially.

4.2.1 Global Natural Gas Supply and Production

Global natural gas production is expected to increase by 1.9 % per year meeting an increase in global demand. The growth in production will mainly be met from non-OECD countries (73%), while the growth in OECD countries is primarily caused by increased production of shale gas in the US (British Petroleum, 2015). Figure 7 shows the total world production by region from 1990 to 2012.

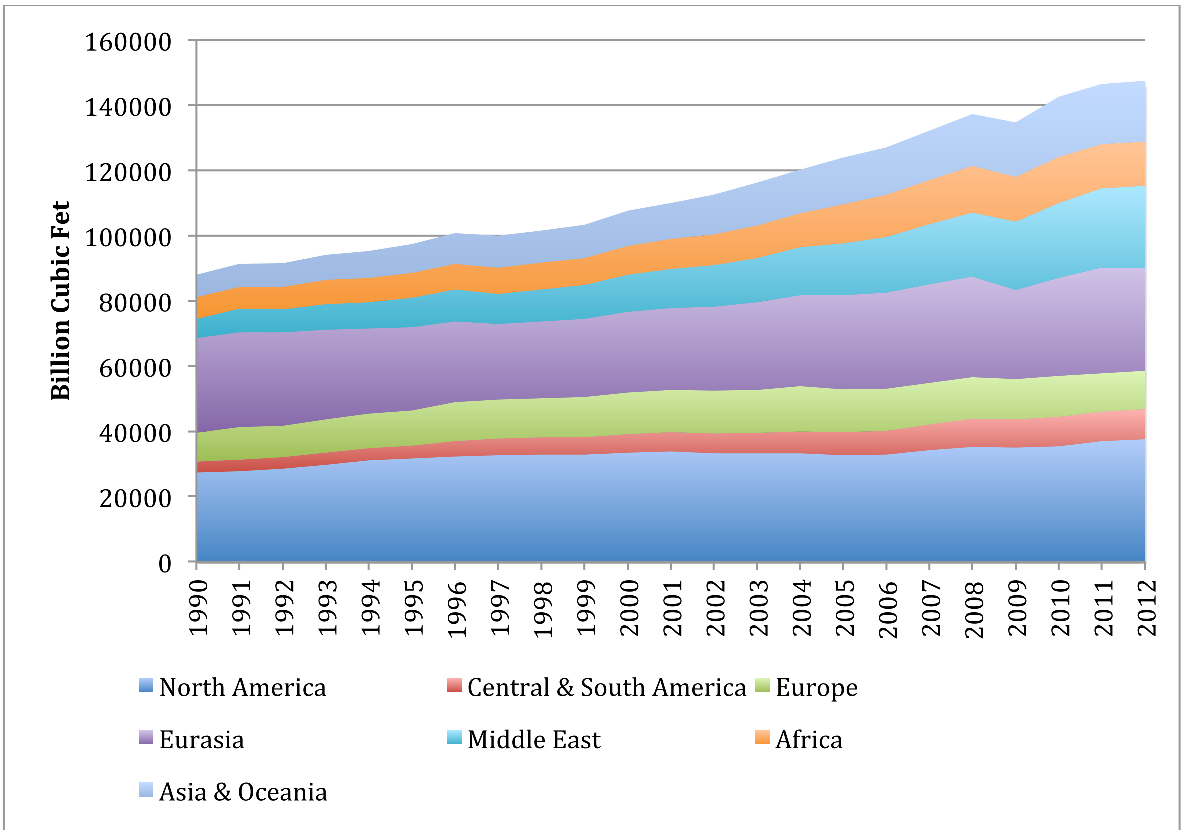

Figure 7: World Production Natural gas by region. Source: EIA

As shown in figure 7 the biggest natural gas producer in the world by region is North America followed by Eurasia in second place. By country the US is the largest producer followed by Russia. As can be seen from the figure, each region has experienced a growth in its production since 1990. This is driven by an increase in global demand as shown in the next section.

4.2.2 Global Natural Gas Demand and Consumption

Figure 8 shows that natural gas demand on a global level has increased in every region since 1990. In later years the growth in demand has been especially strong in the Asia Pacific region, a trend that is expected to continue (British Petroleum, 2015).

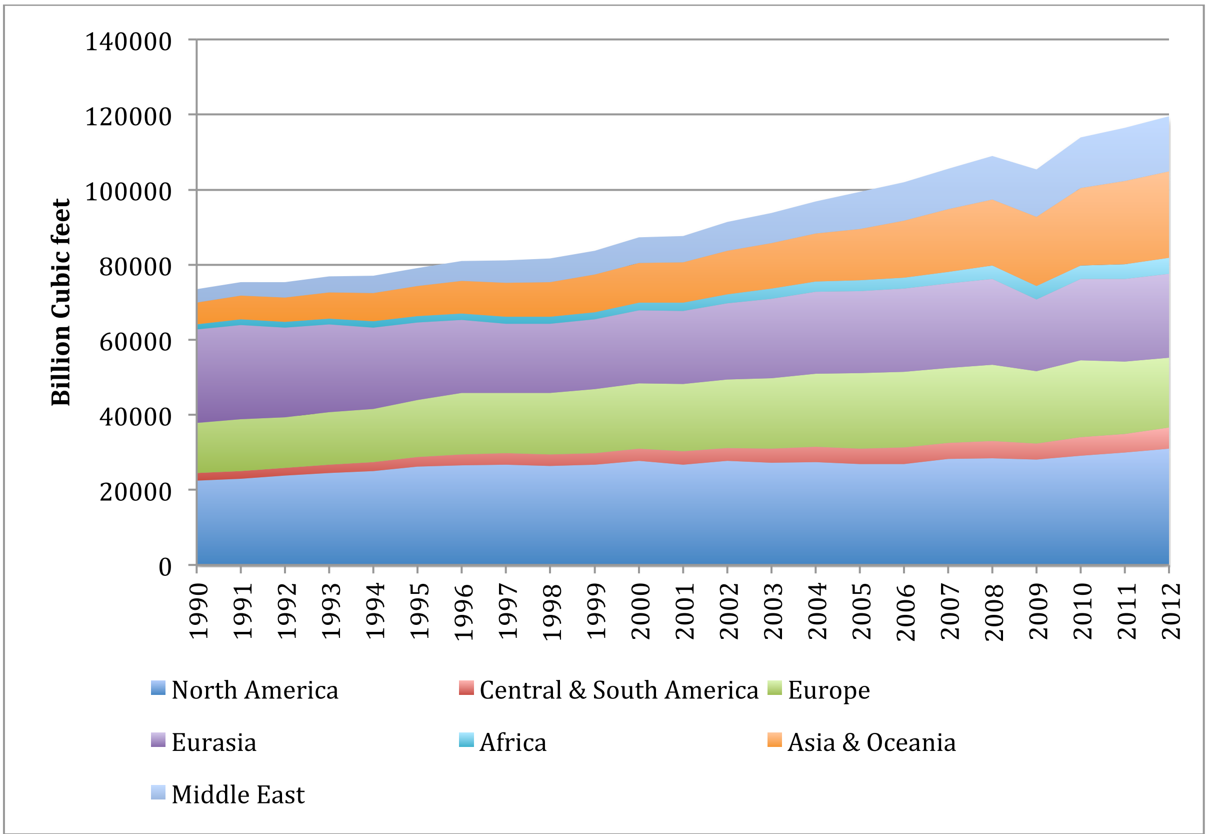

Figure 8: Global Natural Gas Demand. Source: EIA

By country the US is at the moment the country with the highest consumption for natural gas, with Russia and Iran on second and third respectively.

Global growth in natural gas demand is expected to increase by an average of 1,9 % per year up until 2035 and will in 2031 surpass oil as the primary energy source in OECD countries (British Petroleum, 2015). The increase in demand is led by many factors, the two most important are:

- Relatively cheaper natural gas compared to coal and oil together with a technological development in the natural gas turbine field (increased efficiency and cheaper generators) has caused a shift in fuel for electricity generation from coal and petroleum to natural gas.

- This shift is also driven by a stricter emission policy of CO_2 from countries all around the world. Natural gas produces less CO_2 than both coal and oil when burned in a power plant, and changing fuel to natural gas is an effective way of reducing emissions.

4.2.3 Global Price of Natural Gas

Comparing the international gas market to the international oil market, it is a smaller and less mature market. As mentioned before, because of the physical characteristics of natural gas, transportation between seller and buyer is more constraint than for oil. Natural gas must be sent through pipelines or go trough a liquefaction- process and be transported by ship as LNG (Liquefied Natural Gas) to the customers. The international natural gas market has historically therefore been one that consists of several *regions*, rather than a uniform global market. Global market prices however have not differentiated much up until recently. Figure 9 shows the price of natural gas for different regions across the globe, and in addition its close relationship to the price of crude oil. After 2009 the spread between the different regions have increased dramatically. As can be seen from the figure the price of gas dropped all over the world during the financial crisis and the following global recession. After the crisis, European prices and the price in Japan increased in step with the price of crude oil. In the US and Canada however, the prices stayed low despite an increase in demand in both countries.

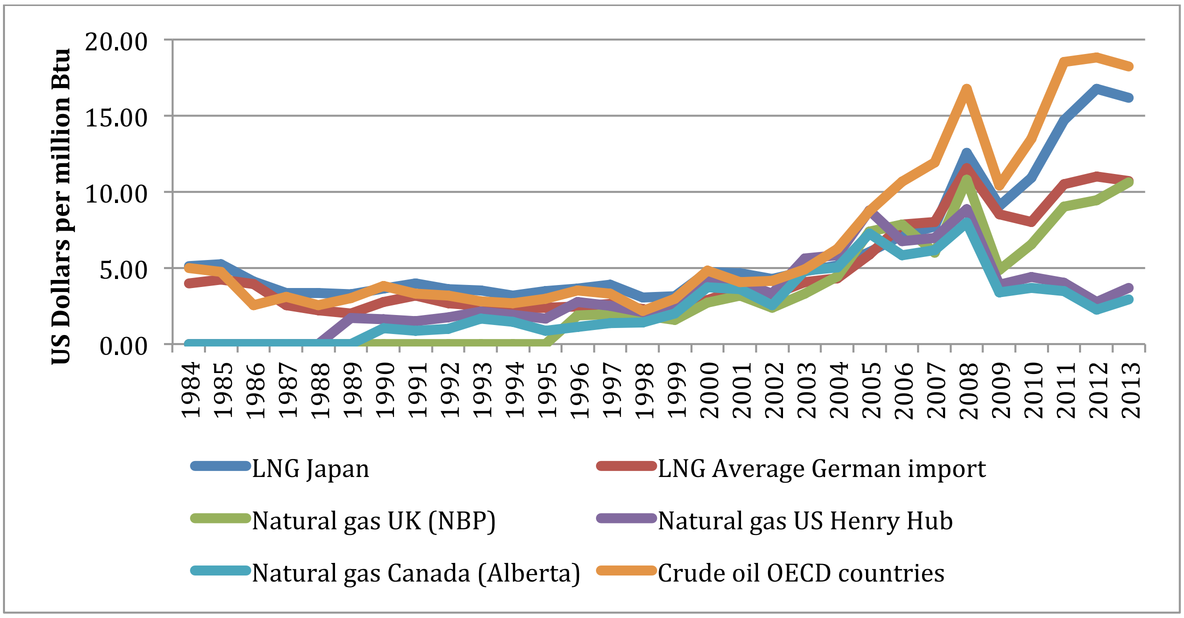

Figure 9: Global Natural Gas Prices. Source: (British Petroleum, 2014)

This change in spread between the different regions was the result of a combination between two different pricing systems and changes in market circumstances (Leidos Inc., 2014). In the global gas market one differentiates between two different pricing systems:

- Gas- on- gas pricing system
- Oil- indexation pricing system

Gas- on- gas is a system where the price is indexed to gas market spot prices, determined by the powers of supply and demand of natural gas. In an oil- indexed pricing system, the price is indexed to spot prices in the oil market, determined by supply and demand for oil.

Historically the suppliers in Europe have sold gas under oil- indexed pricing systems, and in a 2012 almost two- thirds of gas sold in Europe was under oil- indexed pricing contracts (Reuters, 2013). As can be seen from figure 9 the prices in Germany and England increased after the financial crisis as an effect of the increasing price of oil. However there has been a trend towards more spot indexation (gas- on- gas) in Europe in recent years led by suppliers in the UK, Norway and the Netherlands. The prices in Japan (LNG imports) are mostly based on oil- indexing contracts. The price of both WTI and Brent increased rapidly after the crisis reaching historically high levels and the price of natural gas followed in the Asia pacific region.

In North America the price is based on a gas- on- gas system. As mentioned before, the shale gas boom that emerged around 2007 caused a large shift in the supply of natural gas. The growth in demand was not enough to offset the downward pressure on prices that the increase in supply caused and the prices continued to stay low. By looking at the increased spread between the regions it is clear that the shale revolution in the US so far has been a regional phenomenon.

4.2.4 Liquefied Natural Gas Trade

When natural gas is cooled down to approximately −162 °C it condensates and is *liquefied.* Liquefying natural gas is done to ease transportation or storage. As of 2013, LNG´s share of the total global gas trade amounted to 31.4 %. LNG is used to meet both primary (countries like Japan and Korea) and peak demand (Europe). Since 1990, the volume of LNG traded has grown steadily. Together with a growth in volume, the number of LNG exporting countries and importing countries has risen. 17 countries were exporting LNG and 29 countries were importing LNG at the end of 2013 (International Gas Union, 2014). Liquefied natural gas trading between regions has been seen as a way of creating a more globalized natural gas market with more converging prices.

The structure of the contracts between seller and buyer is largely deciding the liquidity of the LNG market. Around two- thirds of the global LNG is supplied through long- term, take- or- pay contracts. In recent years there has been a shift in the structure of the long-term contracts, a change that is caused by the lower gas indexed prices relative to the oil- indexed prices. It is now not unusual with a clausal allowing for re- destination of the cargo, as well hybrid- pricing of the cargo. Hybrid pricing means that a certain percentage of the cargo will be sold under gas- on- gas pricing while the remaining will be under oil- indexed prices (Leidos Inc., 2014).

Before the shale gas revolution hit in 2007 the US was expected to become one of the main LNG importers in the world and was to account for much of the future global demand. Based on these forecasts, heavy investments were made in LNG regasification plants and infrastructure that would support LNG imports to the US. After the shale revolution the need for LNG import was largely reduced and many of the previously initiated LNG projects in the US failed. The situation has actually been turned around, and many argue that LNG exports *from* the US can be considerably profitable for US natural gas producers because of arbitrage opportunities.

4.3 The US Natural Gas Market

After many years of deregulation, the natural gas market in the US is fully liberalized and highly competitive. Market participants trade natural gas in a large number of regional markets and most of the trading is done in spot markets located at major market centers and hubs around the country.

In this section I will provide an overview of the physical flow of natural gas in the US, the participants in the natural gas market, how natural gas is traded and the fundamental market forces that determine the price of natural gas in the US.

4.3.1 Physical Flow of Natural Gas in the US

Figure 10 provides an overview of the physical flow of natural gas in the US. Gas is extracted from wells and sent directly trough pipelines to processors, LNG terminals, underground storages, local distribution companies or electric power generators. For the gas to be transported in the high- pressure pipelines to its final destination, pipeline companies have developed physical standards for the gas. If the gas does not meet these standards it will not be allowed to enter the North American pipeline- grid.

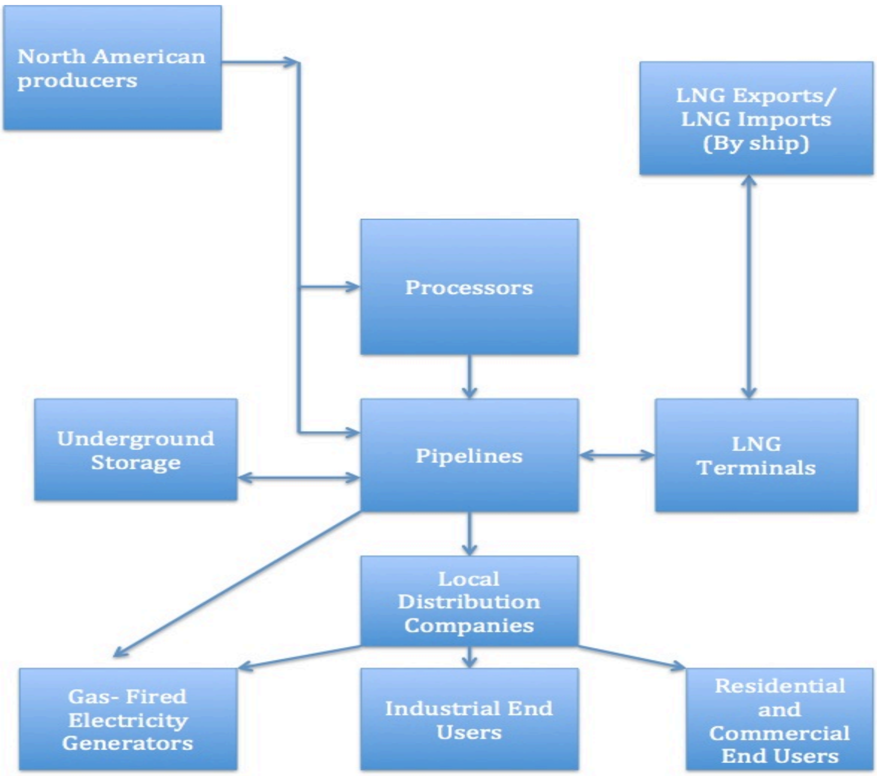

Figure 10: Physical Flow of Natural Gas in the US. Source: (American Petroleum Institute, 2014)

In the processor plants impurities in the gas are removed and higher- valued products are separated from the gas stream. The higher- level products are referred to as *Natural Gas Liquids*, or NGL, which is sold in separate markets.

Underground storage facilities are used during times of peak demand. The production and pipeline system in the US is not design to handle the highest levels of demand that the consumers have during the year. Instead, natural gas is stored in underground storage facilities during periods of lower demand to be able to meet the peak demand. These are either located close to the final customers or at the drilling site. This allows producers to maintain its production level and gives consumers energy security.

In the LNG plants the natural gas is liquefied and made ready for export by ship to overseas markets. Because of the increased production of natural gas in the US, export of natural gas through LNG has become increasingly applicable.

Local distribution companies receive gas from high- pressure lines through smaller pipes to its final destination. The main receivers are residential consumers, commercial consumers, industrial consumers and electric power plants. Some large electric power plants however, will receive their gas directly from the high- pressure main- pipelines (American Petroleum Institute, 2014).

4.3.2 Market Participants and Natural Gas Trading

As previously mentioned the price of natural gas in the US is determined on a gas- on-gas pricing system. It is a highly competitive market with thousands of suppliers and consumers and the price is determined on basis of supply and demand in the market.

Figure 11 shows some common commercial and financial arrangements for trading of natural gas in the US. An off- system user refers to those that are directly connected to an interstate pipeline. An on- system user is receiving gas through a local distribution company.

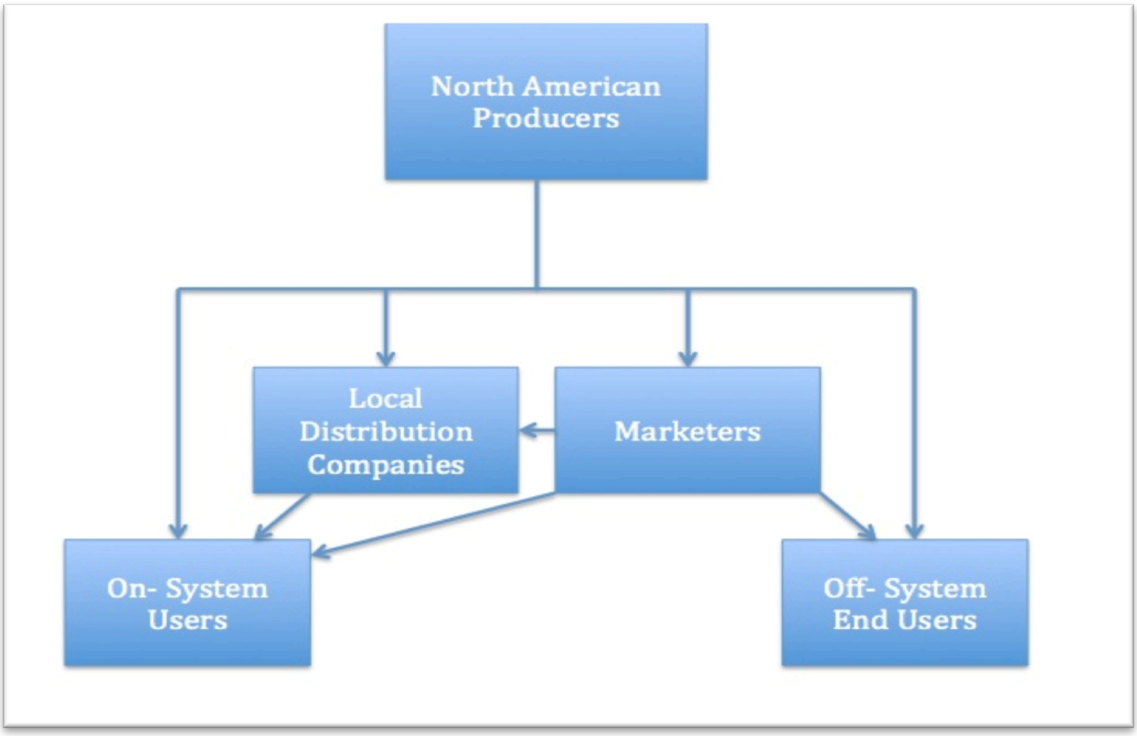

Figure 11: Commercial and Financial Arrangements, Natural Gas. Source: (American Petroleum Institute, 2014)

Producers can be divided in two groups; those that can market and sell their gas directly to a customer and those that sell their gas to marketers. Marketers can aggregate natural gas into amounts that suits the needs of different buyers and to transport the gas to the customers. Marketers deal in a large spectrum of natural gas quantities, and might sell directly to local distribution companies, industrial customers and commercial customers. It is the marketers that ensure that a liquid, transparent market exists for natural gas in the US.

The marketing and trading of natural gas can be divided into two types: Physical trading and financial trading.

Physical Trading

Physical trading of natural gas involves buying and selling the physical commodity. The physical contract is being negotiated between buyer and seller and will usually include information on how much gas to be delivered, at which location, at what point in time and of course- the price. The US natural gas spot market is a highly active market and trading can take place 24- hours a day, 7 days a week. However, the most active time of trading at the spot market is the last week of the month, known as the "bid week". This is the time when producers wish to sell of their core production for the next month and consumers are trying to secure their core consumption for the upcoming month.

Physical trading is performed by brokers at different locations around the country, usually at locations where pipelines connect with each other. Because of its large level of interconnectedness and location, the benchmark price for natural gas in the US is at the *Henry Hub,* located in southern Louisiana.

Financial trading

There is also a significant market for natural gas derivatives and other financial instruments in the US. Natural gas derivatives are traded at the New York Mercantile Exchange, NYMX. In recent years the level of financial trading in natural gas in the US has increased rapidly. As an example, in 1999 roughly 20 million future contracts were traded. In 2013 this number had grown to around 84 million contracts ((American Petroleum Institute, 2014)).

A NYMX futures contract gives the seller an obligation to deliver (and the buyer to receive) natural gas at an agreed price, at a specified future point in time at the Henry Hub. The price to be paid at maturity date for the gas is determined when the contract is sold. As time goes by, the expectation about the value of natural gas at the delivery point will change, and so will the value of the futures contract.

Derivatives, such as the one described above, allows participants in the natural gas market to reduce some of the price volatility that exists in the physical market. As an example, an industrial consumer that uses natural gas as an important part of its production might face large variations in expenses paid for natural gas. The consumer can then purchase natural gas using contracts that are indexed to spot market prices. An additional strategy can be to buy financial derivatives that rise in value when gas prices increase, and fall in value when gas prices decrease. This way the consumer can offset some of the possible additional cost of gas.

Some participants in the financial market for natural gas are non- commercial entities seeking to hedge the risk related to price- fluctuations. Examples are investment banks, hedge funds or other kinds of investors operating in the commodity market. These participants either hold natural gas futures contracts as part of a diversified portfolio, or they buy and sell futures contracts wanting to make a profit for being exposed to risk. It is evident that these non- commercial participants play an important role in making the US natural gas market an efficient one, as they balance out the commercial hedgers in the financial market.

Because the future market represents the expectation of thousands of buyers and sellers, it is a good indicator of expectations of supply and demand for the future. It provides valuable information to market participants that can respond to these expectations. Examples are to put more gas in storage tanks or decide to change fuel to or from natural gas.

4.3.3 The Price of Natural Gas in the US and how it is Determined

The determination of the price of natural gas is a complex matter, as it is driven by several influential factors, the most important being supply and demand fundamentals. Historically the price of natural gas in the US has been closely linked to the price of crude oil. However, with the large shift in the domestic production of natural gas and the corresponding evolvement of the natural gas market, the correlation between the price of crude oil and natural gas has been reduced in recent years (see figure 34). This development can be seen below where the spot price of natural gas at Henry Hub is presented together with the spot price of WTI. One can also see that the price of natural gas has fluctuated significantly in certain periods. This is due to changes in supply and demand fundamentals.

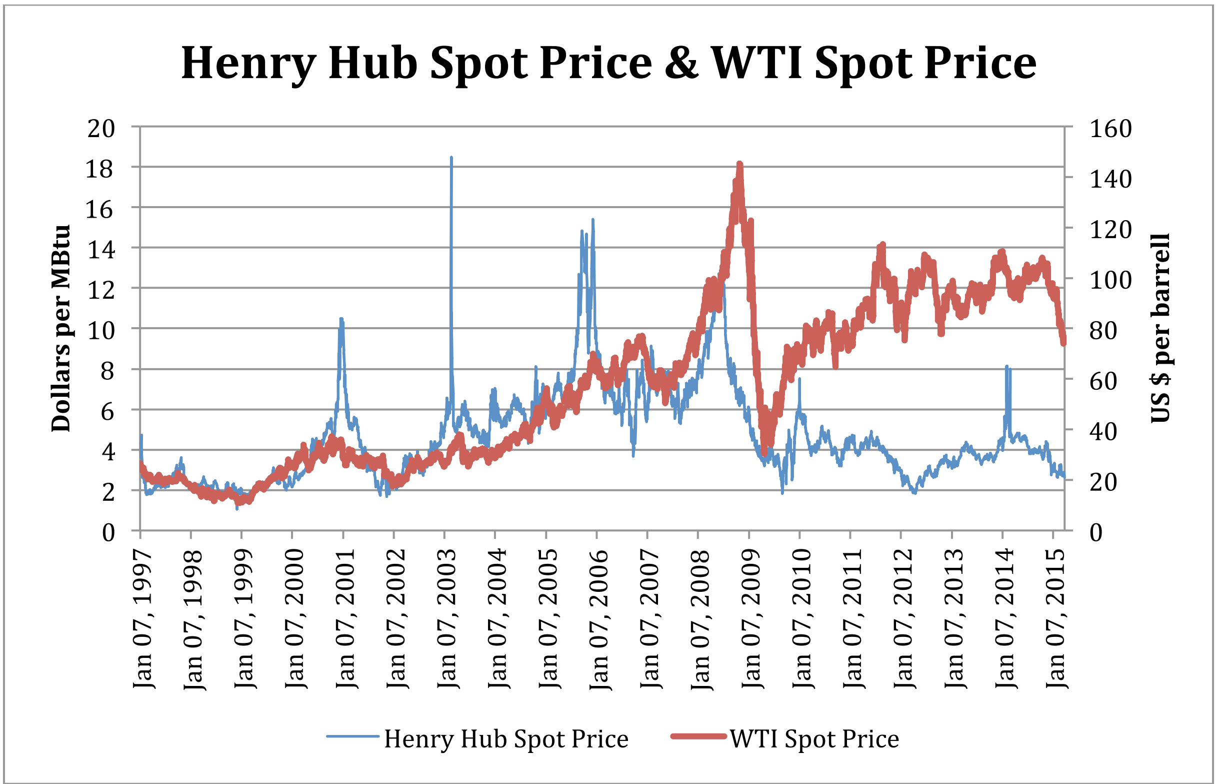

Figure 12: Henry Hub Natural Gas Spot Price and WTI Spot Price. Source: EIA

The natural gas market in the US consists of several participants, mainly being producers, consumers, traders/ hedgers/ speculators and policymakers. It is the interaction between these that eventually determines the price of natural gas, driven by supply and demand fundamentals. The market structure and price formation correspond with the microeconomic concept "perfect competition" which is characterized by many suppliers and buyers, that none of them have market power in the meaning that they cannot determine the price level, the information of prices is transparent, the product is homogenous and the market participants have the option to internalize, to some extent, market risk by using financial instruments. Perfect competition is theoretically a market structure that secures an efficient allocation of productive resources in the economy.

I will in the following sub- section describe the key elements of what drives supply and demand for natural gas in the US. I will also exemplify how a change in supply and demand theoretically affects the market equilibrium price. Note that the elasticity's presented are only used for illustrational purposes and does not necessarily represent the elasticity´s in the real world.

Demand

Demand for natural gas in the US has been rising steadily in the US since 2006. The shale revolution and its implications have sparked a new wave of interest in utilizing natural gas. To analyze and explain the key factors that drive demand and consumption of natural gas in the US, it is rational to divide the main consumers into groups. I have decided to divide the main consumers into the following four groups:

- Industrial consumers
- Commercial consumers
- Residential consumers
- Electric Power consumers

Each of these groups is being affected differently by various factors and the demand within each group will also affect other groups, as natural gas is not an infinite resource. One could also include the transportation sector, but as of 2014 the consumption within this sector is minor compared to the rest. It is therefore neglected.

Weather

Weather in general has a major impact on the demand for natural gas. However, the effect of the variation in weather has not the same impact the different consumer-groups. Because natural gas is used for heating homes the weather has a huge impact on the demand for natural gas in the residential sector. During the winter months, when the demand for heating homes (residential) is the key driver, the consumption of natural gas for this sector is at its greatest. This is also true for the commercial and industrial sector to a certain extent, but the volatility in gas consumption for these sectors is smaller due to the fact that the portion of weather- driven consumption because of weather is smaller in these sectors. It is not just the winter temperature that has an effect on the demand for natural gas. During the summer when the temperature is at its highest electricity is used for running AC- systems. As more and more power- plants are fueled by natural gas in the US, the peaks in the demand for natural gas in the electricity sector are actually found in the summer months. Figure 13 shows how a positive change in demand caused by cold winters or hot summers will affect the market equilibrium price, all else being equal. The demand curve shifts outwards, increasing equilibrium price and quantum.

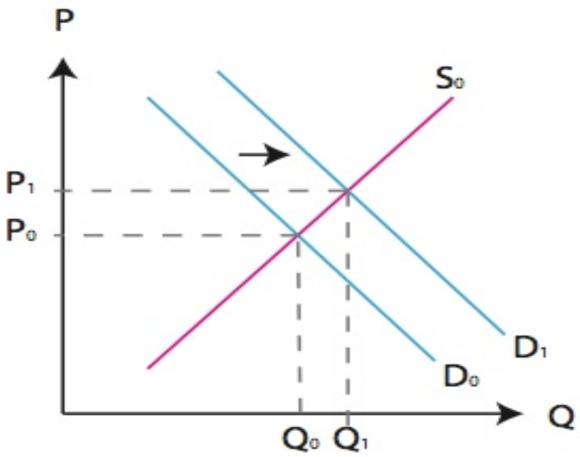

Figure 13: Positive shift in demand

Economic growth

The level of economic growth in the US has great implications for the use of energy in general, and natural gas is no exception. Especially for the industrial sector this is true where many of the processes needed for production are dependent on large- scale energy usage[3]. The output from this sector will be smaller or larger conditioned on the movement of the economic growth. During the financial crisis in 2008/2009 the consumption of natural gas in the industrial sector fell by 7.5 % in 2009 compared to 2008 (EIA, 2015). Figure 14 shows how a negative shift in demand changes both market equilibrium price and consume, all else being equal.

[3] Industrial boilers, preheating of metals, waste treatment, glass melting, etc.

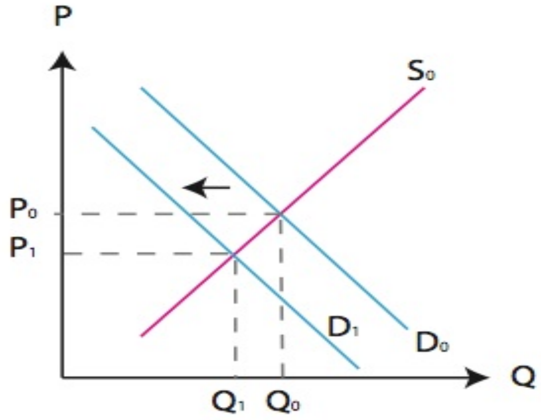

Figure 14: Negative shift in demand

Environmental regulations

In recent years a large part of the investments in natural gas have, in addition to the possibility of making an economic profit, been driven by environmental regulations on CO_2- emissions. The fact that natural gas driven power- plants release less CO_2-emissions compared to coal driven is an incentive for policymakers to develop for example tax regulations that will favor low emission fuels over high- emission fuels. This will stimulate demand for natural gas. It is expected that the main driver behind a future increase in demand of natural gas will be the electricity sector. Figure 15 shows how equilibrium price and quantum, theoretically changes as a result of this development.

Substitution of fuel

For some customers the price of natural gas can affect its demand. This is not unusual for large consumers such as power- plants and industrial consumers who have the ability to change or substitute between different kinds of fuel. As an example one can look at a power plant. If natural gas prices were considered high relative to coal prices, the plant management might decide to alter its fuel consumption and start using coal instead, i.e. a substitution effect would enter, and it will initiate a downward pressure on the demand for natural gas. It could also work the other way around, that coal is substituted for natural gas- a scenario that has been developing in the US in recent years because of the shale gas boom and subsequent drop in gas prices relative to coal prices.

Exports
In light of the recent development in domestic US production of natural gas, export of gas is becoming an increasingly relevant topic. It is estimated that the US will become a net exporter of natural gas within 2020 (British Petroleum, 2015). New markets will arise and especially the increasing demand for natural gas to the Asia- Pacific region is laying the foundation for an extensive LNG- export industry in the US. Higher levels of exports means a positive shift in the demand curve, and the theoretical effects are shown in figure 13.

Storage
Underground storage sites are used during periods when pipeline capacity from production site is not sufficient to meet consumption. This occurs especially in the winter months. Storage capacity in the US increased 10 % from 2008 to 2013 (U.S Energy Information Administration, 2015), and it represents a source of demand in the same way as demand for gas used for heating and electricity generation. The effect of increasing storage capacity on price and quantum can also be shown using figure 13.

Supply
The US natural gas resource base has been upgraded as a result of new advancements within drilling technology and hydraulic fracturing. The huge shale gas resources in the US are now available for extraction. This has affected the supply of natural gas in the US enormously. In addition to the resource base, there are other factors influencing the supply of natural gas, such as pipeline capacity and weather. I will in the following sub-section describe the driving forces of supply of natural gas in the US.

Resource Base
Proven natural gas reserves[4] have seen a huge upturn in recent years due to the new technology that has enabled extraction of gas from the huge shale resources located in the US. The positive shift in supply of gas is illustrated in figure 24. Proven reserves in 2014 were 338 trillion cubic feet (Tcf) compared to 193 Tcf in 2005 (U.S Energy

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[4] "*Proved oil and gas reserves are those quantities of oil and gas, which, by analysis of geoscience and engineering data, can be estimated with reasonable certainty to be economically producible–from a given date forward, from known reservoirs, and under existing economic conditions, operating methods, and government regulations.*"- Security and Exchange Commission definition, 2010. Source: (Independent Petroleum Association of America, 2015)

Inforormation Administration, 2015). In the same period the production of natural gas in the US increased from 64.2 Bcf/d[5] to 82.2 Bcf/d, or 28 % (U.S Energy Information Administration, 2015). The expansion in shale gas production has increased the supply of natural gas and has affected the prices significantly. Figure 15 show that a positive shift in the supply of gas will reduce the prices of gas from P_0 to P_1, given that the demand is stable.

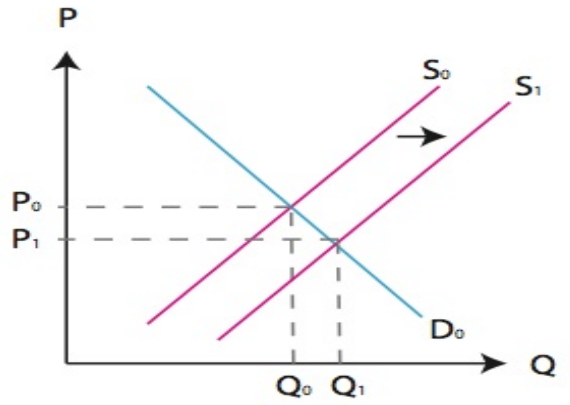

Figure 15: Positive shift in supply

Pipeline Capacity

The economic value of a large resource base of natural gas is low and useless unless the gas can be transported to the market where the consumers are. The US has an extensive pipeline- grid measuring over 305 000 miles of interstate[6] and intrastate[7] transmission pipelines, and there has been a big extension of the grid in recent years.

Drilling activity, technological development and NGL

The technological development within natural gas extraction from shale rock has changed the historical relationship between the number of drilling rigs in operation and the volume of gas being extracted. Number of drilling rigs directed towards gas has gone down[8], while the extracted volume of gas has increased. This tells us something about the efficiency of the new drilling technology. Producers can now access larger areas beneath the ground containing gas, all while using the same borehole.

[5] Billion cubic feet per day
[6] Pipelines that cross one or more States
[7] Pipelines that operate only within State boundaries
[8] They have been directed towards oil instead (EIA)

Another factor that impacts the drilling activity in the US is the price of a byproduct of natural gas extraction, namely Natural gas liquids, or NGL[9]. NGL are naturally occurring elements in natural gas, and is found in so- called "liquid- rich areas"[10]. NGL- prices have generally been high historically, relative to dry gas. This has led to increasing focus on developing liquid- rich areas, and the additional dry gas that is taken out from these areas has increased the supply of natural gas on the market (American Petroleum Institute, 2014).

Weather and natural phenomena

Although not having a long- term effect, incidents such as hurricanes can have a major impact on the supply of natural gas in the short term. As an example, a hurricane or storm can force offshore installations to shut down and stall production for several days, or weeks if important equipment gets damaged. The same can happen on production rigs onshore, but these are usually easier to shut down and start up again. During the winter, production sites might also freeze and thereby stalling production. Figure 16 shows the effects of a reduction in supply on equilibrium price and quantum.

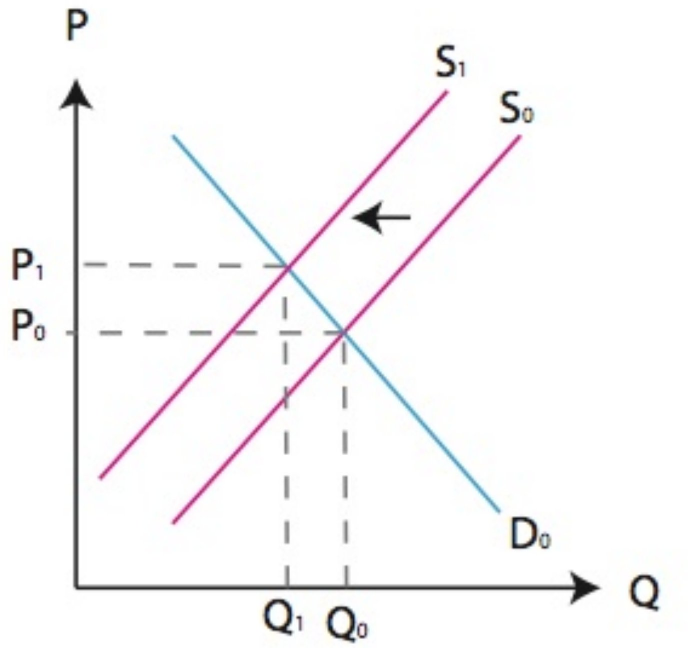

Figure 16: Reduction in supply

[9] Ethane, Propane, Butane, Isobutane and Pentane are typical Natural gas liquids

[10] Wet natural gas contains less than 85 % methane, while dry natural gas contains almost only methane (http://www.usenergydevcorp.com/media_downloads/Natural%20Gas%20Dry%20Vs%20Wet_050913.pdf).

Storage
In the same way as storage represents a source of demand, storage represents a source of supply. During times of peak demand pipeline capacity is in many places not enough to meet demand with gas directly from producer to consumer. Delivery of gas from local storage- sites is used to balance out this bottleneck.

Regulations
As more attention is put on the consequences shale activity might have on the environment, the possibility of new regulations limiting the drilling activity is present. At the moment EPA Office of Water protects drinking water and regulates waste disposal of flowback- water. This is done through the Safe Drinking Water Act and the Clean Water Act (U.S Environmental Protection Agency, 2015). In addition, the Underground Injection Control program regulates the subsurface placement of fluids. So far, lawmakers have been going relatively "easy" on hydraulic fracturing used for oil and gas purposes. In 2005 the Energy Policy Act specifically excluded hydraulic fracturing from the Safe Drinking Water Act. However, the EPA is at the moment conducting a major study of the impacts of hydraulic fracturing on drinking water; a report that is expected to be finished early 2015. The findings and conclusions in this report might affect the regulatory framework regarding shale gas extraction.

Imports
Historically the US consumption of natural gas has been greater than the domestic production, thereby forcing the US to be dependent on imports to cover the gap. Canada has been the main supplier of foreign natural gas to the US natural gas market in addition to a small level of LNG import from various overseas locations. The boom in domestic shale gas production has changed this dependency on imports, and it is expected that it will leave the US as a net exporter of natural gas by 2020.

Market equilibrium

As stated above the price of natural gas is decided by the interaction between supply and demand in a competitive market. The situation where the supply is equal to demand is called the market equilibrium. Since there is no surplus or shortage of natural gas the prices are expected to remain stable in this situation. A shift to either supply or demand will cause the price to change for a period before returning to the market equilibrium. Figure 17 shows the US natural gas consumption and the production. It is easy to see that supply has increased alongside demand, something that in theory should create relatively stable prices. Looking at figure 12, however (spot price Henry Hub), it is obvious that the natural gas market equilibrium has been a fragile one with constant fluctuating prices.

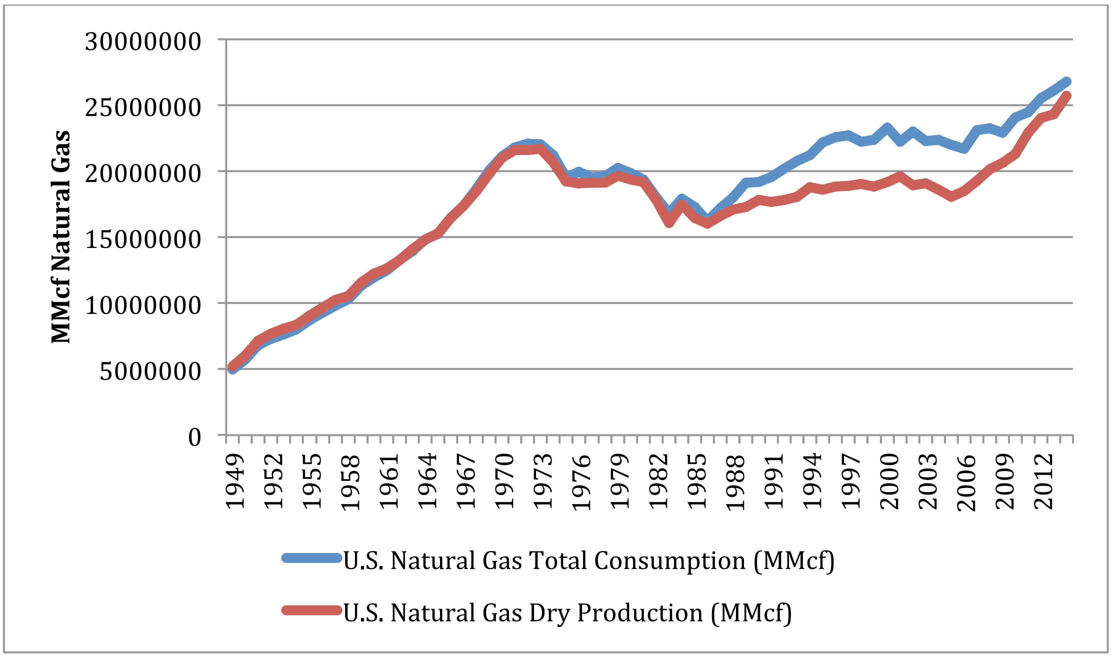

Figure 17: Natural Gas Production vs Consumption. Source: EIA

More or less unexpected events such as hurricanes, colder than expected winters or hotter than expected summers are factors that have increased the price volatility. In addition, events such as the 9/11 terror attacks and the financial crisis also had a huge impact on the short- term prices. It is important to be aware of the fact that since the natural gas market is a more or less a regional market the events that affect supply and demand are mainly regional ones. Unlike the oil market, geopolitical events such as war does not impact the US natural gas market and prices in the same way as it might affect the oil market.

Alterman (Alterman, 2012) argues that since 2006 the US natural gas market has experienced a change in circumstances due to the exploration of unconventional gas resources. In his study she discovers that price volatility has decreased from 17 % to 15 % in the sample period from 1997 to 2011. She finds that after 2010 volatility dropped and remained, with one exception, below 15 %. This coincides with the shale gas boom, which really took off in 2010 as can be seen from figure 3.

In the same study she finds that the importance of events such as hurricanes in relation to price fluctuations has been drastically reduced. Hurricanes have typically affected offshore production first and foremost. This, combined with the fact that the fraction of natural gas coming from offshore installations has been decreasing in recent years, has reduced the impact shut- downs on offshore installations have on the supply of natural gas. Security of supply is greater now than ever in the US natural gas market.

Another factor that has changed is the role that storage capacity is playing for price volatility. Because of the isolated nature (meaning that it is a regional market) of the US natural gas market, storage capacity and storage level is an important factor that influences price fluctuations. Natural gas storage acts to round off peaks in demand when pipeline capacity is unable to meet the demand from consumers with supply directly from producer. This is typically during the winter months when temperatures are cold. Since the shale gas boom emerged Alterman finds that from 2006 to 2011 storage levels were higher than the five- year average. Interestingly, the price volatility decreased in the same period. This was in part due to warmer winters, but mostly due to the large increase in supply caused by shale gas the could fill up storage sites.

Figure 18 shows a simplified illustration of the developments that has occurred in the US natural gas market in recent years with respect to supply and demand, and it clearly shows the effect of the shale revolution in 2009 on equilibrium price and quantum. I assume a shift also in demand because of the recovery of the US economy after the financial crisis in combination with higher focus from policymakers on substituting from high- emission fuels, such as coal and oil, towards low- emission fuels such as natural gas. Notice how the supply has moved relatively more than demand, thereby offsetting the increase in demand and lowering equilibrium price from P_0 to P_1. The large increase in production of unconventional gas from shale rock has clearly had an impact on the US natural gas market.

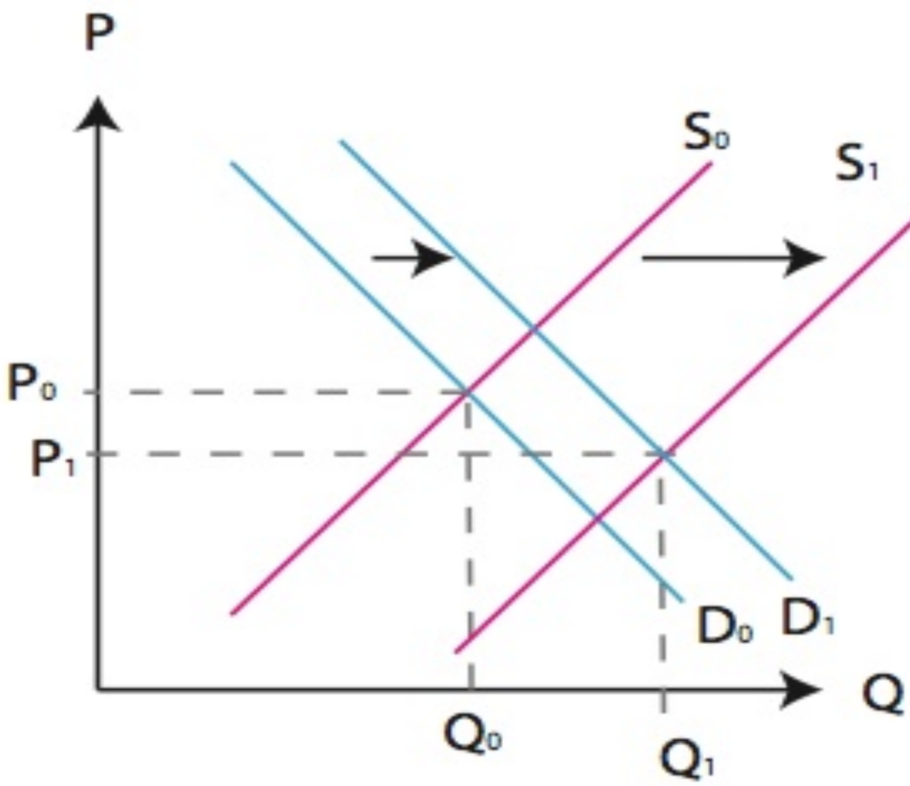

Figure 18: Theoretical effect of the Shale Gas Revolution on US natural gas markets

Chapter 5- Data

The data used in this thesis are gathered from various official US government information services. Data related to consumption, production, spot prices, number of rigs, pipeline capacity, storage levels, etc for natural gas is derived from the US Energy Information Administration database. Data related to Investments in the US Oil and Gas industry and Gross Domestic Product are gathered from the US Bureau of Economic Analysis (BEA). Data on the 10- Year US Treasury Bond Yield are collected from the US Department of Treasury.

In chapter 5, the first part of the analysis, I have used annual, monthly and daily data, depending on what has been most appropriate and accurate to visualize and analyze various effects and changes. In the regression analysis in chapter 6 I have used annual data. The EIA provides data on both a monthly and annual basis, but since the BEA data (the investment data for the dependent variable) are on an annual basis I have been forced to use annual data in the regression analysis.

The regression analysis covers the period 1990 to 2013. Since I also want to examine the effects of the shale revolution I need to include time series data *before* it started in order to analyze the effect it has had on the investments. It is difficult to find any objective criteria for how far back in time it is necessary or sufficient to go back. Today's natural gas market place is very different from the traditionally tight balance between supply and demand that has characterized the US gas market in the past decades. This is illustrated in figure 25 showing the price of the future contract on natural gas, together with annual average price and standard deviation for three different periods.

When deciding on which variables to include in the analysis there are a great many to chose from, and it would be an impossible task to cover all the possible variable combinations. With basis in my analysis- framework (described in chapter 6) I have chosen a set of variables that I believe will have the greatest impact on an investor's judgment regarding the profitability of investing in natural gas. Variables used in the regression analysis are shown in detail in chapter 6.

Variables
The following sub- section describes some of the variables applied in the analysis.

US economy
It is commonly known that there is a strong correlation between the economic growth in a country and its consumption of energy. To reflect this in the analysis I have included the development of the US gross domestic product (GDP) and the S&P 500 Index. The S&P 500 is a stock index covering the leading 500 American companies listed on the NYSE[11] and NASDAQ[12]. Many view it as the leading indicator of the US economy. GDP is used in the regression analysis.

Demand for natural gas
An important variable is the development of the demand- pattern within the different sectors in the US. I have looked at how consumption has changed during my sample period. The numbers are indexed to 1990- levels to better get a view on the changes that have taken place over time. Numbers are on an annual basis. Total consumption of natural gas on an annual basis is used in the regression analysis.

Price of crude oil
Because of the strong historic correlation between the price of crude oil and the price of natural gas I have included the price of Brent and WTI in the analysis. The numbers are on annual basis.

Technological development
Because of lack of information on the development of marginal cost related to gas extraction I have used historical data on number of rigs directed towards natural gas extraction together with the amount of natural gas being extracted in the US to explain some of the development that has happened. The data is on monthly basis.

Price of natural gas and price Volatility
The volatility of the price is derived from the price of gas. Volatility is a measure of risk, and will therefore be important to consider for an investor. Volatility is calculated from

[11] New York Stock Exchange, the biggest stock exchange in the world
[12] National Association of Securities Dealers Automated Quotations

daily spot price changes and is presented on a monthly basis. Average annual price is used in the regression model.

Proven Reserves
The huge technological development within the oil and gas industry has upgraded the US natural gas resource base. It is important to include this variable in the analysis to examine its effect on investments. Proven reserves are collected from EIA on an annual basis.

Total flow capacity
Investigating how changes in flow capacity of the natural gas grid affects investments are vital because it represents a possible bottleneck for producers. Changes in flow capacity are presented on an annual basis in chapter 6 and is also used in the regression analysis in chapter 7.

Total Storage Capacity
Storage capacity is derived from EIA and is presented on an annual basis in chapter 6. The regression analysis utilizes annual numbers.

Alternative return on investment
To reflect the alternative return on investment, or the cost of capital, I have included the development of the interest rate of 10- Year US Treasury Bond. Numbers are presented on an annual basis.

Chapter 6- Descriptive Analysis

The objective in this thesis is to explain which factors influence the willingness to invest in the production of natural gas and particularly shale gas. The chapter starts by discussing briefly the incentives and preferences an investor has to invest in projects or assets with different risk profiles. The risk associated with an asset is normally measured as the variance or standard deviation of the rate of return for a given time interval. The objective of an investor is to maximize the utility of the expected return on assets. Normally, the return on an asset is exposed to risk, and the size of the expected return increases with risk. Investor´s attitude towards risk influences the relative allocation of money between risk free and risky assets. A risky asset could be an investment in a shale gas project. Normally an investor demand higher rate of return the larger a project is exposed to risk. The variance of return on a risk free asset is zero. An investor tries to maximize the utility of the expected return by diversifying the portfolio of assets by eliminating the unsystematic risk in order to minimize the variance of the expected return on the portfolio. The investor is compensated by a risk premium by holding risky assets exposed to systematic market risk.

In the financial world investing is defined as the process of creating or buying an asset with the expectation of receiving a return from that asset. An investment decision is dependent on the expected return and on the degree of risk involved in the project or asset. Investing in production- plants is most often used when talking about a long- term perspective of investments in natural gas, as opposed to trading or speculation. In the natural gas industry the return on investment will mainly be derived from the potential profit that can be made from extracting gas and selling it on the natural gas market.

6.1 Methodology- Net Present Value

A method that is used extensively in deciding whether a project is worth putting money into is the calculation of the *Net Present Value* or NPV of the investment. The advantage of this method is that it accounts for the time- value of money. A dollar received today is worth more than a dollar received tomorrow because of the power of reinvesting. In addition, the interest rate represents the alternative value of money given comparable exposition of risk. The formula for the net present value is as follows:

$$NPV = -I_0 + \frac{\sum_{t=1}^{T} P_t * Q_t - C_t * Q_t}{(1+r)^t}$$

where:

- $-I_0$= Initial investment
- P_t= Price of product sold at time t
- Q_t= Quantity of product sold at time t
- C_t= Cost of producing per unit produced of the product at time t
- r= Discount rate
- T = The time horizon of the project

All economic variables measured in monetary terms are real values adjusted for inflation. According to the "net present value rule" an investment should be accepted if the present value of the investment is greater than zero. Investment theory states that a firm participating in a positive NPV- project will increase its firm/shareholders wealth. The degree of risk involved in the project is reflected in the discount rate. Generally, the more risk involved in the investment, the higher the discount rate. During this analysis I have used the NPV- formula as a conceptual framework for analyzing many of the factors an investor has to evaluate before he decides to invest in the natural gas business.

The first expression in the nominator is the gross income, $P_t * Q_t$, which measures price and quantity of natural gas. Multiplied together this represents the gross income a firm realizes when selling its production. In the analysis I have looked at development of price fluctuations/volatility of natural gas, and trends in demand quantity (consumption). Needless to say, the size of gross income- price and quantity, are important factors when deciding to invest. In the analysis I show how the price of gas varies over given time period. In some periods the price is volatile and in others it is tranquil. In relation to what I have mentioned about risk, it is to expect that a volatile gas price indicate higher market risk compared to a market characterized by stable prices. I can therefor argue that the higher the volatility in the market, the higher the market risk. It then follows that the exposition of risk will influence the willingness to invest in the natural gas industry.

The second part of the nominator, $C_t * Q_t$, deals with the unit cost associated with extracting the natural gas. Alternatively, I could express unit or marginal cost as a function of produced quantity. I cannot exclude the possibility that size of the production plant and quantity produced influence the marginal cost of production, for example due to economies of scale. I have simplified the expression by assuming constant marginal costs. Unit cost multiplied with units sold equals the total cost. The income subtracted the cost yields the revenue. In the analysis I have tried to assess how various factors might affect the cost related to natural gas extraction. In addition, I have focused on how the technological development has affected costs.

The denominator in the fraction deals with the required return of the investment. This reflects the rate of return that could be earned in the financial markets with a similar amount of risk, also called the opportunity cost of capital. It reflects the rate of return the market requires. In the analysis I have looked at the historic development of the yield of a 10- year US Treasury bond to determine the alternative return that could be received for a risk- free investment.

In addition to the points mentioned above, I have looked into factors such as development of pipeline- capacity, storage capacity, the price of crude oil, general economic growth in the US economy, proven reserves and the chance of natural gas being substituted for other fuels (so- called “backstop technology”), to explain which factors are determinative for investments in natural gas.

6.2 Descriptive Analysis

Historical investment levels

Figure 19 shows the invested funds in private fixed assets related to oil and gas extraction on an annual basis in the US. These numbers plays an important part in my analysis, as they are key to understanding the present activity and production level in the oil and gas industry in the US. Because there is a lag between investments and production, even though this lag is short in the shale gas industry, it does provide us with information about the natural gas industry in relation to which levels of production we can expect to see in the future. It is also important to notice that the lag is not as big as we see in for example offshore projects in the North Sea, and it is also much easier to shut down production sites temporarily if prices drop below marginal cost. This could indicate a relatively low exit cost. In that sense, the US shale gas/oil industry is more flexible than many other oil and gas projects around the world.

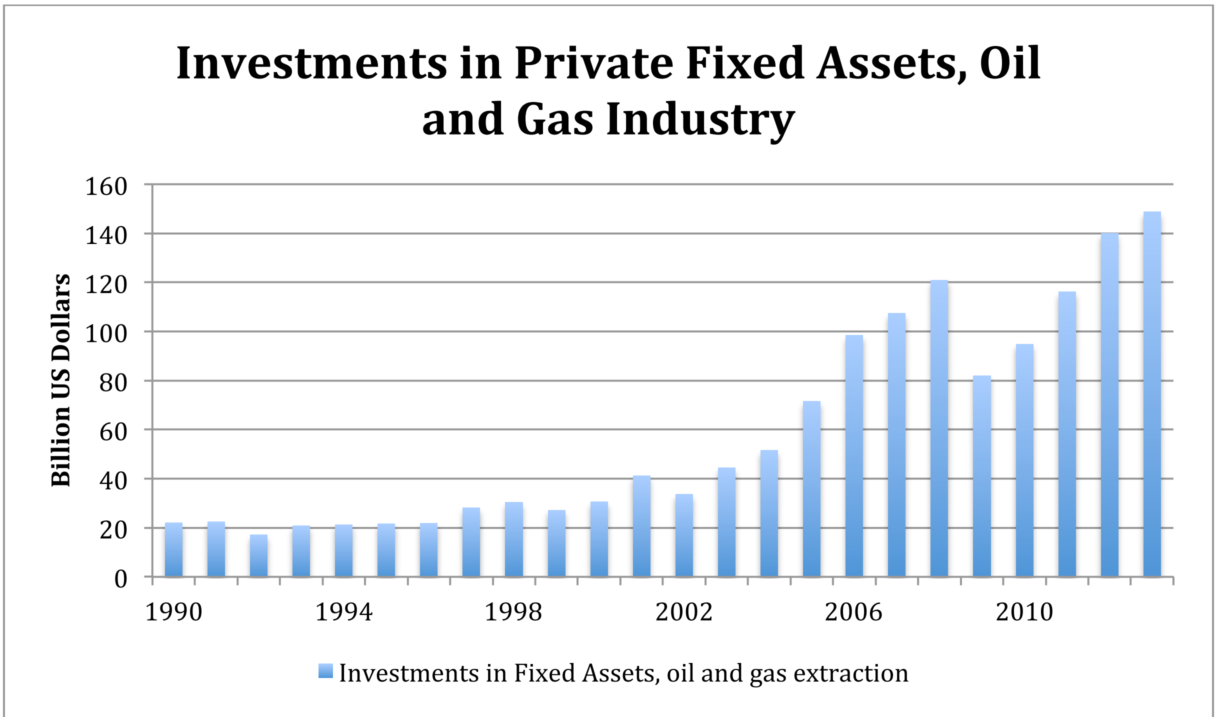

Figure 19: Investments in Private Fixed Assets, Oil and Gas Industry. Source: Bureau of Economic Analysis

Figure 19 shows that the level of investments in the 1990´s stayed on a somewhat constant level; around 20 billion US dollars annually. At the start of the 2000´s there is a strong, marked shift in investments levels as they start to increase rapidly. Obviously, the expansion of the shale industry reflects that investors expected to realize a high rate of return compared to alternative market investments with similar exposition to risk. In

2000, 30.6 billion dollars was invested. In 2006 the number rose to 98.4 billion, a 221 % increase. Investments reached a local maximum in 2008 before they declined drastically in 2009 as a result of the financial crisis and the global recession. In 2010 investment-levels picked up again and a sharp and steady growth could be observed, as seen in the figure.

The numbers presented here does not distinguish between oil and gas, or between conventional sources of natural gas and unconventional sources. However, a large portion of the investments made in the oil and gas industry in the US has been towards unconventional gas and oil. This conclusion can be drawn from the fact that *new* production in the market has mainly been from unconventional sources, such as shale rock. Therefor, the numbers presented here are also a good proxy for investments in unconventional sources of gas and oil.

In the following sections I will use the methodology described earlier in this chapter to explain how various factors have influenced the investment data presented.

Demand for gas

Given constant supply of a commodity, a stable demand is vital for maintaining price levels. A favorable market situation for a producer is to experience growth in demand. Given a constant supply, this situation will put upward pressure on prices. Increasing demand, all else being equal, should also increase the willingness to invest in the commodity because when real prices increase, the potential profit will also increase. The downside of increasing prices for the producer of a particular commodity is the risk generated from the substitution effect, i.e. that consumers of gas have incentives to substitute gas for other energy sources- for example green energy from renewables.

Figure 20 shows the change in consumption of natural gas, relative to 1990- levels, presented for the various sectors. In addition, the total consumption of natural gas is also shown. Starting with the total consumption, natural gas experienced a steady growth from 1990 to 1997 before stagnating and even dropping off somewhat towards 2006. There is a clear shift from 2006/2007 with a time- period of rapid growth in consumption until recent dates. This coincides with the shale revolution entering the natural gas market, creating an abundant supply of gas.

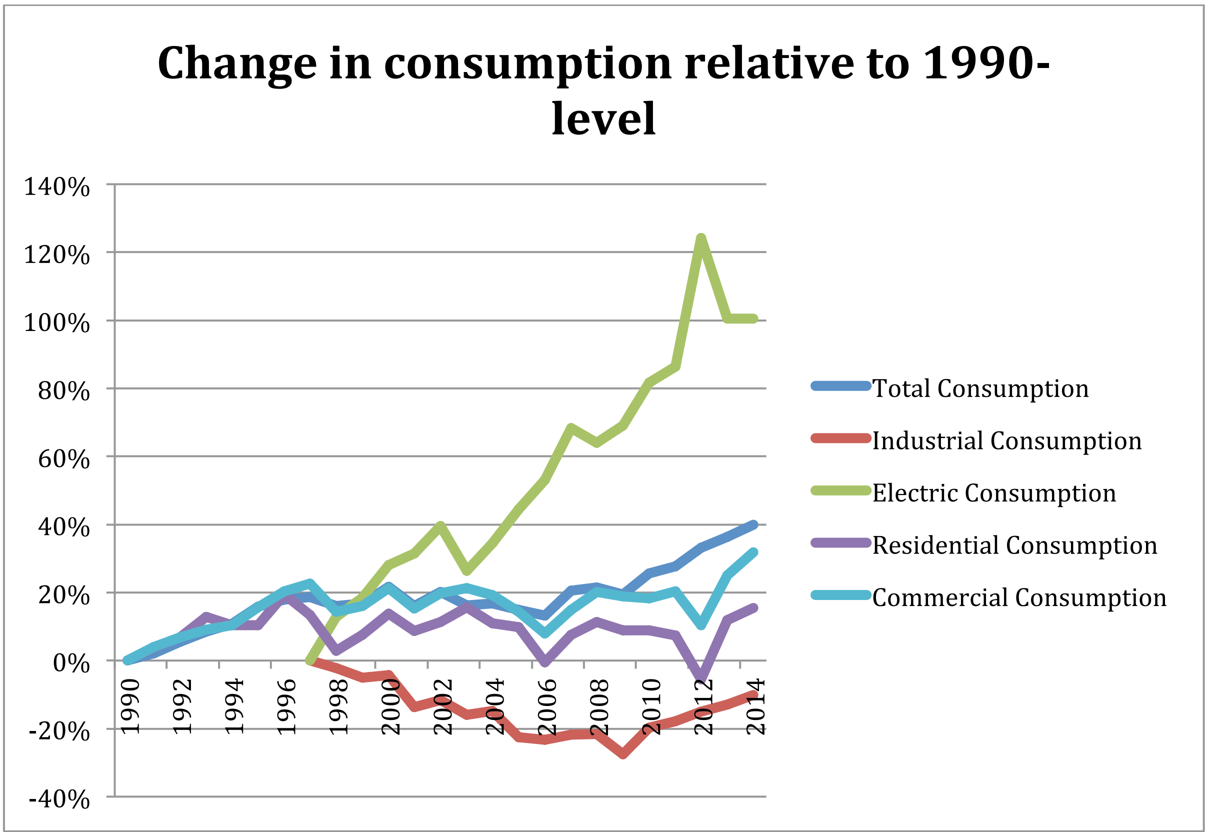

Figure 20: Change in consumption relative to 1990- level. Source: EIA

From figure 20 it is obvious that the biggest contributor in relative terms to the growth in demand is from the electric power generation sector. From 1997 to its so far peak year 2012, consumption grew by 124 %. Considering the short time- period, the growth-rate is quite astonishing. The strong development that has been happening in the electric power generation sector is due to that natural gas- driven power plants are replacing coal- driven plants. Historically, gas fired plants has been used as peak- load in periods with high electricity demand because of its flexibility in load regulations, while coal fired plants has been used as base load to the grid. This is now changing and there is a development towards more and more gas- fired plants used as base loads, while coal plants are shut down. This is due to stricter environmental regulations from the government put on each state in the US, as well as the substitution effect caused by a period of low prices on gas in the market. There has also been a huge development within the natural gas turbine field, creating higher efficiencies than what can be achieved using coal- fired generators. These changes are driving the demand for gas in the electricity sector. The increasing demand should in theory put upward pressure on prices, thereby affecting the NPV formula in a *positive* manner, all else being equal. The substitution from coal to natural gas in electricity generation is shown in figure 21 below.

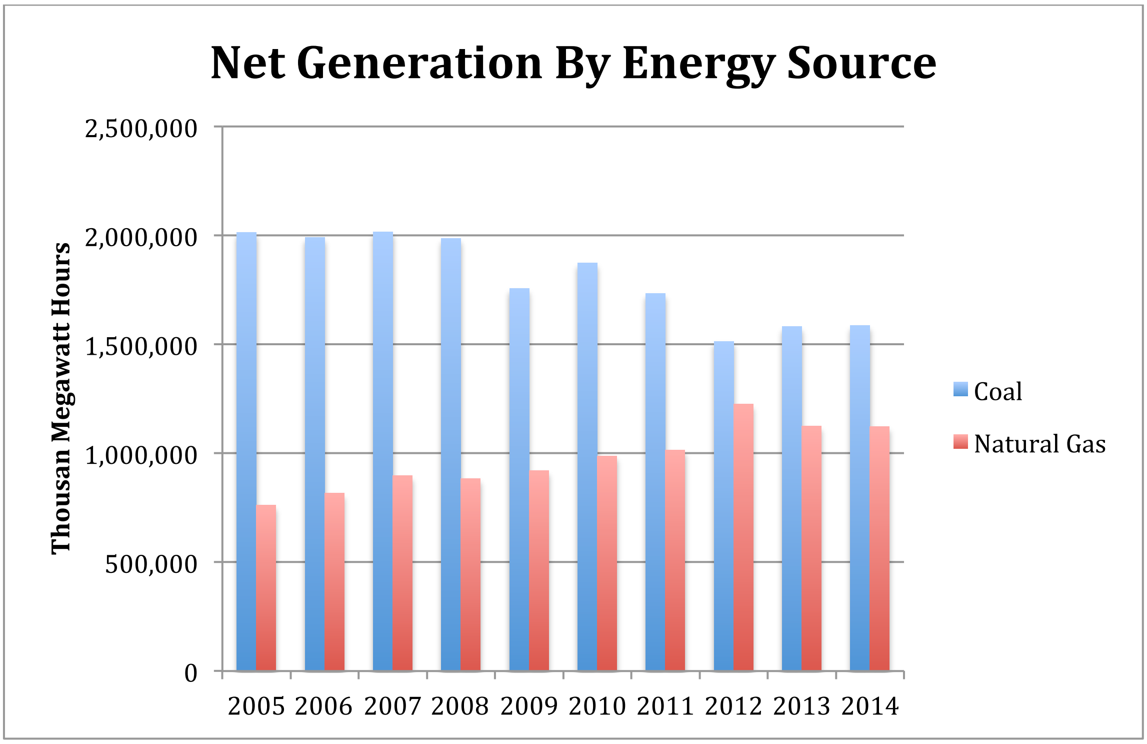

Figure 21: Net Generation By Energy Source. Source: (EIA, 2015)

Another interesting change in consumption is measured in the industrial sector. Since 1997 the use of gas in the industrial sector decreased all the way towards 2009 as a result of record high prices on natural gas during that period. After 2009 consumption started to increase also for the industrial sector. According to figure 20 and 12, this pattern coincides with the drop in prices of natural gas that appeared in 2008/2009. This implies that the industrial sector´s choice of fuel is quite price- sensitive, a reasonable assumption given that it is a highly profit- driven sector.

At the same time it is interesting to notice that for the long lasting period from 1997 to 2006 the total consumption of natural gas in the US remained at a pretty stable level, and yet investments increased during most of this period. In that sense one could imagine that there was a weak connection between demand and investments in natural gas. What is more likely is that investors anticipated a future growth in demand of gas. According to theory of rational expectations this links demand to investments.

As stated in the introduction to this section, growth or shift in demand should in theory increase prices, all else being equal. Higher prices should in turn increase the risk of a good being substituted for another good, in this case substituted by an alternative energy source. Observations show that even though the demand has grown, prices have decreased in the same period. The growth in demand has not been strong enough to balance off the abundant supply of gas, thereby keeping prices at a low level. This has in turn limited the possibility of substitution away from gas. Large levels of supply together with stricter emission standards has strengthened natural gas´s grip on the US energy market, and is definitely a positive feature for investors.

Price of crude oil and the effect of technological development

Figure 22 shows the price of crude oil, both West Texas Intermediate and Brent, plotted against investments in oil and gas industry. One can easily see how close they move, and there is not unreasonable to assume a relationship between the price of oil and the investments in oil and gas. As mentioned earlier, the investment- data contains both oil and gas, and the relationship between gas-only- related investments and the price of oil might not be as close as it seems by looking at figure 22.

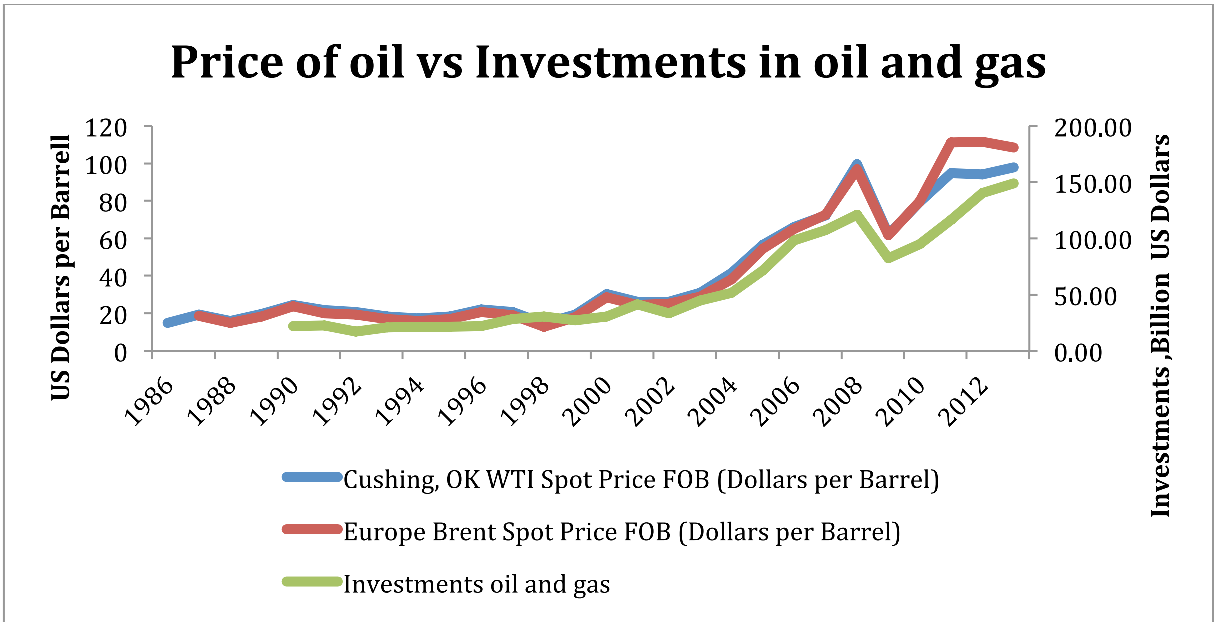

Figure 22: Price of oil vs Investments in Oil and Gas. Source: EIA & BEA

The high oil and gas prices during the early 2000´s were important determinants behind the development of the shale revolution, which strongly increased the production of gas and oil. High prices implied that unconventional sources of fossil fuels, such as shale rock reservoirs, could be made profitable despite their higher extraction costs relative to conventional sources. The high prices allowed companies to justify taking the risk of investing money into developing the necessary technology and obtaining the knowledge they needed for a large- scale production from shale rocks. The potential profit that could be made from these reservoirs could be huge, given the vast volume of gas available. In other words, the high oil and gas prices during the 2000´s might have given the investors incentives to invest in the shale gas and oil industry during this period.

As previously mentioned in this thesis, and as can be seen in figure 12, the price of gas has historically been closely linked to the price of oil. Up until 2009 there was a close correlation between price movements on gas and oil. However, after the financial crisis in 2008, which caused a drop in demand, and temporarily weakened the shale gas boom (investments) that emerged around the same time, it could be observed a large positive shift in supply of shale gas. In addition one could observe that the oil and gas prices became more delinked in the US market. The demand side of the gas market experiences today much lower prices and it is timely to ask the question whether this will affect further investment in natural gas. Has there been a change in the willingness to invest after 2009 because of lower prices?

It is hard to determine this solely on the numbers in figure 19 (investments in oil and gas) as it includes both oil and gas. However, using the number of drilling rigs directed towards oil and gas, respectively, one can make a qualified assumption of whether or not investors sees natural gas as a profitable investment in the future. This is presented below in figure 23. It shows the number of drilling rigs directed towards natural gas presented together with production of natural gas, as well as the number of drilling rigs directed towards oil. It is important to note that most of the drilling activity that has been performed in the latest years in the US has been occurring in regions where unconventional gas and oil are being extracted. This means that the numbers presented in figure 19 can be directly linked to the shale revolution in the US.

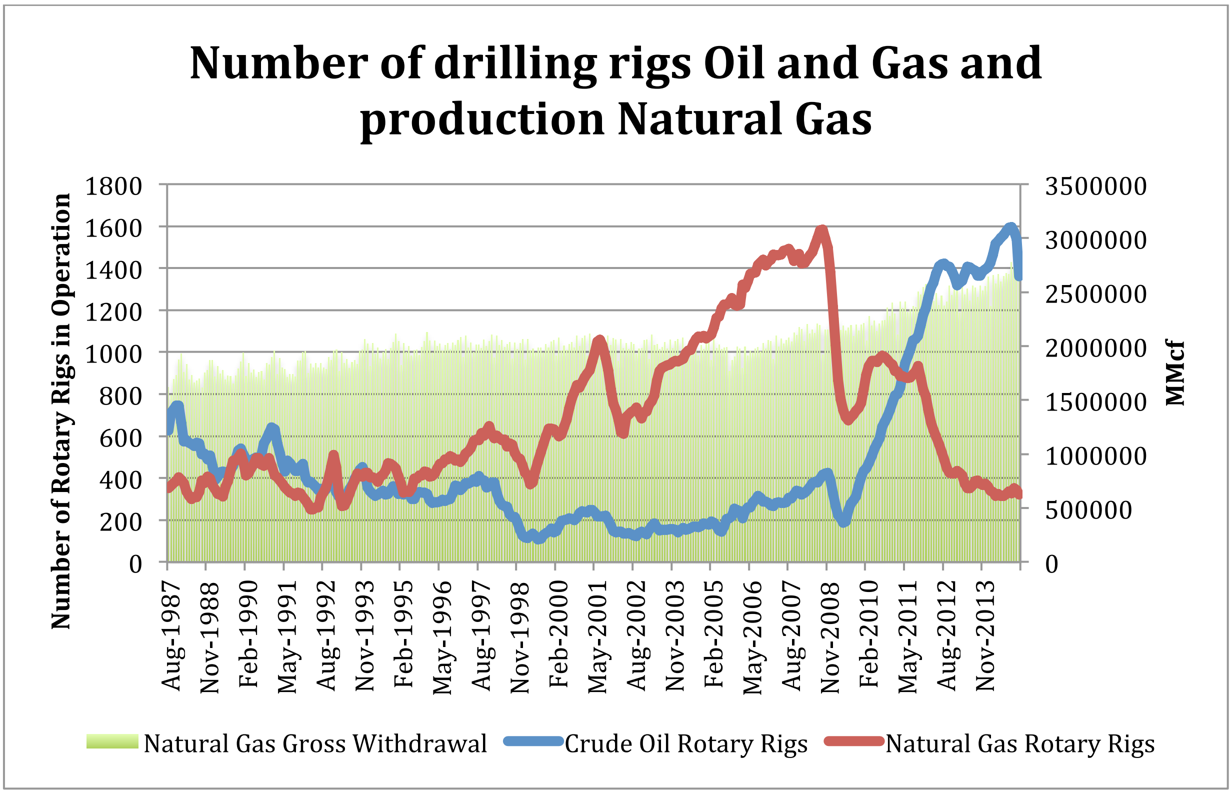

Figure 23: Number of Rotary Rigs in operation and gross withdrawal of natural gas. Source: EIA & Baker Hughes

Looking at the number of drilling rigs directed towards natural gas isolated it seems that the focus has been shifted towards oil. The number of natural gas rigs increased rapidly during the early 2000´s before plummeting from in 2008. The correlation between the decrease in natural gas rigs and the increase in oil- rigs is strong. One would expect that production of natural gas should decline as well as a result of this development, but figure 23 shows that this has not been the case. Production has actually increased during these years.

There will always be a lag between the time a well is drilled and the time it starts to produce. However, the decrease in number of drilling rigs has been going on for such a long period that if this was the only explanation the production should also start to decrease by now. There must be other reasons to explain this phenomenon as well:

- The technological development and learning curve for natural gas producers have been steep during the few years the shale revolution has lasted so far. In the Eagleford formation in Texas, average drilling time for a well dropped from 23 to 19 days from 2011 to 2012 according to EIA. This translates into the need for fewer rigs needed to produce the same amount of wells. Also, horizontal drilling means that you can reach a much larger area of the reservoir using fewer wells. Producers have through the years also gained geological knowledge about the “sweet spots” in the various plays. They now where the areas with the most potential are located and does not have to drill as many wells as before to extract the same amount of gas.

- As mentioned there is a lag between the time a well is drilled and until it starts to produce. Logistics, such as pipeline connections is a common reason for this lag. Another reason can be that producers simply do not want to extract the available gas yet, and are waiting for higher prices. Many wells that was drilled, but not completed throughout the last decade, have began to come online, helping to maintain and increase production.
- Although the counting of rigs is performed by dividing between natural gas directed rigs and oil directed rigs, the distinction is not so black and white in reality. Natural gas is being extracted from oil wells and vice versa. The additional production of gas from oil wells is important for the overall production of gas. However, the rig is not reported as a natural gas rig even though it extracts natural gas as a byproduct of the oil.

The factors above are the most important explanations for the disconnection between the number of drilling rigs and production level. Most importantly for this thesis is the large increase in efficiency within the gas industry. Higher efficiency leads to lower marginal cost, meaning that the critical price for gas, i.e. price less than marginal costs or variable costs ($P< MC$) is being lowered. Low gas prices are not necessarily synonymous with lower investment will. It largely depends on the differential between price and cost of extraction. Lower costs will increase the Net Present Value formula.

Proven reserves

As mentioned in chapter 1, there has been a huge technological development within the oil and gas industry that has boosted the extraction of oil and gas from unconventional sources such as shale rock. This new technology has also increased the potential resources that can be extracted. Proven reserves (see chapter 4.3.3 for definition of proved reserves) of natural gas in the US have risen steadily in the past decades as shown in figure 24.

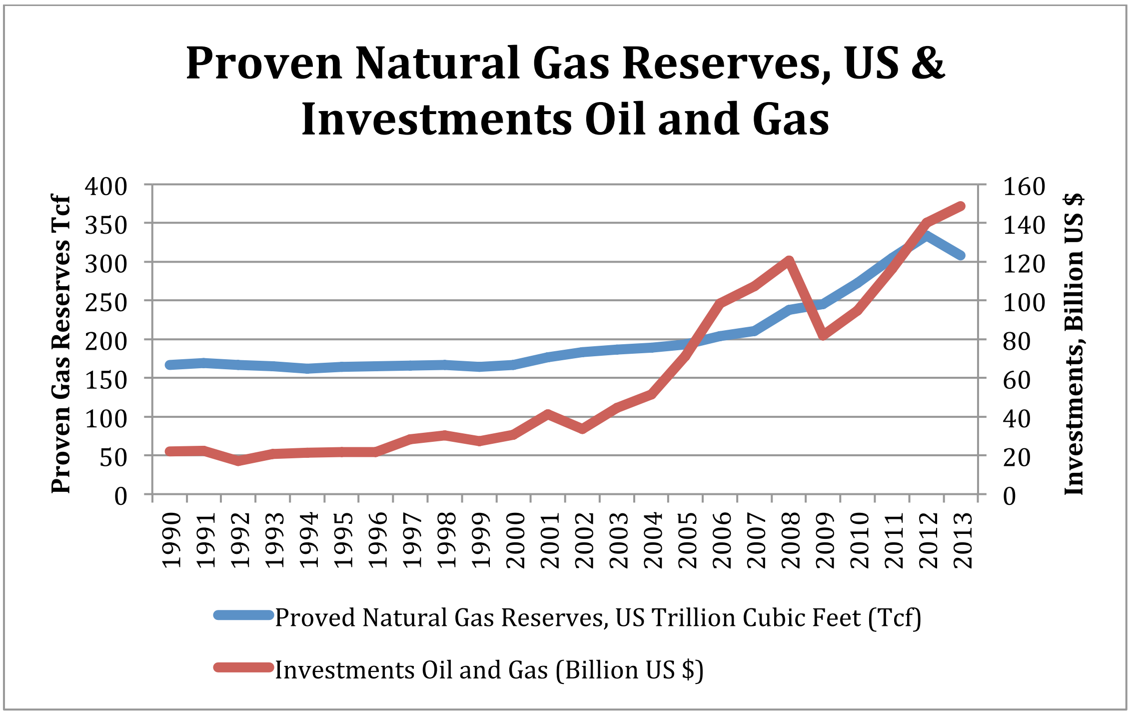

Figure 24: Proven Natural Gas Reserves & Investments Oil and Gas. Source: EIA

Proven reserves remained at a steady level throughout the 90´s before slowly rising approximately linearly from 2000 to 2006. In 2006 the rate of proven reserves changes and it starts to increase. This happens at the same time as the shale revolution starts to gain momentum in the US gas market. Investments in oil and gas are also plotted in the figure. It seems like there is a relationship between these two variables. What is interesting is the timing of the changes in the variables. The increasing rate in proven reserves happened at the same time as the investments increased, close to the new millennium. An increase in proven reserves means a possibility of increasing quantity sold to consumers. As long as price is larger than the marginal cost of extracting, selling another unit will increase NPV.

Price of natural gas

Today's market place of natural gas is very different from the traditionally tight supply-demand balance that has characterized the US gas market in the past decades (see figure 17 for production and consumption). Figure 25 shows the price of the futures contract[13] at NYMEX for natural gas plotted for the period 1994 to 2015. In addition, I have calculated the average price and standard deviation for three different periods.

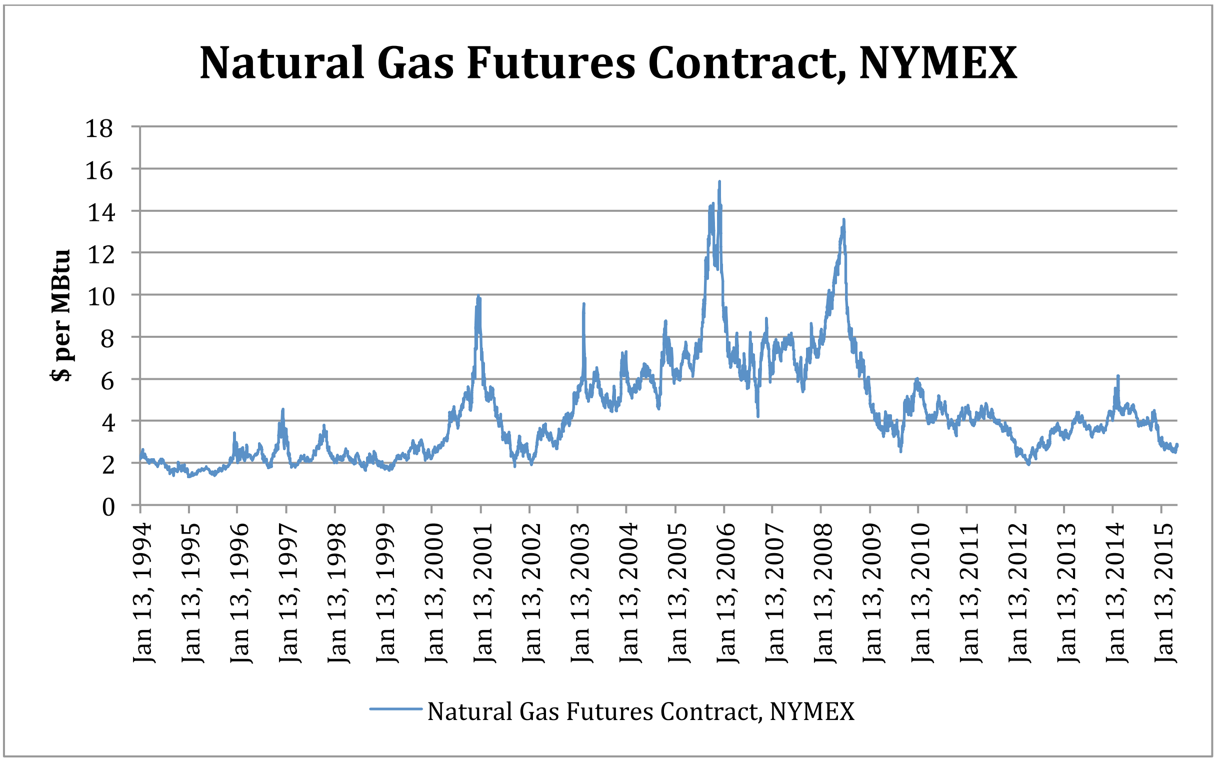

Figure 25: Price of Natural Gas Futures contract. Source: EIA

Year	Average Price ($ per Mbtu)	Standard Deviation
1994-1999	1.82	0.31
2000-2008	6.41	2.55
2009-2015	4.00	0.75

Table 3: Average Price and Standard Deviation. Source: EIA

As can be seen from table 3 the natural gas market has evolved through different periods when it comes to price and price movement. 1994-1999 was characterized by low and stable prices. The period was tranquil. In the period of 2000-2008 prices

[13] Natural gas futures contracts expire three business days prior to the first calendar day of the delivery month. Thus, the delivery month for this contract is the calendar month following the trade date (source: http://www.eia.gov/dnav/ng/TblDefs/ng_pri_fut_tbldef2.asp)

increased drastically compared to previous levels and the price stability decreased, i.e. the period was volatile. The most recent period from 2009-present date has seen somewhat lower prices than the preceding period but the price stability was better. Comparing the price levels of these three periods with the investment data in figure 19, one can see that the increase in investments during the 2000´s coincides with increasing price of natural gas. The stable and much lower investment level before the 2000´s coincides with the relatively lower and more stable prices during that period. Although not unexpected, it is interesting to note the apparent close relationship between price of gas and investments.

Price volatility

As shown in the previous section the price of natural gas is apparently connected with how much is invested in natural gas. However, it is not just the price of natural gas measured in absolute terms that are important for an investor. The relative price movement, or volatility, is also important to consider. Volatility can be used as a measure of risk based on the standard deviation of the asset return. Investors are concerned with volatility for several reasons:

- The higher the volatility the harder it is not to worry emotionally for the investor
- Volatility has implications for the asset allocation of a portfolio
- Generally, the higher the volatility for the asset the more risk is associated with the asset.

The level of risk involved in an investment is important to consider for any investor when deciding to invest or not. I have in the introduction of the chapter remarked that an investor´s attitude to risk, i.e. whether he is risk averse, risk neutral or prefers risk, influences the willingness to invest in a project. Analyzing the historic volatility for natural gas prices can be an important contributing explanation- factor for historic levels of natural gas investments.

Figure 26 shows the monthly price volatility for natural gas. Volatility is calculated using daily spot prices at Henry Hub over a period from 1997 to 2015.

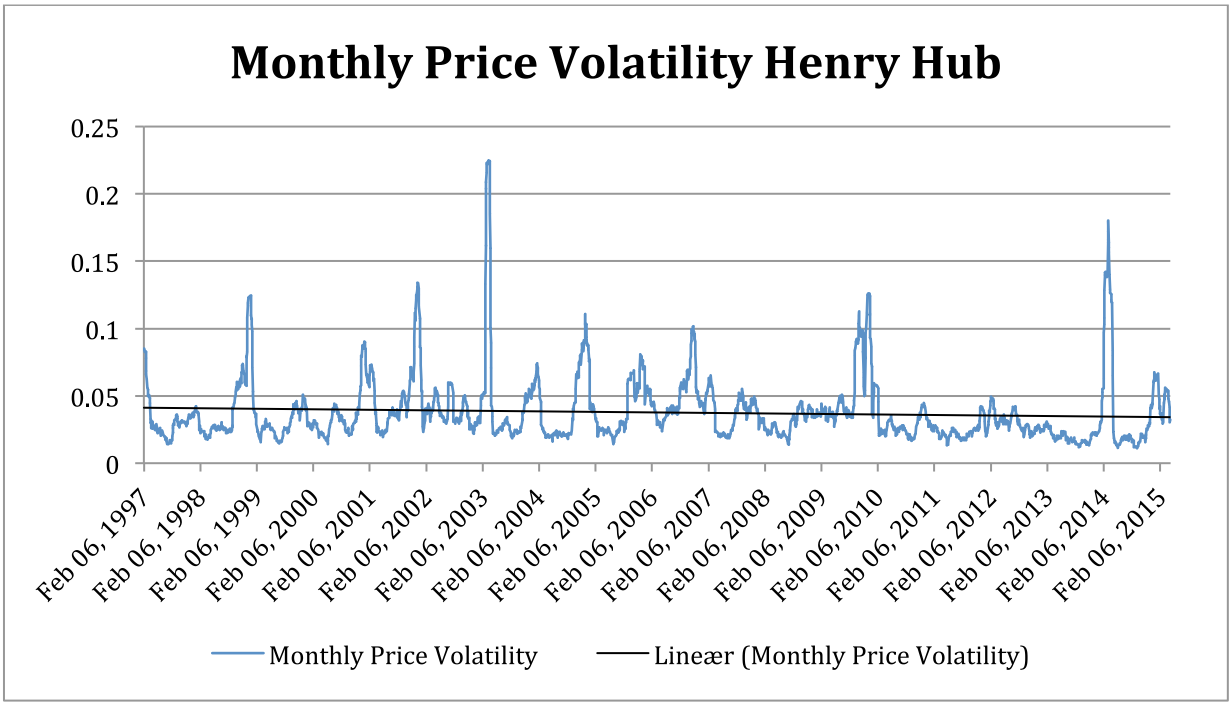

Figure 26: Monthly Price Volatility Henry Hub. Source: EIA

Looking at the chart one can see that there are quite a few periods with high spikes. These are usually called price shocks. It is a large relative movement of the price in a very short period of time. These shocks can be caused by many different incidents. As stated in section 4.3.3 the price of natural gas in the US is mainly determined by supply and demand fundamentals. Sudden changes in supply or demand can cause such shocks, either sending the price skyrocketing or plummeting. As an example, consider the high spike in February 2003: Storage levels for natural gas are presented on a weekly basis and, especially during the winter months, the market reacts to these reports depending on whether they are above average or below average. Given that the available supply from storage is pretty much given at the start of the winter season, unanticipated changes in demand such as colder than usual winters, can cause concerns regarding security of supply. The winter of 2002/2003 showed inventory levels way below average, leading to high volatility in prices. Another factor that has caused price shocks, especially in the early part of the sample period, is hurricanes affecting production offshore and thereby supply.

A trend line has also been added to the figure to show the development of the volatility in the long term. For investors, short- term fluctuations are not necessarily a big concern. It is often the long- term development of fluctuations that are important to consider. However I cannot exclude the possibility that financial investors have a short-term investment horizon, for example speculators in the futures market, and they have incentives to collect information about the development of the volatility. As can be seen the trend line is pointing slowly downwards, indicating that average volatility is decreasing in the natural gas spot market. But the estimation is only a line- fitting and it does not represent the statistical modeling of the volatility of the price of natural gas. As stated above investors are concerned with volatility for several reasons. A decreasing rate of volatility might encourage a risk- averse investor to invest in natural gas, and the decrease in volatility coincides with increased level of investments. Because volatility can be used as a measure of risk, it can therefore be linked to the discount rate in the NPV formula. A lower discount rate will increase a projects value, all else being equal.

It is interesting to understand some of the underlying causes to the reduced volatility. As mentioned previously storage capacity of natural gas together with adequate pipeline capacity is important to balance out periods of peak demand. The development of the US pipeline capacity is shown in figure 27. Comparing figure 26 (volatility) and figure 27 (pipeline) one can see that reduction in volatility happens in the same period as an increase in pipeline capacity. As can be seen from figure 27 there has been a steady expansion of the US pipeline grid in the past decades.

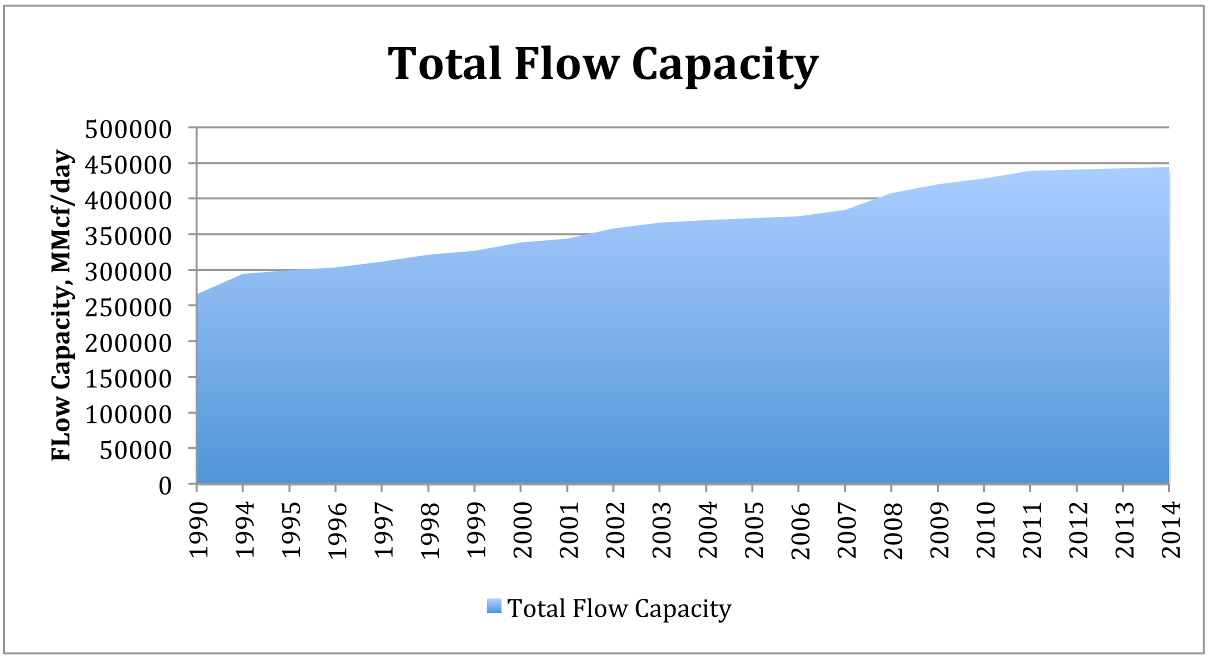

Figure 27: US Flow Capacity. Source: EIA

During the winter months, when demand is at its highest, pipeline capacity has been a bottleneck. Higher pipeline capacity reduces that bottleneck, giving consumers increased security of supply. In addition it increases the producers security of selling their gas, an important factor to consider for an investor. To relate the increase in pipeline capacity to the framework used in this analysis, an increase in pipeline capacity means the opportunity of delivering/selling more gas to consumers. Higher sales mean more revenues, again having a positive effect on the NPV- formula.

Storage capacity also works as an important tool to reduce volatility. Having adequate storage possibility ensures that consumers can receive gas from storage- sites located nearby, thereby increasing security of supply. As stated earlier, price shocks are caused by sudden changes in supply or demand, but storage can act as a way of reducing these shocks. The development of the US storage capacity is presented in figure 28.

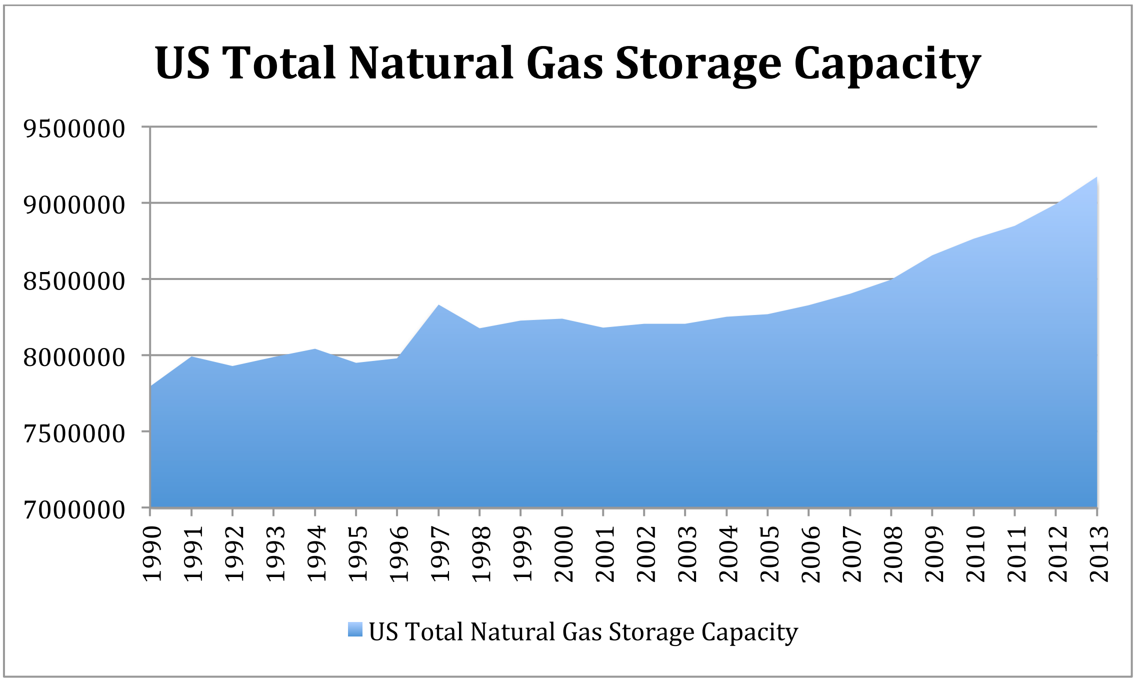

Figure 28: US Total Storage Capacity. Source: EIA

There has in recent years been a steady growth in the US storage capacity, and new capacity is under construction or being planned. In addition to functioning as a security of supply, storage also works as a source of demand for producers. An increase in storage capacity means the possibility of selling more gas. Increasing the quantity- part in the NPV formula will increase its value, as long as the price is higher than the production costs. It is also interesting to note from figure 28 that growth in storage capacity is accelerated around 2006, when the shale revolution emerged.

Economic growth: Gross Domestic Product Development and S&P 500 Index
Available energy is an important input- factor for an expanding economy. The production of any kind of products requires energy in the production process, and the lack of available energy can impose a strong constraint on the growth in economy. From this point of view, historical growth in the economy is an important explanatory factor for the historic consumption level or demand for energy. Off course, this will count for natural gas as well, and it can explain investment levels in the past.

Below is the annual US gross domestic product[14], GDP, plotted together with investments in oil and gas. There has been a steady growth in the US GDP in the sample period, with the exception of the financial crisis between 2007/2008 and 2009. Visual inspection of figure 29 indicates that there is a correlation between these two variables. It is not surprising considering the importance crude oil has as an input factor in industrial production and in general everyday life and the relationship between the price of crude oil and GDP growth has been explored thoroughly by many researchers.

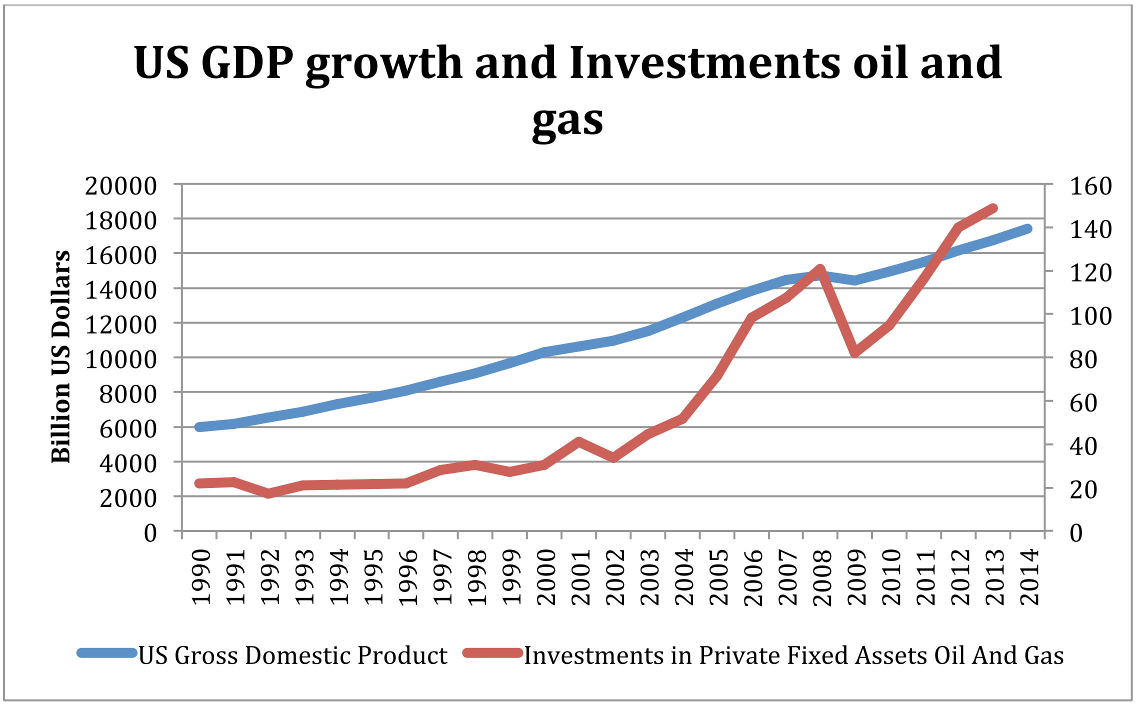

Figure 29: US GDP Growth and Investments in Private Fixed Assets Oil and Gas. Source: BEA

[14] Gross Domestic Product is defined as the monetary value of all the finished goods and services produced within a countries border within a given time period, usually a year.

The problem with the investment- data is that it does not separate between oil and gas. However using table 1 in chapter 2.2 it is possible to understand the important role natural gas has in the US economy. One of the advantages with natural gas is its variety of possible applications. As seen in table 1 it is used extensively in the electric power sector, the industrial sector and in the residential and commercial sector. Together, these groups represent a large contribution to the US GDP, implying that a growth in the overall GDP is likely caused by growth in these sectors as well. One can thereafter draw the line that a growth in these sectors is generating an increase in demand for natural gas- leading to higher investments in the natural gas sector.

Figure 30 shows the historic development of the S&P 500 index since 1990 up until present date. S&P 500 is considered as one of the best indices of economic development in the US. From 1995 to 2000 the index grew from 500 points to 1500, before taking a downturn to 1000 points in 2003. Then, it grew back to its previous top level in 2007 before the financial crisis kicked in and threw the index down to around 800 points. Since 2009 the index has been growing steadily and is now above 2000 points.

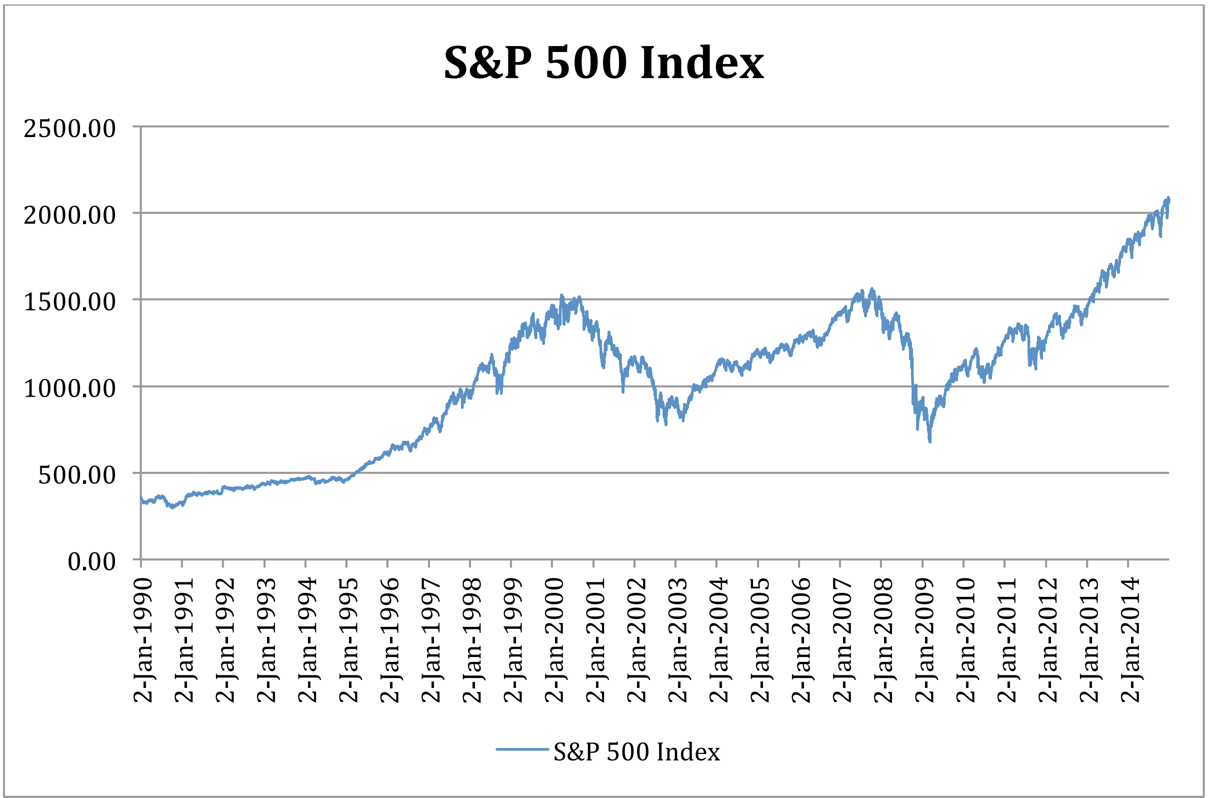

Figure 30: S&P 500 Index. Source: Federal Reserve Bank of St. Louis

Comparing the S&P 500 index with the investments in oil and gas, together with the known correlation between economic growth and energy consumption, it is clear that economic growth in the US has been a contributing factor for investments in natural gas. As mentioned in the section above, the diversity of application for natural gas makes it an important input factor for the economy.

Political regulations

Federal regulations regarding CO_2- emission and other kind of pollution are also playing an important role, especially in the future of natural gas investments. In June 2014 The Obama administration launched their Clean Power Plan, stating that CO2 emissions from existing power plants will be cut by 30 percent from 2005 levels by 2030 (U.S Environmental Protection Agency, 2014). Each state in the US will be given a specific emission target based on their past emissions and their mix of energy sources. The Environmental Protection Agency, EPA, will monitor each state´s progress towards its emission goal.

According to the plan, the cut in emissions is going to be met by an increase in the renewable share as well as coal- fired plants being replaced by natural gas fired plants. This policy from the government is imposing clear guidelines for which priorities each state needs to make to meet required reduction in emission levels, again putting clear guidelines on which fuels to invest in for an investor in order to have the possibility of a *sustainable* return on investment. Coal is being squeezed out of the market while gas is increasing its share in the energy market.

The emission cuts mentioned above is related to country specific pollution and international politics. As shown in section 3.4 there is controversy regarding shale gas. It is especially focused on the potential local pollution related to shale activity. In the past decades, regulations regarding this have been quite easy- going. As mentioned previously, hydraulic fracturing was through the Energy Policy Act of 2005 specifically excluded from existing regulations (except when diesel fuel are used in the process). The EPA is at the moment conducting a study on the impact hydraulic fracturing might have on drinking water resources. So far there has not been any considerable regulations from the US government stalling the exploration and extraction of natural gas.

Depending on the conclusions in this report the regulatory framework for hydraulic fracturing might change. If so, and it becomes more regulated, it is likely that it will increase cost related to safety measures. Higher costs will effect NPV in a negative direction.

Alternative returns on investment

If one considers a rational investor he or she will always put their money in investments that has the possibility of yielding the highest total return given their risk acceptance. It is therefor important to look at the competitive ability natural gas have compared to *other* investments, as this will affect the attractiveness to invest in natural gas. Of course, one cannot consider every other possible investment option, but to assess the alternative return an investor can receive it is possible to use the rate of return on the US- Treasury bond as a close to risk free investment. I have therefor included the historical yield- curve for a 10- year US Treasury bond. The development is presented in figure 31 below.

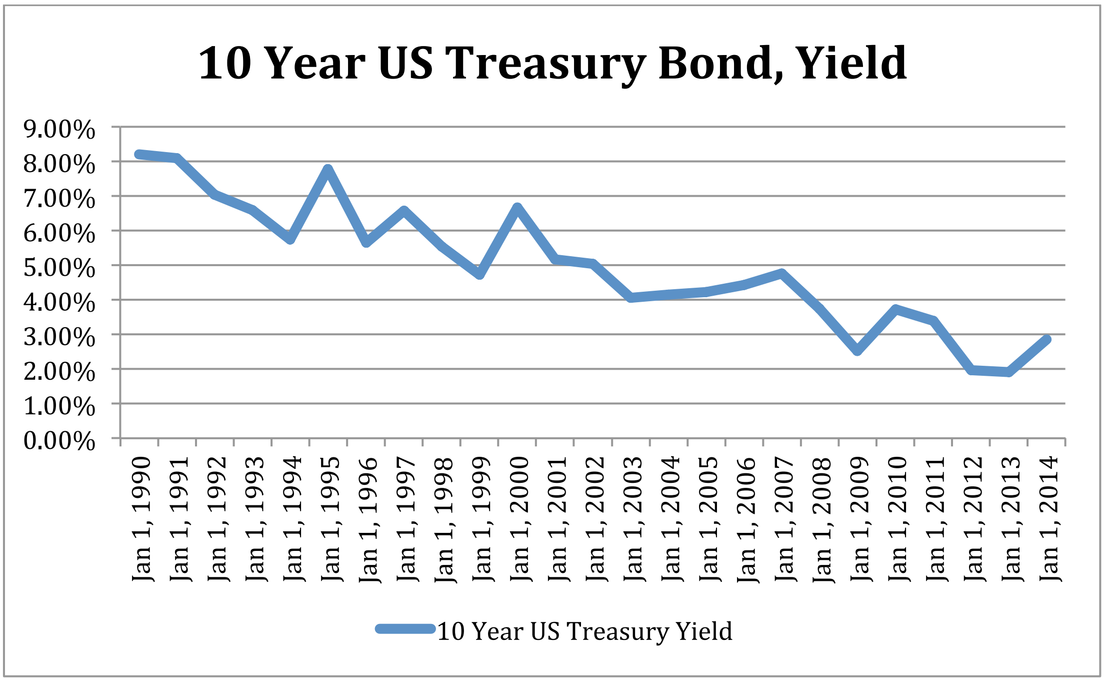

Figure 31: 10 Year US Treasury Bond, Yield. Source: U.S Department of The Treasury

There has been a clear downward trend in the yield for the 10- year US Treasury bond. This means that investing in natural gas not necessarily has been a "bad" or sub- optimal investment, even though gas prices have been reduced. Relative to a risk free investment, which also has had a decreasing return, natural gas investments might still yield an acceptable return and be attractive in the eyes of an investor or investing company. This can be directly related to the discount rate in the NPV formula. The lower the discount rate, the higher the probability of obtaining a positive NPV given that all other factors are constant and the intertemporal realized profit is positive. In addition, lower discount rate gives relative higher weight on the future cash flow compared to higher discount rate.

Chapter 7- Statistical Analysis and Model

7.1 Model and Results

The following section analyzes whether there is any indication that the accelerating shale gas production in 2007 and onwards has had any effect on the investment in the oil and gas sector in the US during the period 2007-2013. Two models are applied in the analysis. The first is an explorative model and the main objective of using the model is to detect changes in the investment time series data, while the objective of the second model is to measure how different economic variables hinges together and influences on the oil and gas sector. The main objective is to explain the investment pattern in the oil and gas industry during the period 2007-2013. The coefficients in both models are estimated by using a linear regression estimator called ordinary least squares, abbreviated OLS.

The descriptive analysis in chapter 6 shows (see Figure 19) that investment in oil and gas in the US increased exponentially during the period 2003-2013. In addition, statistics shows that the total consumption of natural gas in the US started to increase in 2007 and onwards. The US oil production started to increase in 2008 after 18 years of reduction. The increase in oil and gas production can partly be explained by the high oil and gas prices in the recent decade, that allowed for the development of economically viable technological innovations that made it possible to extract large amount of oil and gas from unconventional sources such as shale rock. Production of gas from shale rock started in 2006/2007 (the first registration year at EIA) and the average growth rate was 31% per year during the period 2007-2013. A timely question to ask is to what extent the shale gas production has influenced the total investment in oil and gas in the US? Can the US shale gas revolution be detected in the investment time series, and is it possible to detect statistically the shale gas revolution in the US? These questions are analyzed by using the investment data in the oil and gas sector of the US economy.

Model 1

I want to test whether the shale gas and oil production in 2007 and onwards has had any significant influence on the aggregated investment level in the US oil- and – gas sector. According to the EIA- statistics the shale revolution was registered for the first time in

2007. If the investment in the shale gas production influenced on the aggregated level of investment I expect to find a significant *change* in the time series covering the aggregated investment. If there is a change, I should potentially find it in the aggregated time series as a shift in the level or as a change in the growth rate in investment. I am able to test statistically whether the level or growth rate in investment changed in 2007 and onwards. These potential modes of changes are modeled as dummy variables (see below).

It is important to be aware when formulating a model that investment and production do not take place instantaneously in time. Investment takes place before production. Due to the time lag between investment and production I let the dummy- variables also cover 2006. The dummy variables included in the model measures how the effect of shale gas investment covers the period 2006-2013. The unrestricted model[15] includes changes in the level and growth rate (trend) in the investment pattern.
The unrestricted model is as follows:

$$I_t = \alpha + \beta_1 D_{SG,t} + \beta_2 T_t + \beta_3 (T_t)(D_{SG,t}) + \beta_4 D_{2009} + \varepsilon_t.$$

The variables are explained in table 4 below.

VARIABLE	EXPLANATION
I_T	Gross aggregated investment in oil and gas at time point *t*
$D_{SG,t}$	Dummy variable for shale gas investment at time point t = 2006,…,2013.
T_t	Indicator for year. *T* = 1, 2,….,24 and *T* = 1 indicates year t= 1990.
D_{2009}	Dummy variable D_{2009}= 1 for time point 2009 to absorb the shift due to the financial crisis which started in 2008.
ε_t	Residual at time point *t*

Table 4: Explanation of Variables in the Unrestricted Model

The model coefficient β_1 measures the level in the investment due to the shale gas and oil investment *relative* to non-shale gas investment. Coefficient β_3 measures the *change*

[15] Unrestricted model is a model where we have not imposed any restrictions on the estimated coefficients. ”Restricted” vs ”Unrestricted” model are related to the null and alternative hypotheses.

in the trend in the investment assumed caused by the investment in the shale gas industry. The result of the estimation is as follows (t-values in brackets) and is summarized in table 5:

$$I_t = \underset{(34.7)}{2.75} + \underset{(2.07)}{1.01} D_{SG,t} + \underset{(9.06)}{0.074} T_t - \underset{(-0.96)}{0.024} (T_t)(D_{SG}) - \underset{(-2.55)}{0.31} D_{2009}$$

Variable	**Coefficient**	**t- value**
Interception	2.75	34.7
Dummy variable for shale gas investment at time point t, $D_{SG,t}$	1.01	2.07
Indicator for year t, T_t	0.074	9.06
Dummy variable financial crisis, D_{2009}	-0.31	-1.81
$T_t * (D_{SG})$	-0.024	-0.96
$\boldsymbol{R^2}$	0.96	

Table 5: Results estimated model

The estimation indicates that the investment in the shale gas and oil production has a "close to" significant effect on the aggregated investment in oil and gas in the US in the period 2006-2013: The coefficient estimate of the level- shift indicator $D_{SG,t}$ is significantly different from zero, given a one- sided t- test and a significant level of 5 %. The critical value of a two- sided test and 5 % significance level is 2.093 given 19 degrees of freedom, and the critical value for a one- sided test and 5 % level is 1.729. The estimated model indicates that the growth rate (trend) in the aggregated investment is *not* significantly affected (t-value = 0.96). The statistical properties of the model are good: The model explains 96 % of the variation of the independent variable, i.e. $R^2 = 0{,}96$. The residuals are *not* autocorrelated and the Durbin- Watson test for first-order autocorrelation is DW=1.53. There is no higher- order autocorrelation either. The Jarque- Bera chi- square test shows that the residuals are normally distributed, i.e $\chi^2_{(2)}$ = 2.76.

The model shows that the effect on the trend is not significant and we can remove it from the original model. The result of the re-estimated model is as follows and is summarized in table 6:

$$I_t = \underset{(34.4)}{2.77} + \underset{(4.26)}{0.52} D_{SG,t} + \underset{(8.65)}{0.071} T_t - \underset{(-1.81)}{0.31} D_{2009}$$

Variable	**Coefficient**	**t- value**
Interception	2.77	34.4
Dummy variable for shale gas investment at time point t, $D_{SG,t}$	0.52	4.26
Indicator for year t, T_t	0.071	8.65
Dummy variable financial crisis, D_{2009}	-0.31	-1.81
$\boldsymbol{R^2}$	0.96	

Table 6: Results, estimated model

A re-estimated model without any effect on the growth rate of the aggregated investments, i.e. $\beta_3 = 0$, shows that we still cannot exclude that the investment and production of shale gas increased the total investment in the oil and gas sector significantly. According to the model the shale gas production has increased the investment by about $(e^{0.52} - 1) \cdot 100 \approx 68\%$ compared to the investment level before 2006. The model also includes the effect from the financial crisis, which "materialized" in 2008. The estimation shows that the financial crisis only had a short, but negative shift on the level of investment by about $(e^{-0.31} - 1) \cdot 100 \approx -27\%$. The statistical properties of both models are good. $R^2 = 0.96$, which means that the model explains 96 % of the variation in the investment pattern. There is no first (DW=1.39), or higher order autocorrelation between the residuals. The residuals are normally distributed because the Jarque- Bera chi- square test shows $\chi^2_{(2)} = 2.56$. The critical value is 5.99 given a 5 % significance level. The variance of the residuals is constant. Normally distributed residuals are important in small samples with respect to obtain valid t- test and F- test. If the residuals are autocorrelated and/or the variance of the residuals is *not* constant, it weakens the validity of the t- and F- tests. Figure 32 shows the observed and estimated investment and the figure also includes the hypothesized changes due to investments in shale gas and oil industry.

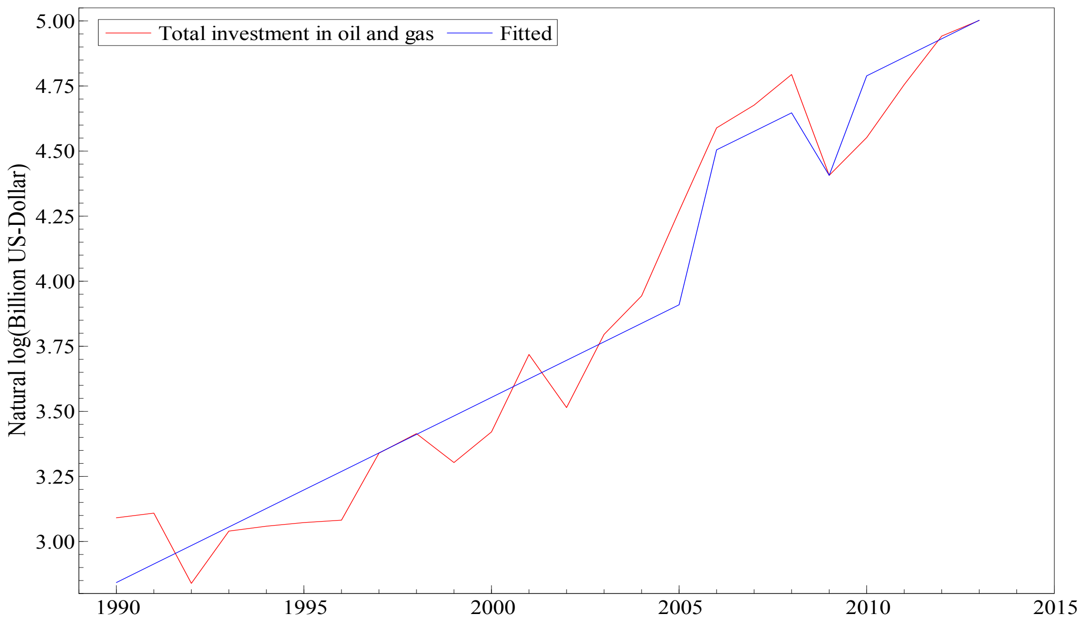

Figure 32: Observed and estimated investments. Includes the changes due to the expansion of the shale gas industry in the period 2006-2013 and the negative shift due to the financial crisis in 2008

Model 2

The descriptive part of the analysis shows that most of the variables are trended variables, and some of them have a non-linear pattern. These characteristics complicate the analysis. The objective is to explain the investment in oil and gas by using linear regression methodology. Regression between trended variables can cause spurious relations. The deterministic trend in each series is therefore eliminated, and the residuals are applied in the empirical analysis. By detrending the variables we also eliminate the effect from general inflation on monetary measures. The economic variables are linked together and the causal direction of how they affect each other is difficult to model in one single equation. Single equation models do not explain the interdependencies between the explanatory variables, nor how the explanatory variables are related to other variables. Some of the economic variables are determined simultaneously, which means that they appear both as dependent and explanatory variables in a set of different equations. The causal direction between the variables is not clear. It is therefore more rational to estimate simultaneous equation- system, which models how the variables are assumed linked together. The structural equation- system consists of three equations that describe how price of gas, aggregated consumption of gas, and investment in oil and gas production are influenced by a set of explanatory variables. These three variables are the endogenous variables, which are determined in the structural equation system. The economic system consists of the following three equations describing the price formation of gas, total consumption of gas and investments in oil and gas (I_t). These variables are the endogenously determined variables in the system:

$$P_{Gas,t} = \alpha_{11} + \beta_{11}TGS_t + \beta_{12}P_{WTI,t} + \beta_{13}PGR_t + \beta_{14}GC_{t-1} + \varepsilon_{1t}$$
$$GC_t = \alpha_{21} + \beta_{21}P_{Gas,t} + \beta_{22}P_{Gas,t-1} + \beta_{23}GDP_{t-1} + \varepsilon_{2t}$$
$$I_t = \alpha_{31} + \beta_{31}CP_t + \beta_{32}PGR_t + \beta_{34}\Delta TB_t + \beta_{35}D_{2009} + \beta_{36}D_{SG,t} + \varepsilon_{3t}$$

The detrended variables are in addition transformed by the natural logarithm. The motivation for transforming the variables logarithmically is that the estimated coefficients are elasticity's, which provide us with information on how the endogenous variables respond to changes in the independent variables. The effects are presented in percentage. Table 7 shows the explanation of the variables included in the model.

VARIABLE	**EXPLANATION**
$P_{Gas,t}$	Price on gas at time point *t*
TGS_t	Total production of gas at time point *t*
$P_{WTI,t}$	Price on crude oil in the US at time point *t*
PGR_t	Proved reserves at time point *t*
GC_t	Total consumption of gas at time point *t*
GC_{t-1}	Total consumption of gas at time point *t-1*
$P_{Gas,t-1}$	Price on gas at time point *t-1*
GDP_{t-1}	Gross domestic product at time point *t-1*
I_t	Gross aggregated investment in oil and gas at time point *t*
CP_t	Pipeline capacity per day at time point *t*
ΔTB_t	Change (percentage points) in the interest rate of the treasury bond at time point *t*
D_{2009}	Dummy variable D_{2009} = 1 for time point 2009 to absorb the shift due to the financial crisis which started in 2008.
$D_{SG,t}$	Dummy variable for shale gas investment at time point *t* = 2006,…,2013.
$\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}$	Residuals for each of the equations at time point *t*

Table 7: Explanation of Variables, Model 2

The objective is to estimate the equation system and evaluate how the investment in natural gas is affected by the explanatory variables. Because the price of gas is both an explanatory and an endogenous variable, it is necessary to estimate the reduced form of the equation where the endogenous variables are determined solely by exogenous variables. Solving the system this way makes a one- way direction of the causality. Each equation in the system is overidentified[16]. 2SLS[17] is applied in order to be able to estimate the coefficients in the structural equation system. The result of the estimation is as follows (t-values in brackets), and the results are summarized in table 8 to 10:

$$P_{Gas,t} = \underset{(0.95)}{0.03} - \underset{(-0.75)}{1.56}\,TGS_t + \underset{(5.96)}{0.90}\,P_{WTI,t} - \underset{(-3.95)}{2.41}\,PGR_t + \underset{(1.07)}{1.88}\,GC_{t-1}$$

$$GC_t = \underset{(0.94)}{0.01} - \underset{(-0.97)}{0.03}\,P_{Gas,t} - \underset{(-3.03)}{0.08}\,P_{Gas,t-1} + \underset{(1.06)}{0.30}\,GDP_{t-1}$$

$$I_t = \underset{(-3.11)}{-0.08} - \underset{(-2.36)}{4.19}\,CP_t + \underset{(2.36)}{0.74}\,PGR_t + \underset{(3.37)}{0.34}\,P_{Gas,t} - \underset{(-0.70)}{0.07}\,\Delta TB_t - \underset{(-1.93)}{0.17}\,D_{2009} + \underset{(3.47)}{0.20}\,D_{SG,t}$$

Estimation of the equation for the gas price

Variable	Coefficient	Std.Error	t-value	t-prob
Total production of gas at time point t, TGS_t	-1.564	2.096	-0.746	0.533
Price on crude oil in the US at time point t, $P_{WTI,t}$	0.895	0.150	5.960	0.027
Proved reserves at time point t, PGR_t	-2.411	0.610	-3.950	0.058
Total consumption of gas at time point t-1, GC_{t-1}	1.876	1.748	1.070	0.395
Interception, α_{11}	0.026	0.028	0.949	0.443
R^2	0.91			

Table 8: Estimation of the equation for the gas price

Estimation of the equation of the total consumption of gas, GC_t.

Variable	Coefficient	Std.Error	t-value	t-prob
Price on gas at time point t-1, $P_{Gas,t-1}$	-0.077	0.026	-3.030	0.094
Price on gas at time point t, $P_{Gas,t}$	-0.026	0.027	-0.973	0.433
Gross domestic product at time point t-1, GDP_{t-1}	0.303	0.285	1.060	0.400
Interception, α_{21}	0.005	0.006	0.936	0.448
R^2	0.91			

Table 9: Estimation of the equation for the total consumption of gas

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[16] Overidentified means that it is more than one way to go back from the reduced form equation system and determine the coefficients in the structural equation.
[17] Two Stage Least Squares (2SLS) is an estimation method, which solves the identification problem in an overidentified equation system so that it is possible to derive consistently the coefficients in the structural equation from the estimated reduced form equations.

Estimation of the equation for the aggregated investments in oil and gas, I_t.

Variable	Coefficient	Std.Error	t-value	t-prob
Pipeline capacity per day at time point t, CP_t	-4.189	1.772	-2.360	0.142
Proved gas reserves at time point t, PGR_t	0.735	0.311	2.360	0.142
Price on gas at time point t, $P_{Gas,t}$	0.336	0.100	3.370	0.078
Change in interest rate, 10 Y US Treas. time point t, ΔTB_t	-0.065	0.093	-0.701	0.556
Dummy variable Fianancial Crisis, D_{2009}	-0.172	0.089	-1.930	0.193
Dummy var. for shale gas investment, time point t, $D_{SG,t}$	0.199	0.057	3.470	0.074
Interception, α_{31}	-0.085	0.027	-3.110	0.090
$\boldsymbol{R^2}$	0.56			

Table 10: Estimation of the equation for the aggregated investment in oil and gas

The estimation shows that the sign of the coefficients in the model is consistent with economic theory. The uppermost equation, which measures the determination of the price of gas, shows that the US-oil price P_{WTI} has significant positive influence on the price of gas. The estimated equation explains about 91 % of the total variation of the price of gas, i.e. $R^2 = 0.91$. The estimation shows that a 1% increase in the oil prices increases the gas price by about 0.9%. The estimation shows in addition that the level of proved reserves of gas have a negative impact on the price of gas. According to the model a 1% increase in proved reserves reduce the price of gas by 2.41%. The estimate is significant at 10 % given a two- sided test. The model shows that an increase in total production of gas (TGS) has a negative impact (-1.56) on the price of gas, but the estimated effect is not significant. The model also shows that total consumption of gas (GS) has a positive influence on the price of gas, but neither this variable has a significant effect on the price.

The second equation endogenizes total consumption of gas (GC) in the US as a function of current and lagged price of gas and the level of gross domestic product (GDP) lagged one period. The estimated equation explains about 91 % of the total variation of the consumption of gas, i.e. $R^2 = 0.91$. The estimation shows that total consumption of gas is negatively correlated with the price of gas and positively related to increase in *GDP*. The model shows that a 1% increase in the lagged price of gas reduces the consumption by 0.08%. The result shows that the consumption of gas is rather inelastic with respect to changes in price. GDP is a proxy for income and the model indicates that a 1% increase in GDP increases the total consumption of gas by 0.3%. Notice though, that the coefficient estimate is not significant.

The lowermost equation models the investment behavior (I) in gas and oil sector. The estimated equation explains about 56 % of total variation, i.e. $R^2 = 0.56$. The investment numbers include production plant and do not include pipelines and infrastructure. The investments are assumed influenced by the capacity of the pipelines (CP), proved gas reserves (PGR), price on gas (P_{Gas}), change in the interest rate of the 10 year US-Treasury bond (ΔTB), a dummy variable (D) which absorbs the shift in the economy due to the finance crisis in 2008, and finally a dummy variable (D_{SG}) which absorbs the effect from the strong increase in investment and production of shale gas which started in 2006/07.

The estimation shows that size of the pipeline capacity has a significantly negative effect on the investment. A 1% increase in the pipeline capacity reduces the investment by -4.72%. The coefficient estimate is *not* significantly different from zero. Even though the result is not significantly different from zero, the sign of the coefficient is negative. This is a rather unexpected result because it is to expect that an increase in pipeline capacity could increase the market and therefor the sale. However, the estimate can alternatively indicate that investment in *production* capacity of gas is *already* done and is history. Note that an investment is a flow- measure while capacity is a stock measure. These two entities do not follow each other instantaneously.

The model shows that proved reserves of gas have a positive, but not significant effect on investment. A 1 % increase in new gas reserves increases the investment by 0.74 %. Price of gas also stimulates investment. The model predicts that a 1% increase in price of gas increases the investment by 0.38%. By including the interest rate of the 10- year US Treasury bond the model measures the long-term price of capital. The model shows that an increase in the interest rate has a negative, but not significant impact on investment. 1 percentage point increase in interest rate reduces investment by 0.07 %. The financial crisis, which started around 2008, is also included in the model, and the coefficient estimate shows that the crisis had a significantly negative impact on the investment in the gas sector and the remaining part of the economy, given a one-sided statistical test on 10 % level. The impact of the crisis on the investment is $(e^{-0.22}-1)\cdot 100 \approx -20\%$. The dummy variable (D_{SG}), which absorbs the strong growth in shale- gas/oil investments and production is also significantly different from zero. The effect of the shale gas and oil industry is about $(e^{0.18}-1)\cdot 100 \approx 20\%$. Notice that the negative effect from the finance crisis is modeled as a short-run one-period effect, while the effect from the expansion of the shale gas industry has multiperiod persistence.

The result of the estimation shows that the model measures a set of effects that are consistent with economic theory. The lack of observations makes it difficult to test and detect structural changes. In addition, the lack of observations implies that I cannot utilize the large sample properties, which mean that the estimates converge toward the true population values as the sample size increases. Unfortunately the model is based on only 22 observations (yearly data for the period 1992-2013) and 16 parameters are estimated. It follows that the degrees of freedom is small. An alternative estimation strategy is to model the investment function by estimating a single multivariate equation. It would have given more degrees of freedom, but a single equation model does not model the complex interrelationship in the economy, which I have tried to do in this analysis. Even though there are a lack of observations and degrees of freedom, the model has good statistical properties. The residuals of each equation are normally distributed and residuals are not heteroscedastic, meaning that the variance is constant. The residuals of each equation are not serially correlated with the exception of the residuals of the total gas consumption-equation (*GS*). These are correlated of first order and the correlation can inflate the *t*-values. Figure 33 shows that the model is forecasting fairly well both the total consumption and the investments for the period 2011-2013. Due to the lack of observations or, equivalently, lack of degrees of freedom, the forecast- horizon is maximum two years in this case. The observed price of gas is close to crossing the lower bound of the 95% confidence interval in 2012, which weaken to some extent the validity of the model.

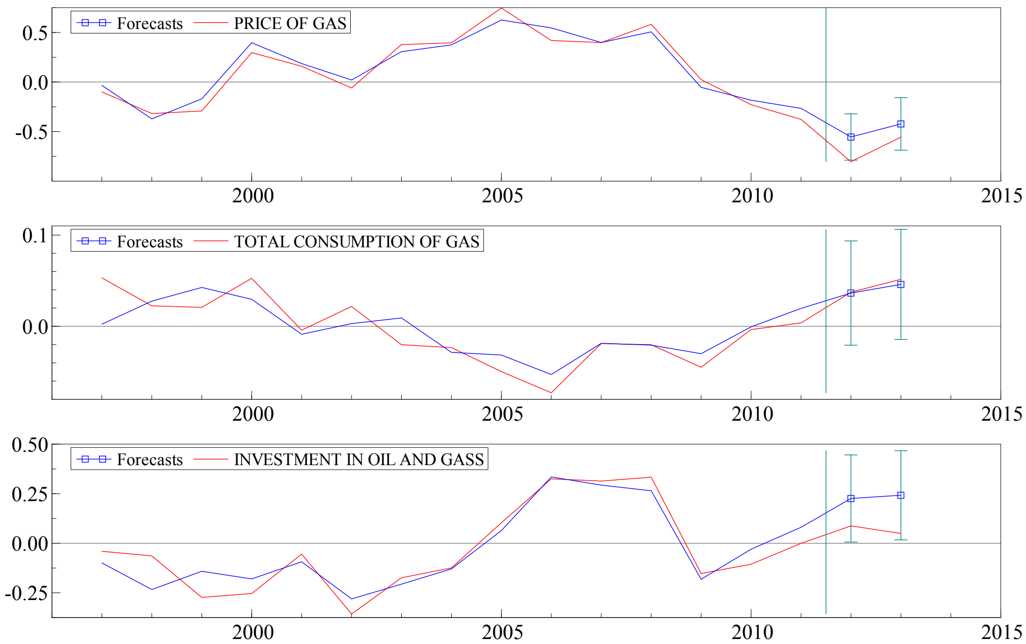

Figure 33: Observed data versus forecast, Model 2

The figure above shows the detrended, observed and estimated investment level in oil and gas and the numbers are logarithmically transformed. The estimation of the economic system has provided us with interesting information about how the variables are linked together and affecting each other. The result of the estimation shows that the model measures effects that are consistent with economic theory. However, the lack of observations makes it difficult to test and detect structural changes, which weakens the validity of the analysis. On the other hand it is consistent to use an equation system to analyze economic behavior in the oil and gas industry. Figure 19 shows that the investment is on a relatively stable, low level from 1992 to 2004 and then the investment starts accelerating. The increase was interrupted by the finance crisis in 2008. In 2010 the investments increases again but decreased in 2013. Figure 32 indicates that the model is able to predict the investment pattern during the period 2006-2010 when the shale gas and oil revolution took off in USA, and the estimated coefficient of the indicator variable (D_{SG}) supports the hypothesis that the shale gas is significantly mapped into the aggregated investment time series.

Chapter 8- Discussion

In this part of the thesis I will discuss the findings in the descriptive analysis and the statistical analysis, and see if they conclude in the same way and if they make sense from an economic point of view.

In the descriptive part of the analysis I have described several factors that might have an affect on investments in natural gas. What is important to be aware of is the possibility that even though the dependent variable (investments) and the independent variable (consumption, proven reserves, GDP, price of oil, etc) seems to be correlated from the figures that might still just be by chance. The question is whether there is just a statistical connection between the numbers or if there is actually a causational relationship between the variables. To explain investments in natural gas the latter is important. By using economic and financial theory I am able to analyze and understand the problem better.

I argue in chapter 3.2 and 6.2 that the high oil and gas prices during the 2000´s had an influence on the investment decisions being made during this period. The regression model also supports the close relationship between the price of oil and the price of gas. Yet, comparing the price of oil and the price of gas after 2009 one can see that they start to delink and the dependency starts to decrease. The price of gas remains low while the oil prices increased. Based on this, and the fact that the investment data contains *both* oil and gas, which can disturb the statistical analysis, I believe there is a valid reason to assume a somewhat weaker relationship between the price of oil and investments in natural gas after 2009 in the US. In figure 34 a rolling correlation between the price of oil (Brent) and the spot price of natural gas is presented on a 5, 6, and 7-year basis. Notice how the correlation coefficient (Pearson Correlation Coefficient) weakens, which supports the hypothesis discussed above. Notice also that the correlation is negative at the endpoint of the period, i.e. in 2011-2013.

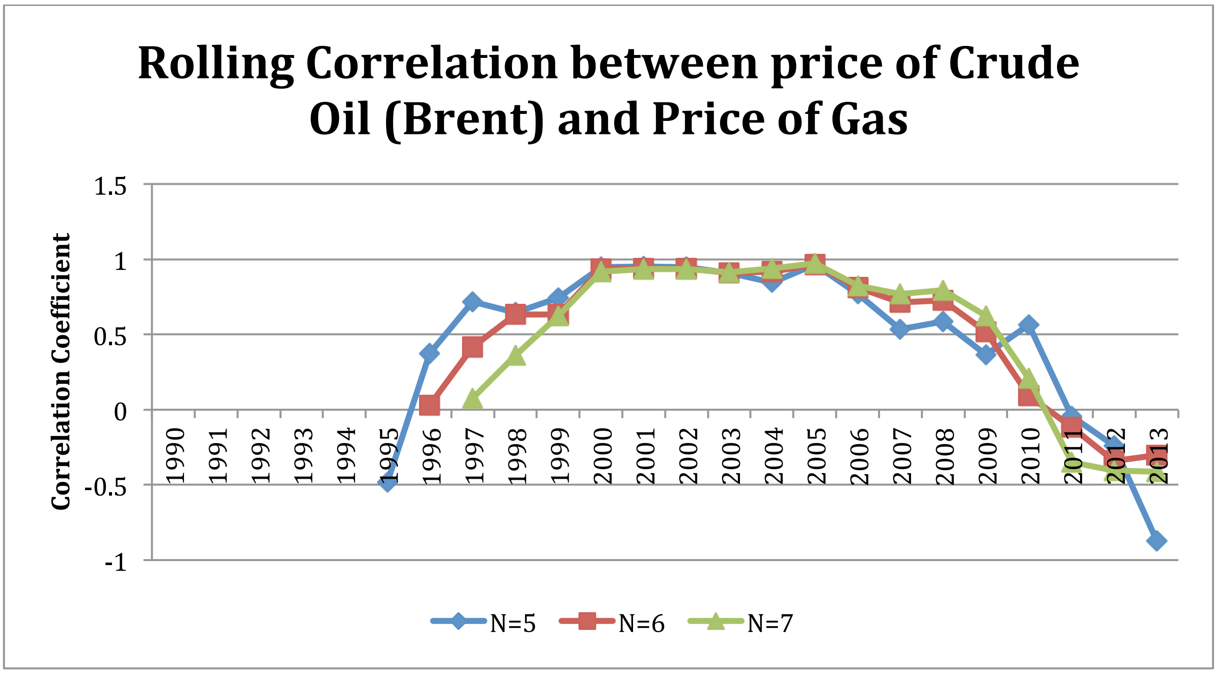

Figure 34: Rolling Correlation between the price of Brent and the Price of Gas

The US natural gas market has evolved greatly in recent years and gas is not just a byproduct of oil anymore. As pointed out earlier in this thesis, forecasts made by British Petroleum expect natural gas to become the number one energy source in the US by 2028.

The regression model finds a close relationship between proven reserves and investments. A 1 % increase in proved reserves increases investments by 0,74 %. This is an interesting, but not unexpected result. When resources are located it is natural to invest in order to extract these. In the term *proven reserves* lies an expectation of extracting the gas with reasonable certainty of economic viability. From rational expectations theory it is therefore natural to conclude that the amount of proven reserves will have an effect on investments. This conclusion is supported by figure 24 in the descriptive analysis, which shows that investments increased as proven reserves increased.

Model 2 also estimates the relationship between proven reserves and the price of gas. According to the model a 1 % increase in proven reserves decreases the price of gas by 2.41%. It is not unreasonable to assume that additions of proven reserves will affect the price of gas, but 2.41 % indicates a large effect. As stated earlier in this thesis the price of gas in the US is mainly determined by supply and demand, and an increase in proven reserves will increase the supply- side. However, investments must be made and the gas must be extracted *before* it can be sent out in the market. Not until the gas enters the market will it affect supply and thereby prices. The reason for the negative effect could be interpreted by using the theory of rational expectation (Lucas, 1972), which means that the market discounts the expected future effects to the present.

Another finding from the regression analysis is that both the level of production and the level of consumption of gas are affecting the price of gas, but neither of them is significantly different from zero. This result should be examined further. The market for natural gas in the US is more efficient and matured compared to other gas markets around the world, and it is also well known that supply and demand are the two fundamental forces that drive the price of gas in the US. The most important are shown in section 4.3.3. There are two important reasons that can cause these two variables to come out as not significant in the regression analysis. First, that the number of observations used in the analysis is few. This represents a source of uncertainty, because few observations weaken the statistical validity of the results obtained. The second deals with what is known as the "Identification problem" within econometrics. The theory behind this problem is beyond this thesis, but the problem arises when both supply and demand changes at the same time. The observed prices and quantities in the market are market- clearing points where supply is equal demand. If the demand curve is stable while the supply curve is shifting, then it is possible to identify the demand curve- and visa versa. In the real world it is usually not so easy, meaning that both supply and demand is changing at the same time. If this happens you don't know if the estimated relationship between price and quantity identify the supply or demand curve. This effect can distort the results obtained from the analysis. The equations I have specified and estimated are not motivated by modeling the market for natural gas, but rather to measure the effect of the shale gas industry on the aggregated investments in the oil and gas sector in the US. However, the specification of the second equation in model 2, which estimates the consumption of gas as a function of price and gross domestic product, is consistent with theory of consumption. Consumption of a commodity is dependent on its price, its substitution and income. Gross domestic product is used as an indicator for income.

Model 1 finds that shale gas production has increased investment levels by approximately 68 % compared to investments before 2006. Looking at the estimated investments in figure 32 one can see that there is a clear shift in the *level* in 2006. The rate of investments is the same as in the years before, but the shale revolution causes a jump in the level before continuing on in the same growth rate. As shown in figure 3 shale gas accounted for most of the increase in total production of natural gas in the US after 2006. From this one can draw the conclusion that shale activity also accounted for a large portion of the investments in the same period. This would explain this result in the model.

Model 1 estimated that the financial crisis in 2008/2009 decreased investments by 27 % before returning to normal growth. It is interesting to note that the financial crisis did not have a *lasting* or permanent impact on investments, only temporarily. Other favorable conditions such as for example increase in demand, growth in GDP and political regulations related to carbon emission standards are stimulating and providing companies with incentives to invest in natural gas.

A rather unexpected result from the analysis is the negative correlation between pipeline capacity and investments. From a logical point of view an increase in pipeline capacity infrastructure should stimulate growth in investments as it increases the potential customer base and thereby the potential of selling *more* gas. As argued in chapter six, the estimate might indicate that investment in *production* is already done and is history.

As expected the model finds that the price of gas and investments is positively correlated. A 1 % increase in the price of gas increases investments by 0,34 %. To illustrate the effect the price of gas has on investments I have included an example using the lowermost equation in the structural equation system. Changes in other influencing factors are ignored and the effect of a change in price is isolated.

Input variables:
$I_0 = 100$ (Investments at time T=0)
$P_0 = 5$ (Price of gas at time T=0)

$P_1 = 6$ (Price of gas at time T=1)

$I_1 = X$ (Investments at time T=1, unknown variable)

Using the lowermost equation from the structural equation system and canceling out all other factors gives:

$$I_t = 0.34P_{Gas,t}$$

To examine the change the following two equations must be used:

$$(1): lnI_0 = \beta lnP_0$$

$$(2): lnI_1 = \beta lnP_1$$

It then follows that:

$$lnI_1 - lnI_0 = \beta lnP_1 - \beta lnP_0$$

Which gives:

$$\ln\left(\frac{I_1}{I_0}\right) = \beta\ln\left(\frac{P_1}{P_0}\right)$$

Using in the input factors in the equation and solving for I_1 gives:

$$\ln\left(\frac{X}{100}\right) = 0.34 * \ln\left(\frac{6}{5}\right) = 0.0619$$

$$\frac{X}{100} = e^{0.0619} = 1.064$$

$X = 1.064 * 100 = \mathbf{106.4} = I_1$

The example shows that a price increase from 5 to 6 increases investments in the natural gas industry by about 6.20 %.

Another interesting result, even though not significant, is the relationship between investments and the interest rate of the 10 Year US Treasury bond. It shows that an increase in interest rates has a negative impact on investments. The weak statistical result could indicate that the long- term interest rate is at "critical" low level such that it has no effect on the investment decisions made by companies. The US central bank has gradually reduced the interest rate over many years- especially during the recession period in the wake of the financial crisis, and I cannot exclude the possibility that this is done because the market did *not* respond to previous changes. This argument supports the lack of a clear relationship between changes in the interest rate on US- Treasury Bonds and the investment behavior in the oil and gas industry. However, according to financial theory and from what is to be expected from a practical economical point of view, is that the higher the cost of borrowing capital for investments, the higher is the exposition to risk. An increased level of risk should in theory give the market expectations of higher return on the investment. If the discount rate increases, only the most profitable and promising projects will be realized.

Model 2 also estimates how the price of gas has influences the consumption of gas. The result is an inelastic relationship. A 1 % increase in price of gas only reduces consumption by 0.08 %. The result can be explained by the characteristics of the market in the period I have analyzed. I cannot exclude that the segments of the market are locked in due to the existing heating- technology and the ability to shift energy sources are limited in the short- term. This is an interesting result because the elasticity in this example tells us something about the ability consumers have of *substituting* gas for an alternative fuel. For example, look at "modern" residential consumers. Many homes are heated with gas, and changing source of fuel may create additional shifting costs (infrastructure needed to change fuel) that are disproportional to the extra cost´s associated with an increase in the price of gas. Residential consumers are therefore reluctant to change their fuel source in the short- term.

Chapter 9- Conclusion

In this thesis I have investigated how investments in natural gas are affected by various influencing factors and how the shale gas revolution, after its entry in 2006/2007, has affected investments. The word "revolution" characterizes the situation well because the extraction of gas and oil from unconventional sources such as shale rock changed, in a relatively short time period, not only the US natural gas and oil market, but also the global oil market. The background of the expansion was the expectation of realizing profits. A combination of high oil and gas prices and the development of effective technology boosted investor's expectation of realizing a high rate of return on investments in the shale gas industry.

In order to obtain necessary results I have used several methods. To understand the US energy market and the in particular the development of the shale gas industry I have used a descriptive approach. To get an idea of the role of the shale gas industry in the US energy market and to understand why the industry expanded, the analysis covers the period 1990 -2013. The energy market, regulations and environmental policy are described. Concepts from microeconomic theory are applied, for example in the section describing the US natural gas market. In addition, theory on consumption and production are applied in order to explain and understand the behavior of consumers of natural gas.

The thesis uses the Net Present Value formulae (NPV) as a conceptual framework in the analysis of the main factors that influence the willingness to investment in the natural gas industry, and especially the shale gas industry. The NPV- formulae includes the following set of economic entities; total investment costs, time horizon of the investment, interest rate (the price of capital or alternative return on capital), price of gas per period, production of gas per period and the production cost per period. The analysis covers the period 1990- 2013. This is a turbulent time, partly due to the fast expansion of the shale gas revolution in 2006/2007 and partly because of the financial crisis in 2009 that startled financial markets all around the globe. The investments are exposed to risk and the analysis also includes a discussion on risk management and a sub- section in the analysis analyses the exposition of risk by evaluating the gas price volatility in the period 1997- 2015.

The thesis also applies statistical methodology to explain how various factors influences investments in natural gas. Linear regression techniques are applied and two models are estimated. The objective of the first model, which is a single equation multivariate model, is to test whether the expansion of the shale gas industry has had any significant effect on the investments. The second model is a simultaneous equation model, which consists of three equations. The three equations explain the price of gas, consumption of gas and investments in natural gas, respectively. The thesis uses an equation system because it shows how a set of potentially influencing variables in the natural gas and oil market are hinged together and mutually influence each other.

The thesis shows that investments in natural gas are influenced by several factors. The descriptive part of the analysis shows that there is a positive co- variation between the price of oil and investments in oil and gas and also a positive relation between proven gas reserves and investments in natural gas. Analysis of daily spot price of gas for the period 1997- 2015 shows that the volatility is not constant over time. There are tranquil periods and there are volatile periods. The variation in the price shows that investments in gas are exposed to risk. The line- fitting development of the variance of the price shows a negative trend in the price- volatility over time. The estimated trend is not evaluated statistically and I will not draw a clear conclusion based on this model. However, investments have increased in the sub- period 2007- 2013 and the negative trend in volatility has, theoretically, had a positive effect on the risk averse investor´s willingness to invest in the natural gas industry.

The descriptive part of the analysis discussed some of the most likely factors and economic variables that influence investments in the natural gas industry. In the empirical part of the thesis a statistical model is estimated to quantify and test whether these factors have any significant affect on the investments in the natural gas sector. The estimated model is consistent with economical theory in the meaning that the sign of the coefficients does not contradict economic theory. The estimated model shows that growth in GDP has a positive effect on investments in the natural gas industry. The analysis also show that the price of gas has a direct positive effect on investments along with proven reserves, which are both positively correlated with investments in natural gas. The price of oil has also a positive effect on investments in natural gas. This is partly because gas is often a bi- product of oil and partly because the price of gas has historically followed the price of oil close. I will however add that since the price of oil and the price of gas has became more delinked following the shale revolution and the financial crisis in 2009, it is reasonable to assume a weaker correlation between the price of oil and investments in natural gas after the decoupling of the price between these two commodities. The analysis also indicates that investments are negatively correlated with the cost of capital, which is measured in the model by the interest rate on the 10- year US Treasury bond. The estimated equation for the total consumption of gas shows a rather inelastic relationship between the price of gas and demand for gas. In practice this means that consumers of natural gas does not change their behavior much if the price of gas changes marginally.

I find that the shale gas revolution has had a significantly positive impact on investments since its occurrence in 2006/2007. The revolution has changed the natural gas landscape in the US in many different ways. Investments are driven by the vast amount of resources that technological development (horizontal drilling and hydraulic fracturing) in recent years has unlocked, and as the development continuous, higher efficiency and lower marginal costs will continue to drive natural gas extraction and investments. However, the expansion will only continue as long as the net present value of the investment is positive. In the wake of the expansion of the shale gas industry, the supply of oil from shale rock reservoirs has increased significantly and taken market shares from and provoked traditional suppliers of oil from OPEC- countries in the Middle East. The expansion of the petroleum sector in the US has to some extent destabilized the global oil market. The global price of oil fell from over $100 per barrel in June 2014 (Brent) to about $60 in December 2014. The low oil price has made many of the US shale gas and oil projects unprofitable and the possibility of reduced production is present as a result of this development.

Based on my previous arguments it is also likely that political regulations with respect to greenhouse gas emissions also have affected investments in a positive manner. The

Clean Power Plan, launched in June 2014 by the Obama administration, is one of the most recent examples of the US government taking actions to reduce the emission of CO_2 in the future. Investments in cleaner fossil fuels, such as natural gas, are needed to reach emission- goals. However, local pollution related to shale activity might put restrains on extraction.

Chapter 10- Weakness

Even though the models presented in chapter 7 are based on few observations, they have relatively good statistical properties. The residuals are normally and independently distributed, except for the autocorrelated residuals in the estimated model for the consumption of natural gas. It is also promising that the sign of the coefficients corresponds with economic theory. However, with 22 observations and 16 parameters estimated, the degrees of freedom are few, and it is not possible to utilize large sample properties. Large sample properties mean that the estimated values converge to the true value of the population with increasing sample size. In addition, lack of observations makes it difficult to adjust autocorrelation, detect structural changes and do valid forecasting. An alternative estimation strategy is to model the investment function as a single multivariate equation. The motivation behind using a simultaneous equation system approach is that the equation system models the interaction pattern and feedback effects between the variables in the economy more profoundly compared to a single- equation approach, which operates with a one- sided direction of the causality.

In the empirical analysis I have utilized the interest rate of the 10- year US Treasury Bond to reflect the cost of capital. It could be questioned whether the interest rate on the long- term bond is a good measure for the cost of capital. The lifetime of shale gas wells varies considerably, depending on the drilling area´s properties. In some cases it might be more appropriate to use a shorter time horizon than 10 years, and in others, a longer time horizon. This means that it for some investment projects might be more appropriate to use the a *shorter* maturity date for the US Treasury Bond to reflect the cost of capital, while others should use a *longer* maturity date. On the other hand, I believe that all types of bonds share the downward trend of the interest rate in the money- market during the period analyzed in the thesis.

In addition, it must be noted that investments are determined by many variables and the connection between them is complicated and intricately. This thesis does not analyze all factors that might have an influence on the willingness to invest in natural gas. Analyzing other variables and their causational relationship with the willingness to investments in natural gas might provide even clearer understanding on the topic. An extension of the analysis can for example look more closely on how political signals of a more strict environmental policy has and will influence investments in the US natural gas industry in the future. One can also look more thoroughly into how an expanding renewable energy sector might affect future investments in natural gas.

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