NORGES HANDELSHØYSKOLE

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The impact of natural gas exports from the U.S. to Europe

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NORGES HANDELSHØYSKOLE

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Abstract

This thesis analyses the quantitative impact of potential liquid natural gas exports from the U.S. to the European market. I establish a simple, analytically transparent and tractable framework for supply and demand. In order to get quantitative estimates I combine this analytical framework with estimated demand and supply elasticities from existing literature. I find that exported quantity from the U.S. market will be approximately 20 % of produced quantity, and that domestic price will increase with approximately 11 %. In Europe the price will decrease by almost a fifth. I also find the future price and traded quantity to be mostly affected by elasticities in the European market, not the U.S. market. Finally, I find the prices in the futures market to adjust in the same pattern as this analysis, but I cannot identify that this is caused by expected LNG exports.

Preface

This thesis is written as a part of my Master of Science in Economics and Business Administration at the Norwegian School of Economics and Business Administration (NHH). During the last year I have developed an interest for the markets of natural gas through two internships with a Norwegian oil and gas company. In addition, I consider natural gas to become an important factor in the environmental debate, which I find very interesting. During my exchange program in Washington D.C., my professor made me realize that I need to find a subject that I could become an expert in, and the energy sector was a natural choice. It is necessary to ascertain that I am not an expert on energy, but I hope to become one during the next forty years.

During the work with this thesis, I have realised that the market of natural gas is very complex. I hope that the simple and powerful model presented in this thesis could contribute in understanding the questions related to global trade of natural gas.

Finally, I have to thank my advisor Espen Henriksen for his accessibility and his helpful and concrete feedback.

Eirik Sønstebø

Contents

1 Introduction

How will export of Liquid Natural Gas (LNG) from the U.S. affect the European and the U.S. natural gas market, regarding price and quantitates? The U.S. has recently been through a "shale gas revolution[1]", and could in 2015 be ready to export LNG (McAllister and Ayesha 2012).

The international market for natural gas is interesting, both in an international context and especially for a gas producing nation as Norway. Therefore it is relevant to study the impact of potential LNG exports from the U.S. to Europe. It will also be relevant to look at the U.S. market and how the development of LNG export could affect the historically low domestic price (U.S. Energy Information Agency, 2012). It will be relevant to identify factors that are important when the new price and traded quantity is established. It will also be relevant to make a comparison of the predicted price with the prices in the future market to identify at which extent the market has taken US export into account. The decision to allow for LNG export is not made. The U.S. government will make their decision based on the question; "is LNG export in the public interest?" It will be interesting to see if the outcome of this thesis could contribute to answer that question.

The framework is easily understood and analytically transparent. I use a static, parsimonious model for supply and demand with ensuing elasticities. The idea is simple; there are two markets with two equilibriums. The two markets are merged, and based on the slope of their curves, a new price is established where the price difference between the two markets equals the transportation costs.

The thesis is organised as follows. In the second chapter I will introduce the natural gas market and the backdrop for the thesis. In the third chapter, the underlying theory will be presented together with the model used to calculate the equilibrium. In chapter four, the actual data for the natural gas markets will be established. In chapter five, the numbers will be used in the model, and the future equilibrium will be established. In chapter six there will be an comparison of the results with the current prices in the

[1] The Shale gas revolution describes the increased production of natural gas from shale rock formations in the U.S. A brief introduction will be given in chapter two.

futures market, and a comparison with other studies. In chapter seven there will be concluding remarks.

2 The natural gas market

The natural gas market is of major importance. In the global energy mix, 23.7 % is natural gas, and this number is increasing(British Petroleum 2012). The usage of natural gas is shared with approximately one third in each of the following sectors, the residential/commercial sector, the industrial sector and the power generation sector.

The transportation cost of natural gas is high, and this has contributed to the absence of an integrated world gas market. Instead, there are three regional markets with different prices; (i) Europe including Russia, (ii) Asia and (iii) North America (International Energy Agency 2012). This leads to major price differences. In 2011, the price in Japan, European Union and the U.S. where respectively 14.73, 10.61 and 4.01 USD/mmBTU. The potential arbitrage opportunities between the markets have made investors attracted to LNG.

In the beginning of this millennium, the U.S. market experienced a shortage of natural gas. LNG suppliers focused on bringing natural gas to the U.S. market. It was built 12 import terminals to exploit the opportunity of supplying the expensive American market (Department of Energy 2012a). This turned out to be a bad investment. So far in 2012, the utilization of these terminals have been around 2.8 percentage (Department of Energy 2012a; International Energy Agency 2012). This is due to the discovery of shale gas, or the "shale gas revolution".

Shale gas is natural gas trapped in small pockets in shale formations. It is difficult to extract, but innovations such as horizontal drilling and hydraulic fracturing have made shale gas commercially viable. The discovery of shale gas was done almost two hundred years ago, but the development of a shale gas industry started in the 1970's with support from federal government (Begos 2012). In 1996, shale gas wells produced around 1.6 % of domestic production. Today the shale gas production provides around 20 percentage of domestic U.S. production, and the U.S. Energy Information Agency is

predicting the shale gas to provide around 46 percentages in 2030(U.S. Energy Information Administration 2012a). From being an importer of natural gas, the shale gas has turned the U.S. into a potential exporter.

There are currently several export projects, and one of them has started construction with scheduled start in 2015(Department of Energy 2012a). But it is not certain that this facility will be accompanied by others. By law, export to nations with a free-trade-agreement (FTA) with the U.S. is in general approved. However, these countries are not large consumers of LNG, and the desired markets for LNG exporters are non-FTA countries. The U.S. government are currently working with the determination of whether or not to allow for further exportation to non-FTA-countries.

The resistance of energy exportation in U.S. is strong. Energy independence has been the goal for many American presidents, and the idea of exporting domestic produced energy is foreign. The cheap American gas also gives manufacturing industry a competitive advantage, and job creation is important in the U.S. today. There are many stakeholders, and the final decision will be both criticized and recognized independent of the outcome. The Department of Energy is expected to make their final decision in the beginning of 2013. Their goal is to identify at which extent the LNG export is constituent with the public interest (Department of Energy 2012b). They have ordered both a microeconomic study, and a macroeconomic study. The first study was released in January 2012 and the conclusion was not good for future LNG export (U.S. Energy Information Administration 2012c). They study predicted a price increase between 14% and 36 %. Now they are waiting for the release of a macroeconomic study, which is expected to be release before 2013.[2] Based on these two reports, the government will make a decision in whether or not to allow for further LNG exports.

The European market is fragmented, and consists of many hubs. The market is highly dependent on imports, and approximately 84 % is imported. There is a highly developed

[2] This study was released late December, but due to the deadline of this thesis, result from this study is not a part of this thesis.

pipeline network in Europe and 19 import terminals for LNG. The utilization of the LNG import plants is about 50 %, so additional LNG from the U.S. would be welcome.

3 Theoretical Framework

There are many ways to model a large market. Most common is making a dynamic and complex model with detailed input data from production, distribution, infrastructure and consumption. Due to the detailed level of these models, it is difficult to understand how the results are found. The framework for this thesis is a parsimonious model which is simple and powerful. The model is based on supply and demand, and the elasticities of these curves. The next section will give a detailed introduction to elasticities.

Elasticities

Elasticities describe the market participants' ability to change quantity demanded or supplied as a result of a change in another variable. A briefing to the basic theory about elasticities could be found in Appendix B.

In a competitive market supply equals demand. Supply and demand are described with curves which illustrates the relationship between price and quantity. By differentiating the curves, we find the slopes. But for us, it is interesting to know how the slopes relate to an absolute change in the variables. While a linear curve always have the same slope, the percentage change in X compared to Y would differ along the curve. When adjusting for absolute change, we get elasticity.

In mathematics elasticity is described as the relative change in output with the respect to the relative change in input. A function y = D(X) describes the relationship between x and y. When x is changing from x to x+Δx, the absolute change is Δx while the relative change is Δx/x (Sydsæter 2000). The absolute change in y is Δy = D(x + Δx) – D(x), while the relative change will be

$$\frac{\Delta y}{y} = \frac{D(x + \Delta x) - D(x)}{D(x)}$$

The relationship between the relative change and the absolute change will be

$$\frac{\frac{\Delta y}{y}}{\frac{\Delta x}{x}} = \frac{x}{y}\frac{\Delta y}{\Delta x} = \frac{x}{D(x)}\frac{D(x+\Delta x) - D(x)}{\Delta x}$$

This expression gives us the elasticity of a defined change in x, but we want a more general expression of the elasticity of the function. We know from the difference quotient or the Newton quotient that $(D(x + \Delta x) - D(x))/\Delta x$ equals $D'(x)$ when Δx is infinitesimal (Sydsæter 2000). This gives us the general expression of elasticity,

$$E\ f(x) = \frac{x}{f(x)}\ f'(x)$$

In economics, elasticity is defined as "Percentage change in one variable resulting from a 1-percent increase in another" (Pindyck and Rubinfeld 2009). Instead of using the derivate of the function, the elasticity is approximately the percentage change in X divided by the percentage change in Y, assuming that change is close to infinitesimal.

$$E_p = \frac{x}{f(x)}\ f'(x) \approx \frac{\%y}{\%x} = \frac{\Delta y/y}{\Delta x/x} = \frac{x}{y}\frac{\Delta y}{\Delta}$$

Source: (Pindyck and Rubinfeld 2009)

The general expression for elasticities describes the relationship between two variables. In this thesis, we are most interested in the relationship between quantity and price. We substitute x and y with quantity and price, noted Q and P, and we get price elasticity. Price elasticity is described with the following equation.

$$E_p = \frac{P}{Q}\frac{\Delta Q}{\Delta P}$$

Elasticity of price is found by multiplying price divided by quantity with quantity change divided by price change.

We separate between inelastic and elastic curves (Pindyck and Rubinfeld 2009). [3] If a supply curve is elastic, the percentage change in volume will be larger than the percentage change in price. If a supply curve is inelastic, the percentage change in volume would be less than the percentage change in price.

$$E_p \frac{Q}{P} = \frac{\Delta Q}{\Delta P}$$

Q and P are fixed, and indicate where we are at the supply curve. When the right side of the equation, expressed with ΔQ and ΔP increases, so does the elasticity on the left side of the equation.

Elasticity of demand will most times be negative. [4] As price increases, the demanded volume will decrease. If a demand curve is elastic, the percentage decrease in demanded volume would be greater than the percentage increase in price. If the demand curve is inelastic, the percentage decrease in volume would be less than the percentage increase in price.

$$E_p \frac{Q}{P} = \frac{\Delta Q}{\Delta P}$$

The equation is the same, but the elasticity would be negative. This means that the percentage decrease in volume grows compared to percentage increase in price as the elasticity grows.

An important concept when discussing elasticities is time. A supplier's ability to increase or decrease production volumes differs in the long- and the short run. In the same way, the demanders' ability to consume more or less differs in time. The expression "long" and "short" is not precise, and Pindyck and Rubinfeld (2009) defines it as more or less

[3] Elastic curves have a magnitude greater than one, inelastic curves have a magnitude less than one. It means that if supply is elastic, volume would increase with more than one percentage if price increase with one percentage. If it is inelastic, supply would increase with less than one percentage.
[4] There are Giffen and Veblen goods (Pindyck and Rubinfeld 2009), which have positive demand curves. We will not look into these kinds of demand curves.

than a year. A more extensive explanation of what affects elasticities and how this change in time is found in Appendix B.

Establishing framework for modelling integrated markets

We want to know how we can use elasticities to predict outcomes in markets that are about to merge. In the first place, both markets have established equilibriums, where prices and quantities are determined by the supply and demand curves in the isolated markets. When these markets are merged, a new equilibrium is established. For this to happen, an arbitrage opportunity is necessary. An arbitrage opportunity occurs when the price difference between the two markets is bigger than the cost related to bringing the good from one market to the other. If there is no arbitrage opportunity, there will be no trading between the markets, and the equilibriums are unchanged. If there is an arbitrage opportunity, the market with the lower price, market L, will reallocate some of its supplied quantum to the market with the higher price, market H (Medlock 2012). Since the consumers in market H have an opportunity in market L, the demand will increase in market L. Producers in market L will see an opportunity in market H, and supply in market H will increase. Price in market L will increase and price in market H will decrease (Medlock 2012). The price will stabilise when the price in market H equals the price in market L plus the cost transportation costs. [5]

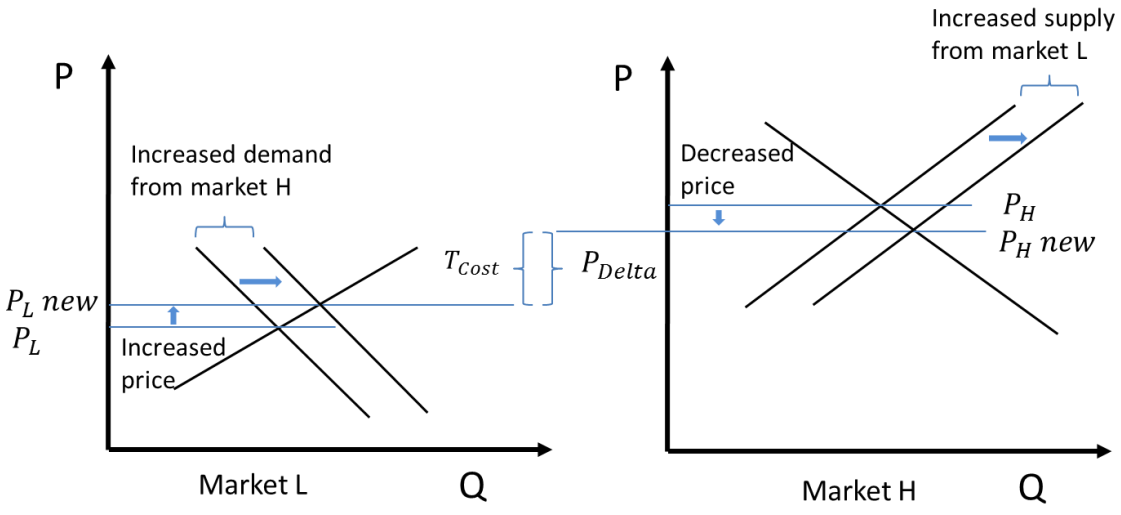

Figure 1: Market L and Market H equilibrium with elastic supply- and demand curves
Source: (Medlock 2012)

[5] Transportation costs includes all cost related to bringing the good from one market to the other. This includes administration, infrastructure etc.

We know that the price will stabilise between P_L and P_H. The elasticities of the demand and the supply impacts the outcome, as illustrated by Figure 2. The initial equilibriums are equal, but due to the change of elasticities, the new equilibrium is completely different.

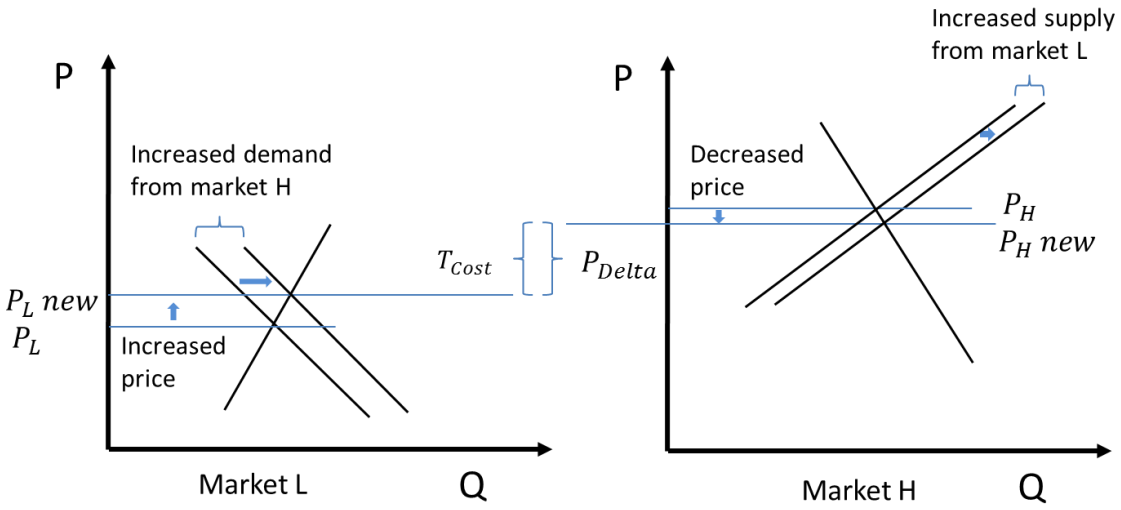

Figure 2 Market L and Market H equilibrium with inelastic supply- and demand curves
Source: (Medlock 2012)

We want to establish a framework making it possible to calculate the new equilibriums based on the elasticities of the supply- and demand curves. We also want to calculate how this influence production and consumption in the isolated markets.

Equilibrium model

Markets are in equilibrium, and we know the elasticities of supply and demand. Elasticities describe the slope of the curve when the change is infinitesimal, but in our model we assume that elasticities also could describe larger changes. Market L and market H have equilibriums, noted (Q_L, P_L) and (Q_H, P_H). The elasticities are noted E_L^S, E_L^D, E_H^S and E_H^D. When know that exported quantity is equal to imported quantity. We also know that the price will stabilise at a point where price in market H equals price in market L plus transportation costs. In market L, production minus consumption will equal exported quantity. In market H, consumption minus production equals imports. We also know that export will equal import.

$$(Q_L + \Delta Q_L^S) - (Q_L + \Delta Q_L^D) = (Q_H + \Delta Q_H^D) - (Q_H + \Delta Q_H^S)$$

$$Export = Import$$

We are using the elasticity equation to describe the change in quantity

$$E_p = \frac{P}{Q}\frac{\Delta Q}{\Delta P} \qquad \Delta Q = \frac{Q}{P} * \Delta P * E_p$$

Replacing all ΔQ with the ensuing elasticity equation gives us the following

$$\left(Q_L + \frac{Q_L}{P_L} * \Delta P_L * E_L^S\right) - \left(Q_L + \frac{Q_L}{P_L} * \Delta P_L * E_L^D\right)$$
$$= \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^D\right) - \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^S\right)$$

The new price in market H will equal the new price in market L plus transportation costs

$$(P_H + \Delta P_H) = (P_L + \Delta P_L) + T_{cost}$$

The potential arbitrage opportunity could be noted as price in market H minus price in the market L minus transportation costs

$$P_H - P_L - T_{cost} = \pi_{arb}$$

Rearranging the two previous equations

$$P_H - P_L - T_{cost} + \Delta P_H = \Delta P_L$$
$$\Delta P_L = \Delta P_H + \pi_{arb}$$

Replacing ΔP_L with $\Delta P_H + \pi_{arb}$ in the export-equals-import equation

$$\left(Q_L + \frac{Q_L}{P_L} * (\Delta P_H + \pi_{arb}) * E_L^S\right) - \left(Q_L + \frac{Q_L}{P_L} * (\Delta P_H + \pi_{arb}) * E_L^D\right)$$
$$= \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^D\right) - \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^S\right)$$

Solving for ΔP_H

$$\Delta P_H = \frac{P_H * Q_L * \pi_{arb} * (E_L^S - E_L^D)}{P_L * Q_H * E_H^D - P_L * Q_H * E_H^S - P_H * Q_L * E_L^S + P_H * Q_L * E_L^D}$$

With ΔP_H we can find new prices and quantities:

$$\text{New price in market H} = P_H + \Delta P_H$$
$$\text{New price in market L} = P_L + (\Delta P_H + \pi_{arb})$$

To find quantity exported/imported we can use one of the equations describing import or export

$$\text{Volume exported} = \left(Q_L + \frac{Q_L}{P_L} * (\Delta P_H + \pi_{arb}) * E_L^S\right) - \left(Q_L + \frac{Q_L}{P_L} * (\Delta P_H + \pi_{arb}) * E_L^D\right)$$
$$\text{Volume imported} = \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^D\right) + \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^S\right)$$

Using the equations calculating exported and imported volume, we could find the new consumed and produced quantity in the two markets

$$\text{Quantity consumed in market H} = Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^D$$
$$\text{Quantity produced in market H} = Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^S$$
$$\text{Quantity consumed in market L} = Q_L + \frac{Q_L}{P_L} * \Delta P_L * E_L^D$$
$$\text{Quantity produced in market L} = Q_L + \frac{Q_L}{P_L} * \Delta P_L * E_L^S$$

With these equations, we would be able to predict the outcome when two markets are merged together. The necessary input is traded quantity and price in the two markets, and the elasticities of supply and demand. The next step will be to establish these.

4 Estimations of demand curves, supply curves and elasticities

We start with a research survey to find relevant elasticities, before we determine the price and quantity in the two markets. The reason for doing a research study instead of an own survey, is the amount of time and resources needed to calculate the elasticities of supply and demand.

Results from other studies

The easiest way to calculate elasticities is to make an equation with volume as a product of price (Dahl and Duggan 1996). The failure to take into account the simultaneous determination of supply and demand often makes these models inaccurate. To compensate for this, other variables have been tried. Changes in exploration of natural gas related to price is an example (Pindyck 1979).

Studies of energy elasticities have been done since Alfred Marhsall developed the theory of supply and demand in 1890. Most of these studies have been done on aggregated energy and oil, but still an extensive amount has been done on natural gas. Dagher (2012) claimed the total number of studies on natural gas elasticities to be 182 in 2007. The results are ambiguous, and there is no consensus apart from the fact that elasticity of supply is positive, and elasticity of demand is negative. On the demand side, elasticity spread from 0 to -48.17, with the majority between 0 and -2.0. On the supply side the elasticity spread from 0 to 5.25, with the majority between 0 and 2. Most studies are done on long-run elasticities, but some of the studies describe the short-run elasticities. In general, the findings are that short run elasticity is highly inelastic, especially in the residential sector.

I will continue with describing how the studies on elasticities have been done and their results. Then I will discuss what affects the elasticities, and based on quantitative analysis, and the qualitative discussion, I will establish a base scenario with reasonable variations.

The different approaches to estimating elasticities

Cross section analysis:

The cross-section analysis is looking at different markets at one time, describing the differences using several variables. Pindyck (1979) did a cross section analysis, and found the elasticity of demand for natural gas to be between -1.4 and -1.7 and the elasticity of supply to be between 1.17 and 1.5. This could be interpreted as long run elasticities. Field and Grebestein (1980, 207) is claiming that cross-section analysis reflects "long run adjustment possibilities, while time series data yield short run estimates."

Dynamic time series analysis

The dynamic time series analysis is using observation over a period of time. The demand is described as a function of GDP, price of gas and heating degree days.[6] When using time series, it is common to use lagged variables in the regression. This could result in correlation between these variables and the gross error term, which causes the least square estimator to be biased and inconsistent (G. Liu 2004). This could be avoided using an instrument variable method or a generalized method of moments (G. Liu 2004). It is common to estimate the equation in a double log-form (Bentzen and Engsted 1993). Griffin (1979) used a pooled dynamic model for 18 OECD countries and found a short run elasticity of -0.95 and a long run elasticity of -2.61. He also did country specific analysis, these ranges from -23.7 to -1.67.

Panel data analysis:

The panel data analysis combines the two approaches above, using a cross-section time-series data set with observations from a group of countries over a period of time (G. Liu 2004). Balerstra and Nerlove (1966) indicated long-run demand elasticities of -0.63. They used the relative price of natural gas and the total new requirements of all types of fuels to calculate demand. They also believed that price changes not induced many costumers to change habits, once deciding to use natural gas. Therefore, the new demand would be decided by consumers in the planning stage. They also argue that the short-run elasticity is very low, close to zero. Brooks (1975) used a similar model to

[6] Definition: "A measure of how cold a location was over a period of time, relative to a base temperature" (U.S. Energy Information Administration 2012b)

calculate elasticities. He found long-run supply between 0 and 5.2, and long run demand between -0.4 and -48. The reason to this wide range is individual calculations for each of the American states. Maddala et al. (1997) found the short run elasticities in the U.S to range from -0.092 to -0.177 and long run elasticity to range from -0.239 to -1.358. Nilsen et al. (2005) used a dynamic log-linear model to do a panel data analysis, and tried different estimators. The ones performing bests revealed short run elasticities of 0 to -0.3, and in the long run 0 to -1.5. Statistics Norway (SSB) estimated demand elasticities in Europe and found it to be between -0.07 and -0.1 in the short run and between -0.24 and -0.36 in the long run (G. Liu 2004). The NEMS-RFF model developed by the U.S. Department of Energy has been used to project supply elasticities for 2030. Dependent of the volumes of shale gas reserves, the supply elasticity range from 0.62 to 1.58 (S. Brown and Krupnick 2010; S. P. A. Brown, Gabriel, and Egging 2010).

It is established that using a panel data set is more accurate than using cross-section analysis or time-series data alone (G. Liu 2004). Therefore most of the analysis is done using this approach. In table 1 and table 2 all the short and long run elasticities are listed.

Europe				The U.S				
Demand		Supply		Demand		Supply		
Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Source
				-0,30	-0,15			Medlock, 2012
				≈0		0,58	0,59	Balestra & Nerlove 1966
-0,10	-0,067			-0,10	-0,067			Lui 2004, SSB
-0,30	0,00							Nielsen et Al 2005
				-0,18	-0,09			Madalla et al, 1997
-0,95				-0,95				Griffin 1979
Average				Average		Average		
-0,39				-0,35		0,59		
Without Griffin				Without Griffin				
-0,12				-0,15		0,59		

Table 1 Short run elasticities

World Wide				Europe				The U.S				Source
Demand		Supply		Demand		Supply		Demand		Supply		
Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	
				-1,70	-1,40							Boots, 2004
										1,52		Medlock, 2012
-3,06	-0,05											Medlock, 2011
				-0,85	-1,00							Holz et al 2004 & Holz 2009
								-0,63		0,58	0,59	Balestra & Nerlove 1966
-0,75	-0,25			-0,75	-0,25							de Joode et Al, 2009
-1,70		1,17	1,5	-1,70	-1,40							Pindyck, 1979
-0,75	-0,25											Egging et Al, 2010
				-0,36	-0,24			-0,36	-0,24			Lui 2004, SSB
								-48,13	-0,46	0,04	5,25	Brooks, 1975
				-1,50	0,00							Nielsen et Al 2005
								-1,36	-0,24			Madalla et al, 1997
				-2,61				-2,61				Griffin 1979
Average		Average		Average				Average		Average		
-1,06		1,34		-1,17				-5,73		1,58		
Without Pindyck 1979				Without Pindyck 1979 and Griffin 1979				Without Brooks 1975, Griffin 1979 and B&N 1966				
-0,85				-0,81				-0,55		1,52		

Table 2 Long run elasticities

Determination of relevant elasticities

In order to determine relevant elasticities, it is necessary to present general arguments that affect both EU OECD supply and demand and U.S supply and demand. Then I will look at the elasticities one by one, and determine its size.

The demand elasticity could be affected by political decisions addressing the challenges related to global warming. One thing that often is mentioned when discussing how to reduce prevent global warming is the establishment of a global price on carbon emissions. Most people will argue that this is farfetched, and that we would not see such an agreement the next 40 years. But this would definitely affect the elasticity of natural gas. Natural gas has lower carbon emissions then other fossil fuel. Brown, Gabriel and Eggings (2010) estimation shows that if implementing a cap-and-trade system to carbon emissions, the demand elasticities of natural gas would significantly increase.

In the total energy mix, natural gas is accountable for about 27 % in the U.S. and 33 % in the European market. When this rate is changing, Medlock and Hartley (2005) argues that as the rate approaches 0 or 1, the elasticity gets less elastic. This is not a problem in our analysis as long as exported volume from the U.S. is comparatively small.

An important argument relates to the mix of end-users. For natural gas consumption, we split the end-users in three sectors; Industrial, power generation and commercial/residential. As seen in table 2, it is also one sector called *energy own use and transformation.* This consumption is not insignificant, but due to lack of knowledge about "energy own use and transformation" elasticities, I ignore this.

	OECD Europe 2009			OECD Europe 2010	
Total consumption	529 880	100 %		563 048	100 %
Energy own use and transformation	25 840	5 %		28 177	5 %
Power generation sector	153 827	29 %		162 184	29 %
Residental and commercial	198 700	37 %		207 078	37 %
Industrial	151 513	29 %		165 609	29 %
	USA 2009			USA 2010	
Total consumption	646 788	100 %		673 133	100 %
Energy own use and transformation	56 316	9 %		57 719	9 %
Power generation sector	194 589	30 %		208 988	31 %
Residental and commercial	222 656	34 %		222 278	33 %
Industrial	173 227	27 %		184 148	27 %

Table 3 End-users, OECD Europe and U.S.
Source: (International Energy Agency 2012)

It has been done some research on the difference between the elasticities in the different sectors. Pindyck (1979) revealed a residential elasticity to be -1.7, while the industrial elasticity to be between -0.41 and -2.34. B. Liu (1983) found higher elasticity in the residential sector than the industrial sector. This is later supported by both G. Liu (2004) and Porter and Kamerschen (2004). On the other hand, Medlock (2011) calculates the elasticity to be just slightly higher in the residential/commercial sector than the industrial sector for the U.S. De Joode (2009)and Boots (2004) have done studies on state/country level which does not support the thesis about higher elasticity in the residential/commercial sector.

Contrary to the discussion above, it is proved that the elasticity of the power generation sector is highly elastic (S. P. A. Brown, Gabriel, and Egging 2010; de Joode and Özdemir 2009). The possibilities of changing between natural gas and other fuel types have already been revealed in the U.S. where coal fuelled power plants have been substituted with natural gas power plants. The same is observed in Germany. When the price of natural gas is high, the power plants ramp down their production.

To summarize, the elasticity of the power generation sector is higher than the residential/commercial and the industrial. It is not empirical evidence to say for sure whether the residential/commercial or the industrial sector has the higher elasticity, so I will leave that out of the discussion.

U.S. supply elasticity

Historically, there have been a strong link between the crude oil supply and the natural gas supply (Krichene 2006). The price elasticity of supply was almost insignificant compared to the cross-price elasticity with oil. This is because natural gas is a by-product at many crude oil production sites. When oil is produced, natural gas is often a part of the hydrocarbon mix that is extracted from the well. Traditionally, this by-product has been burned on site, or flared. But due to environmental regulations and increased prices, producers have stopped treating the by-product as waste, and developed necessary infrastructure to transport the gas to the market. This has caused the elasticity of natural gas to be strongly linked to development of oil production. But during the latest five year, the development of hydraulic fracturing have caused the natural gas production to be more independent from the oil production (Ebinger et al. 2012). There are now many wells which only produce dry gas. This is important when looking at the U.S. Supply curve.

Shale gas and tight oil uses the same rigs to drill for hydrocarbons. In the last five years the relative difference between the price of oil and natural gas has increased significantly in the U.S. In 2008 the relative difference between the price of crude oil and natural gas was 11.2, and in 2011 it was 23.6. This has caused drilling of new wells to move from shale gas wells to tight oil wells (Dove 2012; Ebinger et al. 2012). Shale gas has a strongly hyperbolic production curve. This means that the first year, the well is producing about 50 % of the total volume the well is going to produce in its 20 year lifespan (Leeuwen 2012). Due to the shift from shale gas to tight oil drilling, the production from dry gas wells will decrease. This could make the supply curve less elastic. But tight oil production also produce natural gas, and natural gas production from unconventional resources in the U.S. are expected to increase regardless if the rigs drill for tight oil or shale gas (Leeuwen 2012). Bottom line is that we could expect the

supply curve to become more elastic if the relative price between crude oil and shale gas is reduced.

After the shale gas revolution, there has been an extensive focus on the environmental problems related to fracking. The movie Gasland (Fox 2010) made the average American aware of potential dangers related to fracking. Environmental friendly groups like the Sierra Club have also showed a high resistance against fracking. They attack the regulatory process, and files comments at processes both with the Department of Energy (DoE) and the Federal Energy Regulatory Commission(FERC) (Department of Energy 2012a; Sierra Club 2012). This political noise could affect politicians in congress to change legislation regarding fracking. The Environmental Protection Agency (EPA) is doing a major study of hydraulic fracturing and its potential impact on the drinking water resources (Environmental Protection Agency 2012) This study is expected to be finished in 2014, but there will be released a first progress report in December 2012. [7] This could delay or in worst case stop further fracking, and would make the supply less elastic.

The studies done on U.S. supply elasticities indicate that the elasticity is somewhat less than 1. But the latest studies such as Medlock and Brown indicates higher elasticities. In a study from the Baker Institute, the elasticity after the shale gas revolution has risen over five fold, from 0.29 to 1.52(Medlock, Jaffe, and Hartley 2011). Deloitte Market Point have made a study using the same model as the Baker Institute, and in their study, they do not publish any elasticities, but they draw a cost curve for the remaining reserves of natural gas (Deloitte Market Point 2011). The graph on the next page illustrates that increased production could happen at a slightly higher cost level than today.

[7] This is not released 2012.17.06. Could be postponed to the beginning of 2013.

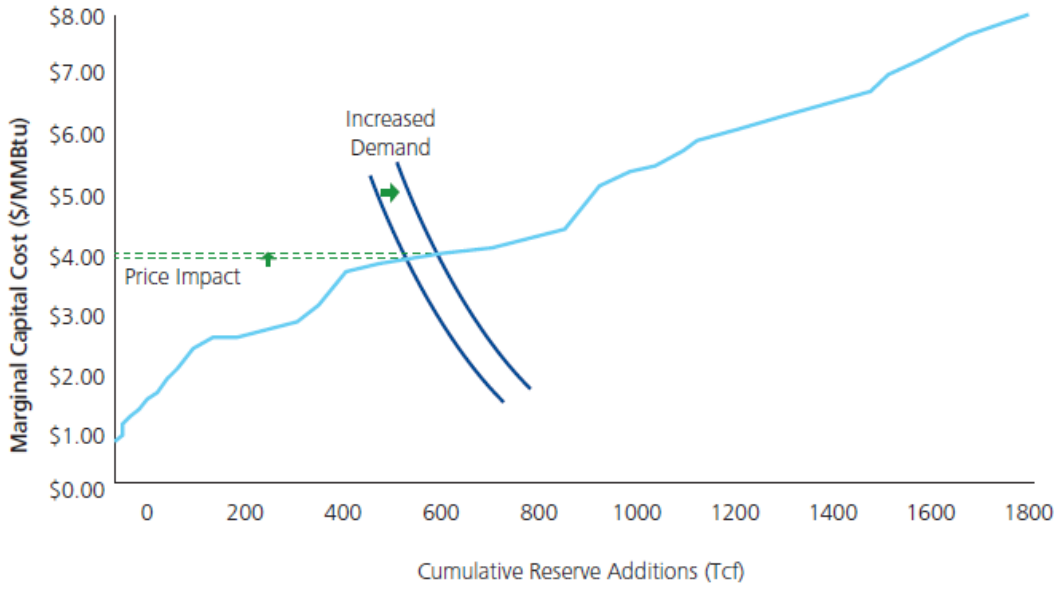

Figure 3 Cost of developing the proved reserves in the U.S.
Source: (Deloitte Market Point 2011, 9)

Short run

There are no recent studies of short term U.S. supply elasticity, and the study done by Balestra and Nerlove (1966) is very old. Recent literature indicates much less elastic curves than the old ones, the short run supply is often argued to be highly inelastic. It is necessary to see the U.S. short run supply elasticity in comparison with the EU OECD. We could argue that the U.S. elasticity is higher, and a reasonable suggestion for the U.S. would be 0.15.

Long run

The long run elasticity ranges from almost zero to 1.52. According to the discussion above, and the most recent studies, a reasonable suggestion for long term U.S. Supply elasticity would be 1.50.

U.S. demand elasticity

After governmental change in environmental legislation, electricity made of coal has been reduced (U.S. Energy Information Administration 2012d). Coal fuelled power production peaked in 2007, and is now close to 2001 levels. Natural gas fuelled power plants are ramping up production, and EIA is expecting this growth to continue. This would make the demand elasticity of natural gas more determined by the power generation sector, and henceforth make the demand more elastic.

Demand elasticities seem to be slightly lower in the studies done on the U.S. than in the studies done on Europe and the world. When looking at the studies indicating higher elasticities, the two studies from the seventies by Pindyck and Griffin contributes to the high elasticity. These studies are done with older data, and the newer studies indicate a much lower elasticity.

Short run

In the short run, the elasticity seems to be almost inelastic, and an average of recent estimates without Griffin indicates an elasticity of -0.10, which seems reasonable.

Long run

In the long run, the elasticity measured of the most recent studies indicates elasticity between -0.24 and -1.36. The studies done on world demand indicate elasticity between -0.25 and -0.75. It is reasonable to assume that increased utilisation of natural gas as a power plant feedstock affects the elasticity, and a reasonable suggestion would be -0.6.

European supply elasticity

The European market is much more regulated than the U.S. market. Significant shares of traded volume are long contracts without links to the spot market. This is about to change as more and more of the supplied volume is linked to the natural gas spot markets in Europe. After the liberalization of the natural gas markets in the U.K. in 1998, the average length of a contract in all of Europe was reduced between 1.5 and 4 years (Neumann and Hirschhausen 2004). In the latest large contract made by Statoil with German Wintershall, the price is linked to the spot market (Statoil ASA 2012). The volume supplied by LNG from the American market will also be linked to the spot market (Cheniere Energy Partners 2012). This makes the price more volatile, and if the growth of natural gas traded on spot markets continues, we could see a more elastic supply in the European market.

Russia, Norway, Algeria and Netherlands produced 76% of consumed natural gas in Europe in 2011 (International Energy Agency 2012). Most of these contracts, as already mentioned, are long contracts with a low volatility in price. After the development of shale gas in the U.S., more countries are experiencing an interest from E&P companies looking for shale gas on other continents. EIA has done a survey, estimating that

technically recoverable shale gas resources in Europe are 18 257 billion cubic metres, which is around 30 years of OECD Europe consumption of natural gas (U.S. Energy Information Administration 2011). 56 % of this is found in Poland and France. France has banned hydraulic fracturing, while Poland has opened for exploration. If the shale gas production in Europe gets significant, the dominant suppliers would be less dominant, and we could experience an increased elasticity of supply.

It is currently two new pipelines projected into Europe, the Nabucco pipeline from Turkey and the South Stream pipeline from Russia. The outcome is uncertain, and we could end up with both or none of the pipelines (Baev and Øverland 2010). The Russian pipeline would supply the European market with Russian gas, and the dominant position of Russian supply will be unchanged. The Nabucco Pipeline would be fed with natural gas from the Caspian Basin, making European supply less dependent on Russia (Nabucco Gas Pipeline 2012). If the Nabucco Pipeline is built, the supply could be more elastic, while the South Stream will probably keep the elasticity unchanged.

Short run

Based on the discussion with the U.S. Supply elasticity, a reasonable suggestion for EU OECD short run elasticity would be 0.1.

Long run

We determined the U.S. supply elasticity to 1.50, but this is too high for the European elasticity. The other supply elasticities estimated are made before 1980, so these are rather old. As we know, most of the natural gas is traded with long contracts, and the volumes supplied are fixed. Some contracts have a flexible price, but the volume is determined. This indicates a slightly inelastic supply curve. A reasonable long run elasticity would be 0.8.

European demand elasticity

Angela Merkel said in 2011 that Germany should get 35 % of their energy from green sources (Hawley 2012). The legislation and subsidizes that followed have made green energy outperform natural gas power plants. The German Renewable Energy Act requires power companies to buy green energy when this is available. The result is that natural gas power plants have to shut down production at unexpected times. The cost of

building a modern natural gas power plant requires a high degree of utilization, and with the Renewable Energy Act, this is difficult. If this kind of legislation is upheld and spread to rest of Europe, we could see a reduction in the natural gas power generation sector. This could lead to a less elastic demand curve.

On the other hand, the shift to a greener energy mix involves the construction of new natural gas power plants. Solar energy and wind energy only produced electricity between 900 and 1380 hours during the year of 8760 hours in 2010 (Federal Ministry of Economics and Technology 2012). It is common to assume that natural gas power plants will be important to provide necessary flexibility to handle the unpredictable production from wind and solar energy. If the natural gas power sector increases, the demand curve would be more elastic.

It is likely that a higher price gives a higher elasticity (Boots, Rijkers, and Hobbs 2004). Due to the high price in the EU OECD compared to the U.S., this should mean that the EU OECD demand is more elastic than the U.S.

Short run

The short run demand would be very inelastic, and a reasonable suggestion would be -0.1.

Long run

The estimations indicate higher demand elasticity is EU OECD than in the U.S. The development of green energy in the European countries supports this, and a reasonable suggestion would be -0.8.

5 Modeling the impact of LNG exports

To model the impact of LNG exports, we need to establish current market equilibriums besides the elasticities determined in the previous section. We treat the current supply to the markets as "domestic supply" even though the natural gas has origin outside the market. We need to know produced and consumed quantity in the two markets, and the transportation costs related to connecting them. We start with the establishing the U.S. market.

The American market:

The U.S. have a domestic consumption of 690 056 million cubic metres (mcm) (U.S. Energy Information Administration 2012). The average price at Henry Hub for the entire 2011 was 4.01 USD/mmBTU. [8] The market is determined to be in short- and long run equilibrium.

The European market

The European market is limited to the OECD countries in Europe.[9] These are the main consumers of natural gas in Europe, and the consumers of potential U.S. LNG Exports. The consumption of natural gas is 511 417 million cubic meters (International Energy Agency 2012), and the average price for Europe natural gas imports was 10.51 USD/mmBTU (Y-Charts 2012). There are several trading points of natural gas in Europe, but the best way to predict the new market equilibrium, is using the average imported price of natural gas. We assume the potential price differences between LNG import points will be levelled. The market is determined to be in short- and long term equilibrium.

Transportation costs

There are various estimates of the transportation costs between the U.S. market and the European market. The price is affected by the daily rates of ships and the liquefaction

[8] In U.S., natural gas is traded at Henry Hub for dollars per mmBTU, but are measuring volumes in bcf. Europe are measuring volumes in mcf. The price of gas in Europe is noted with USD/mmBTU as well. The conversion between USD/mmBTU and USD/bcf equals 1,027, and this leads to a common US misunderstanding, USD/mmBTU = USD / bcf. In our calculations, volumes are noted in mcf and prices in USD/mmBTU.

[9] OECD Europe comprises Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

and regasification costs happening at the LNG terminals in both ends. The estimates are ranging from 3 to 5.6 USD/mmBTU. Three of the studies indicate a exportation cost of 4.1, and this is also supported by Ebinger et al. (2012), who use the numbers from MIT. Thus, 4.1 seems reasonable.

Transportation costs, estimates

	Navigant Consulting, 2012	Medlock, 2012	MIT, 2011
Liquification	2,45	3,00	2,15
Regasification			1,25
Transport	1,55	1,10	0,7
Sum	4	4,10	4,1

	Dorogino et al, 2010	DnB Markets, 2012	Deloitte, 2011
Liquification	1,8	2,8	
Regasification	1,3	0,4	
Transport	1	2,4	
Sum	4,1	5,6	3

Table 4 Estimated transportation costs from U.S. to Europe
Source: (Navigant Consulting 2012; Medlock 2012; MIT 2011; Dorigoni, Graziano, and Pontoni 2010; DNB Markets 2012; Deloitte Market Point 2011)

Different scenarios

The base case

This numbers indicates the base case, and variations are in parentheses. I have made the size of the variations equal throughout the elasticities

	Quantity	Price
EU OECD Market	511 bcm	10.51 USD / mmBTU
US market	690 bcm	4.01 USD / mmBTU
	Supply	Demand
EU OECD Market	0.8 (0.6-1.0)	-0.8 (-0.6 -1.0)
US market	1.5 (1.3 – 1.7)	-0.6 (-0.4 -0.8)

The base case results in following outcome:

	EU OECD Market	U.S. Market
Change in price	-1.98 USD / mmBTU	+ 0.43 USD/mmBTU
Import / Export	154 bcm	
Change in consumption	+77 bcm	-44 bcm
Change in current supply	-77 bcm	+110 bcm

As we can see, the impact is huge for OECD. Current suppliers to the OECD would reduce their supply with 77 bcm. The price is reduced with 1.98 USD/mmBTU, and consumption increased with 77 bcm. The U.S. market experience a price increase of 0.43 USD/mmBTU, and producers will increase their production with 110 bcm. Their consumption will be reduced by 44 bcm. The exported/imported volume will be 154 bcm, approximately 22 % of current U.S. production. The DOE have received LNG export applications with a total volume of 289 bcm (Department of Energy 2012b), which is almost twice the projected exported volume in the base case. Not all projects applying for export licences will materialize, and a reduction of 50% seems reasonable. A price increase of 0.43 USD/mmBTU could be seen as disfavouring to the public interest. On the other side, assuming 154 bcm, and an export price of 4.44 USD/mmBTU gives the U.S. a 24 billion USD surplus to their foreign trade balance, and thus in line with public interest. But the consideration of the trade surplus versus the increased domestic price is outside the mandate of this thesis.

Extreme case

We want to see how large the LNG export could be if variation plays in the most extreme way.

	EU OECD Market	U.S. Market
Change in price	-1.96 USD / mmBTU	+ 0.44 USD/mmBTU
Import / Export	190 bcm	
Change in consumption	+95 bcm	-61 bcm
Change in current supply	-95 bcm	+129 bcm

If all curves are as elastic as the variations admit, we get the extreme case. This means U.S. elasticity of 1.7 and -0.8, and EU OECD elasticity of 1.0 and -1.0. As we can see, the

price increase in the U.S. is not that different from the base case, but change in consumption is high.

Punish U.S. case

In the discussion concerning "public interest", the domestic price is most important to many stakeholders. Some people argue that U.S. manufactures will lose their competitive advantage if the natural gas costs increases. Most analysts say that the impact will not be significant, and this is supported by this thesis. If I try to adjust the elasticities inside the variations to maximize the U.S. disadvantage for U.S. consumers regarding domestic price, this is the outcome:

	EU OECD Market	U.S. Market
Change in price	-1.80 USD / mmBTU	+ 0.60 USD/mmBTU
Import / Export	175bcm	
Change in consumption	+87 bcm	-41 bcm
Change in current supply	-87 bcm	+134 bcm

This outcome is given when U.S. elasticities are less elastic, while the EU OECD is max elastic. The price increases with 0.60 USD/mmBTU, which is a price increase of 15%. It will be make a difference for manufacture industry. The chief executive of Dow Chemicals is fearing prices to rise to Asian levels, but as we can see, this fear is unfounded (Helman 2012).

Spare U.S. case

It is also interesting to simulate what will be the least impact of domestic U.S. price. If the elasticities are maximized in the U.S. and minimized in EU OECD, the affect would be minimized for U.S. consumers.

	EU OECD Market	U.S. Market
Change in price	-2.1 USD / mmBTU	+ 0.29 USD/mmBTU
Import / Export	123 bcm	
Change in consumption	+62 bcm	-39 bcm
Change in current supply	-62 bcm	+84 bcm

The price increase will be 0.29 USD / mmBTU, an increase of 7.2 %.

Transportation costs

The transportation cost is an estimate. We also want to know how the outcome changes if the transportation cost estimate is wrong. DnB Markets and Deloitte have estimated other transportation costs than 4.1, and it could be that their estimates are right.

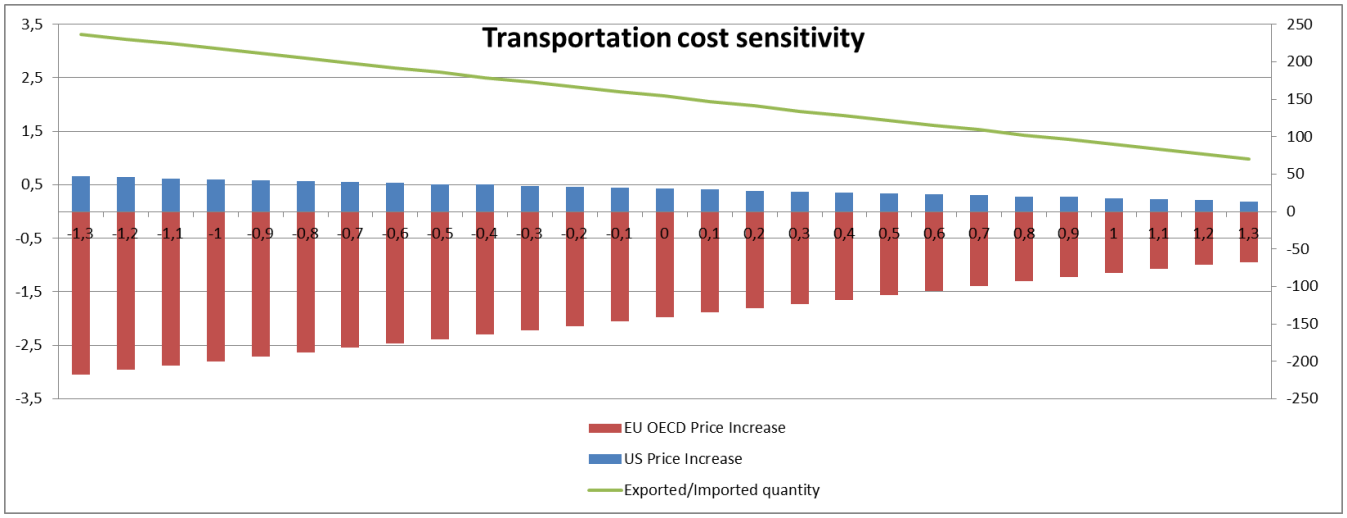

Figure 4 Transportation Cost sensitivity analysis

As we can see from the sensitivity analysis, the impact on American price is quite steady, with a maximum price increase of 0.66 USD/mmBTU if transportation falls with 1.3 USD compared to base case, which equals a transportation cost of 2.8. The price decrease in EU OECD will at this point be -3.05. If the transportation increases to 5.4, the U.S. price increase will be 0.19 USD/mmBTU, while the reduction on EU OECD will be limited to -0.95 USD/mmBTU. The absolute changes differ, but when measuring the difference in change, related to the originally change in the base case, we discover that the EU OECD and US act similar. When transportation costs decrease with 1.3 USD/mmBTU from the base case, the percentage change compared to the original change, is 53% for the U.S. price, and 54% for the EU OECD. If the price increases with 1.3 USD/mmBTU, the new price change equals 44% of the original for U.S. and 48% for EU OECD.

General comments on the case study

It is interesting to see that the adjustments done on the U.S. elasticities results in smaller changes in the outcome than the European elasticities. When I keep U.S. elasticities fixed, and changes the EU OECD within the variations, it changes the exported quantity with 67 bcm. If I do the opposite, keeping EU OECD elasticities fixed and changes the U.S.

elasticities within the variations, the changes in exported quantity amounts to15 tcf. This is interesting when thinking of the U.S. debate where most of the discussion around LNG exports neglects the global market reactions.

6 Relevant comparisons

Comparison with the future market

The future market in UK is called the ICE UK Natural gas futures. The natural gas is traded in pence per therm. There are other future products in Europe as well, but the ICE has the largest volume. But still, the volume is small, and most of the future prices are "suggested prices", not based on actually traded contracts. In U.S. the future prices are settled at the Henry Hub NYMEX. Traded volume here is large, and the futures are volatile. The contracts are priced in USD/mmBTU. To compare the two futures, we need to adjust for expected currency exchange ratio. The future spread between USD and GBP is very steady, with a maximum variation of 0.00971(Bloomberg 2012).

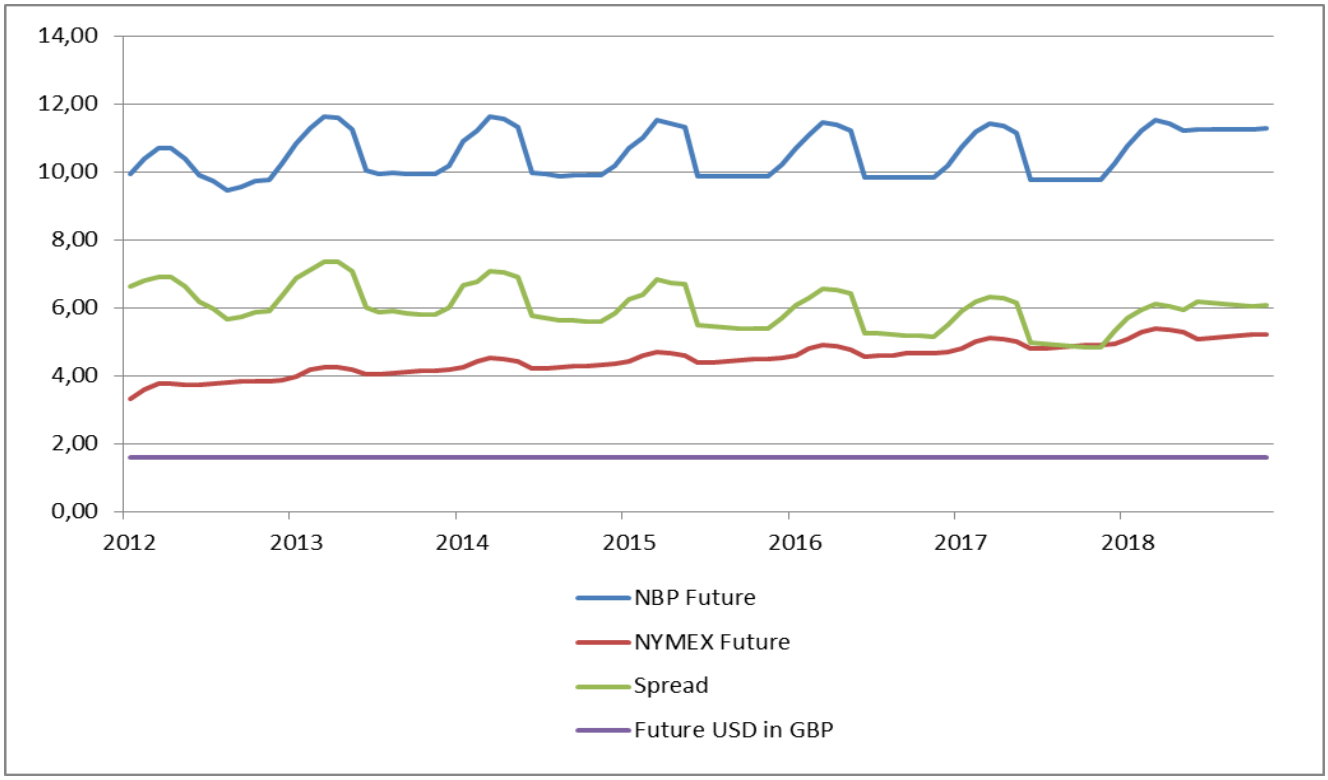

Figure 5 Natural gas futures
Source: (CME Group 2012; Bloomberg 2012; Interncontinental Exchange (ICE) 2012)

As we can see from the graphs, the seasonal pattern in at NBP is very different from the seasonal pattern at NYMEX. This makes the spread rather volatile. But even though the spread is volatile, it looks like it is decreasing throughout the period. The mean spread in 2013 is 6.35 USD/mmBTU, while the mean spread in 2018 is 5.43 USD/mmBTU. The transportation cost is assumed to be 4.1, which gives us a price premium of 1.33 USD /mmBTU in the futures market. But again, if market participants use the same transportation cost estimates as DNB, the price premium is removed. It is likely that the uncertainty about governmental actions related to allowance of LNG exports is a part of the premium, but it is difficult to determine at which extent. It could also be caused by low volatility in the futures market.

Comparison with other studies

To my knowledge, no other studies have tried to look at the impact of the European market. There are other studies that have looked at the impact on the U.S. market, and the base case indicates a slightly higher impact than other, similar studies. The base case indicates a price increase in the U.S of 10 percentages and a total export volume of 154 bcm. Medlock (2012) and Deloitte (2011) have made the same type of studies, where response from foreign markets comes in play. Their models are mode dynamic with several "shale gas" scenarios. Medlocks' base case indicates a price increase of 5% in the period 2011 – 2020, and then a price increase of 23% from 2021 – 2030. Deloitte projects a price increase due to LNG exports of 1.7 % above projected price. [10]

The interference of governmental actions will be decided in the next few months. One of the studies ordered by Congress is a study made by the U.S. Energy Information Agency. This includes different export scenarios where exported volume is between 6 bcf/day and 12 bcf/day. As comparison, my base case projects total export of 14.8 bcf/day. The outcome of this study indicates an increase in price between 14% and 36 %. Contrary to this study, and the before mentioned studies, is that this study does not include foreign dynamic market reactions.

[10] In Deloitte's projection they assume an increase demand for natural gas in the power generation sector that lies almost 50 percentage above EIA assumptions.

7 Concluding remarks

Conclusion

The aim of this thesis was to predict the impact of LNG exports in the merged natural gas market between Europe and the U.S. The thesis uses a parsimonious framework and gives a transparent and tractable model.

The base case indicates a price increase in the U.S. of 0.43 USD/mmBTU, approximately 11 %, and a price decrease in EU OECD of 1.98 USD/mmBTU, approximately 19%. The traded volume will stabilise at 154 bcm, which will be 20% of produced quantity in the U.S. The simulations of the case revealed the outcome to be more sensitive to changes on EU OECD elasticities than U.S. elasticities.

The transportation cost will strongly influence the outcome. Depending of which estimate you choose, the base case will vary with 166 bcm, where the lowest transport cost estimates indicates an exported quantity of 224 bcm. The highest transport cost estimates will result in a quantity exported of 58 bcm. In percentage of estimated production, the transport costs could make the exported quantity to vary from 8% to 26% of domestic production.

When comparing the results with the future market, it looks like the future market is taking into consideration the potential LNG exports. The arbitrage opportunity between U.S. and Europe is reduced, but it is difficult to know whether or not this is due to expected LNG exports or other market factors.

Further research

It would be interesting to do a larger study on elasticities, and not base the model on older findings. Elasticities are dynamic, and a new study could identify recent changes. With new elasticities, the study could become more accurate.

We calculated the produced volume supplied in Europe to decrease with 77 bcm. We know that there are three main suppliers, and it would have been very interesting to

know which of these suppliers that had to reduce their production. Given the market size of these, it should be possible to estimate individual supply curves and elasticities, and thus calculate the new supplied volumes. It could also be interesting to split up the European market into minor demand hubs, and estimate how the LNG export would affect regionally. [11]

The transportation costs are fundamental to the future of LNG exports, and a larger study on these costs would bring valuable insight to the discussion.

It could also be interesting to expand the model to include the Asian market. This would give a more accurate description of the future situation since the Asian market will be a potential destination for U.S. LNG exports.

[11] Boots et al (2004) calculated different country elasticities for Europe.

Appendix

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Appendix B: Theoretical fundament

The supply and demand in a market:

In a market, consumers demand different volumes at different prices, and producers supply different volumes at different prices. As price rises, the producers will increase production, while consumers reduce consumption. The price will stabilise at the level where supplied volume equals demanded volume (Marshall 1890). To find the equilibrium, we need to look at the supply- and demand curves, and how these could be estimated.

Supply- and demand curves

The volume demanded and supplied are dependent of different effects. There are two main things that impacts supply (Pindyck and Rubinfeld 2009). First there is price. As the price increases, the volume supplied will increase. Some goods are limited by access to resources need for production, and supply will not change due to price changes. Other goods do not have variable production costs, and the supply is not dependent on price. Second are production costs. If the cost of production decreases, the volume supplied would increase. Change in production costs could be achieved by technological improvements, access to new resources, change in regulatory environment etc. The demand of a good is more complex than the supply. There are three main things that impact the supply of a product(Pindyck and Rubinfeld 2009):

Change in Income:

When the income of a consumer changes, so will the mix of different demands change. Most goods are normal goods, where the demand increases as the income increases. Some goods are inferior goods, and demand is reduced as the income increases. The change in consumption due to income change could be expressed with income elasticity. When income rises one percentage, how does demand change. If the number is positive, meaning demand will increase as the income increases, it is a normal good. If the number is negative, meaning that demand will decrease as income increases, the good is inferior.

Change in price of other goods:

Goods experience change in demand as a consequence of change in price of other goods. Some goods are complementary, meaning they will be used together. If the price of a left

shoe increases, then the complementary good, the right show will be less demanded. Other goods are substitutes, meaning that the utility gained by consuming one kind of good could be satisfied by consuming another type of good. If the price of butter increases, the demand for margarine would increase since it would replace the need for butter. The change in consumption due to price change of other goods could be described with cross-price elasticity. When the price of this butter product increases with one percentage, how does demand for margarine change. If the number is positive, it means that the demand will increase as the prices increase, making margarine a substituting good. If the number is negative it means that demand will decrease as the price increases, making margarine a complementary good (which is not the case unless you always use the two of them together.)

Change in own-price:

The demand of a good is dependant of the own-price. Some goods are necessities, and the demand for these goods is independent of price. Other demands are dependent of price because of the existing substitutes. Butter could be replaced with margarine, and the demand would be reduced if the price increases. As with cross-price and change in income, change in own-price also use elasticity to describe the response in price changes. Since own-price elasticity will be the fundament of this thesis, we will look further into this. We start with developing an understanding of elasticities.

Impacts on elasticities:

Demand:

Limitation of demand

The limitation of a demand is important when looking at elasticity. When describing the demand for Coca Cola, we need to determine whether the demand is limited to the brand Coca Cola, the soft drink tasting Cola, soft drink in general or a way to obey thirst. As the limitations are expanded, the ability to subsidise increases. And as the ability to subsidise increases, the elasticity grows.

Necessity

Most goods satisfy a need that is a necessity. Food, clothes and transportation are necessities, and dependent of income these needs are satisfied differently. While some consumers eat meat, wear Kashmir wool, and drive cars, others eat rice; wear sacks, and

walks. But some needs are not necessities. These needs often relates to the top of the Maslow's hierarchy of needs, the need of self-actualization. These needs could be neglected, and demand would be inelastic for consumers until the reach a certain income level.

Access to substitutes

If the need is a necessity, the access to substitute will affect the elasticity. Some goods have easy accessible substitutes, where consumers can choose between substitutes, as example the choice of butter or margarine mentioned earlier. The demand would be elastic. Other goods have lack of substitutes. Food could not be substituted, and the demand would be highly inelastic.

Fixed versus variable cost

Some goods require a device to utilize. For the consumer, it represents a fixed cost to buy the utilization device, and then a variable cost to utilize the good. The elasticity would be affected by the relative difference between the investment and the variable cost. If you have a car with gasoline engine, the variable cost of buying gas does not make you substitute the car. If you have a razor from Gillette, the variable cost of the razor blades could make you substitute the Gillette razor into a Johnson razor. Demand of Gillette razor blade would be more elastic than demand for gasoline. In the short run, the investment ties the consumer to the good, but in the long run, it is likely that the elasticity increases.

Durability of good

Some goods have a long durability. A car could last between 15 and 20 years. If the price of new cars increase, car owners with 15 years old cars will keep their cars for a longer time. The short run demand is highly elastic. Eventually, their car needs to be replaced, and they will buy a new car. The long run demand is elastic.

Consumer habits

Consumers have habits, and it is not always rationally choices behind decisions made. Demand for a good could be less elastic than anticipated due to consumer habits. In the short run habits are applicable, but in the long run these disappear.

Supply:

Access to resources

Some goods require special input factors. If these factors are limited, the elasticity of supply be inelastic. The supply of champagne is limited by the land inside the region of Champagne. Other goods require input factors accessible everywhere. The supply of these goods are not limited by access to resources, and would have a more elastic supply.

Capacity constraints

To produce goods, it is necessary with infrastructure. This could be a factory, trained employees, pipelines etc. Most often this infrastructure has an upper constraint. It is possible to increase utilization, and make the employees do double shifts, but in the end it reaches a limit. This constraint limits the supply elasticity, and some supply curves are elastic to a certain output, where the supply turns inelastic. The capacity constraints are fixed in the short run, but in the long run it is possible to expand. This makes the supply curve more elastic in the long run.

Fixed vs variable costs

If the production of a good require a high initially cost, and a low variable production cost, it is likely that the supply is highly elastic. A newspaper would have a high cost of make, but once the paper is written, the cost of producing another copy is very low.

Unexpected vs. expected sudden change

Short run elasticity is used to describe the ability to react to a sudden change, often called a supply- or a demand shock. This is a sudden, *unexpected* change in either supply or demand. It is very important to separate between expected and unexpected sudden change(Medlock 2012). A sudden change could be expected, and then the long run elasticity would be the best indicator for predicting the outcome. Even if the change happens over a day, it does not mean that the stakeholders did not prepare for the change regarding infrastructure and necessary investments.

Criticism of theory

There are several assumptions about the model of supply and demand which has been criticised. A necessary assumption is that the production cost is a U-formed curve with increasing production cost when reaching a certain level, and not L-shaped as many

empirical studies has shown (Cohen 1983, 214). Marshall himself acknowledged that decreasing cost for producers eventually would lead to monopoly (Marshall 1920, 459). Sraffa describes this as the Marshall Dilemma, that decreasing costs was "entirely abounded, as it was seen to be incompatible with competitive conditions (Sraffa 1926, 537–538)". In 1983 Cohen argues that empirical studies proving the fact, is ignored (Cohen 1983, 214). " … theoretically, there is much to be lost by not making the leap of faith over the fiery abyss of empirical reality to the axiomatic domain of perfect competition (Cohen 1983, 216)."

Goodwin et al. argues that while economist are precise when drawing lines for equilibrium, the participants in the markets are aiming to be accurate, but are not very precise (Goodwin et al. 2009, 99). "Equilibrium analysis is limited by the reality of constant change in the world, and nonmarket forces may also effectively combat the equilibrating tendency of market forces. Market adjustment analysis can tell us what to expect from normal market forces: Most generally, disequilibrium situations create forces that will tend to push prices toward an equilibrium level (Goodwin et al. 2009, 93–94)".

The Sonneschein-Mantel-Debreu Theorem states that the aggregated demand curve only inherit some of the properties of the individual demand curve. Thus there could be more than one equilibrium in one market (Sonnenschein 1973; Debreu 1974; Mantel 1974). This issue is difficult to address when calculating the equilibrium based on aggregated market curves and elasticities.

Appendix C: Solving of equations

We know that export equals import:

$$(Q_L + \Delta Q_L^S) - (Q_L + \Delta Q_L^D) = (Q_H + \Delta Q_H^D) - (Q_H + \Delta Q_H^S)$$

We are using the elasticity equation to describe the change in quantity.

$$E_p = \frac{P}{Q}\frac{\Delta Q}{\Delta P} \qquad \Delta Q = \frac{Q}{P} * \Delta P * E_p$$

Replacing all ΔQ with the ensuing elasticity equation gives us the following:

$$\left(Q_L + \frac{Q_L}{P_L} * \Delta P_L * E_L^S\right) - \left(Q_L + \frac{Q_L}{P_L} * \Delta P_L * E_L^D\right)$$
$$= \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^D\right) - \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^S\right)$$

The new price in market H will be the new price in market L plus transportation costs:

$$(P_H + \Delta P_H) = (P_L + \Delta P_L) + T_{cost}$$

The potential arbitrage opportunity could be noted as price in the H market minus price in the L market minus transportation costs:

$$P_H - P_L - T_{cost} = \pi_{arb}$$

Rearranging equation:

$$P_H - P_L - T_{cost} + \Delta P_H = \Delta P_L$$
$$\Delta P_L = \Delta P_H + \pi_{arb}$$

Replacing ΔP_L with $\Delta P_H + \pi_{arb}$ in the export-equals-import equation:

$$\left(Q_L + \frac{Q_L}{P_L} * (\Delta P_H + \pi_{arb}) * E_L^S\right) - \left(Q_L + \frac{Q_L}{P_L} * (\Delta P_H + \pi_{arb}) * E_L^D\right)$$
$$= \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^D\right) - \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^S\right)$$

Removing the constants Q_L and Q_H:

$$\frac{Q_L}{P_L} * (\Delta P_H + \pi_{arb}) * E_L^S - \frac{Q_L}{P_L} * (\Delta P_H + \pi_{arb}) * E_L^D = \frac{Q_H}{P_H} * \Delta P_H * E_H^D - \frac{Q_H}{P_H} * \Delta P_H * E_H^S$$

$$\frac{Q_L}{P_L}(\Delta P_H + \pi_{arb}) * (E_L^S - E_L^D) = \frac{Q_H}{P_H} * \Delta P_H * (E_H^D - E_H^S)$$

Multiplying parentheses:

$$\frac{Q_L}{P_L}(\Delta P_H E_L^S - \Delta P_H E_L^D + \pi_{arb} E_L^S - \pi_{arb} E_L^D) = \frac{Q_H}{P_H} * \Delta P_H * (E_H^D - E_H^S)$$

Removing the denominators by multiplying both sides with P_H and P_L.:

$$P_H Q_L(\Delta P_H E_L^S - \Delta P_H E_L^D + \pi_{arb} E_L^S - \pi_{arb} E_L^D) = Q_H P_L * \Delta P_H * (E_H^D - E_H^S)$$

Removing all parentheses:

$$P_H Q_L \Delta P_H E_L^S - P_H Q_L \Delta P_H E_L^D + P_H Q_L \pi_{arb} E_L^S - P_H Q_L \pi_{arb} E_L^D = Q_H P_L \Delta P_H E_H^D - Q_H P_L \Delta P_H E_H^S$$

Rearranging, and moving all ΔP_H to one side:

$$P_H Q_L \pi_{arb} E_L^D - P_H Q_L \pi_{arb} E_L^S = P_H Q_L \Delta P_H E_L^D - P_H Q_L \Delta P_H E_L^S - Q_H P_L \Delta P_H E_H^S + Q_H P_L \Delta P_H E_H^D$$

Isolating ΔP_H and rearranging the right side of the equation:

$$P_H Q_L \pi_{arb} (E_L^S - E_L^D) = \Delta P_H (P_H Q_L E_L^D - P_H Q_L E_L^S - Q_H P_L E_H^S + Q_H P_L E_H^D)$$

Solving for ΔP_H

$$\Delta P_H = \frac{P_H * Q_L * \pi_{arb} * (E_L^S - E_L^D)}{P_L * Q_H * E_H^D - P_L * Q_H * E_H^S - P_H * Q_L * E_L^S + P_H * Q_L * E_L^D}$$

With ΔP_H we can find new prices and quantities:

$$\text{New price in market H} = P_H + \Delta P_H$$

$$\text{New price in market L} = P_L + (\Delta P_H + \pi_{arb})$$

To find quantity exported/imported we can use one of the equations

$$\text{Volume exported} = \left(Q_L + \frac{Q_L}{P_L} * (\Delta P_H + \pi_{arb}) * E_L^S\right) - \left(Q_L + \frac{Q_L}{P_L} * (\Delta P_H + \pi_{arb}) * E_L^D\right)$$

$$\text{Volume imported} = \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^D\right) + \left(Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^S\right)$$

We want to know how the new equilibriums have changed production and consumption.

$$\text{Quantity consumed in market H} = Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^D$$

$$\text{Quantity produced in market H} = Q_H + \frac{Q_H}{P_H} * \Delta P_H * E_H^S$$

$$\text{Quantity consumed in market L} = Q_L + \frac{Q_L}{P_L} * \Delta P_L * E_L^D$$

$$\text{Quantity produced in market L} = Q_L + \frac{Q_L}{P_L} * \Delta P_L * E_L^S$$

Appendix D: Excel Model used to calculate the equilibrium

U.S.					
Equilibrium Price	4,01		Transportation costs		
Equilibrium Quantity	690		4,1		
Supply Elasticity	1,5	< 1,3-1,7>	Arb		
Demand Elasticity	-0,6	<-0,4,-0,8>	2,4		
Europe OECD					
Equilibrium Price	10,51				
Equilibrium Quantity	511				
Supply Elasticity	0,8	< 0,6 - 1,0>	Equilibrium Non-Linear Curves		
Demand Elasticity	-0,8	< -0,6, -1,0>			
Change in Europe OECD Price	-1,975				
Change in U.S. Price	0,425				
New price Europe OECD	8,535				
New price U.S.	4,435				
New quantity Produced U.S.	800	Change in U.S. Production	109,73		
New quantity Consumed U.S.	646	Change in U.S. consumption	-43,89		
New quantity Produced Europe OECD	434	Change in EU Production	-76,81		
New quantity Consumed Europe OECD	588	Change in EU Consumption	76,81		
Volume imported/exported	154				

Macro:

```
Sub EquilibriumNonLinearCurves()
Dim epl, eql, sel, del, eph, eqh, seh, deh
Dim one, two, three, four, tcost2
Dim deltapl, deltaph, arb
Dim nqplm, nqclm, nqphm, nqchm
Dim cphm, cpusm, cqplm, cqclm, cqphm, cqchm, qIorE

With Worksheets("non-Linear Curves").Activate
'Low market
epl = range("epl").Value
eql = range("eql").Value
sel = range("sel").Value
del = range("del").Value

'High Market
eph = range("eph").Value
eqh = range("eqh").Value
seh = range("seh").Value
deh = range("deh").Value

'transportation cost
tcost2 = range("tcost2").Value

'Calculating arb
arb = eph - epl - tcost2
'Calculating price change in market H
deltaph = (eph * eql * arb * (sel - del)) / (epl * eqh * deh - epl * eqh * seh - eph * eql * sel + eph * eql * del)

'Calculating price change in market H
deltapl = deltaph + arb
```

```
'Inserting new calculations in worksheet
range("cphm").Value = deltaph
range("cpusm").Value = deltapl
range("nphm").Value = eph + deltaph
range("nplm").Value = epl + deltapl

range("nqplm").Value = eql + deltapl * (eql / epl) * sel
range("nqclm").Value = eql + deltapl * (eql / epl) * del
range("nqphm").Value = eqh + deltaph * (eqh / eph) * seh
range("nqchm").Value = eqh + deltaph * (eqh / eph) * deh

range("cqplm").Value = range("nqplm").Value - eql
range("cqclm").Value = range("nqclm").Value - eql
range("cqphm").Value = range("nqphm").Value - eqh
range("cqchm").Value = range("nqchm").Value - eqh
range("qIorE").Value = range("nqplm").Value - range("nqclm").Value

End With

End Sub
```

adh	='Linear curves'!$B$7		newch	='Linear curves'!$C$17
adl	='Linear curves'!$B$4		newcl	='Linear curves'!$C$15
ash	='Linear curves'!$B$6		newpl	='Linear curves'!$C$16
asl	='Linear curves'!$B$3		newprice	='Linear curves'!$B$11
bdh	='Linear curves'!$C$7		NewpriceH	='Linear curves'!$B$12
bdl	='Linear curves'!$C$4		newpriceL	='Linear curves'!$B$11
bsh	='Linear curves'!$C$6		nph	='Linear curves'!$C$18
bsl	='Linear curves'!$C$3		nphm	='non-Linear curves'!$B$15
cphm	='non-Linear curves'!$B$13		nplm	='non-Linear curves'!$B$16
cplm	='non-Linear curves'!$B$13		nqchm	='non-Linear curves'!$B$20
cpusm	='non-Linear curves'!$B$14		nqclm	='non-Linear curves'!$B$18
cqchm	='non-Linear curves'!$D$20		nqphm	='non-Linear curves'!$B$19
cqclm	='non-Linear curves'!$D$18		nqplm	='non-Linear curves'!$B$17
cqphm	='non-Linear curves'!$D$19		qIorE	='non-Linear curves'!$B$21
cqplm	='non-Linear curves'!$D$17		seh	='non-Linear curves'!$B$10
deh	='non-Linear curves'!$B$11		sel	='non-Linear curves'!$B$4
del	='non-Linear curves'!$B$5		tcost	='Linear curves'!$B$9
eph	='non-Linear curves'!$B$8		tcost2	='non-Linear curves'!$D$3
epl	='non-Linear curves'!$B$2		Transportation	='non-Linear curves'!$D$3
eqh	='non-Linear curves'!$B$9		Transportation_costs	='non-Linear curves'!$D$3
eql	='non-Linear curves'!$B$3		transportationcost	='non-Linear curves'!$D$3
nch	='Linear curves'!$C$17			