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Oil Dependencies and Peak Oil's Effects on Oil Consumption

A case study of six countries

Bachelor Thesis within Economics

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Keywords: Peak Oil, Elasticity, Oil Dependency, Nerlove's Partial Adjustment Model, Asymmetric Effects.

Abstract

During the year of 2007, the world has experienced historically high oil prices both in nominal and in real terms, which has reopened discussions about energy sustainability. We therefore found it interesting to research oil dependencies and elasticities for Brazil, China, Norway, South Korea, Sweden and USA; and their possible oil consumption response to a Peak Oil phenomenon. Peak Oil in this thesis, implies that oil production will reach its climax and decline thereafter. To help draw conclusions, appropriate statistical analysis on macroeconomic variables was used as well as the modified Nerlove's partial adjustment equation to calculate price and income elasticities both in the short and long-run. Regression results have shown that short-run price elasticities were low in all countries; in addition income elasticities were also inelastic but more elastic in relation to oil price elasticities. This indicates that oil consumption is more sensitive to changes in income than to changes in oil price. It was concluded that oil dependencies among nations differ and the trend is that developing countries are increasing their oil dependency while developed countries tend to decrease their oil dependency over time. Peak Oil will lead to higher oil prices, which in the short-run will change developing countries oil consumption to a greater extent than developed countries, but in the long-run their response are more similar. It was also noticed, that when GDP decreases in net-oil-importing countries, oil consumption will decrease even further. The opposite could be true for net-oil-exporting countries like Norway and Brazil.

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Nyckelord: Peak Oil, Elasticitet, Oljeberoende, Nerlove's Partial Adjustment Model, Asymmetriska Effekter.

Sammanfattning

Under år 2007 har världen upplevt historiskt höga oljepriser, både i nominella och reala termer, vilket återigen har lyft upp energiförsörjningen på agendan. Vi fann det därför intressant att undersöka oljeberoenden i Brasilien, Kina, Norge, Sydkorea, Sverige, USA och se hur dessa länders oljekonsumtion kan påverkas av Peak Oil. Peak oil betyder att oljeproduktionen når sitt maximum och minskar därefter. För att kunna dra slutsatser har lämpliga statistiska verktyg använts på olika makroekonomiska variabler och applicerat "Nerlove's partial adjustment model" på data har pris-och inkomstelasticiteten av olja i varje land både på kort och lång sikt kunnat utvinnas. Från regressionen har framträtt; priselasticiteten var låg på kort sikt i alla länder och detta gäller även för inkomstelasticiteten, dock var inkomstelasticiteten relativt mer elastisk i alla länder. Detta indikerar att oljekonsumtionen är mer känslig för förändringar i inkomst än för förändringar i pris. Slutsatsen från studien är att olika länder har olika nivåer av oljeberoende och att utvecklingsländer tenderar att öka sitt relativa oljeberoende över tid medan de industrialiserade länderna tenderar att minska sitt relativa oljeberoende över tid. Peak Oil leder till högre oljepriser vilket på kort sikt kommer att påverka utvecklingsländernas oljekonsumtion mer än de industrialiserade ländernas, dock minskar skillnaden på lång sikt. En observation från denna forskning är att när BNP minskar hos olje-importörerna kommer även oljekonsumtionen att minska. För oljeexportörer som Brasilien och Norge kan oljekonsumtionen öka när BNP inkomsterna ökar från Peak Oil.

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1 Introduction

“The World has never confronted a problem like this, and the failure to act on a timely basis is almost certain to have major debilitating impacts” (Hirsch et. al., 2005, p. 60).

Lately the crude oil price has been volatile, reaching an all time high at over 96 dollars a barrel in November 2007 (Bloomberg, 2007). Due to this high price and pressures from other factors such as environmental issues; energy sustainability is a currently highly discussed topic among governments, medias, and businesses. However the issue of Peak Oil has not been given much attention. The global Peak Oil model is recognized but the time of the Peak Oil occurrence is extensively debated. Peaking in this context indicates that oil production has reached its climax and that half of the worlds oil has been consumed, not that the world oil wells are running dry. This also implies that total oil consumption will decrease, but it does not clarify oil consumption changes on a nation level. According to Cavallo (2002), inexpensive oil is vital for the world’s energy demand but its availability is finite, therefore volatility in production volumes will have substantial economic impact. World oil consumption has increased gradually from 1960 to 2005 (EIA, 2006).

Oil is exploited in numerous areas in the world such as the Middle East, the Former Soviet Union, US, Mexico, Canada and the North Sea. The Organization of Petroleum Exporting Countries, OPEC, produced 40% of the world total production (Svenska Petroleum Institutet, 2007) in 2006 and controlled about 78% of world oil reserves in 2000 according to Manfred Horn (2004). Saudi Arabia has a foothold within OPEC nations since it has the largest proven reserves in the world; 264.3 thousand million barrels at the end of 2006 (BP, 2007). Proven oil reserves is the estimated quantities of oil which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under current economic and operating conditions (British Petroleum, 2007).

The threat of a nearby oil shortage has reopened discussions regarding oil dependency reductions as well as the development, enhancement and greater implementation of alternative energy resources. Demand for oil has historically increased over time and at some time oil supply will no longer be capable of supplying the current level of demand (Hirsch et. al., 2006); but the time of this occurrence is also under debate.

We have chosen to investigate oil dependencies and the plausible effects on oil demand of Peak Oil on Brazil, China, Norway, South Korea, Sweden and USA. This specific topic is unique, in the sense that the writers have been unable to find previous conducted researches on the same topic. Energy dependencies and Peak Oil are issues currently debated. Crude oil as a commodity is interesting since the bulk of the world economy is reliant on oil and its refined products. Conventional oil supplied 40% of the global energy need in 2000 as well as being extremely important for the lubricant, transportation, and chemical feedstock industry, according to the International Energy Agency (2007).

Different countries have different levels of oil dependencies, determined by such factors as their economic structure, level of development, access to alternative energy sources, and geographical characteristics. A country's response to a Peak Oil event depends on their level of oil dependency, all else equal. Peak Oil is simplified as the point of maximum world oil production and following this Peak Oil point or plateau is a decline of oil production leading to an inevitable decline in oil consumption. The logic of Peak Oil comes from the well established behaviour that the output of individual oil fields rises after discovery, reaches a peak and declines thereafter (Hirsch et. al., 2006).

1.1 Purpose

The purpose of this thesis is to describe the level of dependency on oil in six countries, and the plausible effects on oil demand of Peak Oil through the use of price and income elasticities.

1.2 Limitations

In this research, a total of six countries were chosen; Brazil, China, Norway, South Korea, Sweden, and USA. Whereas the developing countries or recently developed countries are Brazil, China, and South Korea; while Sweden, Norway, and USA are the developed countries analysed. Brazil is situated in a volatile region which has undergone several economic crises, and is currently recovering economically from these crises. Brazil has also recently become a net exporter of oil and it is therefore appealing to analyse. China is interesting to include in this research due to its enormous size and its dynamic growing economy. Norway is interesting to analyse since it is one of the few democratic nations that is also a net exporter of crude oil. South Korea is an appealing country to consider in this research since it has transformed from a developing to a developed country within the time span of the research. Sweden is selected since it is believed to be one of the most progressive countries in developing and using renewable energy resources. The USA is the largest consumer of crude oil globally, furthermore they have the largest economy; this makes them a necessity for this thesis. The time span between 1970 and 2006 was evaluated since it covers the most recent oil shocks and it is directly after the collapse of the Bretton Woods system, i.e. gold standard, therefore it can be said that it reflects the modern economy. The Arabian light oil price, 1970-1983, and the Brent crude oil price, 1984-2006, will be consistently used and expressed in current US dollars (BP, 2007). It is important to mention that crude oil price is the supply price, therefore it is not the price faced by final consumers for the refined products such as gasoline and diesel. The price faced by the final consumers varies across countries, since tax and subsidy rates differ. This indicates that the final consumer will have different price schemes compared to price schemes faced by the crude oil buyers.

We equal the demand for oil to oil consumption expenditures since plotting the demand figures is a complex procedure. From basic supply and demand theory, oil consumption is the point of equilibrium where the supply and demand curves cross, therefore oil

consumption should be equal to oil demand in a competitive market. We limited the factors affecting oil consumption to only three variables; GDP, crude oil price, and the lagged oil consumption. This due to the fact that several other factors are expected to be too correlated with the variables in question and variables such as innovation, events, and expectations are difficult to quantify.

1.3 Method

Time series analyses in SPSS and Eviews was used to evaluate the secondary data gathered primarily from BP (2007) and the UN (2007) between the years of 1970 and 2006. To increase the relevancy of the regression model a lag was introduced since, due to natural slowness of adjustment, last years oil consumption is a factor of current oil consumption. From these produced time series regressions short and long-run price and income elasticities were extracted as a measure to analyse a country's dependency on oil, consequently its response to Peak Oil. To test for stationarity within the regression and serial autocorrelation in the residuals, the Augmented Dickey-Fuller test and the Breusch-Godfrey test were conducted respectively. Earlier researches, articles, and publications have been studied to increase the writers' knowledge on the topic, to provide a relevant background to the problem, and to create a discussion.

1.4 Outline

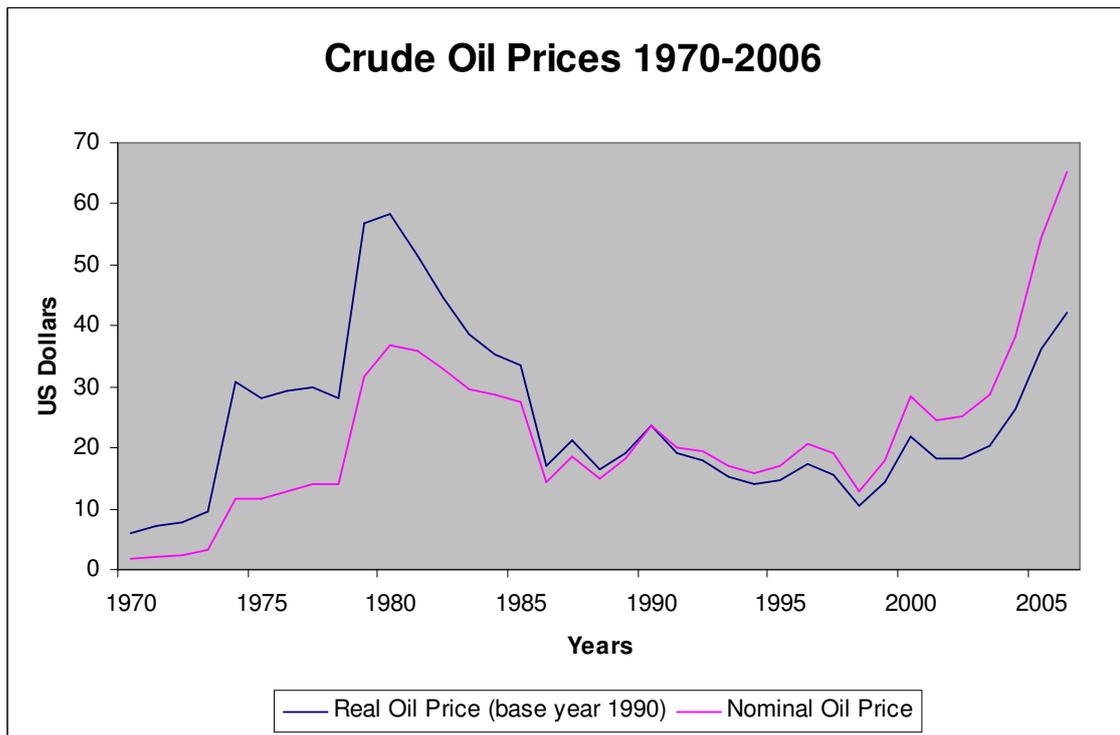
In the first chapter of this thesis the writers have given the reader an introduction to the topic and presented the purpose, limitations, and method. In the next chapter, the writers present a brief history of oil price shocks and Peak Oil; also included in this chapter are previous researches done on similar topics presented in a table. Chapter 3 includes all relevant theories and following this is then the null hypothesis. The next chapter consists of statistics for each country's population and consumption figures as well as their growth averages in Real GDP and crude oil consumption; patterns for crude oil consumption for each country within the time frame from 1970 to 2006 is also displayed in this chapter. Chapter 5 mainly encloses definitions of the relevant macroeconomic variables and the empirical findings originated from the regression model. The Augmented Dickey-Fuller test results and the Breusch-Godfrey test results are also presented and explained in this chapter. Chapter 6 is devoted to short and long-run price and income elasticities as well as the asymmetric effects are detailed here. Also included in this chapter are Peak Oil's plausible effects on crude oil consumption, on the countries in question, with the help of the elasticities provided in the previous chapter. Finally, in Chapter 7, the writers will provide the reader with the conclusions and in the next chapter, Chapter 8, with suggestions for further research.

2 Background

2.1 History of Oil Price Shocks and Peak Oil

Throughout the last 40 years and within the time span analysed in this thesis, the world has experienced several oil price shocks. The oil price shock in 1973-1974 was triggered by OPEC's decision to decrease exports and increase the price of oil immensely to those countries supporting Israel in the Arab-Israeli War (NE, 2007). As a response to this oil embargo, crude oil prices rose by more than 250% within a 4 month time period as can be seen in Figure 1. The second major oil crisis in 1979 was caused by the turmoil produced by the Iranian revolution and the Iran-Iraq war. According to the IEA (2004), both of these events created a downturn in economic growth in most oil importing countries in the proceeding years. IEA (2004) furthermore argues that most of the economic downturns since the 1970's were followed by sudden increases in crude oil prices, although other factors were more important in some cases. Recent oil price shocks such as Iraq's invasion of Kuwait in 1990 and the OPEC's production restraint in 1999 are not as immense as the previous shocks, see figure below.

Figure 1: Real and Nominal Crude Oil Price Pattern



Source: BP, 2007

The oil price shocks of 1973 and 1979 led the industrial world into recession, demonstrating the industrials' economy heavy dependency on cheap crude oil, as stated by Campbell and Laherrere (1998). They also claimed that the upcoming oil shock will not be so temporary, rather permanently since there are no backup reserves remaining.

In the years proceeding 1999, several factors have led to a steady increase in the price of oil such as hurricane Katrina in 2005 and USA's invasion of Iraq in 2003. A new high was reached in November 2007 with the crude oil price trading at 96.3 \$/barrel Western Texas Intermediate, WTI (Bloomberg, 2007).

A peak in oil production has occurred in single oil fields since its extraction started in the 1850's. Individual countries have also peaked such as the USA in 1970, Iran in 1974, United Kingdom in 1999 and most recently Norway in 2001. These countries have experienced a steady decline in their oil production ever since they peaked (Odland, 2006).

2.2 Previous Research

The writers have been unable to find previous conducted researches on the same topic as of this thesis. Although some studies have been separately made on Peak Oil, and price and income elasticities of crude oil demand, none have been made with a combination of the two. Common patterns from previous researches; both income and price elasticities are inelastic in the short-run as concluded by Gately and Huntington (2001), and Cooper (2003). The time of the Peak Oil's occurrence is highly discussed. Several researchers, such as Bakhtiari (2004), Campbell (2003), and Jackson (2004), have reached different predictions of its occurrence ranging from 2006 to 2020. The writers decided to list the previous researches in Table 1 in order to make it more comprehensive to the reader.

Table 1: Previous Research done on Similar Topics

Literature	Key Findings
Sarah K. Odland (2006)	<ul style="list-style-type: none"> • Supplies will be volatile in the future and will not keep up with increasing demands, when Peak Oil occurs. • Full scale transition is needed to deplete the demand for oil and develop sustainable alternative sources of energy.
Robert L. Hirsch, Roger Bezdek and Robert Wendling (2006)	<ul style="list-style-type: none"> • Argued that the upcoming oil energy transition will be abrupt and revolutionary, leading to shortages and economic dislocations. • Believe that crash programs cannot be successfully implemented at the current technology and industrial levels.
John C.B. Cooper (2003)	<ul style="list-style-type: none"> • Price elasticities of oil in the short-run are more inelastic than in the long-run and price elasticities differ between nations depending on their economic configuration. • If oil consumption grows at a slower rate than the rate of real GDP, <i>ceteris paribus</i>, then the rate of oil consumption in the

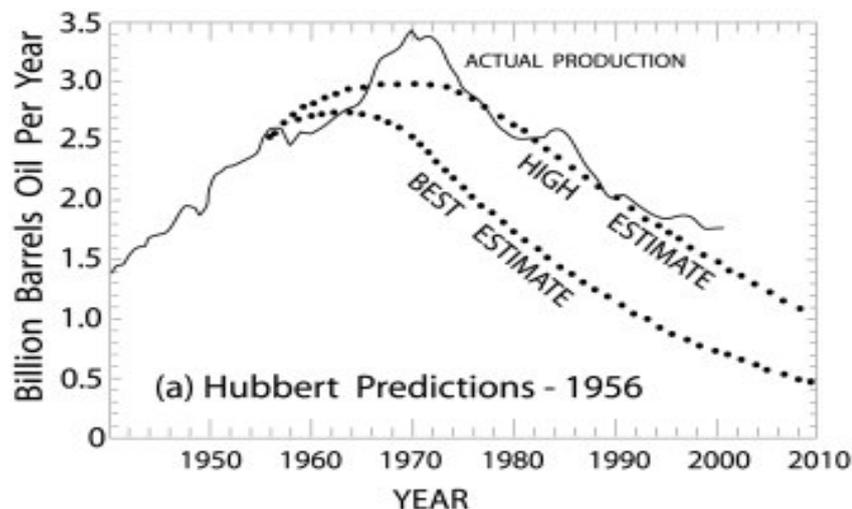
	<p>production of GDP must decline, as he found was the case in Sweden and the US.</p>
International Energy Agency (2004)	<ul style="list-style-type: none"> • High oil prices affect countries differently depending on their level of oil dependency and whether they are net importers. • Oil importing developing countries are usually struck harder than OECD countries since their economies are more concentrated in the industry sector.
Awerbuch and Sauter (2004)	<ul style="list-style-type: none"> • Oil price and GDP relationship is strong. • Believe that the oil price and GDP relationship might be asymmetric, indicating that an increase in oil price has a greater effect on GDP than a decrease in oil price. • Argued that investments in renewable energy can help dampen a sudden oil price increase, therefore a diversified efficient generating portfolio concerning the security of new energy concepts can help avoid these fossil price risks.
Dermot Gately and Hillard G. Huntington (2001)	<ul style="list-style-type: none"> • OECD countries should have a long-run income elasticity of oil demand between 0.5 – 0.6 and about 1.0 for non-OECD countries. • The speed of adjustment to changes in price is slower than to changes in income in almost all countries. • The asymmetric effects of oil price and income changes were taken into account.
Bakhtiari (2004)	<ul style="list-style-type: none"> • Former “Senior Energy Expert” employed by the National Iranian Oil Co. of Tehran, predicted that the world oil production would peak of about 81 million bbl/d in 2006 or 2007 with the help of the “World Oil Production Capacity Model”. Following this, decreasing production will seem irreversible, and world oil production will decline to about 55 million bbl/d by 2020.
Campbell (2003)	<ul style="list-style-type: none"> • Has published several books on the topic of Peak Oil and has concluded that the number of large oil fields being discovered has been decreasing. He therefore claims that a peak of oil production will occur around the year of 2010, depending oil price shocks originating from outside events such as war.
Jackson (2004)	<ul style="list-style-type: none"> • Senior Director of CERA has predicted that global oil production will peak after the year of 2020 using the “liquids production capacity forecasting approach.” • Claims that the Peak Oil plateau will last several decades before production starts to decline due to improvements in technology and upcoming major projects.

3 Theories

3.1 Hubbert's Curve and Peak Oil

M. King Hubbert's, a geophysicist at Shell Oil, created a model in 1956 predicting that oil production in the lower 48 United States would peak between the years of 1965 and 1970. Hubbert's prediction was utterly rejected but when the US oil production peaked in 1970, his model became widely accepted. Hubbert's estimates on a mathematical model, that the resource extraction follows a bell shaped curve; production rises rapidly to a peak and declines just as quickly as can be seen in Figure 2. Petroleum production estimates are required by the model to accurately estimate the size of the total oil endowments. Hubbert plotted two separate bell shaped curves based on his estimates for the size of petroleum resources in the lower 48 states; the highest estimate was 200 billion barrels while his preferred estimate was 150 billion barrels (Hubbert, 1956). The famous Hubbert's curve is based on his highest estimate; see Figure 2.

Figure 2: Hubbert's Bell Shaped Model (Hubbert, 1956)



3.2 Demand and Supply Theory

The demand for oil is based on several factors such as the price of crude oil, innovation, population, income/GDP, taxes, and expectations. Therefore it is a complex procedure to plot demand curves. Intuitively, oil consumption expenditures should be equal to oil demand; it is the equilibrium point where the oil supply curve meets the oil demand curve. According to Bacon and Kojima (2006), there are two principal drivers of the demand for any product; the growth of GDP and the price of the product. For this reason, only GDP and crude oil prices will be used in this research. These two drivers can in turn be divided into four factors:

- The rate of growth of income
- The income elasticity of demand for the product

- The rate of increase of prices
- The price elasticity of demand for the product

The supply side can be analysed just as extensive as the demand or consumption side, but in this thesis it was assumed that when Peak Oil occurs there are no more possibilities for production growth. Therefore it is claimed that, regardless of the economic incentives present, oil production will reach its physical limit and an inevitable decrease in supply will follow. As Lynch (2002) stated; increases in crude oil prices lead to greater exploration expenditures and thus drilling, which causes discoveries; discoveries are developed into capacity which is produced. Several factors such as cost and diminishing production or depletion modify the oil supply outcome, but in theory, all of these would be relevant to simple econometric modelling (Lynch, 2002). Conversely, it has proven impossible to create such a model successfully due to several reasons such as; difficulties in measuring technological advances, unreliable data, and inconsistency present in the dataset. As Adelman and Jacoby (1977) claimed, the major problem in estimating and forecasting oil supply is the ambiguity present in defining and recognizing reported oil reserves and changes therein. Forecasting oil supply has major faults and challenges.

3.2.1 Consumer Theory

Changes in consumption are explained by the income and substitution effects when the price changes (Depken, 2005). In a general scope, the substitution effects advocates that as the price of a good increases, all else equal, the consumer will purchase less of the good. The income effect indicates how the consumer's consumption level changes with a change in their income, all else equal. A consumer uses more of a normal good when their income increases and less of an inferior good when their income increases (Depken, 2005).

3.2.2 Elasticities

Price elasticities show the percentage change in the demand of a good due to a percentage change in the price of the good itself, all else equal (Ramskov and Munksgaard, 2001). Price elasticities have a tendency to be negative since they are derived from the demand curves which generally have a negative slope; corresponds to a decline in the demand of a good when the price of that good increases. Price elasticities are bound to change over time, due to the possible presence of a time lag in the model and information deficits on substitution possibilities. This adjustment process results in the long-run price elasticities being greater than the corresponding short-run price elasticities.

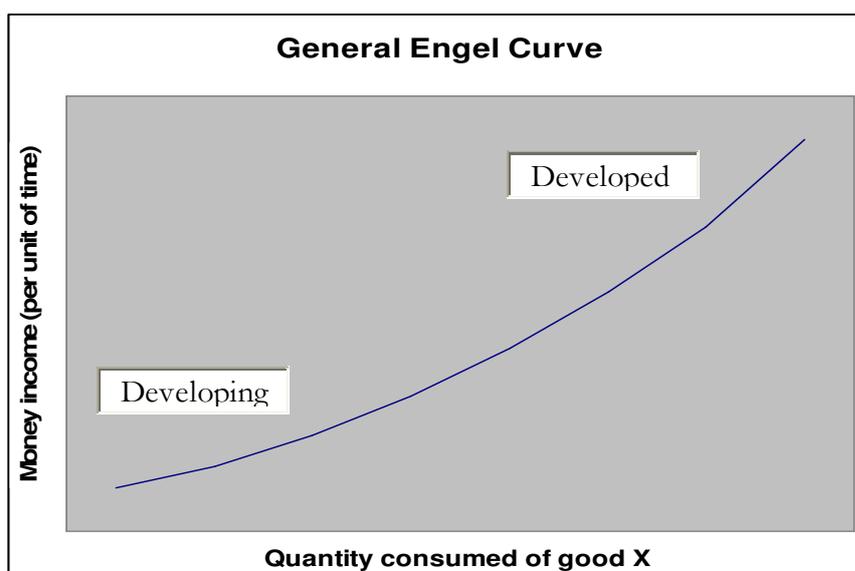
Income elasticities show the percentage increase in the demand of a good as a result of a percentage increase in income, all else equal (Ramskov and Munksgaard, 2001). Generally, the income elasticity for a luxury good is larger than the income elasticity for a necessity good. It is also the case that the income elasticity of a good decreases when the income increases. In the short-run, income elasticities are less elastic than in the long-run.

As confirmed by Gately and Huntington (2001), and Altinay (2007); there is a tendency for the speed of adjustment to changes in price to be slower than to changes in income in almost all countries. In this research, both short and long-run price and income elasticities will be used to explain the concerned countries level of dependency on crude oil. Furthermore, elasticities will be used to describe the country's ability to change their oil consumption in response to Peak Oil.

3.2.3 Engel Curve

An intuitive Engel Curve, as can be seen in Figure 3, can be derived by changing the consumer's money income, all else equal. The Engel Curve shows, given various levels of total income, the amount of a commodity that the consumer would purchase per unit of time (Salvatore, 2006). The steeper the Engel Curve, the more inelastic is the income elasticity; on the contrary a flatter Engel Curve indicates a more elastic income elasticity. In this context, GDP would be the variable used on the Y-axis while the oil consumption variable would be placed on the X-axis. The foundation of the shape of the Engel Curve is determined by the nature of the good that is being analysed. In this case oil is presumed to be a normal good with an increasing, but diminishing marginal quantities consumed as money income increases. In general, according to the Engel Curve; the higher the income, the higher the consumption of a normal good (Salvatore, 2006). Intuitively, developed countries are placed higher up along the Engel Curve and developing countries are placed below due to the differences in their income.

Figure 3: A General Engel Curve



Source: Constructed by the writers based on Salvatore, 2006

3.3 Asymmetric Effects

The phenomenon of imperfect price reversibility, asymmetry; the change in demand to an increase in income is not necessarily matched by an equivalent change in demand due to a decrease in income, nor are the effects of all income increases necessarily the same (Dargay and Gately, 1995). According to Gately and Huntington (2001), the basic idea is that higher crude oil prices encourage incentives for investments in more energy efficient equipment and upgrading existing capital such as greater insulation. Asymmetry can be found when the response to a decrease in crude oil price is not reversed largely due to sunk costs; irreversible investments made during high oil prices. Accordingly, high oil prices increase motivation for technological improvements for oil efficiency which cannot be reversed when oil prices fall, such as automobile technology. Other potential reasons, as provided by Gately and Huntington (2001) for asymmetry may be that some sectors may develop more intensively than others when the economy grows. In contrary, some sectors may decline more intensively than others when the economy contracts; could be due to sectors having diverse energy intensities.

3.4 Hypothesis

We address the following research questions in accordance with theories and previous researches.

- How dependent are the observed countries on oil, and how has these dependencies changed between the years of 1970 and 2006?
- Is there a difference in price and income elasticities between developed and developing countries and how does their oil consumption response to Peak Oil differ?

Since this research is primarily a case study, no statistically testable hypothesis will be conducted. Instead we chose to create a hypothesis which can be tested intuitively through the interpretation of patterns in price and income elasticities. The implication of this, in accordance to Peak Oil, is to show the relative effects on oil consumption.

H_0 : Developing countries oil consumption is **not** more sensitive to price and income changes than developed countries oil consumption.

H_A : Developing countries oil consumption is more sensitive to price and income changes than developed countries oil consumption.

4 Consumption and Income Data

4.1 Current Macroeconomic Data

In order to illustrate how each country's characteristics differ the following Table 2 displays each country's crude oil consumption figures with global total oil consumption and population for the year 2006.

Table 2: Statistics for each Country's Population and Oil Consumption

Country	Crude Oil Consumption in Barrels per day Bbl/d	Percentage of Global Consumption	Population*	Crude Oil Consumption per capita bbl/day	Real GDP per capita* in dollars/year
Brazil	2,097,000	2.50%	186,770,562	0.01123	5,640
China	7,445,000	9.04%	1,303,720,000	0.00571	2,055
Norway	217,000	0.26%	4,623,291	0.04693	71,525
South Korea	2,312,000	2.80%	48,297,200	0.04787	18,164
Sweden	312,000	0.38%	9,089,400	0.03432	42,170
USA	20,589,000	25%	296,410,404	0.06946	43,562

Source: BP, 2007; UN, 2007*

As can be seen on the table above, Brazil, which is the largest country in Latin America and also recently a net exporter of oil, consumes a mere 2.5% of the global total oil consumption. In per capita terms, Brazil only consumes 0.01123 bbl/day, which is low compared to the other countries in this research. China with the highest global population has the lowest crude oil consumption per capita bbl/d even though they consume more than 9% of global oil. China and Brazil are two of the developing countries in this research and the differences in current oil consumption could be due to the fact that China still employs a large fraction of its population in labour intensive agriculture. Brazil on the other hand employs a more capital and thus energy intensive agricultural industry, such as the sugar and lumber industry (Worldbank, 2007). Norway with the smallest population and being a net exporting country of oil has a significantly higher per capita consumption of 0.04693 bbl/d than China and Brazil. South Korea which is a newly developed country with a large heavy industry sector (Worldbank, 2007) has a similar per capita consumption of crude oil as Norway, 0.04787 bbl/d. Sweden with its mixed modern economy has a per capita consumption of 0.03432 bbl/d. USA stands out from the others since it consumes 25% of global total oil consumption and has by far the largest per capita consumption with 0.06946 bbl/d.

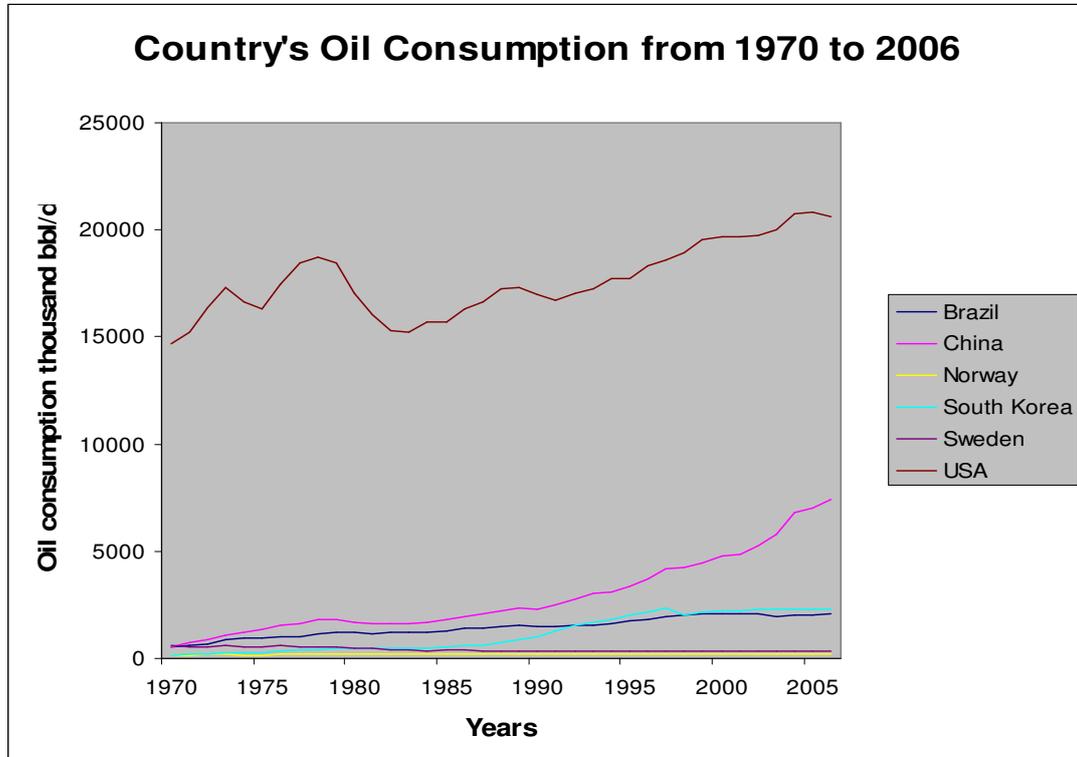
It is clear from the information above that China and Brazil have the smallest per capita oil consumption of the six countries, but with 9% and 2.5% respectively of total global oil

consumption, these countries play a substantial role in world oil market. Brazil and China also have similar crude oil consumption to GDP per capita ratio. South Korea and Norway can be said to be the middle oil consumption countries in this research, with similar per capita oil consumption. Even though Norway's Real GDP per capita is nearly four times that of South Korea's, the similar rates of oil consumption per capita could be explained by their different economic structure; where South Korea, according to Worldbank (2007), has an energy intensive manufacturing industry such as automobiles and electronics. An interesting comparison lies between Sweden and USA where both countries have similar real GDP per capita ratios but substantially different per capita oil consumption. The USA consumes nearly twice as much oil per capita as Sweden; any clear structural explanation is difficult to find since both countries have similar economical characteristics.

4.2 Historical Consumption Pattern

As can be seen on Figure 4, which displays each country's crude oil consumption pattern in bbl/d between the years of 1970 to 2006, all countries except for Sweden, have increased their oil consumption. China experienced the most significant increase in oil consumption while Sweden, on the other hand, decreased its oil consumption gradually. On this figure, it is clear to see that both Sweden and Norway have substantially lower absolute consumption volumes than the other countries in this research.

Figure 4: Crude Oil Consumption for each Country from 1970 to 2006



Source: BP, 2007

4.3 Annual Growth Averages

Table 3 contains each country's growth averages in the variables; Oil Consumption and Real GDP. Starting with Brazil, their oil consumption has grown at a faster rate than real GDP, then ceteris paribus, the rate of oil consumption in the production of GDP must have increased. The same is true for China and to a lesser extent South Korea. On the contrary, Norway's and USA's oil consumption grew at a slower rate than Real GDP, ceteris paribus; indicating that the rate of oil consumption in the production of GDP must have declined. Sweden, having a negative oil consumption growth rate, and at the same time a positive real GDP growth rate, could indicate that their GDP growth is now being fuelled by a relatively less energy concentrated service sector, rather than a more energy-intensive industrial sector. This could of course also be true, less extensively, for Norway and the USA. The real crude oil price grew on the average of 11.25% annually in all countries, since it is the world oil price (BP, 2007).

Table 3: Country's Real GDP and Oil Consumption Growth Averages

Country	Oil consumption % growth averaged annually percentage (1971-2006)	Real GDP % growth averaged annually percentage (1971-2006)*
Brazil	4.01	3.55
China	7.72	6.6
Norway	0.84	4
South Korea	7.96	7.67
Sweden	-1.56	4
USA	0.99	2.25

Source: BP, 2007; UN, 2007*

5 Data

5.1 The Augmented Dickey-Fuller (ADF) Test

As stated by Gujarati (2002), if a time series is stationary; its mean, variance, and auto-covariance remain time invariant. Stationary time series are important, because if a time series is non-stationary, then only the behavior for the considered time period could be analyzed. Therefore it is difficult to forecast with a non-stationary time series since it is impossible to generalize it to other time periods. An additional dilemma associated with regressions that are suffering from non-stationarity, is that the regressions might display less relevant R^2 and F-values, and the variables might obtain less valid t-values. In order to test for stationarity in the time series, the Augmented Dickey-Fuller unit root test, ADF, was used. The critical value for ADF is -3.544284 given 95% confidence; this critical value originated from the Monte Carlo experiments listed in MacKinnon (1991). If the computed absolute value of the ADF exceeds the MacKinnon (1991) critical values, the writers reject the hypothesis that $\delta=0$, in which case the time series is stationary. The null hypothesis that the consumption time series has a unit root, and therefore is non-stationary was

considered. Furthermore, the more negative the ADF is the stronger the rejection of the hypothesis that there is a unit root.

ADF null hypothesis:

$H_0: \delta = 0$, then $p=1$, series contains at least one unit root, the time series is non-stationary.

$H_A: \delta < 0$, then $p<1$, series contains no unit root, the time series is stationary.

As can be seen in Appendix 7, the writers cannot reject the null hypothesis at 5% critical level in China, Norway, South Korea, Sweden, and USA's case; it can therefore be claimed that these country's consumption series are non-stationary; see also Appendix ADF Tables 7-13. In addition, it can be concluded that it is difficult to forecast consumption patterns for these countries.

In Brazil's case, shown in the table below, a sample of 37 observations and a model which includes a constant and a time trend yields the ADF statistic of -4.183250. This is greater in absolute value than the given critical value of -3.544284 at the 5% critical level; therefore the null hypothesis of a unit root can be rejected, in which case the time series is stationary.

5.2 Breusch-Godfrey LM Test

The most serious problem with a time series analysis containing lagged dependent variables is the threat of serial correlation or autocorrelation in the residuals. As stated by Gujarati (2002, p. 454), autocorrelation makes the OLS estimators no longer efficient; violates the assumption of minimum variance. The Durbin Watson test is not appropriate to use under the conditions of a lagged dependent variable, and accordingly, the Breusch Godfrey Lagrange Multiplier Test was used instead; the results are listed in Table 5. Breusch Godfrey Multiplier Lagrange is the most flexible test for detecting higher order autocorrelation and is appropriate whether or not a dependent variable is lagged.

The statistic labelled "obs R-squared" is the Breusch-Godfrey LM test statistic for the null hypothesis of no serial correlation in the residuals; see Appendix LM Tables 14-19. The LM test was conducted with 1 yield or lag; a test against first-order serial correlation. The results shown in Table 5, indicate that there is serial correlation in the residuals present in all countries since all p-values are close to zero; reject null hypothesis of no serial correlation in the residuals. A zero probability value strongly indicates the presence of serial correlation in the residuals. As a consequence, t-statistics can be overestimated.

5.3 Elasticities and Regression Model

One important aspect in oil dependencies is the level of price and income elasticities. Since elasticities explains how responsive each country's oil demand is to changes in price and income. These relationships are essential since they show how attached a country is on oil, *ceteris paribus*. Hence, a country with inelastic price and income elasticities is more reliant on oil compared to one with more elastic price and income elasticities. This can be interpreted as; if the demand response is inelastic it could entail that the country's economy and its consumers have difficulties in exchanging oil for other energy sources.

5.3.1 Macroeconomic Variables

Table 4: Explanations of Macroeconomic Variables used in the Regression

Variables	Definition	Reference
Crude Oil Consumption	The total consumption of crude oil expressed in barrels per day bbl/d. Hence, crude oil consumption does not account for the consumption of gasoline, diesel or other transformed oil products. As BP stated, one barrel of oil is also equivalent to 42 US gallons or 158,987 Litres.	BP (2007)
Gross Domestic Product (GDP)	GDP expressed in current prices in a common currency, US Dollars, represents the market value of all goods and services produced by labor and property in the given country.	Bureau of Economic Analysis (2007)
Crude Oil Price	The crude oil prices used in this research are based on current prices and are expressed in US dollars. The crude oil prices posted originated from two different types of oil within the time frame. From 1970 to 1983 the crude oil prices used were based on the Arabian Light posted at Ras Tanura. From 1984 and forward to 2006 the crude oil prices used in this context were based on the Brent crude oil from the North Sea.	BP (2007)
Lagged Oil Consumption	How Y responds to X with a lapse of time is called a lag. The dependent variable oil consumption was lagged one year and it is therefore assumed that last years oil consumption is a factor in determining current oil consumption.	Gujarati (2002)

Source: BP, 2007; Bureau of Economic Analysis, 2007; Gujarati, 2002

5.3.2 Price Elasticity

The coefficient of price elasticity of demand " e_p ", measures the percentage change in the quantity of a commodity demanded per unit of time resulting from a given percentage

change in the price of the commodity, as is presented as Equation 1. In this thesis it will explain the chosen country's oil demand response to a change in world crude oil prices. The relationships can be inelastic (if $e < 1$), unit elastic (if $e = 1$), or elastic (if $e > 1$). From Salvatore (2006, p. 39), letting ΔQ represent the change in the quantity demanded of a commodity resulting from a given change in its price " ΔP ".

Equation 1:

$$e_p = (\Delta Q/Q)/(\Delta P/P) = - (\Delta Q/\Delta P)*(P/Q)$$

5.3.3 Income Elasticity

The coefficient of income elasticity of demand " e_m ", presented as Equation 2, measures the percentage change in the amount of a commodity purchased per unit time ($\Delta Q/Q$) resulting from a given percentage change in a consumer's income ($\Delta M/M$) (Salvatore, 2006, p. 42). In this thesis, income elasticities will be used to measure the response of the quantity of oil demanded to a change in GDP in a given country.

Equation 2:

$$e_m = (\Delta Q/Q)/(\Delta M/M) = (\Delta Q/\Delta M)*(M/Q)$$

5.3.4 Regression Model

In order to model the time series data of crude oil consumption, which in this context is equal to demand, the partial adjustment equation was used, as is given as Equation 3. This was provided by Cooper (2003); it is an adaptation and modification of Nerlove's adjustment equation (Nerlove, 1956).

Equation 3:

$$\ln D_t = \alpha + \beta \ln P_t + \gamma \ln Y_t + \delta \ln D_{t-1} + \varepsilon_t$$

D_t = Total consumption of crude oil in year t

P_t = Nominal price of crude oil in year t

Y_t = Nominal total GDP in year t

D_{t-1} = Total consumption of crude oil lagged 1 year

ε_t = Assumed random error term

$\varepsilon, \beta, \gamma, \delta$ are coefficients to be estimated

An attractive feature of this log-linear model is that the coefficients β and γ can be interpreted respectively as the short-run price and income elasticity's. As was calculated by John C.B. Cooper (2003), the long-run price elasticity can be calculated for each country from the formula $\beta/(1-\delta)$. The long-run income elasticity of each country can also be calculated from a similar formula $\gamma/(1-\delta)$.

6 Empirical Findings and Analysis

The results from the regression model in Equation 3, using the available time series data for the concerned countries, are tabulated in Table 5; also refer to Appendix Tables 1 to 6.

Table 5: Country's Regression Results

Country	Brazil	China	Norway	South Korea	Sweden	USA
Constant	0.456582***	-0.103103	2.403838***	-0.172118	0.479685	0.137598
(t-stats)	(-3.23161)	(-0.730164)	(-3.66709)	(-1.583506)	(-0.54141)	(-0.23279)
$P_t(\beta)$	-0.042859***	-0.073851***	-0.017474	-0.077595***	-0.029518	-0.038351***
(t-stats)	(-3.982956)	(-4.547877)	(-1.200879)	(-4.224202)	(-1.791588)	(-4.638662)
$Y_t(\gamma)$	0.062148**	0.109922**	0.069681***	0.200703***	0.007417	0.025624***
(t-stats)	(-2.48674)	(-2.15791)	(-3.01678)	(-5.40391)	(-0.20618)	(-2.75259)
$D_{t-1}(\delta)$	0.850155***	0.865280***	0.405283**	0.712861***	0.916622***	0.958072***
(t-stats)	(-16.5741)	(-10.92)	(-2.51237)	(-14.0184)	(-10.7738)	(-14.2557)
R^2	0.991731	0.994117	0.807417	0.996453	0.950555	0.924116
F-Value	75.40487	60.53039	65.11154	56.13530	58.37977	82.18217
BG LM (p-value)	18.63426 (0.000016)	15.74339 (0.000073)	7.315836 (0.006835)	28.25088 (0.000000)	22.06808 (0.000003)	30.20062 (0.000000)

**=Significant at 5% level. (2.021)

***=Significant at 1% level. (2.704)

Critical t-value:

Given $n=37$ observation, the t-critical value is 2.021 at the 5% significance level.

Critical F-value:

Given numerator = 4, and denominator = 33 then the F-critical value is 2.69 at the 5% significance level.

Where the coefficients for P_t and Y_t are estimated and then interpreted as the short-run price and income elasticities respectively. Long-run elasticities for both price and income are calculated with the help of the coefficient of D_{t-1} . The writers assume the significance level to be 5% throughout the thesis. As can be seen in the Table 5, all R^2 values are high, between the values of approximately 0.80 and 0.99, indicating that the independent variables; GDP, crude oil price, and oil consumption lagged explain a change in the dependent variable to a large extent. In addition, all log likelihood or F-values are significant at the 5% significance level, indicating that at least one of the variables is significant. The t-statistics for some countries are insignificant, as is the case with the GDP and oil price in Sweden and the oil price in Norway. For that reason, we will exclude Sweden from the analysis and Norway in the price elasticity analysis. As can be seen from the Breush-Godfrey test given in Table 5, autocorrelation exists in the model which could make the t-statistics seem overestimated. Although this problem exists, the writers chose to conduct the analysis, due to the fact that they could give an indication of the actual values.

6.1.1 Elasticities

The coefficients β and γ can be interpreted respectively as the short-run price and income elasticity's. Long-run price and income elasticity can be calculated from $\beta/(1-\delta)$ and $\gamma/(1-\delta)$ respectively, see Appendix Tables 1 to 6.

Table 6: Price and Income Elasticities, Short and Long-run

Country	Price Elasticity Short-Run β	Price Elasticity Long-run	Income Elasticity Short-Run γ	Income Elasticity Long-Run
Brazil	-0.042859***	-0.286022***	0.062148**	0.4147486**
China	-0.073851***	-0.5481814***	0.109922**	0.815929**
Norway	-0.017474	-0.029382	0.069681***	0.117166***
South Korea	-0.077595***	-0.270235***	0.200703***	0.69897***
Sweden	-0.029518	-0.354026	0.007417	0.088956
USA	-0.038351***	-0.914687***	0.025624***	0.0611142***

**=Significant at 5% level. (2.021)

***=Significant at 1% level. (2.704)

The price elasticity implies that a 1% change in price will change consumption by the amount of its coefficient at the 5% significant level, all else equal. The income elasticity entails that a 1% change in income will change consumption by the value of its coefficient at the 5% significant level, all else equal. In Brazil's case, a price elasticity of -0.042859 significant at 5% level, in the short-run means that if price were to increase by 1% then consumption would decrease by 0.042859%, all else equal. As expected, the long-run price elasticity is considerably more elastic -0.286022; implying that a 1% increase in price will decrease oil consumption by 0.286022% in the long-run, all else equal.

One interesting interpretation of the insignificant t-statistics in Sweden, as can be seen in the tables above, could be external factors. In this case the writers believe that the extensive government intervention in Sweden could be the reason for why consumption is not as correlated with GDP and oil price as in the other countries. This could be due to outside government distortions being levelled on the energy market, leading to insignificant t-statistics. Due to the insignificant t-statistics present in the regression results for Sweden, we chose to exclude Sweden from the analysis.

The estimations from China, South Korea, and USA's price elasticities in both short and long-run are comparable with the estimates conducted by Cooper (2003). The elasticities calculated in this research are similar with his presented elasticities but with some exceptions; the differences could be due to the fact that Cooper (2003) used observations from the years 1971 - 2000, hence less observations than in this research. One example of this similarity is present in South Korea's case, where Cooper's (2003) short and long-run price elasticities were -0.094 and -0.178 respectively. This could be compared with the writers' price elasticities; -0.077595 in the short-run and -0.0270235 in the long-run. The difference could be explained by the different time periods used.

According to Gately and Huntington (2001), the long-run income elasticity of oil demand should be around 0.5 and 0.6 for the OECD countries, and about 1.0 for non-OECD countries whose income is growing steadily. This goes in line with the results from this research, where the three developing or recently developed countries; Brazil, China, and South Korea have significantly higher long-run income elasticities compared to the two significant developed countries in this research; Norway and USA.

Short-run price elasticities follow the same pattern as income elasticities in the matter that developing countries are more sensitive to price changes on oil demand compared to developed countries. In the long-run, price elasticities among developed and developing countries are more similar with the exception of USA, which has a significantly higher elasticity than the others. This indicates that USA's consumption is particularly sensitive to a change in price in the long-run.

A general pattern was noticed, when analysing Table 6, that all short-run price elasticities were relatively low in all countries, and as expected, all price elasticities both in the short-run and the long-run were negatively related to oil consumption, in addition as presumed the long-run price elasticities were more elastic than in the short-run. Signifying that in the long-run, consumers have more time to adapt to the new price and reallocate their resources to substitutes accordingly. Income elasticities in the short-run follow the pattern from price elasticities in the fact that they are inelastic, but in this case a positive relationship with consumption was distinguished. It is clear from Table 6 that China and South Korea have considerably higher income elasticities in the short-run compared to other countries, and thus seem to be more sensitive to changes in income on oil demand. Consequently, if an Engel Curve were constructed, it would be significantly steeper for

developing countries than for the developed countries implying that their oil demand is more elastic and that they are less dependent on oil compared to developed countries. The US has close to unit elastic price elasticity in the long-run, this entails that they could exchange their oil demand in the same magnitude as a given price change in the long-run, all else equal. Long-run income elasticities are, as expected, higher than in the short-run, indicating that in the long-run consumers have more time to reallocate their expenditures on substitutes or increase energy efficiency accordingly.

The price and income elasticities are nonetheless a bit miss-informing due to the phenomenon of imperfect price and income reversibility; asymmetry. An increase in the price of crude oil will presumably decrease oil consumption to a larger magnitude compared to a decrease in crude oil price, largely due to sunk costs induced at higher crude oil prices, as discussed by Gately and Huntington (2001). A period of high oil prices followed by a period of lower crude oil prices tends to give an asymmetric demand response. This could have been the case in the period between 1980 and 1990, where crude oil prices were volatile and large sunk costs were induced at high crude oil prices, such as increased fuel efficiency; Gately and Huntington (2001). Similar patterns can be seen on the income side as well; decreases in income tend to change oil demand to a greater extent than income increases. If applied to the data above the asymmetric effect can help to interpret the elasticity coefficients more efficiently. The coefficient for price elasticity should be higher during price increases than during price decreases, and the coefficient for income elasticity should be higher during income decreases compared to income increases. Subsequently, higher crude oil prices and lower income will affect oil consumption to a greater extent than suggested from the table above.

6.2 Peak Oil

In this section, an interpretation of Peak Oil's plausible effects on oil consumption on each country based on their short and long-run price and income elasticities will be conducted. Peak Oil, in Hubbert's bell shaped model, is the climax point or plateau which is followed by a steady decline in production; Campbell (2003). A decrease in supply will lead to an increase in price, all else equal. According to IEA (2004), an increase in the price of crude oil could induce changes in the exchange rate and balance of trade between countries. A normal occurrence due to an increase in crude oil prices for net oil importing countries is deterioration in their balance of payments leading to downward pressures for the exchange rates and currency appreciation. As a consequence, the real national income will drop since their imports become more expensive and their exports less valuable.

6.2.1 Peak Oil's Effects Interpreted using Elasticities

Since Peak Oil will lead to an increase in crude oil price, price elasticity is an appropriate measure to use in order to see changes in oil consumption. An increase in crude oil price will in the short-run decrease oil consumption more in the developing countries of China, Brazil, and South Korea compared to the only statistically significant developed country, USA. This is due to more elastic price elasticities in the short-run for the developing

countries indicating that the short-run response to Peak Oil on oil demand will be experienced to a greater magnitude in developing countries than in developed countries. Long-run adaptations to price increases do not follow the same pattern as the short-run price elasticities. Both developing and developed countries adapt to a greater extent in the long-run than in the short-run, the difference is that the developed countries have increased their elasticities to a greater extent than developing countries. Indicating that as time progresses, developed countries consumption will be able to respond in an equal or greater magnitude than developing countries to an oil price increase.

Following upon the arguments given by IEA (2004) above that an increase in the oil price will affect each country's terms of trade. If importing countries were to experience decreasing GDP rates, this would in turn affect their consumption of oil through income elasticities. In this research, four countries are net importers of oil; Sweden, China, USA, and South Korea. Due to Peak Oil and therefore higher crude oil prices, these countries could experience deteriorating GDP rates. Since income elasticities, in general, are higher than price elasticities in both the short and long-run, this could have a large effect on these countries oil consumption. This is especially true for China and South Korea, where an income change affects oil consumption more so than the other net importing countries, USA. In Sweden's case, the effects are unclear since the coefficients are statistically insignificant. By the same token, the exporting countries of Norway and Brazil could experience their GDP rate increase as a consequence of higher oil prices due to Peak Oil. This could actually indicate that Brazil and Norway could increase their oil consumption depending on the relative magnitudes between the price elasticity effects and the income elasticity effects. Clear is though that Brazil and Norway's oil consumption should decrease less in relative terms than the net oil importing countries due to the positive income elasticity effect on oil consumption.

7 Conclusion

The writers can conclude that the countries in this study have different levels of oil dependencies. Crude oil consumption has increased in absolute terms in all countries in this research except for in Sweden, indicating that world crude oil demand is also increasing, as the Energy Information Administration (2006) confirmed. Large growing developing or recently developed economies such as China, Brazil and South Korea have seen their oil consumption increasing at a faster rate, even in relative terms, in relation to their Real GDP growth. The three developed countries in the sample have decreased their oil consumption in relative terms since the 1970's. Furthermore, developed countries consume more crude oil than developing countries, as is presumed from the Engel Curve.

Price elasticities of approximately 0.05 in the short-run makes the writers conclude that the countries in this research are not very sensitive to price changes in the short-run; this also goes in line with conclusions from Cooper (2003). As presumed, the long-run price elasticities are more elastic than in the short-run. It can also be concluded that the calculated income elasticities in this research are comparable with the results from Gately and Huntington (2001), where non-OECD countries have higher long-run income elasticities than OECD countries. Since this is also true for price elasticities, the writers can intuitively **reject the null hypothesis** that developing country's oil consumption is not more sensitive to price and income changes than developed country's oil consumption. Although the regression model presented insignificant price and income coefficients for Sweden, and price coefficients for Norway; it is interesting to note that all elasticities are inelastic both in short and long-run for the statistically significant countries. Therefore the writers can conclude that oil is a necessity commodity for all the countries in this context and is consequently difficult to substitute for other energy resources even in the long-run.

An additional conclusion that can be drawn is that developed countries tend to decrease their relative oil consumption gradually while fast growing developing countries, on the contrary, increase their relative oil consumption. This makes the writers apprehend the ever increasing energy sustainability problem in developing countries. Furthermore, the writers are also of firm believe that increasing oil consumption makes especially developing countries ever more vulnerable to Peak Oil.

To sum up this thesis, oil dependencies among nations differ and the trend is that developing countries are increasing their oil dependency while developed countries tend to decrease their oil dependency over time. Peak Oil will lead to higher oil prices, which in the short-run will change developing countries oil consumption to a greater extent than developed countries. In the long-run, developed country's price elasticities have a tendency to grow closer to the developing country's price elasticities, indicating that in the long-run the effect will be similar in both developed and developing countries. A second effect was noticed, that when GDP falls in net-oil-importing countries, oil consumption will decrease even further. The opposite could be true for net-oil-exporting countries of Norway and Brazil.

8 Suggestions for Further Research

For a more in depth study, one could analyze a country's dependencies on oil relative to their efforts in developing and implementing alternative energy resources. A further extension of this is to analyze the crude oil prices effects on investments into alternative energy resources.

Another interesting topic would be to analyze two countries in a deeper fashion considering more variables such as government policies, events, and innovation. The advantage of this approach is that the model should contain less bias and the analyses could be more extensive and comprehensive.

In a broader sense, one could analyze the impact of high oil prices on the global economy. How prices could affect the macro-economy would be interesting to investigate while assessing quantity values. In addition, the extent to which the economies of non-OECD's and OECD's remain susceptible to a continuous period of high oil prices can be researched.

Finally research could be done on the differences of marginal costs for exchanging oil for substitutes for different countries with different economical characteristics, such as whether they are net exporters or importers of oil, developing or developed, etc.

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Appendix

C(1) = coefficient of constant

C(2) = coefficient of GDP

C(3) = coefficient of crude oil price

C(4) = coefficient of consumption lagged 1 year

Regression Appendix Table 1: Brazil

Dependent Variable: LCONSUMPTION

Method: Least Squares

Date: 10/31/07 Time: 16:25

Sample (adjusted): 1971 2006

Included observations: 36 after adjustments

LCONSUMPTION=C(1)+C(2)*LGDP+C(3)*LPRICE+C(4)
*LCONSUMPTIONLAG

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.456582	0.141286	3.231614	0.0028
C(2)	0.062148	0.024992	2.486741	0.0183
C(3)	-0.042859	0.010761	-3.982956	0.0004
C(4)	0.850155	0.054239	15.67414	0.0000
R-squared	0.991731	Mean dependent var		7.248849
Adjusted R-squared	0.990956	S.D. dependent var		0.332273
S.E. of regression	0.031599	Akaike info criterion		-3.966937
Sum squared resid	0.031952	Schwarz criterion		-3.790990
Log likelihood	75.40487	Durbin-Watson stat		1.580057

Long-run price elasticity = $\beta_3 / (1 - \beta_4)$

$$= -0,042859 / (1 - 0,850155) = \mathbf{-0,286022}$$

Long-run income elasticity = $\beta_2 / (1 - \beta_4)$

$$= 0,062148 / (1 - 0,850155) = \mathbf{0,4147486}$$

Regression Appendix Table 2: China

Dependent Variable: LCONSUMPTION

Method: Least Squares

Date: 10/31/07 Time: 17:12

Sample (adjusted): 1971 2006

Included observations: 36 after adjustments

LCONSUMPTION=C(1)+C(2)*LGDP+C(3)*LPRICE+C(4)

*LCONSUMPTIONLAG

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.103103	0.141206	-0.730164	0.4706
C(2)	0.109922	0.050939	2.157906	0.0385
C(3)	-0.073851	0.016239	-4.547877	0.0001
C(4)	0.865280	0.079238	10.92004	0.0000
R-squared	0.994117	Mean dependent var	7.818148	
Adjusted R-squared	0.993565	S.D. dependent var	0.595451	
S.E. of regression	0.047766	Akaike info criterion	-3.140577	
Sum squared resid	0.073010	Schwarz criterion	-2.964630	
Log likelihood	60.53039	Durbin-Watson stat	1.657500	

Long-run price elasticity = $\beta_3 / (1 - \beta_4)$

$$= -0,073851 / (1 - 0,865280) = \mathbf{-0,5481814}$$

Long-run income elasticity = $\beta_2 / (1 - \beta_4)$

$$= 0,109922 / (1 - 0,865280) = \mathbf{0,815929}$$

Regression Appendix Table 3: Norway

Dependent Variable: LCONSUMPTION

Method: Least Squares

Date: 10/31/07 Time: 16:55

Sample (adjusted): 1971 2006

Included observations: 36 after adjustments

LCONSUMPTION=C(1)+C(2)*LGDP+C(3)*LPRICE+C(4)

*LCONSUMPTIONLAG

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	2.403838	0.655517	3.667086	0.0009
C(2)	0.069681	0.023098	3.016778	0.0050
C(3)	-0.017474	0.014551	-1.200879	0.2386
C(4)	0.405283	0.161315	2.512373	0.0172
R-squared	0.807417	Mean dependent var		5.282595
Adjusted R-squared	0.789362	S.D. dependent var		0.091640
S.E. of regression	0.042058	Akaike info criterion		-3.395085
Sum squared resid	0.056605	Schwarz criterion		-3.219139
Log likelihood	65.11154	Durbin-Watson stat		1.773138

Long-run price elasticity = $\beta_3 / (1 - \beta_4)$

$$= -0,017474 / (1 - 0,405283) = \mathbf{-0,029382}$$

Long-run income elasticity = $\beta_2 / (1 - \beta_4)$

$$= 0,069681 / (1 - 0,405283) = \mathbf{0,117166}$$

Regression Appendix Table 4: South Korea

Dependent Variable: LCONSUMPTION

Method: Least Squares

Date: 10/31/07 Time: 16:44

Sample (adjusted): 1971 2006

Included observations: 36 after adjustments

LCONSUMPTION=C(1)+C(2)*LGDP+C(3)*LPRICE+C(4)

*LCONSUMPTIONLAG

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.172118	0.108694	-1.583506	0.1231
C(2)	0.200703	0.037140	5.403906	0.0000
C(3)	-0.077595	0.018369	-4.224202	0.0002
C(4)	0.712861	0.050852	14.01835	0.0000
R-squared	0.996453	Mean dependent var	6.752724	
Adjusted R-squared	0.996120	S.D. dependent var	0.866432	
S.E. of regression	0.053968	Akaike info criterion	-2.896405	
Sum squared resid	0.093202	Schwarz criterion	-2.720459	
Log likelihood	56.13530	Durbin-Watson stat	1.598562	

Long-run price elasticity = $\beta_3 / (1 - \beta_4)$

$$= -0,077595 / (1 - 0,712861) = \mathbf{-0,270235}$$

Long-run income elasticity = $\beta_2 / (1 - \beta_4)$

$$= 0,200703 / (1 - 0,712861) = \mathbf{0,69897}$$

Regression Appendix Table 5: Sweden

Dependent Variable: LCONSUMPTION

Method: Least Squares

Date: 10/31/07 Time: 16:38

Sample (adjusted): 1971 2006

Included observations: 36 after adjustments

LCONSUMPTION=C(1)+C(2)*LGDP+C(3)*LPRICE+C(4)

*LCONSUMPTIONLAG

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.479685	0.885990	0.541411	0.5920
C(2)	0.007417	0.035972	0.206178	0.8380
C(3)	-0.029518	0.016476	-1.791588	0.0827
C(4)	0.916622	0.085079	10.77382	0.0000
R-squared	0.950555	Mean dependent var		5.972402
Adjusted R-squared	0.945920	S.D. dependent var		0.218043
S.E. of regression	0.050706	Akaike info criterion		-3.021099
Sum squared resid	0.082276	Schwarz criterion		-2.845152
Log likelihood	58.37977	Durbin-Watson stat		2.228348

Long-run price elasticity = $\beta_3 / (1 - \beta_4)$

$$= -0.029518 / (1 - 0.916622) = \mathbf{-0,354026}$$

Long-run income elasticity = $\beta_2 / (1 - \beta_4)$

$$= 0,007417 / (1 - 0,916622) = \mathbf{0,088956}$$

Regression Appendix Table 6: USA

Dependent Variable: LCONSUMPTION

Method: Least Squares

Date: 10/31/07 Time: 16:48

Sample (adjusted): 1971 2006

Included observations: 36 after adjustments

LCONSUMPTION=C(1)+C(2)*LGDP+C(3)*LPRICE+C(4)

*LCONSUMPTIONLAG

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.137598	0.591076	0.232792	0.8174
C(2)	0.025624	0.009309	2.752593	0.0097
C(3)	-0.038351	0.008268	-4.638662	0.0001
C(4)	0.958072	0.067206	14.25569	0.0000
R-squared	0.924116	Mean dependent var		9.778054
Adjusted R-squared	0.917002	S.D. dependent var		0.090862
S.E. of regression	0.026177	Akaike info criterion		-4.343454
Sum squared resid	0.021927	Schwarz criterion		-4.167507
Log likelihood	82.18217	Durbin-Watson stat		1.269766

Long-run price elasticity = $\beta_3 / (1 - \beta_4)$

$$= -0,038351 / (1 - 0,958072) = \mathbf{-0,914687}$$

Long-run income elasticity = $\beta_2 / (1 - \beta_4)$

$$= 0,0025624 / (1 - 0,958072) = \mathbf{0,061114}$$

Augmented Kickey-Fuller (ADF) Test Appendix

ADF Appendix Table 7: All Countries, Unit Root Test of Oil Consumption

Country	Augmented Dickey-Fuller (ADF)
Brazil (Prop.)	-4.183250** (0.0116)
China (Prop.)	-1.913713* (0.6262)
Norway (Prop.)	-3.069171* (0.1292)
South Korea (Prop.)	-0.747333* (0.9611)
Sweden (Prop.)	-1.346496* (0.8590)
USA (Prop.)	-2.975850* (0.1530)

* Cannot reject H_0

**Reject H_0

ADF Appendix Table 8: Brazil

Null Hypothesis: LCONSUMPTION has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Fixed)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.183250	0.0116
Test critical values:		
1% level	-4.243644	
5% level	-3.544284	
10% level	-3.204699	

ADF Appendix Table 9: China

Null Hypothesis: LCONSUMPTION has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
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Augmented Dickey-Fuller test statistic		-1.913713	0.6262
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Test critical values:	1% level	-4.243644	
	5% level	-3.544284	
	10% level	-3.204699	

ADF Appendix Table 10: Norway

Null Hypothesis: LCONSUMPTION has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
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Augmented Dickey-Fuller test statistic		-3.069171	0.1292
<hr/>			
Test critical values:	1% level	-4.243644	
	5% level	-3.544284	
	10% level	-3.204699	

ADF Appendix Table 11: South Korea

Null Hypothesis: LCONSUMPTION has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
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Augmented Dickey-Fuller test statistic		-0.747333	0.9611
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Test critical values:	1% level	-4.243644	
	5% level	-3.544284	
	10% level	-3.204699	

ADF Appendix Table 12: Sweden

Null Hypothesis: LCONSUMPTION has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
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Augmented Dickey-Fuller test statistic		-1.346496	0.8590
<hr/>			
Test critical values:	1% level	-4.243644	
	5% level	-3.544284	
	10% level	-3.204699	

ADF Appendix Table 13: USA

Null Hypothesis: LCONSUMPTION has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
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Augmented Dickey-Fuller test statistic		-2.975850	0.1530
<hr/>			
Test critical values:	1% level	-4.243644	
	5% level	-3.544284	
	10% level	-3.204699	

Breusch-Godfrey LM Test Appendix

LM Appendix Table 14: Brazil

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	33.48250	Probability	0.000002
Obs*R-squared	18.63426	Probability	0.000016

LM Appendix Table 15: China

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	24.44096	Probability	0.000022
Obs*R-squared	15.74339	Probability	0.000073

LM Appendix Table 16: Norway

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	8.133043	Probability	0.007443
Obs*R-squared	7.315836	Probability	0.006835

LM Appendix Table 17: South Korea

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	106.5569	Probability	0.000000
Obs*R-squared	28.25088	Probability	0.000000

LM Appendix Table 18: Sweden

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	48.77114	Probability	0.000000
Obs*R-squared	22.06808	Probability	0.000003

LM Appendix Table 19: USA

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	146.5751	Probability	0.000000
Obs*R-squared	30.20062	Probability	0.000000
