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What Drives Natural Gas Consumption in Europe? Analysis and Projections

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ABSTRACT

Natural gas is an important fuel source for Europe and it is expected to remain so in the near future. The market power of suppliers is an important structural element of the European natural gas market and long-term investment and contracts necessitate reliable projections of natural gas demand. This research attempts to address this need. It investigates the impact of income, real natural gas prices and the underlying energy demand trend (UEDT) on OECD-Europe natural gas consumption by applying the structural time series technique to annual data over the period 1978 to 2011. The results suggest that, in order of importance, income, the UEDT and natural gas prices all play a role in driving OECD-Europe natural gas consumption with the estimated UEDT having both increasing (gas using) and decreasing (gas saving) periods over the estimation period and the estimated long run income and price elasticities being 1.19 and -0.16 respectively. Furthermore, based upon the estimated relationship, OECD-Europe natural gas consumption is predicted to be somewhere between 572 and 646 bcm (about 472 and 533 mtoe) by 2020.

JEL Classifications: C22; Q41; Q47; Q48.

Key Words: OECD-Europe Gas Demand; Structural Time Series Model (STSM); Gas Demand Modelling and Future Scenarios.

What Drives Natural Gas Consumption in Europe?
Analysis and Projections

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1. Introduction

Natural gas is an important fuel resource for Europe and it is expected to remain important in the next few decades (Holz et al., 2006; EC, 2008, 2009; EIA, 2009 and IEA, 2010) due to increasing environmental concerns and related policies. Compared to other fossil fuels, natural gas has lower carbon intensity and higher fuel efficiency in electricity generation (EIA, 2009). It is also used as a backup fuel for intermittent renewable sources (Ghafghazi et al., 2010, Samseth, 2013). Hence, the use of natural gas in electricity generation is expected to increase in Europe as well as in the rest of the world (EIA, 2009 and IEA, 2010). In addition to the effect of environmental concerns, there are also increasing trends in the indigenous demand for natural gas in the supplier countries and in the demand of developing countries (Remme et al., 2008; EIA, 2009). Indigenous natural gas production in Europe, however, is declining. Thus, the OECD-Europe's natural gas import dependence is expected to increase (Honore, 2010; Remme et al., 2008) at a time of global competition for accessing natural gas sources.

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Increasing energy demand in general is a global trend and given that fossil fuel reserves remain limited[1], energy security has become one of the primary economic and political objectives of both developed and developing countries over the last few decades (Yergin, 2006; IEA, 2010). From a theoretical viewpoint, liberalisation of fuel markets is seen as adequate (Radetzki, 1999) for delivering both energy security and efficient allocation of scarce resources. Nonetheless, as identified by Bilgin (2009) and Helen (2010), structural and institutional conditions often impede efficiency of fuel markets.

Such structural and institutional conditions are also relevant to OECD-Europe's natural gas market. Conditions including the market power of supplier countries, the requirement of long-term investment pipelines across countries to facilitate cost-efficient transportation, and the prevalence of long-term contracts raise concerns about the efficiency of the market. More than half of the proven global natural gas reserves are located in Russia, Iran and Qatar (BP, 2005). The Gas Exporting Countries Forum (GECF), which was created in 2001, has become another concern for net importers. Although GECF currently operates as a facilitator of logistic collaboration between member countries, the possibility that it may act as a cartel to gain control over the gas supplies and prices in the future raises concerns (Stern, 2002; Massola and Tchung-Ming, 2010). Regarding the operations of the natural gas market, generally, the most cost efficient alternative for transporting natural gas is via pipelines (Hafner et al, 2008; see also Pirani et al 2009). This, however, requires long-term infrastructure investment and the energy security of the transit countries may become important at times of crisis, such as the Russia-Ukraine gas conflicts in 2006 and 2009. Regarding the institutional conditions, long-term contracts, which are often in the form of

[1] Although the recent improvements in unconventional oil and gas production increase the amount of recoverable fossil fuels, they are still finite.

take-or-pay obligations between 80-90% of the annual contract quantity for a period up to 25 years (Newbery, 1984), has long been the *modus operandi* in the natural gas market. Although the increasing volumes of more flexible LNG and unconventional gas (such as shale gas, tight gas and coalbed methane) could alter the drivers of long-term contracts in the future (Talus, 2011). Long-term contracts in natural gas markets have ambiguous effects on the market structure and social welfare; on one hand they are considered as barriers to entry for potentially more efficient suppliers and on the other hand they are thought to facilitate market entry by encouraging long-term investments (Hauteclocque and Glachant, 2009).

European countries can adopt energy policies that address some of these issues, for instance, by increasing the diversification of natural gas suppliers could reduce the share of Russia and increase the shares of Middle Eastern and Caspian sources, which could reduce the market power of major suppliers and improve the energy security of Europe (Bilgin, 2009). Regarding the institutional conditions, the European natural gas market is undergoing a significant liberalisation process (Talus, 2011) and the European Commission has the objective of shortening the contract period of natural gas transactions (Kavalov et al, 2009).

On the other hand, the political impacts of strong actors and major suppliers such as Russia cannot be ignored while assessing diversification strategies. Russia relies on the gas exports that are mainly directed to Europe via pipelines and thus encourages Caspian countries to divert their export routes to the east rather than west. Furthermore, there are certain interdependencies between structural and institutional conditions. For instance, diversification of natural gas sources requires investment in new pipelines and long-term contracts may be preferred to secure such investments (Oren, 2003). According to Neuhoff and von Hirschhausen (2005), the suppliers would also prefer long-term contracts as long as the elasticity of demand is significantly higher in the long run than in the short run. These interdependencies can lead to the emergence of new institutional arrangements; China, for instance has started to provide package solutions covering finance, field development and pipeline construction (Hall and Grant, 2009; Remme et al., 2008) in order to gain access to Caspian energy sources and secure long-term production sharing agreements. Hence, despite the developments in the spot markets, the drivers of long-term contracts are likely to continue to be influential in the European natural gas market over the next two decades (Stern, 2002; Neuhoff and von Hirschhausen, 2005; Hauteclocque and Glachant, 2009).

Overall, natural gas is likely to remain an important fuel in the next few decades and the global competition for accessing natural gas sources will be increasing in parallel to European demand. On the supply side, OECD-Europe's indigenous production is likely to decline while the global suppliers that are already low in number may initiate cartel-like organisations. Furthermore, the physical and institutional conditions of the market will probably require long-term measures to help deliver energy security. Not surprisingly, these developments create anxiety across an import dependent Europe (see, for example, EC, 2009). Volatility in natural gas prices or supply can have devastating effects on European economies and therefore, identification of future natural gas needs is a vital and urgent issue for policy makers in OECD-Europe (Christoffersen, 1998; Bilgin 2009).

This paper addresses this need by analysing OECD-Europe[2] natural gas consumption, which in 2010 accounted for about 17.5% of total world natural gas consumption (EIA, 2013). The

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[2] OECD-Europe consists of the EU member and candidate countries, hence the study covers the natural gas consumption of Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

relationship between OECD-Europe natural gas demand and the determinants income, natural gas prices, and an underlying energy demand trend (UEDT) is investigated by applying the structural time series model (STSM) to annual data over the period 1978 to 2011.[3] From this, the estimated natural gas demand function is used to produce future scenarios for OECD-Europe natural gas demand.

This is, as far as known, the first study that allows for a stochastic UEDT when estimating an OECD-Europe natural gas demand function. The benefits of using the STSM in order to underpin energy forecasts are explained in the following sections. It suffices to mention here that this methodology helps overcome some of the perceived shortcomings of previous studies by allowing for a stochastic UEDT and therefore the estimated model will hopefully perform better than previous models for producing forecasts. Given the importance of reliable natural gas forecasts for assessing European energy security, forecasts that are produced are useful for European policy makers, natural gas producing companies and financial institutions.

The paper is organised as follows. The next section reviews previous studies of natural gas demand in Europe. The third section explains the methodology of the paper with a short introduction to the STSM and the UEDT and a discussion on why this is an appropriate approach for natural gas demand modelling. The fourth section introduces the dataset and presents the results. The fifth section presents forecast scenarios of future OECD-Europe natural gas demand and the last section concludes.

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[3] Both STSM and UEDT will be further discussed in details in the Methodology section.

2. Literature Review

In this section, the key literature is discussed in two parts. Firstly, previous studies that have estimated natural gas demand elasticities are reviewed. Secondly, previous projections for future natural gas consumption are summarised.

2.1 Previous Studies on Price and Income Elasticities of Natural Gas Demand

Pindyck (1979) analysed the structure of world energy demand for different fuels and sectors for the OECD countries Canada, France, Italy, Netherlands, Norway, Sweden, Japan, the UK, the US and West Germany over the period 1955-1974. He estimated that natural gas price elasticities for the residential and industrial sectors ranged from -0.9 to -1.8 and -0.41 to -2.34 respectively. Griffin (1979) estimated natural gas demand functions for different sectors of the OECD countries Austria, Belgium, Canada, Denmark, France, Greece, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, Turkey, the UK, the US. and West Germany over the period 1955 to 1972. He concluded that the price elasticity of natural gas demand varied between -0.83 to -1.60.

Estrada and Fugleberg (1989) investigated the price responsiveness of natural gas demand for West Germany and France and found estimated price elasticities between -0.75 and -0.82 for West Germany and between -0.61 and -0.76 for France. Nilsen et al. (2005) examined residential natural gas demand per capita for the European countries Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Spain, Switzerland and the UK over the period 1978-2002. Their results suggest that the short run and long run price elasticities vary between 0 to -0.3 and 0 to -0.6 respectively, whereas the short and long run income elasticities range from 0.3 to 0.7 and 1.9 to 2.2 correspondingly.

The above illustrates that these previous estimates of natural gas price and income elasticities of demand varied considerably across a range of countries. This is further highlighted in Table 1, which summarises some surveys of previous studies that investigate the price and income elasticities of natural gas demand. One reason for this might be that previously applied models are insufficient in terms of identifying the structural changes in natural gas demand. Hence, one of the aims in this research is to attempt to identify key structural changes in OECD-Europe natural gas demand behaviour by using the UEDT/STSM approach. However, before this method is introduced, previous studies focusing on European natural gas demand projections are reviewed in the next section.

Table 1: Summary of Estimated Elasticities of Natural Gas Demand Surveys

Survey	***Short Run Price Elasticity***	***Short Run Income Elasticity***	***Long Run Price Elasticity***	***Long Run Income Elasticity***
Taylor (1977)	0 to -0.38	0.01 to 1	0 to -3.85	-0.29 to 3.11
Bohi (1981)	0.09 to -0.50	-0.03 to 0.05	0.33 to -2.42	0.02 to 2.18
Kirby (1983)	-	-	-0.3	0.4
Bohi and Zimmerman (1984)	0.16 to -0.63	0.02 to 0.78	0.99 to -3.44	0.09 to 3.08
Dahl (1993)	0.02 to -1.63	-0.33 to 1.74	1.56 to -10	-2.19 to 4.46

2.2 Previous Projections of European Gas Demand

There appear to have been few academic authors and institutions working on natural gas demand projections. Mackay and Probert (1995), one of the early studies, predicted that French natural gas consumption will be somewhere between 46 – 58 bcm (38-43 million tonnes of oil equivalent, mtoe)[4] by 2010.[5] According to Eurogas (2010), natural gas consumption of EU-27 would be between 535-562 bcm (482-507 mtoe) in 2020. However, this is somewhat lower than Eurogas's previous estimates (Eurogas, 2006) where they projected EU natural gas consumption to be 641 bcm (578 mtoe) in 2020.[6] One possible reason for the revision to its projections could well be the European economic crises of the late 2000s.

Honore (2006) focuses on EU-25 natural gas consumption by the power sector and concludes that in 2015 natural gas consumption by the power sector and the non-power sector would be 195 bcm and 406 bcm (161 mtoe and 335 mtoe) respectively; a total of 601 bcm (496 mtoe).[7] There are two institutions, the US Energy Information Administration (EIA) and the International Energy Agency (IEA) that produce annual forecasts for OECD-Europe. EIA (2010) projected that OECD-Europe natural gas demand would be between 575 and 609 bcm (474 and 502 mtoe)[8] by 2020, whereas IEA (2010) predicted that OECD-Europe natural gas demand would be somewhere between 534 and 589 bcm (440 and 486 mtoe)[9] by 2020. However, both of these institutions reduced their reference case projections considerably

[4] Mackay and Probert (1995) present their natural gas projections in mtoe; the bcm figures are based upon the IEA conversion factor of 1 mtoe = 1.2125 bcm (IEA, 2010).

[5] Which looks to be a little high given that French natural gas consumption was 40 bcm (33 mtoe) in 2008 (IEA, 2011).

[6] Eurogas (2010) and Eurogas (2006) present their natural gas projections in mtoe; the bcm figures are based upon the conversion factor of 1 mtoe = 1.11 bcm (as it is used in Eurogas publications).

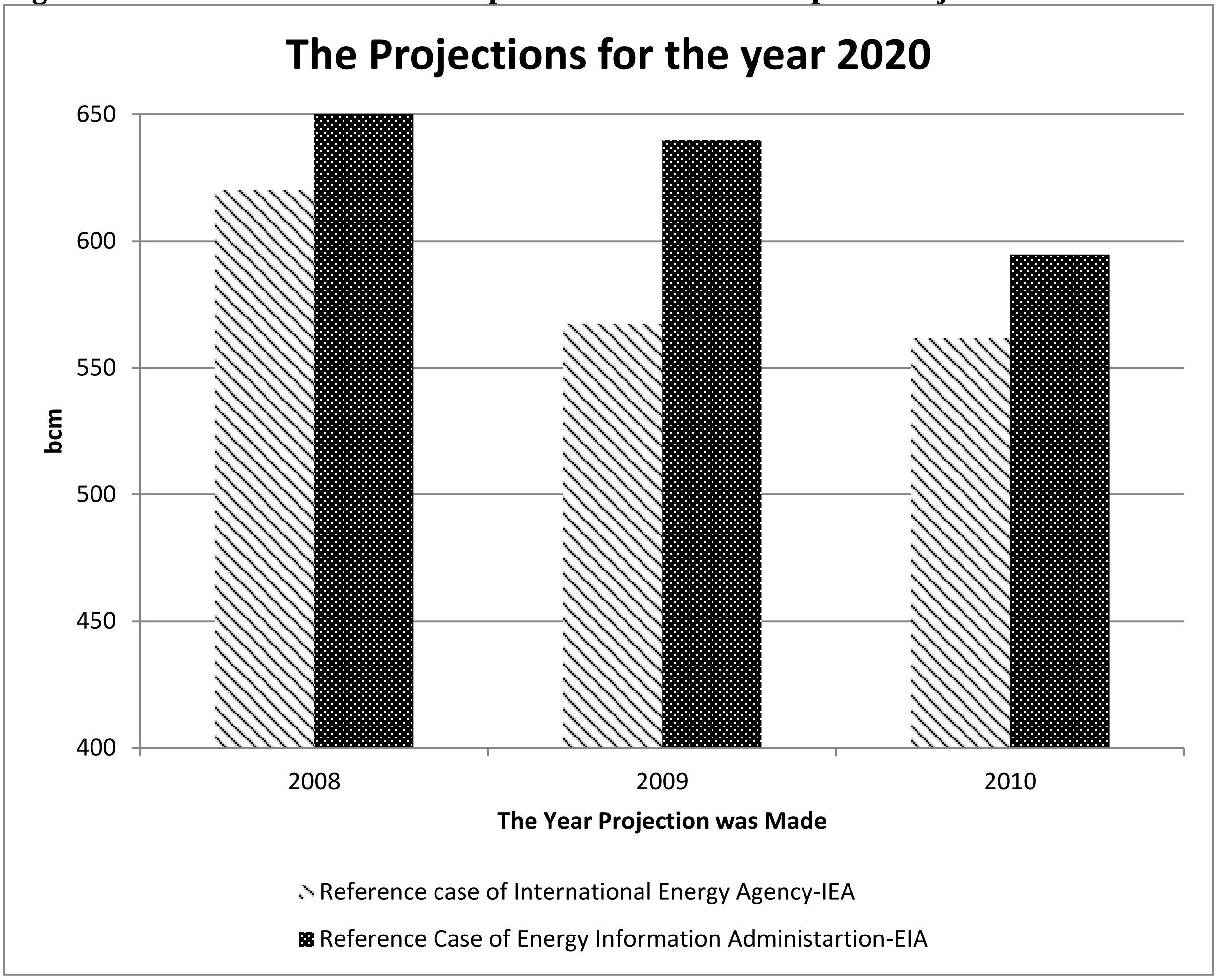
[7] Honore (2006) present their natural gas projections in bcm; the mtoe figures are based upon the IEA conversion factor of 1 mtoe = 1.2125 bcm (IEA, 2010).

[8] EIA (2010) present their natural gas projections in tcf, these figures have first been converted to bcm and then to mtoe based upon the IEA conversion factor of 1 mtoe = 1.2125 bcm (IEA, 2010).

[9] IEA (2010a) present their natural gas projections in both bcm and mtoe.

from previous forecasts in 2008; the EIA's natural gas demand reference scenario projection for 2020 was 644 bcm (531 mtoe) and for the IEA was 699 bcm (576 mtoe) (EIA, 2008 and IEA, 2008). The differences are illustrated in Figure 1 (EIA, 2008, 2009, 2010 and IEA, 2008, 2009, 2010).

Figure 1: IEA and EIA OECD-Europe Natural Gas Consumption Projections for 2020



Although it is not possible to compare the above studies directly,[10] it is clear that there is a wide range of projections related to European natural gas demand. One reason might be the

[10] This is primarily due to the differences in country groups, but also the different definitions and conversion factors used.

quickly changing structure of European natural gas demand that makes it difficult to minimize the uncertainty about the future. This study therefore attempts to help uncover the structural changes in the European natural gas market and help to reduce the uncertainty by utilizing the STSM with the UEDT concept that is explained in the next section.

3. Methodology

As stated above, the STSM approach with the UEDT concept is utilised for estimating an OECD-Europe natural gas demand relationship. This methodology is becoming established as an appropriate way for modelling time series demand relationships; hence, a brief overview is given here with reference to previous studies.

3.1 Underlying Energy Demand Trend (UEDT) and Structural Time Series Modelling (STSM)

Natural gas, consumption like all energy consumption, results from demand for energy services ranging from warm homes to cooking as well as a range of energy services that require electricity, given natural gas is now one of the main fuels used for power generation. In other words, the demand for natural gas is a derived demand; hence, the factors that influence these energy services play an important role in the demand for natural gas. In industry and households alike, natural gas is used as an input into a productive process (be it an industrial process or to produce heat in homes) and the ‘production function’ is largely determined by the level and nature of the capital appliance stock. Hence the demand for natural gas is equally influenced by both the quantity and quality (or efficiency) of the capital and appliance stock. It is therefore important to reflect this in any estimated natural gas function.

Additionally, it has also been argued that that technical progress is not the only exogenous factor that influences energy demand (see for example Hunt et al., 2000). Factors such as consumer tastes, change in regulations, change in economic structure, change in lifestyles and values, might all play an important role in driving natural gas demand. Therefore, in the absence of appropriate data to capture all the different exogenous effects, a stochastic UEDT is included in the natural gas demand specification below in line with previous research (such as: Harvey and Koopman 1993; Hunt et al., 2000, 2003a and, 2003b; Hunt and Ninomiya, (2003); Dimitropoulos et al., 2005; Amarawickrama and Hunt, 2008; Doornat et al., 2008; and Dilaver and Hunt, 2011a, 2011b, and 2011c). To achieve this, the STSM is utilised given it allows for the impact of unobserved components in a time series model to be a captured by a stochastic trend (see Harvey et al., 1986; Harvey, 1989; Harvey and Shephard, 1993; Harvey and Scott, 1994; and Harvey, 1997). The natural gas demand specification using the UEDT/STSM approach is therefore illustrated in the next section.

3.2 Empirical Framework

It is assumed that OECD-Europe natural gas demand is identified by:

$$G_t = f(Y_t, P_t, UEDT_t) \quad (1)$$

Where: G_t = OECD-Europe total natural gas demand;

Y_t = GDP (US Dollar 2005=100 PPP)

P_t = OECD Europe natural gas price index (2005=100); and

$UEDT_t$ = Underlying Energy Demand Trend for OECD-Europe Natural Gas

For the econometric estimation of equation (1), the dynamic autoregressive distributed lag specification is utilised as follows:

$$A(L)\, g_t = B\,(L)\, y_t + C\,(L)\, p_t + UEDT_t + \epsilon_t \qquad (2)$$

where *A (L)* is the polynomial lag operator $1 - \lambda_1 L - \lambda_2 L^2 - \lambda_3 L^3 - \lambda_4 L^4$; *B (L)* is the polynomial lag operator $1 + \varphi_1 L + \varphi_2 L^2 + \varphi_3 L^3 + \varphi_4 L^4$; *C (L)* is the polynomial lag operator $1 + \sigma_1 L + \sigma_2 L^2 + \sigma_3 L^3 + \sigma_4 L^4$ and;

$g_t = Ln\,(G_t)$;

$y_t = Ln\,(Y_t)$;

$p_t = Ln\,(P_t)$;

B(L)/A(L) = the long run income elasticity of natural gas demand;

C(L)/A(L) = the long run price elasticity of natural gas demand; and

ε_t= a random error term.

The UEDT is stochastic and can be estimated by the STSM, using the following formulation:

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \;; \qquad \eta_t \sim NID\,(0, \sigma_\eta^2) \qquad (3)$$

$$\beta_t = \beta_{t-1} + \xi_t \;; \qquad \xi_t \sim NID\,(0, \sigma_\xi^2) \qquad (4)$$

Where μ_t and β_t represent the level and slope of the UEDT respectively. The variances of these σ_η^2 and σ_ξ^2 (known as hyperparameters) along with the other parameters of the model are estimated by combination of maximum likelihood and the Kalman filter (Kalman, 1960) using the software package STAMP 8.10 (Koopman et al., 2007). The estimation strategy therefore involves estimating Equations (2), (3) and (4) and excluding statistically insignificant variables, providing the model passes an array of diagnostic tests[11] and conforms to *a-priori* economic theory. In addition, the normality of the level and slope hyperparameters is checked and, if necessary, some irregular, level and/or slope interventions are included to assure normality is maintained. As explained by Koopman et al. (2007), these

[11] See results section below for further details.

interventions in the STSM generally give information about important breaks and structural changes at certain dates with the estimation period. If existences of such interventions are identified the UEDT is given by:

$$UEDT_t = \mu_t + \text{irregular interventions} + \text{level interventions} + \text{slope interventions} \quad (5)$$

In order to try to understand what drives OECD-Europe natural gas further, once the preferred model is obtained the relative contribution of income, price and the UEDT to the annual change in natural gas demand is estimated in a similar way to Broadstock and Hunt (2010), i.e.

$$\widehat{\Delta g_t} = \widehat{\kappa_Y}\Delta y_{t-1} + \widehat{\kappa_P}\Delta p_{t-1} + \Delta\widehat{UEDT}_t \quad (6)$$

where $\widehat{\kappa_Y},$ and $\widehat{\kappa_P}$ are the estimated coefficients and $\Delta\widehat{UEDT}_t$ the estimated UEDT. So that $\widehat{\kappa_Y}\Delta y_{t-1}$, $\widehat{\kappa_P}\Delta p_t$ and $\Delta\widehat{UEDT}_t$ represent the estimated contributions to the change in OECD-Europe natural gas demand (in logs) from income, the real natural gas price and the UEDT respectively.[12] This is shown in the next section after the presentation of the results.

[12] Note that given the estimated preferred model presented below does not have any lagged dependent variables and just a one-year lag on income and price, the contributions are easily calculated in this way. Furthermore, given the model is in logs the change approximates the percentage change.

4. Data and Estimation Results

4.1 Data:

Annual time series data from 1978-2011 for E (natural gas consumption bcm), Y (GDP 2005 constant US dollar-PPP) and P (OECD-Europe Real natural gas price index 2005 =100) are used for the analysis. All variables are obtained from the International Energy Agency (IEA, 2012a, 2012b, 2012c).

4.2 Results:

The final preferred equation along with the diagnostics resulting from the estimation procedures outlined above is given in Table 2 and Figure 2. It can be seen that the preferred model passes all the diagnostic tests including the additional normality tests for the auxiliary residuals generated by the STSM approach, with limited estimated dynamic terms. The estimated impact elasticities for both income and price are zero, whereas the estimated long run income elasticity of 1.19 and the estimated long run and price elasticity of -0.16 come through after a lag of one year. This might be explained by the capital-intensive nature of natural gas demand, which would tend to prolong any adjustments following a change in to price or income.

The estimated UEDT from this procedure is a local level model without a slope, but despite this the estimated UEDT illustrated in Figure 3 and summarised in Table 3 is clearly non-linear given the estimated level hyper-parameter, with periods when it increases and periods when it is decreases, with a sharp decrease after 2004.

Table 2: OECD-Europe Total Natural Gas Demand STSM Estimates and Diagnostics Sample 1978-2011

Variables	***Coefficients***	***T-Values***	***Probabilities***
y_{t-1}	1.18964	5.865	0.000
p_{t-1}	-0.15936	-2.436	0.022
Lvl1988	-0.0849	-2.765	0.009
Outlier 2010	0.1217	5.956	0.000
Hyperparameters:		**Goodness of fit:**	
Level:	0.00073	***p.e.v***	***0.0006***
Irregular:	0.00000	***p.e.v/m.d.^{2}***	***1.2455***
		R^2	***0.9931***
$UEDT_{2011}$: 2.5666		***R_d^2***	***0.6273***

Diagnostics

Residuals:		*Auxiliary Residuals:*		
			Irregular	*Level*
Std. Error	0.91	Std. Error	0.87	0.96
Normality	0.44	Normality	0.54	0.59
Skewness	0.23	Skewness	0.27	0.31
Kurtosis	0.67	Kurtosis	0.95	0.99
$H_{(9)}$	0.99			
$r_{(1)}$	0.15		**Nature of Trend:** Local Level	
$r_{(5)}$	-0.04			
$Q_{(5,4)}$	1.38			

Predictive Tests(2004-2011)		**LR TEST**	27.782	(0.000)
Failure	0.62			
Cusum $t_{(8)}$	1.88			

Notes:

- *Model estimation and t-statistics are from STAMP 8.10;*
- *Model includes a level intervention for the year 1988 and an outlier for the year 2010;*
- *Prediction Error Variance (p.e.v.), Prediction Error Mean Deviation (p.e.v./m.d.2) and the Coefficients of Determination (R^2 and R_d^2) are all measures of goodness-of-fit;*
- *Normality (corrected Bowman - Shenton), Kurtosis and Skewness are error normality statistics, all approximately distributed as $\chi^2_{(2)}$; as $\chi^2_{(1)}$; as $\chi^2_{(1)}$ respectively;*
- *$H_{(9)}$ is a Heteroscedasticity statistic distributed as $F_{(9,9)}$;*
- *r(1) and r(5) are the serial correlation coefficients at the equivalent residual lags, approximately normally distributed;*
- *DW is the Durbin-Watson statistic;*
- *$Q_{(5,4)}$ is the Box – Ljung statistic distributed as $\chi^2_{(4)}$;*
- *Failure is a predictive failure statistic distributed as $\chi^2_{(8)}$ and Cusum is a mean stability statistic distributed as the Student t distribution; both are STAMP prediction tests found by re-estimating the preferred model up to 2003 and predicting for 2004 thru 2011;*
- *LR Test represents a likelihood ratio tests on the same specification after imposing a fixed level and no slope hyperparameter and distributed as χ2(1) and probabilities are given in parenthesis.*

Figure 2: Prediction Graphics of European Natural Gas Consumption 2004-2011

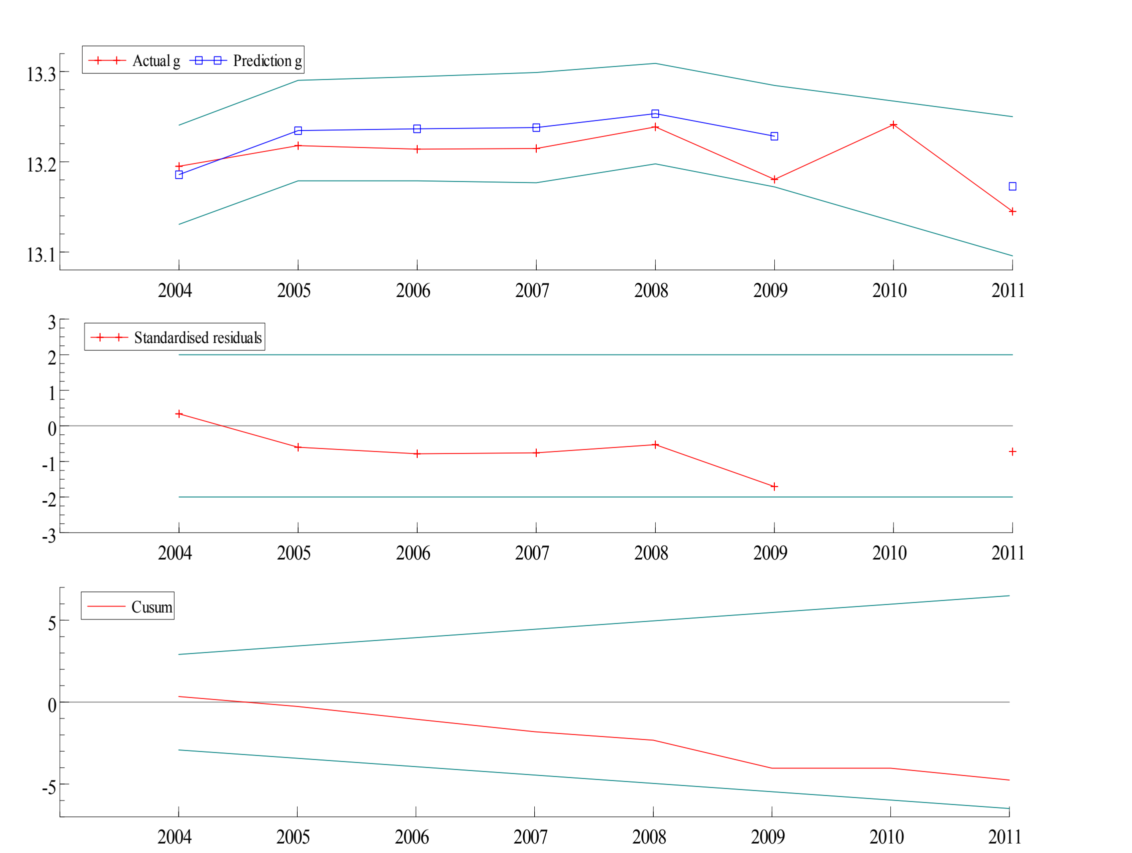


Figure 3: The Estimated OECD-Europe Natural Gas UEDT 1978-2011

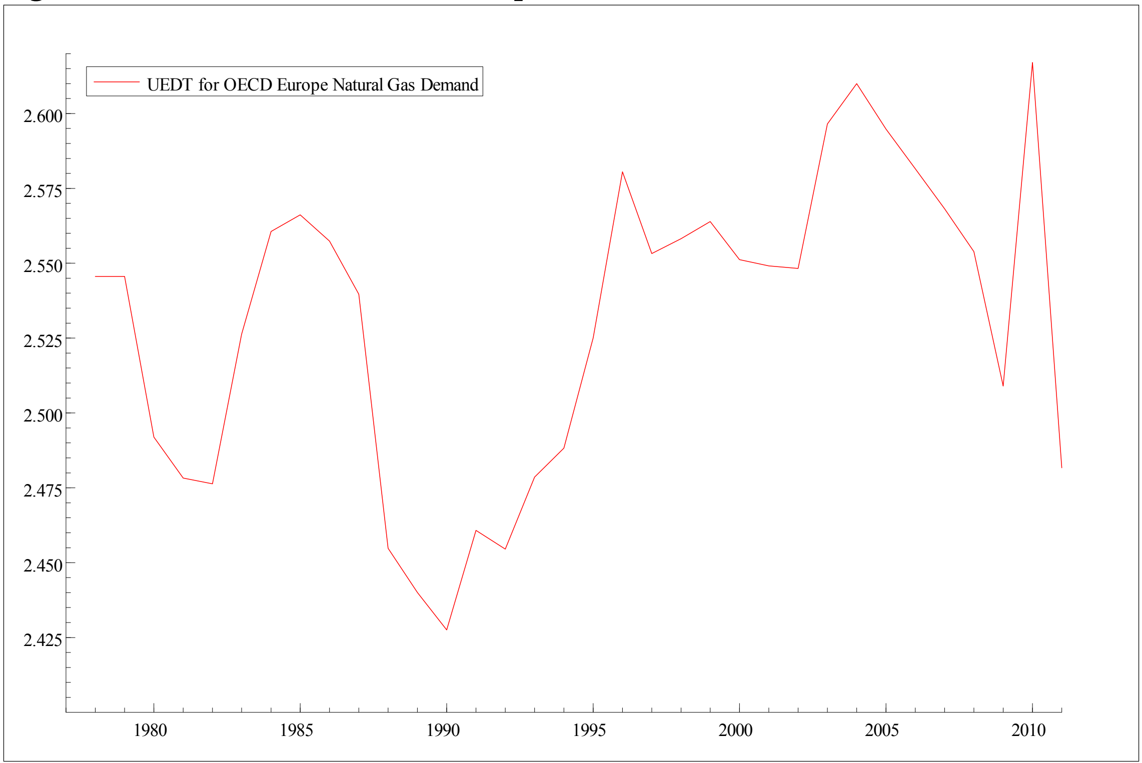


Table 3: The Average Annual Change of the UEDT

Period	Average Annual Change of UEDT
1979-1989	- 0.01056
1989-1999	0.01239
1999-2011	- 0.00685
1979-2011	- 0.00199

As explained in the methodology section above, in order to illustrate the UEDT's importance relative to income and price, their estimated contributions to the change in OECD-Europe natural gas demand are estimated using the method proposed by Broadstock and Hunt (2010) by decomposing the change in natural gas consumption as follows:

$$\widehat{\Delta g}_t = 1.18964\Delta y_{t-1} - 0.15936\Delta p_{t-1} + \Delta\widehat{UEDT}_t \qquad (7)$$

The decomposition is shown in Figure 4 and summarised in Table 4. To show this more clearly, the contributions are re-calculated in absolute terms, presented as shares in Figure 5 and summarised in Table 5. This shows that the share of the contribution of income is the largest and generally, increases over the estimation period. The second largest share is clearly the UEDT, which was at its highest in the 1990s when it was making a positive contribution (see Table 4) compared to the 1980s and the 2000s when it was making a negative contribution. One of the reasons might be the replacement of town gas by natural gas, which required technical adjustments in gas burning appliances. However, the 1980s debt crises affected many developing countries so that they did not have sufficient funds to develop the appropriate gas infrastructures (Stevens, 2010). Furthermore, there were some obstacles in natural gas markets, such as limited import options, high transport costs and technological limitations for LNG. Nevertheless, as Stevens (2010) points out, natural gas became preferable from the 1990s due to changes in natural gas market conditions and environmental concerns coupled with technological improvements. Finally, the negative contribution of the UEDT during the 2000s might be explained by concerns over security of supply and high import dependence, which created an anxiety in European nations, together with increasing technological improvements and improved efficiency (Stevens, 2010). Price clearly makes the smallest contribution. Given the relative importance of the UEDT, it should arguably be taken into account when modelling and forecasting OECD-Europe natural gas demand. The preferred estimated equation will therefore now be used to construct future scenarios for OECD-European natural gas demand, as explained in the next section.

Figure 4: Estimated Contributions to the Annual Percentage Change in OECD-Europe Natural Gas Demand

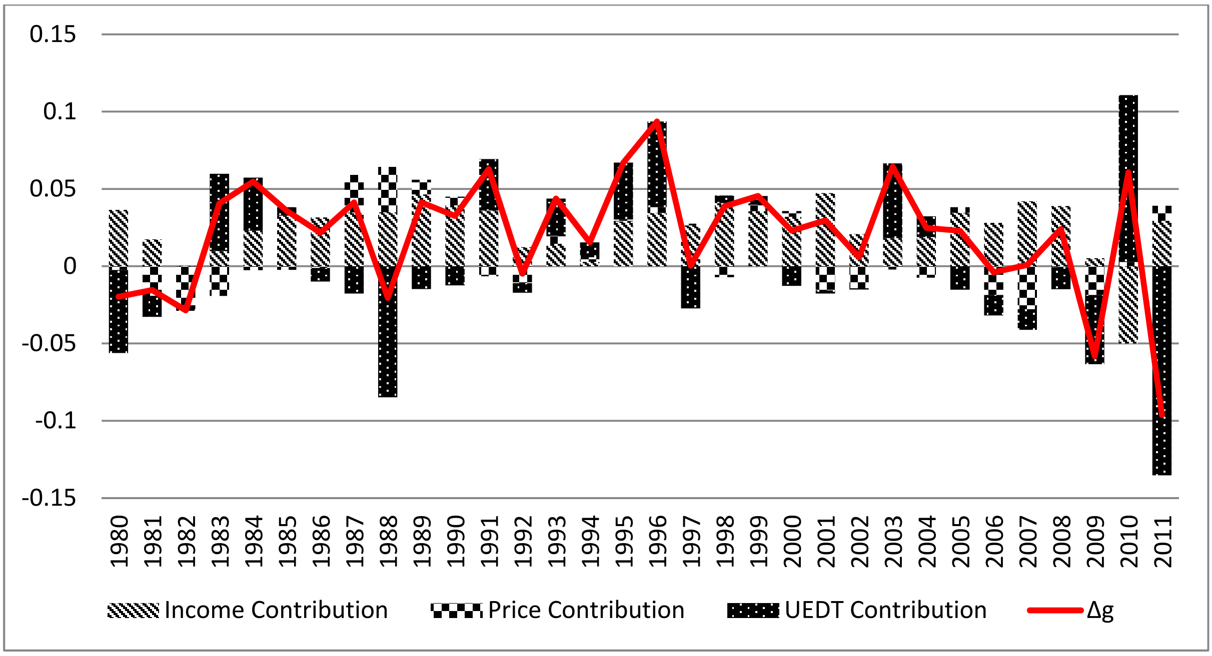


Table 4: Summary of the Estimated Contributions to the Average Percentage Change per Annum in OECD-Europe Natural Gas Demand

Period	Contribution from:			Total change in Gas demand
	Income	Price	UEDT	
1979-1989	2.67	-0.11	-1.06	1.51
1989-1999	2.71	-0.004	1.24	3.95
1999-2011	2.21	-0.71	-0.69	0.81
1979-2011	2.51	-0.30	-0.20	2.01

Note: Following from equation (7) the estimated annual changes per annum contributions are approximated as follows: $((\Sigma 1.1894\Delta y_{t-1})/n)\%$, $((\Sigma - 0.1594\Delta p_{t-1})/n)\%$, and $((\Sigma\widehat{\mathrm{UEDT}}_t/n)\%$ for the contributions of income, price, and the UEDT respectively. (The total change being approximated by $(\Sigma\widehat{\Delta g_t}/n)\%$.) Where *n* is the span of years that the change is calculated.

Figure 5: Estimated Shares of the Contributions to the Change in OECD-Europe Natural Gas Demand

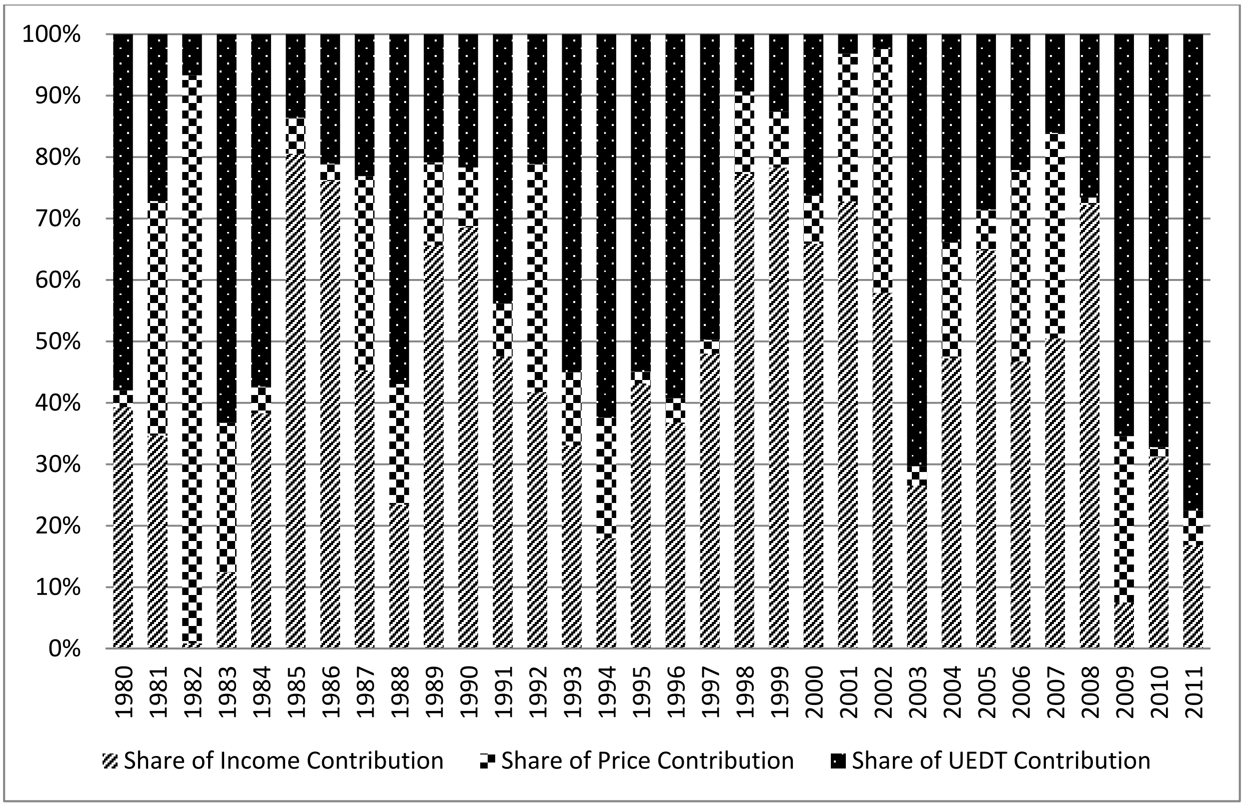


Table 5: Summary of the Estimated Shares of the Contributions to the Change in OECD-Europe Natural Gas Demand

Period	Average shares of contribution from:		
	Income	Price	UEDT
1979-1989	41.65%	23.55%	34.80%
1989-1999	49.24%	11.76%	39.00%
1999-2011	46.67%	16.69%	36.64%
1979-2011	45.91%	17.29%	36.80%

Note: The shares of the contributions to the change in OECD-Europe Natural Gas Demand per annum are approximated as follows:

$((\frac{|\Sigma 1.189\Delta y_{t-1}|}{|\Sigma 1.189\Delta y_{t-1}|+|\Sigma -0.159\Delta p_{t-1}|+|\Sigma\Delta\widehat{UEDT_t}|})/n) \times 100$,

$((\frac{|\Sigma -0.159\Delta p_{t-1}|}{|\Sigma 1.189\Delta y_{t-1}|+|\Sigma -0.159\Delta p_{t-1}|+|\Sigma\Delta\widehat{UEDT_t}|})/n)) \times 100$, and

$((\frac{|\Sigma\Delta\widehat{UEDT_t}|}{|\Sigma 1.189\Delta y_{t-1}|+|\Sigma -0.159\Delta p_{t-1}|+|\Sigma\Delta\widehat{UEDT_t}|})/n) \times 100$ for the shares of the contributions of income, price, and the UEDT respectively. Where *n* is the span of years that the change is calculated.

5. Forecasting Assumptions and Results

This section outlines the assumptions about the future UEDT and other variables that are used to construct the scenarios and presents the forecast scenarios based on these assumptions.

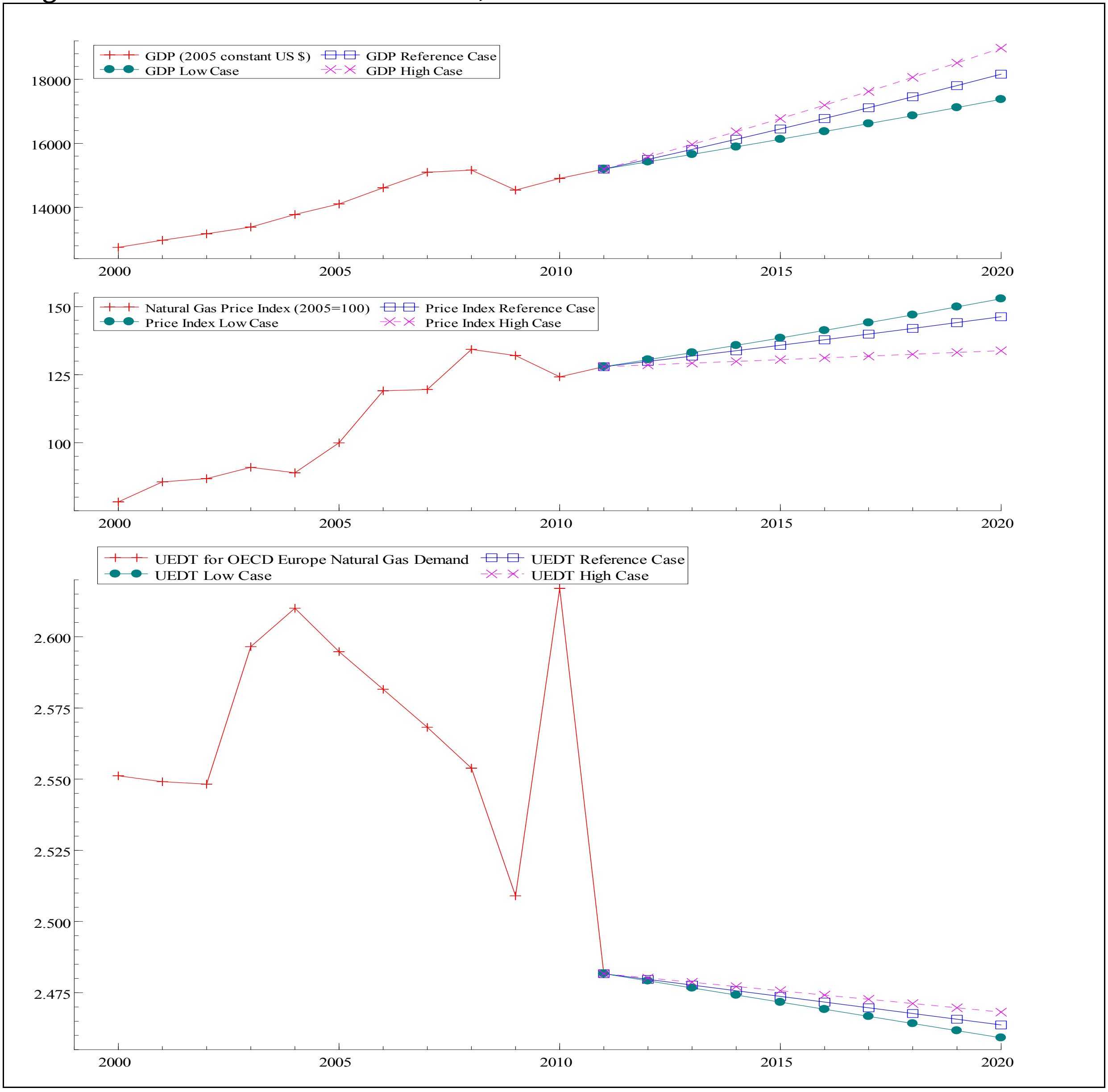
5.1 Forecast Assumptions

Three scenarios are implemented in this study, namely high case, reference and low case. For the *reference scenario*, it is assumed that real natural gas OECD Europe prices will increase 1.5% annually over period 2012-2020, being slightly less than the average annual rise in prices of around 2% over the estimation period however. GDP grew on average by about 2% per annum over the estimation period and this long trend will be restored over the forecast scenario period following the global economic slowdown. For the UEDT[13], a slope of -0.002 is projected for the period 2012-2020, which is the same as the average decrease of the estimated UEDT over the estimation period (Table 3); this implicitly assumes that because of environmental concerns, more natural gas consumption will be encouraged in the power sector but will be counterbalanced by energy efficiency measures.

For the *high case scenario,* for the period 2012 and 2020 the natural gas price is assumed to increase 0.5% per annum (less than the increase observed over the estimation period and the reference scenario) but GDP will increase 2.5% per annum (more than the increase observed over the estimation period and the reference scenario). Furthermore, it is assumed that the use of natural gas in the power transformation sector will be somewhat higher than the reference scenario, hence the UEDT has a slope of -0.0015 over the forecast scenario period.
In the low case scenario, it is assumed that the rise in natural gas prices will be 2% per annum (similar with the estimation period). For GDP it is assumed to increase annually 1% per year (lower than the estimation period average) until 2020. For the UEDT, it is assumed that it will have a slope of -0.0025 per annum (less than it was observed for 1979 and 2011) between 2012 and 2020. A graphical presentation of the scenario assumptions for GDP, real natural gas price index, and the UEDT are illustrated in Figure 7.

[13] Although the estimated slope of UEDT is zero over the estimation period, in order to create future values of UEDT, a series of slope values for UEDT is assumed based on the estimated past values of the UEDT and future expectations.

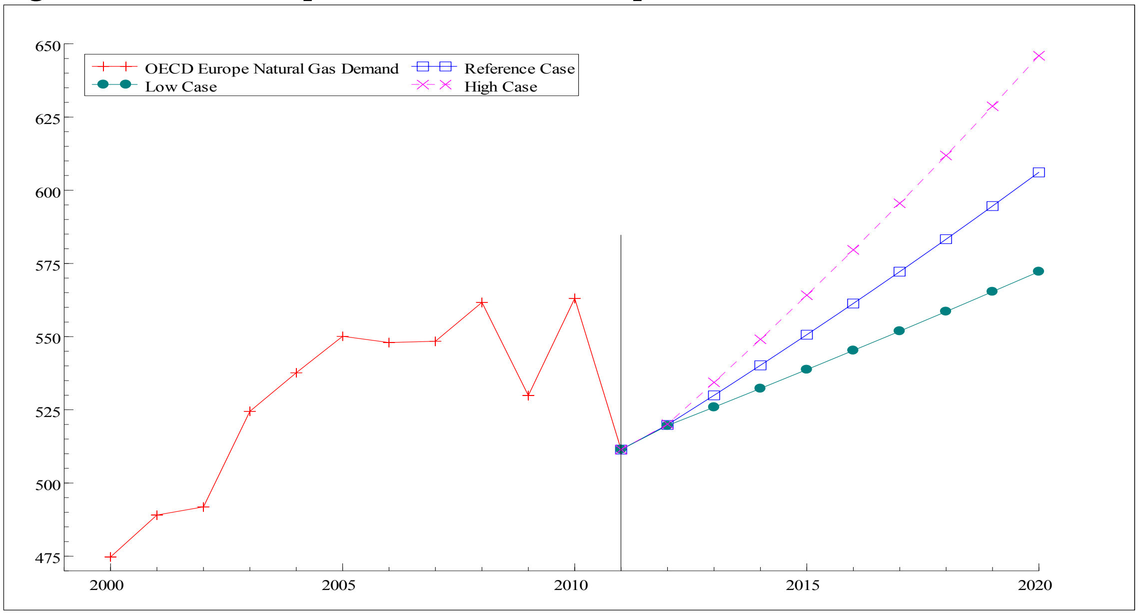
Figure 7: Forecast Scenarios for Price, GDP and UEDT



5.2 Forecast Scenario Results:

The three scenarios up to 2020 are illustrated in Figure 8. These show that OECD Europe natural gas consumption are predicted to grow to 572, 606 and 646 bcm (472, 500 and 533 mtoe) by 2020 according to the low reference and high case scenarios respectively. The 74 bcm difference between the low case and the high case scenarios is mainly because of the uncertainties regarding to the long-term including economic growth, fuel prices, technological progress and change in market conditions. However, these findings might provide valuable information for long-term planning for market players such as construction of natural gas infrastructures, natural gas import agreements and implementation of policies for natural gas market and energy security.

Figure 8: OECD Europe Natural Gas Consumption Forecast Scenarios



6. Summary and Conclusion

This paper estimates an OECD-Europe Natural gas demand function by using the STSM over the period 1978-2011. As far, as is known this is the first attempt to estimate a non-linear UEDT for OECD-Europe natural gas demand. The results suggest the following:

* In order of importance, Income, the UEDT and real natural gas prices are all factors that shape European natural gas demand.

* The income and the price elasticities are 1.19 and -0.16 respectively. Income has a greater impact on OECD-Europe natural gas demand than price over the estimation period and this finding is consistent with previous studies.

* The estimated UEDT is a non-linear with periods when it increases and periods when it decreases over the estimation period; however starting from 2004 it follows a decreasing (gas saving) path, perhaps due to improved energy efficiency standards. However the environmental concerns make natural gas a popular choice rather than other fossil fuels for power generation, therefore it is expected that the power sector will widely use natural gas as a fuel in the future, which might partially offset the energy efficiency gains and might also affect the future shape of the UEDT.

* OECD-Europe natural gas consumption is expected to be 572, 606 and 646 bcm (472, 500 and 533 mtoe) by 2020, according to the generated low, reference and high case scenarios.

As discussed in previous sections, some of the main challenges of OECD-Europe in terms of natural gas are import dependency and increasing global demand for natural gas, security and diversity of gas supply, liberalization of natural gas markets and investment requirements of the gas sector. For policy makers, energy companies and financial institutions alike, it is important to minimize the uncertainty around future natural gas demand in order to establish appropriate energy security measures. Furthermore, reliable information about future natural gas demand is needed in order to realize large-scale energy infrastructure projects, such as LNG import terminals and natural gas pipelines. Moreover, this information should be useful for agents thinking long-term purchase contracts and evaluating policy options in a large spectrum from foreign policy to market regulation.

This study contributes in this area further by identifying the structure and composition of OECD-Europe natural gas demand and its responsiveness to its main determinants and provides invaluable information for the stakeholders. This study suggests that a collection of exogenous factors (represented by the estimated UEDT) is the second most important driver of OECD-Europe natural gas demand (after income), having a greater effect than price movements. Consequently, this suggests that policies like improving energy efficiency standards of gas-fuelled appliances rather than price-induced policies such as carbon taxes, than might be more helpful if the aim is to attempt to curtail natural gas consumption.

References:

Amarawickrama, HA and Hunt, LC. Electricity Demand for Sri Lanka: A Time Series Analysis. Energy, 2008, 33, 724-739.

Bilgin, M. Geopolitics of European Natural Gas Demand: Supplies from Russia, Caspian and Middle East. Energy Policy, 2009, 37, 4482-4492.

Bohi, DR. Analyzing Demand Behaviour: A Study of Energy Elasticities. Johns Hopkins University Press: Baltimore, US; 1981.

Bohi, DR and Zimmerman, MB. An update on Econometric Studies of Energy Demand Behaviour. Annual Review of Energy, 1984, 9, 105-154.

BP: British Petroleum. Statistical Review of World, 2005.

Broadstock, DC. and Hunt, LC. Quantifying the Impact of Exogenous Non-Economic Factors on UK Transport Oil Demand. Energy Policy, 2010, 38, 1559-1565.

Christoffersen, G. China's Intentions for Russian and Central Asian Oil and Gas. The National Bureau of Asian Research; 1998, Vol. 9, No: 2, 1-34.

Dahl, CA. A Survey of Energy Demand Elasticities in Support of Development of the NEMS. US Department of Energy, 1993.

Dilaver, Z. and Hunt, LC. Industrial Electricity for Turkey: A Structural Time Series Analysis. Energy Economics, 2011a, 33, 426-436.

Dilaver, Z. and Hunt, LC. Modelling and Forecasting Turkish Residential Electricity Demand. Energy Policy, 2011b, 39, 3117-3127.

Dilaver, Z. and Hunt, LC. Turkish Aggregate Electricity Demand: An Outlook to 2020. Energy, 2011c, 36, 6686-6696.

Dimitropoulos, J., Hunt, LC. and Judge, G. Estimating Underlying Energy Demand Trends Using UK Annual Data, Applied Economics Letters, 2005, 12, 239-244.

Doornat, V., Koopman, SJ. Ooms, M., Dessertaine, A. and Collet, J. An Hourly Periodic State Space Model for Modelling French National Electricity Load. International Journal of Forecasting, 2008, 24, 566-587.

EIA: US Energy Information Administration, 2008. International Energy Outlook 2008. DOE/EIA-0484(2008). (retrieved on 15 November 2008 from www.eia.doe.gov/oiaf/ieo/index.html.

EIA: US Energy Information Administration, 2009. International Energy Outlook 2009. DOE/EIA-0484(2009). (retrieved on 10 July 2009 from www.eia.doe.gov/oiaf/ieo/index.html.

EIA: US Energy Information Administration, 2010. International Energy Outlook 2010. DOE/EIA-0484(2010). (retrieved on 18 September 2010 from www.eia.doe.gov/oiaf/ieo/index.html.

EIA: US Energy Information Administration, 2013. International Energy Outlook 2013. DOE/EIA-0484(2013). (retrieved on 13 August 2013 from www.eia.doe.gov/oiaf/ieo/index.html.

Estrada, J. and Fugleberg, O. Price Elasticities of Natural Gas Demand in France and West Germany. The Energy Journal, 1989, 10, 77-90.

Eurogas Statistical Report 2006. (retrieved on 12 April 2012 from http://www.eurogas.org/uploads/media/Statistics_2006_01.01.06.pdf).

Eurogas Statistical Report 2010. (retrieved on 12 April 2012 from http://www.eurogas.org/uploads/media/Statistics_2010_29.11.10.pdf).

European Commission, Second Strategic Energy Review - Securing our Energy Future. EC, 2008 (retrieved on 11 February 2011 from http://ec.europa.eu/energy/strategies/2008/2008_11_ser2_en.htm).

European Commission, The January 2009 Gas Supply Disruption to the EU: An Assessment, Commission Staff Working Document Accompanying Document, 2009, SEC(2009) 977 final (retrieved on 11 February 2011 from http://ec.europa.eu/energy/strategies/2009/doc/sec_2009_0977.pdf).

Ghafghazi, S., Sowlati, T., Sokhansanj, S. and Melin, S. Techno-economic analysis of renewable energy source options for a district heating project. International Journal of Energy Research, 2010 34(12), 1109-1120.

Griffin, JM. Energy Conservation in OECD: 1980-2000. Ballinger Publishing Company Cambridge; 1979.

Hall, G. and Grant, T. Russia, China and Energy Security Politics of the Caspian Region After Cold War. Mediterranean Quarterly, 2009, 2, 113-137.

Hafner, M., Karbuz, S. and Andaloussi, HE. Long-Term Natural Gas Supply to Europe: Import Potential, Infrastructure Needs and Investment Promotion. Energy and Environment, 2008,Vol.19, No: 8, 1131-1153.

Harvey, AC. and Shephard, N. Structural Time Series Models. In: Maddala, GS., Rao, CR. and Vinod, HD. (Eds), Handbook of Statistics, Vol. 11 North Holland: Amsterdam; 1993, 261-302.

Harvey, AC. and Koopman, SJ. Forecasting Hourly Electricity Demand Using Time Varying Splines. Journal of American Statistical Association, 1993, Vol.88, Issue 424; 1228-1236

Harvey, AC. and Scott, A. Seasonality in Dynamic Regression Models. Economic Journal, 1994, 104; 1324–1345.

Harvey, AC., Henry, SGB., Peters, S. and Wren-Lewis, S. Stochastic Trends in Dynamic Regression Models: An application to the Employment–Output Equation. Economic Journal, 1986, 96, 975–985.

Harvey, AC. Forecasting, Structural Time Series Models and the Kalman Filter. Cambridge University Press: Cambridge; 1989

Harvey, AC. Trends, Cycles and Auto Regressions. Economic Journal, 1997, 107, 192–201.

Hauteclocque, A. and Glachant, JM. Long-term Energy Supply Contracts in European Competition Policy: Fuzzy not Crazy. Energy Policy, 2009, 37, 5399–5407.

Helen, H. The EU's Energy Security Dilemma with Russia. University of Leeds, Polis Journal; 2010, Vol. 4, 1-40.

Holz, F. Hirschhausen, C. and Kemfert, C. A Strategic Model of European Gas Supply (GASMOD). German Institute for Economic Research. Berlin; 2006.

Honore, A. Future Natural Gas Demand in Europe: The Importance of the Power Sector. Oxford Institute for Energy Studies Working Papers, UK, 2006 (retrieved on 08 February 2011 from www.oxfordenergy.org).

Honore, A. European Gas demand, Supply and Pricing: Cycles, Seasons and the Impact of LNG Price Arbitrage. Oxford University Press: Oxford, UK, 2010.

Hunt, LC., Judge, G. and Ninomiya, Y. Modelling Technical Progress: An Application of the Stochastic Trend Model to UK Energy Demand. Surrey Energy Economics Discussion Paper, 2000, 99.

Hunt, LC., Judge, G. and Ninomiya, Y. Modelling Underlying Energy Demand Trends In Hunt, LC (Ed) Energy in Competitive Market: Essays in Honour of Colin Robinson. Edward Elgar: UK, 2003a, 140-174

Hunt, LC., Judge, G. and Ninomiya, Y. Underlying Trends and Seasonality in UK Energy Demand: A Sectoral Analysis. Energy Economics, 2003b, 25, 93–118.

Hunt, LC. and Ninomiya, Y. Unravelling Trends and Seasonality: A structural Time Series Analysis of Transport Oil Demand in the UK and Japan. The Energy Journal, 2003, 24, 63-69.

IEA: International Energy Agency, 2012a. Natural Gas Information (Edition 2012) ESDS International, University of Manchester. DOI: http://dx.doi.org/10.5257/iea/ng/2012

IEA: International Energy Agency, 2012b. World Energy Balances (Edition 2012) ESDS International, University of Manchester. DOI: http://dx.doi.org/10.5257/iea/web/2012

IEA: International Energy Agency, 2012c. Energy Prices and Taxes (Edition 2012, Quarter 3) ESDS International, University of Manchester. DOI: http://dx.doi.org/10.5257/iea/ept/2012q3

IEA: International Energy Agency, 2010. World Energy Outlook 2010. International Energy Agency: France.

IEA: International Energy Agency. World Energy Outlook -2009. International Energy Agency: France, 2009.

IEA: International Energy Agency. World Energy Outlook -2008. International Energy Agency: France, 2008.

Kalman, RE. A New Approach to Linear Filtering and Prediction Problems. Journal of Basic Engineering, 1960, 82, 35-45.

Kavalov, B., Petric, H. and Georgakaki, A. Liquefied Natural Gas for Europe: Some Important Issues for Consideration. European Commission Joint Research Centre Reference Reports: Netherlands, 2009.

Kirby, SN. Residential Demand for Energy: A Review of the Empirical Literature and Some New Results. Rand Corporation, Santa Monica, US, 1983.

Koopman, SJ., Harvey, AC., Doornik, JA. and Shephard, N. Structural Time Series Analyser and Modeller and Predictor - STAMP Version 8, Econometric Software, 2007.

Mackay, RM. and Probert, SD. Crude Oil and Natural Gas Supplies and Demands up to AD 2010 for the Unified Germany. Applied Energy, 1995, 3, 185-208.

Massol, O. and Tchung-Ming, S. Cooperation Among Liquefied Natural Gas Suppliers: Is Rationalization the Sole Objective? Energy Economics, 2010, 32(4), 933-947.

Neuhoff, K. and von Hirschhausen, C. Long-Term vs. Short-Term Contracts: A European Perspective on Natural Gas, Cambridge Working Papers in Economics, 2005 (retrieved on 08 January 2011 from www.dspace.cam.ac.uk/handle/1810/131595).

Newbery, DMG. The Manipulation of Futures Markets by a Dominant Producer, in Anderson, RW. (ed) The Industrial Organization of Futures Markets, 1984, Lexington.

Nilsen, OB., Asche, F. and Tveteras, R. Natural Gas Demand in the European Household Sector. Institute for Research in Economics and Business Administration: Bergen, 2005.

Oren, S. Ensuring Generation Adequacy in Competitive Electricity Markets', Berkley, University of California Energy Institute, 2003, WP 007.

Pindyck, RS. The Structure of World Energy Demand. MIT Press: Cambridge, 1979.

Pirani, S., Stern, J. and Yafimava, K. The Russo-Ukrainian Gas Dispute of January 2009: A Comprehensive Assessment. Oxford Institute for Energy Studies Working Papers, UK, NG27, 2009 (retrieved on 08 January 2011 from www.oxfordenergy.org).

Radetzki, M. European natural gas: market forces will bring about competition in any case. Energy Policy, 1999, 27, 17-24.

Remme, U., Markus, B. and Fahl, U. Future European Gas Supply in the Resource Triangle of the Former Soviet Union, the Middle East and North Africa. Energy Policy, 2008, 36, 1622-1641.

Samseth, J. Will the introduction of renewable energy in Europe lead to CO2 reduction without nuclear energy? Environmental Development, 2013, 6, 130–132.

Stern, J. Security of European Natural Gas Supplies. The Royal Institute of International Affairs, UK, 2002.

Stevens P. The History of Gas. Polinares (EU Policy on Natural Resources Working paper No:5, 2010

Talus, K. Long-term Natural Gas Contracts and Antitrust Law in the European Union and the United States, Journal of World Energy Law and Business, 2011, 4(3), 260-315.

Taylor, LD. The Demand for Energy: A Survey of Price and Income Elasticities' in Nordhaus, W. (Ed) International Studies of the Demand for Energy, North Holland: Amsterdam, 1977.

Yergin, D. Ensuring Energy Security. Foreign Affairs, 2006, 85, 69-75.

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