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Is it all oil?

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Abstract

After opening up of the Interconnector, the liberalized UK natural gas market and the regulated Continental gas markets became physically integrated. The oil-linked Continental gas price became dominant, due to both the large volume of the Continental market and to the fact that the significant call options embedded in the complex take-or-pay contracts make these contracts the marginal source of supply. However, in an interim period – after deregulation of the UK gas market (1994) and the opening up of the Interconnector (1998) – the UK gas market had neither government price regulation nor a physical Continental gas linkage. We use this period – which for natural gas markets displays an unusual combination of deregulation and autarky – as a natural experiment to explore if decoupling of natural gas prices from prices of other energy commodities, such as oil and electricity, took place. Using monthly price data, we find a highly integrated market where the wholesale demand seems to be for energy rather than a specific energy source.

Keywords: Energy markets; Price interlinkages, Cointegration analysis

JEL classification: C32; L10; L90; Q48

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1. Introduction

Perceived beneficial effects of restructuring industries with naturally monopoly elements – such as network industries – led to the inclusion of the electricity and gas markets in the liberalization scope of the European Commission during the first half of the 1990s. Despite the trend towards deregulation of energy markets at the EU level – supported by the Electricity and Gas Directives – most markets are still highly regulated and dominated by national monopolies.[1] There are exceptions, however, the most notable being the UK electricity and gas markets, c.f. Newbery (1999) for a thorough account of the British gas and electricity restructuring process.

Liberalization of the electricity industry in UK started in 1990, the last of the Thatcher years. From 1995, when the market for natural gas was opened up for competition and a spot market was established, an interesting experiment took place. For a limited number of years the UK constituted a separate unregulated energy market, as the level of import capacity for electricity was low and the gas market physically isolated from the continental gas markets. This situation ended in 1998 when the Interconnector pipeline linked the UK natural gas grid to the Continent. Subsequently, UK natural gas prices took a leap up to the price level given by the long-term take-or-pay contracts in continental Europe. Due to the high volumes of these contracts and the extensive swing facilities (call options) they comprise, the supply conveyed by the take-or-pay contracts represented the price setting marginal source of supply.

It is well known that oil prices dominate the pricing formulas for the take-or-pay contracts of natural gas in continental Europe, and to such an extent that the import prices in the different markets are proportional (Asche, Osmundsen and Tveterås, 2002). On the other hand, the

[1] For a description of the legislative process culminating in the Electricity Directive 96/92/EC and Gas Directive 98/30/EC, see Smeers (1997).

industry does not think there is a link between oil and electricity prices. This is confirmed in Gjølberg (2000). The fact that European electricity and natural gas markets gradually become fully deregulated can, however, lead to fundamental changes in the traditional price structures. Moreover, demand for natural gas is likely to rise substantially as its use in power generation is expected to increase more than other fuels, c.f. World Energy Outlook 2002. One can then ask, will there still be a link between oil and natural gas prices? Or will this link dissolve and a new link between natural gas and electricity prices be created? Alternatively, will there be three different markets or one single energy market in Europe in the future?

The objective of this paper is to shed some light on these questions by testing for market integration, using prices of crude oil, natural gas, and electricity in the UK during the period in which the natural gas and electricity markets were deregulated and isolated. By using the Johansen test (Johansen, 1991) and the Generalized Composite Commodity Theorem (GCCT) of Lewbel (1996), we will be able to test more hypotheses and, therefore, derive more information that in earlier studies investigating relationships between energy prices. Moreover, in the case the three energy markets are integrated, we will examine price leadership by testing for exogeneity in the system. This is of particular interest if the crude oil price is part of the market, as the energy prices in the UK then will be determined in the global oil market, i.e. to a large extent be exogenously given. Moreover, if the relative prices are constant, the GCCT will hold, and the goods in question can be aggregated into a single commodity with a single price index, allowing one to speak about a single energy market.

If one looks at North America, the evidence with respect to deregulation and energy market integration produces a mixed picture. After the U.S. Federal Energy Regulatory Commission (FERC) granted natural gas customers access to pipelines in 1985, the number of open access pipelines and spot markets grew rapidly (De Vany and Walls, 1994). By 1989 almost all the major pipelines had open access and by 1991 more than 65% of the regional markets had become cointegrated (De Vany and Walls, 1993). Doane and Spulber (1994) also find, using empirical tests on spot market data from 1984-1991, that the geographic scope of the market for natural gas broadened considerably after 1985 and conclude that open access has led to the development of a national competitive natural gas market. The strong integration on the field level, as the above studies reflect, was however not mirrored on the city gate level, as shown in Walls (1994) using data from July 1990 to June 1991; natural gas prices were much less integrated between the field and city markets. Results from an analysis of electricity spot prices from 11 market locations on the western electricity transmission system of the United States during 1994 to 1996, documented in De Vany and Walls (1999), give evidence of a high degree of market integration of wholesale electricity spot prices in that region.

The restructuring process in the electricity industry has, however, developed relatively slowly and unevenly across states after the federal Energy Policy Act 1992 – which opened access for non-utility generating plants – visualized a more competitive and market oriented electricity industry. Moreover, in contrast to the national transmission network for natural gas, which is under the jurisdiction of FERC, there is no single entity with mandate over the national electricity grid, yet. Consequently, different regions have followed different strategies with respect to investing in interstate transmission capacity, which encumber a corresponding rapid broadening of the regional scope of the U.S. electricity markets. It is therefore not surprising that analyses of market integration across energy carriers receive different results depending on the specific region under study. In an analysis of energy prices in the mid-Atlantic area (Pennsylvania, New Jersey, Maryland, and Delaware), for example, Serletis and Herbert (1999) find that natural gas prices compete with oil prices, but not with electricity. Conversely, Emery and Lui (2002) show, using daily settlements futures prices for California Oregon Border (COB) and Palo Verde (PV) contracts of the New York Mercantile Exchange, that electricity and natural gas futures contracts compete. Finally, in a study of the Canadian oil and natural gas markets Watkins and Plourde (2000) find that natural gas and oil is not competing in Canada after deregulation.

One advantage with analysing UK markets – in comparison to North American markets – is the relatively smaller geographical region, which makes the impact of limited transmission capacity less important. Additionally, substantial overcapacity in the UK market at the time of deregulation – reducing peak load problems – may increase the likelihood of finding a larger degree of competition in the UK data. A sign that overcapacity in the transmission system has been substantial and that long-run capital cost has not been fully covered is the significant jump in natural gas prices after the Interconnector was opened. Alternatively, operators in the UK natural gas market must now earn substantial pure profits.

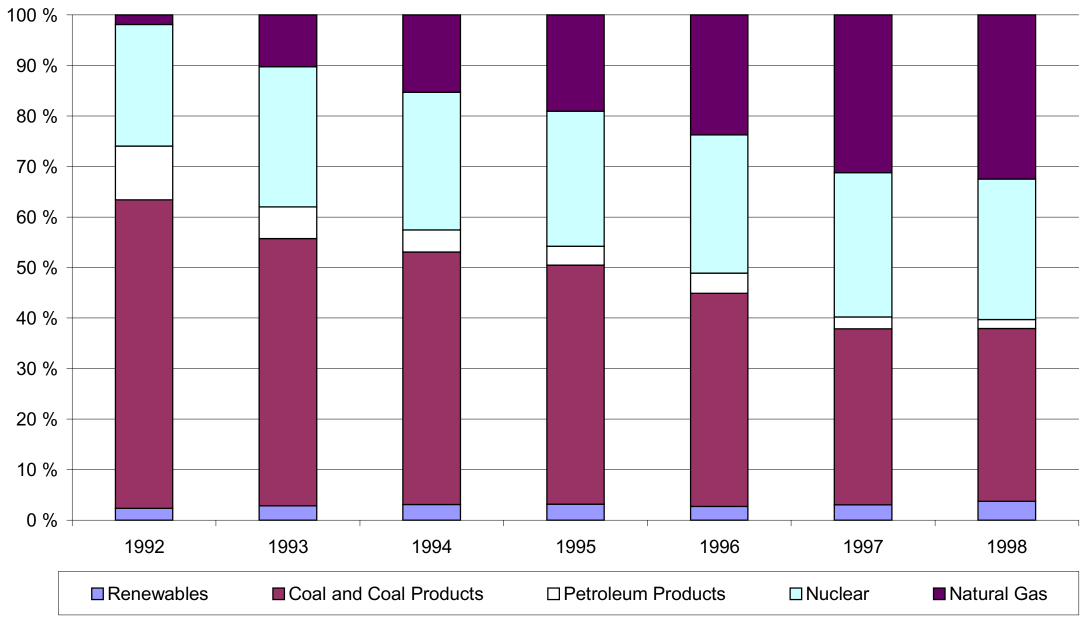
The paper is organized as follows. In the subsequent section we briefly discuss convergence of electricity and gas sectors, with particular focus on the development in the U.K. Next, in Section 3, we present the methodology and data. The results of the analysis are reported in Section 4, and Section 5 concludes.

2. Convergence of the electricity and gas industries

As the electricity and gas markets within the European Community move towards a single competitive market, scheduled for 2007, a changed relationship between the electricity and gas industries is a likely result. The convergence trend has been evident the last decade, for example in terms of cross-sectoral M&A activities, particularly in North America where the restructuring process of the gas industry dates back to the 1980s. Regulatory similarities, stemming from the network elements of transportation as well as technical developments are important drivers behind this trend. More specifically, the use of combined cycle gas turbine (CCGT) technology in gas-fired power plants has increased fuel efficiency and requires lower capital and operating costs. Moreover, construction times are short, 2-3 years, which has lead to a substantial increase in the use of natural gas in electricity generation, as was also the case in the UK.

In Figure 0.1 we have depicted the relative share of the different fuels used in electricity generation in the UK from 1992 to 1998. The consumption of natural gas constituted slightly less than 2% of electricity output in 1992. By the end of 1998 the relative share of natural gas had grown to nearly 33%. In comparison, the relative share of natural gas in electricity generation increased from 7 to 12% in the EU (not including the UK) during the same period.

Figure 0.1 The relative share of various fuels used in electricity generation (GWh) in the UK, 1992 – 1998



Source: IEA

Improved technology was, however, not the sole reason for the so-called "dash for gas", that resulted in a considerable increase in the number of gas-fired CCGT power stations in the UK during the 1990s. The relative prices of gas and coal at the time, in combination with tighter sulphur emission limits, made coal less attractive in electricity generation and contributed to a rapid retirement of old coal-fired capacity. Later, the deregulation process brought the spot prices of gas further down, CCGT-technology became even more efficient, and stricter sulphur targets were imposed. In addition, two dominant electricity suppliers, British Power and PowerGen, used their marked power to lift electricity prices above marginal cost (Wolfram 1999), precipitating a new "dash for gas" in the second half of the 1990s.

3. Methodology

When investigating market integration using time series data on prices, the basic relationship to be investigated is

$$\ln p_{1t} = \alpha + \beta \ln p_{2t} \tag{1}$$

where α is a constant term (the log of a proportionality coefficient) that captures differences in the levels of the prices and β gives the relationship between the prices. If β=0, there are no relationship between the prices, while if β=1 the prices are proportional. This also implies that the relative price is constant, sometimes known as the Law of One Price (LOP).[2] In this case the goods in question are perfect substitutes. If β is different from zero but not equal to one there is a relationship between the prices, but the relative price is not constant – implying imperfect substitutes. Equation (1) describes the situation when prices adjust immediately. However, often there will be a dynamic adjustment pattern. This can be accounted for by introducing lags of the two prices (Ravallion, 1986, Slade, 1986). It should be noted here that

[2] It is not entirely clear from the literature whether the LOP is restricted to test for homogenous goods in geographical space, or the term also can be used for products of different quality in product space.

even when dynamics are introduced, the long-run relationship will have the same form as equation (1).

Traditionally, relationships like equation (1) or its dynamic counterpart have been estimated with ordinary least squares (OLS). However, since the late 1980s it has become evident that traditional econometric tools cannot be used, when price series are nonstationary, since normal inference theory breaks down (Engle and Granger, 1987). Instead cointegration analysis is the appropriate tool to infer causal long run relationships between nonstationary time series. Two different tests for cointegration are commonly used in the literature. They are the Engle and Granger test (Engle and Granger, 1987) and the Johansen test (Johansen, 1988; 1991). In this study the latter will be used, since it allows for hypothesis testing on the parameters in the cointegration vector.

The Johansen test

The multivariate Johansen approach can be represented as follows. Let X_t denote an $n \times 1$ vector, where the maintained hypothesis is that X_t follows an unrestricted vector autoregression (VAR) in the levels of the variables

$$\mathbf{X}_t = \Pi_1 \mathbf{X}_{t-1} + \dots\dots\dots + \Pi_{\mathbf{k}} \Delta \mathbf{X}_{t-k} + \boldsymbol{\mu} + \boldsymbol{\varepsilon}_t \tag{2}$$

where each of the Π_i is an $n \times n$ matrix of parameters, μ a constant term and $\boldsymbol{\varepsilon}_t$ are identically and independently distributed residuals with zero mean and contemporaneous covariance matrix Ω. The VAR system in (2) written in error correction form (ECM) is

$$\Delta \mathbf{X}_t = \Gamma_1 \Delta \mathbf{X}_{t-1} + \dots\dots\dots + \Gamma_{k-1} \Delta \mathbf{X}_{t-k+1} + \Pi \mathbf{X}_{t-k} + \boldsymbol{\mu} + \boldsymbol{\varepsilon}_t \tag{3}$$

with $\Gamma_i = -I + \Pi_1 + \dots + \Pi_i$, $i = 1, \dots, k-1$ and $\Gamma_i = -I + \Pi_1 + \dots + \Pi_i$, $i = 1, \dots, k-1$. Hence, Π is the long-run "level solution" to (2). If X_t is a vector of $I(1)$ variables, the left-hand side and the first (k-1) elements of (3) are $I(0)$, and the kth element of (3) is a linear combination of $I(1)$ variables. Given the assumptions on the error term, the kth element must also be $I(0)$; $\Pi X_{t-k} \sim I(0)$. Hence, either X_t contains a number of cointegration vectors, or Π must be a matrix of zeros. The rank of Π, r, determines how many linear combinations of X_t are stationary. If $r=n$, the variables in levels are stationary; if $r=0$ so that $\Pi=0$, none of the linear combinations are stationary. When $0<r<n$, there exist r cointegration vectors – or r stationary linear combinations of X_t. In this case one can factor Π; $\Pi = \alpha\beta'$, where both α and β are $n\times r$ matrices, and β contains the cointegration vectors (the error correcting mechanism in the system), and α the factor loadings or adjustment parameters. Johansen suggests two tests for the number of cointegration vectors in the system, the maximal eigenvalue test and the trace test. We will here only report the trace test, as this is found to be the more powerful of the two (Gonzalo, 1994).

The Johansen procedure allows hypothesis testing on the coefficients α and β, using likelihood ratio tests (Johansen and Juselius, 1990). When testing hypothesis with respect to price differences between markets, it is the restrictions on parameters in the cointegration vectors β we wish to test. Information about central market is formally tested as exogeneity tests on the α coefficients. More specifically, in the bivariate case there are two price series in the $\boldsymbol{x}_t$ vector. Provided that the price series are cointegrated, the rank of $\Pi = \alpha\beta'$ is equal to 1 and α and β are 2x1 vectors. In this case, testing the restriction $\beta'=(1,-1)'$ provides test of constant relative price or the Law of One Price (LOP). The α vector contains information about weak exogeneity. When both elements in the α vector are different from zero, there will be causality in both directions and the two price series should be modeled as a system. However, if one of the elements are zero, there will be no long-run causation towards this variable in this system, and hence, this variable will be weakly exogenous in this system. In the case of market integration this implies that this good is a price leader.

In the multivariate case when all prices have the same stochastic trend, there must be n-1 cointegration vectors in the system. This follows from Stock and Watson (1988) who show that in a system with n variables, if there are r cointegration vectors there must be n-r stochastic trends. It then follows from the identification scheme of Johansen and Juselius (1994) that each cointegration vector can be represented so that all but two elements are zero.[3] This gives each long-run relationship the form in equation (1). However, as the cointegration vectors are identified only up to a nonsingular transformation, which normalization is used is still arbitrary. When the identifying normalization is imposed in the case with three price series, one representation of the matrix of cointegration vectors is:

$$\beta = \begin{bmatrix} 1 & 1 \\ -\beta_1 & 0 \\ 0 & -\beta_2 \end{bmatrix} \tag{4}$$

If both β parameters are equal to 1, the relative prices will be constant or the LOP hold.

Moreover, in a system with n data series and r stochastic trends there can at most be r exogenous variables (Johansen and Juselius, 1994). With the structure one expects to find in well functioning commodity markets (i.e. a long-run relationship between price in the different markets), one expects to find n-1 cointegration vectors and one stochastic trend. Hence, there can at most be one price that leads the system. Only in this case will it be valid to model the system as bivariate relationships with the exogenous variable on the right hand

[3] See Asche, Bremnes and Wessells (1999) for a discussion of these issues in a market integration context.

side. This has two important implications. First, if there are no exogenous variables in the system, the full system must be estimated. This also implies that the full system in general must be estimated if one is to test for exogeneity. However, one can certainly obtain some, but possibly conflicting information on this issue from bivariate systems.

Market integration and aggregation

The composite commodity theorem of Hicks (1936) and Leontief (1936) states that for a bundle of goods, if individual prices move proportionally over time, the bundle can be characterized using a composite price index. Hence, a test for proportionality of prices over time, i.e., a test for the LOP, provides evidence of whether the goods can be aggregated. In this case one does not need information about consumer preferences as with different separability concepts. A problem with the composite commodity theorem in empirical work is that for the theorem to hold, the prices must be exactly proportional. However, Lewbel (1996) provides an empirical useful generalization of the theorem that allows for some deviations from proportionality.[4] There are several ways to test for the generalized composite commodity theorem. One method is to investigate whether the LOP holds in a market delineation context when prices are nonstationary (Asche, Bremnes and Wessells, 1999). If so, aggregation can occur according to the generalized composite commodity theorem. This is consistent with our intuition that goods that are equivalent for consumers or producers can be treated as one good. Moreover, this is interesting because it provides a clear link between aggregation theory and market integration.

[4] As always, there is some cost involved. Aggregates constructed using the generalized composite commodity theorem cannot be used in welfare comparisons.

The Data

The analysis is based on monthly wholesale price series of crude oil, natural gas and power in the period of January 1995 to June 1998, giving 42 observations. One could wish that the data set was longer, however, it is restricted by the period the independent deregulated market structure lasted in the UK. The short data set may cast doubt on the robustness of the conclusions, but it will be shown in the empirical results section that misspecification tests do not give any evidence against the models, and there is certainly enough information in the data to provide evidence against different hypothesis. The crude oil price is Brent, i.e. crude oil originating from the UK continental shelf converted into £/barrel to make it comparable to the other two prices. The natural gas price is denoted as £/btu (british termal unit) and is the price at the National Balance Point (NBP). The electricity price is denoted in £/MWh, and is the National Grid Price. The prices are graphed in Figure 1, with the electricity price on the right hand y-axis to remove the unit difference. As one can see, there is substantial short run variation in the prices, but the long-run trends do not seem to move far apart.

(Figure 1 about here)

Several studies have indicated that oil and natural gas prices are nonstationary (e.g. Gjølberg and Johnsen, 1999; Serletis and Herbert, 1999; Asche, Osmundsen and Tveterås, 2002). We investigate the time series properties of the data series investigated here with the Augmented Dickey Fuller (ADF) test.[5] The test indicates that while all price series in levels are nonstationary, all prices are stationary in first differences. Hence the data series seem to be integrated of order one and cointegration test is the appropriate econometric approach.

[5] The results from the ADF test are available upon request from the authors.

4. Empirical results

To delineate the markets we started by testing bivariate relationships to reduce the potential dimensionality problems. Two outliers, 1995:12 in the electricity price and 1997:12 in the natural gas price, caused rejection of normality tests for the residuals and substantially biased the result. These outliers were therefore removed from the data set and new observations interpolated. There are at most n-1 cointegration vectors in any system with n prices (Stock and Watson, 1988). All other possible vectors are then redundant, since they are linear combinations of these n-1 vectors. We report the pairs including the oil price, as this is the natural price to normalize upon given the results below. The results from the tests are reported in Table 1. Lag lengths were chosen to whiten the error term and Lagrange multiplier tests (LM) for autocorrelation up to the 12th order are reported as evidence against dynamic misspecification together with normality tests.[6] As one can see, the null hypothesis of no misspecification is not rejected for any of the tests, and the models therefore seem to give reasonable descriptions of the data. In both cases the cointegration tests indicate one cointegration vector, and hence, all prices seem to follow the same stochastic trend. Furthermore, proportionality or the Law of One Price cannot be rejected, indicating stable relative prices. Consequently, the tests indicate a highly integrated market.

In table 2, a multivariate cointegration test is reported. Again the misspecification tests give no evidence against our model specification. The cointegration test indicates, as expected from the bivariate tests, that there are one stochastic trend and therefore two cointegration vectors in the system. However, the second vector is only found at a 10% level and not at a 5% level. This is most likely due to our relatively short data set, but together with the results from the bivariate cointegration tests, one stochastic trend in the system seems to be the most

[6] Tests against ARCH and heteroscedasticity were also performed. No evidence of misspecification was found, as the null hypothesis never was rejected.

reasonable conclusion. A test for proportionality (the Law of One Price) gives a $\chi^2(2)$ test statistic of 2.429. With a p-value of 0.297, this hypothesis cannot be rejected at any conventional significance level. Consequently, also the multivariate cointegration test provides evidence of a highly integrated market in the UK in the period the market was independent and deregulated. Moreover, since the relative prices are constant, the GCCT of Lewbel (1996) holds, allowing one to aggregate these three commodities into a single quantity with a single price index. Hence, in the period studied, there appears to have been a single wholesale energy market in the UK.

The final issue to investigate is whether there is an energy commodity that serves as a price leader in this market. This is done by testing if any of the prices are exogenous or is determined outside the system. With two cointegration vectors these tests are distributed as $\chi^2(2)$, and the test statistics are reported in Table 3, together with p-values. The null hypothesis of exogeneity cannot be rejected for the crude oil price, but is rejected both for the electricity and the natural gas price. Hence, the crude oil price seems to be the price leader in this system, which allows these relationships to be modelled in single equation specifications with crude oil as the exogenous variable. Moreover, in this period, when the UK energy market was an isolated deregulated market, not only were the markets for the three energy sources oil, natural gas and electricity highly integrated, but the prices were lead by the oil price, and accordingly by the global oil market.

5. Concluding remarks

Testing for market integration between natural gas, electricity and crude oil prices in the UK in the period when the market was deregulated but not yet linked to the continental European natural gas market, we find a highly integrated energy market. We cannot reject the hypothesis that the relative prices are constant and, accordingly, the Generalized Composite Commodity Theorem holds. This implies that during this period, there was a single energy market in the UK. Moreover, we find that the crude oil price is exogenous and therefore the leading price. This is natural if any price is to be exogenous, as there is a global market for oil (Sauer, 1995) but not for the other two products. The energy prices in the UK in this period are therefore determined in the global oil market.

If this result is true in general for sufficiently competitive energy markets, it has substantial implications. The marginal consumers of energy will not put any emphasis on the carrier, only on the energy it provides. Moreover, the cause for different development in the prices for various energy sources then is primarily created by regulations or by limits in transmission capacity, either temporary bottlenecks or complete absence of connecting lines. As is evident from North American, limited transmission capacity and different regulatory systems can create regional markets with different characteristics allowing various degrees of substitution between energy carriers.

Capacity constraints on transmission networks can be the result of too weak incentives to invest in capacity, due to a number of factors. Deregulation in itself will not automatically bring out the right amount of investments. Vertical unbundling and separation of production and transmission activities, along with appropriate market design, are necessary factors. Still this leaves the conclusion that the only reason why energy sources are not fully substitutable is because the markets are not complete and consumers of energy are not able to substitute between different sources. It may, however, be economically inefficient to make the energy markets complete due to the substantial network costs.

To conclude, the results indicate that if consumers of energy are allowed to substitute between different carriers, they are only concerned about the energy provided, not the source. In the UK the geographical area under study was fairly limited, having a high population density and the same regulatory system. This provides a substantial contrast to North-American studies, and are at least a part of the reason why the market is more integrated. Hence, in a well designed deregulated energy market there should be substantial interfuel competition, and even if transmission capacity is limited between some markets, the link to the oil market should still provide a similar price development.

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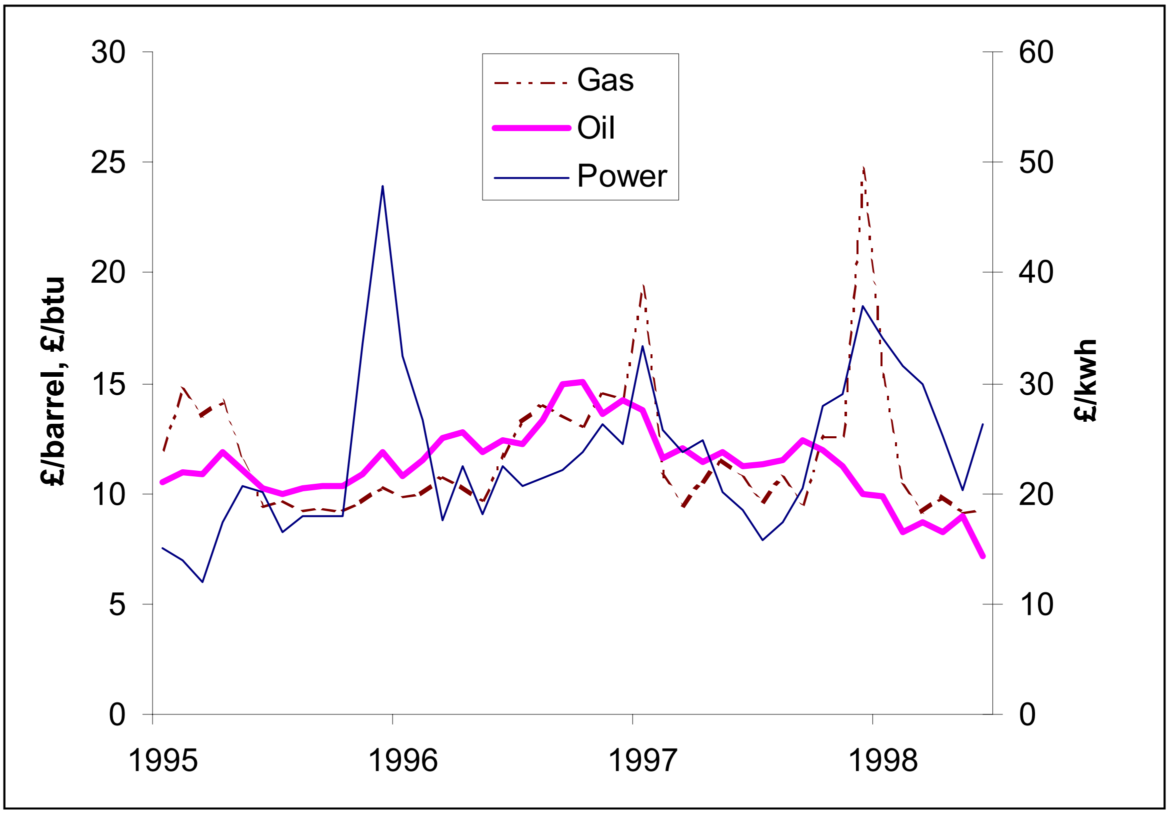

Figure 1. Oil, natural gas and power price

Table 1. Bivariate cointegration tests

Variables	H_0:rank = p	Trace test[a)]	LM[c)]	Normality	LOP
Crude oil and power	P==0 P<=1	14.98** 0.739	1.032 (0.450) 0.703 (0.734)	3.601 (0.165) 0.041 (0.979)	2.385 (0.122)
Crude oil and natural gas	P==0 P<=1	17.08* 0.284	0.846 (0.606) 0.624 (0.803)	2.622 (0.269) 4.550 (0.103)	0.999 (0.317)

*indicates significance at 5% level, ** significance at a 10% level

a) Critical values for the cointegration test can be found in Johansen and Juselius (1990).

b) The test is distributed as $\chi^2(1)$, which have a critical value at 3.84 at a 5% level.

c) LM is a Lagrange multiplier test against autocorrelation up to twelve lags for the associated variable in column 1. The test are distributed as *F*(##), *p*-values in parentheses

d) The test is distributed as $\chi^2(1)$, which have a critical value at 3.84 at a 5% level, ** indicates statistical significance at 1% while * indicates statistical significance at 5% level, *p*-values in parentheses.

Table 2. Multivariate cointegration test

H_0:rank= =p	Trace test	Critical value at 5%	LM	Normality
p= =0	32.41*	29.7	0.996 (0.479)	3.852 (0.145)
p<=1	15.03**	15.4	0.636 (0.792)	0.289 (0.865)
p<=2	0.78	3.8	0.689 (0.747)	4.551 (0.103)

*indicates significance at 5% level, ** significance at a 10% level. Critical values for the cointegration test can be found in Johansen and Juselius (1990)

Table 3. Weak Exogeneity Tests

Variable	Test Statistic	*p*- value
Crude Oil	5.983	0.051
Natural Gas	15.689*	0.001
Power	8.651*	0.013

*indicates significance at 5% level