An Analysis of Coal Generation in the UK and Gas Market interaction (2000 – 2009)

Abstract

This report examines the relationship between the physical coal and gas markets in the UK from 2000 to 2009 and investigates the hypothesis that these markets exhibit marked correlations. A sample set of 40 Quarterly data points and 27 cross-correlations indicated a strong relationship between the two markets in some aspects, the growing influence of Liquefied Natural Gas and a suggestion of rapid market evolution in both Coal and Gas.

Name: Patrick Avis

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EDF Trade Price Database

1) Introduction

Modern life in unimaginable without electricity, it's used almost everywhere, in our homes, offices, hospitals and in every corner of our urban environments. Over 65% of the world's electrical energy is generated by steam turbine generators and large scale fossil fuelled plants provide most of the world's base load generating capacity. Globally, the energy mix is predominantly built around the burning of coal (60%) or the combustion of gas (30%) with heavy fuel-oil (10%) soaking up the remaining requirement. However, the availability of local fuels, transportation constraints and historical determinants result in significant polarisation of this mix. For example, the fuel mix of Poland is weighted heavily towards solid fuel (90%) whilst France sources just 5.2% of primary generation capacity from such sources.

UK electricity generation has historically been based upon indigenously sourced solid fossil fuels with the generating capacity being located close to source. In effect this lead to a clustering of coal burning power stations in and around the coal seams of the Midlands and North of England and an associated distribution network radiating from these to the major population hubs.

During the 1940's in excess of 90% of generating capacity was fired by coal with oil providing the rest. A decade later, primarily as a result of the production of weapons-grade plutonium, the UK commenced construction of a series of nuclear reactors which would eventually meet almost 30% of electricity demand. The 1960's witnessed the discoveries of large deposits of natural gas under the North Sea, further adding to the potential indigenous sources of power and most recently, the ability to delivery large quantities of Liquefied Natural Gas to the UK has added to the energy equation.

Given this broad background, this project aims to focus its analysis on the UK solid fossil fuel and how this market interacts with the UK Gas Market. It is the hypothesis of this report that the UK Coal and Gas markets will exhibit correlated prices and market mechanisms .

2) Data

All the markets under investigation are mature, developed and well reported. Coal and Gas have been actively traded and consumed in the UK for significant periods of time and a large body of available data was available for sampling.

The primary sources of data were the Department for Energy and Climate Change, The Office for National Statistics and market pricing databases held within EDF Energy. This spread of sources allowed data to be summarised at granularities from annual to monthly and from markets as diverse as Liquefied Natural Gas shipments to Generators Coal stock piles.

In all, over thirty tests were performed and a broad range of results obtained in three principle categories; market price trends, seasonality & generation burn and cross correlation analysis. The summarised data is given in the Appendix and the full data set in the attached electronic file. The following gives a digest of the data sources and the challenges these presented.

2.1. Annual price and volume data

Indigenous coal mines were taken under government control during World War II and nationalised with the formation of the National Coal Board (NCB) in 1946. Publicly accessible records detailing mine output, nominal price and other metrics are only available on an annual basis for large portions of the period up to 1993. The Office of National Statistics holds monthly inflation data for this period which can be annualised using a simple arithmetic mean to derive a proxy annual price index and hence a Real price (relative to 2000) was derived.

2.2 Quarterly price and volume data

The NCB was re-named to the British Coal Corporation in 1987 but remained the statutory body in charge of indigenous coal production until privatisation in 1993. As part of this process more data relating to the corporation's activities was made publicly available, reporting became Quarterly and the first large scale electronic records kept. Finally, the Department for Energy & Climate Change (DECC) centralised all energy related statistics under the Direct.gov initiative in the mid-2000's.

2.3 Natural Gas Production and Supply

Natural Gas arrives in the UK via pipeline from either Norway, North Sea storage or increasingly from Russian sources. Additionally, Liquefied Natural Gas is shipped from North America to arbitrage the price differential between the European and North American markets.

As previously noted, the UK utilises a range of power generation sources and DECC also provides standardised data to support their analysis. As could be expected with different commodities operating in different markets, the reporting mechanisms between Coal, Oil and Gas are distinct. Whilst the foremost is most often reported quarterly, the Gas and Oil markets have settled on monthly tenors.

An initial monthly data set was up-scaled to quarterly data by aggregating the three monthly periods corresponding to that quarter:

$$2000Q1_{vol} = 2000Jan_{vol} + 2000Feb_{vol} + 2000Mar_{vol}$$

Consideration was given to the variability in the lengths on the months within in each quarter. To obtain exact quarterly data the report would weight prices so that each quarter consisted of the same number of days. For markets operating at this (or smaller) granularities, this is entirely possible, and indeed would be preferred the mechanism. However, this approach would be counterproductive in this case due to the tenor size.

2.4. Energy unit standardisation

Each of the markets under examination has their own pricing and volumetric standardisations. However, when buying Gas, Oil or Coal the end user is fundamentally purchasing a bundle of energy equivalence to a function of the power they wish to generate (given the efficiency of the process they operate). Market conventions and vastly different physical properties has resulted in bespoke terms and standards evolving; the coal market will talk about the Calorific value of Coal, the gas market will price gas as a measure of Therms and oil will measure the British Thermal Units. Direct comparison between these units is not possible but conversion to a standard unit does permit analysis. The standard base unit used in this report was Pence per kWh (p/kWh) and can be derived for each commodity as shown in Table 2.1.5.

It should be noted that DECC provides all their data in both the market quoted unit and also in p/kWh but in order to reduce the sources of error, where possible, the DECC processed data set has been used.

Commodity	*Traded Unit*	*Equivalence (kWh)*
Oil	1 BTU	0.00029
Gas	1 Therm	29.31
Coal	1 Giga joule (Gj)	277.8

Table 2.1.5 – Conversion of market instrument to kWh

2.1.6 Correlations

A series of cross correlations were calculated to investigate the nature of the UK generation market. The data provided by DECC was further processed to generate a bespoke set of data. Since the data was mostly standardised around p/kWh, as described in 2.1.5, a Covariance analysis could have been employed (since this is dependent upon the variables having the same units). However, to allow the broadest range of analysis to be conducted, it was decided to employ Pearson's coefficient correlation.

This correlation was held to be suitable if both the standard deviations of the variables were finite and nonzero. Data not meeting these conditions was excluded. All statistical packages will calculate the correlation coefficient but in order to independently verify the calculation was accurate, a sample data set was analysed and coefficient compared to that generated by the package. These were found to match and for efficiency the inbuilt Pearson correlation coefficient function was used in all subsequent tests.

The example calculation is given in the Appendix in Table 2.1.6 and in the attached data file.

3) Analysis

3.1 Historical price trends

Annual nominal UK coal price data from 1949 to 2009 reveals four distinct price phases categorised by two periods of relative price stability (1949 to 1970 and 1986 to 2003) and two periods of rapid price increases (1971 to 1982 and 2004 to Present).

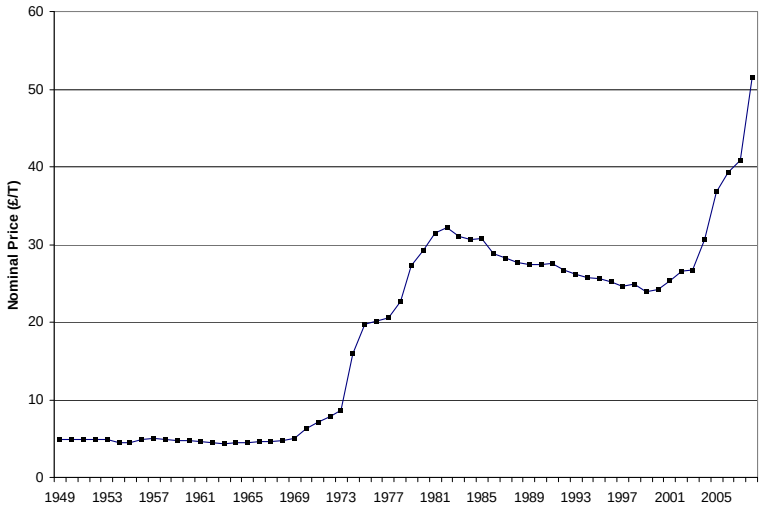

Figure 3.1.1 - FOB Benchmark Prices for UK Coals (1949 - 2008)

Prima facia, it appears that current market prices are an order of magnitude greater than they were 59 years previously (£51.45/T in 2008 and £4.90 in 1949). Whilst this is true in nominal terms, is that actually reflected in the buying capacity of the generator?

Calculating real prices, by adjusting for inflation, reveals the same general price morphology as seen in Fig 3.1.1 of low and high prices. It provides additional information and indicates that, in real terms, prices exhibit a broad cyclical form with floors of £20 (1968 and 2000) to a cap of £55.12 (1979). In addition, prices in real terms fell by 37% from 1949 to 1968, rose by 292% before returning in 2000 to prices comparable to those 30 years earlier.

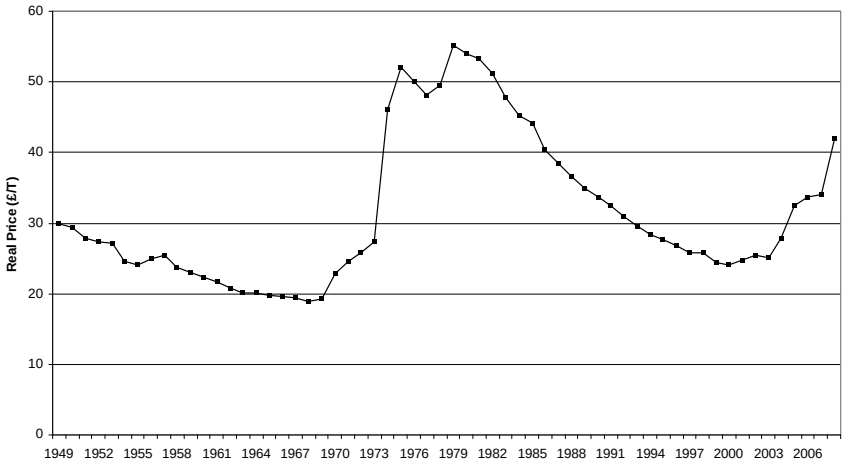

Figure 3.1.2 - Real Prices for UK Bitumous Coals (1949 - 2008) with index as at 2000

Finally, it should be noted that while the annual price sample size (n=60) was significant enough to allow meaningful analysis to be conducted on the annual data set, the granularity of the data meant direct comparisons with later data sets (quarterly) impossible.

3.2 Seasonality

Coal-Power generation exhibits marked seasonality being negatively correlated to temperature. Hence, during periods of cold weather it is expected that generation burn would increase. Analysing weather data for seasonal temperature variations is beyond the scope of this report, but on the assumption that Winter periods (Q1 and Q4) are colder than Summer (Q2 and Q3) and that coal generation is primarily for power generation and not for secondary reasons (to clear stocking space for example), it should be possible to see the general effect in the sourced data.

While primarily qualitatively illustrating the seasonality, Figure 3.2.1 clearly reinforces the cyclical component to coal generation that earlier reports had indicated. Furthermore, the addition of a trend line (---) to the data set gives the first indication that there is an underlying change in the nature of the generation.

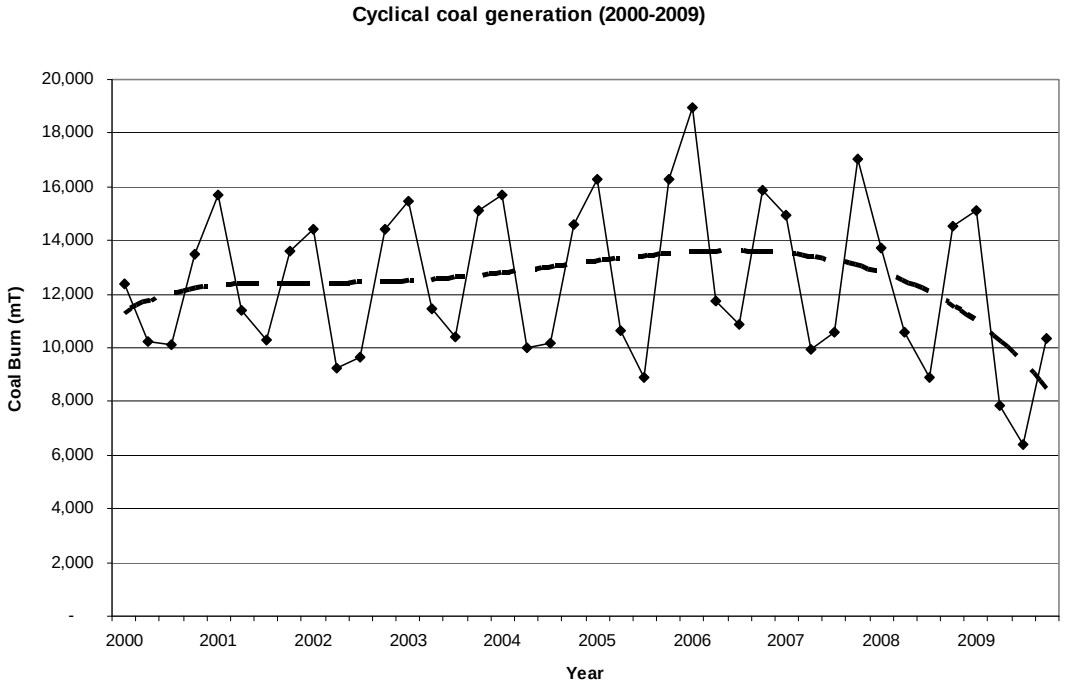

Figure 3.2.1 – Illustration of the cyclical seasonality in coal generation

The data sets were further examined to investigate whether the season trends could be observed in gas generation. Figure 3.2.2 would appear to indicate that there is both a strong seasonality in UK gas powered generation and that there is also a changing market dynamic effect in progress as indicated by the growth in the underlying trend line (---).

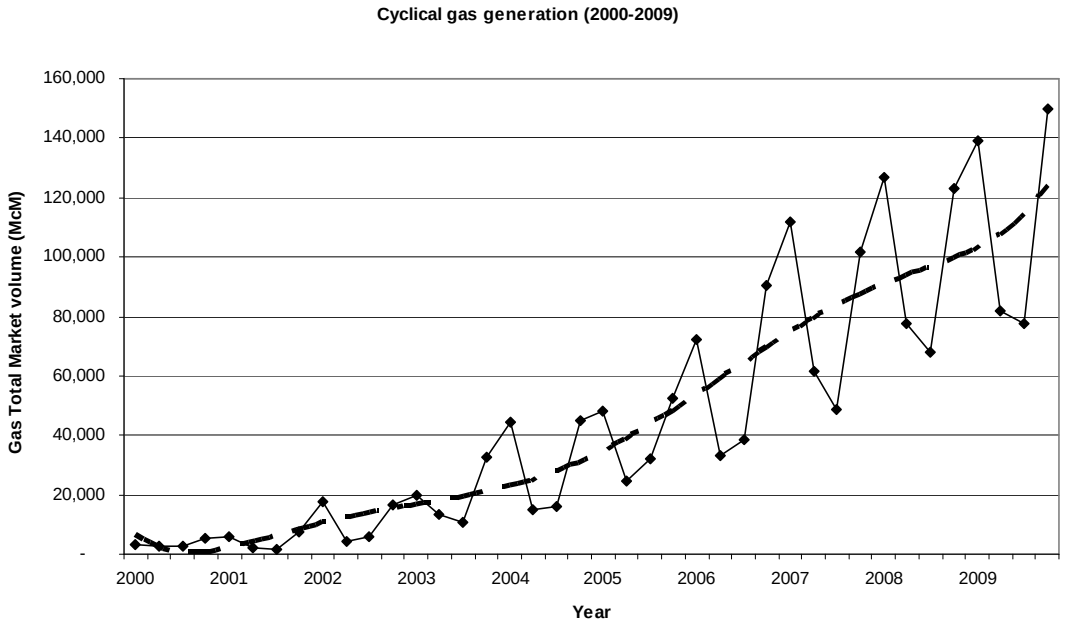

Figure 3.2.2 – Illustration of the cyclical seasonality in gas generation

3.3 Market and Price Correlations

To support the hypothesis, a total of 27 cross correlations using the Pearson correlation coefficient were calculated to provide a broad basis for analysis. Each test was based on a sample size of 40 observations per variable and held to be valid by the terms given in Section 2.6.

The results of these crosses are given in Table 3.3.1 with negative r values given in bold to assist with recognition and no undue significance should be given to this formatting.

Test Number	*Variables to test*	*n*	*r*
1a	Coal to Oil (£/T)	40	0.78
1b	Coal to Oil (p/kWh)	40	0.78
1c	Coal to Gas (p/kWh)	40	0.84
1d	Oil to Gas (p/kWh)	40	0.75
2a	Coal (p/kWh) to Gas Import (Pipeline)	40	0.79
2b	Oil (p/kWh) to Gas Import (Pipeline)	40	0.70
2c	Gas (p/kWh) to Gas Import (Pipeline)	40	0.93
3a	Coal (p/kWh) to Gas Import (LNG)	40	0.41
3b	Oil (p/kWh) to Gas Import (LNG)	40	0.62
3c	Gas (p/kWh) to Gas Import (LNG)	40	0.44
4a	Coal (p/kWh) to Gas Import (Total)	40	0.78
4b	Oil (p/kWh) to Gas Import (Total)	40	0.75
4c	Gas (p/kWh) to Gas Import (Total)	40	0.91
5a	Indigenous Coal and Coal Imports	40	**-0.74**
5b	Indigenous Coal and Coal Exports	40	0.23
5c	Indigenous Coal and Net Port Flow	40	**-0.74**
5d	Indigenous Coal and Generation	40	0.08
5e	Indigenous Coal and Stock	40	**-0.34**
5f	Coal Imports and Generation	40	0.32
5g	Coal Imports and Stock	40	**-0.01**
5h	Generation and Stock	40	**-0.60**
5i	Total Coal and Generation	40	0.55
5j	Total Coal and Stock	40	**-0.38**
6a	Coal (p/kWh) to Generation	40	**-0.12**
6b	Coal (p/kWh) to Stock	40	0.36
7a	Gas (Total) on Generation	40	0.21
7b	Gas (Total) on Stock	40	0.35

Table 3.3.1 – Table of Pearson's correlation coefficients

Much discussion has been raised as to how best to interpret the correlation coefficient value (*r*). Given that the interpretation will always be arbitrary, some commentators (Cohen, 1983) have stressed the importance on considering the nature of the nature of the sample set. Discussion and interpretation of the correlations will be given in the *Summary and Conclusions* section but for purposes of this report the following r-values will be held to indicate a null, weak, medium or strong correlation between the test variables.

Correlation	Negative (*r*)	Positive (*r*)
Null	−0.09 to 0.0	0.0 to 0.09
Weak	−0.3 to −0.1	0.1 to 0.3
Medium	−0.5 to −0.3	0.3 to 0.5
Strong	−1.0 to −0.5	0.5 to 1.0

The first set of tests (1a – 1d) looked that the cross correlations of the Gas, Coal and Oil markets based on the quarterly data from 2000Q1 to 2009Q4 and indicated strong positive correlations between the three commodities.

Test sets (2 to 4) examined the correlations the three commodities had to the North Sea Gas arriving via pipeline, to LNG and finally to the combined Pipeline and LNG position. It is not surprising, based on the earlier results, that all three indicated a strong positive correlation and that gas trading within the UK was almost perfectly correlated to gas arriving from the North Sea.

Test sets (5 and 6) examined the correlations within the coal market and highlighted some interesting results. Most noteworthy were the strong negative correlations (5a and 5c) and the weakness exhibited in some dynamics (5d and 6a).

The final batch of tests (7a and 7b) examined the relationship between the total available gas and Coal stock/burn.

3) Summary and Conclusions

From the analysed data it can be concluded that coal prices have undergone a series of marked changes since 1949. During which time the absolute price demonstrated a net positive trend, belying the fact that in experienced mild contraction throughout the 1980's and 1990's, and the real prices experienced two sets of price spikes and prolonged contractions. There would appear to be indications of the classic commodity price instability (Scott & Lal, 1990) and mild evidence for mean-reversal within the sequence. It would be interesting to explore this in

more depth. Additionally, it should be noted that a prolonged series of UK gas price data (equivalent to the 59 year coal data set) was not available despite significant investigation by the author. Whilst the report was intentionally focussed on the UK Coal Market a broader expansion to encompass more UK Gas and European commodity markets would be fruitful.

The fact that Gas and Coal generation show seasonality should come as little surprise and, whilst not in its self proof, the author believes sufficient evidence to propose seasonality has been presented. Applying basic trend analysis to the seasonality data suggests a broadening in the season spreads (the differential between the yearly high and low) in both commodity markets. Additionally, it would appear that a softening in overall coal to power generation is being match by a surge is gas to power generation. The author believes that this is evidence of a longer term trend towards the Gasification of the UK market.

Finally, when interpreting the value of the correlation coefficient, it is important to remember that although a high degree of correlation indicates a good mathematical fit to a linear model, its applied interpretation may be completely nonsensical. Secondly, although a correlation coefficient close to 0 indicates a poor fit to a linear model, it does not mean that there is no correlation between the two sample populations. It is possible that the relationship between X and Y is accurately described by a nonlinear model.

With that in mind, it can be seen that Coal is reported to be strongly correlated to both Oil and Gas. The question to be asked is whether these are directly correlated or priced in relation to third commodity? Whilst not in this reports scope, the author is familiar with the markets in question and has observed that Coal and Gas tend to price off the more liquidly traded Brent and WTI markets.

Taking a moment to look at the correlations between Pipeline, LNG and total market gas it seen that Gas priced in the UK is more correlated to Gas arriving from the North Sea than to the total market. The price of LNG is a function of the origination source price and thus it would be logical to conclude this would be different from the North Sea market. Including this weighting in the overall is bound to diverge the Total price from the North Sea price.

It's a muddier picture when the indigenous coal production and Generation/Stock numbers are examined. A firm case can be made that the strong negative correlations observed are genuine and reflect that a rise in one variable would correspond (either directly or indirectly) to a fall in the other. The addition of indigenous coal to the UK market should,

ceteris paribus, lead to a reduction in imported coal volume (5b). Weak to Null correlations were reported when examining the correlation between commodity market price (5 & 6) and Generation Burn and Stock numbers. The author would suggest that is not unexpected given that the decision to burn or send the commodity to stock is based on factors extrinsic to price.

In summary the author hopes that this report has verified the hypothesis that the prices for coal and gas are strongly correlated within the UK market. It is further suggested that both the Coal and Gas markets continue to evolve and demonstrate longer term structural changes and that there is clear evidence of an interaction between indigenous and imported coal.

4) Bibliography

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http://en.wikipedia.org/wiki/Pearson_product-moment_correlation_coefficient

4.3 Department of Energy & Climate Change
http://www.decc.gov.uk/en/content/cms/statistics/source/coal/coal.aspx

4.4 Office for National Statistics
http://www.statistics.gov.uk/hub/index.html

4.5 Maurice and Deepak (1990). *Public policy and economic development: essays in honour of Ian Little*

5) Appendix

Due to Word formatting constraints, the data tables are attached to the following pages.