Investing in Commodities: 2.Energy prices

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April 15th 2011

Outline

- The energy markets
- the gas market
- the oil market
- the electricity market
- Relationship between prices
- The methodology
- The dataset
- Some results
- Conclusions

An overview

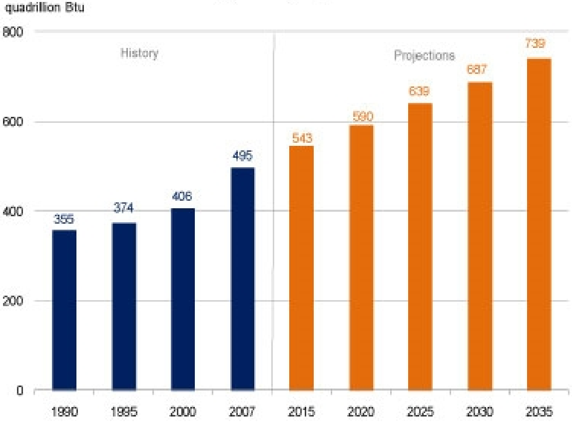
In 2010 According to the Energy Information Administration the world energy consumption increases by 49 percent, or 1.4 percent per year, from 495 quadrillion Btu in 2007 to 739 quadrillion Btu in 2035 (Figure 12 and Table 1).

The global economic recession had a profound impact on world income (as measured by GDP) and energy use.

- GDP had grown at an average annual rate of 4.9% in (2003-2007), 3.0% in 2008, -1.0 % in 2009:
- Growth in world energy use slowed to 1.2% in 2008 and -2.2% in 2009.

An overview

Figure 12. World marketed energy consumption, 1990-2035



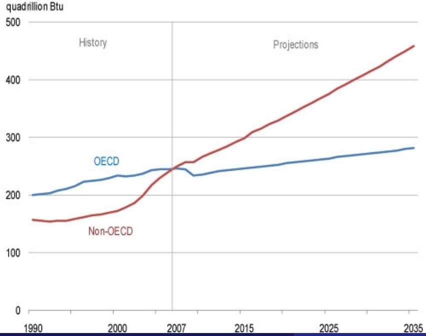
An overview

Historically, OECD countries have accounted for the largest share of current world energy consumption.

In 2007 energy use among non-OECD nations >> OECD nations (Figure 13).

The discrepancy between OECD and non-OECD energy use grows in the future, given the more rapid growth in energy demand expected for the emerging non-OECD economies.

Figure 13. World marketed energy consumption: OECD and Non-OECD,1990-2035



The energy markets

- During the last 10 years the energy sector has seen a broad transformation, which has led energy commodities to assume a strategic role in the global economy.
- Electricity and gas industries, moving from central owned systems to liberalized ones, had a deep impact on the financial choices. So, they required a stronger attention in order to develop new risk management strategies.
- The crude oil market has been also experiencing serious changes over the last decade caused by economic and political issues. The price of crude oil took 4 years to move from $US\$50/bll$ to $US\$143/bll$ and in only 4 months went back to the original price and now is again in turmoil, "if Libya and Algeria were to halt oil production together prices could peak to $220 a barrel...." Nomura 2011.

The energy markets in EU

The factors determining future energy demand in the EU27 include:

- continued economic growth of more than 2% p.a.,
- hardly any rise in population,
- oil prices remaining at a high level,
- gas prices determined by market forces,
- increased environmental awareness in politics and among consumers,
- growing trend to save energy and to improve energy efficiency,
- thoughts at national level to use nuclear energy and expand the use of renewables.

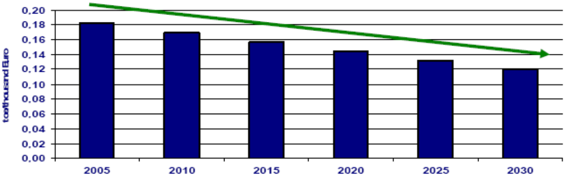
Energy intensity in EU

The increase in energy consumption in the EU27 over the next 25 years will be disproportionately low in comparison to other parts of the world ($+ 1.6\%$).

Investment in new energy efficiency efforts and climate change commitments by the EU will result in a significant 34% improvement of energy efficiency in the EU27.

Energy scenarios developed under a number of different objectives have one common message: fossil energy sources will continue to be the backbone of European energy supply.

Energy Intensity in EU27: PEC to GDP



http://www.eurogas.org/uploaded/Eurogas%20long%20term%20outlook%20
%20final.pdf

Energy intensity in EU

Because of "its green properties" and highly efficient application technologies, natural gas will remain the fuel of choice and will continue to make a growing contribution to energy supply in the EU27.

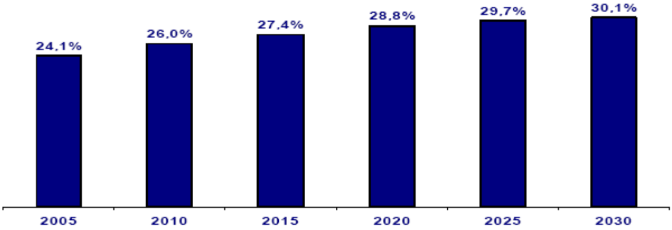
Natural gas can play an important role as a bridging fuel to a sustainable energy future over the coming decades.

Natural gas consumption in EU member states is expected to increase of 43% up to the 2030 . The share of natural gas in the European primary energy demand will rise from 24% in 2005 to 30% in 2030 (18% in 1990). At 60% of the total demand increase, most of the growth will come from power generation.

Natural gas in the form of shale gas has been the major piece of news in the US in 2010

Natural gas reserves are for 100 years or more.

EU market share for natural gas



Why analyzing relationships among prices?

The dynamics of natural gas, fuel oil, and power prices are expected to be related for several reasons.

- Fuel oil and natural gas, for example, are used as substitutes in industrial boiler, and oil and natural gas are used as peaking sources of supply for power generation for cooling loads in the summer and for heating loads in the winter.
- All these types of energy directly serve space heating demands during the winter.
- wholesale prices for these sources of energy are expected to respond similarly to different types of shocks.
- ....??

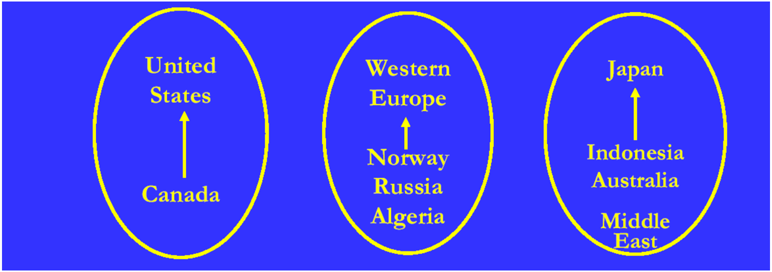
The gas markets

Gas represents to day the fastest growing energy commodity:

1. Severe tensions on oil and other implications for other fossil fuels
2. The increasing role of gas in electricity generation, modern and efficient Combined-Cycle Gas Turbine.
3. Natural gas consumption in the non-OECD countries grows more than twice as fast as in the OECD countries.
4. Production increases in the non-OECD region account for more than 80 percent of the growth in world production from 2006 to 2030.
5. Natural gas produces less carbon dioxide when it is burned than coal or petroleum, governments implementing plans to reduce greenhouse gas emissions may encourage its use to displace other fossil fuels.

The gas markets

- Until recently, three regional markets could be identified in the world, with limited trade between them because of the cost of transportation of gas over long distances



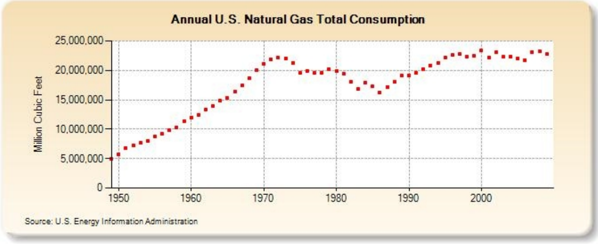
- As a comparison, it costs only $2 to transport a barrel of oil around the world, i.e., less than 5% of the price of a barrel
- Increased LNG transport should help breaking down the barriers to current world segmentation
- Use of Shale gas will increase the supply

The gas markets

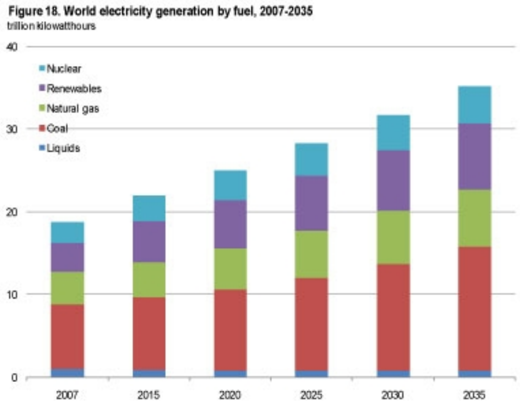
- Share of gas in power generation has increased largely in the last decade (from 1997 to 2007 at a 4.8% per year) and it is expected to grow in the next 20 years at a 2.1% per year rate
- Trading of Liquefied Natural Gas (LNG) has started with gasification plants being built along various shores: giving the opportunity to rerhoute methane thankers in region with shortage of it. Increased LNG transport should help breaking down the barriers to current world segmentation
- Gas price in US and UK is set by supply and demand, in Western Europe where deregulation is not completed yet prices may be thought as a linear function of oil prices...
- The supply of gas in Western country takes places through long term contracts with "take or Pay " clauses.

The gas markets

Also in US the share of gas in electricity generation increased by



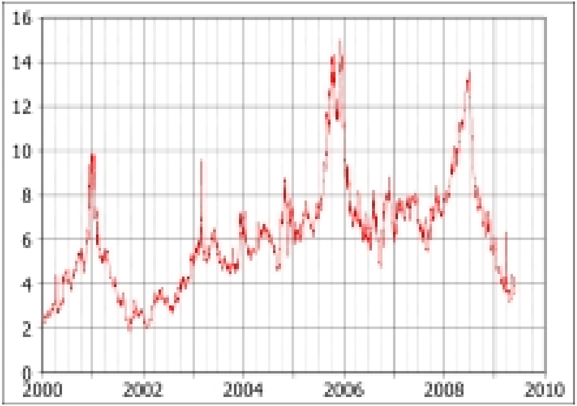
Gas share in Electricty production



The Gas prices dynamics

Gas price at Henry Hub 2010-2011

The Gas prices dynamics



Natural gas prices at the Henry Hub in US Dollars per cubic meter for the 2000-2010 decade.

the oil/gas ratio

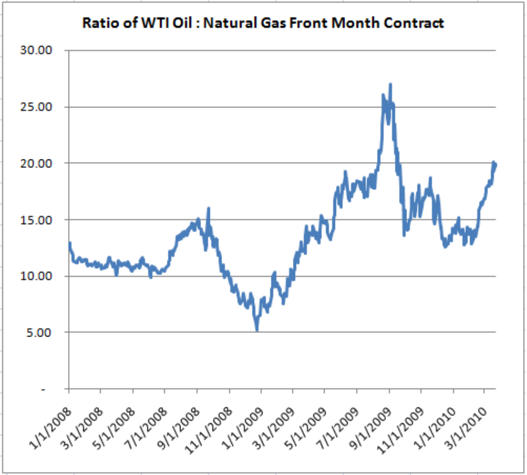
Volatility in the markets for various forms of energy is nothing new. Prices react to weather, political and economic developments, and speculation.
Short term prices of individual commodities can be influenced by any of these factors.
Prrices are compared to those of similar commodities.
Gas-Oil: One measure is the relative price of natural gas compared to crude oil:

- 1 bbl crude oil has approximately 6 times the energy content of one thousand cubic feet (mcf) of natural gas.

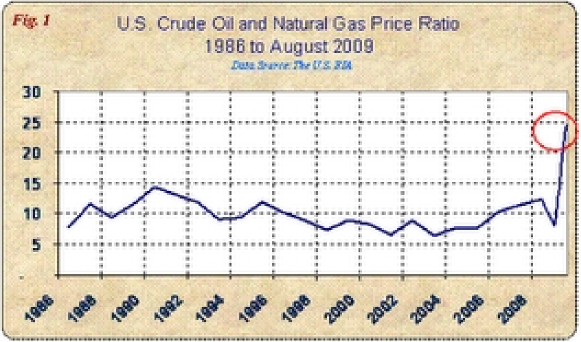
The pricing relationship between oil and natural gas is almost never exactly 6:1.
Oil used to be a global commodity while natural gas is generally considered a commodity that is more influenced by local production and consumption trends.

The oil/gas ratio

Ratio of one barrel of WTI crude oil to one mcf of natural gas since Jan'08



the oil/gas ratio



The oil/gas ratio

The current spike in the ratio has been caused by crude oil prices sustaining a move above the $80 per barrel level.
Natural gas prices have collapsed due to:

- the arrival of warmer weather,
- reports of plentiful inventories,
- continued high expectations for increased productions from unconventional domestic sources such as shale extraction.

Gas price?

$6 Natural Gas to Earn a 5 to 10 Percent Return?
Investors also believe that the industry may be drilling its way to $2 to $4 gas.
Shale gas is far more expensive to extract compared to conventional sources.
In the short run, it appears that the increased production of natural gas is likely to continue depressing the price of the fuel relative to crude oil.
It is difficult to see a scenario in which the ratio of a barrel of crude to one mcf of natural gas can remain at 20 or above.
In the past, prices of natural gas and oil have adjusted to result in a ratio that is more normally between 10 to 15.
This may present an interesting arbitrage opportunity for those inclined to pursue such strategies.

The role of Shale gas

The shale gas boom in the United States has been something of a mixed blessing for independent oil and gas companies.
New technology has opened up vast new areas of exploration and production,
natural gas prices have been in a serious slump since peaking in mid 2008 which has created challenges for companies seeking to justify the cost of shale production.
At recent prices, shale plays may be delivering only marginal profitability at best given the high cost of production.

The role of Shale gas and shale oil

According to a recent article in FT, a shift from natural gas to oil production may be starting to take place.
Independent oil and gas companies are taking steps to sell natural gas assets in order to participate in the booming market for **shale oil**.
While the big story in shale has been natural gas, it is also possible to extract oil using newer technology.
The number of rigs drilling for oil in the United States (shale and conventional) has climbed from 180 in May 2009 to 720 in November 2010.
During the time period presented above, the average oil to gas ratio was 11.8, although the measure fluctuated wildly between a low of 4 on December 13, 2005 and a high of 27 on September 3, 2009.
A ratio of 20 or higher is a major long term anomaly, but one that has been appearing much more frequently over the past two years.

Ratio changing?

Current Oil to Gas Ratio Unlikely to Persist Indefinitely

Some speculators may try to forecast the short term price of natural gas and oil, this is likely to be a futile effort for investors.

Eventually, substitution by consumers and/or supply changes by producers should bring the ratio down to more normal levels.

The ratio could correct either by a decline in crude oil or an advance in natural gas.

other factors: The combined effect of OPEC member discomfort with the U.S. Dollar and voracious oil demand by China and other emerging countries is more likely than not to keep an upward bias on oil prices barring a global economic depression.

Some hypothesis

- Increased domestic supply by independents shifting from shale gas to shale oil is not likely to materially impact the price of crude oil but could potentially have a more significant impact on the supply of U.S. natural gas production.
- natural gas is not a true global commodity like crude oil, lower domestic supplies of natural gas could result in a greater impact to U.S. gas prices versus the impact of increased shale oil production on global oil prices.
- for investors interested in natural gas, owning shares of low cost producers able to make money even in the current low pricing environment could mitigate risk while providing benefits in the event of higher gas prices in the long run.

Gas and Power generation in EU

The role of natural gas for power generation has increased significantly, ever since the 1990s, developments in the UK, in Italy and Spain.

Gas-fired power stations produce one fifth of the electricity in the EU27 (7.5% in 1990).

Various special factors must be borne in mind when assessing the future use of gas in power generation.

The present situation for gas is heterogeneous between the individual member states.

Developments depend on the energy policy (mainly nuclear) of the individual countries, the integration of renewables in electricity generation and the evolution of the European trading scheme.

The price of gas will determine the load factor in which gas-fired power generation may/will be used.

LNG role

LNG will globalize the gas market and open further potential gas sources for Europe.
LNG is a fast growing sector in the world gas market.
LNG was big in Japan and will be biggerthan ever now.
In 2009 LNG imports in Europe rose to almost 52 mtoe/y, representing a share of 15% of the total gas market.
A number of new LNG terminals are under construction, while existing terminals are expanded.
The regasification capacity in Europe from 2005 to 2010 doubled.

LNG role

In the long term LNG could represent 25% of the total EU supplies.
Investments are needed and planned at all stages of the supply chain: exploration and development, transmission systems incl. LNG infrastructure as well as storage capacity.
Whether or not it proves possible in the future to mobilise gas reserves and direct them towards European markets finally depends on the general framework for the energy industry on sales markets, on the availability of investments as well as on how the market value obtainable for gas develops in the course of time.

UK interconnector

UK Wholesale Gas is traded at the National Balancing Point (NBP)
There are two liquid exchanges - APX (on-the-day trading) and ICE (futures contracts).
The NBP, is a virtual trading location for the sale and purchase and exchange of UK natural gas. It is the pricing and delivery point for the ICE natural gas futures contract
It is the most liquid gas trading point in Europe and is a major influence on the price that domestic consumers pay for their gas at home. Gas at the NBP trades in pence per therm.
It is similar in concept to the Henry Hub in the United States - but differs in that it is not an actual physical location.

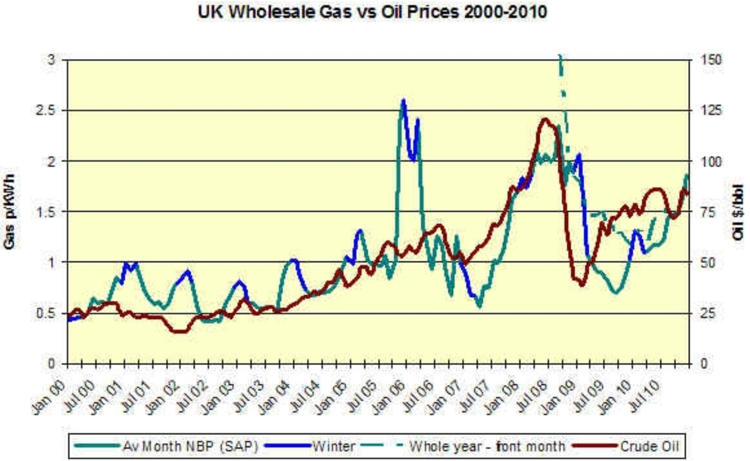
UK interconnector

Unlike continental European trading hubs such as Zeebrugge and TTF, trades made at the NBP are not required to be balanced, and there is no fixed penalty for being out of balance.
The unbalanced positions are 'cash-out'and balance their position at the marginal system buy or sell price for that day.
The cash-out prices are often very close to the spot price. As a result of this daily market liquidity, the UK's NBP is frequently used to balance a shipper's position on the continent by way of the Bacton - Zeebrugge interconnector.

UK prices

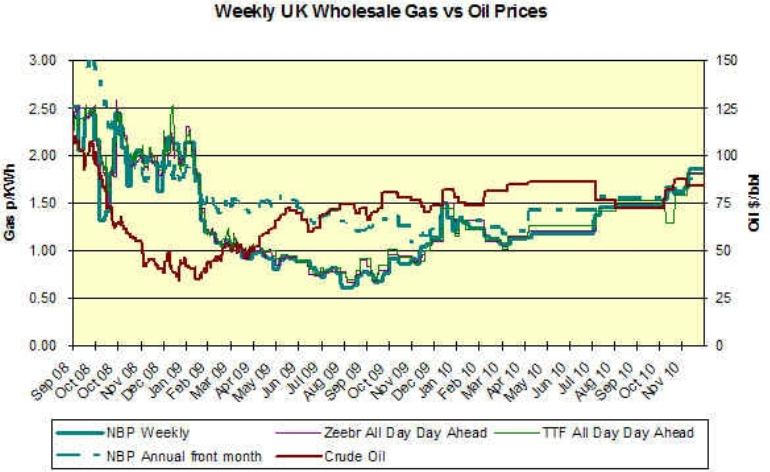
Over the last two years the oil price led the UK daily gas price upwards. The price seasonality (winter prices have been higher due to the use of expensive storage etc) seems to have largely disappeared, even with the cold weather in 2009.
The price of wholesale gas is now one third of what it was in September 2008, tumbling after the oil price.

UK prices



source http://sshassociates.co.uk/nbp.aspx

UK prices



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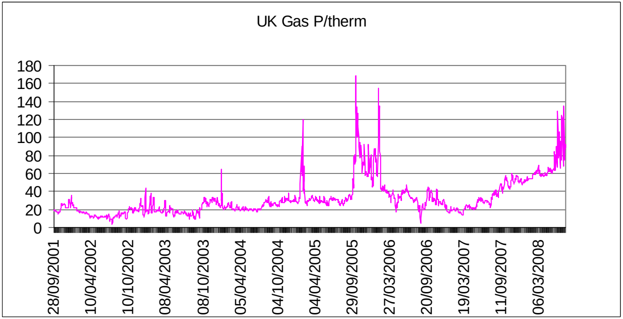
UK prices



UK Gas P/therm
180
160
140
120
100
80
60
40
20
0
28/09/2001
10/04/2002
10/10/2002
08/04/2003
08/10/2003
05/04/2004
04/10/2004
04/04/2005
29/09/2005
27/03/2006
20/09/2006
19/03/2007
11/09/2007
06/03/2008

The oil markets

- Over the past 30 years daily oil consumption has risen by appr. 33 milions barrels, Asia accounting for more than half of this growth in demand.
- Oil is not renewable and sooner or later the worldwide use of oil must peak! (Simmons "Twilight in the Desert")
- Most arguments about peak oil are based on anedoctal information, vague references and ignorance about how the oil industry goes about finding fields and extracting petroleum
- Oil engineers use fuzzy logic to estimate reservoir holdings
- Price dynamics: Is mean reversion dead? (Geman 2002)

The oil markets

The peak belief is based upon poor analyses of data and misinterpretation of technical material:

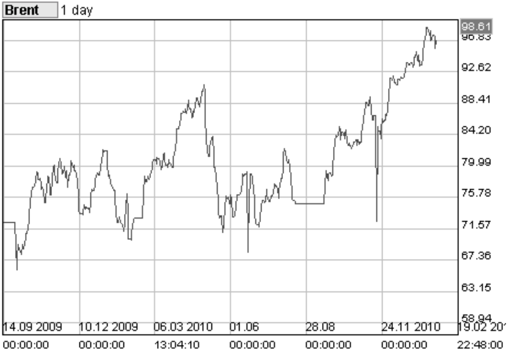
1. the world is discovering only one barrel for every 3 or 4 produced ! (!not knowing the industry terminology);
2. the political instability in oil producing countries puts us at an unprecedented risk of having the sigouts turned off (shift investments into new regions)
3. Half of the 2 trillion barrels of the oil that the earth contained have all been used ! (actually there should be 10 trillion barrels...).

The oil markets

1. When a new field is found it is given a size estimate that indicates how much is thought to be recoverable at that point in time. But the estimate is always revised upward (but they tend to ignore it!)
2. Easy oil is still at hand
3. Additional investments can keep a field's overall production from falling (as the Ghawar field in Saudi Arabia)
4. Political risk is hardly new. 1973 embargo, 1991 Iraqui invasion, Today Nigeria and Venezuela instability
5. Today geologists agree that there are 10 trillion barrels out there of recoverable oil and not only 2 trillions as previously said.

The oil markets

Do oil price increase for a speculative bubbles or simply reflects fundamental factors?
They do not passively reflect the fundamental conditions of ndemand and supply
There is first some fundamental change, such as the increase in demand from emerging countries...
There is a misinterpretation of the new trend in prices that results from the change and this may cause speculative activity (bubble).



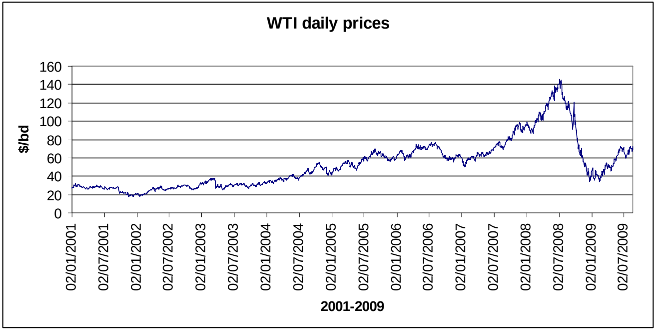
http://www.livecharts.co.uk/MarketCharts/brent.php

OIL STORIES????

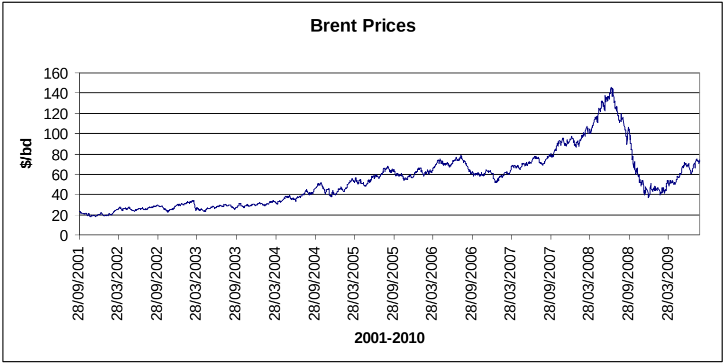
US Light crude oil futures for December 2010 delivery was trading at \$86.70 a barrel,
The EIA believes that oil demand across the globe will continue to push higher.
The EIA has raised its 2011 world oil demand forecast by 33000 barrels per day, to 87,77 million, from its previous monthly forecast, and now sees a year on year rise of 1,44 million barrels per day.
“If you have some confidence that the worst is over in terms of inventories, it’s pretty important for oil prices.” said Tony Nunan, a risk manager with Mitsubishi Corp.
IEA Says Oil Output Has Peaked, \$200 Oil?
"Conventional crude oil output has already peaked and would flatten out in the next 10 years" the IEA said three weeks ago.
The IEA predicts that oil prices will rise beyond \$200 a barrel as global oil supplies, strained by rising demand from China, India and other emerging economies, near their peak, but don’t worry, that’s the forecast for the year 2035.

http://stockcharts.com/h-sc/ui

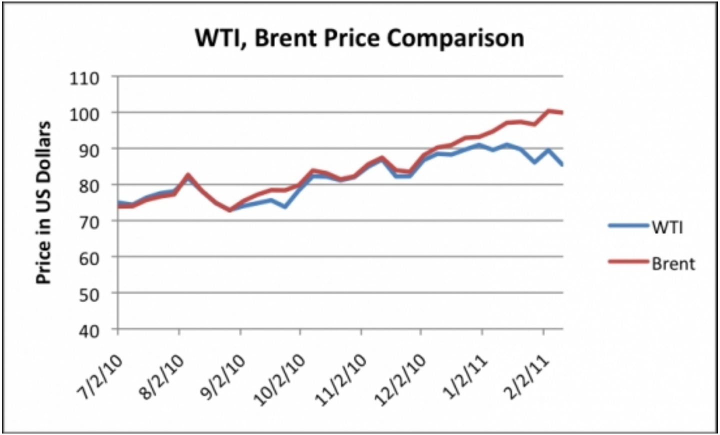
The oil markets US



The oil markets EU



global oil market?



The Electricity Market

- The introduction of competition in the electricity industry has been justified by the perceived benefits of introducing market forces in an industry previously viewed as monopoly.
- Electricity a very special commodity:
  1. Electrical energy cannot be stored (with the exception of hydroelectric power);
  2. electricity must be generated at the instant it is consumed;
  3. It has to be transported in a transmission network;no alternative;
  4. the demand is highly inelastic very sensitive to weather conditions;
  5. generation (supply) is characterized by generators with low marginal costs emergency units with high marginal costs

The Electricity Market

- It is a substitute for oil and gas.
- Can be produced using both commodities
- a competitive market for electricity implies that spot market prices may promptly respond to price changes in input fuel source markets. Oil and gas prices should be integrated with electricity prices.

The Electricity Market EU

The liberalisation of EU electricity markets is part of a wider move towards a common energy policy -
19 Sept. 2007: Commission tables third energy liberalisation package
13-14 March 2008: EU summit agrees to reach political agreement by June 2008
6 May 2008: Vote in Parliament's Industry (ITRE) and Internal Market (IMCO) Committees (EurActiv 07/05/08).
6 June 2008: Energy Council reaches broad political agreement on the Commission's third liberalisation package.
Mid-June 2008: Vote in Parliament's plenary (first reading) (EurActiv 19/06/08).
12 Jan. 2009: EU Council of Ministers adopts common position on third energy liberalisation package.
25 June 2009: Council adopts internal energy market package.

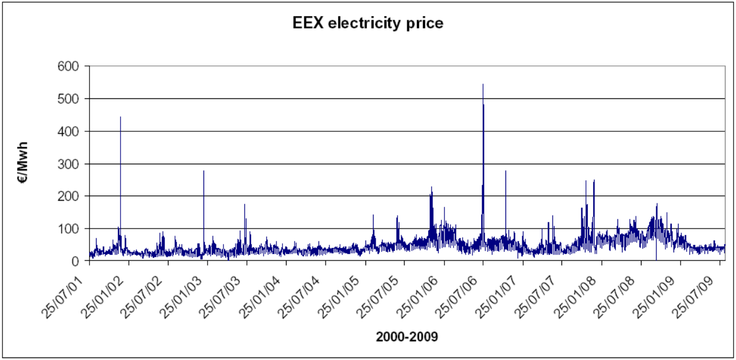
The EEX in EU

The European Energy Exchange AG (EEX) was founded in 2002 as a result of the merger of the two German power exchanges Leipzig and Frankfurt. Since then EEX has established itself as a leading trading market in European energy trading.

EEX has evolved into a corporate group which is open for European and international partnerships.

EEX relies on an open business model which generates increased flexibility, market coverage and volumes through systematic spin-offs and partnerships.

The EEX prices



Power market

Electricity Markets	Marginal fuel type	Generating capacity (MW)	Capacity reserve (MW)	reserve margin	average price (2009) $/MWh	N. of States	RTO/ISO
California	natural gas	56,347	6,077	12%	34.35	1	YES
Midwest	Coal	137,232	21,025	18%	$46.12	13	YES
New England	natural gas	36,820	9,600	35.30%	$67.97	7	YES
New York Iso	natural gas	39,704	5,765	17%	$47.08	1	YES
Northwest	Hydro and natural gas	57,120	16,822	42%	$35.25	8	no
PJM	Coal (74%) and natural gas (22%)	167,454	40,649	32%	$38.71	14	YES
Southeast	Coal and natural gas	299,712	64,188	27%	$36.31	12	no
Southwest	Natural gas	45,459	8,940	24%	$61.74	6	no
SPP	Natural gas (55%) and coal (35%)	50,600	7,709	18%	$68.77	9	YES
Texas (ERCOT)	Coal and natural gas	71,244	8,744	14%	$29.78	1	YES

Northwest

It covers all or most of Washington, Oregon, Idaho, Utah, Nevada, Montana, Wyoming and part of California.
Marginal fuel type: Hydro and natural gas
Generating capacity (winter 2005): 57,120 MW
Capacity reserve (winter 2005): 16,822 MW
Reserve margin (winter 2005): 42%
When taken together, hydro, fossil fuels, nuclear energy, and renewable resources, were adequate to provide electricity in excess of in-region needs.

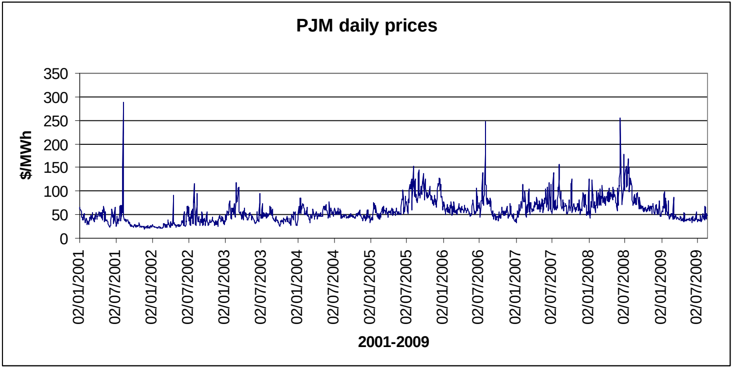
Northwest

Index Annual Average of Daily Bilateral Day Ahead On-Peak Prices
ICE “California-Oregon Border (COB) Hub”
2006: \$51.68/MWh
2007: \$59.86/MWh
2008: \$73.42/MWh
2009: \$35.40/MWh
ICE “Mid-Columbia (Mid-C) Hub”:
2006: \$47.98/MWh
2007: \$53.59/MWh
2008: \$64.48/MWh
2009: \$35.25/MWh

PJM Power market

PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia, an area that includes more than 51 million people. As of December 31, 2009, it had installed generating capacity of 167,326 megawatts (GW) and over 500 market buyers, sellers and traders of electricity. In 2009 demand peaked at 126.8 MW on August 10, the lowest annual peak since the last transmission integration.
Marginal fuel type: *Coal (74%) and natural gas (22%)*
Generating capacity (summer 2009): 167,454 MW
Capacity reserve (summer 2009): 40,649 MW
Reserve margin (summer 2009): 32%

PJM Power prices



Challenges with Electricity

Issue	In Financial Markets	In Energy Markets
Maturity of market	Several decades	Relatively new
Fundamental price drivers	Few, simple	Many, complex
Impact of economic cycles	High	Low
Frequency of events	Low	High
Impact of storage and deliver; the convenience yield	None	Significant
Correlation between short and long term pricing	High	Low, 'split personality'
Seasonality	None	Key to natural gas and electricity
Regulation	Little	Varies from little to very high
Market activity ('liquidity')	High	Low
Market centralization	Centralized	Decentralized
Complexity of derivative contracts	Majority of contracts are relatively simple	Majority of contracts are relatively complex

Electricty as call option

An electricity system essentially provides capacity for immediate consumption, and we as users have acquired a call option, to exercise at our convenience, essentially unconstrained in volume up to the limit of our fuse-box.
The total utilisation of this capacity by all customers on the system is referred to as the "load" and the basic unit of the load is the "watt"
– A typical bright domestic light bulb may use 100W. kW=1000W
– A typical domestic electric heating appliance use 2kW
– A small commercial building use 100kW – 1000kW=1MW
Energy consumption is generally integrated over time and sold to general retail customers in kW.
Wholesale power prices are denominated in MWh

The relationship

Understanding energy prices relationship:

- To investigate the short and long run relationship between energy commodity prices;
- A rolling correlation analysis is first performed among each pair of commodities.
- To verify if an "integration" of energy markets may be assumed.
- To use a cointegration framework to investigate a possible meaningful relationship among energy commodities

Over the period 1996-2003 evidences of relationship among gas prices and oil prices

- **Gjølberg and Johnsen (1998)**: analyze co-movements between the prices of crude oil and major refined products during the period 1992-98. they study a long-run equilibrium price relationships, and whether deviations from the estimated equilibrium can be utilized for predictions of short-term price changes and for risk management.
- **Panagiotidis and Rutledge (2006)**: (1996-2003) investigate whether oil and gas decoupled. The existence of a cointegration relationship prior to the inauguration of the Interconnector indicates that despite the highly liberalized nature of UK gas market, gas prices and oil prices are moving together in the long-run
- **Bachemeir and Griffin (2006):** evaluate the degree of market integration both among and between crude oil, coal, and natural gas market. (ECM) framework to daily price data they find that crude oils from around the world trade in a highly integrated world market. Oil and natural gas are cointegrated in the long run and exhibit stronger

Based on US data

- **Hartley, Medlock and Rosthal (2007)**; evidence of cointegration relationship. find that seasonal fluctuations and other factors such as weather shocks and changes in storage have significant influence on the short run dynamic adjustment of prices. In addition they perform an ECM to include shocks as stationary exogenous variables and consider technology rather than a time trend as an explanatory factor in the evolving relationship.
- **Brown and Yucel (2007):** evidence of a cointegration relationship. They also find that short run deviations from the estimated long run relationship could be explained by influence of weather, seasonality, natural gas storage, and production in the Gulf of Mexico.A complete understanding of the long and short run

Literature Review

Based on US data

- **Villar and Joutz (2006)**: cointegration relationship between them despite periods where they may have appeared to decouple. A statistically significant trend term is found: natural gas prices grow at a slightly faster rate than crude oil prices. The prices exhibit a long run relationship that is slowly evolving rather than constant. While oil prices may influence the natural gas price, the impact of natural gas prices on the oil price is negligible.
- **Serletis et al.(1999),** use North America natural gas, oil and power prices from 1996 to 1997 to find a cointegrating relationship between them.

Literature Review

Based on US data

- **Mjelde and Bessler (2009)**;using a multivariate time series framework and prices from two diverse markets: PJM and Mid-Columbia (Mid-C), and four major fuel sources: natural gas, crude oil, coal, and uranium find that the eight price series are cointegrated. However, they are not able to detect one single source of randomness (one common trend) but find that fuel source prices move electricity prices.
- **Mohammadi (2009)**: They find that the three fossil fuels (coal, natural gas and crude oil) do not affect electricity prices significantly. Significant long-run relationships are found only between electricity and coal prices.

Literature Review

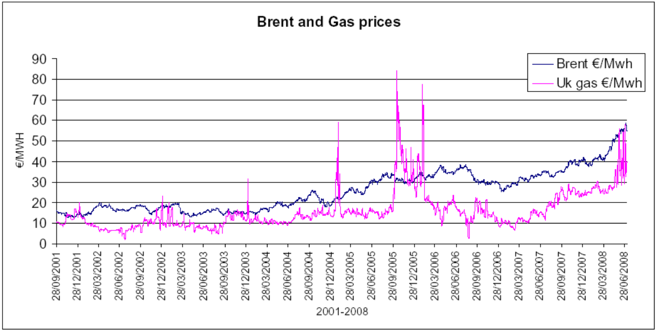
The relationship between electricity and fossil fuel prices (2000-on)
European DATA

- **Gjolberg (2001):** assumes the existence of a medium and long term correlation between electricity and fuel oil, since they are to some extent substitutes, but not perfectly substitutes given the considerable constraints related to technology, storage and transportation. This is technically equivalent to have cointegrated prices.
- **Asche, Osmudsen and Sandsmark (2006)**: investigate the dynamic of gas, oil and electricity during an interim period 1995-1998 - after deregulation of the UK gas market (1995) and the opening up of the Interconnector (1998). Cointegration between natural gas, crude oil and electricity prices is found and a leading role of crude oil is also identified. Monthly price data for the period 1995-1998 indicates a highly energy integrated market where wholesale demand refers to energy commodities more than a specific source.

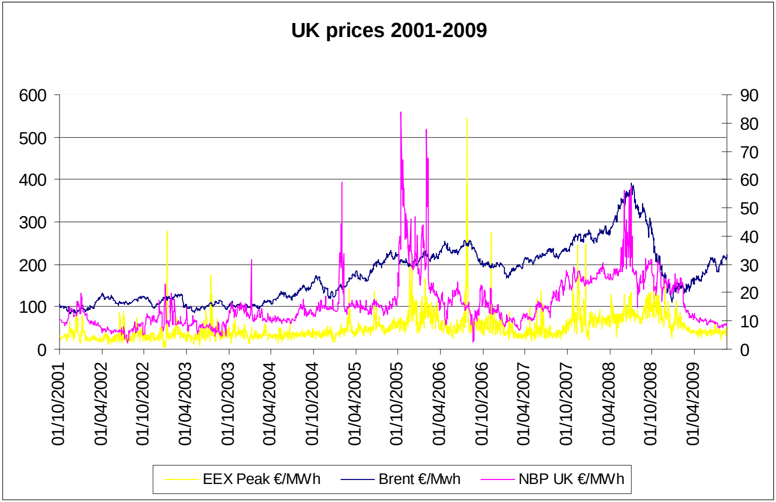
Literature Review

- Bosco et al. (2006): examine electricity price interdependencies at European level analyzing the main electricity exchanges for the period 2004-2006. They find the presence of strong integration among various European exchanges (APX, EEX, EXAA and Powernext) and the presence of a common trend among electricity prices which is in turn cointegrated

Price Dynamics



Price Dynamics



The methodology

- Analysis of the stationarity of the data.
- Analysis of correlation: Rolling correlation, $\rho_s(x, y)$, over a window of 100 days (Eydeland (2003) for the period 2001-09 is estimated for each pair of commodities (Elect;gas)(Elect;oil), (gas;oil):
- The long run relationship is analyzed using:
  - a VECM framework (Johansen)
  - an ECM approach (Granger and Engle).

The stationarity analysis

We test the order of integration using the Augmented Dickey-Fuller (ADF) type regression:

$$\Delta y_t = \alpha_0 + \alpha_1 t + \gamma y_{t-1} + \sum_{j=1}^{k} \beta_j \Delta y_{t-j} + \epsilon_t \tag{1}$$

where $\Delta y_t = y_t - y_{t\text{-}1}$ and the lag length k is automatic based on Scharwz information criterion (SIC).
We run the test without any exogenous variable, with a constant and a constant plus a linear time trend as exogenous variables

The rolling correlation approach

Rolling correlation over $\tau_j = 100$ days is estimated to measure the short term relationships according to:

$$\rho_s[x,y] = \frac{\frac{1}{\tau_j - 1}\sum_{i=s}^{s+\tau_j}(x_i - \widehat{x})(y_i - \widehat{y})}{\widehat{\sigma}_x \widehat{\sigma}_y} \qquad s = 1, ..., T - \tau_j$$

where the entire period 2001-2009 is made by T observations, $\widehat{\sigma}_x$ $\widehat{\sigma}_y$ are the standard deviation of x and y, estimated on the corresponding time window.

Cointegration framework (long run)

- If two or more series are non-stationary, a linear combination of them may be stationary. In this case the series are said cointegrated.
- Several tests may be used to test the presence of cointegration amon various time series:
  - The Johansen and Stock and Watson , based on VAR, to find all possible cointegrating relationships.
  - The Engle-Granger method, to assess whether single equation estimates of the equilibrium errors are stationary, tests the cointegration among two variables and allows to understand the relationship between each pair of commodities.

Johansen Method (long run)

To examine the number of cointegrating vectors we estimate a vector error correction model (VECM) based on the so called reduced rank regression method .

Assume that the n-vector of non-stationary $I(1)$ variables Y_t follows a vector autoregressive (VAR) process of order p

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + ... + A_p Y_{t-p} + \epsilon_t \tag{2}$$

with ϵ_t as the correponding n-dimensional white noise, and nxn A_i matrices of coefficients.

The VECM framework (long run)

(2) is equivalently written in a VECM framework,

$$\Delta Y_t = D_1 \Delta Y_{t-1} + D_2 \Delta Y_{t-2} + ... + D_p \Delta Y_{t-p} + \epsilon_t \tag{3}$$

with $D_1 = -\left(A_{i+1} + ... + A_p\right)$ $i = 1, 2, ...p-1$. and
$D = \left(A_1 + .. + A_p - I_n\right)$
The Granger's representation theorem asserts that if D has reduced rank $r \in (0, n)$, then $n \times r$ matrices Γ and B exist, each with rank r, such that $D = -\Gamma B'$ and $B' Y_t$ is $I(0)$. r is the number of cointegrating relations and the coefficients of the cointegrating vectors are reported in the columns of B.

The ECM framework (long run)

To better analyze the dynamics of the markets we use the Engle-Granger two-step methodology.
This method follows two steps:

- estimating the parameters of the cointegrating vector,
- using the parameters in the Error Correction form:

$$y_{1,t} = \alpha + \beta y_{2,t} + z_t \tag{4}$$

is estimated only to fit the long run or equilibrium relationship. The coefficients β's in Eq.4, which represent the factors of proportionality for the common trend, are estimated by ordinary least squares (OLS), getting the linear combination with the smallest variance. OLS estimates provide consistent coefficients of long run model but standard errors are unreliable.

The ECM framework (long run)

The OLS residuals z_t fare estimates of the equilibrium errors.
In step 2, the OLS residuals are tested for stationarity using the ADF test with critical values compared with MacKinnon tables.
The basic ECM (Engle and Granger) is commonly used to investigate the degree of integration among different markets.
The basic ECM, focusing on the pairwise series analysis, has the merit to be more transparent and elegant than its
generalization, VECM (Bachmeier and Griffin): if two markets are integrated, prices tend to be affected by common factors, therefore price changes in one market tend to be linked with price changes in the second market.

The advantage of the ECM is that it tests not only for the existence of a long run equilibrium relationship between two variables, like the standard tests for cointegration, but it also provides summary statistics on the degree of the market integration.

$$\Delta y_{1,t} = \phi \Delta y_{2,t} + \theta \left(y_{1,t-1} - \alpha - \beta y_{2,t-1} \right) + \epsilon_t \tag{5}$$

where $\left(y_{1,t-1} - \alpha - \beta y_{2,t-1} \right)$ represents the error correction term $z_{t,1}$, ϕ measures the contemporaneous price response, θ represents the speed of the adjustment towards the long term cointegrating relationship, and ϵ_t is $i.i.dN(0, \Sigma)$.

The dataset

The US and European daily prices for natural gas, crude oil and electricity are used.
Period October 2001-August 2010 for both markets.

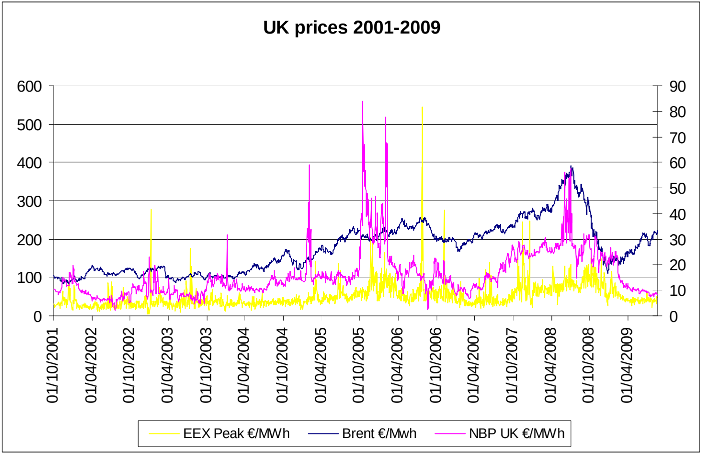
- The European dataset is made by daily prices for ICE Brent crude oil, for natural gas at the National Balancing Point (NBP), and for European Energy Exchange (EEX) electricity.
- The US dataset is made by daily prices data for natural gas at the Henry Hub (HH, West Texas Internediate (WTI) for crude oil and Pennsylvania, New Jersey, Maryland (PJM) electricity.

Conversion factors

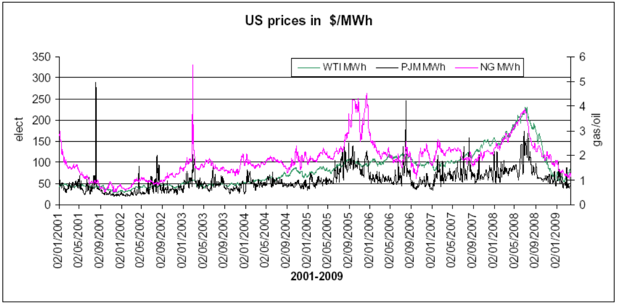
All prices are converted in €/MWh using the conversion factors for energy content provided by the EIA:

- 1 barrel of crude oil is equal to 0.136 tons of oil equivalent (toe),
- 1 toe=39.68 MBtu and
- 1MBtu=293.1 kilowatt hour (KWh)
- the daily series of US$/€ exchange rates.

Price Dynamic EU



Price Dynamic US

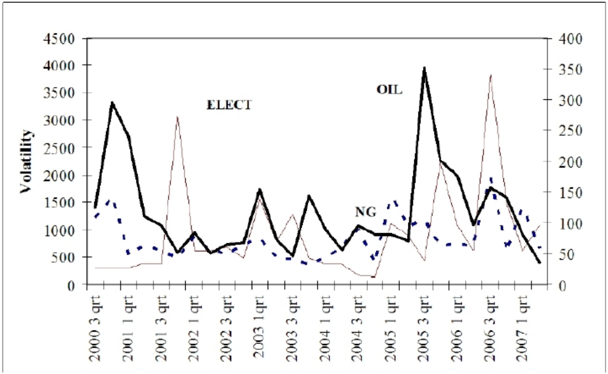


The statistical features EU

Table 1. Descriptive Statistics for crude oil, natural gas and electricity time series (1749 observations in all). Data expressed in €/MWh.

Series	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis
Oil	22.40978	19.55279	38.61227	12.59362	6.964128	0.594954	1.981763
Gas	17.08501	17.06196	43.92360	6.763734	6.063457	1.529624	6.254072
Elect.	45.76490	38.48000	543.7200	0.800000	30.71776	6.300120	74.90917

Quarterly volatility of each series is estimated.



Oil price σ varies between 34.6% and 351%.
Gas price σ between 30.8% and 174%.
Electricity price σ between 129.7% and 3,825%.

The results of stationarity

Table 1
Unit root test results for the logged EU price series.

Series	t_γ	τ_0	τ_1	τ_d	Decision
Brent	0.36 (1)	−1.56 (1)	−1.46 (1)	−48.4 (0)	I(1)
NBP	−0.54 (6)	−3.44** (6)	−5.82** (2)	−22.7 (5)	I(1)
EEX	−0.19 (14)	−3.40* (15)	−4.75** (15)	−20.4 (13)	I(1)

Table 2
Unit root test results for the logged US price series.

Series	t_γ	τ_0	τ_1	τ_d	Decision
WTI	0.57 (1)	−1.64 (1)	−1.48 (1)	−46.7 (0)	I(1)
HH	−0.46 (2)	−3.02* (2)	−2.71 (2)	−37.7 (1)	I(1)
PJM	−0.28 (6)	−4.45** (6)	−5.76** (6)	−26.5 (5)	I(1)

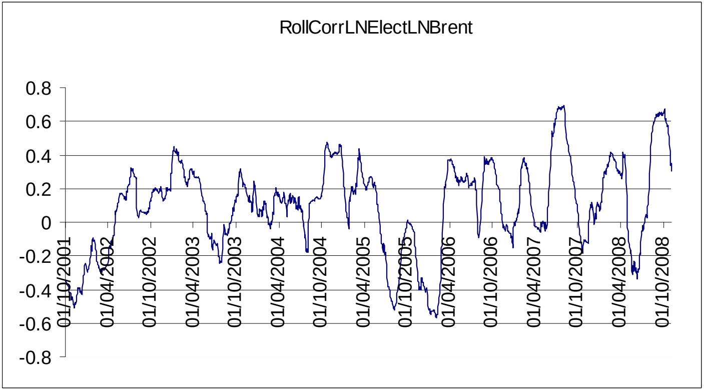
The short run relationship

Rolling Correlation in Europe T=1897

Elec Oil	Elec Gas	Oil Gas
Mean over the period		
-0.0226	0.6039	-0.1279
DevSt		
0.462	0.103	0.360
Max		
0.304	0.676	0.126
Min		
-0.349	0.531	-0.382
Unconditional Correlation		
0.6131	**0.3270**	**0.6777**

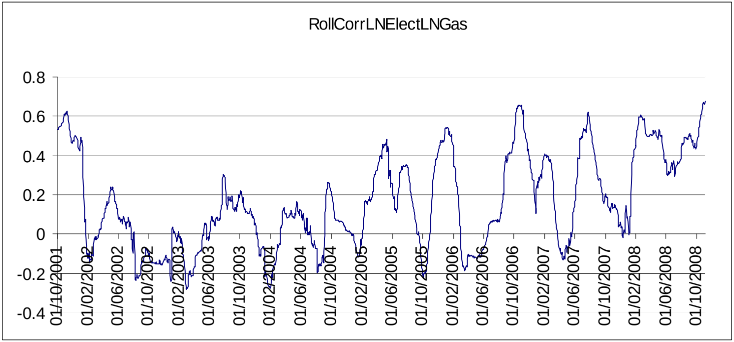
The rolling correlation

Rolling Correlation in Europe OIL vs Elect



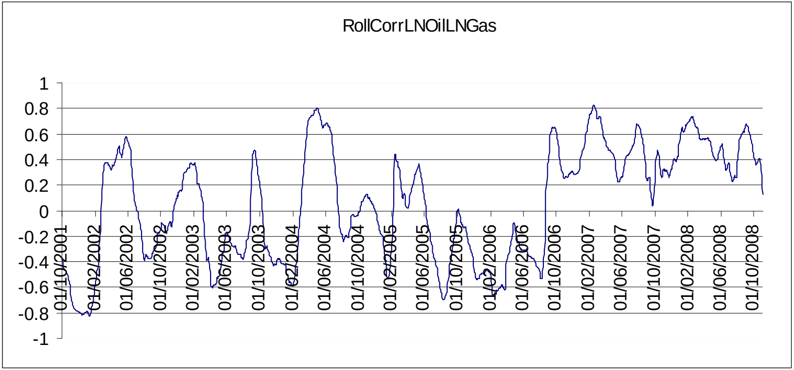
The short run relationship

Rolling Correlation in Europe: Elect vs Gas



The short run relationship

Rolling Correlation in Europe: Oil vs Gas



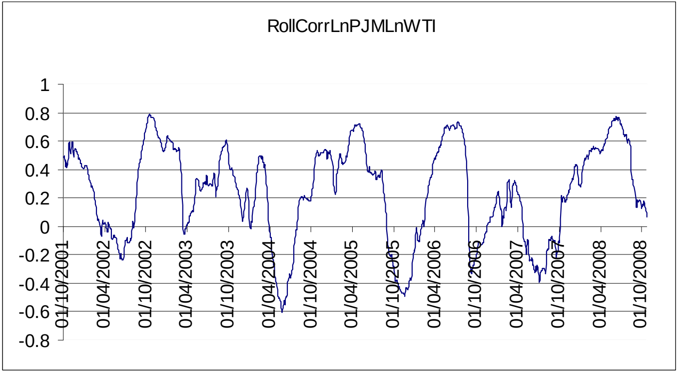
The short run relationship

Rolling Correlation in US T=1856

Elec Oil	Elec Gas	Oil Gas
	Mean	
-0.125	0.400	0.394
	DevSt	
0.275	0.090	0.220
	Max	
0.069	0.464	0.549
	Min	
-0.320	0.336	0.238
	Unconditional Correlation	
0.7499	**0.8137**	**0.8004**

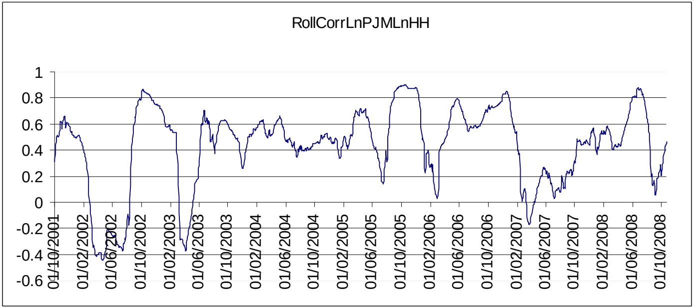
The short run relationship

Rolling Correlation in US oil vs Elect



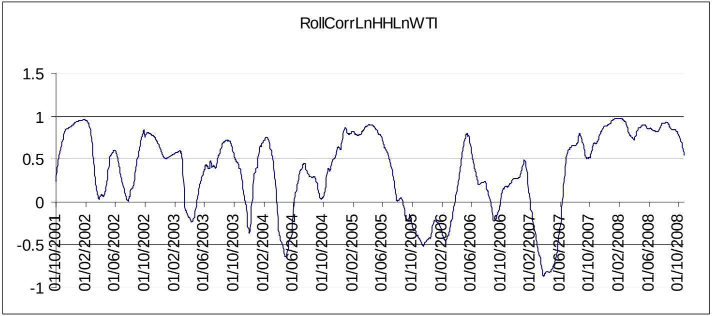
The short run relationship

Rolling Correlation in US: elect Gas



The short run relationship

Rolling Correlation in US: Oil vs Gas



Short run relationship

- The price volatility is strongly time dependent for these energy commodities
- The covariance and the unconditional correlation are time dependent as well.
- The high volatile correlation measure does not allow to capture the real nature of the relationship between the main characters of the energy market.

Cointegration results: Europe

$$\Delta Y_t = D_1 \Delta Y_{t-1} + D_2 \Delta Y_{t-2} + ... + D_p \Delta Y_{t-p} + \epsilon_t \tag{6}$$

Two cointegrating vectors are found : r = 2
$n - r = 3 - 2 = 1$ common trend

Cointegration results: Europe

Table 5
Cointegration rank test for the EU log prices.

Nr. of coint. vec.	Eigenvalue	λ_{trace}	$\lambda_{\text{trace}}^{0.05}$	$\lambda_{\max}$	$\lambda_{\max}^{0.05}$
$r = 0$	0.044	116.6	29.79	86.92	21.13
$r \leq 1$	0.014	29.74	15.49	27.03	14.26
$r \leq 2$	0.001	2.708	3.841	2.708	3.841

Cointegration results: US

Table 6

Cointegration rank test for the US log prices.

Nr. of coint. vec.	Eigenvalue	λ_{trace}	$\lambda_{\text{trace}}^{0.05}$	$\lambda_{\max}$	$\lambda_{\max}^{0.05}$
$r = 0$	0.063	139.0	29.79	120.6	21.13
$r \leq 1$	0.008	18.45	15.49	15.45	14.26
$r \leq 2$	0.001	2.995	3.841	2.995	3.841

ECM results: EU

$$\Delta y_{1,t} = \phi \Delta y_{2,t} + \theta \left(y_{1,t-1} - \alpha - \beta y_{2,t-1} \right) + \epsilon_t \tag{7}$$

Table 9
ECM parameters for the EU log prices.

Dep. variable	Indep. variable	ϕ	t_ϕ	P-value	θ	t_θ	P-value
Δ NBP	Δ Brent	-0.020	-0.175	0.860	−0.053	−7.224	0.000
Δ EEX	Δ Brent	−0.291	−0.954	0.339	−0.425	−22.70	0.000
Δ EEX	Δ NBP	0.094	1.558	0.119	−0.437	−23.19	0.000

ECM results: EU with lag

Table 10
ECM parameters with lags for the EU log prices.

Dep. variable	Indep. variable	ϕ	t_ϕ	P-value	θ	t_θ	P-value
Δ NBP	Δ Brent (-7)	-0.223	-1.944	0.051	-0.053	-7.258	0.000
Δ EEX	Δ Brent (-1)	0.752	2.455	0.014	0.422	22.50	0.000
Δ EEX	Δ NBP (-2)	-0.260	-4.318	0.000	-0.443	-23.54	0.000

ECM results: US

$$\Delta y_{1,t} = \phi \Delta y_{2,t} + \theta \left(y_{1,t-1} - \alpha - \beta y_{2,t-1} \right) + \epsilon_t \tag{8}$$

Each couple of commodities result to be integrated.

Table 11: ECM parameters for the US log prices.

Dep. variable	Indep. variable	ϕ	t_ϕ	P-value	θ	t_θ	P-value
Δ HH	Δ WTI	0.224	5.243	0.000	−0.023	−4.852	0.000
Δ PJM	Δ WTI	0.251	1.984	0.047	−0.158	−12.58	0.000
Δ PJM	Δ HH	0.711	10.88	0.000	−0.194	−14.15	0.000

Conclusions

- The price volatility is strongly time dependent and, as consequence, the covariance and the unconditional correlation are time dependent as well.
- The simple correlation analysis among the various time series results non effective and it does not allow to capture the real nature of the relationship between the main characters of the energy markets, even if the rolling correlation records more positive values for the US market.
- The existence of two cointegrating relationships, hence one common (stochastic) trend, among the three commodity price series in both markets is provided using the Johansen method. The common trend may be interpreted as a source of randomness (the oil market) which affects the the dynamics of the two other commodities (electricity and gas) within each market.

Conclusions

- The Engle-Granger approach witnesses a long run equilibrium between electricity and oil prices as well as between electricity and gas prices or gas and oil prices both for the European and the American markets
- The integration of energy markets in Europe is less strong than in the US:
    - the gas and the oil markets.
    - electricity/oil or electricity/gas for the European dataset the integration seems to be stronger, the contemporaneous price adjustment in the short run may be identified with a lag of some day (less than one week).

References

1. Asche F., Osmundsen P., Sandsmark M., (2006),The UK market for natural gas, oil and electricity: are the prices decoupled?, *The Energy Journal*, 27(2), 27-40
2. Bachmeier L.J., Griffin J.M., (2006), Testing for market integration: crude oil, coal, and natural gas, *The Energy Journal,* 27(2), 55-72.
3. Bencivenga C., Sargenti G., D'Ecclesia R.L., (2010), Energy commodity prices: comparison in US and in Europe, Working Paper, Department of Economic Theory and Quantitative Methods for Political Choices.
4. Brown S.P.A., Yaucel M.K., (2007), What drives natural gas prices?, Research Department Working Paper 0703, Federal Reserve Bank of Dallas.
5. Gjolberg O., (2001), When (and how) will the markets for oil and electricity become integrated? Econometric evidence and trends 1993-99, Discussion paper, D:20.

References

1. Hartley P.R., Medlock III K.B., Rosthal J., (2008), The relationship of natural gas to oil prices, Energy Journal, 29(3), 47-65.
2. Mjelde J.W., Bessler D.A., (2009), Market integration among electricity markets and their major fuel source markets, Energy Economics, 31 482-491.
3. Mohammadi H., (2009), Electricity prices and fuel costs: long-run relations and short-run dynamics, Energy Economics, 31, 503-509.
4. Panagiotidis T., Rutledge E., (2006) Oil and gas markets in the UK: evidence from a cointegratig approach, Discussion paper, n. 2004-18.

References

1. Park H., Mjelde J.W., Bessler D.A., (2006), Price dynamics among U.S. electricity spot markets, Energy Economics, 28, 81-101.
2. Park H., Mjelde J.W., Bessler D.A., (2008), Price interactions and discovery among natural gas spot markets in North America, Energy Policy, 36, 290-302.
3. Serletis A., Herbert J., (1999), The message in North America energy prices, Energy Economics, 21, 471-483.
4. Villar J.A., Joutz F.L., (2006), The relationship between crude oil andnatural gas prices, Energy Information Administration, Office of Oil and Natural Gas. Washington, D.C.