ISCTE Business School
Instituto Universitário de Lisboa

Econometric Study of the Spanish Electricity Spot Market and Primary Energy Markets using VAR/VECM methodology (cointegration and nonstationary time series)

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Dissertation submitted in partial fulfilment of the requirements for the degree of
Master in Finance

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RESUMO

Pretende-se com este trabalho estudar a relação dinâmica entre os preços de electricidade do mercado grossista em Espanha e os preços das principais referências de combustível para a geração de electricidade (carvão, petróleo, gasóleo e o gás natural). A relação dinâmica entre os diferentes sistemas eléctricos interligados (Espanha e Portugal, Espanha e França), utilizando como referência os preços de electricidade dos mercados grossistas formados em cada sistema eléctrico, também é relevante para efeitos de análise, pois impacta na evolução dos preços de electricidade do mercado grossista em Espanha.

Os resultados sugerem: cointegração entre os preços de electricidade do mercado grossista em Espanha e das variáveis em análise (combustíveis e preços de electricidade grossistas); relação de longo prazo entre os preços de electricidade do mercado grossista em Espanha, os preços do carvão, os preços do petróleo, os preços do gasóleo, os preços do gás natural do mercado holandês TTF e os preços de electricidade do mercado grossista em Portugal; relação de curto prazo entre os preços de electricidade do mercado grossista em Espanha e os preços do gás natural do mercado inglês NBP e do mercado belga Zeebrugge; foi encontrada exogeneidade forte na relação entre os preços de electricidade do mercado grossista em Espanha e os preços de electricidade do mercado grossista em França; proporcionalidade entre os preços do petróleo, os preços do gás natural do mercado holandês TTF e os preços de electricidade do mercado grossista em Espanha; e a evidência de assimetria dos preços de electricidade do mercado grossista em Portugal com movimentos “abruptos” na sua relação com os preços de electricidade do mercado grossista em Espanha. Uma série de implicações serão abordadas.

Palavras-chave: energia; integração de mercados; preço da energia eléctrica e cointegração.

Classificação JEL:

C32 – Multiple or Simultaneous Equation Time-Series Models

G12 – Asset Pricing

Q43 – Energy and the Macroeconomy

ABSTRACT

The aim of this work is to study the dynamic relationship between prices of wholesale electricity market in Spain and prices of the main fuel references to generate electricity (coal, crude oil, gasoil and natural gas). The dynamic relationship between the various interconnected electrical systems (Spain and Portugal, Spain and France), using as reference prices for wholesale electricity markets formed in each electrical system, is also relevant for analysis purposes due to impacts on prices of wholesale electricity market in Spain.

The results suggest: cointegration between prices of wholesale electricity market in Spain and the variables under analysis (fuel and wholesale electricity market prices); a long-term relationship between prices of wholesale electricity market in Spain, coal prices, crude oil prices, gasoil prices, natural gas prices of the Dutch TTF market and the prices of wholesale electricity market in Portugal; a short-run relationship between prices of wholesale electricity market in Spain and natural gas prices of the English NBP market and Belgian Zeebrugge market; the presence of strong exogeneity in the relationship between prices of wholesale electricity market in Spain and prices of wholesale electricity market in France; proportionality between crude oil prices, natural gas prices of the Dutch TTF market and prices of wholesale electricity market in Spain; and the evidence of asymmetry in the electricity prices from the wholesale market in Portugal with "steep" movements in relation to prices of wholesale electricity market in Spain. A number of implications will be addressed.

Keywords: energy; market integration; electricity pricing and cointegration.

JEL Classification:

C32 – Multiple or Simultaneous Equation Time-Series Models

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1 INTRODUCTION

Electricity is a form of energy used for a very wide range of applications. It is easy to control, non-polluting at the location of its usage and convenient; it is used in the application of heat, light and power. As a secondary energy source, electricity is generated from the conversion of other energy sources, such as coal, natural gas, oil, nuclear power, hydro power and other renewable sources. This implies that electricity markets and electricity prices are fundamentally linked to markets for primary fuels and environmental conditions such as wind and rain.

Moreover, from a financial and commodity markets perspective, wholesale electricity[1] prices can generally be viewed as the result of investors having created real options upon various underlying primary fuel commodities such as natural gas, oil or coal. Thus, as electricity is often traded on exchanges close to an hour before it is needed, in this short term, the variable cost of power generation is essentially just the cost of the fuel.

Economic theory suggests a relationship should exist between input and output prices. Consider the simplest case of a single factor of production (input) used to produce a single product, a static supply and demand model suggests that increasing the marginal cost[2] of the input leads to an increase in the product price. Likewise, an increase in demand leads to an increase in quantity demanded for the product, therefore, a higher price. Associated with these changes are increasing marginal costs caused by the increased use of the input. Economic theory, however, does not state how such relationships will respond in a dynamic framework. Further complicating the issue are numerous locations using multiple inputs for power generation with different substitutability and complementary relationships. The degree of price transmission from input to output, therefore, may depend on the cost share of the input factor in question.

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[1] Energy supplied by one producer or marketer to another for eventual resale to consumers.

[2] The MIT Dictionary of Modern Economics (Pearce, 1992) defines marginal cost as “the extra cost of producing an extra unit of output”. Paul Samuelson defines marginal cost more cautiously as the “cost of producing one extra unit more (or less)”. The “or less” is important. The assumption behind this definition is that producing one more unit of output would cost exactly as much as producing one less unit would save.

However, the current volatile commodities market makes it very difficult to predict the price behaviour even more in the case of the power market. That makes it crucial to know what the possible external causes might be.

This study examines the long-run relations and short-run dynamics between electricity prices and other factors that may impact the Spanish wholesale electricity spot prices. The factors under analysis are mainly three fossil fuels (coal, natural gas and crude oil), one refined oil product (gasoil) and also the wholesale electricity spot prices formed in Portugal and France. Providing information on the dynamics of electricity and fuel source prices allows for a better understanding of price information flow among the markets.

First, coal and natural gas serve as important sources of fuel supply in electricity generation process, being basically the marginal technologies that define the wholesale electricity spot price formation. According to 2008 data published by the Spanish transmission system operator[3] REE[4], about 49% of the electricity in Spain was generated using coal, natural gas and fuel oil, with natural gas accounting for more than one third of the electricity generation and coal for around 16%. Thus, changes in coal and natural gas prices can directly affect the cost of generating electricity and contribute to its price at the retail level. Second, crude oil prices may also contribute to form electricity prices directly by raising electricity generation costs and indirectly through changes in market sentiments. The major long-term natural gas contracts that use crude oil as a price reference can be another relevant issue to discuss.

In the context of MIBEL[5], Portugal and Spain use OMEL[6] power exchange[7] platform as electricity wholesale market operator. Wholesale electricity spot price formation in OMEL uses "market splitting" procedure to solve cross-border congestion management (one single Iberian price area if there is no congestion in the interconnection between Spain and

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[3] Transmission System Operator is a body responsible for operating and maintaining the physical electricity network.

[4] Red Eléctrica de España.

[5] An acronym for Mercado Ibérico de Electricidade, the joint Spanish-Portuguese electricity market that came into effect in July 2007 and allows participants to buy and sell power on either side of the Spain / Portugal border to create a pan-Iberian market with more than 28 million business customers.

[6] Compañia Operadora del Mercado de Electricidad.

[7] Power exchange is an entity set up to provide an efficient, competitive trading arena, open on a non-discriminatory basis to all electricity suppliers, which meets the load of all exchange customers at efficient prices.

Portugal and with distinct price areas if there is congestion in the interconnection between both countries). France is also another country connected with Spain that uses the interconnection between them for exporting and importing electric energy. In France the wholesale electricity spot price is determined by the Powernext power exchange which nowadays belongs to the European Power Exchange Spot (EPEX Spot, a former cooperation between EEX[8] and Powernext). Interconnection capacity makes it possible to trade electricity between countries. So, the wholesale electricity market price evolution in each country as an impact on the cross-border electricity flows between the two systems and dictates the transit of the energy flow from one system to another (if the electricity price in Spain is greater than the electricity price in France, a transit of energy flow between France and Spain should occur; if the electricity price in Spain is lower than the electricity price in France, a transit of energy between Spain and France should occur). Studying the relations and dynamics between interconnected systems using as an input the electricity spot price formed in each electrical system is also relevant because it might also have an impact on the evolution of the Spanish wholesale electricity spot prices.

This thesis aims to present a synthesis of econometric models that allow an explanation for the relationship between electricity prices and fuel prices. The study is organized as follows:

Chapter 2 begins with energy commodities and their impact on world economy. This chapter also makes an introduction to each relevant primary energy commodity with impacts on power generation fuel cost. A brief overview of the Spanish Electricity Market can be found in Chapter 3. This chapter begins with a description about Electricity Markets and ends with a reference to the Spanish Electricity Market in the context of MIBEL. Since the vast majority of economic and financial series show clear evidence of nonstationarity, this concept is introduced in Chapter 4 and tests for nonstationarity are presented. It continues with the notion of cointegration from which it is possible to infer market integration. Additionally, to validate certain issues about some cointegration properties, a study about exogeneity, proportionality and asymmetry will also be shown. Following the data presentation in Chapter 5, Chapter 6 shows the empirical findings to verify the concepts derived in the theoretical framework described in Chapter 4. Finally, conclusions are presented in Chapter 7.

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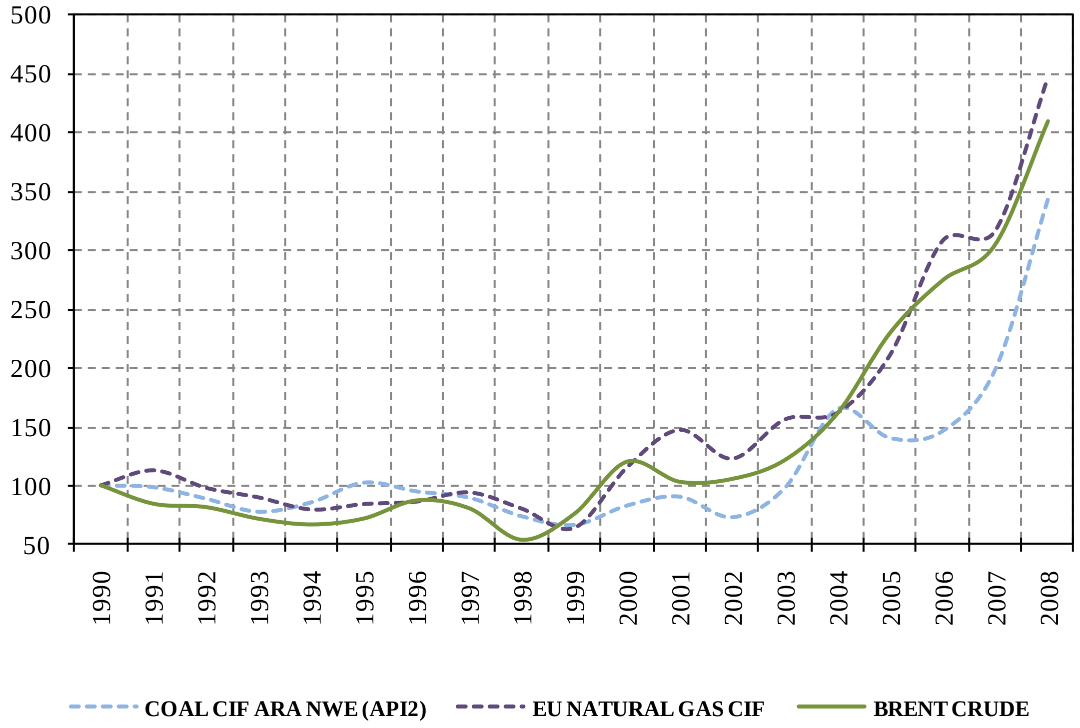
[8] European Energy Exchange: Germany's energy exchange, is the leading energy exchange in Central Europe.

2 ENERGY COMMODITIES: A BRIEF DESCRIPTION

Over the past years, the entire world economy has been affected by a massive increase in energy prices. Yet only a few years ago, there was complete confidence that cheap energy would last indefinitely.

Energy use is crucial for modern society and world energy demand is growing constantly. In recent years, public interest in the energy sector has risen sharply with rapidly increasing oil prices, the liberalization of energy markets, and the first noticeable effects of climate change caused by the burning of fossil fuels. Securing a reliable and sustainable energy supply in light of declining resources and climate change mitigation will be a key challenge for the 21st century.

Figure 1 - Historical evolution of fuel prices



Source: BP Statistical Review of World Energy, June 2009 (1990 = 100, prices in USD)

Until the mid-20th century, energy demand was almost exclusively met by domestic energy sources. Since then, fossil fuels have become traded internationally and for electricity regional interconnected markets have evolved. Liberalization of energy markets in many regions of the world has led to new electricity and gas markets and to a significant increase in trading volumes.

Besides the energy companies and besides large consumers and emitters, banks and other speculative traders participate in these growing markets. In recent years, commodities have been increasingly recognized as an important asset class in fund management which can improve a portfolio's risk profile. Energy and emissions markets are often described as unstable and erratic. They are characterized by a multitude of complex products, by high price volatility, and by fundamental interactions between each other. For example, gas prices will not develop independently of oil prices in the long run, as these fuels can be used as substitutes for each other in many applications. Electricity prices depend on electricity generation costs, which are directly impacted by prices for fuels and in the case of environmental restrictions derived from climate change policies the use of fossil fuels directly impact on CO_2 emissions pricing trough its more extensive use.

2.1 CRUDE OIL

The Oil Market is certainly the most prominent among the energy markets. Crude Oil (or petroleum) is found in reserves spread across particular regions of the earth's crust, where it can be accessed from the surface. Even though petroleum has been known and used for thousands of years, it became increasingly important during the second half of the 19th century as a primary energy source and as a raw material for chemical products.

Today, crude oil is still the predominant source of energy in the transportation sector and is often taken as a benchmark for the price of energy in general. In Europe, for example, prices of natural gas are typically derived from oil prices. Therefore oil prices also have an impact on electricity prices, even though oil plays a minor role as a primary energy source for electricity generation.

The physical crude oil market has to deal with a large variety of different oil qualities (viscosity, sulphur contents) and with different means of transportation (pipeline, shipping). All of these characteristics influence the oil price. Nevertheless, a liquid oil market has been developed, using few reference oil qualities as benchmarks for pricing an individual oil quality. The most popular benchmark oils are:

- **West Texas Intermediate Crude Oil (WTI):** Reference for the US market, Sulphur content: 0.3%;
- **Brent Crude Oil:** Reference for the North Sea oil market with a similar quality as WTI. Sulphur content: 0.3%;

- **Dubai Crude Oil:** Reference for the Middle East and Far East markets. Sulphur content: 2%.

2.2 REFINED OIL PRODUCTS

Crude oil is never consumed "as it is" in final uses but undergoes refining processes, producing many oil products which are used by both intermediate industries and end users. The refining process in its basic form is a distillation process, where crude oil is heated in a distillation column. The lightest components can now be extracted at the top of the column whereas the heaviest components are taken out of the bottom of the column. To increase the yield of the more valuable lighter products, a cracking process is used, breaking up the longer hydrocarbon molecules. Other processes are needed to remove the sulphur content. Ordered by increasing density, the most important oil products are:

- **Liquefied petroleum gases (LPG):** Propane or butane;
- **Naphtha:** Mainly used in chemical industry;
- **Gasoline:** Mainly used for transportation;
- **Middle distillates:** Kerosene, heating oil and diesel (gasoil);
- **Fuel oil:** Used in thermal power plants and large combustion engines.

Owing to the combined production process, prices of different oil products are usually tightly related to each other and can be expressed in terms of price spreads[9] against crude oil. The lighter and more valuable products have higher spreads against crude oil than the heavier products. In special circumstances, such as a military crisis, prices for certain products (e.g. jet fuel) can spike upwards in relation to crude oil because of the limited refining capacities and the limited flexibility of refineries to change the production ratios among the different products.

The European market in refined products is highly competitive, and the industry is quite large and developed, as Europe accounts for more than 17%[10] of total world refining capacity. European refiners transform and move a significant amount of risk in the market since they not only buy crude oil but also sell refined products. Both crude and refined

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[9] Spread is the difference between the prices of a distinct security or asset.

[10] Source: BP Statistical Review of World Energy, June 2009.

products are volatile even in the short term, and correlation among these prices, especially in the medium and long term, is able to transfer downward in the energy markets a part of the risk they incur from crude oil inputs; the rest of the risk is borne by them. Anyway, the amount of risk borne directly by refiners is not trivial. In fact, the refining margin, which is the difference between refined product prices and crude oil prices, has always been quite volatile.

The most important refined product in Europe is gasoil, which is used for domestic heating and for transportation (diesel engines). Improvements in diesel engine technology and tax incentives have led to a strong growth of diesel consumption in Europe. Fuel oil plays a limited role, but is still frequently used as a price reference for natural gas contracts.

The market for refined oil products in Europe is divided into NWE ARA (North-western Amsterdam-Rotterdam-Antwerp) and MED (Mediterranean, Genoa).

One typical financial instrument for European gasoil is Gasoil swaps[11] traded OTC[12] and typically refer to the monthly average gasoil price (ARA or MED) as published by Platts[13] for setting the floating payments.

2.3 COAL

Coal is a fossil fuel, usually with the physical appearance of a black or brown rock, consisting of carbonized vegetal matter. It is formed plant remains that have been compacted, hardened, chemically altered, and metamorphosed by heat and pressure over geological time. It is used as a main source of fuel for the generation of electricity worldwide and for steel production. Coal is heterogeneous source of energy, with a significantly varying quality. Coal types are distinguished by their physical and chemical characteristics. Characteristics defining coal quality are, for example, carbon, energy,

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[11] A Gasoil Swap is derivative used as a hedge or as a speculative tool against the price of a physical commodity. Its price is dependent on the price of the underlying commodity. In this case, Gasoil swap is a derivative used to hedge on the price of physical Gasoil. This commodity is traded daily on a fixed price basis to be settled against a floating price.

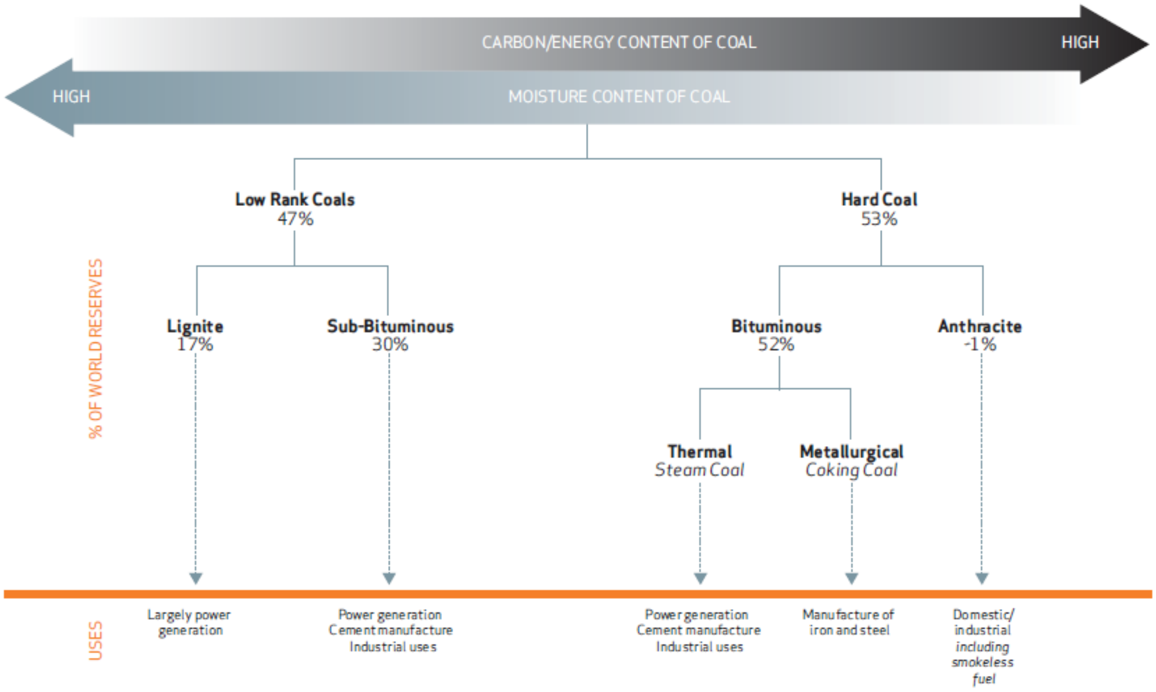
[12] Over-the-Counter trading is to trade financial instruments such as stocks, bonds, commodities or derivatives directly between two parties. It is contrasted with exchange trading, which occurs via facilities constructed for the purpose of trading (i.e., exchanges).

[13] Platts is a provider of energy and metals information and a source of benchmark price assessments in the physical energy markets.

sulphur, and ash content. The higher the carbon content of a coal the higher its rank or quality. These characteristics determine the coal's price and suitability for various uses.

There are three main categories of coal. These are hard coal, sub-bituminous coal and lignite.

Figure 2 - Types of Coal



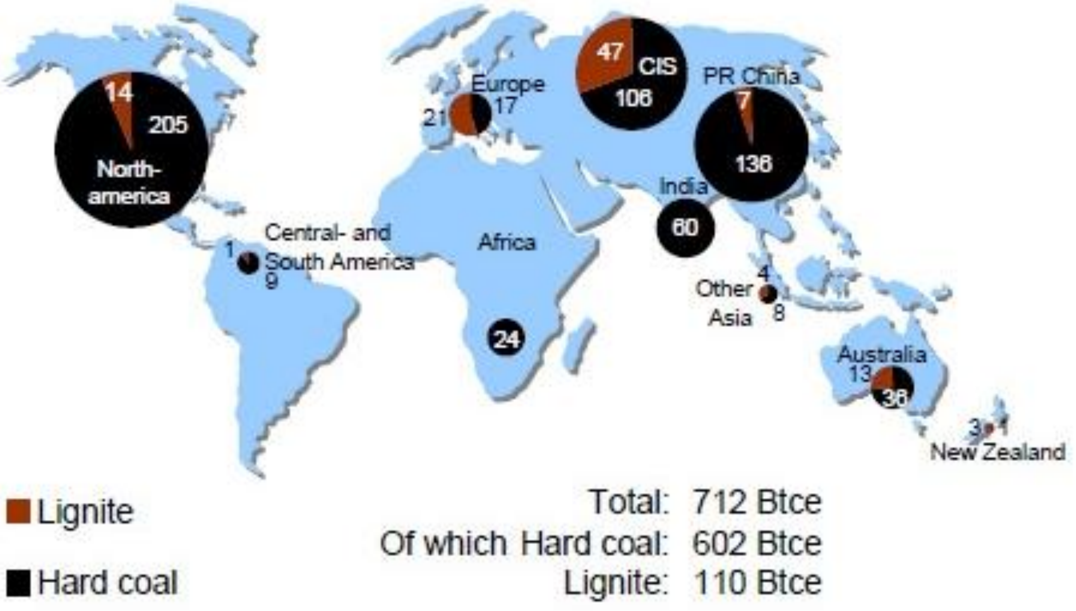
Source: World Coal Institute

Hard coal has a high gross calorific value greater than 5700 kcal/kg and can be categorized as follows:

- **Coking coal** is a premium-grade bituminous coal at the top end of the quality spectrum used to manufacture coke for the steelmaking process;
- **Steam coal** is coal used for steam raising and space heating purposes. It includes all anthracite coals and bituminous coals not classified as coking coal. As primary fuel for hard coal fired power plants, steam coal with a calorific value greater than 6000 kcal/kg and with low moisture, ash and sulphur (less than 1%) is used.

There are two main trading regions, the Atlantic and the Pacific region. South Africa, Columbia and Russia are the main coal suppliers for the Atlantic region and Indonesia, Australia and China for the Pacific region. There is also a small interexchange with Australia and Indonesia supplying both the Pacific and the Atlantic region.

Figure 3 - Worldwide distribution of coal reserves



Source: CIAB (2009)

Because coal transportation can be expensive, in some instances "it accounts for up to 70% of the delivered cost of coal" (Burguer *et al.*, 2007), coal prices depend on the point of delivery. Standard delivery points in international coal trading are, for example, Richards Bay in South Africa, Newcastle in Australia, ARA for Central Europe or the Central Appalachian in the United States.

The characteristics defining the quality of coal also determine its price. Energy content is the most price relevant characteristic, and quoted prices per tonne always refer to a specified quality and in particular to a specified energy content.

Price information for hard coal can be obtained either from exchanges, from brokers or from independent information service providers. Price information published by the information service is typically generated by telephone or e-mail survey covering sellers of physical coal, utility buyers, trading companies and broking companies. Market analysts then assess the price of the standard specified coal that conforms to the required specification. In contrast to an exchange, an information service has no secured information about the concluded trades.

Traditional Financial Services (TFS), a broker of OTC physical and derivative products, averages prices originally published by Argus Media and McCloskey's[14] and generates the well-accepted All Publications Index (API). The TFS API indices are published in the Argus/McCloskey Price Index Report. There are the following API indices:

- **API#2:** is the index for the NWE ARA region quoted as CIF[15] ARA and is an important benchmark for Central Europe. Delivery must be within the next 90 days, the energy content is specified at 6000 kcal/kg and the sulphur content must be less than 1%;
- **API#3:** is the index for FOB[16] Newcastle, Australia. It is also a benchmark for CIF Japan prices by adding a Panamax[17] freight assessment. Delivery must be within the next 90 days, the energy content is specified at 6700 kcal/kg and the sulphur content must be less than 1%;
- **API#4:** is the index for the FOB Richards Bay, South Africa. Delivery must be within the next 90 days, the energy content is specified at 6000 kcal/kg and the sulphur content must be less than 1%.

The delivery price of coal is determined in part by ocean freight rates. They are an important factor for the price of coal in different regions and for the competitiveness of coal against other fuels. The main factor that will affect the future movement of freight rates is the overall development of dry bulk[18] trade. Mainly Cape[19] and Panama sized vessels are employed in international coal trading. Cape sized vessels, used, for example, for the route Richards Bay to ARA, are also employed in the iron ore trade. As the shipping capacity is limited, the activity of the world's steel industry has an impact on coal freight rates.

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[14] McCloskey is a premier source of news, analysis and data on the international coal industry.

[15] Cost, Insurance and Freight: The selling price includes the cost of the goods, the freight or transport costs and also the cost of marine insurance. However, the transfer of risk takes place at the ship's rail.

[16] Free On Board: The seller pays for transportation of the goods to the port of shipment and for loading costs. The buyer pays for freight, insurance, unloading costs and further transportation to the destination. The transfer of risk is at the ship's rail.

[17] Panamax ships are the largest ships that can pass through Panama Canal. The size is limited by the dimensions of the lock chambers and the depth of the water in the canal. An increasing number of ships are built to the Panamax limit to carry the maximum amount of cargo through the canal.

[18] A bulk carrier, bulk freighter, or bulker is a merchant ship specially designed to transport unpackaged bulk cargo, such as grains, coal, ore, and cement in its cargo holds.

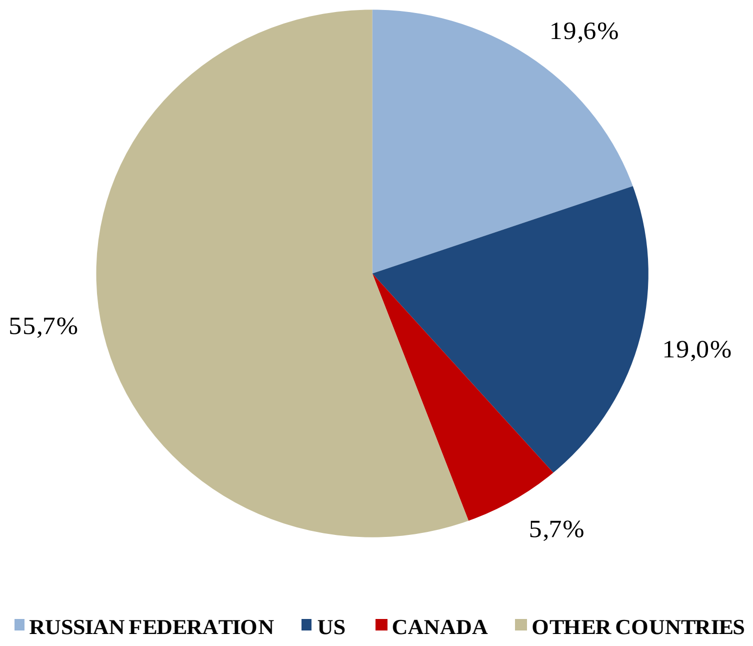
[19] Capesize ships are cargo ships originally too large to transit the Suez Canal (i.e., larger than both panamax and suezmax vessels).

2.4 NATURAL GAS

Next to oil and coal, natural gas is one of the most important primary energy sources covering about 24% of worldwide energy consumption in 2008 (BP Statistical Review of World Energy, 2009). It is primarily used as a fuel for electricity generation, for transportation and for domestic heating.

Natural gas is found in the earth's crust mostly in gas or oil fields. Unlike oil, because of its low density, gas is difficult to store and transport. In the past, gas found in oil fields was simply burned without any economic use. With growing demand for primary energy sources, gas prices have risen and large investments have been made to build an infrastructure for gas transportation, either in the form of pipelines or in the form of liquefied natural gas (LNG) terminals.

Figure 4 - Worldwide production share of Natural Gas in 2008



Source: BP Statistical Review of World Energy, June 2009

The countries with the highest gas production are Russia, the United States and Canada selling most of their gas via pipeline. LNG exports, however, are becoming more and more important in rising gas prices and new investments in LNG terminals are being made.

Compared to oil, the natural gas market is more regional due to the high costs of gas transportation. The following regional markets can be distinguished:

- The North American market;
- The European market;
- The Asian market.

Historically, these regional markets have had little interaction, since LNG played a significant role only in the Asian market. With declining gas reserves and growing demand in North America and Western Europe, the importance of LNG for these markets, and therefore the market interaction, will increase over the next decades.

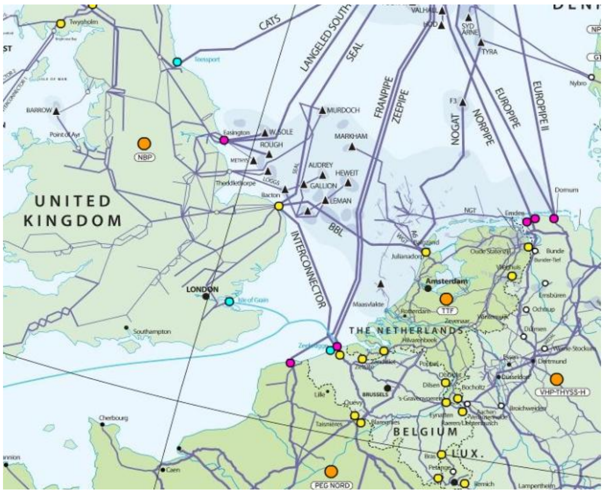
Another important issue to discuss is the contractual relationship between the different players of the natural gas business. Producers mostly sell the gas to intermediaries and traders, very often through long-term contracts. Gas prices are mainly set, at least in Europe, using algebraic formulae whose inputs are prices of other primary and secondary energy sources. The real formulae usually contain additive and multiplicative terms. There are always time lags for the calculation of average energy input prices, consequently reducing short-term gas price volatility. Moreover, energy input prices are generally expressed in US dollars, so exchange rates are also included in the formulae. Finally, these formulae are never used to calculate prices on a daily basis but over longer intervals, say, every one to three months, and during this time, prices remain fixed at the most recently calculated level. Each first partial derivative in the formula will express the sensitivity of the gas price to energy input prices; they are normally positive and constitute a distinct feature as they change from formula to formula. Very often, the energy input prices in the formulae are crude and refined product prices. The price that the European importers pay for natural gas is determined by a formula set in a long-term contract, and they are usually able to sell gas to customers (power generators, firms and households) according to a very similar formula, to which they add a fixed mark-up. The result, which is often referred to as a cost "pass-through", brings a nearly perfect contractual risk transfer and residual risk being close to zero. This long-established practice is welcomed by producers, as gas is often extracted in association with crude oil, and also by gas traders because this link will always assure that gas prices are competitive against the two main available substitutes, which are fuel oil in the electricity industry and heating gasoil in the households market.

Traditionally, the European gas market has been supplied by three large exporters: Russia, Norway and Algeria. The most important gas trading hubs[20] in Europe are listed below:

- **The National Balancing Point (NBP) in the United Kingdom (UK):** a notional point within the UK gas pipeline network (basis for most UK gas trades);
- **Title Transfer Facility (TTF) in Netherlands:** physical natural gas delivery at the notional trading point, the Dutch Title Transfer Facility;
- **Zeebrugge in Belgium:** physical natural gas delivery at the Zeebrugge hub operated by Huberator.

The continental European market and the UK market are linked by the Interconnector pipeline that began operation in 1998 and by the BBL[21] pipeline that began operation in 2006. The Interconnector connects the NBP gas trading hub to the Zeebrugge gas trading hub while the BBL pipeline connects the NBP gas trading hub to the TTF gas trading hub.

Figure 5 - Natural Gas pipeline connections between UK and Continental Europe



Source: The European Network of Transmission System Operators for Gas (ENTSO-G)

Since the Interconnector and BBL make arbitrage trading possible between the UK and continental Europe (within the technical capacity restrictions of the Interconnector and BBL

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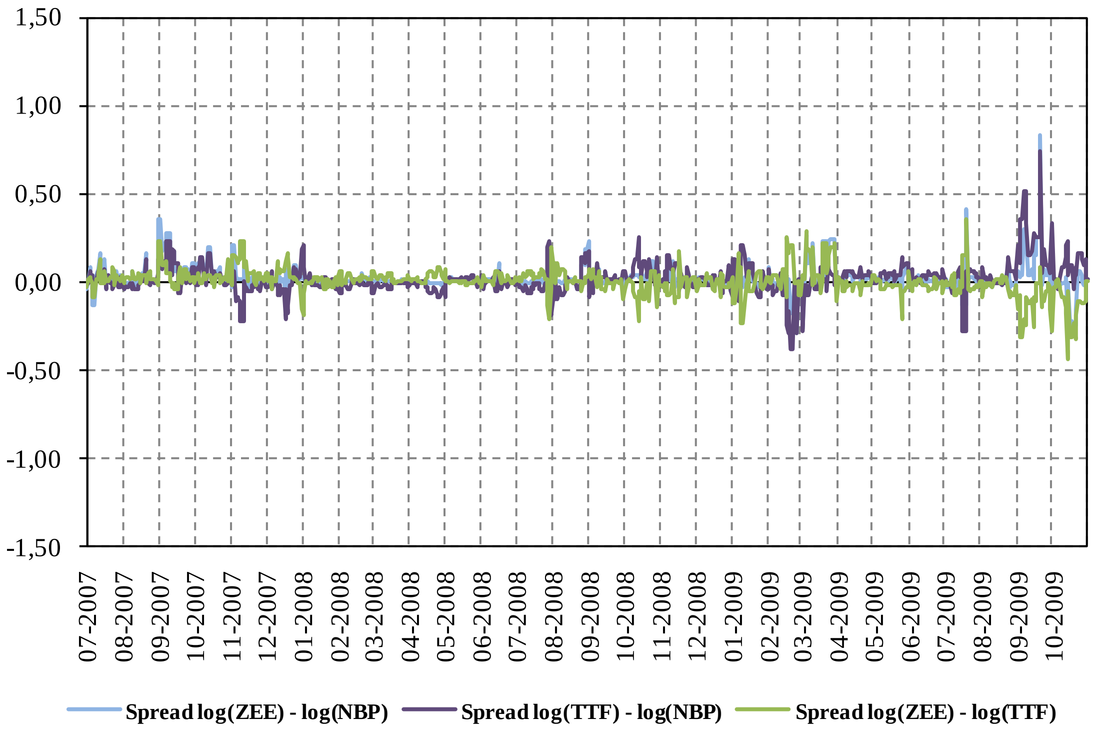
[20] A successful gas trading hub has two basic characteristics: first and foremost it must be possible to easily move gas into and out of the market, whether the market is defined as a single point or as a whole area (virtual hub); second, there must be a use for the gas, either through the existence of a significant customer base, or through the demand from other markets that can be reached from the traded hub.

[21] The Balgzand-Bacton Line is a 235 kilometre pipeline between Balgzand in the Netherlands and Bacton in the UK.

pipeline), the gas spot prices at NBP, TTF and Zeebrugge are closely connected. Therefore the spreads between NBP, Zeebrugge and TTF are most of time near zero. Besides this, there are short periods of time where the spreads are significantly different from zero (historically, this was regularly the case when the Interconnector or BBL was shut down for maintenance work). However, there is one circumstance that possibly turns the Zeebrugge and NBP natural gas markets into a more integrated market than TTF and Zeebrugge. This circumstance is characterized by technical restrictions of BBL pipeline usage since it is not capable of physical reverse flow (actually the only physical capable flow is delivering natural gas from TTF to NBP) while natural gas in the Interconnector pipeline physically flows in both directions.

Figure 6 - Spreads evolution between the major European natural gas trading hubs



Source: THOMSON REUTERS (European natural gas prices in natural logarithms)

3 THE SPANISH ELECTRICITY MARKET: A BRIEF OVERVIEW

3.1 ELECTRICITY MARKETS

The electricity market is characterized by a number of specific features which affect both its market design and the nature of competition. The most notable feature is that, unlike gas, electricity cannot be stored on a significant scale and needs to be consumed instantaneously. The lack of storability, coupled with the fact that final electricity demand varies considerably during the day and according to seasons, means that electricity production levels need to be able to adjust rapidly on an hourly basis and have to constantly match demand requirements. This implies that some generation capacity needs to be available primarily to meet demand peaks (but will not be needed at lower demand levels), and that prices can rise significantly during peak periods (to allow peaking capacity to recover both its fixed and variable costs). The fact that final demand does not respond significantly to price changes (typically because it does not face real-time prices due to the absence of hourly metering of consumption) accentuates the need for spare capacity during peak demand periods.

The features of the electricity market described above imply that a combination of power plants is used to optimally meet demand at any given point in time. Plants with high fixed costs and low marginal costs are used to meet baseload demand (i.e., the constant minimum level of demand across a time period, e.g., a year). Baseload plants typically include nuclear, run-of-river hydro plants and also renewable capacity which cannot be modulated (e.g., wind power). Plants with low fixed costs and high marginal costs (e.g., gas and/or oil turbines) are used instead to meet demand peaks. Reservoir hydroelectric power and pumped storage capacity are also used to meet demand peaks. Finally, plants with intermediate marginal and fixed costs (e.g., coal and CCGT[22] plants) often operate as "mid-merit" generation (i.e., they do not produce in the periods of lowest demand, but generate in all other periods).

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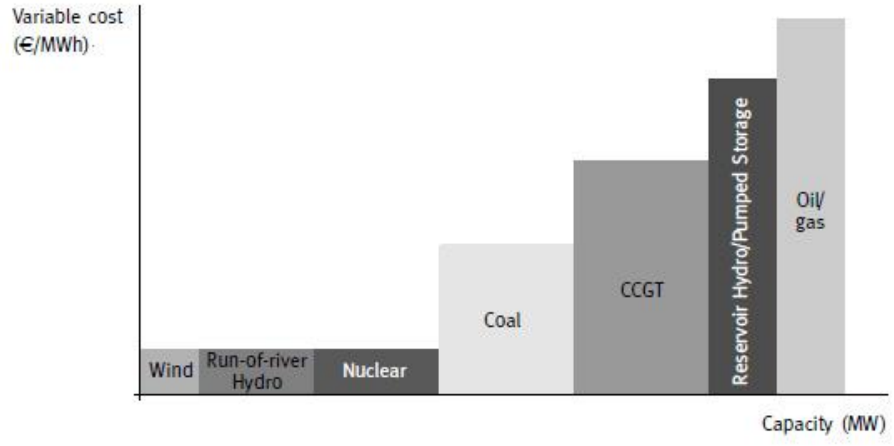
[22] Combined-Cycle Gas Turbine (CCGT): an energy efficient gas turbine system, where the first turbine generates electricity from the gas produced during fuel combustion. The hot gases pass through a boiler and then into the atmosphere. The steam from the boiler drives the second electricity-generating turbine.

A “merit order” of plants of different technologies can therefore be constructed in generation markets, ranking capacity from the cheapest to the most expensive (in terms of variable costs). Fluctuations in relative fuel prices (including CO_2 emission costs) affect the position of different technologies in the merit order (and in particular can cause the relative position in the merit order of coal and CCGT to “flip”).

Figure 7 - Hypothetical merit order in the wholesale electricity market

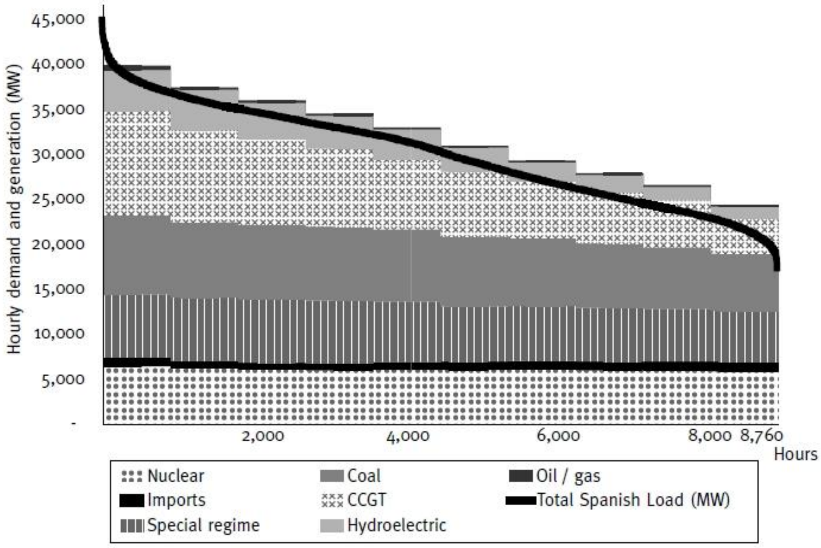


Source: Competition and Regulation in the Spanish Gas and Electricity Markets (Federico and Vives, 2008)

In the paradigm, competitive generation market (i.e., one with low concentration levels), plants face incentives to offer their energy at variable cost during most hours of the year. Hourly prices are therefore set at the marginal cost of the most expensive plant in the merit order that is needed to meet demand in that hour (i.e., the marginal plant). Plants with lower marginal costs than the marginal plant can also produce during that hour and earn “infra-marginal rents” that allow them to recover their fixed costs (e.g., capital costs and fixed operation and maintenance costs). At the very peak, prices need to rise above the variable cost of the marginal plant in that hour to allow it to recover its fixed costs, and can therefore reach (in the theoretical model) the maximum willingness to pay for electricity.

For a given generation merit order, the distribution of demand levels across a given time period (e.g., a year) will therefore affect the distribution of electricity spot prices. Both demand and prices can be described as annual “duration curves”, i.e., plots of all the demand/price levels observed in a year (i.e., 8760 hours), which rank hourly levels from the highest (0% duration or hour 1) to the lowest (100% duration or hour 8760).

Figure 8 - Hypothetical Load Duration Curve



Source: Competition and Regulation in the Spanish Gas and Electricity Markets (Federico and Vives, 2008)

Congestion on the transmission network can change the theoretically optimal merit order. In situations of network congestion, the operator of the transmission system (which is tasked with ensuring the perfect balance of demand and supply) will have to call on more expensive units located in the congested area to produce, instead of plants that are willing to produce electricity at a lower price in areas with surplus generation.

3.2 THE SPANISH CASE AND MIBEL

The Spanish energy sector was liberalized in the late 1990s. The key pieces of legislation introduced to liberalize the industry were the Electricity Law (Ley del Sector Eléctrico) in 1997 for the electricity market, and the Hydrocarbons Law (Ley de Hidrocarburos) in 1998 for the gas market.

One of the most contentious elements of the liberalization of the Spanish energy industry was the creation of a market for electricity generation. The Spanish electricity generation market was established in 1998 and since then, five firms have been operating in the Spanish market as competitors: Endesa, Iberdrola, Unión Fenosa[23], Hidroelectrica del

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[23] In 2008, Gas Natural SDG made a friendly takeover bid to buy Unión Fenosa.

Cantábrico[24] and Electra del Viesgo[25]. The wholesale electricity market reaches a maximum peak load close to 36 GW and a yearly energy demand of about 232 TWh[26].

Figure 9 - Power Exchanges in Europe

The basic design for the Spanish market was partially based on other liberalized electricity markets (most notably those in the United Kingdom, Scandinavia, California and some other US markets at the time).

Like the UK model, the Spanish market effectively concentrated most liquidity in a single marketplace (creating a potentially visible and reliable price signal) and introduced a mechanism for remunerating capacity. Unlike the British market, however, in Spain

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[24] In 2005, Hidroeléctrica del Cantábrico was acquired by Energias de Portugal SA.

[25] In 2008, EON bought Electra del Viesgo to his major stakeholder ENEL.

[26] Source: 2008 data statistics, OMEL.

generators could vary their bids hour by hour and were also subject to a stranded cost recovery mechanism which reduced incentive to increase wholesale prices.

Another important market design reform implemented in the Spanish (and Iberian) wholesale electricity market in 2007 was the launch of MIBEL on 1st July 2007. Since then, the daily market is managed by OMEL while the derivatives market is managed by OMIP[27].

Generation units located in each country and consumption both take part in the daily market. The method which forms the marginal clearing price is totally valid, resulting, in general, in a single price for the entire Iberian system and in a flow of electric energy between the two countries.

The method currently used to manage congestion in the interconnection is called "Market Splitting" which allows solving congestion in a non-discriminatory environment for operators in addition to the reduction of problems associated to the possible existence of a dominant position. This method is similar to that used in NordPool[28] for congestion management when it occurs in the interconnections between Norway, Sweden, Finland and Denmark. If there is congestion on the interconnection Spain-Portugal in any direction, OMEL runs the "market splitting" procedure (Figure 10) which basically consists of making two separate procedures of price formation, one for the Portuguese market players and another for the Spanish market players taking into account the maximum amount of energy that can be exchanged between both systems and resulting in a different price for each country.

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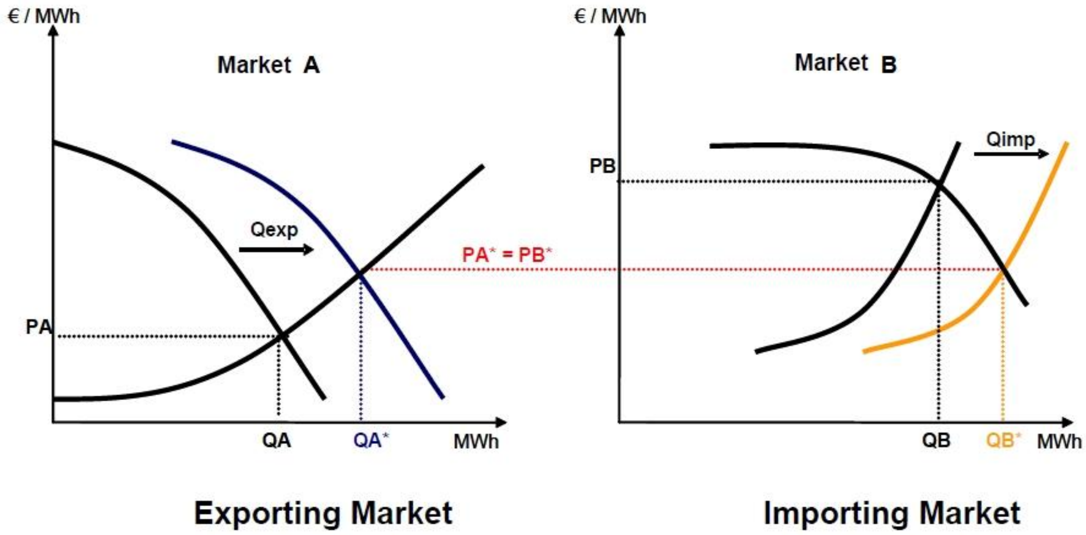
[27] OMIP is the managing entity responsible for the organisation of the Portuguese division of MIBEL, ensuring the management of the MIBEL derivatives market, jointly with OMIClear (Energy Markets Clearing Company), a company constituted and totally owned by OMIP, which has the role of Clearing House and Central Counterparty for operations carried out in the market.

[28] Nordic electric power exchange that provides market places for trading in physical and financial contracts in the Nordic countries (Finland, Sweden, Norway, Denmark and recently Germany), which listed the world's first exchange-traded electricity futures contract in October 1995. It now operates the world's largest power derivatives exchange and also provides a carbon market for trading contracts on emission allowances and carbon credits. In 2002, Nordpool's physical market was organized into a separate company, Nordpool Spot.

Figure 10 - Market Splitting Mechanism

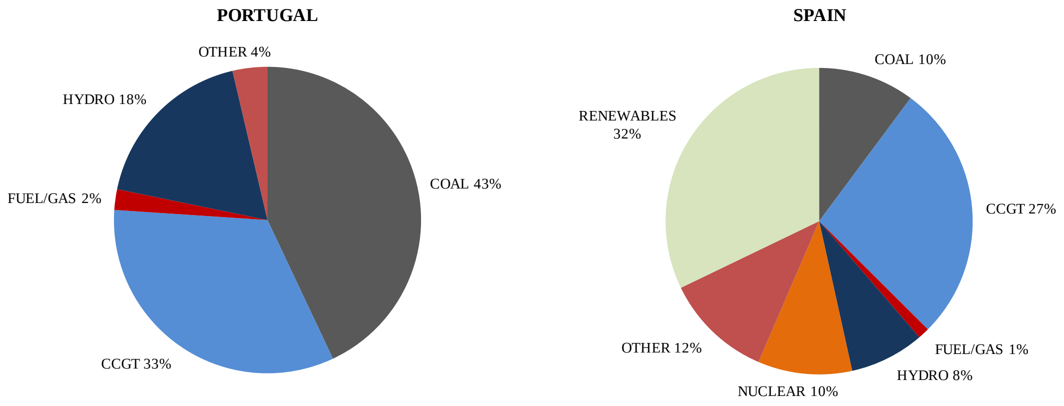


Source: EPEX Spot

Therefore, whilst MIBEL has established the mechanism for integration between the Spanish and Portuguese markets to take place, effective integration of the two markets has not been fully achieved yet. Greater interconnection capacity between the two systems is required for full market integration to take place. The expectation is also that, over time, the convergence of market design across the two systems (e.g., the harmonization of trading rules and of the mechanism for capacity payments) should also lead to greater convergence in market structures and technology mixes, and allow for the creation of an effective single Iberian market.

In practice, given the different cost structures of the wholesale markets in Spain and Portugal (this can be seen in Figure 11) and the amount of interconnection capacity (an average of roughly 1243 MW of export capacity into Portugal during the period 1st July 2007 to 31th October 2009), MIBEL has experienced market splitting for a significant amount of the time since July 2007.

Figure 11 - Generation share by technology in the daily market OMEL (from 01/07/2007 to 31/10/2009)



Spain has more diversified generation assets by technology type in the wholesale market. Renewables[29] offer their energy in the wholesale market in Spain while in Portugal their energy is bilaterally contracted by the last resource supplier[30]. Excluding the matched energy from the Renewables in the wholesale market, Spain has only 57% of generation share that comes from fossil fuels thermal power plants (CCGT, thermal coal and fuel/gas power plants) while Portugal has 78%.

So, it seems that Spain is less dependent of fossil fuels power plants than Portugal due to a more diversified generation portfolio. In Portugal, electricity generation and electricity pricing is more dependent of fuel prices such as coal, natural gas and fuel oil. Looking at 2008 generation statistics published by the Portuguese transmission system operator REN[31] and also by the Spanish transmission system operator REE (Figure 12), it is also possible to see the structural differences between the generation share of each technology in each country, particularly in Fossil Fuel technologies.

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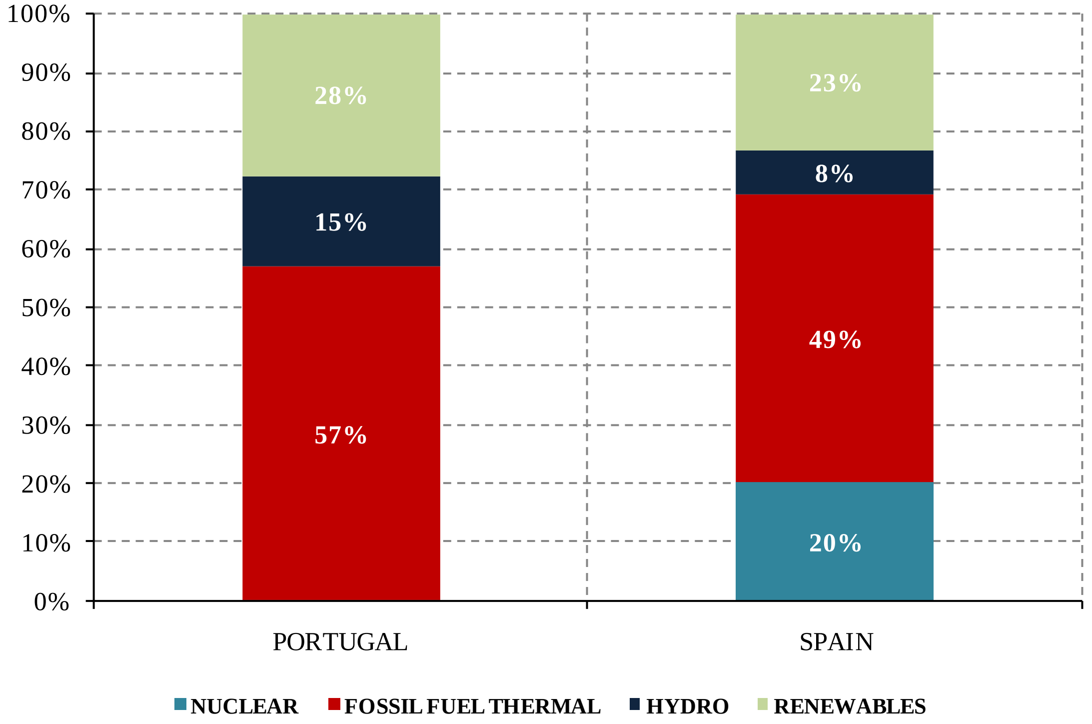
[29] Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable.

[30] In Portugal, the last resource supplier company is Energias de Portugal Serviço Universal which has established tariffs for electricity consumers defined by the Portuguese energy regulator, ERSE.

[31] Rede Eléctrica Nacional, a company of Redes Energéticas Nacionais Group.

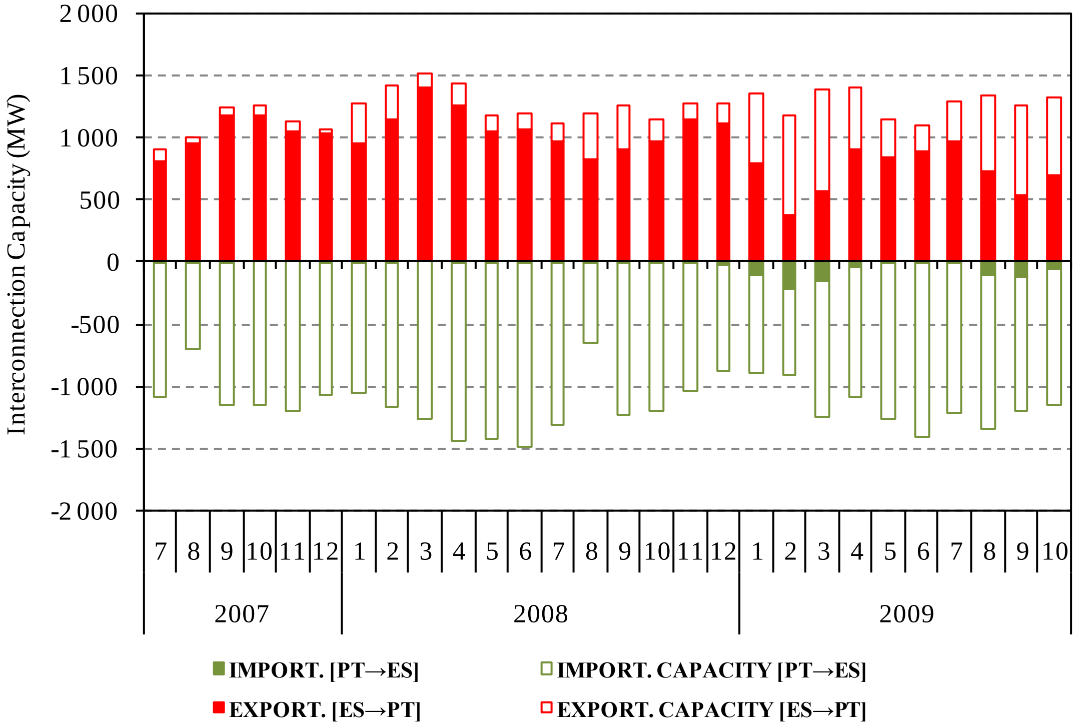
Figure 12 - Portugal and Spain generation share by technologies (2008)



Nuclear is the baseload technology that makes the difference between the two electrical systems because their variable costs are extremely low when compared with other technologies but with the disadvantage of having a long payback investment period to recover the fixed costs. Theoretically, the Spanish wholesale market merit order is cheaper than the Portuguese wholesale market merit order.

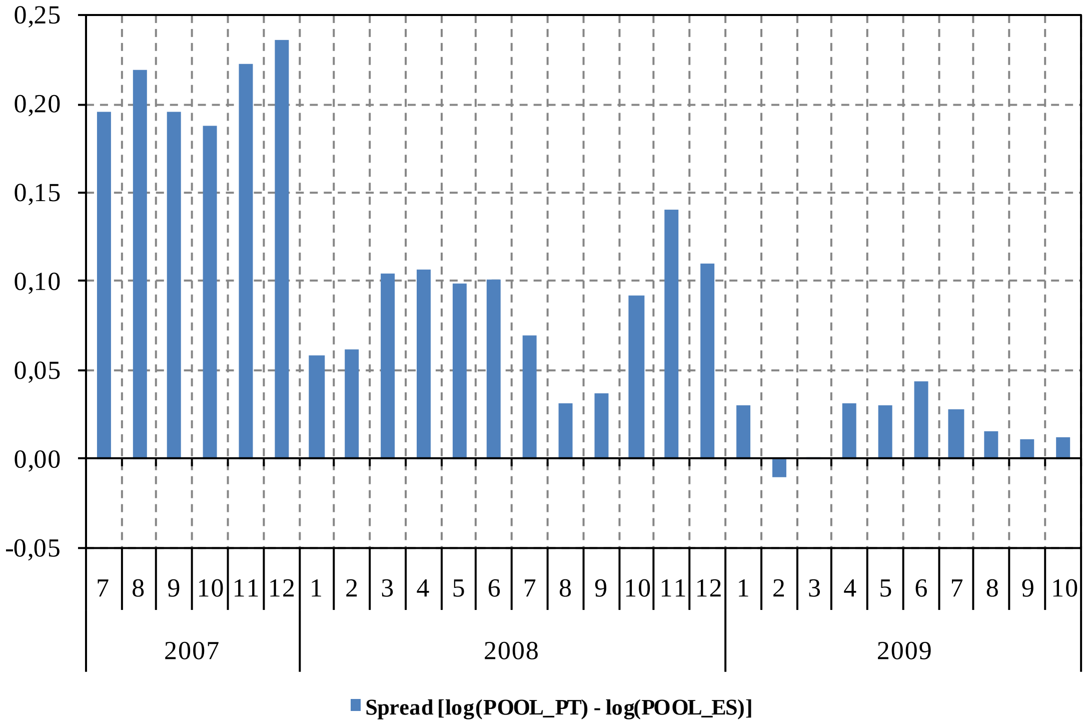
Figure 13 shows that it is possible to see that in the period that covers 1st July 2007 to 31th October 2009, Spain exported 19355 GWh of electric energy to Portugal in the daily market and imported 688 GWh from Portugal. The interconnection balance is 18667 GWh, indicating that, on average, the Spanish spot price is cheaper than the Portuguese Spot price. Only 76% of the available interconnection capacity to export was used, while only 3% of the available interconnection capacity to import was used (an average of roughly 1150 MW).

Figure 13 - Interconnection capacity and average energy flows between Portugal and Spain



However, it is possible to observe that during the same period the market spread prices evolution between both countries has been decreasing since the start of MIBEL (Figure 14).

Figure 14 - Spreads evolution in MIBEL spot prices



In 2008, the spread value fell by 60% when compared to the spread value in the second half of 2007. When compared to the 2008 spread value the 2009 spread value suffered a decrease of 77%. It is therefore possible to conclude that some structural changes in the distribution of the generation share by technologies were made over time.

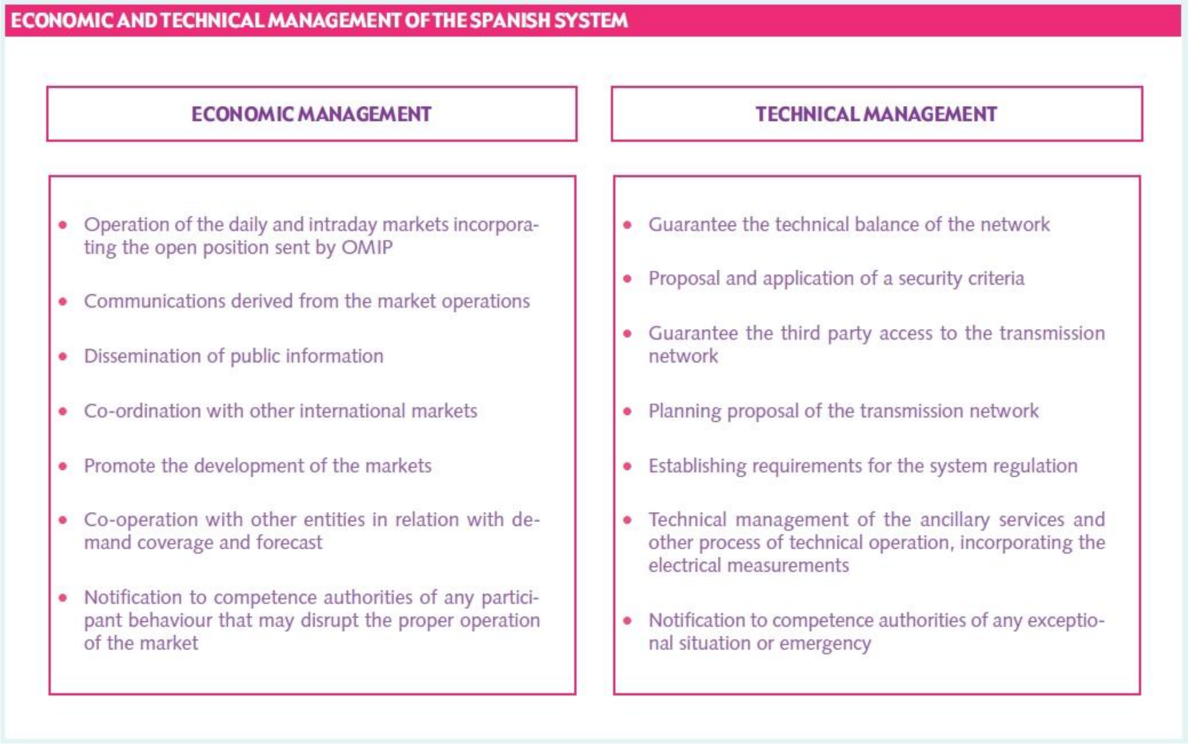
3.3 OMEL: THE MIBEL WHOLESALE MARKET OPERATOR

3.3.1 ELECTRICITY MARKET ORGANIZATION

Two independent bodies, namely the Market Operator and the System Operator are responsible for operating the electrical system.

Operador del Mercado Ibérico de Energía - Polo Español, S.A. (OMEL) is responsible for managing the daily and intra-day markets, it is also responsible for settlement and communication of payment obligations and collection rights deriving from the energy contracted in the aforementioned daily and intra-day electricity production markets.

Figure 15 - Economic and Technical Management of the Spanish System



ECONOMIC AND TECHNICAL MANAGEMENT OF THE SPANISH SYSTEM

ECONOMIC MANAGEMENT	TECHNICAL MANAGEMENT
• Operation of the daily and intraday markets incorporating the open position sent by OMIP • Communications derived from the market operations • Dissemination of public information • Co-ordination with other international markets • Promote the development of the markets • Co-operation with other entities in relation with demand coverage and forecast • Notification to competence authorities of any participant behaviour that may disrupt the proper operation of the market	• Guarantee the technical balance of the network • Proposal and application of a security criteria • Guarantee the third party access to the transmission network • Planning proposal of the transmission network • Establishing requirements for the system regulation • Technical management of the ancillary services and other process of technical operation, incorporating the electrical measurements • Notification to competence authorities of any exceptional situation or emergency

Source: OMEL

REE, the system's operator, is responsible for the technical management of the electrical system, for carrying out all those functions deriving from the operation of ancillary services, abnormalities in the electricity market, as well as for settlement and communication of payment obligations and collection rights deriving from ancillary services and the capacity. The Portuguese system operator REN is responsible for the technical management of the Portuguese system.

In relation to its organisation, the electric energy production market involves the conjuncture of economic transactions deriving from the participation of market agents in daily and intraday market sessions, bilateral contracts and forward contracting, as well as the application of ancillary services and deviations.

Market agents are those bodies which are entitled to act directly in the electricity market as sellers and/or buyers of electricity. Producers, external agents, distributors and resellers can act as market agents, together with consumers of electrical power and the representatives of any of the aforementioned entities.

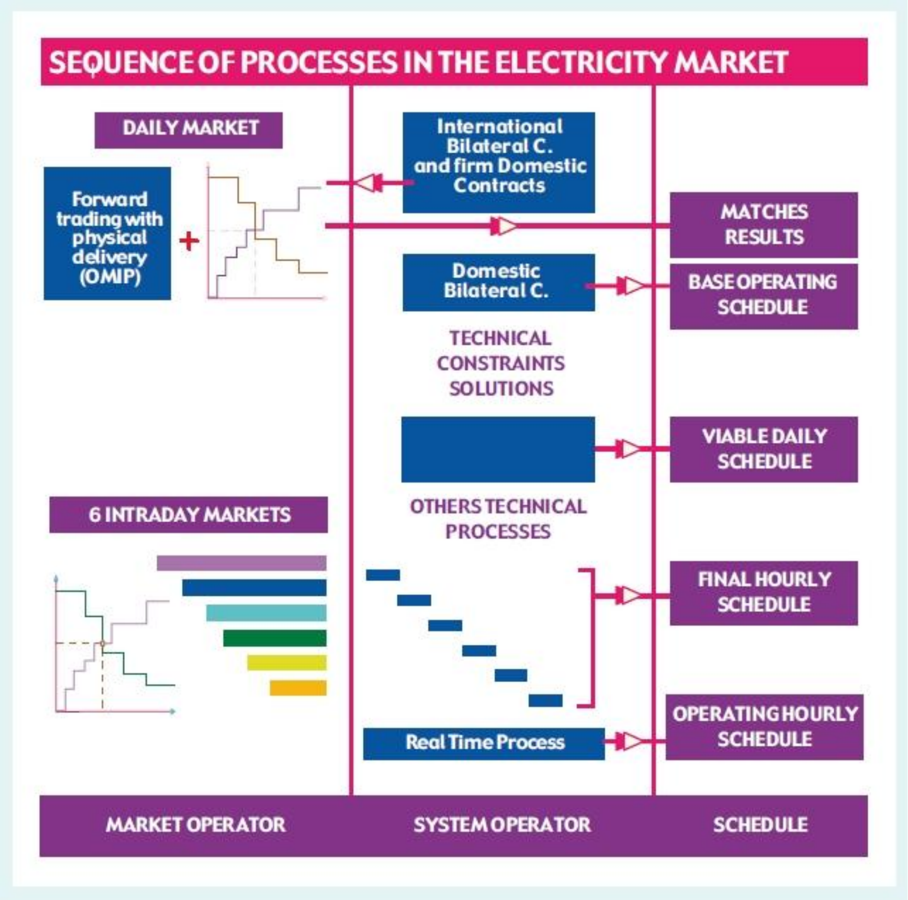
In this way, the deregulation model in Spain is configured as a model which enables both trading inside an official and organised market (forward supply, daily market and intraday market) and trading outside of it (bilateral contracts between producers, retailers and its qualified consumers including financial contracts). A key aim of the aforementioned model is to provide different trading possibilities on equal terms for all, allowing for the right price determination.

The daily market includes, in addition to sale and purchase bids directed towards it, OMIP's open positions of forward procurement, the purchases of the vendors of bilateral contracts with distribution companies, the positions of vendors and purchasers of the primary emission auctions executed with physical delivery and the sales or purchases of energy arising from the declarations of rights of use of the auctions of interconnections.

Once the daily market session has been held by the market operator, and considering the bilateral contracts executed, the system operator studies the operating schedule's technical viability to ensure the safety and reliability of the supply. If the resulting programme of the daily market plus the bilateral contracts does not comply with safety requirements, the system operator resolves these technical restrictions by modifying the programme of production units or pumping consumption units, resulting from the daily market and from the bilateral contracts, proceeding to strike a balance between production and demand through a competitive tender procedure.

The intraday market consists of six sessions held over 24 hours period which can be attended by all agents who have participated in the daily market or executed a bilateral contract, in compliance with the limitations set by the System Operator in order to avoid constraints.

Figure 16 - Sequence of Processes in the Electricty Market



Source: OMEL

3.3.2 THE DAILY MARKET

The purpose of the daily market, as an integral part of electricity power production market, is to handle electricity transactions for the following day through the presentation of electricity sale and purchase bids by market agents.

Submitting bids to the daily market can be done as follows:

- The open positions communicated by OMIP/OMIClear forward market will be integrated as sale or purchase instrumental price bids;
- The results of the communications of the execution of the power auctions of energy purchased by the distributors are integrated through the presentation by the sellers at these auctions of purchase bids at instrumental price;
- The results of the execution with physical delivery of the options acquired by purchasers in primary power emissions can be integrated through the presentation of sale or purchase bids at open prices;
- Owners of production units that are subject to the ordinary regime submit sales bids, as long as such units are available and their energy is not linked to a bilateral contract;
- The distributors of electricity will submit specific sales bids for the amount of energy they are required to purchase according to the special system[32]. Nevertheless, electric energy generated by this special system is paid by a regulated tariff. In return, special system will sell their energy through the system of bids managed by OMEL, either directly or through their agent, by means of zero-price energy sales bids on the daily market and, as appropriate, bids on the intraday market;
- External agents, retailers, and owners of production units subject to special regime, can also submit sale bids;
- Purchase bids are presented by producers for the acquisition of the ancillary services of power plants and purchasing agents owning acquisition units, whether they are resellers, distributors, consumers, external agents or holders of pumping plants.

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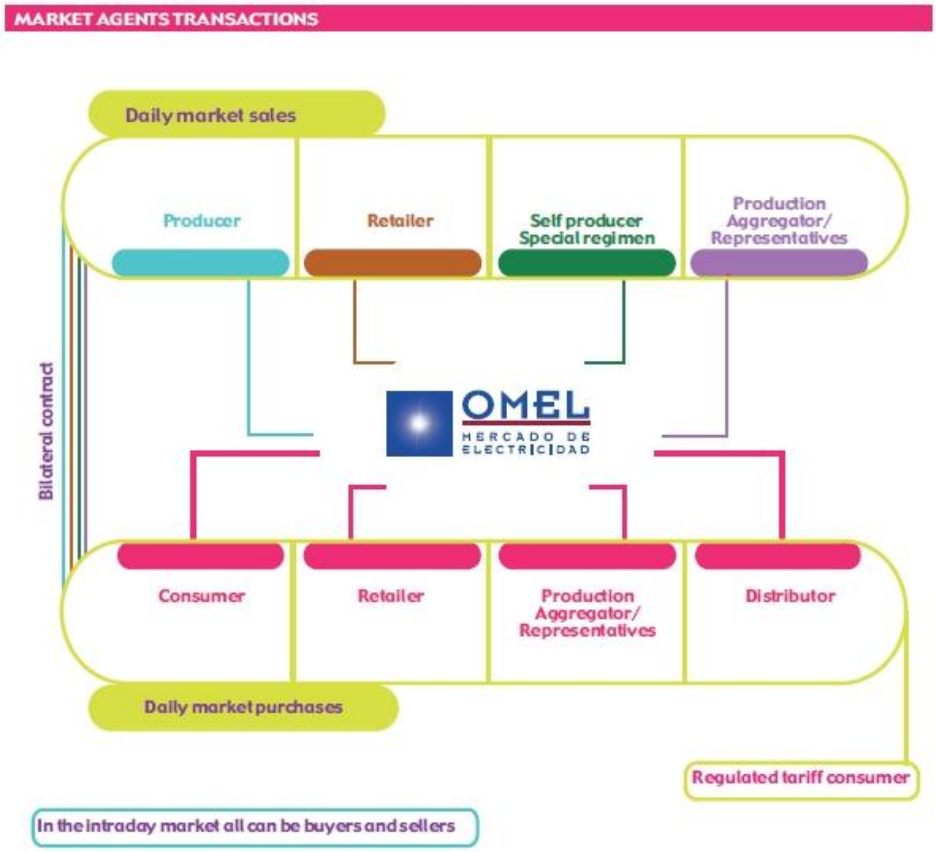
[32] Is a regime in which electric energy is produced by Renewables sources.

Figure 17 - Market Agents Transactions



Source: OMEL

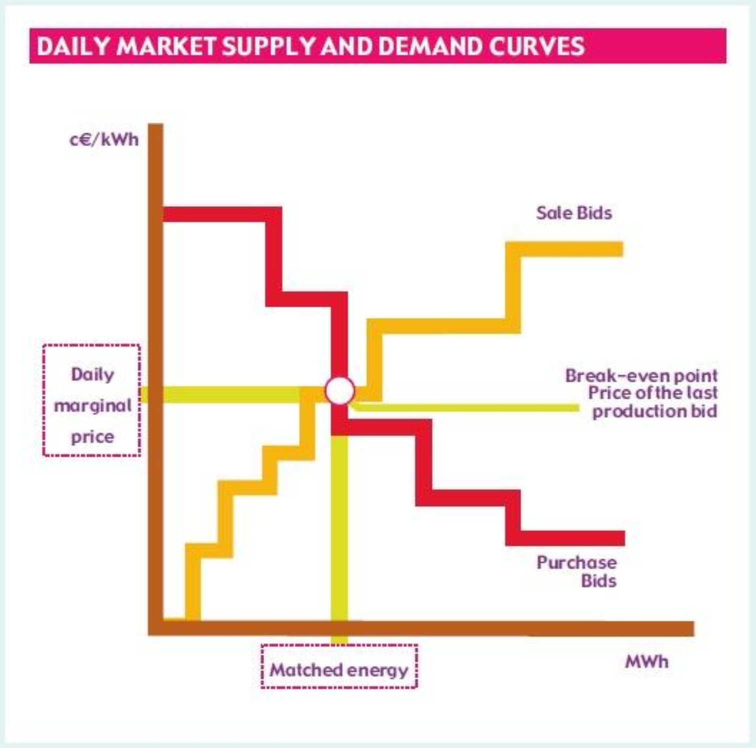
Sale and purchase bids can be made using between 1 and 25 energy blocks in each hour, with power and prices offered in each block. In the case of sales, the bid price increases with the block number, and it decreases in case of purchases.

The sale bids may be simple, or may include additional conditions:

- **Simple bids** are presented for each hourly period and production unit, indicating a price and an amount of energy;
- **Complex bids** are those which, fulfilling the simple bid requirements, also include some or all the technical or economic conditions.

OMEL matches purchase and sale bids received prior to 10 a.m. each day, whereby the price in each hour will be equal to the price of the last block of the sale bid of the last production unit whose acceptance has been required in order to meet demand that has been matched.

Figure 18 - Daily Market Supply and Demand Curves



Source: OMEL

The price or prices on the daily market are determined according to the following process. The matching algorithm first calculates a solution by considering that all international interconnections have unlimited import and export capacity. Once this solution has been calculated, a check is made to see whether there is a surplus of net energy balance in any one of the interconnections in the Iberian electrical system, considering bilateral contracts and declarations of use of rights. Depending on the interconnection involved, the process continues as follows:

- In case of congestion in the French interconnection, the energy that creates congestion will be removed in the direction of the congestion until congestion disappears. In order to do so, the process consists of removing the energy of the units without previous capacity rights (those units which have not obtained rights in the explicit auctions previous to the daily market) following the price merit order until there is no congestion. Ifcongestion continues, energy will be taken out of the units with previous capacity rights (those units which have obtained transmission rights in the explicit auctions previous to the daily market) following the price merit order until there is no congestion;

- Once the interconnections in the Iberian system have been adjusted, the next step is to calculate the transactions between the Spanish and Portuguese systems. In the event that the previous transactions are incompatible with the commercial capacity published by the systems' operators market splitting is performed at the Portuguese border. The aggregated curves of sale and purchase in both electrical systems are plotted. Each electrical system has a different price that will be the one applied to all purchase and sale bids in its electrical system at that time.

The matching result contains, for each hour, the marginal price and the schedule of production and demand for each electrical system established by OMEL, based on the matching of sale and purchase bids. The results of the matching process are then communicated by OMEL to the system operators who receive the schedules of the units of their competence.

The daily base operating schedule is drawn up by each one of the system operators and the result of the matching is accompanied by the notifications of the executions of the bilateral contracts.

4 THEORICAL OVERVIEW

Mjelde and Bessler (2009:4) refer that “there are strong prior beliefs that economic data are nonstationary”, meaning that any particular price measured over time will not be tied to its historical mean. Further, as discussed earlier, electricity and fuel prices are expected to be linked. That is, similar economic forces are expected to influence each market; although price or price movements are not expected to be identical across the different markets.

As Engle and Granger (1987) have pointed out, individual economic variables may be nonstationary and wonder through time, but a linear combination of them may, over time, converge to a stationary process. Such a process, if present, may reflect the long-run equilibrium relationship, and is referred to as the cointegrating equation. To summarize, it is expected that the different prices will be tied together, so that prices from one market will not wander off independently of the behaviour of prices in the other markets.

The presence of a cointegrating relation among energy prices forms the basis for the specification of the vector-error-correction model (VECM). This study uses the error-correction model (ECM) for electricity prices in order to capture their dynamic relations with fuel prices and other wholesale electricity spot price data from which it would be possible to analyze the price dynamics between those prices and the Spanish wholesale electricity spot prices. The ECM represents the change in electricity prices as a linear function of its past changes, past changes in fuel prices and also the other electricity prices under analysis, and an error-correction term. For a cointegrated system, the error-correction term represents the deviation from the equilibrium relationship. Thus, an ECM provides two alternative channels of the interaction among electricity prices and fuel prices: short-run causality through past changes in energy prices, and long-run causality through adjustments in the equilibrium error.

Moreover, it is also imperative to validate issues concerning some properties of such equilibrium relationship by studying exogeneity, proportionality and asymmetry of each cointegrated relationship.

4.1 NONSTATIONARITY

Most economic and financial time series that are trend stochastically nonstationary are also integrated of first order, i.e., differencing once is enough to achieve stationarity. Suppose, for instance, that one is interested in the long-run properties that rule the relationship between two or more first-order integrated price series. In this case, one needs to focus on the variables measured in levels. However, a linear combination of first-order integrated variables usually generates a residual variable that is also first-order integrated. Under these circumstances, the usual t and F tests carried out on the Ordinary Least Squares (OLS) estimates do not follow, respectively, the t and F distributions and are, thus, meaningless (Phillips, 1986). What the model is most possibly capturing is a common stochastic trend between the variables in levels and not a causal relationship as required. Additionally, the residuals are strongly autocorrelated and the Durbin-Watson statistic converges to zero. Thus, the time series being analyzed are not related in the long-run although they may be related in the short-run, as is the case of the relationship between two random walks.

Stochastic nonstationarity can be examined on the basis of unit root tests, of which the most popular is the Augmented Dickey-Fuller or ADF test (Dickey and Fuller, 1981).

The ADF test is based on the following regression model:

$$\Delta x_{it} = \mu_0 + \mu_1 t + (\rho - 1)x_{i,t-1} + \sum_{k=1}^{p} \gamma_k \Delta x_{i,t-k} + e_t \qquad (1)$$

Where μ_0 is a constant term, $\mu_1 t$ is a linear deterministic trend in the data, $(\rho - 1)x_{i,t-1}$ denotes the corresponding stochastic trend and the residuals $e_t \sim niid(0, \Omega)$. The symbol Δ denotes a first difference, as usual, and the summation term captures any autocorrelation of the left-hand side variable. Taking $\mu_1 = \gamma_k = 0$, the ADF equation reduces to an AR(1) process. The null hypothesis in the ADF test is $\rho = 1$, using for the effect the MacKinnon critical values (MacKinnon, 1996).

The distribution of the ADF test under the null hypothesis is given by (Dufrénot and Mignon, 2002):

$$t_\rho \sim \frac{W^2(1) - 1}{2\sqrt{\int_0^1 W^2(s)ds}} \qquad (2)$$

where $W(s)$ represents a Brownian Motion over $[0,\ 1]$. Under the null hypothesis the variable is nonstationary, i.e., it contains a stochastic trend. The alternative hypothesis postulates that $|\rho| < 1$, under which the variable is stationary. In fact, under the alternative hypothesis the time series is a stationary $AR(p + 1)$ process with or without deterministic terms.

Despite their popularity, the ADF tests suffer from low power problems when the process is stationary with roots close to one (Blough, 1992). Additionally, some unit root processes behave more like a white noise than like a random walk in finite samples. By this reason, it is convenient to use alternative tests in order to conclude more accurately about the stationary nature of the series under analysis.

An alternative to the ADF test is the KPSS test (Kwaitkowski *et al.*, 1992), which postulates in the null hypothesis that the time series is trend stationary, against the alternative that it contains a stochastic trend.

The data generation process of the KPSS test is given by:

$$\begin{gathered} x_{it} = \mu t + z_t + u_t \\ z_t = z_{t-1} + e_t \end{gathered} \qquad (3)$$

Where x_{it} is the sum of a deterministic trend (μt), a random walk (z_t) and a stationary residual variable (u_t) and where $e_t \sim niid(0, \Omega)$. The null hypothesis of stationarity is given by $\Omega = 0$ where the initial value z_0 is a constant. Given that u_t is a stationary residual variable, then x_{it} is a trend stationary process (TSP). Indeed, given the null hypothesis $\Omega = 0$, the residuals e_t must all be zero and, therefore, $z_t = z_{t-1}, \forall t$, which is a constant. Thus, under the null hypothesis, the first equation in (3) represents a trend stationary process. The test statistic of the KPSS is a Lagrange Multiplier test where the numerator is the sum of squared residuals obtained from regressing x_{it} on a constant and a deterministic trend and the denominator is an estimator of the variance of the residuals u_t.

Another alternative to the tests described before is the Phillips-Perron (PP) Unit Root Tests (Phillips and Perron, 1988). Phillips and Perron have developed a more comprehensive theory of unit root nonstationarity. This method uses nonparametric statistical methods to take care of the serial correlation in the error terms without adding lagged difference terms. Brooks (2008:330) refers that this “test often gives the same conclusion as the ADF test”.

Stationarity tests have stationarity under the null hypothesis, reversing the null and alternative under the Dickey-Fuller and Phillips-Perron approaches. Thus, under stationarity tests, the data will appear stationary by default if there is little information in the sample. One such stationarity test is the KPSS test. Brooks (2008:331) argues that the results of this test can be compared with the ADF/PP procedure to see whether the same conclusion is drawn. The null and alternative hypotheses under each testing approach are as follows in Table 1:

Table 1 - Nonstationarity and Stationarity Hypothesis for Unit Root Tests

ADF/PP	**KPSS**
$H_0: x_t \sim I(1)$	$H_0: x_t \sim I(0)$
$H_1: x_t \sim I(0)$	$H_1: x_t \sim I(1)$

There are four possible outcomes:

1. Reject H_0 (ADF/PP) and Do not Reject H_0 (KPSS);
2. Do not Reject H_0 and Reject H_0;
3. Reject H_0 and Reject H_0;
4. Do not Reject H_0 and Do not Reject H_0.

For the conclusions to be robust, the results should fall under outcomes 1 or 2, which would be the case when both tests concluded that the series is stationary or non-stationary, respectively. Outcomes 3 or 4 imply conflicting results. The joint use of stationarity and unit root tests is known as confirmatory data analysis.

4.2 COINTEGRATION AND EC MODEL

Econometric theory says that cointegration is a rigorous way of defining stable long-term relationships between variables. So, this method was used to test and estimate the potential long-run relationship between electricity prices and fuel costs.

We will investigate the relationships between the Spanish electricity spot prices and fuel prices using the Johansen test. The Johansen test is based on a vector autoregressive (VAR) system. As in Johansen and Juselius (1990), a vector x_t, containing the N variables to be tested for cointegration, is assumed to be generated by an unrestricted k^{th} order vector autoregression in the levels of the variables:

$$x_t = \Pi_1 x_{t-1} + \cdots + \Pi_k x_{t-k} + \Phi D_t + \mu + e_t \tag{4}$$

where each Π_i is a $(N \times N)$ matrix of parameters, μ a vector of constant terms and $e_t \sim niid(0, \Omega)$. The VAR system of equations in (4) written in error correction form (ECM) is:

$$\Delta x_t = \sum_{i=1}^{k-1} \Gamma_i \Delta x_{t-i} + \Pi_k x_{t-k} + \mu + e_t \tag{5}$$

Where Δ is the first difference operator, with $\Gamma_i = -I + \Pi_1 + \cdots + \Pi_i$ and $\Pi_k = -I + \Pi_1 + \cdots + \Pi_k$. Hence, Π_k is the long-run 'level solution' to (4). If x_t is a vector of $I(1)$ variables, the left-hand side and the first $(k-1)$ elements of (5) are $I(0)$, and the last element of (5) is a linear combination of $I(1)$ variables. Given the assumption on the error term, this last element must also be $I(0)$: $\Pi_k x_{t-k} \sim I(0)$. Hence, either x_t contains a number of cointegration vectors, or Π_k must be a matrix of zeros. The rank of Π_k, 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 $\Pi_k = 0$, 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 factorize Π_k; $-\Pi_k = \alpha\beta'$, 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. Two asymptotically equivalent tests exist in this framework, the trace test and the maximum Eigenvalue test.

The test for cointegration between different variables is calculated by looking at the rank of the Π matrix via its eigenvalues[33]. The rank of a matrix is equal to the number of its characteristic roots (eigenvalues) that are different from zero. The eigenvalues, denoted λ_i are put in ascending order $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_g$. If the λs are roots, in this context they must be less than 1 in absolute value and positive, and λ_1 will be the largest (i.e. the closest to one), while λ_g will be the smallest (i.e., the closest to zero). If the variables are not cointegrated, the rank of Π will not be significantly different from zero, so $\lambda_i \approx 0, \forall_i$. The test statistics actually incorporate $\ln(1-\lambda_i)$, rather that the λ_i themselves, but still, when $\lambda_i = 0, \ln(1-\lambda_i) = 0$.

There are two test statistics for cointegration under the Johansen approach, which are formulated as:

$$\lambda_{trace}(r) = -T\sum_{i=r+1}^{g} ln\left(1-\hat{\lambda}_i\right) \qquad (6)$$

and

$$\lambda_{\max}(\mathrm{r}, \mathrm{r}+1) = -\mathrm{T}\ln\left(1-\hat{\lambda}_{\mathrm{r}+1}\right) \qquad (7)$$

Where r is the number of cointegrated vectors under the null hypothesis and $\hat{\lambda}_i$ is the estimated value of the i^{th} ordered eigenvalues from the Π matrix. Intuitively, the larger is the

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[33] Strictly, the eigenvalues used in the test statistics are taken from rank-restricted product moment matrices and not of Π itself.

$\hat{\lambda}_i$, the more large and negative will be $ln(1-\hat{\lambda}_i)$ and hence the larger will be the test statistic. Each eigenvalues will have associated with it a different cointegrating vector, which will be eigenvectors. A significantly non-zero eigenvalues indicates a significant cointegrating vector.

λ_{trace} is a joint test where the null is that the number of cointegrating vectors is less than or equal to r against an unspecified or general alternative that there are more than r. It starts with p eigenvalues, and then successively the largest is removed. $\lambda_{trace}=0$ when all the $\lambda_i=0$, for $i=1,\dots,g$.

λ_{max} conducts separate tests on each eigenvalues, and has as its null hypothesis that the number of cointegrating vectors is r against an alternative of $r+1$.

Johansen and Juselius (1990) provide critical values for the two statistics, The distribution of the test statistics is non-standard, and the critical values depend on the value of $g-r$, the number of non-stationary components and whether constants are included in each of the equations. If the test statistic is greater than the critical value from Johansen's tables, reject the null hypothesis that there are r cointegrating vectors in favour of the alternative that there are $r+1$ (for λ_{trace}) or more than r (for λ_{max}). The testing is conducted in a sequence and under the null, $r=0,1,\dots,g-1$ so that the hypothesis for λ_{max} are:

$$\begin{array}{ccc} H_0\colon r=0 & versus & H_1\colon 0<r\le g \\ H_0\colon r=1 & versus & H_1\colon 1<r\le g \\ H_0\colon r=2 & versus & H_1\colon 2<r\le g \\ \vdots & \vdots & \vdots \\ H_0\colon r=g-1 & versus & H_1\colon r=g \end{array}$$

The first test involves a null hypothesis of no cointegrating vectors (corresponding to Π having zero rank). If this null is not rejected, it would be concluded that there are no cointegrating vectors and the testing would be completed. However, if $H_0\colon r=0$ is rejected, the null that there is one cointegrating vector (i.e. $H_0\colon r=1$) would be tested and so on. Thus the value of r is continually increased until the null is no longer rejected.

r is the rank of Π. Π cannot be of full rank (g) since this would correspond to the original x_t being stationary. If Π has zero rank, then by analogy to the univariate case, Δx_t depends only on Δx_{t-i} and not on x_{t-1}, so that there is no long-run relationship between the elements of x_{t-1}. Hence there is no cointegration. For $1<rank(\Pi)<g$, there are r cointegrating vectors. Π is then defined as the product of two matrices, α and β', of dimension $(g\times r)$ and $(r\times g)$, respectively, i.e.:

$$\Pi=\alpha\beta' \qquad (8)$$

The matrix β gives the cointegrating vectors, while α gives the amount of each cointegrating vector entering each equation of the VECM, also known as the “adjustment parameters”.

The VEC model represented in (5) can be interpreted for example as a relationship between prices and returns in a given market. What it says is that the current returns or price changes are a linear function of previous returns or price changes and historical prices. Such historical prices form a long-run or equilibrium relationship, where the involved variables co-move over time independently of the existence of stochastic trends in each of them, so that their difference is stable. The long-run residuals measure the distance of the system to equilibrium at each moment t, which may be due to the impossibility of the economic agents to adjust instantaneously to new information or to the short-run dynamics also present in the data. There is, therefore, a whole complex adjustment process involving short-run and long-run dynamics when the variables are cointegrated.

4.3 COINTEGRATED RELATIONSHIP PROPERTIES

4.3.1 EXOGENEITY

Economic variables are often classified into two broad categories, endogenous and exogenous:

- **Endogenous variables** are the equivalent of the dependent variable in the single-equation regression model;
- **Exogenous variables** are the equivalent of the n variables, or regressors, in such a model, provided the n variables are uncorrelated with the error term in that equation.

To keep the exposition simple, suppose we consider only two variables, y_t and x_t, and further suppose we regress y_t on x_t. We say that x_t is weakly exogenous if y_t also does not explain x_t. In this case estimation and testing of the regression model can be done, conditional on the values of x_t. As a matter of fact, you will realize that our regression modelling was conditional on the values of the n variables. x_t is said to be strongly exogenous if current and lagged y values do not explain (i.e., no feedback relationship). And x_t is super-exogenous if the parameters in the regression of y on x do not change even if the x values change; that is, the parameter values are invariant to changes in the values of x.

“The reason for distinguish the three types of exogeneity is that, in general, weak exogeneity is all that is needed for estimating and testing, strong exogeneity is necessary for forecasting and super exogeneity for policy analysis (Cuthbertson *et al.*, 1990)”.

The factor loadings α are of interest as they contain information about exogeneity (Johansen and Juselius, 1990), and therefore also about price leadership. If a row in α contains only zeros (or in our case one element since α is a column vector), the price in question will be weakly exogenous, or determined outside of the system. Hence, if the factor loading parameter in the equation for the exchange rate is zero, the data indicate that the exchanges rate is determined outside of the system. Furthermore, if the factor loading parameter associated with one of the prices is zero, this price will be determined outside of the system, and therefore be the price leader. With one cointegration vector, at least one factor loading parameter must be different from zero (Johansen and Juselius, 1990). Please also note that only in the case when just one factor loading parameter is different from zero, there will be no simultaneity problems if a system is represented with a single equation (normalized on the correct variable).

The test used to verify the presence of weak exogeneity brings into play the matrix α in which contains information on the dynamic adjustment of the long run relationships. Thus, in order to test whether the price of product i drives the price of product j in a bivariate cointegrating relation, one can use a test of the null hypothesis that $\alpha_{i1} = 0$ $(i = 1, 2)$. This test can be applied to all price combinations of relevance to our study. If the null hypothesis is not rejected then, one says that the endogenous variable i is weakly exogenous with respect to the parameters β (Johansen, 1991). This test follows a χ^2 distribution with one degree of freedom.

Strong exogeneity can be confirmed by the principle of Granger causality, after testing the weak exogeneity for a certain variable. Granger causality alone is neither necessary nor sufficient to establish exogeneity. On the other hand, Granger causality is necessary (but not sufficient) for strong exogeneity.

4.3.2 GRANGER CAUSALITY

In econometric terms it is often necessary in practice to define a concept of “causality” which identifies the type of relationship between two or more variables.

The concept of causality that this section aims to analyze is called Granger causality (Granger, 1969). This type of causality is usually examined or tested in the context of VAR models, which contributed to make it quite popular.

Although regression analysis deals with the dependence of one variable on other variables, it does not necessarily imply causation. In other words, the existence of a relationship between variables does not prove causality or the direction of influence. But in regressions involving time series data, the situation may be somewhat different because time does not run backward. That is, if event X happens before Y, then it is possible that X is causing Y. However, it is not possible that Y is causing X. This is roughly the idea behind the so-called Granger causality test.

As noted above, one way to analyze the extent of market integration, is by using Granger causality tests (Granger, 1969) which can be defined as follows: X_{2t} Granger causes X_{1t} if, ceteris paribus, the past values of X_{2t} help to improve the current forecast of X_{1t}, that is:

$$MSE\left(\hat{X}_{1t} \middle| I_{t-1}\right) < MSE\left(\hat{X}_{1t} \middle| I_{t-1} \backslash IX_{2,t-1}\right) \qquad (9)$$

where MSE is the mean squared error, I_{t-1} represents the set of all past and present information existing at moment $t-1$, $IX_{2,t-1}$ represents the set of all past and present information existing on X_2 at moment $t-1$, i.e., $IX_{2,t-1} = \{X_{21}, X_{22}, \dots, X_{2t-1}\}$, X_{1t} is the value of X_1 at the moment t ($X_{1t} \subset I_t$) and $\hat{X}_{it}$ is a non biased predictor of X_{1t}. On the other hand, X_{2t} instantaneously causes X_{1t} in the sense of Granger if, ceteris paribus, the past and present values of X_{2t} help to improve the prediction of the current value of X_{1t}, that is:

$$MSE\left(\hat{X}_{1t} \middle| I_t \backslash X_{1t}\right) < MSE\left(\hat{X}_{1t} \middle| I_t \backslash IX_{2,t}, X_{1t}\right) \qquad (10)$$

Given these definitions, consider the following ADL(p, q) price relationship:

$$X_{it} = \theta + \sum_{k=1}^{p} \rho_{ik} X_{1,t-k} + \sum_{j=0}^{q} \beta_j X_{2,t-j} + \nu_{it} \qquad (11)$$

where X_{it} ($i = 1, 2$) denotes the prices (in natural logs) of product i at time t, ρ_{ik} captures the extent of autocorrelation in X_{it}, β_{ij} measures the relationship between prices (in levels and lags) and ν_{it} is a white noise disturbance. One can say that X_{2t} causes X_{1t} if the null hypothesis that all parameters β_{ij} are simultaneously zero is rejected. The relationship can be bidirectional and, in this case, we say that there is a feedback relationship. If there is just one unidirectional causal relationship, then one of the markets can effectively influence the other market prices, but the reverse is not true. If the null hypothesis is not rejected in both cases, then there is no causal relationship between the underlying prices and one can say that they do not belong to the same market space.

Gujarati and Porter (2009:654) refer that causality can be distinguished in four types, as follows:

1. Unidirectional causality from X_2 to X_1 is indicated if the estimated coefficients on the lagged X_2 are statistically different from zero as a group (i.e. $\sum \beta_{1j} \neq 0$) and a set of estimated coefficients on lagged X_1 is not statistically different from zero (i.e. $\sum \beta_{2j} \neq 0$);
2. Unidirectional causality from X_1 to X_2 is indicated if the estimated coefficients on the lagged X_1 are statistically different from zero as a group (i.e. $\sum \beta_{2j} \neq 0$) and a set of estimated coefficients on lagged X_2 is not statistically different from zero (i.e. $\sum \beta_{1j} \neq 0$);
3. Feedback or Bilateral causality is suggested when the sets of lagged X_1 and X_2 coefficients are statistically significantly different from zero in both regressions;
4. Independence is suggested when the sets of lagged X_1 and X_2 coefficients are not statistically significant in both regressions.

More generally, since the future cannot predict the past, if variable X_1 (Granger) causes variable X_2, then changes in X_1 should precede changes in X_2. Therefore, in a regression of X_2 on other variables (including its own past values) if we include past or lagged values of X_1 and it significantly improves the prediction of X_2, then we can say that X_1 (Granger) causes X_2.

4.3.3 PROPORTIONALITY

The Johansen procedure allows hypothesis testing on the coefficients α and β, using likelihood ratio tests (Johansen and Juselius, 1990). In this case, restrictions on the parameters in the cointegration vectors β should be considered. More specifically, in our case there are two data series in the x_t vector. Provided that the data series cointegrate and we find one cointegration vector due to bivariate cointegration, the rank of $\Pi = \alpha\beta'$ is equal to 1 and α and β are (2×1) vectors. A test of full price transmission is a test of whether

$\beta' = (1, -1)$ and is distributed as $\chi^2(2)$. This restriction can be tested for each pair of prices making $\beta_{11} = 1$ and $\beta_{12} = -1$ in matrix β'.

4.3.4 ASYMMETRY

Two important tests are used for testing asymmetry, the threshold autoregressive (known as TAR) and momentum threshold autoregressive (known as MTAR) models as in Enders and Granger (1998), Enders and Siklos (2001) and Enders (2001). These models allow verifying asymmetries in the dynamics of the adjustment between the Spanish electricity spot prices and the other independent data in study (fuel prices and electricity spot prices from near countries).

More specifically, let the long-run relationship among electricity prices and fuel costs be represented by:

$$pool_{es} = \beta_0 + \beta_1 p + e_t \qquad (12)$$

Where e_t is the equilibrium error. Examination of the long-run relationship using the TAR and M-TAR models requires estimating Equation (12), obtaining the residuals, $\hat{e}_t$, estimating the following modified ADF model:

$$\Delta\hat{e}_t = \rho_1 M_t \hat{e}_{t-1} + \rho_2 (1 - M_t)\hat{e}_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta\hat{e}_{t-i} + u_t \qquad (13)$$

Where $u_t \sim niid(0, \Omega)$. The Heaviside indicator, M_t, differs between the TAR and MTAR models. In the TAR model M_t is set according to:

$$\begin{array}{lll} M_t = 1 & if & \hat{e}_{t-1} \geq 0 \\ M_t = 0 & if & \hat{e}_{t-1} < 0 \end{array} \qquad (14)$$

While in the M-TAR model, it is set as according to:

$$\begin{array}{lll} M_t = 1 & if & \Delta\hat{e}_{t-1} \geq 0 \\ M_t = 0 & if & \Delta\hat{e}_{t-1} < 0 \end{array} \qquad (15)$$

TAR and M-TAR models allow the residuals to exhibit different degrees of autoregressive decay depending on the behaviour of the lagged residual and its first-difference respectively.

TAR model allows for different coefficients for positive and negative variations. "A sufficient condition for the stationarity of e_t is $-2 < (\rho_1, \rho_2) < 0$" (Menezes and Dionísio, 2003).

The TAR model is also designed to capture asymmetrically "deep" movements in the series of the deviations from the long-run equilibrium. Furthermore, the M-TAR model allows the residual series to exhibit more momentum in one direction than the other, useful to capture the possibility of asymmetrically "steep" movements in the series.

The test statistic Φ_μ and Φ_μ^* are used to test the null hypothesis of no-cointegration (that is $\rho_1 = \rho_2 = 0$, which we obtain the sample values of the *F*-statistic) in the TAR and M-TAR models respectively. Critical values are reported in Enders and Siklos (2001). If the null hypothesis of no cointegration is rejected, then one may proceed to test for the null hypothesis of symmetry (that is $\rho_1 = \rho_2$, hypothesis tested using the usual F-statistic). If the null hypothesis of symmetry is rejected and $\rho_1 > \rho_2$ then the model exhibits more decay for positive (changes in) errors.

5 DESCRIPTIVE STATISTICS AND GRAPHICAL OVERVIEW

This section carries out a descriptive analysis of the daily Spanish wholesale electricity spot prices in euros per MWh (POOL_ES), the daily Portuguese wholesale electricity spot prices in euros per MWh (POOL_PT), the daily French wholesale electricity spot prices in euros per MWh (PNX), the daily coal OTC prices in euros per ton (API2 and API4 index), the daily European crudes OTC prices in euros per barrel[34] (BRENT, FORTIES and URALS), the daily gasoil OTC prices as a European refined oil product in euros per ton (GO_ARA) and the daily European natural gas OTC prices in euros per MWh (NBP, TTF and ZEE).

The daily Spanish, Portuguese and French electricity spot prices are defined by the arithmetic average of the day-ahead hourly price per day considered in the study period. The day-ahead wholesale electricity spot prices for Spain (POOL_ES) and Portugal (POOL_PT) are formed in the OMEL power exchange. The French electricity spot prices are formed in EPEX Spot power exchange, a former cooperation between the French Power Exchange Powernext (PNX) and the German Power Exchange (EEX).

The indicated coal price series, as mentioned in Chapter 2, represent the CIF price reference (API2) and the FOB price reference (API4) for Europe. The difference between API2 and API4 gives an approximation to the freight cost for the maritime route between South Africa and North-western Europe.

The indicated crude oil price series have the following specifications:

- **Brent Crude Oil (BRENT):** UK Brent crude oil is a blend of crude oil from various fields in the East Shetland Basin between Scotland and Norway in the North Sea. The crude is landed at the Sullom Voe terminal and is used as a benchmark for the pricing of much of the world’s crude oil products. Currently, the API gravity[35] is estimated at 38 degrees and the sulphur content at 0.45% sulphur, but the qualities of all crude oils tend to change over time;

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[34] Standard measure of quantity for crude oil and petroleum products (Barrel, US Barrel and standard barrel are all equal to 42 US gallons).

[35] The American Petroleum Institute gravity, or API gravity, is a measure of how heavy or light petroleum liquid is compared to water.

- **Forties Crude Oil (FORTIES):** Physical Forties crude oil is produced in the Forties oilfield (the largest oilfield in the UK sector of the North Sea, 110 miles east of Aberdeen). The assessment for Forties blend is based on FOB Hound Point, UK. Currently, the API gravity of Forties is 40.3 degrees and the sulphur content is around 0.58%;
- **Urals Crude Oil (URALS):** The assessment for Urals is based in Russia. Urals is an oil benchmark that aggregates a mix of Russian oil exports. It is a mix of heavy crude oil from the Volga and Urals regions with light crude oil from western Siberia. Urals crude oil is supplied through Novorossiysk pipeline system and Druzhba pipeline. API gravity is approximately 32 degrees. The sulphur content reflects the normal pipeline quality which is typically 1.3%.

Due to different crude oil specifications, these European crude oil prices will be considered in this analysis.

Gasoil price data (GO_ARA) has also been chosen to represent a refined oil product because of its market liquidity. One gasoil price reference for Europe is the European NWE FOB gasoil (typically the FOB assessment is derived at a freight differential to the CIF assessment, based on the following routes: Ventspils, Antwerp, Stockholm) assessments currently reflect 0.1% maximum sulphur as a result of European Union directives aimed to reduce the sulphur in gasoil to 0.1% maximum.

In Europe, as mentioned in Chapter 2, there are three major natural gas trading hubs interconnected between them. In this study, natural gas prices data from NBP, TTF and ZEE will also be considered.

The study covers the period starting on July 1st, 2007 and ending on October 31th, 2009. This sample period was chosen to coincide with the date in which MIBEL (the Iberian Electricity Market) started (July 1st, 2007).

All data came from the market information platform THOMSON REUTERS 3000XTRA. These data series are denominated in euros. In series quoted in US dollars such as crude oil data, coal data and gasoil data, a daily exchange rate conversion have been applied using the daily foreign exchange spot rate USD/EUR. In series quoted in British pounds (GBP) such as NBP data and ZEE data, a daily exchange rate conversion has also been applied using the daily foreign exchange spot rate GBP/EUR.

Working days are used because, although POOL_ES, PNX and POOL_PT are available for all calendar days, the other data are only available for working days. In the case of holidays, the missing value is replaced by the last trading value.

The number of observations used in each series is 854.

For all data, a natural logarithm transformation has been computed to deal with asymmetry and nonnormality and also because it make it easier to visualize the data in analysis (the points will be spread more uniformly in the graph).

The data are analyzed using the econometric software EVIEWS for Windows V6.0.

Summary statistics of these series are shown in Table 2.

Table 2 - Summary descriptive statistics

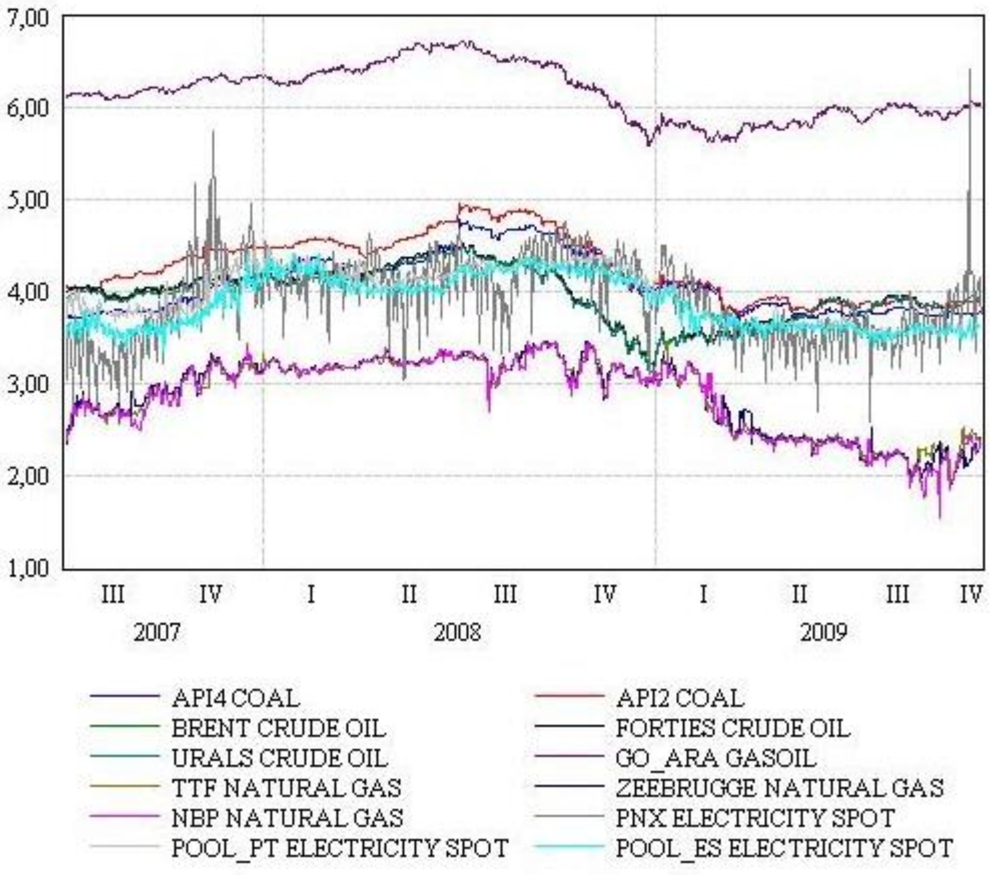
Log Descriptive Stats	API4	API2	BRENT	FORTIES	URALS	GO_ARA
Mean	4,087	4,271	3,979	3,971	3,949	6,174
Median	4,043	4,212	4,018	4,009	3,968	6,182
Maximum	4,785	4,955	4,516	4,514	4,486	6,725
Minimum	3,705	3,749	3,186	3,135	3,136	5,601
Std. Dev.	0,312	0,342	0,29	0,294	0,289	0,293
Skewness	0,514	0,217	-0,349	-0,386	-0,398	0,067
|Skewness / Std. Error of Skewness|	10.413,012	4.396,155	7.070,313	7.819,888	8.062,994	1.357,338
Kurtosis	2,024	1,798	2,447	2,556	2,587	1,950
Jarque-Bera	71,564	58,127	28,233	28,231	28,563	39,847
Probability	0,000	0,000	0,000	0,000	0,000	0,000
Sum	3.490,463	3.647,849	3.397,639	3.391,099	3.372,222	5.272,749
Sum Sq. Dev.	83,123	99,793	71,893	73,963	71,488	73,276
Observations	854	854	854	854	854	854

Log Descriptive Stats	TTF	ZEE	NBP	PNX	POOL_PT	POOL_ES
Mean	2,880	2,884	2,862	3,927	3,965	3,877
Median	3,056	3,069	3,060	3,954	3,978	3,864
Maximum	3,450	3,465	3,456	6,418	4,536	4,408
Minimum	1,946	1,895	1,524	2,586	3,481	3,336
Std. Dev.	0,395	0,415	0,423	0,439	0,297	0,282
Skewness	-0,522	-0,636	-0,615	0,122	-0,039	0,131
|Skewness / Std. Error of Skewness|	10.575,082	12.884,583	12.459,148	2.471,571	790,092	2.653,900
Kurtosis	1,854	2,020	2,070	3,814	1,421	1,462
Jarque-Bera	85,519	91,865	84,665	25,676	88,882	86,594
Probability	0,000	0,000	0,000	0,000	0,000	0,000
Sum	2.459,572	2.462,578	2.444,323	3.353,458	3.386,082	3.311,198
Sum Sq. Dev.	133,265	147,025	152,464	164,030	75,078	67,963
Observations	854	854	854	854	854	854

From the summary statistics it is possible to conclude that all data exhibit asymmetry (significant skewness[36]) and significant kurtosis; so there is not any data that follow a Gaussian distribution. This result is also confirmed by the Jarque-Bera test.

Time plots of the natural logarithm of each price series are given in Figure 19. All price series appear to be mean non-stationary, as trends through time are noticeable.

Figure 19 - Time plots of each price series transformed in natural logarithms



Source: THOMSON REUTERS

The graphical evolution of the POOL_ES, POOL_PT and PNX can be seen in Figure 20. PNX appears to be the most volatile (around 0.11), as measured by coefficient of variation. POOL_ES and POOL_PT have basically the same volatility (around 0.07). The volatility in

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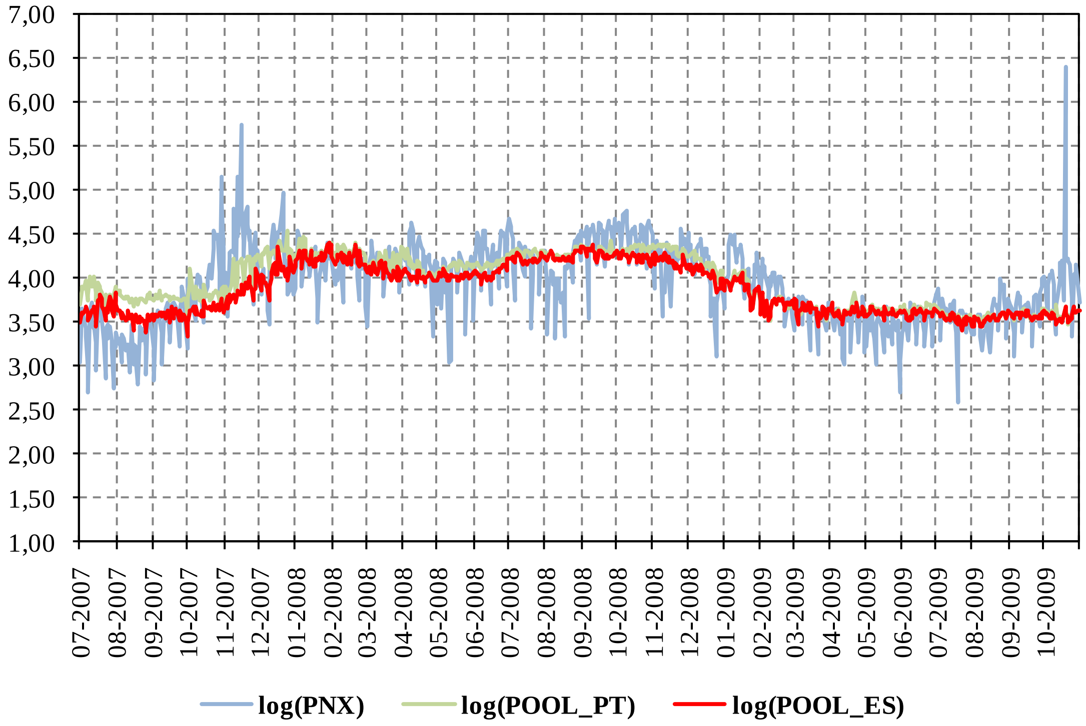
[36] A skewness coefficient is considered significant if the absolute value of the ratio (skewness / standard error of skewness) is greater than 2. The standard error of skewness: $\left(\frac{6}{N}\right)^2$.

PNX is about 1.6 greater than the volatility of the wholesale electricity spot prices formed in MIBEL. One reason that can justify this is the market liquidity of MIBEL. When compared with Powernext, Portugal and Spain combined have a spot volume traded in OMEL of around 290 TWh. Besides this, Powernext has less volume, with a total of 82 TWh of electricity traded. The reason for such less liquidity in the French electricity market is due to a major percentage of bilateral power contracts settlement between power producers and retailers. Portugal and Spain are more integrated than France and Spain (the correlation between POOL_ES and POOL_PT is 0.950; the correlation between POOL_ES and PNX is 0.694).

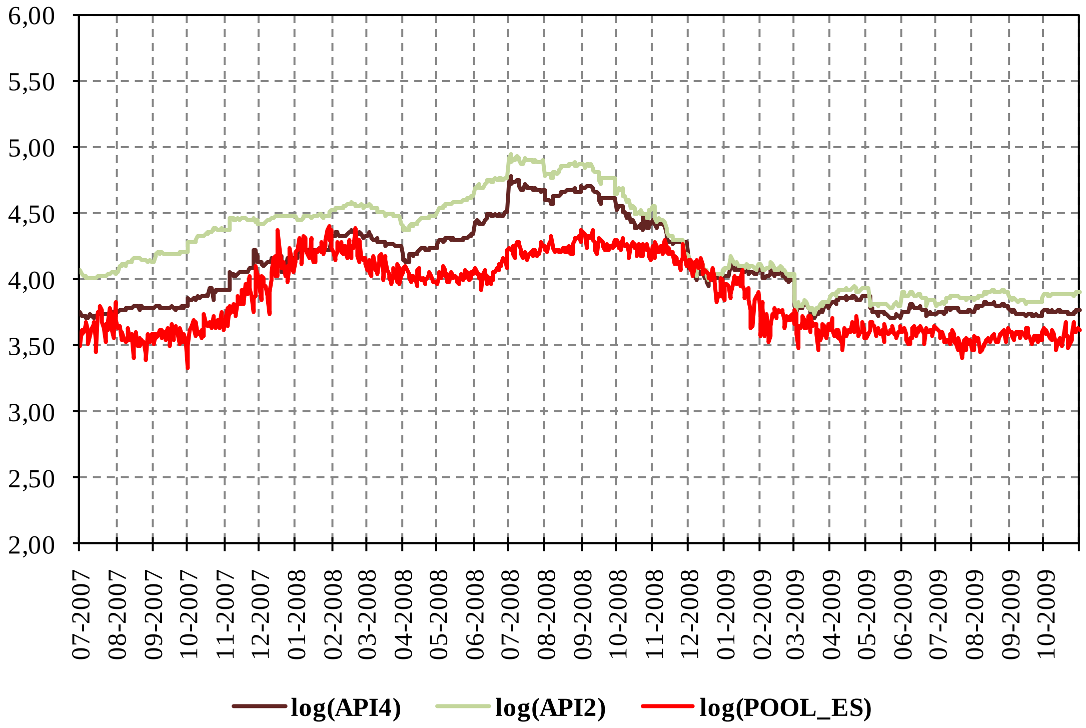
Figure 20 - Wholesale electricity spot prices



Source: THOMSON REUTERS

In Figure 21, it is possible to see the evolution of both API4 and API2 against POOL_ES. Coal prices increased steadily throughout 2007 and 2008, with rapid increases in the Asian market leading the way and illustrating the effect that Chinese demand for coal, other commodities and shipping continues to have on world markets. So, the price evolution of API4 during this period is a consequence of an increase in coal demand. In the second half of 2007 and into 2008, European coal spot prices (API2) again led the rapid increase in prices, driven by demand in that region and influenced by continuing infrastructure constraints affecting Australian exports (API3). API2 peaked in July 2008. By December 2008 however, API4 had followed API2 in their rapid fall into levels not seen since mid-2007. Both API4 and API2 have practically the same volatility of 0.08. Observing the correlations between these series, API4 is more strongly correlated with POOL_ES than API2 (the correlation between POOL_ES and API4 is 0.91; the correlation between POOL_ES and API2 is 0.83).

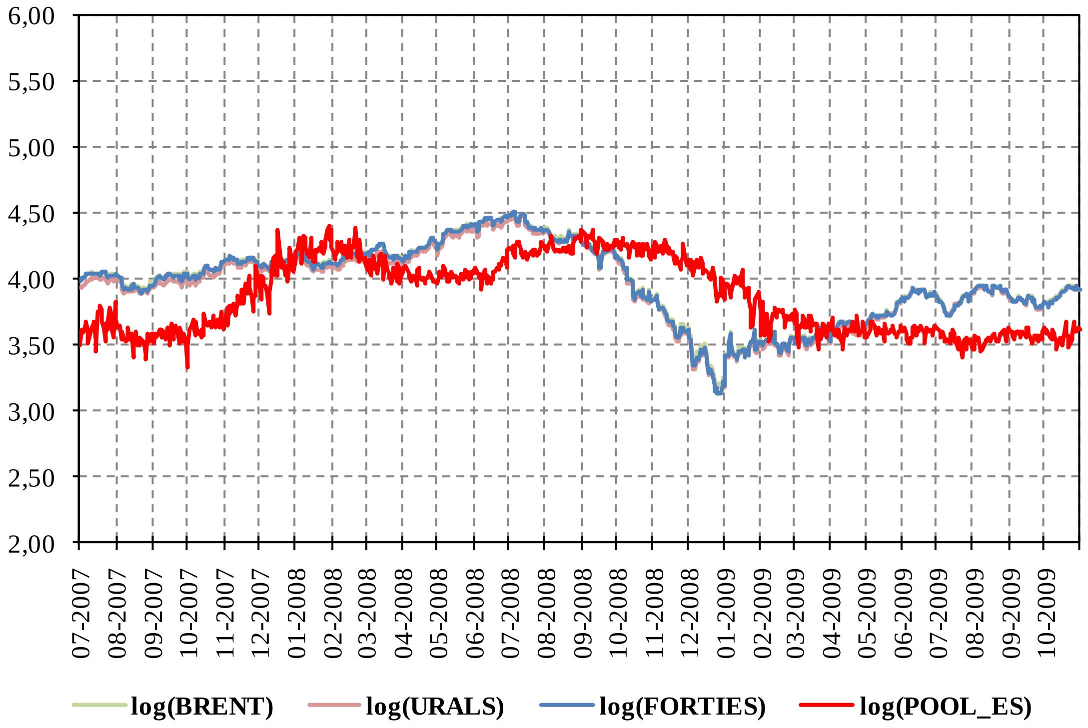
Figure 21 - Coal prices and the Spanish wholesale electricity spot prices



Source: THOMSON REUTERS

In Figure 22, it is possible to see the evolution of European Crude Oil prices (BRENT, URALS and FORTIES) against POOL_ES. These crude oil prices increased steadily throughout 2007 and 2008, reaching a maximum price in early July – a record even on an inflation-adjusted basis. However, the economy had already started to slow down, most likely not unrelated to the high price of energy and to the T financial crisis which started in September 2008 and later triggered a sharp recession – with critical implications for global energy consumption. Crude oil prices collapsed, falling by more than 70% by the end of 2008. All crude oil prices have the same volatility as POOL_ES. Observing the correlations between these series, all crude oil prices have basically the same weaker correlation levels with POOL_ES (around 0.43 and 0.45). The reason for this same correlation level is motivated by a perfect correlation between BRENT and the others European Crude Oils (URALS and FORTIES). So, it is possible to consider BRENT crude oil as a benchmark crude oil reference for Europe.

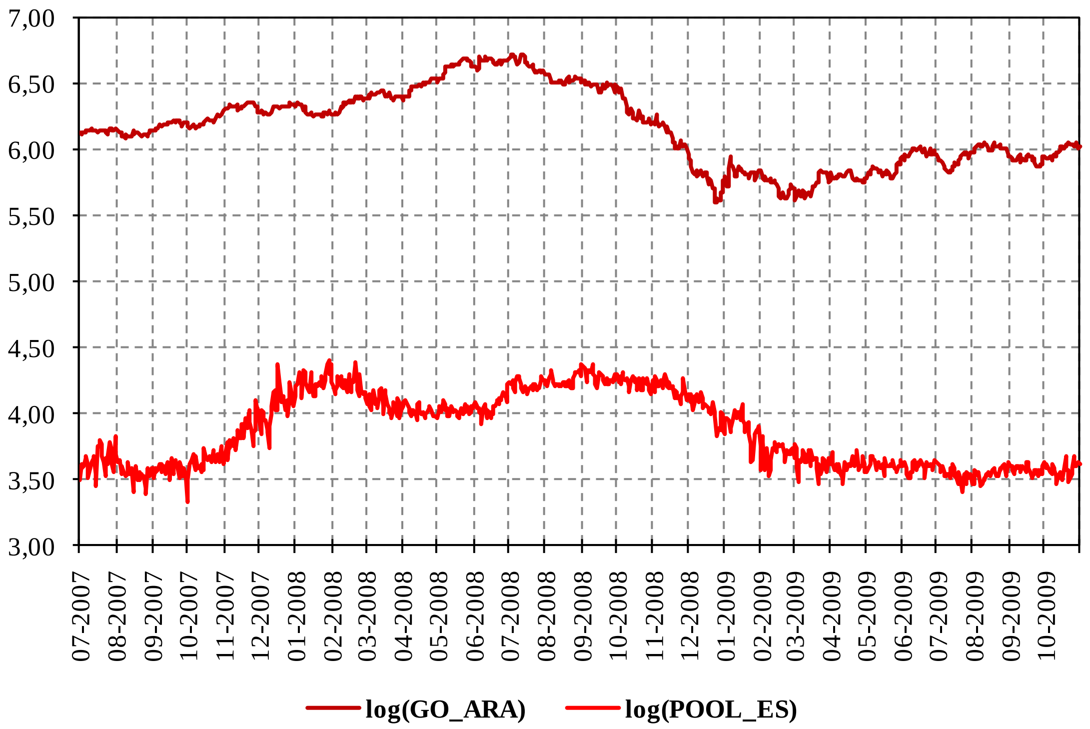
Figure 22 - European Crude Oil prices and the Spanish wholesale electricity spot prices



Source: THOMSON REUTERS

Figure 23 shows the evolution of GO_ARA against POOL_ES. GO_ARA practically follows the same trend of European Crude Oils. GO_ARA appears to be the less volatile (around 0.05) than POOL_ES. Observing the correlations between these series, GO_ARA has a stronger correlation with POOL_ES than European Crude Oils (the correlation between POOL_ES and GO_ARA is 0.635). One possible reason that can justify this level of correlation when compared with crude oil could be the inclusion of this type of refined fuel in the price formula definition of long-term natural gas contracts to supply Spanish CCGT power plants in operation and also by being one refined oil product source for the Spanish Fuel/Gas thermal power plants in operation.

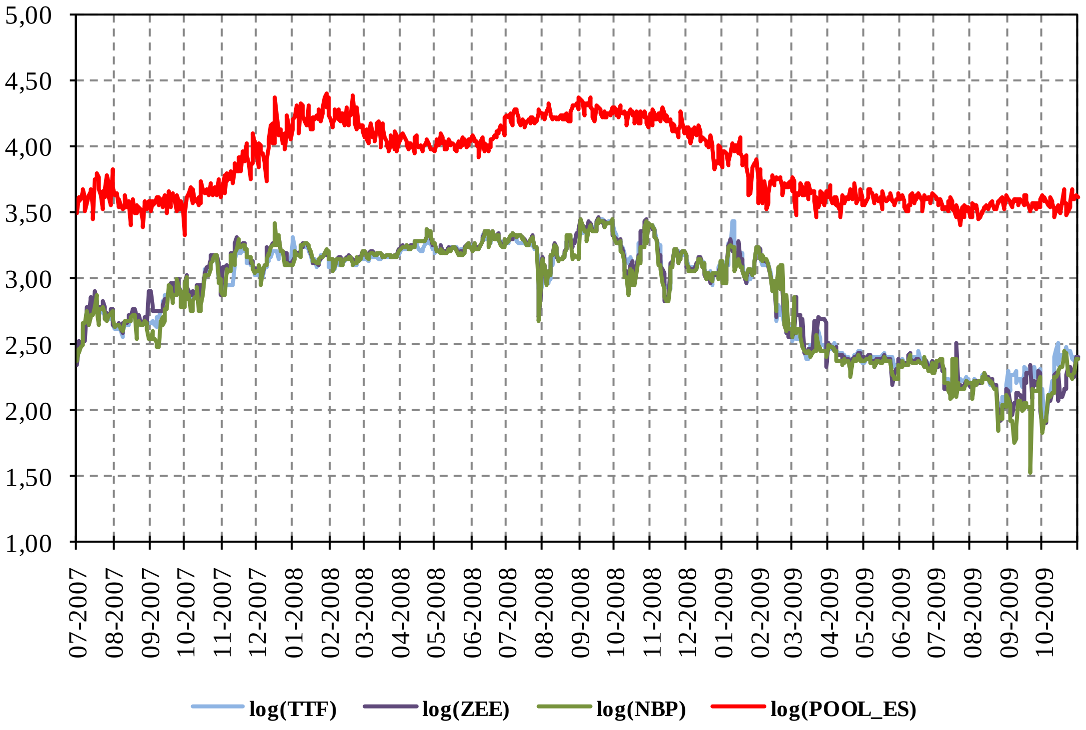
Figure 23 - Gasoil prices and the Spanish wholesale electricity spot prices



Source: THOMSON REUTERS

In Figure 24, it is possible to see the evolution of European Natural Gas prices (NBP, TTF and ZEE) against POOL_ES. In a similar manner to the prices of other energy commodities, natural gas prices were also affected by declining economic activity. Both natural gas prices have higher volatility than POOL_ES (around 0.14). Observing the correlations between these series, all natural gas prices have basically the same correlation levels with POOL_ES (around 0.81 and 0.83). The correlation levels of each of the European Natural gas prices with the others are near perfect correlation (around 0.98). Meanwhile, it seems that NBP and ZEE have a more approximated volatility value (NBP has 0.148 and TTF has 0.144) rather than TTF (with 0.137). Checking correlations between both natural gas prices, the correlation value between NBP and TTF is approximately the smaller value (0.98) when compared with other bivariate correlations. So, this distinct behaviour of TTF against NBP and ZEE can be justified by the fact that NBP and ZEE are common fungible products while TTF is not (British pounds is the currency used to quote NBP and ZEE while TTF is quoted in euros). The usage restriction of the BBL pipeline (with single flow direction of natural gas) that connects the TTF market with the NBP market could also be an important factor with strong impacts on the correlation between TTF and NBP.

Figure 24 - European Natural Gas prices and the Spanish wholesale electricity spot prices



Source: THOMSON REUTERS

6 EMPIRICAL FINDINGS

After examining Figure 19, it seems intuitively clear that the time series under analysis are nonstationary time series in the sense that they move together, which means that the difference between observations at any given time remains approximately constant throughout the whole time period. This is the intuitive idea of cointegration, introduced by Granger (1981) and later published by Engle and Granger (1987) in their seminar paper.

As has been previously mentioned, the concept of cointegration is applied to nonstationary time series; so before testing cointegration, it will be necessary to check if these time series are integrated of order one[37].

Considering cointegration as a global characteristic of the series while threshold behaviour as local characteristic (Balke and Fomby, 1997), the analysis is conducted as follows:

1. First the degree of integration of the variables was tested by using the augmented test of Dickey and Fuller (Said and Dickey, 1984) known as ADF test, the Philips–Perron test (PP) and also the Kwiatkowski–Phillips–Schmidt–Shin test (KPSS);
2. Second, bivariate cointegration analysis was made by using the Johansen Cointegration test. Both trace statistic and maximum eigenvalue statistic were used to confirm the presence of one cointegrating long-run relationship between POOL_ES and each variable in study. With the cointegration condition valid, a VEC model estimation for each cointegration relationship was made;
3. Finally, the properties of exogeneity, proportionality and asymmetry of each cointegrating relationship were analyzed.

All the empirical analysis followed the principle of parsimony proposed by Granger[38] in 1990.

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[37] I(1) in abbreviated form.

[38] If two models appear to fit the data equally well, choose the simpler model (that is the one involving the fewest parameters). This principle is proposed by Box and Jenkins (1972) when considering the modelling of time series. They suggest that the fewer parameters that have to be estimated, the better estimates will result.

6.1 UNIT ROOT TESTS AND NONSTATIONARITY

Table 3 shows the results of the ADF, PP and KPSS tests, where the Δ in front of every variable name indicates the differentiated series.

Table 3 - Unit Root and stationarity tests in levels and in first differences

Variables	ADF[a,b,e]	PP[c,f]	KPSS[d,g]
API4	-1,556821	-0,047841	0,929356 **
API2	-1,780020	-0,340710	1,548652 **
BRENT	-1,464773	-0,182589	1,343613 **
FORTIES	-1,512793	-0,190653	1,320776 **
URALS	-1,526983	-0,121613	1,233448 **
GO_ARA	-1,526558	-0,213790	1,537871 **
TTF	-2,881464	-0,186579	1,674533 **
ZEE	-3,099051	-0,133243	1,802888 **
NBP	-2,931282	-0,186595	1,716500 **
PNX	-2,627483	-0,121424	0,641809 *
POOL_PT	-1,526576	-0,194723	1,395568 **
POOL_ES	-1,715359	0,036374	0,978581 **
ΔAPI4	-28,619410 **	-28,687250 **	0,455187
ΔAPI2	-22,468920 **	-28,653440 **	0,400462
ΔBRENT	-30,018950 **	-30,052960 **	0,161225
ΔFORTIES	-30,413970 **	-30,446620 **	0,150894
ΔURALS	-30,467520 **	-30,501980 **	0,156881
ΔGO_ARA	-32,025530 **	-31,984280 **	0,206697
ΔTTF	-28,779070 **	-28,794860 **	0,417435
ΔZEE	-24,423090 **	-39,261880 **	0,391727
ΔNBP	-24,991140 **	-39,805190 **	0,338879
ΔPNX	-9,082943 **	-84,796160 **	0,086777
ΔPOOL_PT	-9,346984 **	-50,180180 **	0,261421
ΔPOOL_ES	-9,437233 **	-48,964720 **	0,337606

(**) and (*) indicate the reject of the null at 0,01 and 0,05 significance levels

Notes: a) exogenous terms in levels: constant and linear trend (MacKinnon critical values: -3.96 ~ 1% and -3.41 ~ 5%); b) exogenous terms in 1st differences: constant (MacKinnon critical values: -3.43 ~ 1% and -2.86 ~ 5%); c) exogenous terms in levels and 1st differences: none (MacKinnon critical values: -2.56 ~ 1% and -1.94 ~ 5%); d) exogenous terms in levels and 1st differences: constant (KPSS critical values: 0,73 ~ 1% and 0,46 ~ 5%); e) automatic lag length based on SIC[39]; f) automatic lag length based on Newey-West using Bartlett kernel; g) 25 lag length fixed based on Bartlett kernel.

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[39] Optimum lag lengths are based on Schwarz Information Criterion (SIC).

It emerges that all the differentiated price series are $I(1)$. However, the KPSS test shows that the rejection of null hypothesis of nonstationarity in levels $H_0\colon Y_t \sim I(0)$ is only significant at 5% for PNX. Apart from this, the results are, therefore, consistent in both cases and lead to the conclusion that the logarithm of price series[40] under analysis are, in fact, integrated of first order $I(1)$.

Thus, it is possible to conclude that all energy prices are first-difference stationary, and proceed with tests of cointegration.

6.2 COINTEGRATION AND ESTIMATED VEC MODEL

6.2.1 COINTEGRATION

Since the price series are all nonstationary and integrated of the same order, cointegration analysis is the appropriate tool for investigating the relationships between POOL_ES and the other considered prices series under analysis.

The proposed methodology for doing this is investigating the bivariate relationships between the POOL_ES and each other considered price series, considering many VAR systems as the relevant price combinations, and tested for the presence of cointegration and the optimum lag length following the well known Johansen procedure (Johansen, 1988, 1992; Johansen and Juselius, 1990), which involves a system based on a likelihood ratio test that contemplates two steps. Firstly, the lag number of VAR representation is determined using information matrices based on Akaike (1973), Hannan and Quinn (1979) and Schwarz (1978) information criteria (IC). Secondly, given the optimal lag length, the cointegration rank is obtained through the Trace test and the Maximum Eigenvalue test (both test statistics have non-standard distributions and their critical values have been tabulated by Johansen in 1988).

The two tests are used to determine the rank of the coefficient matrix Π, i.e., the Trace and the Maximum Eigenvalue test, are reported in Table 4.

The column Rank $r = p$ identifies the null hypothesis of each cointegration test performed. Here, $p = 0$ corresponds to the null hypothesis that there are no cointegrating vectors, that

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[40] In what follows, when prices are referred it means logarithm of prices.

is, the cointegrating rank is zero, and $p \leq 1$ corresponds to the null hypothesis that there is at most one cointegrating vector, that is, the cointegrating rank is less than or equal to one. The next column reports the eigenvalues for each hypothesis. The last two columns present the results of the Trace and Maximum Eigenvalue test statistics.

Table 4 - Bivariate Johansen test for cointegration

Variables	Rank	Eigenvalue	Trace Statistic	Max. Eigenvalue Statistic
POOL_ES-API4	r = 0	0,020323	17,431750 **	17,431650 **
	r ≤ 1	0,000000	0,000105	0,000105
POOL_ES-API2	r = 0	0,031431	28,362450 **	27,113000 **
	r ≤ 1	0,001471	1,249451	1,249451
POOL_ES-BRENT	r = 0	0,015429	13,286240 *	13,201600 *
	r ≤ 1	0,000001	0,084643	0,084643
POOL_ES-FORTIES	r = 0	0,014966	12,888630 *	12,802450 *
	r ≤ 1	0,000102	0,086185	0,086185
POOL_ES-URALS	r = 0	0,015037	12,913010 *	12,863390 *
	r ≤ 1	0,000058	0,049619	0,049619
POOL_ES-GO_ARA	r = 0	0,017674	15,204460 *	15,139490 **
	r ≤ 1	0,000077	0,064968	0,064968
POOL_ES-TTF	r = 0	0,026505	26,350430 **	22,806530 **
	r ≤ 1	0,004166	3,543900	3,543900
POOL_ES-ZEE	r = 0	0,028223	28,092310 **	24,306100 **
	r ≤ 1	0,004450	3,786207	3,786207
POOL_ES-NBP	r = 0	0,028129	27,942180 **	24,223540 **
	r ≤ 1	0,004370	3,718645	3,718645
POOL_ES-PNX	r = 0	0,056151	49,074460 **	49,063260 **
	r ≤ 1	0,000013	0,011192	0,011192
POOL_ES-POOL_PT	r = 0	0,024675	21,315280 **	21,211670 **
	r ≤ 1	0,000122	0,103604	0,103604

Lags Interval: 1 to 4 for all series (selected by AIC, SC and HQ criteria)

(**) and (*) indicate the reject of the null at 0,01 and 0,05 significance levels

Using the 5% significance level, both Trace and Maximum Eigenvalue statistics fail to reject the null of no-cointegration in each bivariate relationship.

However, at 1% significance level, both Trace statistic and Maximum Eigenvalue statistic tend to reject the null hypothesis in the considered crude oil prices series (BRENT, FORTIES and URALS). Moreover, the Trace statistic at 1% significance level applied to the cointegration analysis between POOL_ES and GO_ARA fails to reject the null hypothesis, suggesting the possibility of unique long-run relationships between POOL_ES and the considered coal prices, POOL_ES and the considered natural gas prices, POOL_ES and the considered wholesale electricity spot prices (PNX and POOL_PT).

Hence, at 5% significance level, it is possible to conclude that the results from the cointegration analysis indicate that there are long-run relationships between POOL_ES and each of the other considered price series, implying that each of the other considered price series is integrated with POOL_ES. This study will consider cointegration at 5% significance level to undertake the empirical analysis.

6.2.2 ESTIMATED BIVARIATE VEC MODEL

The estimated vector error correction model for each bivariate cointegrated relationship between POOL_ES and other considered price series was defined according to the deterministic trend specification[41] applied to each bivariate cointegration relationship. In addition to this, the number of lags to include in each bivariate vector error correction model was determined by the Wald Lag length Criteria[42].

Table 5 reports the coefficient estimates included in the vectors α and β for each bivariate vector error correction model between POOL_ES and each considered price reference.

The results in column β refer to the first lag of the respective variable. Moreover, the results of column coefficients α represent the residuals of the long-term equation expressed in relation to the first difference of corresponding variable.

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[41] The determinist trend specification is also selected by AIC, SC and HQ criteria in the Johansen cointegration test.

[42] The Wald Lag length Criteria carries out lag exclusion tests for each lag in the VAR. For each lag, the χ^2(Wald) statistic for the joint significance of all endogenous variables at that lag is reported for each equation separately and jointly.

Table 5 - Bivariate VEC Model

Indepent Variable	β	Test statistic$_β$ ~ *t*	α	Test statistic$_α$ ~ *t*
API4	-0,948218	-118,5870 **	-0,056292	-3,2859 **
API2	-0,770165	-9,1189 **	-0,057831	-4,1687 **
BRENT	-0,974806	-53,2769 **	-0,025529	-3,7009 **
FORTIES	-0,976917	-51,5636 **	-0,025033	-3,7039 **
URALS	-0,982637	-51,9056 **	-0,025021	-3,6871 **
GO_ARA	-0,628294	-65,3028 **	-0,026108	-2,7505 **
TTF	-0,895236	-9,2667 **	-0,033000	-2,3659 *
ZEE	-0,921927	-7,9522 **	-0,022689	-1,7782
NBP	-0,871451	-7,6251 **	-0,019970	-1,5469
PNX	-0,985181	-93,4229 **	-0,013617	-1,6433
POOL_PT	-0,979847	-224,0200 **	-0,075691	-3,0838 **

(**) and (*) indicate the reject of the null at 0,01 and 0,05 significance levels

Notes: *t* statistic critical values: -2.58 ~ 1% and -1.96 ~ 5%.

All coefficients β of the long-term relationship equation are significantly different from zero at 1%. The equation is normalized to the POOL_ES. Concerning the adjustment coefficients, α, only those for ΔZEE, ΔNBP and ΔPNX appear to be non significant at 5%, indicating that in each one of these bivariate equations there is not a long-term relationship between one of these variables and POOL_ES. The results also mean that the variables in question should be exogenous, the remainder being endogenous, as will be confirmed in the next section.

6.3 EXOGENEITY

A test for weak exogeneity will provide information as to whether any of the considered price series are price leaders, finding which price actually adjusts to maintaining the long-run equilibrium (Asche *et al.*, 1999). Following Johansen (1992, 1995), a weak exogeneity test has been applied to each series, testing every element of the adjustment matrix coefficient against zero. The likelihood ratio test is χ^2 distributed with degrees of freedom equal to the number of cointegrating vectors.

The weak exogeneity results are reported in Table 6.

Table 6 - Weak exogeneity tests

Independent Variable	Test statistic ~ χ^2	P-value	Result
API4	10,947750 **	0,000937	Reject
API2	16,313060 **	0,000054	Reject
BRENT	13,699310 **	0,000215	Reject
FORTIES	13,719620 **	0,000212	Reject
URALS	13,635230 **	0,000222	Reject
GO_ARA	7,625843 **	0,005754	Reject
TTF	4,927169 *	0,026438	Reject
ZEE	2,619982	0,105526	Fail to reject
NBP	1,955906	0,161952	Fail to reject
PNX	2,757824	0,096780	Fail to reject
POOL_PT	9,538064 **	0,002013	Reject

(**) and (*) indicate the reject of the null at 0,01 and 0,05 significance levels

The null hypotheses of weak exogeneity can be rejected in all cointegrating relations at the 5% significance level or better, except for the natural gas prices NBP and ZEE and also for the French wholesale electricity spot price (PNX).

The impact of this weak exogeneity refers to the absence of significant adjustment coefficient in the long-term relationship of the corresponding VEC Model (see column α of Table 5). Nevertheless, for each one of these weak exogenous variables remains only a short-term relationship between one of these weak exogenous variable and POOL_ES.

Weak exogeneity of NBP, ZEE and PNX also implies that these same prices cannot be used to forecast POOL_ES in the long-run. For this to be also the case in the short-run, these prices must be strongly exogenous and hence not affected by the short-run movements in POOL_ES.[43] Moreover, this weak exogeneity test shows that TTF is endogenous to POOL_ES, probably because some long-term oil indexed contracts still dominate in this market, setting up the TTF spot price.

However, some remarks[44] made by the International Energy Agency (IEA) refer that the majority of natural gas in UK is sold at the NBP prices (around 60%), while the remainder is sold by long-term oil indexed contracts. Research by Neumann *et al.* (2005) has provided evidence that there is a strong evidence of market integration between NPB and ZEE (see

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[43] See Hendry (1996) for a discussion of different exogeneity concepts and their implications.

[44] See Cronshaw *et al.* (2008).

Section 2.4 and Chapter 5), so it seems reasonable to conclude that NBP and ZEE are weakly exogenous in relation to POOL_ES because in Spain the majority of CCGT power plants have long-term oil indexed contracts for natural gas supply.

Observing the Granger causality tests (Table 7), for the considered price series in levels, to check if there were any signs of strong exogeneity for the weak exogenous variables, a causal relationship was found for the pair PNX-POOL_ES. It is possible to say that the French wholesale electricity spot price (PNX), where evidence of strong exogeneity was found, doesn't have a long-term and a short-term relationship with POOL_ES.

Table 7 - Granger Causality test

Pairwise Granger Causality	Test statistic ~ F
API4 - POOL_ES	24,29990 **
API2 - POOL_ES	15,34570 **
BRENT - POOL_ES	3,82309 *
FORTIES - POOL_ES	3,81237 *
URALS - POOL_ES	3,75001 *
GO_ARA - POOL_ES	6,01908 **
TTF - POOL_ES	11,91660 **
ZEE - POOL_ES	9,17206 **
NBP - POOL_ES	8,96279 **
PNX - POOL_ES	0,66767
POOL_PT - POOL_ES	7,41976 **

(**) and (*) indicate the reject of the null at 0,01 and 0,05 significance levels

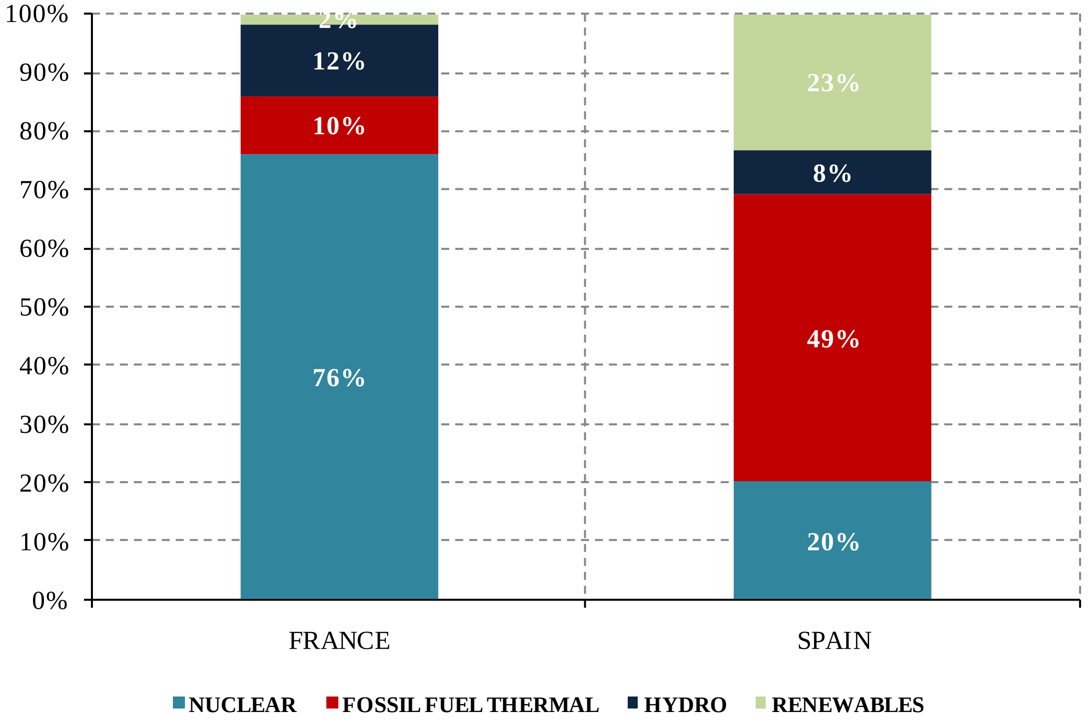
Notes: H_0: X_{jt} is not Granger Cause of Y_t ($Y_t \sim POOL\_ES_t$)

A possible justification for this strong exogeneity of PNX could be the fact that PNX is a price formed in the day-ahead spot market Powernext, separated from the Iberian market by interconnections with limited capacity (interconnections capacity restrictions between countries is also an issue that can create some obstacles to a greater market integration among adjacent markets).

Moreover, the share structure of the French wholesale electricity market is quite different from the Spanish one (in terms of levels of demand and technologies supported) with different fuel price references associated to French generation assets in the wholesale market. Correlation levels between PNX and POOL_ES and the PNX price volatility (measured by coefficient of variation) when compared with POOL_ES could demonstrate this fact as referred in Chapter 5. Looking at the 2008 generation statistics published by the

French transmission system operator RTE[45] and by the Spanish transmission system operator REE, it is possible to see the structural differences between the generation share of each technology in each country (Figure 25).

Figure 25 - France and Spain generation share per technology (2008)



6.4 PROPORTIONALITY

Finally, this section will address the issue whether POOL_ES and each considered price series, for which a long-run relationship was found, are proportional, i.e., whether the spreads and relative prices are constant.

To obtain more information about these relationships, a test for price proportionality in bivariate relationships between POOL_ES and each considered price series was carried out. The results are reported in Table 8.

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[45] Réseau de Transport d'Electricité.

Table 8 - Price proportionality tests

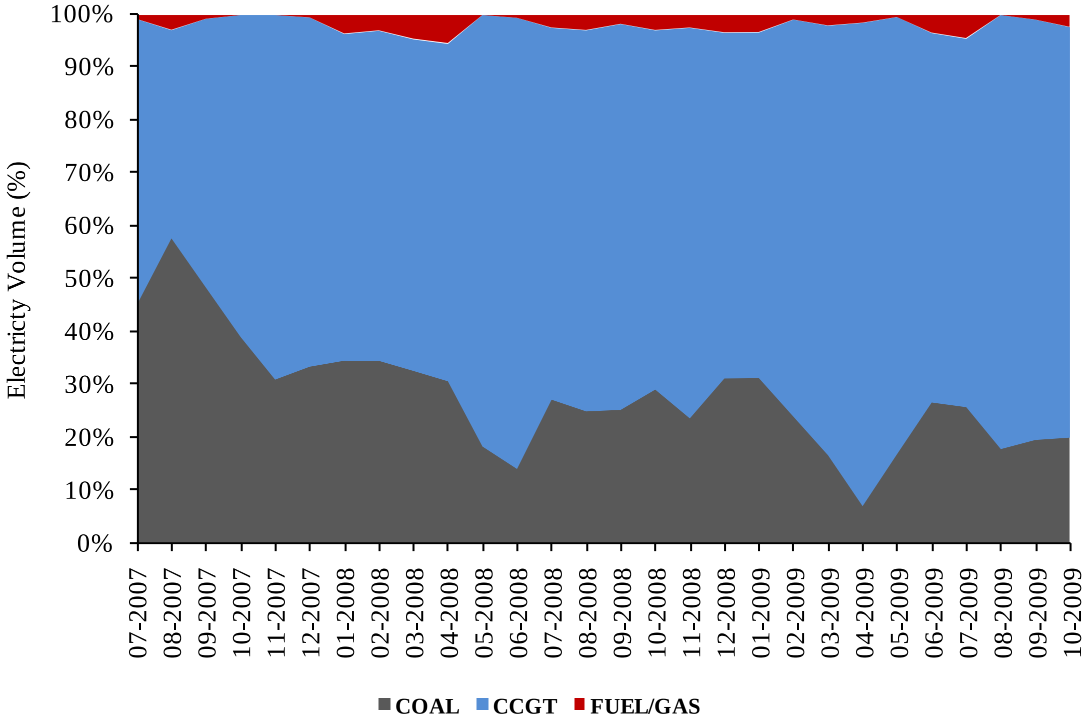
Indepedent Variable	Test statistic ~ χ^2	P-value	Result
API4	8,978173 **	0,002732	Reject
API2	4,463002 *	0,034637	Reject
BRENT	1,654986	0,198282	Fail to reject
FORTIES	1,323658	0,249937	Fail to reject
URALS	0,787408	0,374885	Fail to reject
GO_ARA	11,368120 **	0,000747	Reject
TTF	0,708763	0,399855	Fail to reject
ZEE	0,254005	0,614269	Fail to reject
NBP	0,632427	0,426467	Fail to reject
PNX	1,865580	0,171982	Fail to reject
POOL_PT	9,063862 **	0,002607	Reject

(**) and (*) indicate the reject of the null at 0,01 and 0,05 significance levels

The hypothesis of price proportionality is rejected, at 5% (significance level), between POOL_ES and coal prices (API4 and API2), gasoil prices (GO_ARA) and POOL_PT prices. The other considered prices are proportional with POOL_ES. These results indicate that changes in crude oil prices, natural gas prices and also in the French wholesale electricity spot prices are fully reflected in the prices of the Spanish wholesale electricity spot prices, but only partly in coal, gasoil and in the electricity spot prices formed in Portugal. However, it is important to remember that the following price series are weak exogenous: the natural gas prices NBP and ZEE and also PNX. So, it is not correct to affirm that changes in these variables are fully reflected in POOL_ES because these variables in question do not have long-run relationships with POOL_ES. So, the only variables that fail to reject the possibility of being proportional with POOL_ES are crude oil prices and the TTF natural gas.

In Figure 26 it is possible to see the evolution of the electricity volume by thermal technologies matched over 95% of marginal price POOL_ES. One method to check what kind of thermal technologies are setting the wholesale marginal spot price is looking at their bidding structure in terms of price, reflecting fuel costs and volume.

Figure 26 - Electricity volume by thermal technologies matched over 95% of marginal price

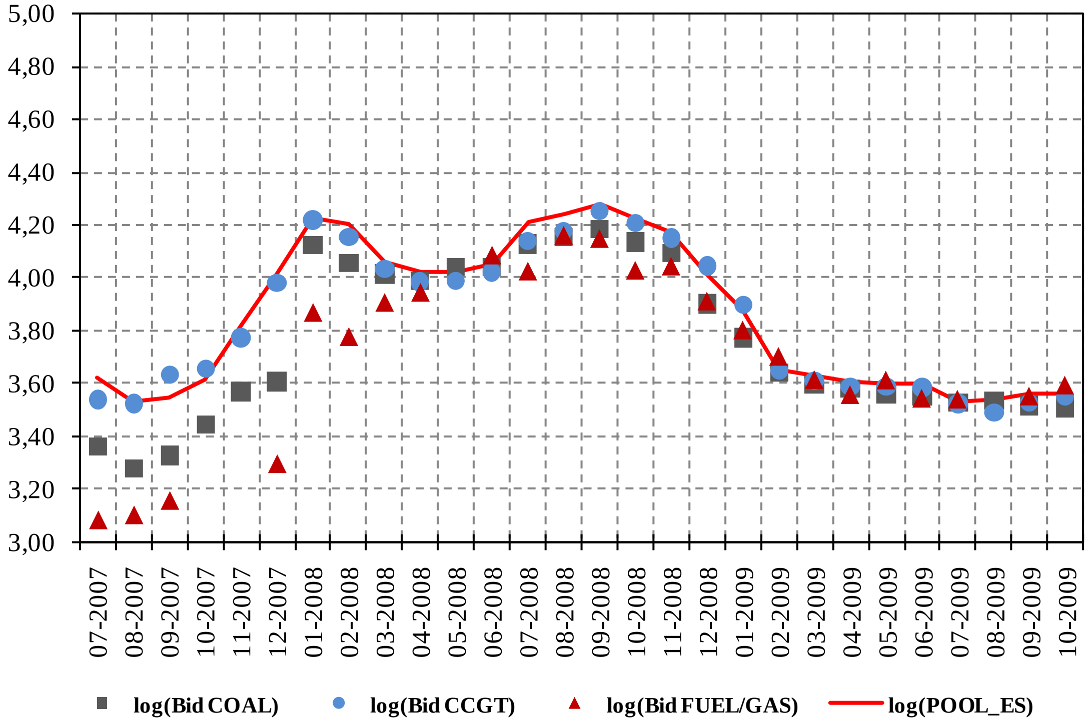


In period under analysis, 8692 GWh of thermal technologies matched over 95% of marginal price POOL_ES. From this total volume, CCGT power plants have a share of 69%, Coal power plants have a share of 28% and Fuel/Gas power plants with the residual share of 3%.

Figure 27 shows the evolution of the price bid by thermal technologies matched over 95% of marginal price and also the evolution of POOL_ES, BRENT and TTF.

Observing Figure 26 and Figure 27, it is easy to conclude that CCGT is the most used technology that basically formed the marginal price of OMEL wholesale market. So, analyzing the impact of its fuel costs into their bidding structure is an important issue to discuss.

Figure 27 - Electricity average price bid by thermal technologies matched over 95% of marginal price



The proportionality test offered conclusive results that there is a full price reflection between BRENT[46] and POOL_ES prices. TTF is also proportional with POOL_ES. Since CCGT is the major marginal technology which determines the power pool prices and CCGT fuel is natural gas, full reflection of the crude oil prices and TTF in the natural gas formula of the long-term natural gas supply should certainly occur.

Coal prices and gasoil prices are partly reflected in POOL_ES because the remaining thermal power plants have a minor influence in the determination of the marginal price of the Spanish wholesale market (coal technology with 28% and fuel/gas technology with 3%). Gasoil price, as referred in Chapter 5, can be a fuel reference for the Fuel/Gas thermal power plants.

Changes in POOL_PT are partly reflect in POOL_ES because during the analysis period, Portugal has been more an importer of electric energy than exporter (with electricity spot prices higher than the Spanish area) due to different structural market conditions in which

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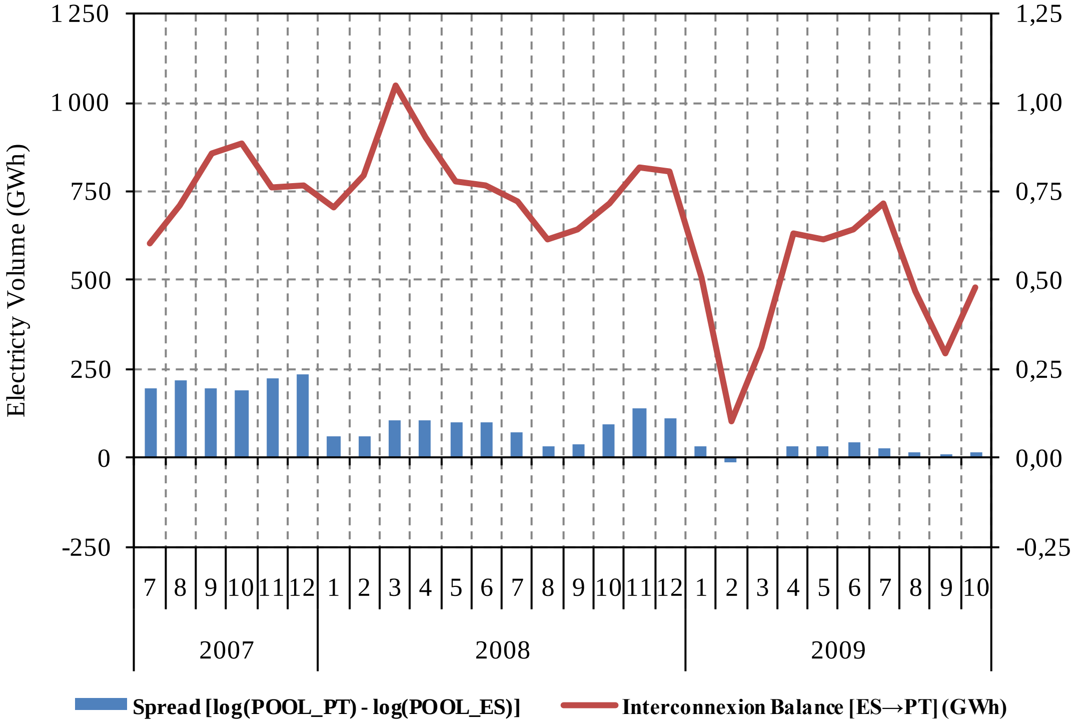
[46] To simplify this analysis, since there is a strong correlation and practically the same volatility among the considered crude oil prices, only BRENT shall be considered the benchmark crude oil reference.

Spain has more considerably efficient power generation assets than Portugal. These conditions can be found in Figure 28.

Figure 28 - Spreads evolution of the Portuguese and the Spanish OMEL spot prices



The positive spread values indicate that the Portuguese electricity spot price is higher than the Spanish electricity spot price. The use of the cross-border interconnection between Portugal and Spain also reflects the direction of the energy flow from the cheaper area to the more expensive one (in this case the majority of electric energy flows from Spain to Portugal). Cross-border available interconnection capacity is the main restriction that does not facilitate price transmission between both systems. If there were more capacity available due to new interconnections investments between Portugal and Spain, probably the convergence to a unique MIBEL spot price would occur, with full price transmission between POOL_PT and POOL_ES.

6.5 ASYMMETRY

To conclude the empirical analysis presented here, this section shows the results of asymmetry tests conducted on the residuals of each long-term equation, with the aim of confirming the symmetrical adjustment of the estimated models.

Using the threshold methodology (TAR and MTAR approach) as described in Section 4.3.4 in order to verify whether price adjustment of each considered price series in analysis is asymmetric to POOL_ES. Eleven OLS equations were estimated in the same sequence as shown in Table 9.

POOL_ES is the dependent variable, object of this study, and the above mentioned independent variables are the explanatory variables. The OLS residuals obtained from each simple regression model were then used to estimate the thresholds. Table 9 summarizes the results for the relevant tests of the null hypotheses that:

1. $\rho_1 = 0$ and $\rho_2 = 0$;
2. $\rho_1 = \rho_2 = 0$;
3. $\rho_1 = \rho_2$.

Notice that the third test only makes sense when the two previous tests conclude the rejection of the null hypothesis. That is, if the ρ coefficients estimated for the threshold are significantly different from zero, then the regression is non-trivial and testing for symmetry makes all the sense.

Table 9 - Asymmetry Tests using TAR/MTAR (1 lag length)

Independent Variable	Model	ρ_1	ρ_2	$\rho = 0$	t-Max		$\rho_1 = \rho_2 = 0$	Φ		Cointegration	$\rho_1 = \rho_2$		Asymmetry
				t-Max	99%	95%	Φ	99%	95%		*F*	*p-value*	
API4	TAR	-0,111494	-0,184364	-4,560049 **	-2,51	-2,10	28,389640 **	7,81	5,79	Yes 1%	3,731510	0,0537	No
	MTAR	-0,107977	-0,170901	-3,961973 **	-2,42	-1,99	27,926360 **	8,40	6,28	Yes 1%	2,859226	0,0912	No
API2	TAR	-0,068917	-0,085993	-3,477077 **	-2,51	-2,10	14,330550 **	7,81	5,79	Yes 1%	0,362799	0,5471	No
	MTAR	-0,063760	-0,088891	-3,055948 **	-2,42	-1,99	14,548600 **	8,40	6,28	Yes 1%	0,784827	0,3759	No
BRENT	TAR	-0,023853	-0,032231	-2,015796	-2,51	-2,10	5,068771	7,81	5,79	-	-	-	-
	MTAR	-0,023035	-0,031515	-1,778511	-2,42	-1,99	5,071714	8,40	6,28	-	-	-	-
FORTIES	TAR	-0,023250	-0,032289	-1,975827	-2,51	-2,10	5,031679	7,81	5,79	-	-	-	-
	MTAR	-0,024080	-0,030052	-1,864559	-2,42	-1,99	4,954846	8,40	6,28	-	-	-	-
URALS	TAR	-0,023519	-0,031528	-1,996520	-2,51	-2,10	4,949055	7,81	5,79	-	-	-	-
	MTAR	-0,023148	-0,030467	-1,789638	-2,42	-1,99	4,931198	8,40	6,28	-	-	-	-
GO_ARA	TAR	-0,032595	-0,044910	-2,386111 *	-2,51	-2,10	7,044946 *	7,81	5,79	Yes 5%	0,363027	0,5470	No
	MTAR	-0,041581	-0,034942	-2,503005 **	-2,42	-1,99	6,914495 *	8,40	6,28	Yes 5%	0,106275	0,7445	No
TTF	TAR	-0,083745	-0,080831	-3,761516 **	-2,51	-2,10	15,119140 **	7,81	5,79	Yes 1%	0,009859	0,9209	No
	MTAR	-0,093950	-0,071902	-3,568560 **	-2,42	-1,99	15,408500 **	8,40	6,28	Yes 1%	0,568688	0,4510	No
ZEE	TAR	-0,079749	-0,083116	-3,597526 **	-2,51	-2,10	15,001990 **	7,81	5,79	Yes 1%	0,013214	0,9085	No
	MTAR	-0,092426	-0,072499	-3,618507 **	-2,42	-1,99	15,236080 **	8,40	6,28	Yes 1%	0,465421	0,4953	No
NBP	TAR	-0,083592	-0,093549	-3,733394 **	-2,51	-2,10	16,628120 **	7,81	5,79	Yes 1%	0,108897	0,7415	No
	MTAR	-0,109961	-0,071387	-3,454529 **	-2,42	-1,99	17,419340 **	8,40	6,28	Yes 1%	1,631895	0,2018	No
PNX	TAR	-0,128050	-0,148873	-4,721764 **	-2,51	-2,10	25,182990 **	7,81	5,79	Yes 1%	0,308654	0,5787	No
	MTAR	-0,165017	-0,107710	-3,833963 **	-2,42	-1,99	26,250920 **	8,40	6,28	Yes 1%	2,325642	0,1276	No
POOL_PT	TAR	-0,137617	-0,182205	-3,712179 **	-2,51	-2,10	32,314740 **	7,81	5,79	Yes 1%	1,037058	0,3088	No
	MTAR	-0,216735	-0,133180	-4,803637 **	-2,42	-1,99	33,847480 **	8,40	6,28	Yes 1%	3,889176	0,0489	Yes 5%

(**) and (*) indicate the reject of the null at 0,01 and 0,05 significance levels

The presence of autocorrelation in the residuals of each TAR and MTAR equation was tested by Durbin–Watson (DW) statistic[47]. Results from the DW statistic shows that there is not autocorrelation in the residuals of each TAR and MTAR equation defined for each relationship between POOL_ES and each of the other considered independent variables.

The negative sign of the coefficients ρ_1 and ρ_2 guarantees the stationarity of the variables. Menezes and Dionísio (2003) have provided evidence that "…a sufficient condition for the stationarity of e_t is $-2 < (\rho_1, \rho_2) < 0$".

The test statistic Φ_μ (given by the t-Max distribution) and Φ_μ^* (given by the Φ distribution) are used to test the null hypothesis of no cointegration (i.e., $\rho_1 = \rho_2 = 0$, hypothesis tested using the usual F-statistic)) in the TAR and MTAR models respectively. Critical values are reported by Enders and Siklos (2001). If the null hypothesis of no cointegration is rejected, then one may proceed to test for the null hypothesis of symmetry (i.e., $\rho_1 = \rho_2$, hypothesis tested using the usual F-statistic).

The calculated Φ_μ and Φ_μ^* are above their critical values at 5% (significance level) except for the crude oil prices in which it wasn't possible to determine the asymmetric cointegration level using the TAR/MTAR methodology (the only way to check cointegration between symmetric variables is applying the Johansen cointegration test). The results of Enders and Siklos (2001) show that standard tests of cointegration exhibit low power in the presence of asymmetric cointegration and consequently failure to detect cointegration using standard tests may be due to presence of asymmetric behaviour.

POOL_PT is the only independent variable that is asymmetric with POOL_ES in "steep" movements (at 5% significance level there is rejection of the null hypothesis of symmetry test applied to the MTAR equation). Moreover, POOL_PT doesn't exhibit different degrees of autoregressive decay depending on the behaviour of the lagged residual and its first-difference respectively because the asymmetry test applied to TAR equation doesn't reject the null hypothesis of symmetry). The other independent variables, except the crude oil prices (due to inconclusive asymmetric cointegration test results it was not possible to perform the asymmetry test for each crude oil), are symmetric with POOL_ES.

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[47] The Durbin–Watson statistic is a statistic test used to detect the presence of autocorrelation in the residuals from a regression analysis.

7 SUMMARY AND CONCLUSIONS

Price discovery among wholesale electricity spot prices in Spain and prices of major electricity generating fuels such as crude oil, coal, gasoil and natural gas, is analyzed. By including both fuel (inputs) and electricity (output) prices, this study shows that there are dynamic relationships between input and output prices which confirm that electricity prices are directly impacted by fuel prices. It is also relevant to analyze the dynamic relationship between interconnected systems (Spain and Portugal, Spain and France), using as an input the electric spot price formed in each electrical system, because it might also have an impact on the evolution of the Spanish wholesale electricity spot prices.

The first finding in this study is that Spanish wholesale electricity spots prices, the fuel prices and wholesale electricity spot prices formed in Portugal and France are cointegrated (nonstationarity of each price data was confirmed). Therefore, there is a long-term equilibrium relationship between the Spanish wholesale electricity spot prices and coal prices, crude oil prices, gasoil prices, Portuguese wholesale electricity spot prices and TTF natural gas prices. Short-term relationships have been detected between Spanish wholesale electricity spot prices and natural gas prices from NBP and Zeebrugge natural gas hubs.

Long-term relationships between the Spanish wholesale electricity spot prices and crude oil prices, gasoil prices and TTF natural gas prices show that crude oil prices directly or indirectly (setting the price of refined oil products and natural gas) also have an impact on electricity prices, even though crude oil plays a minor role as a primary energy source for electricity generation. This increasing dependence on these inputs, coupled with the fact that CCGTs are often the price-setting technology in OMEL, implies that the link between the gas and electricity markets is crucial to an understanding of the dynamics of both markets. In addition, the long-term relationship between the wholesale electricity spot prices formed in Portugal and Spain is justified by the integration of Portugal and Spain in the same wholesale market, MIBEL, which confirms why the Portuguese wholesale electricity spot price evolution is strongly linked to the Spanish wholesale electricity spot price evolution.

The second finding determined that the French wholesale electricity spot prices were strongly exogenous to the Spanish wholesale electricity spot prices. Comparing the two electrical systems, the generation structure share of the French wholesale electricity market is quite different from the Spanish one (in terms of levels of demand and technologies supported) with different fuel price references associated to French generation assets in the wholesale market. The difference between the market liquidity in each market is also an issue that could create greater price volatility in the French market when compared to the more liquid Spanish market. Less liquidity in France is due to a higher percentage of bilateral power contracts entered into by power producers and retailers. Furthermore, another issue that can contribute for the presence of exogeneity in the French wholesale electricity spot prices is the price transmission in two interconnected systems with limited capacity, because it is a physical restriction that could create some obstacles to greater market integration among adjacent markets.

Third, no proportionality was found between coal prices, gasoil prices and the Portuguese wholesale electricity spot prices and the Spanish wholesale electricity spot prices. Coal prices and gasoil prices are partly reflected in the Spanish wholesale electricity spot price because the remaining thermal coal and Fuel/Gas power plants have a minor influence on setting up the marginal price of the Spanish wholesale electricity market. Moreover, changes in the Portuguese wholesale electricity spot prices are partly reflected in the Spanish wholesale electricity spot prices because throughout the analysis period, Portugal has imported more electric energy than exported it (with higher electricity spot prices than the ones in Spain because of the “market splitting” mechanism) due to different structural market conditions in which Spain has considerably more efficient power generation assets than Portugal.

However, there is a full price reflection between the crude oil prices, TTF natural gas and the Spanish wholesale electricity spot prices. Given the fact that CCGT is the major marginal technology that sets up the power pool prices and CCGT fuel is natural gas, full reflection of the crude oil prices and TTF in the natural gas formula of the long-term natural gas supply should certainly occur.

Fourth and finally, the Portuguese wholesale electricity spot prices are asymmetric in relation to the Spanish wholesale electricity spot prices in “steep” movements. The difference between both prices (spreads) over time may give a perspective of this movement. Basically, during the second half of 2007, following the official start of MIBEL, major spreads were found when compared with the remaining period. This fact may indicate that some structural changes occurred over time in the distribution of the generation share by technologies in Portugal.

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ANNEX

Figure 29 - Scatter Plot of POOL_ES with each variable in study

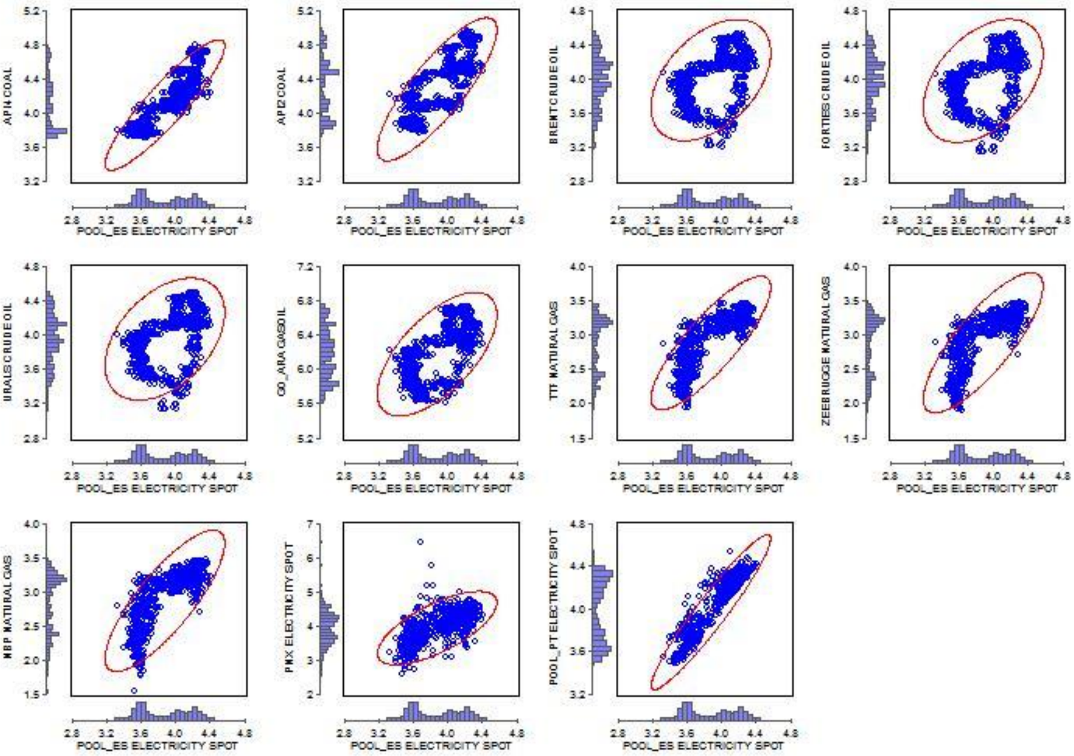


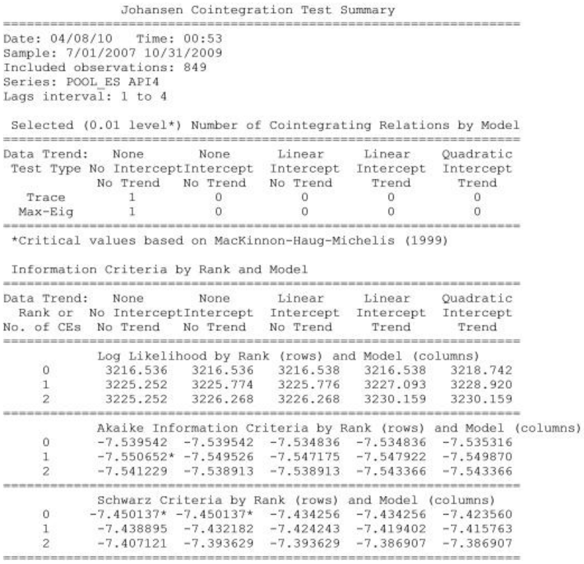
Table 10 - Correlation Matrix in natural logarithms

Log Correlation Matrix	API4	API2	BRENT	FORTIES	URALS	GO_ARA
API4	1,000					
API2	0,930	1,000				
BRENT	0,578	0,761	1,000			
FORTIES	0,569	0,752	1,000	1,000		
URALS	0,570	0,747	0,999	0,999	1,000	
GO_ARA	0,745	0,890	0,951	0,945	0,942	1,000
TTF	0,818	0,858	0,458	0,446	0,434	0,669
ZEE	0,798	0,850	0,457	0,446	0,432	0,659
NBP	0,805	0,846	0,449	0,438	0,425	0,652
PNX	0,634	0,603	0,305	0,299	0,299	0,459
POOL_PT	0,855	0,856	0,495	0,482	0,475	0,685
POOL_ES	0,906	0,834	0,448	0,437	0,435	0,635

Log Correlation Matrix	TTF	ZEE	NBP	PNX	POOL_PT	POOL_ES
API4						
API2						
BRENT						
FORTIES						
URALS						
GO_ARA						
TTF	1,000					
ZEE	0,984	1,000				
NBP	0,980	0,985	1,000			
PNX	0,664	0,628	0,643	1,000		
POOL_PT	0,873	0,852	0,852	0,679	1,000	
POOL_ES	0,834	0,806	0,813	0,694	0,950	1,000

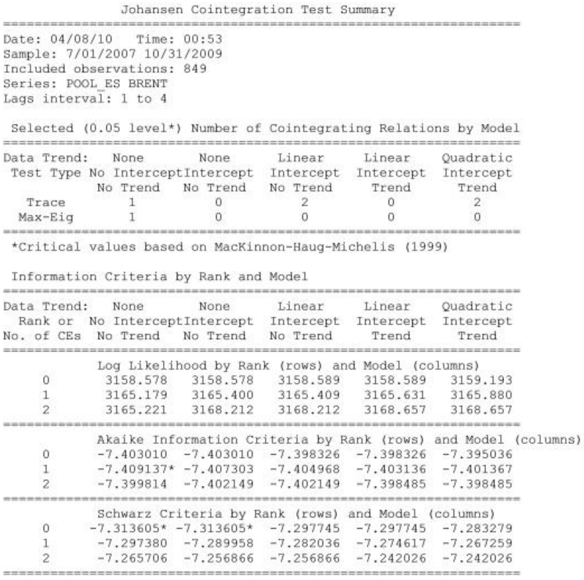
The Correlation Matrix presents high t-ratios values with p-value = 0 < 1%

Table 11 - Johansen Cointegration Test Summary

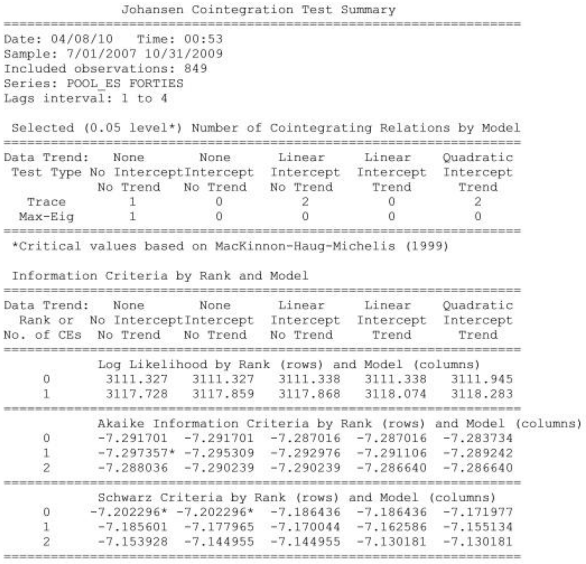


```
               Johansen Cointegration Test Summary
=================================================================
Date: 04/08/10   Time: 00:53
Sample: 7/01/2007 10/31/2009
Included observations: 849
Series: POOL_ES API4
Lags interval: 1 to 4

 Selected (0.01 level*) Number of Cointegrating Relations by Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
 Test Type No InterceptIntercept  Intercept  Intercept  Intercept
            No Trend   No Trend   No Trend    Trend      Trend
  Trace        1          0          0          0          0
 Max-Eig       1          0          0          0          0
=================================================================
 *Critical values based on MacKinnon-Haug-Michelis (1999)

 Information Criteria by Rank and Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
  Rank or   No InterceptIntercept  Intercept  Intercept  Intercept
No. of CEs  No Trend   No Trend   No Trend    Trend      Trend
=================================================================
            Log Likelihood by Rank (rows) and Model (columns)
    0        3216.536   3216.536   3216.538   3216.538   3218.742
    1        3225.252   3225.774   3225.776   3227.093   3228.920
    2        3225.252   3226.268   3226.268   3230.159   3230.159
=================================================================
            Akaike Information Criteria by Rank (rows) and Model (columns)
    0       -7.539542  -7.539542  -7.534836  -7.534836  -7.535316
    1       -7.550652* -7.549526  -7.547175  -7.547922  -7.549870
    2       -7.541229  -7.538913  -7.538913  -7.543366  -7.543366
=================================================================
            Schwarz Criteria by Rank (rows) and Model (columns)
    0      -7.450137* -7.450137*  -7.434256  -7.434256  -7.423560
    1       -7.438895  -7.432182  -7.424243  -7.419402  -7.415763
    2       -7.407121  -7.393629  -7.393629  -7.386907  -7.386907
=================================================================
```

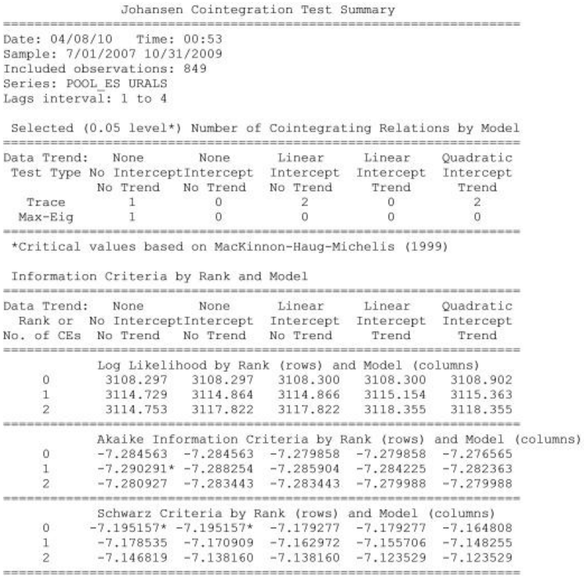
```
               Johansen Cointegration Test Summary
=================================================================
Date: 04/08/10   Time: 00:53
Sample: 7/01/2007 10/31/2009
Included observations: 849
Series: POOL_ES API2
Lags interval: 1 to 4

 Selected (0.01 level*) Number of Cointegrating Relations by Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
 Test Type No InterceptIntercept  Intercept  Intercept  Intercept
            No Trend   No Trend   No Trend    Trend      Trend
  Trace        1          1          1          1          1
 Max-Eig       1          1          1          1          1
=================================================================
 *Critical values based on MacKinnon-Haug-Michelis (1999)

 Information Criteria by Rank and Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
  Rank or   No InterceptIntercept  Intercept  Intercept  Intercept
No. of CEs  No Trend   No Trend   No Trend    Trend      Trend
=================================================================
            Log Likelihood by Rank (rows) and Model (columns)
    0        3326.410   3326.410   3326.435   3326.435   3328.724
    1        3338.336   3339.967   3339.987   3339.998   3340.752
    2        3338.379   3340.591   3340.591   3342.894   3342.894
=================================================================
            Akaike Information Criteria by Rank (rows) and Model (columns)
    0       -7.798375  -7.798375  -7.793723  -7.793723  -7.794404
    1       -7.817046  -7.818531* -7.816224  -7.813894  -7.813313
    2       -7.807724  -7.808224  -7.808224  -7.808938  -7.808938
=================================================================
            Schwarz Criteria by Rank (rows) and Model (columns)
    0      -7.708970* -7.708970*  -7.693142  -7.693142  -7.682647
    1       -7.705289  -7.701187  -7.693292  -7.685374  -7.679206
    2       -7.673616  -7.662941  -7.662941  -7.652479  -7.652479
=================================================================
```



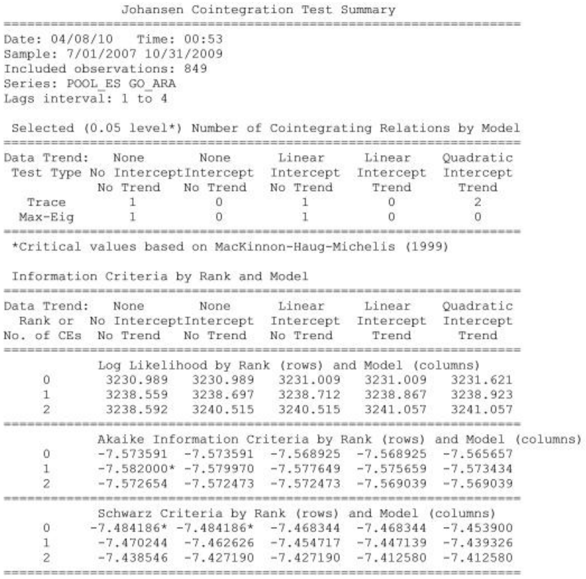
```
               Johansen Cointegration Test Summary
=================================================================
Date: 04/08/10   Time: 00:53
Sample: 7/01/2007 10/31/2009
Included observations: 849
Series: POOL_ES BRENT
Lags interval: 1 to 4

 Selected (0.05 level*) Number of Cointegrating Relations by Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
 Test Type No InterceptIntercept  Intercept  Intercept  Intercept
            No Trend   No Trend   No Trend    Trend      Trend
  Trace        1          0          2          0          2
 Max-Eig       1          0          0          0          0
=================================================================
 *Critical values based on MacKinnon-Haug-Michelis (1999)

 Information Criteria by Rank and Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
  Rank or   No InterceptIntercept  Intercept  Intercept  Intercept
No. of CEs  No Trend   No Trend   No Trend    Trend      Trend
=================================================================
            Log Likelihood by Rank (rows) and Model (columns)
    0        3158.578   3158.578   3158.589   3158.589   3159.193
    1        3165.179   3165.400   3165.409   3165.631   3165.880
    2        3165.221   3168.212   3168.212   3168.657   3168.657
=================================================================
            Akaike Information Criteria by Rank (rows) and Model (columns)
    0       -7.403010  -7.403010  -7.398326  -7.398326  -7.395036
    1       -7.409137* -7.407303  -7.404968  -7.403136  -7.401367
    2       -7.399814  -7.402149  -7.402149  -7.398485  -7.398485
=================================================================
            Schwarz Criteria by Rank (rows) and Model (columns)
    0      -7.313605* -7.313605*  -7.297745  -7.297745  -7.283279
    1       -7.297380  -7.289958  -7.282036  -7.274617  -7.267259
    2       -7.265706  -7.256866  -7.256866  -7.242026  -7.242026
=================================================================
```



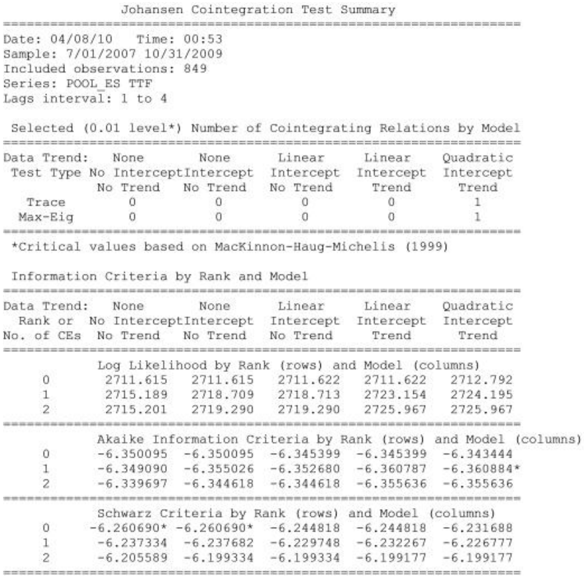
```
               Johansen Cointegration Test Summary
=================================================================
Date: 04/08/10   Time: 00:53
Sample: 7/01/2007 10/31/2009
Included observations: 849
Series: POOL_ES FORTIES
Lags interval: 1 to 4

 Selected (0.05 level*) Number of Cointegrating Relations by Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
 Test Type No InterceptIntercept  Intercept  Intercept  Intercept
            No Trend   No Trend   No Trend    Trend      Trend
  Trace        1          0          2          0          2
 Max-Eig       1          0          0          0          0
=================================================================
 *Critical values based on MacKinnon-Haug-Michelis (1999)

 Information Criteria by Rank and Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
  Rank or   No InterceptIntercept  Intercept  Intercept  Intercept
No. of CEs  No Trend   No Trend   No Trend    Trend      Trend
=================================================================
            Log Likelihood by Rank (rows) and Model (columns)
    0        3111.327   3111.327   3111.338   3111.338   3111.945
    1        3117.728   3117.859   3117.868   3118.074   3118.283
=================================================================
            Akaike Information Criteria by Rank (rows) and Model (columns)
    0       -7.291701  -7.291701  -7.287016  -7.287016  -7.283734
    1       -7.297357* -7.295309  -7.292976  -7.291106  -7.289242
    2       -7.288036  -7.290239  -7.290239  -7.286640  -7.286640
=================================================================
            Schwarz Criteria by Rank (rows) and Model (columns)
    0      -7.202296* -7.202296*  -7.186436  -7.186436  -7.171977
    1       -7.185601  -7.177965  -7.170044  -7.162586  -7.155134
    2       -7.153928  -7.144955  -7.144955  -7.130181  -7.130181
=================================================================
```



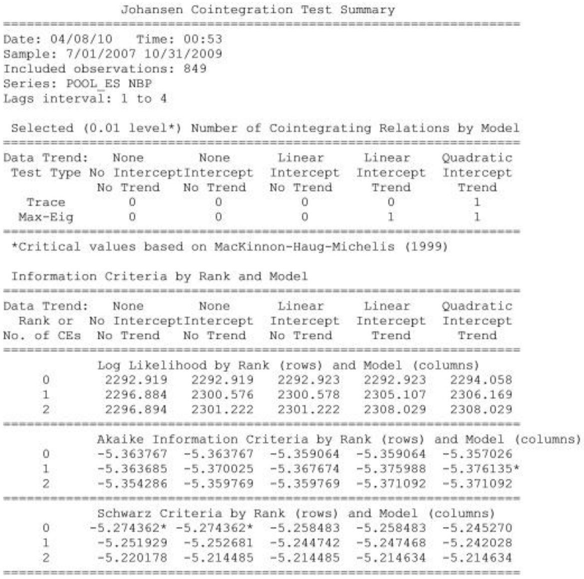
```
               Johansen Cointegration Test Summary
=================================================================
Date: 04/08/10   Time: 00:53
Sample: 7/01/2007 10/31/2009
Included observations: 849
Series: POOL_ES URALS
Lags interval: 1 to 4

 Selected (0.05 level*) Number of Cointegrating Relations by Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
 Test Type No InterceptIntercept  Intercept  Intercept  Intercept
            No Trend   No Trend   No Trend    Trend      Trend
  Trace        1          0          2          0          2
 Max-Eig       1          0          0          0          0
=================================================================
 *Critical values based on MacKinnon-Haug-Michelis (1999)

 Information Criteria by Rank and Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
  Rank or   No InterceptIntercept  Intercept  Intercept  Intercept
No. of CEs  No Trend   No Trend   No Trend    Trend      Trend
=================================================================
            Log Likelihood by Rank (rows) and Model (columns)
    0        3108.297   3108.297   3108.300   3108.300   3108.902
    1        3114.729   3114.864   3114.866   3115.154   3115.363
    2        3114.753   3117.822   3117.822   3118.355   3118.355
=================================================================
            Akaike Information Criteria by Rank (rows) and Model (columns)
    0       -7.284563  -7.284563  -7.279858  -7.279858  -7.276565
    1       -7.290291* -7.288254  -7.285904  -7.284225  -7.282363
    2       -7.280927  -7.283443  -7.283443  -7.279988  -7.279988
=================================================================
            Schwarz Criteria by Rank (rows) and Model (columns)
    0      -7.195157* -7.195157*  -7.179277  -7.179277  -7.164808
    1       -7.178535  -7.170909  -7.162972  -7.155706  -7.148255
    2       -7.146819  -7.138160  -7.138160  -7.123529  -7.123529
=================================================================
```



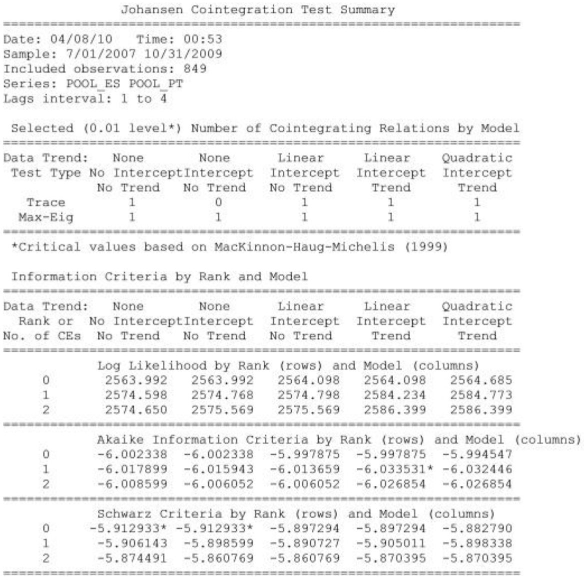
```
               Johansen Cointegration Test Summary
=================================================================
Date: 04/08/10   Time: 00:53
Sample: 7/01/2007 10/31/2009
Included observations: 849
Series: POOL_ES GO_ARA
Lags interval: 1 to 4

 Selected (0.05 level*) Number of Cointegrating Relations by Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
 Test Type No InterceptIntercept  Intercept  Intercept  Intercept
            No Trend   No Trend   No Trend    Trend      Trend
  Trace        1          0          1          0          2
 Max-Eig       1          0          1          0          0
=================================================================
 *Critical values based on MacKinnon-Haug-Michelis (1999)

 Information Criteria by Rank and Model
=================================================================
Data Trend:   None       None      Linear     Linear    Quadratic
  Rank or   No InterceptIntercept  Intercept  Intercept  Intercept
No. of CEs  No Trend   No Trend   No Trend    Trend      Trend
=================================================================
            Log Likelihood by Rank (rows) and Model (columns)
    0        3230.989   3230.989   3231.009   3231.009   3231.621
    1        3238.559   3238.697   3238.712   3238.867   3238.923
    2        3238.592   3240.515   3240.515   3241.057   3241.057
=================================================================
            Akaike Information Criteria by Rank (rows) and Model (columns)
    0       -7.573591  -7.573591  -7.568925  -7.568925  -7.565657
    1       -7.582000* -7.579970  -7.577649  -7.575659  -7.573434
    2       -7.572654  -7.572473  -7.572473  -7.569039  -7.569039
=================================================================
            Schwarz Criteria by Rank (rows) and Model (columns)
    0      -7.484186* -7.484186*  -7.468344  -7.468344  -7.453900
    1       -7.470244  -7.462626  -7.454717  -7.447139  -7.439326
    2       -7.438546  -7.427190  -7.427190  -7.412580  -7.412580
=================================================================
```



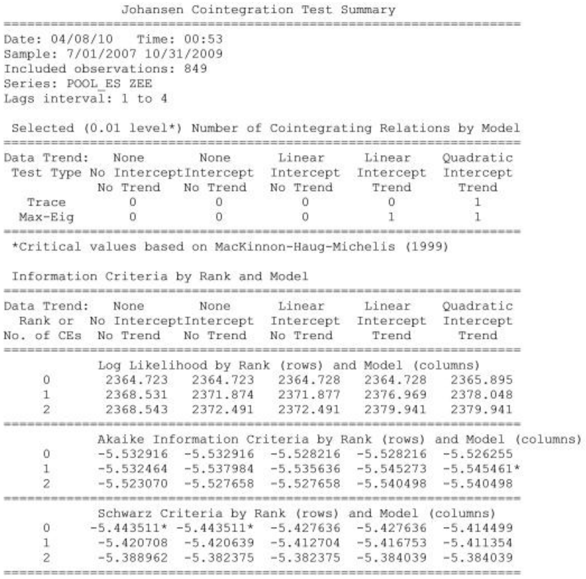
```
               Johansen Cointegration Test Summary
==================================================================
Date: 04/08/10   Time: 00:53
Sample: 7/01/2007 10/31/2009
Included observations: 849
Series: POOL_ES TTF
Lags interval: 1 to 4

 Selected (0.01 level*) Number of Cointegrating Relations by Model
==================================================================
Data Trend:   None        None       Linear     Linear    Quadratic
 Test Type No InterceptIntercept  Intercept  Intercept  Intercept
           No Trend   No Trend   No Trend     Trend      Trend
  Trace        0          0          0          0          1
 Max-Eig       0          0          0          0          1
==================================================================
 *Critical values based on MacKinnon-Haug-Michelis (1999)

 Information Criteria by Rank and Model
==================================================================
Data Trend:   None        None       Linear     Linear    Quadratic
  Rank or  No InterceptIntercept  Intercept  Intercept  Intercept
No. of CEs No Trend   No Trend   No Trend     Trend      Trend
==================================================================
           Log Likelihood by Rank (rows) and Model (columns)
    0       2711.615   2711.615   2711.622   2711.622   2712.792
    1       2715.189   2718.709   2718.713   2723.154   2724.195
    2       2715.201   2719.290   2719.290   2725.967   2725.967
==================================================================
           Akaike Information Criteria by Rank (rows) and Model (columns)
    0      -6.350095  -6.350095  -6.345399  -6.345399  -6.343444
    1      -6.349090  -6.355026  -6.352680  -6.360787  -6.360884*
    2      -6.339697  -6.344618  -6.344618  -6.355636  -6.355636
==================================================================
           Schwarz Criteria by Rank (rows) and Model (columns)
    0     -6.260690* -6.260690* -6.244818  -6.244818  -6.231688
    1      -6.237334  -6.237682  -6.229748  -6.232267  -6.226777
    2      -6.205589  -6.199334  -6.199334  -6.199177  -6.199177
==================================================================
```



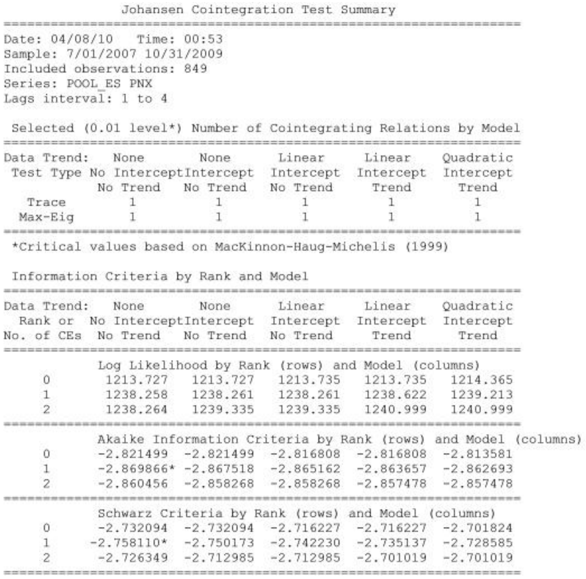
```
               Johansen Cointegration Test Summary
==================================================================
Date: 04/08/10   Time: 00:53
Sample: 7/01/2007 10/31/2009
Included observations: 849
Series: POOL_ES NBP
Lags interval: 1 to 4

 Selected (0.01 level*) Number of Cointegrating Relations by Model
==================================================================
Data Trend:   None        None       Linear     Linear    Quadratic
 Test Type No InterceptIntercept  Intercept  Intercept  Intercept
           No Trend   No Trend   No Trend     Trend      Trend
  Trace        0          0          0          0          1
 Max-Eig       0          0          0          1          1
==================================================================
 *Critical values based on MacKinnon-Haug-Michelis (1999)

 Information Criteria by Rank and Model
==================================================================
Data Trend:   None        None       Linear     Linear    Quadratic
  Rank or  No InterceptIntercept  Intercept  Intercept  Intercept
No. of CEs No Trend   No Trend   No Trend     Trend      Trend
==================================================================
           Log Likelihood by Rank (rows) and Model (columns)
    0       2292.919   2292.919   2292.923   2292.923   2294.058
    1       2296.884   2300.576   2300.578   2305.107   2306.169
    2       2296.894   2301.222   2301.222   2308.029   2308.029
==================================================================
           Akaike Information Criteria by Rank (rows) and Model (columns)
    0      -5.363767  -5.363767  -5.359064  -5.359064  -5.357026
    1      -5.363685  -5.370025  -5.367674  -5.375988  -5.376135*
    2      -5.354286  -5.359769  -5.359769  -5.371092  -5.371092
==================================================================
           Schwarz Criteria by Rank (rows) and Model (columns)
    0     -5.274362* -5.274362* -5.258483  -5.258483  -5.245270
    1      -5.251929  -5.252681  -5.244742  -5.247468  -5.242028
    2      -5.220178  -5.214485  -5.214485  -5.214634  -5.214634
==================================================================
```



```
               Johansen Cointegration Test Summary
==================================================================
Date: 04/08/10   Time: 00:53
Sample: 7/01/2007 10/31/2009
Included observations: 849
Series: POOL_ES POOL_PT
Lags interval: 1 to 4

 Selected (0.01 level*) Number of Cointegrating Relations by Model
==================================================================
Data Trend:   None        None       Linear     Linear    Quadratic
 Test Type No InterceptIntercept  Intercept  Intercept  Intercept
           No Trend   No Trend   No Trend     Trend      Trend
  Trace        1          0          1          1          1
 Max-Eig       1          1          1          1          1
==================================================================
 *Critical values based on MacKinnon-Haug-Michelis (1999)

 Information Criteria by Rank and Model
==================================================================
Data Trend:   None        None       Linear     Linear    Quadratic
  Rank or  No InterceptIntercept  Intercept  Intercept  Intercept
No. of CEs No Trend   No Trend   No Trend     Trend      Trend
==================================================================
           Log Likelihood by Rank (rows) and Model (columns)
    0       2563.992   2563.992   2564.098   2564.098   2564.685
    1       2574.598   2574.768   2574.798   2584.234   2584.773
    2       2574.650   2575.569   2575.569   2586.399   2586.399
==================================================================
           Akaike Information Criteria by Rank (rows) and Model (columns)
    0      -6.002338  -6.002338  -5.997875  -5.997875  -5.994547
    1      -6.017899  -6.015943  -6.013659  -6.033531* -6.032446
    2      -6.008599  -6.006052  -6.006052  -6.026854  -6.026854
==================================================================
           Schwarz Criteria by Rank (rows) and Model (columns)
    0     -5.912933* -5.912933* -5.897294  -5.897294  -5.882790
    1      -5.906143  -5.898599  -5.890727  -5.905011  -5.898338
    2      -5.874491  -5.860769  -5.860769  -5.870395  -5.870395
==================================================================
```

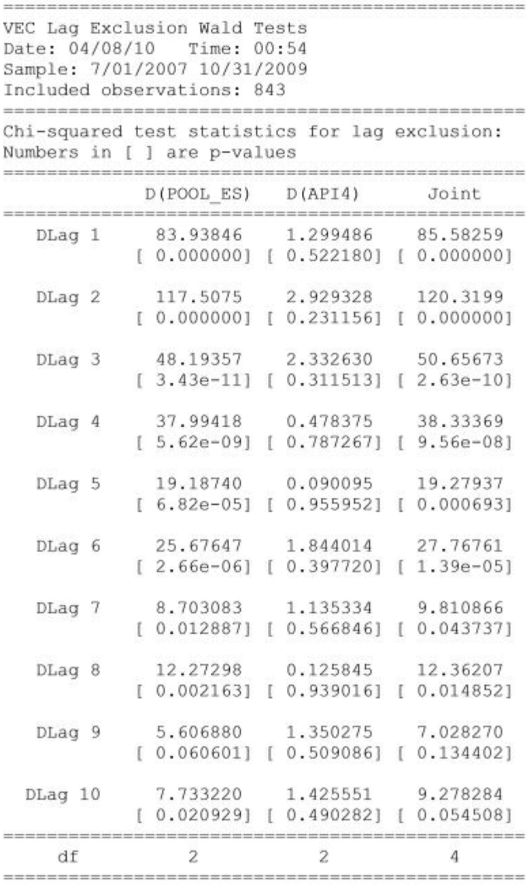


```
               Johansen Cointegration Test Summary
==================================================================
Date: 04/08/10   Time: 00:53
Sample: 7/01/2007 10/31/2009
Included observations: 849
Series: POOL_ES ZEE
Lags interval: 1 to 4

 Selected (0.01 level*) Number of Cointegrating Relations by Model
==================================================================
Data Trend:   None        None       Linear     Linear    Quadratic
 Test Type No InterceptIntercept  Intercept  Intercept  Intercept
           No Trend   No Trend   No Trend     Trend      Trend
  Trace        0          0          0          0          1
 Max-Eig       0          0          0          1          1
==================================================================
 *Critical values based on MacKinnon-Haug-Michelis (1999)

 Information Criteria by Rank and Model
==================================================================
Data Trend:   None        None       Linear     Linear    Quadratic
  Rank or  No InterceptIntercept  Intercept  Intercept  Intercept
No. of CEs No Trend   No Trend   No Trend     Trend      Trend
==================================================================
           Log Likelihood by Rank (rows) and Model (columns)
    0       2364.723   2364.723   2364.728   2364.728   2365.895
    1       2368.531   2371.874   2371.877   2376.969   2378.048
    2       2368.543   2372.491   2372.491   2379.941   2379.941
==================================================================
           Akaike Information Criteria by Rank (rows) and Model (columns)
    0      -5.532916  -5.532916  -5.528216  -5.528216  -5.526255
    1      -5.532464  -5.537984  -5.535636  -5.545273  -5.545461*
    2      -5.523070  -5.527658  -5.527658  -5.540498  -5.540498
==================================================================
           Schwarz Criteria by Rank (rows) and Model (columns)
    0     -5.443511* -5.443511* -5.427636  -5.427636  -5.414499
    1      -5.420708  -5.420639  -5.412704  -5.416753  -5.411354
    2      -5.388962  -5.382375  -5.382375  -5.384039  -5.384039
==================================================================
```

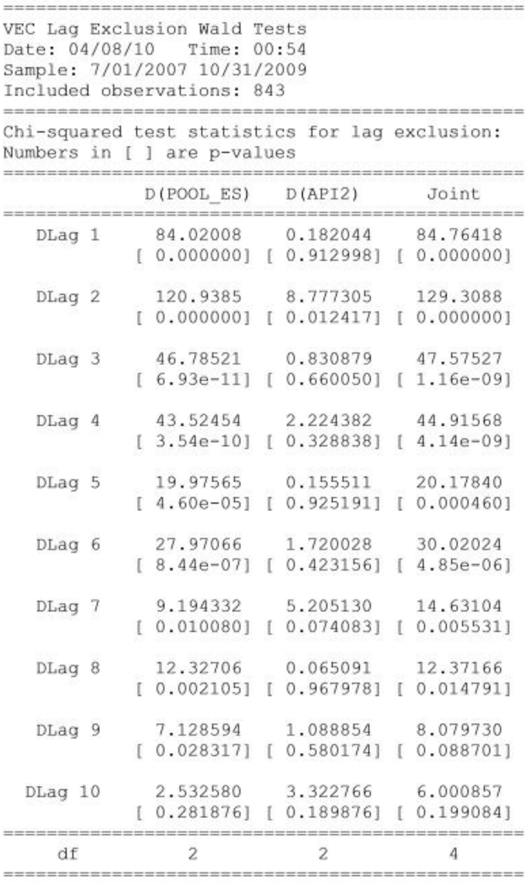


```
               Johansen Cointegration Test Summary
==================================================================
Date: 04/08/10   Time: 00:53
Sample: 7/01/2007 10/31/2009
Included observations: 849
Series: POOL_ES PNX
Lags interval: 1 to 4

 Selected (0.01 level*) Number of Cointegrating Relations by Model
==================================================================
Data Trend:   None        None       Linear     Linear    Quadratic
 Test Type No InterceptIntercept  Intercept  Intercept  Intercept
           No Trend   No Trend   No Trend     Trend      Trend
  Trace        1          1          1          1          1
 Max-Eig       1          1          1          1          1
==================================================================
 *Critical values based on MacKinnon-Haug-Michelis (1999)

 Information Criteria by Rank and Model
==================================================================
Data Trend:   None        None       Linear     Linear    Quadratic
  Rank or  No InterceptIntercept  Intercept  Intercept  Intercept
No. of CEs No Trend   No Trend   No Trend     Trend      Trend
==================================================================
           Log Likelihood by Rank (rows) and Model (columns)
    0       1213.727   1213.727   1213.735   1213.735   1214.365
    1       1238.258   1238.261   1238.261   1238.622   1239.213
    2       1238.264   1239.335   1239.335   1240.999   1240.999
==================================================================
           Akaike Information Criteria by Rank (rows) and Model (columns)
    0      -2.821499  -2.821499  -2.816808  -2.816808  -2.813581
    1      -2.869866* -2.867518  -2.865162  -2.863657  -2.862693
    2      -2.860456  -2.858268  -2.858268  -2.857478  -2.857478
==================================================================
           Schwarz Criteria by Rank (rows) and Model (columns)
    0      -2.732094  -2.732094  -2.716227  -2.716227  -2.701824
    1     -2.758110*  -2.750173  -2.742230  -2.735137  -2.728585
    2      -2.726349  -2.712985  -2.712985  -2.701019  -2.701019
==================================================================
```

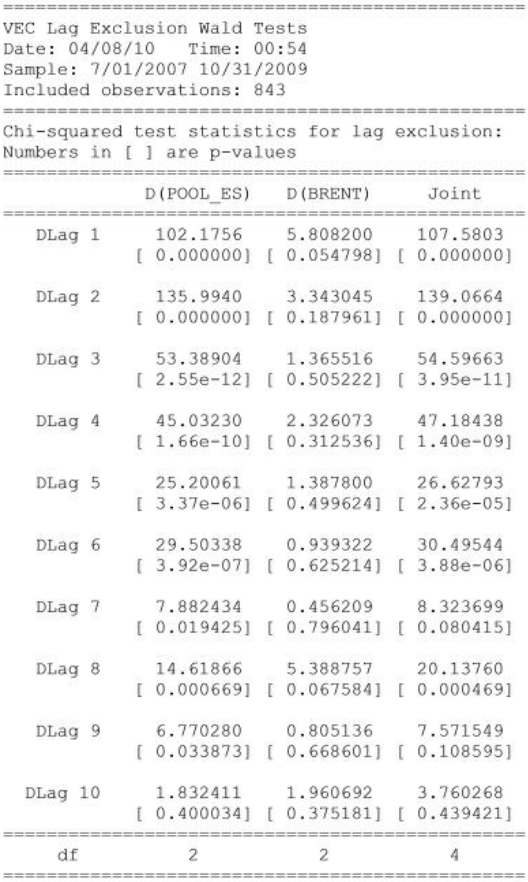
Table 12 - Lag Exclusion Wald Tests



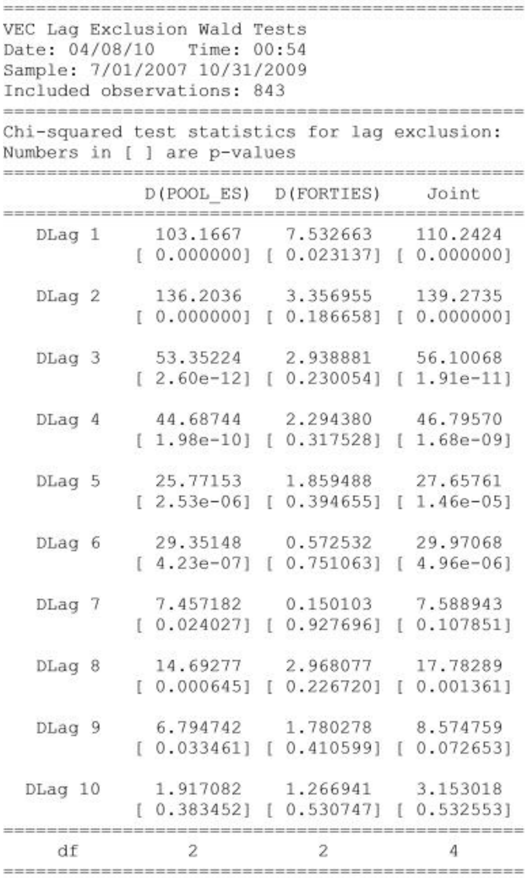
```
================================================
VEC Lag Exclusion Wald Tests
Date: 04/08/10   Time: 00:54
Sample: 7/01/2007 10/31/2009
Included observations: 843
================================================
Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values
================================================
              D(POOL_ES)   D(API4)      Joint
================================================
   DLag 1      83.93846    1.299486    85.58259
             [ 0.000000] [ 0.522180] [ 0.000000]

   DLag 2      117.5075    2.929328    120.3199
             [ 0.000000] [ 0.231156] [ 0.000000]

   DLag 3      48.19357    2.332630    50.65673
             [ 3.43e-11] [ 0.311513] [ 2.63e-10]

   DLag 4      37.99418    0.478375    38.33369
             [ 5.62e-09] [ 0.787267] [ 9.56e-08]

   DLag 5      19.18740    0.090095    19.27937
             [ 6.82e-05] [ 0.955952] [ 0.000693]

   DLag 6      25.67647    1.844014    27.76761
             [ 2.66e-06] [ 0.397720] [ 1.39e-05]

   DLag 7      8.703083    1.135334    9.810866
             [ 0.012887] [ 0.566846] [ 0.043737]

   DLag 8      12.27298    0.125845    12.36207
             [ 0.002163] [ 0.939016] [ 0.014852]

   DLag 9      5.606880    1.350275    7.028270
             [ 0.060601] [ 0.509086] [ 0.134402]

  DLag 10      7.733220    1.425551    9.278284
             [ 0.020929] [ 0.490282] [ 0.054508]
================================================
     df           2           2           4
================================================
```



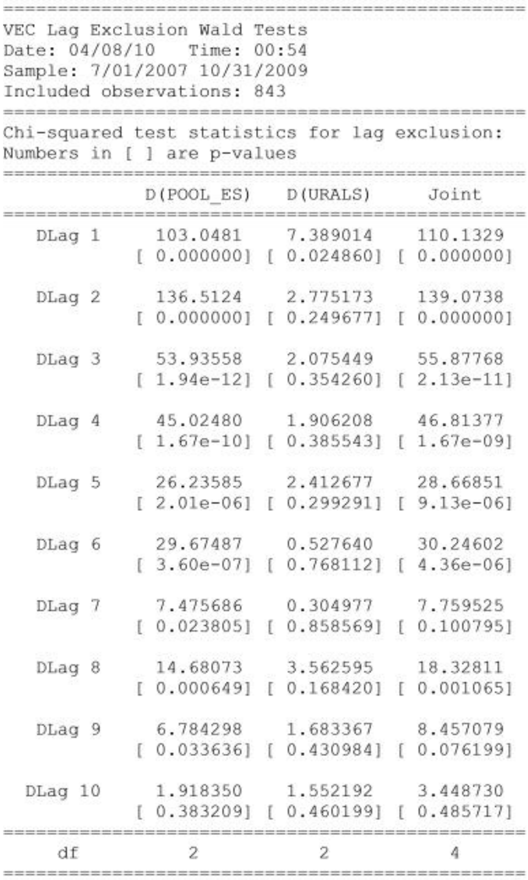
```
================================================
VEC Lag Exclusion Wald Tests
Date: 04/08/10   Time: 00:54
Sample: 7/01/2007 10/31/2009
Included observations: 843
================================================
Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values
================================================
              D(POOL_ES)   D(API2)      Joint
================================================
   DLag 1      84.02008    0.182044    84.76418
             [ 0.000000] [ 0.912998] [ 0.000000]

   DLag 2      120.9385    8.777305    129.3088
             [ 0.000000] [ 0.012417] [ 0.000000]

   DLag 3      46.78521    0.830879    47.57527
             [ 6.93e-11] [ 0.660050] [ 1.16e-09]

   DLag 4      43.52454    2.224382    44.91568
             [ 3.54e-10] [ 0.328838] [ 4.14e-09]

   DLag 5      19.97565    0.155511    20.17840
             [ 4.60e-05] [ 0.925191] [ 0.000460]

   DLag 6      27.97066    1.720028    30.02024
             [ 8.44e-07] [ 0.423156] [ 4.85e-06]

   DLag 7      9.194332    5.205130    14.63104
             [ 0.010080] [ 0.074083] [ 0.005531]

   DLag 8      12.32706    0.065091    12.37166
             [ 0.002105] [ 0.967978] [ 0.014791]

   DLag 9      7.128594    1.088854    8.079730
             [ 0.028317] [ 0.580174] [ 0.088701]

  DLag 10      2.532580    3.322766    6.000857
             [ 0.281876] [ 0.189876] [ 0.199084]
================================================
     df           2           2           4
================================================
```



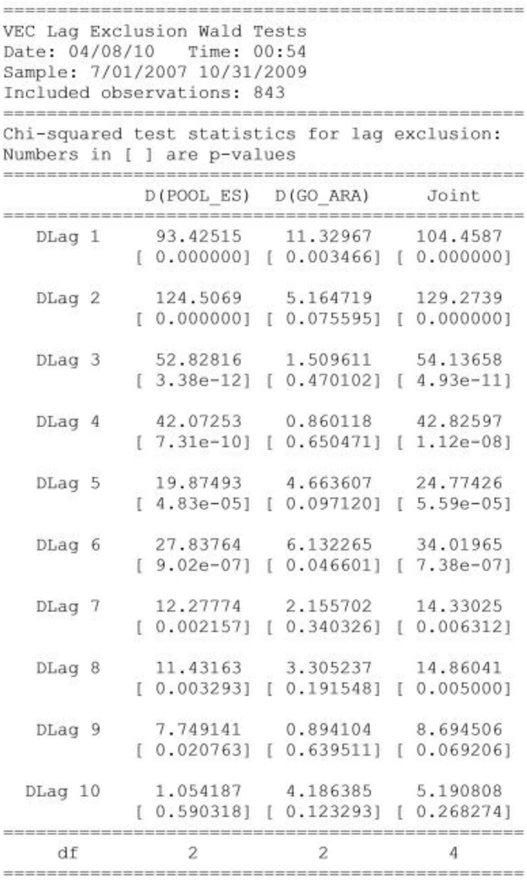
```
================================================
VEC Lag Exclusion Wald Tests
Date: 04/08/10   Time: 00:54
Sample: 7/01/2007 10/31/2009
Included observations: 843
================================================
Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values
================================================
              D(POOL_ES)   D(BRENT)     Joint
================================================
   DLag 1      102.1756    5.808200    107.5803
             [ 0.000000] [ 0.054798] [ 0.000000]

   DLag 2      135.9940    3.343045    139.0664
             [ 0.000000] [ 0.187961] [ 0.000000]

   DLag 3      53.38904    1.365516    54.59663
             [ 2.55e-12] [ 0.505222] [ 3.95e-11]

   DLag 4      45.03230    2.326073    47.18438
             [ 1.66e-10] [ 0.312536] [ 1.40e-09]

   DLag 5      25.20061    1.387800    26.62793
             [ 3.37e-06] [ 0.499624] [ 2.36e-05]

   DLag 6      29.50338    0.939322    30.49544
             [ 3.92e-07] [ 0.625214] [ 3.88e-06]

   DLag 7      7.882434    0.456209    8.323699
             [ 0.019425] [ 0.796041] [ 0.080415]

   DLag 8      14.61866    5.388757    20.13760
             [ 0.000669] [ 0.067584] [ 0.000469]

   DLag 9      6.770280    0.805136    7.571549
             [ 0.033873] [ 0.668601] [ 0.108595]

  DLag 10      1.832411    1.960692    3.760268
             [ 0.400034] [ 0.375181] [ 0.439421]
================================================
     df           2           2           4
================================================
```



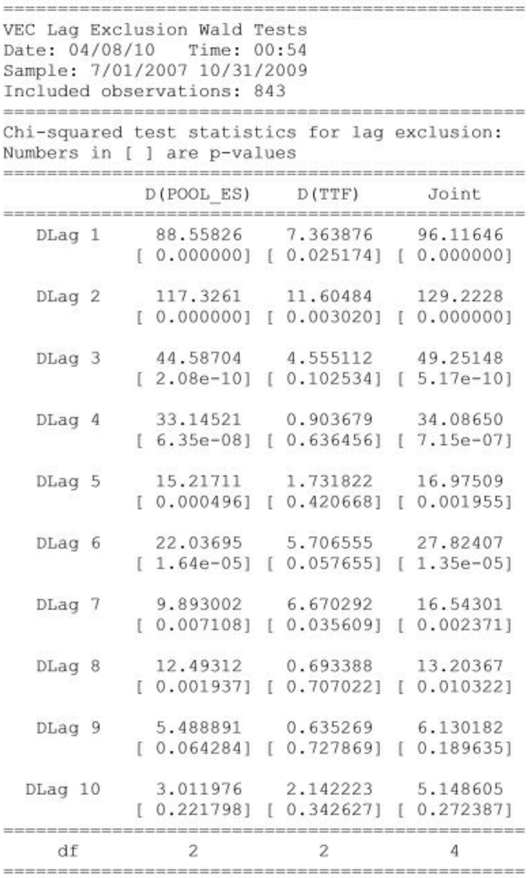
```
================================================
VEC Lag Exclusion Wald Tests
Date: 04/08/10   Time: 00:54
Sample: 7/01/2007 10/31/2009
Included observations: 843
================================================
Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values
================================================
              D(POOL_ES)  D(FORTIES)    Joint
================================================
   DLag 1      103.1667    7.532663    110.2424
             [ 0.000000] [ 0.023137] [ 0.000000]

   DLag 2      136.2036    3.356955    139.2735
             [ 0.000000] [ 0.186658] [ 0.000000]

   DLag 3      53.35224    2.938881    56.10068
             [ 2.60e-12] [ 0.230054] [ 1.91e-11]

   DLag 4      44.68744    2.294380    46.79570
             [ 1.98e-10] [ 0.317528] [ 1.68e-09]

   DLag 5      25.77153    1.859488    27.65761
             [ 2.53e-06] [ 0.394655] [ 1.46e-05]

   DLag 6      29.35148    0.572532    29.97068
             [ 4.23e-07] [ 0.751063] [ 4.96e-06]

   DLag 7      7.457182    0.150103    7.588943
             [ 0.024027] [ 0.927696] [ 0.107851]

   DLag 8      14.69277    2.968077    17.78289
             [ 0.000645] [ 0.226720] [ 0.001361]

   DLag 9      6.794742    1.780278    8.574759
             [ 0.033461] [ 0.410599] [ 0.072653]

  DLag 10      1.917082    1.266941    3.153018
             [ 0.383452] [ 0.530747] [ 0.532553]
================================================
     df           2           2           4
================================================
```



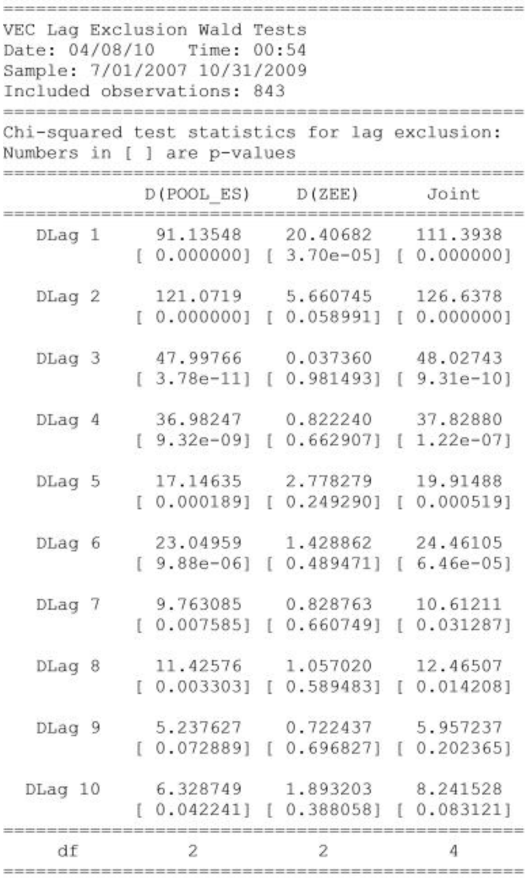
```
================================================
VEC Lag Exclusion Wald Tests
Date: 04/08/10   Time: 00:54
Sample: 7/01/2007 10/31/2009
Included observations: 843
================================================
Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values
================================================
              D(POOL_ES)   D(URALS)      Joint
================================================
   DLag 1      103.0481    7.389014    110.1329
             [ 0.000000] [ 0.024860] [ 0.000000]

   DLag 2      136.5124    2.775173    139.0738
             [ 0.000000] [ 0.249677] [ 0.000000]

   DLag 3      53.93558    2.075449    55.87768
             [ 1.94e-12] [ 0.354260] [ 2.13e-11]

   DLag 4      45.02480    1.906208    46.81377
             [ 1.67e-10] [ 0.385543] [ 1.67e-09]

   DLag 5      26.23585    2.412677    28.66851
             [ 2.01e-06] [ 0.299291] [ 9.13e-06]

   DLag 6      29.67487    0.527640    30.24602
             [ 3.60e-07] [ 0.768112] [ 4.36e-06]

   DLag 7      7.475686    0.304977    7.759525
             [ 0.023805] [ 0.858569] [ 0.100795]

   DLag 8      14.68073    3.562595    18.32811
             [ 0.000649] [ 0.168420] [ 0.001065]

   DLag 9      6.784298    1.683367    8.457079
             [ 0.033636] [ 0.430984] [ 0.076199]

  DLag 10      1.918350    1.552192    3.448730
             [ 0.383209] [ 0.460199] [ 0.485717]
================================================
     df           2           2           4
================================================
```



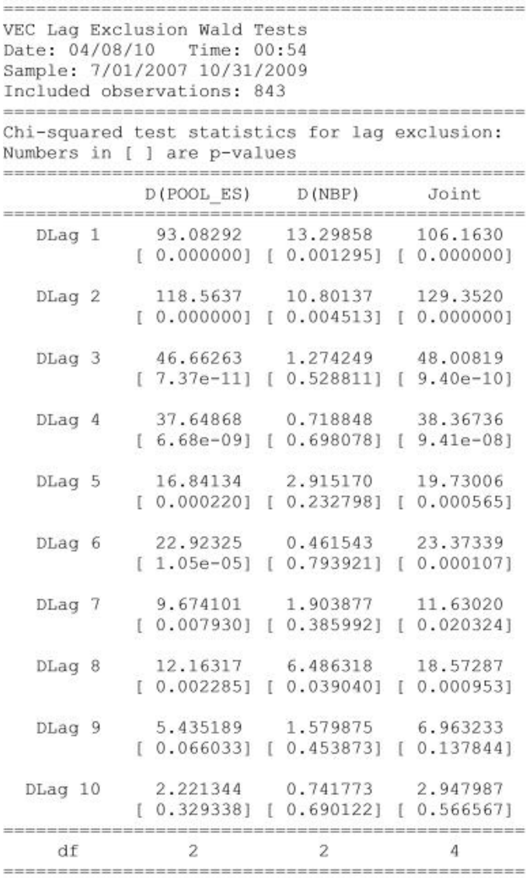
```
================================================
VEC Lag Exclusion Wald Tests
Date: 04/08/10   Time: 00:54
Sample: 7/01/2007 10/31/2009
Included observations: 843
================================================
Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values
================================================
              D(POOL_ES)  D(GO_ARA)      Joint
================================================
   DLag 1      93.42515    11.32967    104.4587
             [ 0.000000] [ 0.003466] [ 0.000000]

   DLag 2      124.5069    5.164719    129.2739
             [ 0.000000] [ 0.075595] [ 0.000000]

   DLag 3      52.82816    1.509611    54.13658
             [ 3.38e-12] [ 0.470102] [ 4.93e-11]

   DLag 4      42.07253    0.860118    42.82597
             [ 7.31e-10] [ 0.650471] [ 1.12e-08]

   DLag 5      19.87493    4.663607    24.77426
             [ 4.83e-05] [ 0.097120] [ 5.59e-05]

   DLag 6      27.83764    6.132265    34.01965
             [ 9.02e-07] [ 0.046601] [ 7.38e-07]

   DLag 7      12.27774    2.155702    14.33025
             [ 0.002157] [ 0.340326] [ 0.006312]

   DLag 8      11.43163    3.305237    14.86041
             [ 0.003293] [ 0.191548] [ 0.005000]

   DLag 9      7.749141    0.894104    8.694506
             [ 0.020763] [ 0.639511] [ 0.069206]

  DLag 10      1.054187    4.186385    5.190808
             [ 0.590318] [ 0.123293] [ 0.268274]
================================================
     df           2           2           4
================================================
```



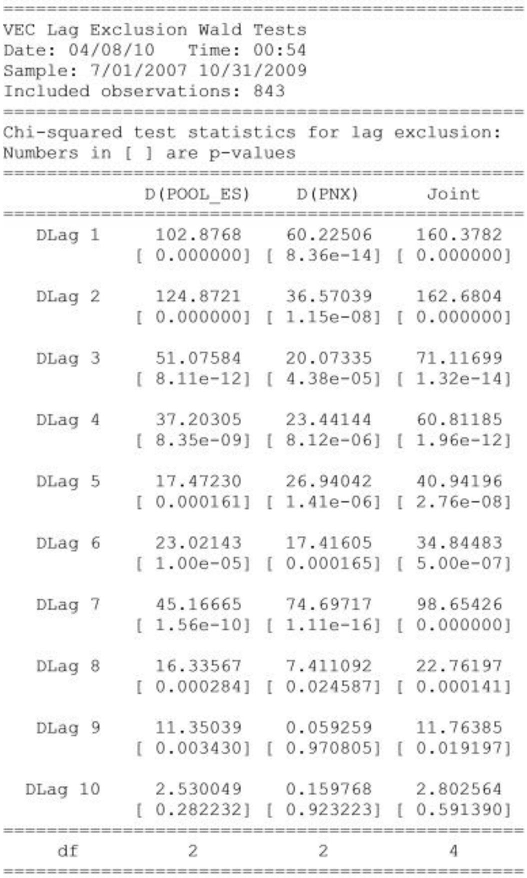
```
================================================
VEC Lag Exclusion Wald Tests
Date: 04/08/10   Time: 00:54
Sample: 7/01/2007 10/31/2009
Included observations: 843
================================================
Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values
================================================
              D(POOL_ES)    D(TTF)       Joint
================================================
   DLag 1      88.55826    7.363876    96.11646
             [ 0.000000] [ 0.025174] [ 0.000000]

   DLag 2      117.3261    11.60484    129.2228
             [ 0.000000] [ 0.003020] [ 0.000000]

   DLag 3      44.58704    4.555112    49.25148
             [ 2.08e-10] [ 0.102534] [ 5.17e-10]

   DLag 4      33.14521    0.903679    34.08650
             [ 6.35e-08] [ 0.636456] [ 7.15e-07]

   DLag 5      15.21711    1.731822    16.97509
             [ 0.000496] [ 0.420668] [ 0.001955]

   DLag 6      22.03695    5.706555    27.82407
             [ 1.64e-05] [ 0.057655] [ 1.35e-05]

   DLag 7      9.893002    6.670292    16.54301
             [ 0.007108] [ 0.035609] [ 0.002371]

   DLag 8      12.49312    0.693388    13.20367
             [ 0.001937] [ 0.707022] [ 0.010322]

   DLag 9      5.488891    0.635269    6.130182
             [ 0.064284] [ 0.727869] [ 0.189635]

  DLag 10      3.011976    2.142223    5.148605
             [ 0.221798] [ 0.342627] [ 0.272387]
================================================
     df           2           2           4
================================================
```



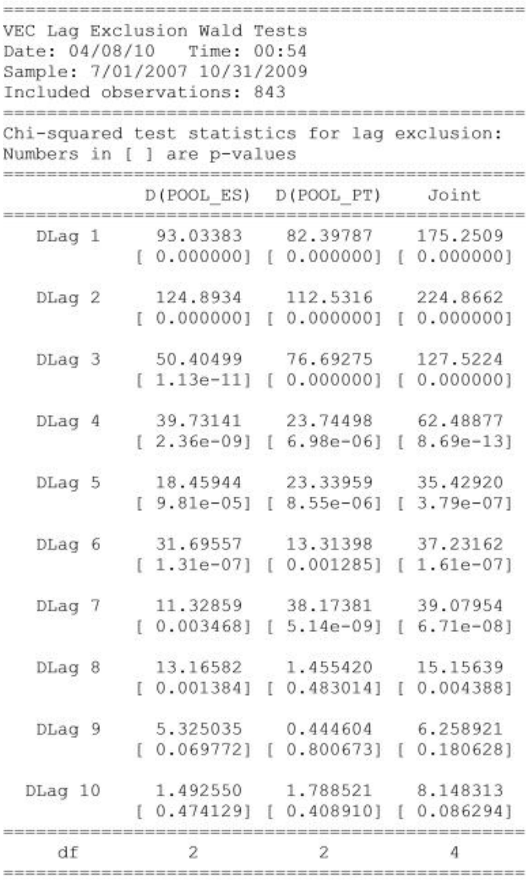
```
================================================
VEC Lag Exclusion Wald Tests
Date: 04/08/10   Time: 00:54
Sample: 7/01/2007 10/31/2009
Included observations: 843
================================================
Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values
================================================
              D(POOL_ES)    D(ZEE)       Joint
================================================
   DLag 1      91.13548    20.40682    111.3938
             [ 0.000000] [ 3.70e-05] [ 0.000000]

   DLag 2      121.0719    5.660745    126.6378
             [ 0.000000] [ 0.058991] [ 0.000000]

   DLag 3      47.99766    0.037360    48.02743
             [ 3.78e-11] [ 0.981493] [ 9.31e-10]

   DLag 4      36.98247    0.822240    37.82880
             [ 9.32e-09] [ 0.662907] [ 1.22e-07]

   DLag 5      17.14635    2.778279    19.91488
             [ 0.000189] [ 0.249290] [ 0.000519]

   DLag 6      23.04959    1.428862    24.46105
             [ 9.88e-06] [ 0.489471] [ 6.46e-05]

   DLag 7      9.763085    0.828763    10.61211
             [ 0.007585] [ 0.660749] [ 0.031287]

   DLag 8      11.42576    1.057020    12.46507
             [ 0.003303] [ 0.589483] [ 0.014208]

   DLag 9      5.237627    0.722437    5.957237
             [ 0.072889] [ 0.696827] [ 0.202365]

  DLag 10      6.328749    1.893203    8.241528
             [ 0.042241] [ 0.388058] [ 0.083121]
================================================
     df           2           2           4
================================================
```



```
================================================
VEC Lag Exclusion Wald Tests
Date: 04/08/10   Time: 00:54
Sample: 7/01/2007 10/31/2009
Included observations: 843
================================================
Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values
================================================
              D(POOL_ES)    D(NBP)       Joint
================================================
  DLag 1       93.08292    13.29858    106.1630
             [ 0.000000] [ 0.001295] [ 0.000000]

  DLag 2       118.5637    10.80137    129.3520
             [ 0.000000] [ 0.004513] [ 0.000000]

  DLag 3       46.66263    1.274249    48.00819
             [ 7.37e-11] [ 0.528811] [ 9.40e-10]

  DLag 4       37.64868    0.718848    38.36736
             [ 6.68e-09] [ 0.698078] [ 9.41e-08]

  DLag 5       16.84134    2.915170    19.73006
             [ 0.000220] [ 0.232798] [ 0.000565]

  DLag 6       22.92325    0.461543    23.37339
             [ 1.05e-05] [ 0.793921] [ 0.000107]

  DLag 7       9.674101    1.903877    11.63020
             [ 0.007930] [ 0.385992] [ 0.020324]

  DLag 8       12.16317    6.486318    18.57287
             [ 0.002285] [ 0.039040] [ 0.000953]

  DLag 9       5.435189    1.579875    6.963233
             [ 0.066033] [ 0.453873] [ 0.137844]

 DLag 10       2.221344    0.741773    2.947987
             [ 0.329338] [ 0.690122] [ 0.566567]
================================================
    df            2            2           4
================================================
```



```
================================================
VEC Lag Exclusion Wald Tests
Date: 04/08/10   Time: 00:54
Sample: 7/01/2007 10/31/2009
Included observations: 843
================================================
Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values
================================================
              D(POOL_ES)    D(PNX)       Joint
================================================
  DLag 1       102.8768    60.22506    160.3782
             [ 0.000000] [ 8.36e-14] [ 0.000000]

  DLag 2       124.8721    36.57039    162.6804
             [ 0.000000] [ 1.15e-08] [ 0.000000]

  DLag 3       51.07584    20.07335    71.11699
             [ 8.11e-12] [ 4.38e-05] [ 1.32e-14]

  DLag 4       37.20305    23.44144    60.81185
             [ 8.35e-09] [ 8.12e-06] [ 1.96e-12]

  DLag 5       17.47230    26.94042    40.94196
             [ 0.000161] [ 1.41e-06] [ 2.76e-08]

  DLag 6       23.02143    17.41605    34.84483
             [ 1.00e-05] [ 0.000165] [ 5.00e-07]

  DLag 7       45.16665    74.69717    98.65426
             [ 1.56e-10] [ 1.11e-16] [ 0.000000]

  DLag 8       16.33567    7.411092    22.76197
             [ 0.000284] [ 0.024587] [ 0.000141]

  DLag 9       11.35039    0.059259    11.76385
             [ 0.003430] [ 0.970805] [ 0.019197]

 DLag 10       2.530049    0.159768    2.802564
             [ 0.282232] [ 0.923223] [ 0.591390]
================================================
    df            2            2           4
================================================
```



```
================================================
VEC Lag Exclusion Wald Tests
Date: 04/08/10   Time: 00:54
Sample: 7/01/2007 10/31/2009
Included observations: 843
================================================
Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values
================================================
              D(POOL_ES)  D(POOL_PT)     Joint
================================================
  DLag 1       93.03383    82.39787    175.2509
             [ 0.000000] [ 0.000000] [ 0.000000]

  DLag 2       124.8934    112.5316    224.8662
             [ 0.000000] [ 0.000000] [ 0.000000]

  DLag 3       50.40499    76.69275    127.5224
             [ 1.13e-11] [ 0.000000] [ 0.000000]

  DLag 4       39.73141    23.74498    62.48877
             [ 2.36e-09] [ 6.98e-06] [ 8.69e-13]

  DLag 5       18.45944    23.33959    35.42920
             [ 9.81e-05] [ 8.55e-06] [ 3.79e-07]

  DLag 6       31.69557    13.31398    37.23162
             [ 1.31e-07] [ 0.001285] [ 1.61e-07]

  DLag 7       11.32859    38.17381    39.07954
             [ 0.003468] [ 5.14e-09] [ 6.71e-08]

  DLag 8       13.16582    1.455420    15.15639
             [ 0.001384] [ 0.483014] [ 0.004388]

  DLag 9       5.325035    0.444604    6.258921
             [ 0.069772] [ 0.800673] [ 0.180628]

 DLag 10       1.492550    1.788521    8.148313
             [ 0.474129] [ 0.408910] [ 0.086294]
================================================
    df            2            2           4
================================================
```

Figure 30 - VEC Stability Condition Check

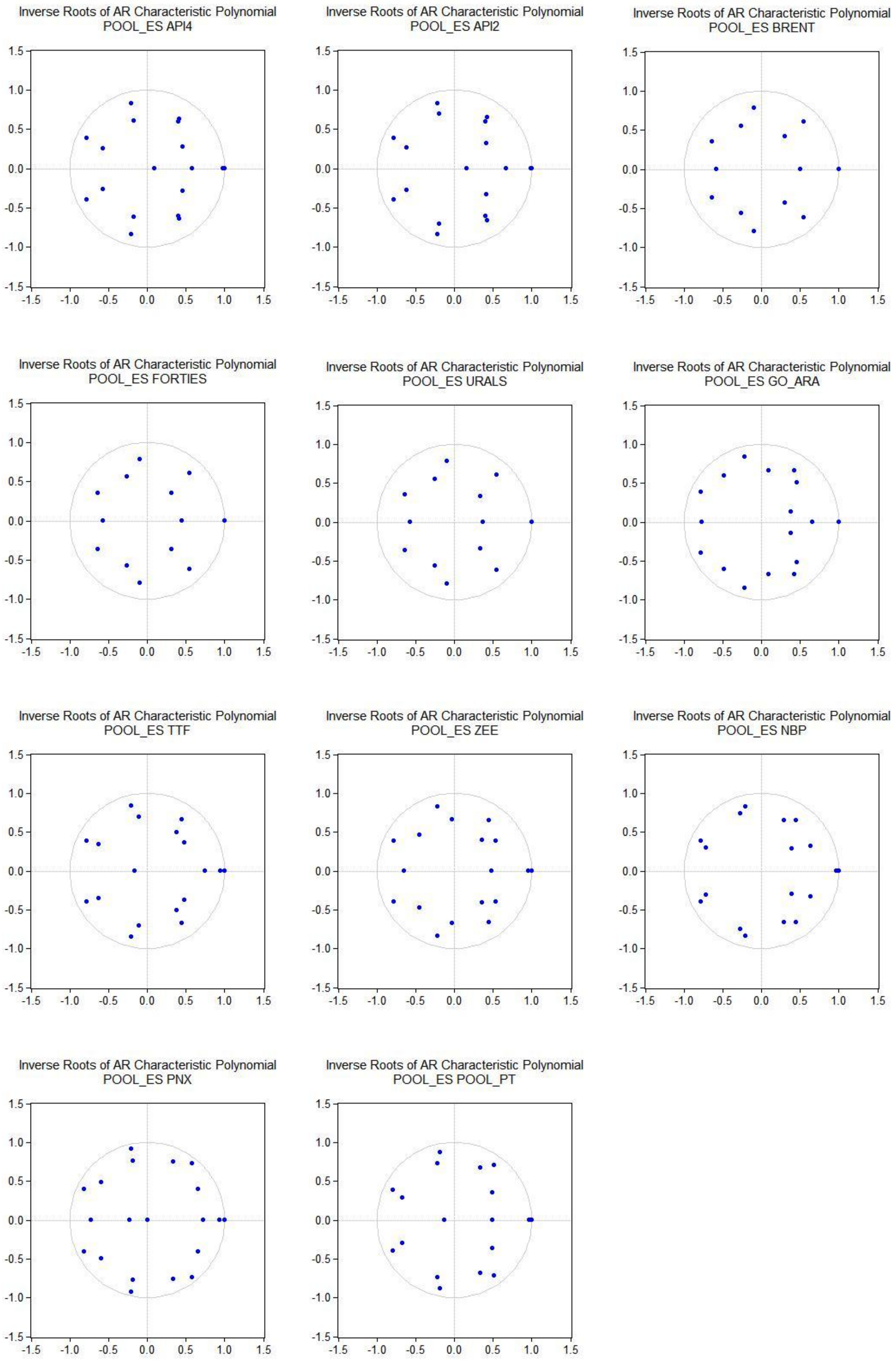
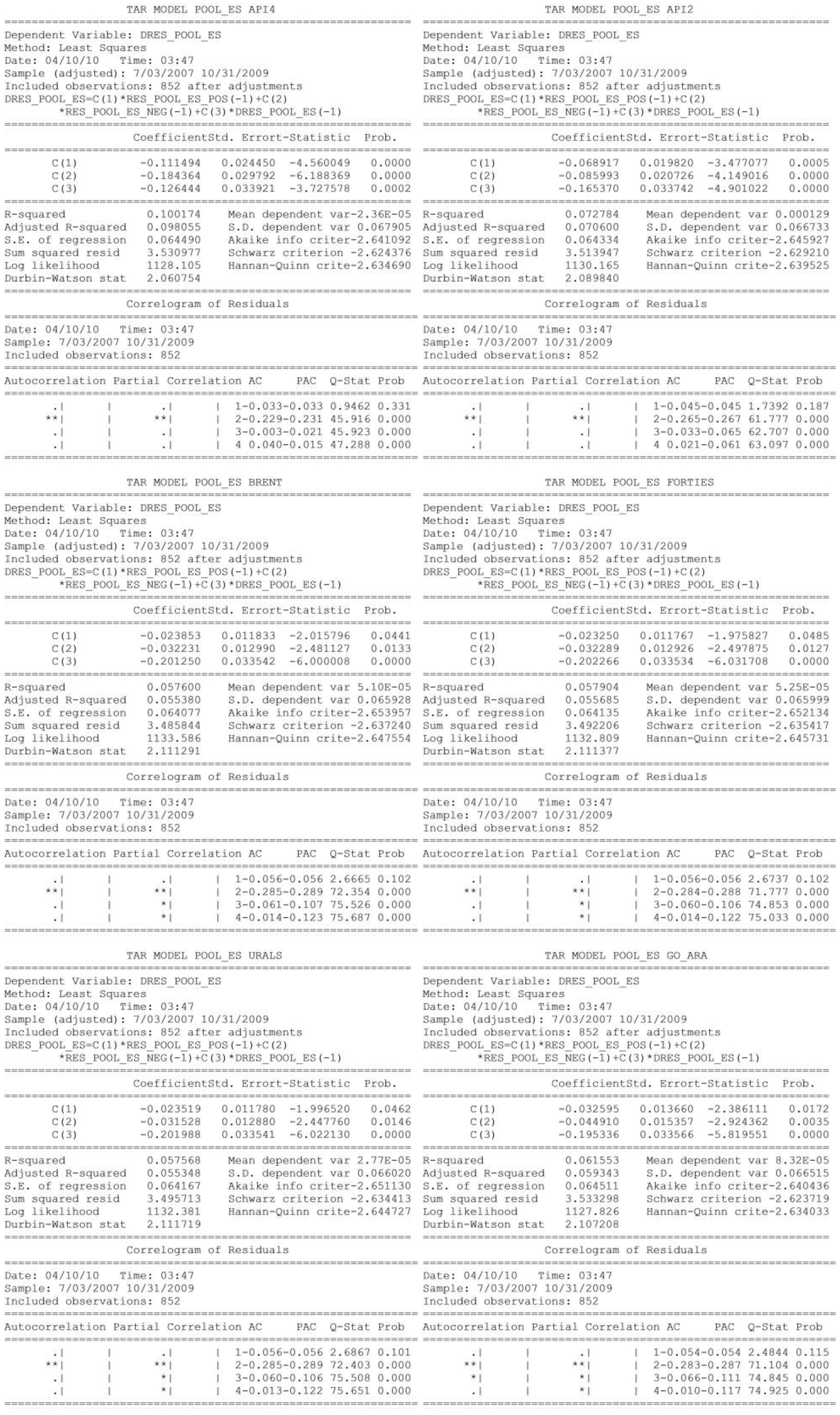
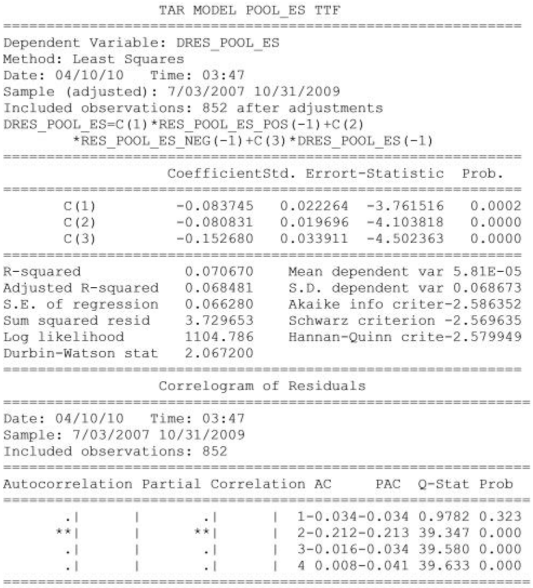


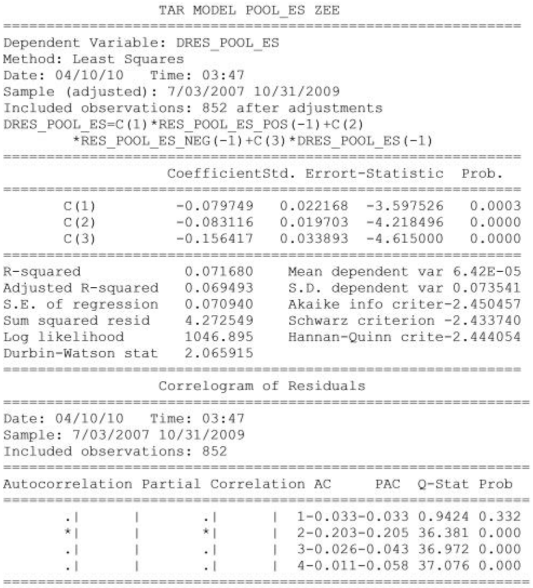
Table 13 - TAR Model and Autocorrelation Tests (DW Statistic and Q-Statistic)



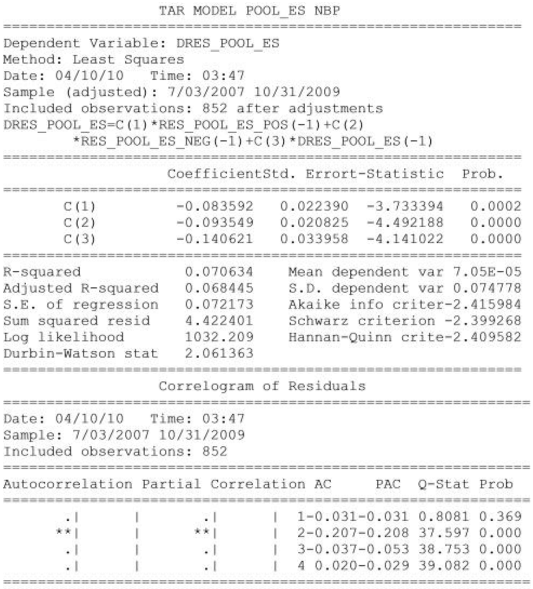
```
                  TAR MODEL POOL_ES API4                                      TAR MODEL POOL_ES API2
============================================================  ============================================================
Dependent Variable: DRES_POOL_ES                              Dependent Variable: DRES_POOL_ES
Method: Least Squares                                         Method: Least Squares
Date: 04/10/10   Time: 03:47                                  Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009                       Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments                 Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*RES_POOL_ES_POS(-1)+C(2)                    DRES_POOL_ES=C(1)*RES_POOL_ES_POS(-1)+C(2)
        *RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)                    *RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================  ============================================================
                   CoefficientStd. Errort-Statistic  Prob.                       CoefficientStd. Errort-Statistic  Prob.
============================================================  ============================================================
       C(1)         -0.111494  0.024450  -4.560049   0.0000          C(1)         -0.068917  0.019820  -3.477077   0.0005
       C(2)         -0.184364  0.029792  -6.188369   0.0000          C(2)         -0.085993  0.020726  -4.149016   0.0000
       C(3)         -0.126444  0.033921  -3.727578   0.0002          C(3)         -0.165370  0.033742  -4.901022   0.0000
============================================================  ============================================================
R-squared            0.100174   Mean dependent var-2.36E-05  R-squared            0.072784   Mean dependent var 0.000129
Adjusted R-squared   0.098055   S.D. dependent var 0.067905  Adjusted R-squared   0.070600   S.D. dependent var 0.066733
S.E. of regression   0.064490   Akaike info criter-2.641092  S.E. of regression   0.064334   Akaike info criter-2.645927
Sum squared resid    3.530977   Schwarz criterion -2.624376  Sum squared resid    3.513947   Schwarz criterion -2.629210
Log likelihood       1128.105   Hannan-Quinn crite-2.634690  Log likelihood       1130.165   Hannan-Quinn crite-2.639525
Durbin-Watson stat   2.060754                                Durbin-Watson stat   2.089840
============================================================  ============================================================
                  Correlogram of Residuals                                    Correlogram of Residuals
=============================================================  =============================================================
Date: 04/10/10   Time: 03:47                                  Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009                                  Sample: 7/03/2007 10/31/2009
Included observations: 852                                    Included observations: 852
=============================================================  =============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob   Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================  =============================================================
      .|      |      .|      | 1-0.033-0.033 0.9462 0.331         .|      |      .|      | 1-0.045-0.045 1.7392 0.187
     **|      |     **|      | 2-0.229-0.231 45.916 0.000        **|      |     **|      | 2-0.265-0.267 61.777 0.000
      .|      |      .|      | 3-0.003-0.021 45.923 0.000         .|      |      .|      | 3-0.033-0.065 62.707 0.000
      .|      |      .|      | 4 0.040-0.015 47.288 0.000         .|      |      .|      | 4 0.021-0.061 63.097 0.000
=============================================================  =============================================================

                  TAR MODEL POOL_ES BRENT                                     TAR MODEL POOL_ES FORTIES
============================================================  ============================================================
Dependent Variable: DRES_POOL_ES                              Dependent Variable: DRES_POOL_ES
Method: Least Squares                                         Method: Least Squares
Date: 04/10/10   Time: 03:47                                  Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009                       Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments                 Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*RES_POOL_ES_POS(-1)+C(2)                    DRES_POOL_ES=C(1)*RES_POOL_ES_POS(-1)+C(2)
        *RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)                    *RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================  ============================================================
                   CoefficientStd. Errort-Statistic  Prob.                       CoefficientStd. Errort-Statistic  Prob.
============================================================  ============================================================
       C(1)         -0.023853  0.011833  -2.015796   0.0441          C(1)         -0.023250  0.011767  -1.975827   0.0485
       C(2)         -0.032231  0.012990  -2.481127   0.0133          C(2)         -0.032289  0.012926  -2.497875   0.0127
       C(3)         -0.201250  0.033542  -6.000008   0.0000          C(3)         -0.202266  0.033534  -6.031708   0.0000
============================================================  ============================================================
R-squared            0.057600   Mean dependent var 5.10E-05  R-squared            0.057904   Mean dependent var 5.25E-05
Adjusted R-squared   0.055380   S.D. dependent var 0.065928  Adjusted R-squared   0.055685   S.D. dependent var 0.065999
S.E. of regression   0.064077   Akaike info criter-2.653957  S.E. of regression   0.064135   Akaike info criter-2.652134
Sum squared resid    3.485844   Schwarz criterion -2.637240  Sum squared resid    3.492206   Schwarz criterion -2.635417
Log likelihood       1133.586   Hannan-Quinn crite-2.647554  Log likelihood       1132.809   Hannan-Quinn crite-2.645731
Durbin-Watson stat   2.111291                                Durbin-Watson stat   2.111377
============================================================  ============================================================
                  Correlogram of Residuals                                    Correlogram of Residuals
=============================================================  =============================================================
Date: 04/10/10   Time: 03:47                                  Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009                                  Sample: 7/03/2007 10/31/2009
Included observations: 852                                    Included observations: 852
=============================================================  =============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob   Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================  =============================================================
      .|      |      .|      | 1-0.056-0.056 2.6665 0.102         .|      |      .|      | 1-0.056-0.056 2.6737 0.102
     **|      |     **|      | 2-0.285-0.289 72.354 0.000        **|      |     **|      | 2-0.284-0.288 71.777 0.000
      .|      |      *|      | 3-0.061-0.107 75.526 0.000         .|      |      *|      | 3-0.060-0.106 74.853 0.000
      .|      |      *|      | 4-0.014-0.123 75.687 0.000         .|      |      *|      | 4-0.014-0.122 75.033 0.000
=============================================================  =============================================================

                  TAR MODEL POOL_ES URALS                                     TAR MODEL POOL_ES GO_ARA
============================================================  ============================================================
Dependent Variable: DRES_POOL_ES                              Dependent Variable: DRES_POOL_ES
Method: Least Squares                                         Method: Least Squares
Date: 04/10/10   Time: 03:47                                  Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009                       Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments                 Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*RES_POOL_ES_POS(-1)+C(2)                    DRES_POOL_ES=C(1)*RES_POOL_ES_POS(-1)+C(2)
        *RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)                    *RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================  ============================================================
                   CoefficientStd. Errort-Statistic  Prob.                       CoefficientStd. Errort-Statistic  Prob.
============================================================  ============================================================
       C(1)         -0.023519  0.011780  -1.996520   0.0462          C(1)         -0.032595  0.013660  -2.386111   0.0172
       C(2)         -0.031528  0.012880  -2.447760   0.0146          C(2)         -0.044910  0.015357  -2.924362   0.0035
       C(3)         -0.201988  0.033541  -6.022130   0.0000          C(3)         -0.195336  0.033566  -5.819551   0.0000
============================================================  ============================================================
R-squared            0.057568   Mean dependent var 2.77E-05  R-squared            0.061553   Mean dependent var 8.32E-05
Adjusted R-squared   0.055348   S.D. dependent var 0.066020  Adjusted R-squared   0.059343   S.D. dependent var 0.066515
S.E. of regression   0.064167   Akaike info criter-2.651130  S.E. of regression   0.064511   Akaike info criter-2.640436
Sum squared resid    3.495713   Schwarz criterion -2.634413  Sum squared resid    3.533298   Schwarz criterion -2.623719
Log likelihood       1132.381   Hannan-Quinn crite-2.644727  Log likelihood       1127.826   Hannan-Quinn crite-2.634033
Durbin-Watson stat   2.111719                                Durbin-Watson stat   2.107208
============================================================  ============================================================
                  Correlogram of Residuals                                    Correlogram of Residuals
=============================================================  =============================================================
Date: 04/10/10   Time: 03:47                                  Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009                                  Sample: 7/03/2007 10/31/2009
Included observations: 852                                    Included observations: 852
=============================================================  =============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob   Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================  =============================================================
      .|      |      .|      | 1-0.056-0.056 2.6867 0.101         .|      |      .|      | 1-0.054-0.054 2.4844 0.115
     **|      |     **|      | 2-0.285-0.289 72.403 0.000        **|      |     **|      | 2-0.283-0.287 71.104 0.000
      .|      |      *|      | 3-0.060-0.106 75.508 0.000         *|      |      *|      | 3-0.066-0.111 74.845 0.000
      .|      |      *|      | 4-0.013-0.122 75.651 0.000         .|      |      *|      | 4-0.010-0.117 74.925 0.000
=============================================================  =============================================================
```



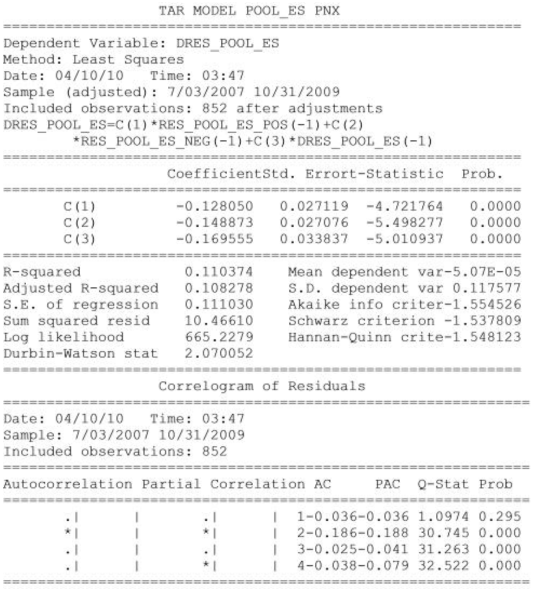
```
                    TAR MODEL POOL_ES TTF
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*RES_POOL_ES_POS(-1)+C(2)
        *RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                     CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)          -0.083745   0.022264  -3.761516   0.0002
       C(2)          -0.080831   0.019696  -4.103818   0.0000
       C(3)          -0.152680   0.033911  -4.502363   0.0000
============================================================
R-squared             0.070670    Mean dependent var 5.81E-05
Adjusted R-squared    0.068481    S.D. dependent var 0.068673
S.E. of regression    0.066280    Akaike info criter-2.586352
Sum squared resid     3.729653    Schwarz criterion -2.569635
Log likelihood        1104.786    Hannan-Quinn crite-2.579949
Durbin-Watson stat    2.067200
============================================================
                    Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |       .|       |  1-0.034-0.034 0.9782 0.323
      **|       |      **|       |  2-0.212-0.213 39.347 0.000
       .|       |       .|       |  3-0.016-0.034 39.580 0.000
       .|       |       .|       |  4 0.008-0.041 39.633 0.000
=============================================================
```



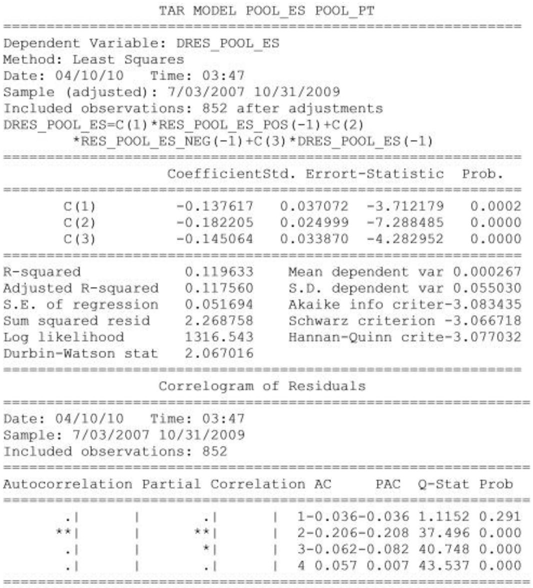
```
                    TAR MODEL POOL_ES ZEE
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*RES_POOL_ES_POS(-1)+C(2)
        *RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                     CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)          -0.079749   0.022168  -3.597526   0.0003
       C(2)          -0.083116   0.019703  -4.218496   0.0000
       C(3)          -0.156417   0.033893  -4.615000   0.0000
============================================================
R-squared             0.071680    Mean dependent var 6.42E-05
Adjusted R-squared    0.069493    S.D. dependent var 0.073541
S.E. of regression    0.070940    Akaike info criter-2.450457
Sum squared resid     4.272549    Schwarz criterion -2.433740
Log likelihood        1046.895    Hannan-Quinn crite-2.444054
Durbin-Watson stat    2.065915
============================================================
                    Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |       .|       |  1-0.033-0.033 0.9424 0.332
       *|       |       *|       |  2-0.203-0.205 36.381 0.000
       .|       |       .|       |  3-0.026-0.043 36.972 0.000
       .|       |       .|       |  4-0.011-0.058 37.076 0.000
=============================================================
```



```
                    TAR MODEL POOL_ES NBP
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*RES_POOL_ES_POS(-1)+C(2)
        *RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                     CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)          -0.083592   0.022390  -3.733394   0.0002
       C(2)          -0.093549   0.020825  -4.492188   0.0000
       C(3)          -0.140621   0.033958  -4.141022   0.0000
============================================================
R-squared             0.070634    Mean dependent var 7.05E-05
Adjusted R-squared    0.068445    S.D. dependent var 0.074778
S.E. of regression    0.072173    Akaike info criter-2.415984
Sum squared resid     4.422401    Schwarz criterion -2.399268
Log likelihood        1032.209    Hannan-Quinn crite-2.409582
Durbin-Watson stat    2.061363
============================================================
                    Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |       .|       |  1-0.031-0.031 0.8081 0.369
      **|       |      **|       |  2-0.207-0.208 37.597 0.000
       .|       |       .|       |  3-0.037-0.053 38.753 0.000
       .|       |       .|       |  4 0.020-0.029 39.082 0.000
=============================================================
```

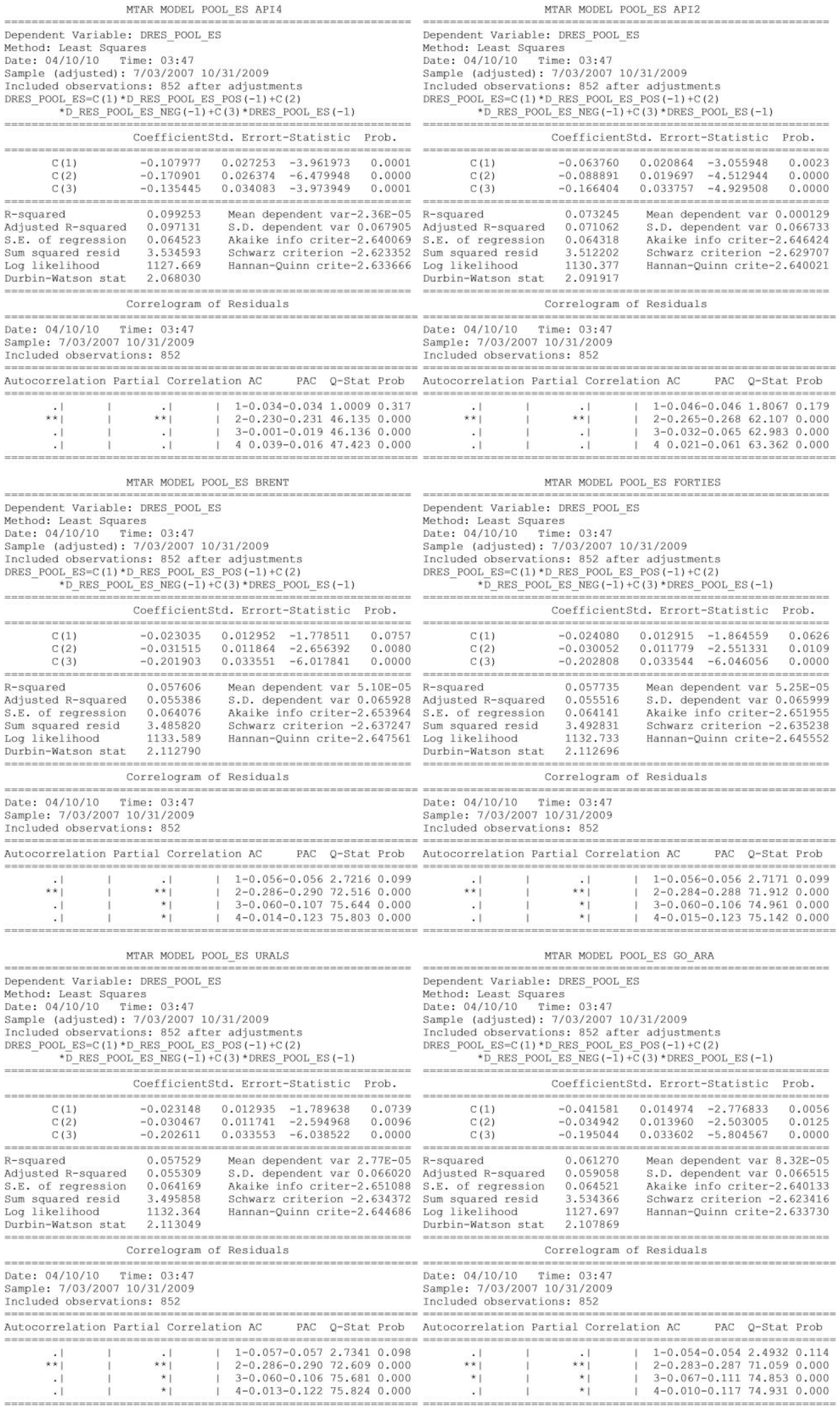


```
                    TAR MODEL POOL_ES PNX
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*RES_POOL_ES_POS(-1)+C(2)
        *RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                     CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)          -0.128050   0.027119  -4.721764   0.0000
       C(2)          -0.148873   0.027076  -5.498277   0.0000
       C(3)          -0.169555   0.033837  -5.010937   0.0000
============================================================
R-squared             0.110374    Mean dependent var-5.07E-05
Adjusted R-squared    0.108278    S.D. dependent var 0.117577
S.E. of regression    0.111030    Akaike info criter-1.554526
Sum squared resid     10.46610    Schwarz criterion -1.537809
Log likelihood        665.2279    Hannan-Quinn crite-1.548123
Durbin-Watson stat    2.070052
============================================================
                    Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |       .|       |  1-0.036-0.036 1.0974 0.295
       *|       |       *|       |  2-0.186-0.188 30.745 0.000
       .|       |       .|       |  3-0.025-0.041 31.263 0.000
       .|       |       *|       |  4-0.038-0.079 32.522 0.000
=============================================================
```



```
                    TAR MODEL POOL_ES POOL_PT
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*RES_POOL_ES_POS(-1)+C(2)
        *RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                     CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)          -0.137617   0.037072  -3.712179   0.0002
       C(2)          -0.182205   0.024999  -7.288485   0.0000
       C(3)          -0.145064   0.033870  -4.282952   0.0000
============================================================
R-squared             0.119633    Mean dependent var 0.000267
Adjusted R-squared    0.117560    S.D. dependent var 0.055030
S.E. of regression    0.051694    Akaike info criter-3.083435
Sum squared resid     2.268758    Schwarz criterion -3.066718
Log likelihood        1316.543    Hannan-Quinn crite-3.077032
Durbin-Watson stat    2.067016
============================================================
                    Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |       .|       |  1-0.036-0.036 1.1152 0.291
      **|       |      **|       |  2-0.206-0.208 37.496 0.000
       .|       |       *|       |  3-0.062-0.082 40.748 0.000
       .|       |       .|       |  4 0.057 0.007 43.537 0.000
=============================================================
```

Table 14 - MTAR Model and Autocorrelation Tests (DW Statistic and Q-Statistic)



```
                 MTAR MODEL POOL_ES API4
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*D_RES_POOL_ES_POS(-1)+C(2)
        *D_RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                  CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)        -0.107977  0.027253  -3.961973   0.0001
       C(2)        -0.170901  0.026374  -6.479948   0.0000
       C(3)        -0.135445  0.034083  -3.973949   0.0001
============================================================
R-squared            0.099253   Mean dependent var-2.36E-05
Adjusted R-squared   0.097131   S.D. dependent var 0.067905
S.E. of regression   0.064523   Akaike info criter-2.640069
Sum squared resid    3.534593   Schwarz criterion -2.623352
Log likelihood       1127.669   Hannan-Quinn crite-2.633666
Durbin-Watson stat   2.068030
============================================================
                 Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |        .|      |  1-0.034-0.034 1.0009 0.317
      **|       |       **|      |  2-0.230-0.231 46.135 0.000
       .|       |        .|      |  3-0.001-0.019 46.136 0.000
       .|       |        .|      |  4 0.039-0.016 47.423 0.000
=============================================================
```

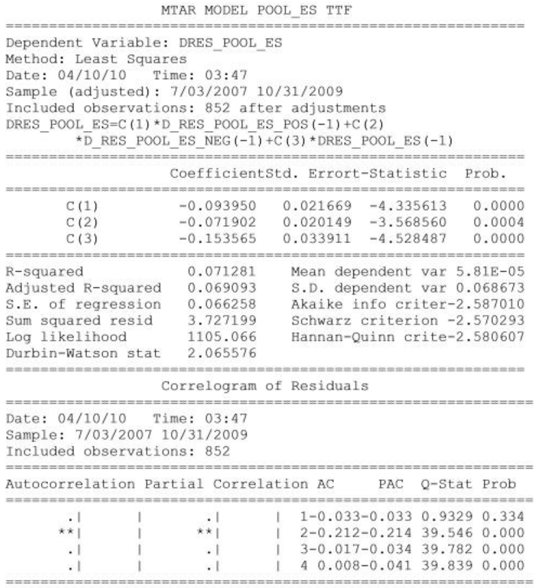
```
                 MTAR MODEL POOL_ES API2
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*D_RES_POOL_ES_POS(-1)+C(2)
        *D_RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                  CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)        -0.063760  0.020864  -3.055948   0.0023
       C(2)        -0.088891  0.019697  -4.512944   0.0000
       C(3)        -0.166404  0.033757  -4.929508   0.0000
============================================================
R-squared            0.073245   Mean dependent var 0.000129
Adjusted R-squared   0.071062   S.D. dependent var 0.066733
S.E. of regression   0.064318   Akaike info criter-2.646424
Sum squared resid    3.512202   Schwarz criterion -2.629707
Log likelihood       1130.377   Hannan-Quinn crite-2.640021
Durbin-Watson stat   2.091917
============================================================
                 Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |        .|      |  1-0.046-0.046 1.8067 0.179
      **|       |       **|      |  2-0.265-0.268 62.107 0.000
       .|       |        .|      |  3-0.032-0.065 62.983 0.000
       .|       |        .|      |  4 0.021-0.061 63.362 0.000
=============================================================
```

```
                 MTAR MODEL POOL_ES BRENT
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*D_RES_POOL_ES_POS(-1)+C(2)
        *D_RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                  CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)        -0.023035  0.012952  -1.778511   0.0757
       C(2)        -0.031515  0.011864  -2.656392   0.0080
       C(3)        -0.201903  0.033551  -6.017841   0.0000
============================================================
R-squared            0.057606   Mean dependent var 5.10E-05
Adjusted R-squared   0.055386   S.D. dependent var 0.065928
S.E. of regression   0.064076   Akaike info criter-2.653964
Sum squared resid    3.485820   Schwarz criterion -2.637247
Log likelihood       1133.589   Hannan-Quinn crite-2.647561
Durbin-Watson stat   2.112790
============================================================
                 Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |        .|      |  1-0.056-0.056 2.7216 0.099
      **|       |       **|      |  2-0.286-0.290 72.516 0.000
       .|       |        *|      |  3-0.060-0.107 75.644 0.000
       .|       |        *|      |  4-0.014-0.123 75.803 0.000
=============================================================
```

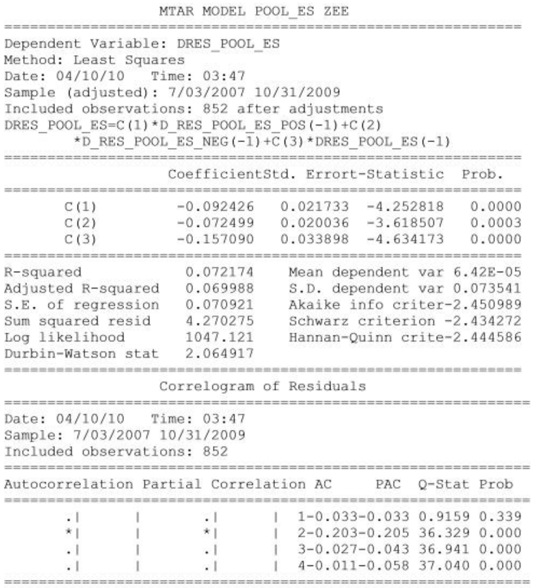
```
                 MTAR MODEL POOL_ES FORTIES
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*D_RES_POOL_ES_POS(-1)+C(2)
        *D_RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                  CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)        -0.024080  0.012915  -1.864559   0.0626
       C(2)        -0.030052  0.011779  -2.551331   0.0109
       C(3)        -0.202808  0.033544  -6.046056   0.0000
============================================================
R-squared            0.057735   Mean dependent var 5.25E-05
Adjusted R-squared   0.055516   S.D. dependent var 0.065999
S.E. of regression   0.064141   Akaike info criter-2.651955
Sum squared resid    3.492831   Schwarz criterion -2.635238
Log likelihood       1132.733   Hannan-Quinn crite-2.645552
Durbin-Watson stat   2.112696
============================================================
                 Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |        .|      |  1-0.056-0.056 2.7171 0.099
      **|       |       **|      |  2-0.284-0.288 71.912 0.000
       .|       |        *|      |  3-0.060-0.106 74.961 0.000
       .|       |        *|      |  4-0.015-0.123 75.142 0.000
=============================================================
```

```
                 MTAR MODEL POOL_ES URALS
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*D_RES_POOL_ES_POS(-1)+C(2)
        *D_RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                  CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)        -0.023148  0.012935  -1.789638   0.0739
       C(2)        -0.030467  0.011741  -2.594968   0.0096
       C(3)        -0.202611  0.033553  -6.038522   0.0000
============================================================
R-squared            0.057529   Mean dependent var 2.77E-05
Adjusted R-squared   0.055309   S.D. dependent var 0.066020
S.E. of regression   0.064169   Akaike info criter-2.651088
Sum squared resid    3.495858   Schwarz criterion -2.634372
Log likelihood       1132.364   Hannan-Quinn crite-2.644686
Durbin-Watson stat   2.113049
============================================================
                 Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |        .|      |  1-0.057-0.057 2.7341 0.098
      **|       |       **|      |  2-0.286-0.290 72.609 0.000
       .|       |        *|      |  3-0.060-0.106 75.681 0.000
       .|       |        *|      |  4-0.013-0.122 75.824 0.000
=============================================================
```

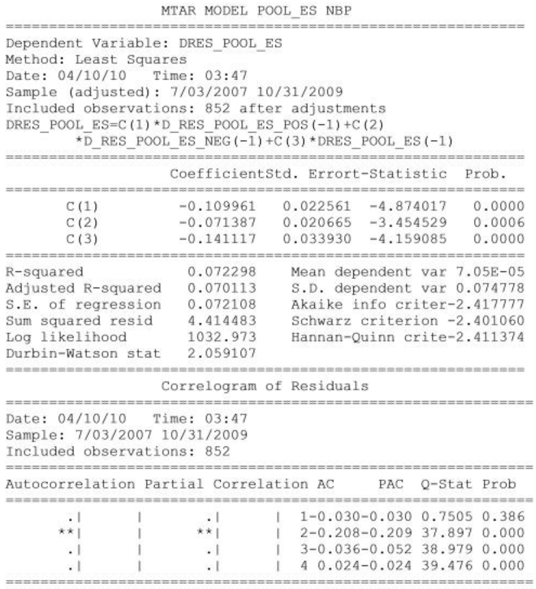
```
                 MTAR MODEL POOL_ES GO_ARA
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*D_RES_POOL_ES_POS(-1)+C(2)
        *D_RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                  CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)        -0.041581  0.014974  -2.776833   0.0056
       C(2)        -0.034942  0.013960  -2.503005   0.0125
       C(3)        -0.195044  0.033602  -5.804567   0.0000
============================================================
R-squared            0.061270   Mean dependent var 8.32E-05
Adjusted R-squared   0.059058   S.D. dependent var 0.066515
S.E. of regression   0.064521   Akaike info criter-2.640133
Sum squared resid    3.534366   Schwarz criterion -2.623416
Log likelihood       1127.697   Hannan-Quinn crite-2.633730
Durbin-Watson stat   2.107869
============================================================
                 Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |        .|      |  1-0.054-0.054 2.4932 0.114
      **|       |       **|      |  2-0.283-0.287 71.059 0.000
       *|       |        *|      |  3-0.067-0.111 74.853 0.000
       .|       |        *|      |  4-0.010-0.117 74.931 0.000
=============================================================
```



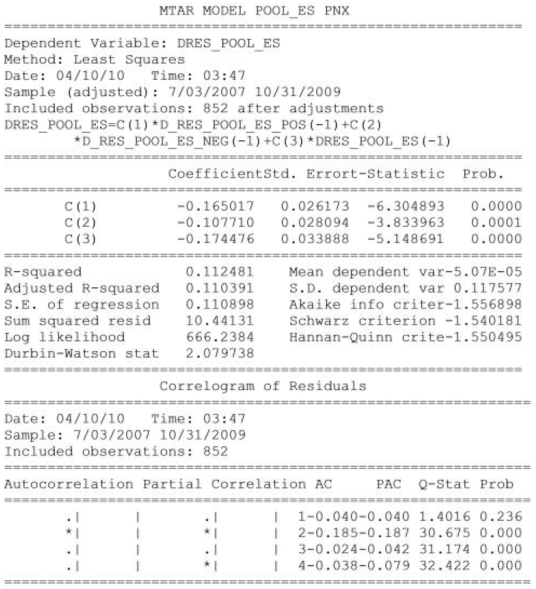
```
                  MTAR MODEL POOL_ES TTF
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*D_RES_POOL_ES_POS(-1)+C(2)
        *D_RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                   CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)          -0.093950  0.021669  -4.335613   0.0000
       C(2)          -0.071902  0.020149  -3.568560   0.0004
       C(3)          -0.153565  0.033911  -4.528487   0.0000
============================================================
R-squared             0.071281    Mean dependent var 5.81E-05
Adjusted R-squared    0.069093    S.D. dependent var 0.068673
S.E. of regression    0.066258    Akaike info criter-2.587010
Sum squared resid     3.727199    Schwarz criterion -2.570293
Log likelihood        1105.066    Hannan-Quinn crite-2.580607
Durbin-Watson stat    2.065576
============================================================
                  Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |        .|       |  1-0.033-0.033 0.9329 0.334
      **|       |       **|       |  2-0.212-0.214 39.546 0.000
       .|       |        .|       |  3-0.017-0.034 39.782 0.000
       .|       |        .|       |  4 0.008-0.041 39.839 0.000
=============================================================
```



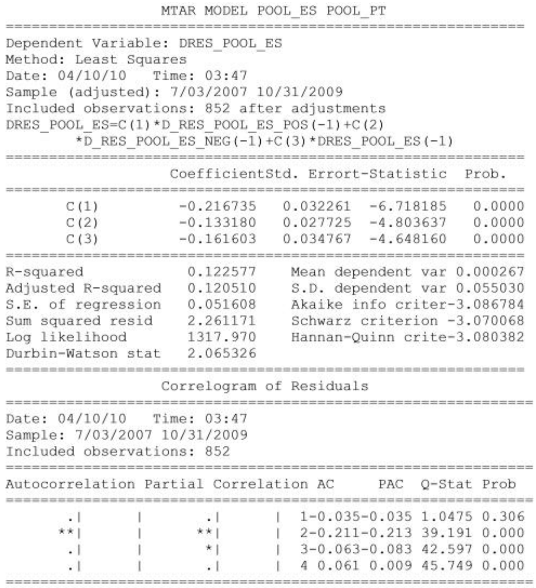
```
                  MTAR MODEL POOL_ES ZEE
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*D_RES_POOL_ES_POS(-1)+C(2)
        *D_RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                   CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)          -0.092426  0.021733  -4.252818   0.0000
       C(2)          -0.072499  0.020036  -3.618507   0.0003
       C(3)          -0.157090  0.033898  -4.634173   0.0000
============================================================
R-squared             0.072174    Mean dependent var 6.42E-05
Adjusted R-squared    0.069988    S.D. dependent var 0.073541
S.E. of regression    0.070921    Akaike info criter-2.450989
Sum squared resid     4.270275    Schwarz criterion -2.434272
Log likelihood        1047.121    Hannan-Quinn crite-2.444586
Durbin-Watson stat    2.064917
============================================================
                  Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |        .|       |  1-0.033-0.033 0.9159 0.339
       *|       |        *|       |  2-0.203-0.205 36.329 0.000
       .|       |        .|       |  3-0.027-0.043 36.941 0.000
       .|       |        .|       |  4-0.011-0.058 37.040 0.000
=============================================================
```



```
                  MTAR MODEL POOL_ES NBP
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*D_RES_POOL_ES_POS(-1)+C(2)
        *D_RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                   CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)          -0.109961  0.022561  -4.874017   0.0000
       C(2)          -0.071387  0.020665  -3.454529   0.0006
       C(3)          -0.141117  0.033930  -4.159085   0.0000
============================================================
R-squared             0.072298    Mean dependent var 7.05E-05
Adjusted R-squared    0.070113    S.D. dependent var 0.074778
S.E. of regression    0.072108    Akaike info criter-2.417777
Sum squared resid     4.414483    Schwarz criterion -2.401060
Log likelihood        1032.973    Hannan-Quinn crite-2.411374
Durbin-Watson stat    2.059107
============================================================
                  Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |        .|       |  1-0.030-0.030 0.7505 0.386
      **|       |       **|       |  2-0.208-0.209 37.897 0.000
       .|       |        .|       |  3-0.036-0.052 38.979 0.000
       .|       |        .|       |  4 0.024-0.024 39.476 0.000
=============================================================
```



```
                  MTAR MODEL POOL_ES PNX
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*D_RES_POOL_ES_POS(-1)+C(2)
        *D_RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                   CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)          -0.165017  0.026173  -6.304893   0.0000
       C(2)          -0.107710  0.028094  -3.833963   0.0001
       C(3)          -0.174476  0.033888  -5.148691   0.0000
============================================================
R-squared             0.112481    Mean dependent var-5.07E-05
Adjusted R-squared    0.110391    S.D. dependent var 0.117577
S.E. of regression    0.110898    Akaike info criter-1.556898
Sum squared resid     10.44131    Schwarz criterion -1.540181
Log likelihood        666.2384    Hannan-Quinn crite-1.550495
Durbin-Watson stat    2.079738
============================================================
                  Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |        .|       |  1-0.040-0.040 1.4016 0.236
       *|       |        *|       |  2-0.185-0.187 30.675 0.000
       .|       |        .|       |  3-0.024-0.042 31.174 0.000
       .|       |        *|       |  4-0.038-0.079 32.422 0.000
=============================================================
```



```
                  MTAR MODEL POOL_ES POOL_PT
============================================================
Dependent Variable: DRES_POOL_ES
Method: Least Squares
Date: 04/10/10   Time: 03:47
Sample (adjusted): 7/03/2007 10/31/2009
Included observations: 852 after adjustments
DRES_POOL_ES=C(1)*D_RES_POOL_ES_POS(-1)+C(2)
        *D_RES_POOL_ES_NEG(-1)+C(3)*DRES_POOL_ES(-1)
============================================================
                   CoefficientStd. Errort-Statistic  Prob.
============================================================
       C(1)          -0.216735  0.032261  -6.718185   0.0000
       C(2)          -0.133180  0.027725  -4.803637   0.0000
       C(3)          -0.161603  0.034767  -4.648160   0.0000
============================================================
R-squared             0.122577    Mean dependent var 0.000267
Adjusted R-squared    0.120510    S.D. dependent var 0.055030
S.E. of regression    0.051608    Akaike info criter-3.086784
Sum squared resid     2.261171    Schwarz criterion -3.070068
Log likelihood        1317.970    Hannan-Quinn crite-3.080382
Durbin-Watson stat    2.065326
============================================================
                  Correlogram of Residuals
=============================================================
Date: 04/10/10   Time: 03:47
Sample: 7/03/2007 10/31/2009
Included observations: 852
=============================================================
Autocorrelation Partial Correlation AC     PAC  Q-Stat Prob
=============================================================
       .|       |        .|       |  1-0.035-0.035 1.0475 0.306
      **|       |       **|       |  2-0.211-0.213 39.191 0.000
       .|       |        *|       |  3-0.063-0.083 42.597 0.000
       .|       |        .|       |  4 0.061 0.009 45.749 0.000
=============================================================
```