12. ESTIMATING COAL PRICE DYNAMICS WITH THE PRINCIPAL COMPONENTS METHOD

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Abstract

The future use of coal depends on environmental protection measures and the Kyoto Protocol, the price of CO_2 emission coupons, consumption, new technologies, the price of other energy sources and the liberalization of the electricity markets. The prices of emission coupons will impact the costs of electricity energy production.

Due to the relatively higher reference costs of alternative energy sources, we can not expect that the share of coal as an energy source will lower significantly as a source of electricity production in the future. From the point of view of regional economic aspects and the reference costs of electricity production, we could state that using coal in the near future is also tied to the socio-economic aspects of mining domestic coal. Using it in thermo plants is also enabled by the conditions of priority dispatching (since 2000) in the EU economies.

We assessed the influence of prices and the use of other energy sources, environmental measures, energy efficiency and the influence of electricity market liberalisation on coal price movements. Our estimation shows that, if the prices of other energy sources and electricity increase, the price of coal increases. If the use of other energy sources increases, and if the gross uses of industrial waste and renewable resources increase, the price of coal decreases. Environmental protection measures contribute to an increase in coal prices. A higher quotient of energy efficiency decelerates the price of coal. And the euro (to dollar) appreciation decelerates coal prices.

Keywords: coal prices, environmental protection measures, priority dispatching

JEL Classification: C22, C40, C50, Q31, Q40

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1. Introduction

Energy demand is met differently in different world regions, the decisive factor being the natural resources in individual regions. Europe depends on the importing of primary resources, thus making nuclear energy an important energy resource. Lately, natural gas has gained importance as a primary energy resource. In the US, a country with one of the highest black coal reserves, black coal is the most important energy resource for generating electricity. Oil and petroleum-product consumption still prevails worldwide, with the present situation likely to remain the same until 2025. World consumption growth has been estimated to 1.9% annually and by 2025 is supposed to increase from the present 80 million barrels a day to 118 million barrels per day (Energy Security, 2008).

Industrial growth in developing countries like China and India constitute an additional pressure on energy price growth. It is expected that, in the following thirty years, the demand for energy will increase by approximately 60%. Two thirds of this increase will stem from needs in developing countries, which is expected to reach 50% of world energy consumption by 2030. Price movements do not exempt any energy resource, because they are – in addition to increased demand – dictated by relatively expensive alternative sources and new technological solutions. Thus, further rises in energy prices can be expected on world markets (Clean Energy, 2008).

In the chapter two, we will present an overview of coal resources and prices, the consumption dynamics of coal, environmental measures, the forecasts of coal prices and future trends. In the third chapter, we will present an empirical analysis of the determinants of coal price movement. We used the principal components method (PCA) to estimate coal price movements by employing the explanatory variables of electricity prices, consumption, the prices of oil, natural gas and uranium, different environmental measures, energy efficiency, nuclear energy and renewable resource consumption. The discussion regarding the reference cost of electricity production from different energy sources and the impact of emission certificates on electricity production and the prices in thermo plants are given in the sub-chapter. The implications and results are presented in the conclusion.

2. Prices, reserves and use of coal

Worldwide, coal is one of the most important energy sources in the production of primary energy, where it contributes, on average, one fourth of all primary energy. In 2004, the share of coal in global primary energy consumption amounted to 27%, in 2005 to 25% (WCI, 2007). By 2030, according to estimates, approximately 39-40% of global electricity requirements will be produced by coal (Lajevec *et al.*, 2007). Thus, coal is likely to remain an important energy resource in the future.

Coal price movements during the last decades can be compared with the movements of oil and natural gas prices, but with regard to energy content, the dynamics are on a substantially lower level (WEC, 2008).

The price of coal depends on its quality, where much depends on its calorific value, sulphuric content and the level of moisture (Eurocoal, 2008b).[1] According to the standard international qualification of coals Antwerp - Rotterdam - Amsterdam (cif ARA) appropriate quality coal has an energy content of 6000 kcal/kg (29.31 MJ/kg), 1% sulphur content and 16% ash content.

In comparison with reserves of natural gas and oil, the reserves of coal are much higher and the distribution of reserves, especially black coal, is much more even than the distribution of oil and natural gas. Russia has a considerable share of the global reserves of coal, with important deposits of black coal in North America, Asia, Australia and South Africa, where there is less oil and natural gas. The countries with the largest coal reserves include: the USA, Russia, China, India and Australia (75% of proven reserves are found in these countries). In contrast to the reserves of oil and natural gas, there are large deposits of coal in the EU, but with substantial differences in its quality (Lajevec *et al*., 2007).

The World Energy Council (WCI 2008) report for 2007 states that world reserves at the end of 2005 amounted to 847.5 Gt, which is 61.5 Gt or 6.8% less than at the end of 2002 (WCI 2007). Taking into account global consumption for 2004, proven reserves of black coal will last for 172 years, and the reserves of brown coal for 218 years.

In Europe, the demand for coal, which on average amounted to around 770 million tons annually, has not changed considerably in recent times. In 2007, in comparison to 2006, the demand has slightly decreased. In the first half of 2007, total coal consumption was 398.4 million tons, of which slightly more than one fourth was imported. In the period between 2003–2007, there was a trend of reduced consumption of coal in the USA, especially in the commercial sector and households, except in the production of electricity, where consumption increased by 4% (EIA 2007).

On average, the EU uses one fifth of domestic black coal, the consumption of which decreases by 1-2% a year. The deficit in the EU is covered by imports (roughly one third).[2] More than one half of the demand is covered by lignite, which has, due to the market situation, become more competitive at the end of 2006 and the beginning of 2007. The consumption of lignite in the EU increased slightly during this period: from 48% of total consumption in 2005, its share increased to 53% of total consumption in the first half of 2007. The reasons for this were to be found in the relatively high price of natural gas and surplus of emission coupons, which reached a price lower than 10 €/t CO_2 in October 2006 (at the beginning of 2007 the price of coupons decreased to around 1€/t CO_2) (Eurocoal, 2008, 2008a).

In 2005, 16% of global electricity production was generated by hydroelectric power stations, 15% from nuclear power stations, 20% from natural gas, 7% from oil and 40% from coal (WCI, 2007, http://www.worldcoal.org). The share of electricity produced from coal varies. In Poland and South Africa, this share exceeds 90%. In

[1] It was expected that the coal demand would grow mainly because of the growth of the Chinese and Indian economy. The EU Directive EC/2001/77 obliges EU member states to produce at least 33.6% of their electricity from renewable sources by 2010, which means that increased environmental measures also increase the price of electricity produced by coal.

[2] Germany is the biggest coal consumer in the EU. Together with the UK, Germany is also the biggest black coal importer.

Israel, Kazakhstan, India, China and Morocco it constitutes up to 70%. Coal will continue to have the most important role in the production of electricity in the future. Projections until 2030 show an only 1% decrease in coal-powered electricity, which means that its share will remain at 39% (EIA 2008).

2.1. Environmental measures influencing the consumption and price of coal

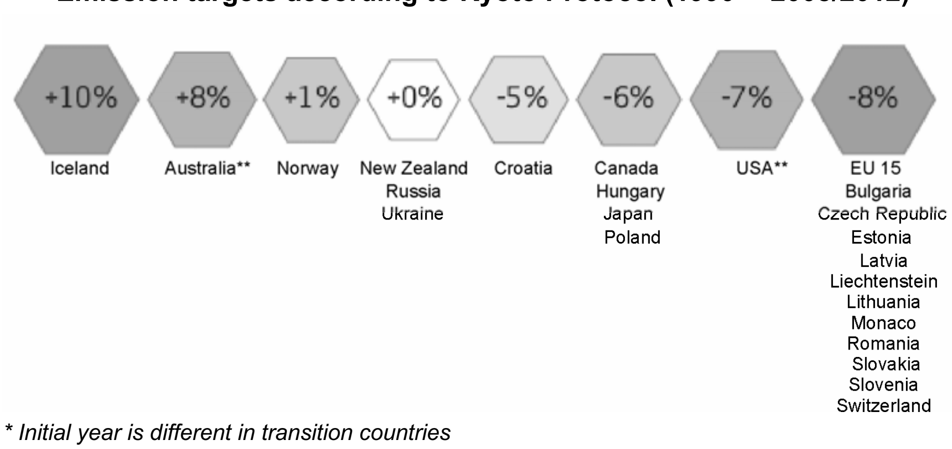
Future coal reserve consumption depend, and is conditional, on environmental requirements. The price of coal is influenced by the price of coal production and preparation technologies, i.e. transportation costs, environmental legislation, the price of coal burning technology, the price of gas purification, the price of CO_2 permissions or emission coupons, the consumption and price of other energy sources (natural gas and oil) and liberalization of the electricity markets. Forecasted emissions of CO_2 are increasing due to increased energy consumption until 2030 (Kucewitz, 2007).

Coal mining has numerous environmental impacts, especially in the case of surface mining on large areas of land that may become permanently degraded, and are subject to soil erosion, dust, noise, the creation of waste waters and leachate, as well as damaging the local biodiversity. In underground mining, methane is released (CH_4) – a greenhouse gas emission (GHG). Around 8% of global methane emissions are due to coal burning, of which China, Russia, Poland and the United States account for over 77 % of coal mine CH_4 emissions (WEC, 2008).

The consumption of coal causes further environmental stress because of CO_2 emissions, sulphur oxides (SO_x) and nitrogen oxides (NO_x) – responsible for acid rain, and flying ash, which includes dust particles and heavy metals, particularly mercury (Hg) and selenium (Se). In addition, the effects of coal mining and burning include the emission of toxic substances in soil, surface water and indirectly into groundwater.

Figure 1

Emission targets according to Kyoto Protocol (1990* - 2008/2012)



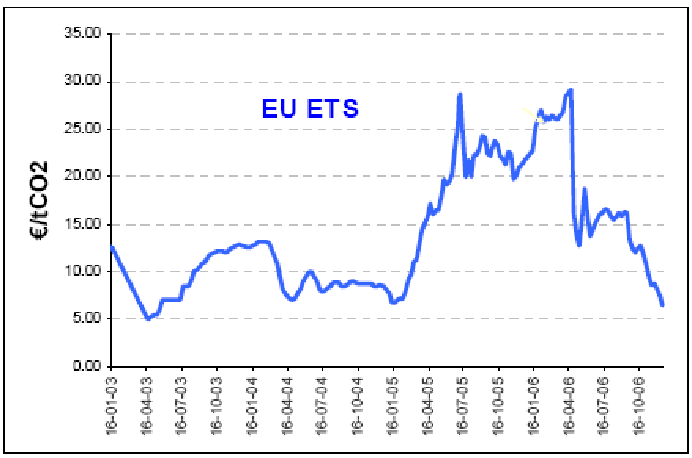
** Initial year is different in transition countries*
*** Countries, which did not ratify the Kyoto Protocol*
Source: The Coal Resource, WCI (2007).

Environmental issues influencing the consumption and price of coal can thus be summarised as follows: mining technologies, transportation, the preparation and combustion procedure, technology gas purification, all of which have the main aim of improving coal efficiency with the lowest possible emissions of dust, CO_2,SO_2 in NO_x (WCI, 2004). Due to these environmental issues, different technologies are being developed in order to improve combustion that, as already noted, consumes 40% of global coal production.

Coal CO_2 emissions are similar to those of other fossil fuels (21% natural gas, 38% coal and 41% oil). In order to reduce emissions, the Kyoto Protocol was adopted in 1997, which entered into force on February 16, 2005 (WCI, 2004). Figure 1 shows data on emission targets for different countries.

Figure 2

Price movements of emission coupons in the European emissions market



Source: Reinaud (2007).

The Kyoto Protocol also introduced emissions trading, which became the key mechanism in efforts to reduce GHG emissions. When the emission trading system was introduced, it involved around 11,500 plants across the EU-25. It is based on the exchange of unused emission allowances, with €14.6 billion transactions in 2006 (Reinaud, 2007). In OECD countries, the biggest participant in emission trading are thermal power plants, which represent 50% EU-ETS in the EU. Within the first trading period, the relationship between the price of emission coupons, the price of electricity and industrial expenses was established. Figure 2 illustrates the price movements of emission allowances for 2003 - 2006 in the EU-ETS.

Until 2030, the price of electricity is likely to increase due to increased demand, expensive energy and capital intensive technologies and reach 58-73 €/MWh (Brečevič *et al.*, 2008). Such estimates take into account prices for emission coupons ranging from 2 to 12 €/t CO_2ekv.

The price on January 1. 2008, was 5,53 € but dropped to 2 c€ by December 2008 of the same year. The price of coupons on the free market was around 1 c€ by the end of March 2008, which, according to the opinion of some experts, equals zero (EEX, 2008). How the price will move in the new trading period 2008-2012, which will try to correct some mistakes from the first trading period, is difficult to forecast. According to some estimates, the price of emission coupons is likely to be higher, because there will not be so many coupons available. During this period, the price was likely to be in the range of 20 to 21 €/t CO_2ekv (Energy, 2008).

The use of coal in the EU will also be influenced by the price of natural gas and emission coupons. If natural gas is relatively expensive, it will only be competitive when the price of emission coupons exceeds 30 €/t CO_2ekv. In order to decrease emissions, the price of coupons should be at least 45 €/t CO_2ekv. If the price of natural gas is low, coal will only be competitive on the liberalised energy market if the price of coupons is lower than 15 €/t CO_2ekv. In comparison with other fossil fuels, coal is relatively cheap.

New carbon capture and storage technologies (»Carbon Capture and Storage« - CCS) will increase the range of possibilities for coal use within the next decades (Eurocoal, 2007a, 2007b, 2007). Estimates in studies show (Kavalov and Peteves, 2007; Eurocoal, 2007b) that the use of coal on the liberalized European energy market will remain competitive in the next twenty years in highly efficient thermal power plants by implementing so-called CCS technologies (this is done on the assumption that the price of emission coupons will remain slightly below 30 €/t CO_2ekv). Technological progress has enabled ecologically friendly alternative technologies using coal and methane (captured in coal mines), which could be expected to become an important energy source for electricity production. Underground gasification could become an alternative technology using deep-lying coal and clean gasification of fuel used for the production of electricity energy (there are also some alternative technologies, like integrated gasification with a combined cycle).

2.2 Forecast and trends

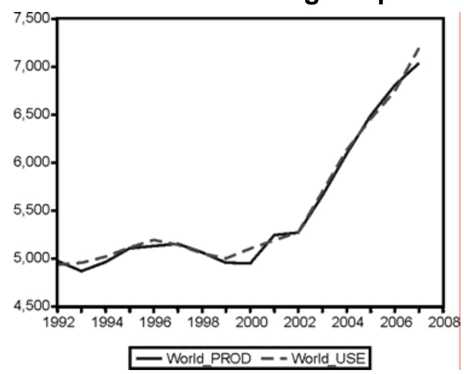
We have to consider global energy prognoses after 2008. The International Agency for Energy published a research paper entitled »Global anticipations on the field of energetic after 2008« (WEO, 2008) that included their estimates until the year 2030. They reported that coal was the second most important source of energy in 2006. They also estimated that the price of coal is going to increase until 2015 by an average of 3.1% annually and by an average of 1.3% annually between the years 2015 and 2030. The global use of coal is expected to increase by 32% until 2015 and eventually reach 7011 Mtce by 2030. The share of coal in the whole supply of energy is expected to increase until 2025. The share of coal as a part of primary energy in OECD economies is expected to fall from 21% in 2006 to 19% by 2030, which is an insignificant decrease of two percentage points (the reason for the decline in the use of coal is a switch to the use of gas and renewable sources). Attractive coal prices have stimulated the demand for coal, especially in China and India; the share of coal in the energy sector is expected to increase in the period from 2006 until 2030 by an average of 2.2% annually (WEC, 2008).

Demand for electrical energy is expected to increase by 3.2% annually during the period between 2006 and 2015; afterwards growth is expected to decelerate till 2030 and reach 2% per annum.

Coal, as a fossil fuel with a world stock estimated at 10^{12} t, has the longest time perspective for use in the energy production sector. The world production of coal in 2007 reached 7,036 mega short tons (MST) according to data from the Energy Information Administration (EIA) and the use of coal topped 7,193 short tons (MST) (EIA, 2007). The production and use of coal have been increasing rapidly around the world from 2000 on (when figures were around 5000 MST) Figure 3 shows the world production and use of coal from 1992 onwards. Based on economic criteria, coal is the most attractive energy source for the production of electricity. Figure 4 shows the prices of fossil fuels for the production of electricity in the period from 1995 to 2008.

Figure 3

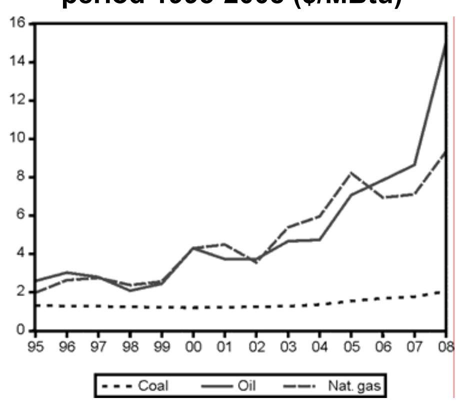
World production and use of coal during the period 1992-2007 (MST)



Source: Energy Information Administration (2007).

Figure 4

The price of fossil fuels used in the production of electricity during the period 1995-2008 ($/MBtu)



Source: Energy Information Administration (2007).

The starting point for the estimation of coal price dynamics are Richard Bay and Amsterdam-Rotterdam-Antwerp (ARA) while the European energy market is also covered by data from the European Energy Exchange EEX. The price for products in 2009 is calculated as the average of quarterly term contracts (futures) in the previous year. The price for coal until 2013 is obtained from term contracts (annual level). For 2014 and 2015, we anticipated a 3% annual growth rate of coal prices. Prices are given in USD/t and changed into EUR/GJ. We supposed that the average energy value of coal used for the production of electricity is 27 GJ/t (Bioenergy Conversion Factors). We also supposed that the exchange rate EUR/USD was 1.29 and is suitable for the entire observed period. The results are given in Table 1. The prices of coal in the European market are expected to range from 1.75 to 1.87 EUR/GJ in 2009 and in 2015 from 2.38 to 2.63 EUR/GJ.

Table 1

The estimation of coal price dynamics on the European market

	2009	2010	2011	2012	2013	2014	2015
	USD/t						
RB	61.11	68.81	73.13	76.88	78.13	80.47	82.89
ARA	65.26	74.40	80.35	85.20	86.45	89.04	91.71
	USD/GJ						
RB	2.26	2.55	2.71	2.85	2.89	2.98	3.07
ARA	2.42	2.76	2.98	3.16	3.20	3.30	3.40
	EUR/GJ						
RB	1.75	1.98	2.10	2.21	2.24	2.31	2.38
ARA	1.87	2.14	2.31	2.45	2.48	2.56	2.63

Source: EEX, own calculation (2009).

Note: RB – Richard Bay, South Africa;

ARA – Amsterdam-Rotterdam-Antwerp (60% Africa, 30% Columbia, 10% Australia)

- *The exchange rate EUR/USD 1.29 is assumed to be the same during the entire observed period.*
- The average energy value of coal is 27 GJ/t.

The calculation in Table 1 is based on the supposition of exchange prices of coal, which can significantly differentiate from the purchase price. We have to add to exchange prices the costs of shipment, railway and other handling costs.

Table 2 shows the calculation of the purchased coal price from imports based on Richard Bay and the ARA European Energy Exchange. Regarding the average transport costs of ship and railway we supposed that the share of ship transport costs amount to 35% of the purchase price (Average transport costs shipment, 2002). We added other handling costs in the amount of 12 EUR/t that means 1.2 EUR for 100 kg of initial actual mass) and the costs of railway transport in the amount of 13.7 EUR/t for a distance between 161-170 km covered at the amount of 15 t. We also supposed that the items of railway and handling costs are fixed, while the dynamics of ship transport costs follow the dynamics of coal prices. The results are shown in Table 2.

Table 2

Estimation of coal price dynamics from import

	2009	2010	2011	2012	2013	2014	2015
Richard Bay ($/t)	61.11	68.81	73.13	76.88	78.13	80.47	82.89
costs of ship transport ($/t)	21.39	24.08	25.60	26.91	27.35	28.16	29.01
costs of railway transport ($/t)	17.67	17.67	17.67	17.67	17.67	17.67	17.67
handling costs ($/t)	15.48	15.48	15.48	15.48	15.48	15.48	15.48
whole costs ($/t)	54.54	57.24	58.75	60.06	60.50	61.32	62.16
purchase price of coal ($/t)	115.65	126.05	131.88	136.94	138.63	141.79	145.05
purchase price of coal ($/GJ)	4.28	4.67	4.88	5.07	5.13	5.25	5.37
purchase price of coal *(EUR/GJ)*	*3.32*	*3.62*	*3.79*	*3.93*	*3.98*	*4.07*	*4.16*
ARA ($/t)	65.26	74.4	80.35	85.2	86.45	89.04	91.71
costs of ship transport ($/t)	22.84	26.04	28.12	29.82	30.26	31.16	32.10
costs of railway transport ($/t)	17.67	17.67	17.67	17.67	17.67	17.67	17.67
handling costs ($/t)	15.48	15.48	15.48	15.48	15.48	15.48	15.48
whole costs ($/t)	55.99	59.19	61.28	62.97	63.41	64.32	65.25
purchase price of coal ($/t)	121.25	133.59	141.63	148.17	149.86	153.36	156.96
purchase price of coal ($/GJ)	4.49	4.95	5.25	5.49	5.55	5.68	5.81
purchase price of coal *(EUR/GJ)*	*3.48*	*3.84*	*4.07*	*4.25*	*4.30*	*4.40*	*4.51*

Source: Table 1, Slovenian railway tariff, [1], own calculations.

Note: RB – Richard Bay, South Africa;

ARA – Amsterdam-Rotterdam-Antwerp (60% Africa, 30% Columbia, 10% Australia)

- *The exchange rate EUR/USD 1,29 was assumed to be the same for the entire observed period.*
- *The average energy value of coal is 27 GJ/t.*

The calculations show that (according to the included suppositions) the interval of purchased coal price from import lies between 3.32 EUR/GJ and 3.48 EUR/GJ in 2009; during the years when the interval is increasing, it reaches 4.16 EUR/GJ to 4.51 EUR/GJ in 2015.

3. Coal price dynamic factors by principal component method

Methodology. In order to assess the influence of individual explanatory variables on coal price movements, we used the least squares method (OLS regression) by employing principal components (PCA). Models were assessed on quarterly data within the period from the first quarter of 1995 until the fourth quarter of 2007. EIPF, OECD and EUROSTAT (2008) databases were used.

We assessed the influence of prices and the use of other energy sources, environmental measures and the influence of electricity market liberalization on the movement of coal prices.[3] By implementing the method of Principal Components Analysis – PCA (Harris 1997), the number of data or explanatory variables was narrowed down (see: Table A, Appendix). The PCA method explains the variance-covariance structure of the investigated variables by introducing some additional new variables, which present the linear combination of the primary variables, and are known as principal components (Fuentes and Godoy, 2005). An analysis of principal components often reveals relationships that were not previously suspected and thereby allows interpretations that would not ordinarily appear (Rao, 1964). The main advantage of PCA is that once you have found these patterns in the data, and you compress the data, i.e. by reducing the number of dimensions, there is no serious loss of information (Favero *et al.*, 2005). By obtaining the eigenvector (component) with the highest eigenvalues, we obtain the principle component of the data set (Wetzstein and Green, 1978). Once we have chosen the components (eigenvectors) that we wish to keep in our data and form a feature vector, we simply take the transpose of the vector and multiply it on the left of the original data set, transposed (Harris, 1997). The final data is the final data set (Rovan 2006, Baxter *et al.*, 1990).

Principal components analysis can either be done on raw or mean-corrected data on one hand or on standardized data on the other. The influence of an individual variable on principal components is determined by the magnitude of its variance. The higher the variance of the variable, the stronger the effect of a variable on principal components. In the case of standardized data, the basis for principal component analysis is a correlation matrix. All the variances are equal to one and therefore they all have the same influence on principal components. In cases where there is a reason to believe that the variances of the variables indicate the importance of a given variable and the units of the measure are commensurable, the raw or the mean-corrected data should be used (Rovan, 2006; Graffelman and Aluja-Banet, 2003). In all other cases, standardized data constitutes a preferable alternative (Kaciak and Koczkodaj, 1989; Rovan, 2006). In order to find the number of principal components, we could use Kaiser's rule. Standardized data suggests only retaining those components whose eigenvalues are greater than one. The rationale for this rule is that for standardized data, the amount of variance extracted by each component should, at a minimum, be equal to the variance of at least one variable (Cattell, 1966).

The interpretability of the principal components is used in deciding on how many principal components should be retained (Sharma, 2000). Since principal components

[3] The price of high quality coal (27 GJ/t) is given as ARA price in EUR/t (OECD, 2008).

are linear combinations of the original variables, one can use correlations between the original variables and principal components for interpreting principal components. The higher the loading of a variable, the more influence it has in the formation of the principal component score (a loading of 0.5 or above is used as a cutoff point) (Rao, 1964).

Data. For the explanatory variable on the use of other energy sources, we merged a time series for gross domestic electricity consumption, gross domestic renewable energy sources consumption (wind power, biomass, photovoltaic cells and hydro energy) and industrial waste, gross domestic crude oil and petroleum products consumption, natural gas and nuclear energy (for the EU-25, in kTOE).[4] We used the principal components for interpretations instead of the original variables due to the substantial amount of total variance in the data set, which was accounted for by a few first principal components. From six variables we arrived at three vectors, or explanatory variables, with an explanatory power of 95.4% variance of basic explanatory variables. The explanatory variable for the price of other energy sources includes the price of oil, natural gas and uranium.[5] From the above-mentioned three energy prices we arrived at the explanatory variable with an explanatory power of 90.4% variance of basic explanatory variables. Because the price of coal depends on the dollar exchange rate fluctuations, we used the dollar-euro exchange rate as an additional explanatory variable.

The following variables were used as explanatory variables for environmental measures: industrial air pollution (CO, CO_2 and SO_X in 1000 tons), expenses for environmental protection in all industries within the EU-25 (1000 EUR), the share of renewable energy resources in primary energy production (in kTOE), taxes on environment pollution (in millions of euros) and gross domestic consumption of renewable energy resources (in kTOE). Thus, we arrived at three new explanatory variables with an explanatory power of 93.4% variance of basic variables.[6]

The explanatory variable for the price of electricity (in EUR/MWh) explains the influence of electricity market liberalisation. Due to the positive correlation between the price of electricity and the export or import of electricity (0,365/0,366), imports and exports were not included in the regression. Due to the strong positive correlation between the export and import of electricity (with a coefficient of 0.981), it can be concluded that the security of electricity supply is important in a different time-scale. Energy efficiency was used as the second explanatory variable for the explanation of the liberalization of the electricity market (as a ratio between the available amount of energy for consumption and gross domestic consumption).

Estimation and results. The regression equation is estimated with a logarithm difference (dlog) of chosen variables and by taking into account the optimal time lag and best Akaike criterion. We calculated the presence of a common square (H_0 =

[4] TOE is a unit of oil equivalent, which is the amount of energy released by burning one tonne of crude oil. Toe is a unit used mainly to show the use of energy in energy balances. 1000 toe = 41,868 TJ.

[5] Natural gas price is given in EUR/Mbtu (OECD, IEA). The price of oil is in EUR/barrel (brent). The price of uranium is in EUR/kg of uranium.

[6] Variables were standardized.

common square) in variables. The augmented Dickey-Fuller test (ADF) for chosen variables (in dlog form) refuted the hypothesis regarding the existence of the common square, because ADF values exceeded critical values with a 1% degree of significance (Dickey and Fuller, 1979). The applied time series were standardized in order to match units, in which some time series are given.

The statistical significance of the coefficients of regression equations was accepted when response variables had P-values lower than 0.05. The Breusch-Godfrey test was used to check the hypothesis behind the existence of the serial autocorrelation of residuals; and due to the good results of the Breusch-Godfrey test (low F-statistics and high P-values, see: Table 3), we accepted the hypothesis H_0 about the non-existence of the serial autocorrelation of residuals (Breusch, 1979).[7] We had appropriate adequacy criterion for the equation R^2 (Table 3) and the normality test (see Appendix, Table B). The stability of the chosen model was confirmed with the Ramsey-Reset stability test (Ramsey, 1969), which has given us good results with low F-statistics values and a high P-value (see: Table 3). According to the Chow forecast test (Table 3), which was used for proving the stability of the estimated functions, we accepted the hypothesis regarding structural stability (Thursby, 1982). The regression was analyzed on the basis of the following model:

$$Dlog(P\_coal\_et)_t = b_1 \cdot Dlog(FAC1\_2)_{t-4} + b_2 \cdot Dlog(FAC2\_2)_{t-4} + b_3 \cdot Dlog(FAC3\_2)_{t-4} + b_4 \cdot Dlog(FAC1\_4)_{t-1} + b_5 \cdot Dlog(FAC1\_1)_{t-1} + b_6 \cdot Dlog(FAC2\_1)_{t-1} + b_7 \cdot Dlog(FAC3\_1)_{t-1} + b_8 \cdot Dlog(G\_Electricity)_{t-3} + b_9 \cdot Dlog(energy\_effici)_{t-3} + b_{10} \cdot Dlog(exch\_r)_t + \varepsilon_t$$

where Dlog represents the logarithm difference, b_x the coefficient of regression equations, FAC1_2, FAC2_2 and FAC3_2 the main components of the consumption of other energy source variables, of which coefficients are aggregated (b_1+b_2 +b_3), FAC1_4 as the main component of the energy price variable (with b_4 coefficient), while FAC1_1, FAC2_1 and FAC3_1 are the main components of the environmental measures variable, of which coefficients are aggregated (b_5+b_6+b_7), G_electricity is a variable for the price of electricity, "energy_effici" is a variable for the quotient between the available energy for final consumption and gross domestic consumption and "exch_r" is the variable for the dollar-euro exchange rate, and ε_t is the error term.

Table 3

Regression estimates for factors influencing coal price movements

Dependent Variable: DLOG(P_COAL_ET) Method: Least Squares, n=52				
	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(FAC1_2(-4))	-1.551347	0.244672	-6.340506	0.0000
DLOG(FAC2_2(-4))	0.381896	0.089121	4.285158	0.0001
DLOG(FAC3_2(-4))	-0.914823	0.155957	-5.865877	0.0000
DLOG(FAC1_3(-1))	0.611380	0.203826	2.999528	0.0048

[7] Equally good results were arrived at by using correlograms. The Q-Statistics (Appendix, Table C) were employed to check autocorrelation in residuals. We accepted the hypothesis of no autocorrelation of residuals: with high probabilities and low Q-statistics.

Dependent Variable: DLOG(P_COAL_ET) Method: Least Squares, n=52				
	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(FAC1_1)	1.870693	0.333605	5.607513	0.0000
DLOG(FAC2_1)	-0.233555	0.110978	-2.104515	0.0422
DLOG(FAC3_1)	-0.058241	0.033560	-1.735416	0.0874
DLOG(G_ELECTRICITY(-3))	0.387955	0.169635	2.287004	0.0280
DLOG(ENERGY_EFFICI(-3))	-0.322184	0.139892	-2.303101	0.0270
DLOG(EXCH_R)	-0.546229	0.070890	-7.705335	0.0000
Breusch-Godfrey Serial Correlation LM Test: F-statistic = 0.002432 (Prob. F(1, 36) =0.9609), F-statistic = 1.126017 (Prob. F(3, 34) =0.3523). Ramsey Reset Test: F-statistic = 0.216592 (Prob. F(1, 36) =0.6445); F-statistic = 0.224476 (Prob. F(2, 35) =0.8001); F-statistic = 1.265623 (Prob. F(9,28) =0.3981). Chow Forecast Test: Forecast from 1999:1 to 2007:4, F-statistic = 4.796227 (Prob. F(1, 36) =0.3493).				

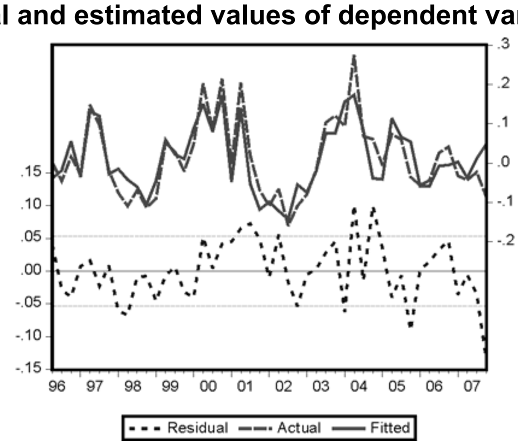
R-squared	0.754391	Mean dependent var	0.011372
S.E. of regression	0.053198	S.D. dependent var	0.096270
Sum squared resid	0.104710	Akaike info criterion	-2.843301
Log likelihood	76.81757	Schwarz criterion	-2.449653
Durbin-Watson stat	1.562021	Hannan-Quinn criter.	-2.695168

Source: Own calculations (2009).

Optimal time lags in regression were calculated by taking into account Akaike criterion. The use of other energy influences the dynamics of coal prices with a time lag of four quarters. The dynamics of coal price movements respond to the dynamics of price movements of other energy sources with a time lag of one quarter and to the dynamics of electricity price movements and energy efficiency with a time lag of three quarters. Environmental measures and the influence of the exchange rate influence coal prices in the same quarter (Table 3).

Figure 5

Actual and estimated values of dependent variables



Due to the standardised data, we will discuss the results in the following way: a 1% change of standard deviation of constituent components of the main component or dependent variable is multiplied by the coefficient (b_x) and the st. dev. of the coal price. Alternatively, the obtained values can be transformed with regard to a coal price change of one EUR/t.

If the prices of other energy sources increase, i.e. if crude oil price is increased by 1.962 EUR/barrel, the price of natural gas by 0.172 EUR/Mbtu and the price of uranium by 0.332 EUR/kg, the price of coal increases by 0.531 EUR/t (ceteris paribus). Or, if the price of other energents increases so that the price of crude oil increases by 3.695 EUR/barrel, the price of natural gas by 0.323 EUR/Mbtu and the price of uranium by 0.625 EUR/kg, then the price of coal increases by 1.00 EUR/t (ceteris paribus).

If the consumption of other energents increases so that the gross domestic electricity consumption increases by 8.789 kTOE, gross domestic consumption of industrial waste by 7.439 kTOE, gross domestic consumption of renewable resources by 139.486 kTOE, gross domestic consumption of crude oil by 88.533 kTOE, gross domestic consumption of natural gas by 402.542 kTOE and gross domestic consumption of nuclear power by 115.052 kTOE, the price of coal decreases by -0.181 EUR/t. Or if the consumption of other energy sources increases so that the gross domestic consumption of electricity increases by 48.583 kTOE, gross domestic consumption of industrial waste by 41.121 kTOE, gross domestic consumption of renewable resources by 771.065 kTOE, gross domestic consumption of crude oil by 489.402 kTOE, gross domestic consumption of natural gas by 2,225.218 kTOE and gross domestic consumption of nuclear energy by 635.998 kTOE, the price of coal decreases by -1.00 EUR/t.

Environmental measures contribute to (cumulative) rising prices for coal. If the energy industry contributes to air pollution by 0.504 kt CO, 351.865 kt CO_2 and 18.345 kt SO_x, and if the environmental protection costs in the whole industry sector within the EU-25 increases by 40.884 million EUR, the share of renewable resources consumption in primary energy production by 108.375 kTOE, taxes on environment pollution by 23.644 million EUR and gross domestic renewable resources consumption by 139.486 kTOE, then the price of coal increases by 0.137 EUR/t. Or if the energy industry contributes 3.678 kt CO, 2,566.487 kt CO_2 and 133.810 kt SO_x to air pollution and if the cost for environment protection in the whole industry within the EU-25 increases by 298.206 million EUR, the share of renewable sources consumption in primary energy production by 790.482 kTOE, taxes on environmental pollution by 171.456 million EUR and gross domestic consumption of renewable sources by 1,017.400 kTOE, the price of coal increases by 1.00 EUR/t.

The price of electricity causes an increase in the price of coal. If the price of electricity increases by 0.0606 EUR/MWh, the price of coal increases by 0.0337 EUR/t, or the price of electricity increases by 1.799 EUR/MWh contributes to a price of coal increase by 1.00 EUR/t.

The increase of the energy efficiency quotient by $4.48 \cdot 10^{-5}$ decreases the price of coal by -0.028 EUR/t. The increase of the energy efficiency quotient by 0.002 decreases the price of coal by -1.00 EUR/t.

The increase in the dollar-euro exchange rate decreases the price of coal. If the dollar-euro exchange rate (EUR appreciation) increases by 0.00153, the price of coal decreases by -0.047 EUR/t. On the other hand, if the dollar-euro exchange rate (EUR appreciation) increases by 0.032, the price of coal decreases by -1.00 EUR/t.

3.1. Discussion

The target value for the production of electricity from renewable resources is targeted to increase by 3.146 GWh by 2020 in Slovenia and eventually account for 20% of the energy to be produced from renewable energy sources. However, we can not expect the share of coal in energy production to decrease significantly in the future. Since the power plants using coal are the most polluting technologies, it could be expected that an increase in energy demand would be met by alternative technologies using alternative energy resources. But from the point of view of regional economic aspects and reference costs, we can state the argument for using coal in the near future: the socio-economic aspects of mining domestic coal and using it in thermo plants is enabled by the conditions of priority dispatching (since 2000) in the EU economies with an annual premium usually set by governments (Festić, Repina and Volčjak, 2009).

Due to the fact that the legitimacy of a government subvention scheme for the production of electricity - in order to obtain reliable energy provisioning – is not questionable from a legislative and practical point of view in the EU, the question about the priority dispatching of electricity produced by primary sources will be discussed in the context of the survival of energy plants using domestic coal. There is a strategic interest regarding the preservation of an existing energy location, socio-economic arguments and the question of reliable energy provision. In the frame of admissible measures of European Energetic Legislation (15% possible protection of domestic sources, priority dispatching) and on the basis of the Ordinance of Council for government subvention to coal mining (EC No. 1407/2002) it is necessary to enable adequate support for coal technologies, an adequate profile and social restructuring of the labour force and the necessary closing works (NEP, 2009).

The principle of a gradual lowering of subventions to domestic coal mining (not available for low quality coal) should enable the redistribution of help to the energy sector using renewable resources. Coal stock (in the regime of priority dispatching) is expected to gradually become exhausted by the end of 2010, when the EC regulative No. 1407/2002 regarding government subvention to coal mining expires. After this date, it will be possible to use sources of regional funding for help if the mines are in underdeveloped districts. The possibilities for qualifying for government regional subvention are treated in accordance with article 87(3)(a), the Contract on European Union and Directives regarding government regional subvention scheme. Priority dispatching (enabled by article 11 of Directive 2003/54/ES regarding the common rules of the internal electricity market) is of temporary importance and used in the context of reliable electricity energy provisioning (for example, the Irish case of priority dispatching of electrical energy produced by domestic peat expires in 2019). The Ordinance - following the Directives of EU reliable energy supply and safety preserving domestic coal mining and regional subvention scheme – explains the rules for assigning government subventions to coal mining and electricity produced by domestic coal sources. The main purpose of this subvention scheme is its orientation to the restructuring of undeveloped districts; the scheme considers the regional and social consequences; it also considers the need for preserving a minimum quantity of domestic coal in order to ensure access to a coal stock.

According to the fulfillment of economic criteria of technologies on renewable energy sources and their contribution to the macro-economic environment, there is a need for the establishment of an adequate system of fiscal stimulations, due to relatively higher production costs. The criteria for an adequate system of fiscal stimulations of investment in technologies on renewable energy sources is the price of electricity produced by a specific technology on renewable sources.[8] According to the facts mentioned above, and the facts that new technologies improved the ecological aspect of alternative technologies using coal, we believe that coal will be an important energy source in the future as well.

Table 4 presents the reference costs of electricity energy production obtained from different sources. The reference costs of electricity energy production produced by different energy sources have been calculated according to the methodology developed by the Center for Energy Efficiency Institute Jožef Stefan (2008) and according to the methodology "Ordinance of stimulation, No. 37/09" (2009):

Table 4

The reference costs of electricity energy for different energy sources and alternative technologies[9]

Types of energy plant	Reference costs (EUR/MWh)
Hydro small plant	92.16
Hydro large plant	76.57
Wind energy	86.74
Photovoltaic	269.22
Geothermal	152.47
Biomass	167.43
Biogas	140.77
Electricity power station on solid fuel (coal, underground gasification)	84.38
Gas-steam electricity power station	74.62

** The case of Slovenia and available technologies using alternative energy sources in Slovenia.*
Source: Festić, Kavkler and Repina, (2009).

[8] We can state the implications for energetic policy: approch of lowering the capital costs, stimulations schemes, which are adopted to life-cycle of technology and technical efficiency; and a combination of instruments, which are related to supply and demand for electricity energy obtained from renewable sources (Festić, Kavkler and Repina, 2009).

[9] We could expect that the marginal costs of electricity production in individual energy plants will increase with the increasing production of electricity, especially if the production is on the upper maximal capacity of a production unit. Outside research usually does not confirm the increase of marginal electricity production costs in an individual production unit at the actual capacity of production. According to this fact, the supply function of electricity production are usually partly horizontal (Bole and Volčjak, 2006).

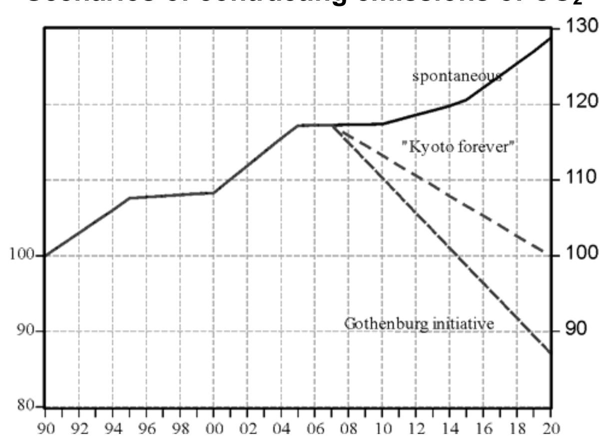
According to the relatively higher reference costs of alternative energy sources (Table 4) we can not expect that the share of coal in the consumption of energy sources for electricity production will decline in the future. But the technologies are expected to be improved and become more ecologically friendly (Festić, Kavkler and Repina, 2009).

The use of coal in the EU will also be influenced by the price of emission coupons. In year 2008, the second phase of the emission certificates contraction started in the EU. The higher prices of emission certificates for CO_2 is relatively increasing the electricity produced in thermo power plants compared with other producers of electricity. Due to the fact that imported electricity usually comes from countries using a higher share of alternative energy sources (for example, Austria) or that economies are less responsive to the contraction of CO_2 due to their underdevelopment, we can expect that higher prices of emission certificates could lead to a supply of imported electrical energy to be put in gear before the thermo plants.

Figure 6 presents the emission of CO_2 for both alternative scenarios and for spontaneous scenarios without measures. It is necessary to contract the volume of available certificates for both scenarios (see Figure 7).

Figure 6

Scenarios of contracting emissions of CO_2

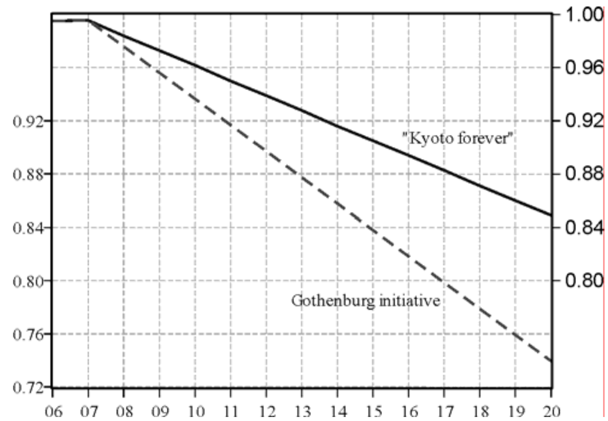


Source: European Commission (2004), own calculations.
Note: Ordinate presents the emission as a share regarding the year 1990.

The potential effects of changing the emission certificates prices on the supply on electricity could be explained according to two scenarios of contracting the available emission certificates for CO_2 (European Commission, 2004). The first scenario, »Kyoto forever«, supposes a volume of CO_2 emissions in the EU contracting by 5.5% below the 1990 level and staying at that level until 2030. The second scenario, the »Gothenburg initiative«, supposes a contraction of the volume of CO2 emissions in the EU by 13% until 2020 and 21% by 2030, in comparison with 1990.

Figure 7

The contracting of allocated emission certificates in the scenario of contracting emissions of CO_2



Source: European Commission (2004), own calculations.
Note: The values on ordinate present the volume of allocated certificates as a share in volume of certificates in the year 2006.

The significant contraction of available emission certificates would contribute to a significant increase in prices. The estimations for the lower frontier of emission certificate price increases until 2030, according to the first scenarios, reaches the level of 41 EUR per ton of CO_2, and, according to the second scenario, more than 136 EUR per ton of CO_2 (expressed in prices 2000). The prices of emission coupons will impact the reference cost of electricity energy produced by new coal technologies.

4. Conclusion

Coal - an important source for the production of primary energy - contributes ¼ of all primary energy production. According to some estimates, around 39-40% of global electricity requirements will be produced by coal until 2030. Thus, coal is likely to remain an important energy source in the future.

We estimated the influence of the consumption and price of other energy sources, environmental measures and the influence of electricity-market liberalization on coal price movements via the principal components method. The results show that if the price of other energy sources increases – specifically, if the price of crude oil increases by 3.695 EUR/barrel, the price of natural gas by 0.323 EUR/Mbtu and the price of uranium by 0.625 EUR/kg -- the price of coal increases by 1.00 EUR/t. If the consumption of other energy sources increases so that the gross domestic electricity consumption increases by 48.583 kTOE, the gross domestic consumption of industrial waste by 41.121 kTOE, the gross domestic consumption of renewable sources by 771.065 kTOE, gross domestic consumption of crude oil by 489.402 kTOE, gross domestic consumption of natural gas by 2,225.218 kTOE and gross domestic consumption of nuclear energy by 635.998 kTOE, then the price of coal decreases by -1 EUR/t. If the energy industry contributes towards air pollution 3.678 kt CO, 2,566.487 kt CO_2 and 133.810 kt SO_x; and if the expenditures of environment protections in the whole EU-25 industry sector increases by 298.206 million EUR, the share of consumption of renewable resources in primary energy production by 790.482 kTOE, taxes on environmental pollution by 171.456 million EUR and gross domestic consumption of renewable energy sources by 1,017.400 kTOE, then the price of coal will increase by 1 EUR/t. The increase of electricity prices by 1.799 EUR/MWh causes an increase in coal price of 1 EUR/t. The increase in the quotient of energy efficiency by 0.002 decreases coal prices by -1 EUR/t. If the dollar-euro exchange rate (EUR appreciation) increases by 0.032, the price of coal decreases by -1 EUR/t.

The higher prices of emission certificates for CO_2 is relatively increasing the electricity produced in thermo power plants, as compared with other producers of electricity. Questions about the extension of the priority dispatching of electricity produced by coal could be discussed in the context of the survival of energy plants using domestic coal -- a strategic interest with regard to the preservation of an existing energy location, socio-economic arguments and the reliability of energy provisioning.

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SOFTWARE: Eviews 6.0; SPSS 15.0; Excel

List of symbols:

Dlog	logarithm difference
b_x	coefficient of regression equations
FAC1_2, FAC2_2 in FAC3_2	main components of other energents consumption variables
FAC1_4	main component of energent price variables
FAC1_1, FAC2_1 in FAC3_1	main components of environmental measures variable
energy_effici	quotient between the available final consumption of energy and gross domestic consumption variable
a_ap_ei_co	Air pollution – energy industries CO
a_ap_ei_co2	Air pollution – energy industries CO_2
a_ap_ei_sox	Air pollution – energy industries SO_x
B_EPE_IND_TD	Environmental protection expenditure in EU – Manufacturing, total domains
P_OIL	The oil price - EUR/barrel
P_GAS	The gas price - EUR/Mbtu

Dlog	logarithm difference
P_COAL_ET	The high quality coal price (27 GJ/t) is given as ARA price - EUR/t
P_URAN	The uranium price – EUR/kg
D_NRG_EFFICI_EFC	Supply, transformation, consumption – Energy available for final consumption
D_NRG_EFFICI_GIC	Supply, transformation, consumption – Gross inland consumption
E_NRG_SHARE_PP	Share of renewable energy – primary production
G_ELECTRICITY	The electricity prices in EUR for MWh – final industrial consumption
H_ETAXREVE	Environmental tax revenue – taxes on pollution in % of GDP
exch_r	Dollar to Euro exchange rate (expressed as a price for 1 EUR in dollars)
I_CON_ELECT	Gross consumption of electricity
J_CON_RENEWO02_IW	Consumption of renewable resources – industrial wastes (1000 toe)
J_CON_RENEW02_RE	Consumption of renewable resources – renewable energies (1000 toe)
L_CON_OIL	Crude oil and petroleum products consumption
M_CON_GAS	Gas consumption
N_CON_URAN	Nuclear energy consumption

Appendices

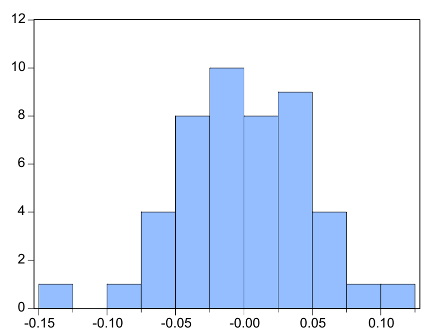
Table A

Descriptive statistic of PCA analysisct

	N	Mean	Std. Deviation
a_ap_ei_co	52	563.3669	50.41557
a_ap_ei_co2	52	1454326.2571	35186.52533
a_ap_ei_sox	52	5714.8504	1834.53168
B_EPE_IND_TD	52	43607988.4725	4088405.84193
P_OIL	52	32.7829	19.62181
P_GAS	52	3.5029	1.71445
P_COAL_ET	52	42.9611	8.68069
P_URAN	52	6.2788	3.32317
D_NRG_EFFICI_EFC	52	1200364.1542	35658.88630
D_NRG_EFFICI_GIC	52	1686795.4615	57760.67369
E_NRG_SHARE_PP	52	898969.3088	10837.50864
G_ELECTRICITY	52	67.8031	6.05561
H_ETAXREVE	52	9284.7542	2364.36510
Euro/Dolar	52	1.1465	.15311
I_CON_ELECT	52	1109.4615	878.87505
J_CON_RENEWO02_IW	52	2879.8462	743.88111
J_CON_RENEW02_RE	52	99583.1550	13948.55899
L_CON_OIL	52	643870.3077	8853.27558
M_CON_GAS	52	384392.9235	40254.18904
N_CON_URAN	52	241590.3854	11505.19908
energy_effici	52	.7117	.00448
Valid N (listwise)	52		

Table B

Histogram – normality test



Series: Residuals
Sample 1996:2 2007:4
Observations 47

Mean	0.000172
Median	-0.005412
Maximum	0.101374
Minimum	-0.133045
Std. Dev.	0.047710
Skewness	-0.174161
Kurtosis	3.219653
Jarque-Bera	0.332087
Probability	0.847009

Table C

Autocorrelations

Sample: 1996:2 2007:4, Included observations: 47.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.127	0.127	0.8026	0.370
		2	0.201	0.187	2.8599	0.239
		3	0.089	0.047	3.2780	0.351
		4	-0.181	-0.245	5.[illegible]11	0.283
		5	0.040	0.062	5.1271	0.401
		6	-0.090	-0.019	5.5860	0.471
		7	0.032	0.064	5.6451	0.582
		8	0.099	0.067	6.2248	0.622
		9	-0.131	-0.162	7.2693	0.609
		10	0.092	0.062	7.7926	0.649
		11	-0.138	-0.098	9.0100	0.621
		12	-0.006	0.054	9.0126	0.702
		13	0.022	-0.003	9.0440	0.770
		14	-0.151	-0.117	10.640	0.714
		15	-0.005	-0.064	10.641	0.778
		16	-0.060	0.029	10.908	0.815
		17	-0.140	-0.107	12.417	0.774
		18	0.010	-0.009	12.425	0.825
		19	-0.047	0.044	12.606	0.858
		20	0.037	-0.012	12.725	0.889