CARBON TRADING UNDER THE EU ETS AND ENERGY PRICES: A CASE OF THE CZECH REPUBLIC[1]

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RESUME

Climate change is quite generally perceived as one of greatest threats that our planet together with all human beings will have to face in future. It has been proven that if the Earth's temperature rises by more than 2 °C above pre-industrial levels, climate change is likely to become irreversible and the long-term consequences could be immense (for details see e.g. Stern, 2006). On the other hand, if one takes an early action, climate change might be rather a challenge than a threat. It may be the impulse needed in order to turn the existing economic order on a more sustainable, low-carbon and energy- efficient path. In this respect the European Union introduced the Emission Trading Scheme (ETS). It came into operation in January 2005 as the largest multi-country, multi-sector GHG trading system world-wide. Initially it was considered to help the European Union to meet its Kyoto commitment but in the course of time it has developed into a more ambitious system enabling the European Union to tame its emissions for at least the next decade. The system is a kind of cap-and-trade system, i.e. it is based on a given cap on emissions and trade in emission allowances and thus gives value to reducing CO2 emissions. A key achievement is the ability of the system to put a price on carbon. Like any market, the key to pricing is scarcity, and the price depends on both the stringency of a cap (the absolute quantity of allowances available), the demand for allowances and expectations about the future. The most fundamental difference of trading in emissions from any other type of market is that the amount available depends directly on government decisions about allocations; and expectations about the future are largely expectations about future emission targets (Grubb, Neuhoff 2006). The new regulatory scheme is deemed to have serious implications for European business and may transform the way business is done in the power and heat

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sector, as well as in other relevant industries. That is why the authors decided to try to deal with this issue; however, due to clear limits on the data availability they will centre their attention exclusively on the case of the Czech Republic. The authors consider this paper a theoretic exercise enabling them to explore the possibility to build a simple model, the aim of which is to draw relevant conclusions about the impacts of the introduction of the ETS system in the Czech Republic. The model should actually describe, through calculating the change in the prices of electricity, the impact of the ETS primarily on power sectors and consequently on the other sectors covered in the ETS.

Key words: *EU ETS; carbon price; allocation; carbon pricing; energy prices; coal prices; prices of emission allowances; climate change; structural co-integrated VAR model*

1 Introduction

In 2007 the Intergovernmental Panel on Climate Change (IPCC) concluded that global CO2 emissions have to be reduced to half of today's levels by 2050 to limit the risk of temperatures rising more than 2 degrees. In 2008 the G8 leaders agreed on the need to cut global carbon emissions by at least 50 per cent by 2050. The challenge is now to implement policy instruments to deliver the necessary emissions reductions. According to the Stern Review 2006 there are three sets of instruments, including a pursuit for putting a price on carbon.

The logic behind carbon pricing is that it creates incentives for the use and innovation of more carbon efficient technologies, and induces substitution towards lower carbon fuels, products and services by industry and final consumers. The price signal feeds into individual decisions that would be difficult to target with regulation. It also makes it profitable to comply with carbon-efficiency regulations, thus facilitating their implementation. On the other hand, many energy efficiency measures are not implemented despite their cost-effectiveness, which suggests a need for complementary measures to overcome the barriers that restrict their use, as well as for a solid regulation complementing the carbon pricing. Finally, a carbon price mitigates concern about the rebound effect[2]. This theory, however, fails in case of power

[2] Regulation prescribing or subsidising the use of energy efficient or low-carbon technologies might have reduced effect without carbon pricing as a complement because of the 'rebound effect'. The increased efficiency from insulation of houses, for example, reduces fuel consumption and heating costs in cold climates or air-conditioning costs in hot climates. In response, in the case of heating, some households will increase room temperatures, heat rooms for longer periods, and might not bother to turn down the heat when they are out of the house. Thus, the envisaged energy demand

generation sector, where any kind of direct regulation might not be, due to security of energy supplies, working good.

Carbon prices can be delivered with a carbon tax or cap and trade schemes. In this term, the implementation of carbon pricing using cap and trade schemes is crucial. It draws on the early experience of trading schemes for SO2 and NOX in the US and the subsequent European Union Emissions Trading Scheme (EU ETS) for CO2 allowances, with an annual value of about 40 billion Euro making the EU ETS the biggest scheme worldwide[3]. Cap and trade schemes can gain support from stakeholders such as governments, or industry and political groups, in order to deliver a carbon price they need for aid coordination across countries, too.

The experience from the pilot phase, which operated from 2005 to 2007, highlighted the drawback caused by free allowance allocation. Such allocation intensifies lobbying and can inflate the cap. Repeated free allocation also creates various perverse incentives that undermine the economic efficiency of the scheme. Free allocation to emitters can also have undesired distributional impacts. In most markets emitters will pass carbon costs onto product prices and thus to consumers. As a result emitters profit from the free allocation, while consumers bear the costs. This is in contradiction to a desired sub-goal which is a system based on „polluter pays“ principle. As a result, measures to compensate households for the distributional implications of carbon pricing may be needed and deserve careful consideration to ensure equity and political support.

Large scale emissions reductions – with continued economic prosperity – cannot be delivered by operational choices alone. They require changes to investment choices (Neuhoff, 2008). Here the size, type, longevity as well as carbon intensity ambitions of investment matter. Investors will only pursue choices that can deliver large scale emissions reductions on a significant scale only if they bear profit. Both in case of project based low-carbon investment as well as large scale investments such as investment in infrastructure, new product lines and technology development are conditioned by a robust price

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reduction from efficiency measures would be partially offset by a ‘rebound effect’. Carbon pricing compensates for the reduced fuel costs and discourages a rebound effect. (Neuhoff, 2008)

3 The first evaluations of the link between the European Union Emissions Trading Scheme and carbon emissions of our economies suggest that already in 2005 the scheme reduced emissions of installations covered by the scheme by about 2.5%-5% (Ellerman and Buchner 2007).

signal of carbon. A cap and trade scheme can meet the needs of such different investors. For example under EU ETS for the short-term an increasingly robust carbon price is evolving. What is crucial here is the ability of a system to control the price of carbon through allowance prices. The options include: i) banking and borrowing in order to diminish short term divergences in prices; ii) multi-year compliance period providing space to smooth out annual energy demand fluctuations; iii) delayed implementation and gradual tightening of cap by giving installations enough time to adjust; iv) circuit breaker and safety-valve prices. Finally, government can act as a market maker and thus has some opportunity to adjust auctions – in case of the EU ETS from 2012 this argument may not be correct, as regular auctioning calendar are to be introduced and auctions are to be governed by the Commission. At the same time a clear, binding emissions target such as the one for the year 2020 under the third phase of the EU ETS can offer strategic investors sufficient confidence in market opportunities for low-carbon processes, products and services. The cap and trade scheme defined for the same time frame allows the carbon price to respond to changes in fuel and commodity prices or technology costs and thus contributes to the delivery and credibility of the target.

Closely related to the issue of emissions cap and allowance prices is the allocation method. Economic textbooks usually state that the method of allocation does not affect the economic efficiency of cap and trade schemes because trading allows market participants to find the least costly emissions reduction opportunities. The implicit assumption is that the allocation is based on one, fixed, historic line. This is true only if we do not take into consideration a dynamic element of decision-making on allowances and their use. Today's decisions of the investors formulate future allocation decisions of the government. On the other hand, a decision on future free allowance allocation impacts the investors´ decisions. Initial free allocation of some allowances is frequently implemented to gain industry's support and to motivate it for a transformation to a low-carbon economy. But if free allocation is repeated, and then the expectations of market participants about future free allocation will distort the carbon price signal. This results in inefficient operation and investment choices (Neuhoff, 2008). The pilot phase of the ETS unveiled that over-allocation based on wrong information could significantly influence a carbon signal and threatens the system as a whole. It also proved that grandfathering method is not optimal and a move to auctioning with only limited free allocation based on benchmarks is viable.

At a global level, joint efforts are needed. In a world with asymmetric carbon prices stemming from, inter alia, different efforts and political will, concerns about carbon leakage are quite frequent. This can be interpreted as follows: higher carbon prices in a country with more stringent carbon legislation might induce some industries to shift production or investment to countries with low or no carbon pricing. Here we can distinguish direct emissions effect as well as indirect one. The former can be somehow limited when best available technology for a new production is applied or when the production is closer to a place of consumption and thus transportation is reduced. This might be the case of emerging economies. The latter is more troubling as it can deteriorate the initial cap by other producers[4]. In case of the EU ETS, the ETS Directive foresees that sectors exposed to a significant risk of carbon leakage should receive free allowances at one 100% of the benchmark. The list of those sectors should be determined based on specific criteria outlined in the Directive (COM, 2009). Of course, the perception of this kind of risk varies, since potentially harmed sectors tend to perceive the situation to be much more serious than the Commission or "independent" think-tanks and agencies. Nonetheless, it is important to mention here that providing allowances for free to those sectors compensates only for direct costs. They do not solve the problem of indirect costs (given by the impact on electricity prices) which may also be for some sectors significant.

2 Modelling exercise

The model

For the purpose of describing the dependence between prices of electricity and emission permits we establish a structural co-integrated VAR model. To start with, in the commonly used classical VAR approach proposed by Sims (1980), every endogenous variable in the system is treated as a function of

[4] As some production is relocated, the emissions are no longer accounted for under the cap of the respective trading scheme. Thus other sectors can reduce their decarbonisation efforts and use the freed up allowances. Some of the production will be replaced by production in countries that have not committed to an ambitious emission reduction target and will thus increase emissions in that country. Thus global emissions would increase (Neuhoff, 2008).

lagged values of all of the endogenous variables in the system, i.e. as:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} \ldots + A_p y_{t-p} + e_t$$

where y_t is a vector of a given number of endogenous variables, $A_1, \ldots, A_p$ are coefficient matrices to be estimated and e_t the vector of error terms. However, error terms in this VAR form are usually correlated,[5] which consequently presents a problem in recovering of the underlying structural disturbances from the VAR. This problem can be solved by imposing certain identification restrictions so that a given shock can then be fully attributed to a particular variable. In a traditional approach, Cholesky decomposition method, based on recursive structure of restrictions, is proposed. In this case, the choice of the ordering of the variables has a vital effect on the results and the interpretation by itself also may not be necessarily straightforward.
For the purpose of this modelling exercise, we rather use the structural VAR technique as a basis, where the restrictions in principle should be guided by theoretical reasoning. A structural VAR can be written in this form:

$$B_0 y_t = B_1 y_{t-1} + B_2 y_{t-2} \ldots + B_p y_{t-p} + \varepsilon_t$$

Furthermore, if n is the number of variables, one has to impose $n*(n-1)/2$ on the matrix B_0 to fully identify the system (considering only the short-run restrictions).

However, price variables, such as those we examine, often exhibit dynamic behaviour which is consistent with non-stationary, i.e. I (1) processes. In this respect, using I (1) variables in a VAR model would likely bring spurious regression problems. A widely used approach is to use first differencing to obtain stationary, i.e. I (0) processes; however, valuable information about long-run co-integrating relations is deleted by this procedure. Nevertheless, if all variables are I (1) processes and are co-integrated at the same time, a different approach may be used. This is commonly referred to as co-integrated VAR (CVAR) model or as vector error correction model (VECM), see Johansen (1996).

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5 They are uncorrelated only in the special case when there are no contemporaneous effects between endogenous variables.

Given the underlying behaviour of variables we are investigating and the need for a sound interpretability of the results implying the need for a structural model, we therefore use the structural vector error correction model as follows:

$$B_0 \Delta y_t = \Psi y_{t-1} + \Lambda_1 \Delta y_{t-1} + \Lambda_2 \Delta y_{t-2} \ldots + \Lambda_{p-1} \Delta y_{t-p+1} + C d_t + \varepsilon_t$$

It can be rewritten to its reduced form:

$$\Delta y_t = \alpha\beta' y_{t-1} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} \ldots + \Gamma_{p-1} \Delta y_{t-p+1} + D d_t + e_t$$

Where y_t is a vector of endogenous variables, α a vector of parameters measuring speed at which the variables approach the long-run equilibrium, β' a vector of estimates for the long run co-integrated relationship between the variables, Γ_p's matrices of parameters for endogenous variables of a given lag, *d* a vector of exogenous variables, i.e. in our case seasonal dummy variables and *D* a matrix of parameters associated with these exogenous variables.

The interpretation of equation (4) is simply that Δy_t can be explained by the error correction term $\alpha\beta' y_{t-1}$ and by lagged Δy_t up to a chosen level, while using seasonal adjustment. Note that y_{t-1} can be explained as equilibrium error that occurred in the previous period: if it is non-zero, the model is out of equilibrium and vice versa.

The data

For our modelling requirements, we use three variables that we consider a priori as endogenous (all in EUR): one year forward prices of Czech electricity, one year forward prices of ARA coal (using daily USD/EUR exchange rate), and emission allowance prices. The rationale for choosing forward over spot prices is twofold: firstly, year forwards are not affected by short-term demand fluctuations, and secondly, the share of electricity denominated in spot contracts is comparatively low at the Czech market. The underlying daily data for all three variables was transformed to monthly basis using simple arithmetical average.

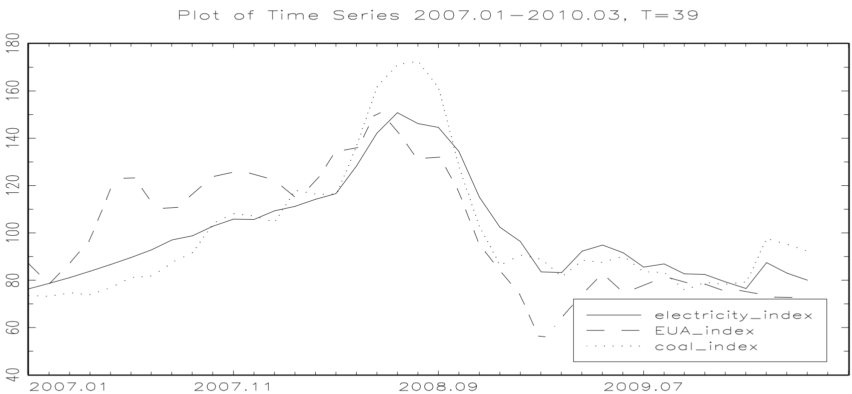
However, it should be stressed that for determining the relationships between these variables, the length of the time series is quite far from being ideal. Specifically, energy has been traded on the energy exchange since August 2007 and for each of the preceding years, electricity prices were set on administrative basis. To prolong the time series (and at the same time assuming that market forces were at least partially playing their role in the interdependence between these three variables), rearward data for additional months until January 2007 were obtained using Hodrick-Prescott filter. To avoid poor performance at ends associated with this filter, a new HP-filtered auxiliary time series running from January 2005 to March 2010 was constructed (with λ = 400, using both administrative and market prices on daily basis) and the resulting period from January to July 2007 was then appended to the original market-driven time series.

Finally, we add seasonal monthly dummies to capture seasonality in each of these variables, which can be potentially detrimental especially while evaluating energy related prices. The final data used in the model runs from January 2007 to March 2010. All calculations were undertaken using the software JMulTi and EViews.

Initial univariate and multivariate tests

As a first step before modelling the data, a visual inspection of the time series is shown in Figure 1. For a better overview, the data has been scaled so that the respective means are equal to 100. Coal and energy prices seem to be closely related, as well as emission allowance prices, though to a lesser extent.

Figure 1: Scaled data for electricity, emission permit and coal prices



Source: Simulation of the data in econometric package EViews 7

In case of all three series, augmented Dickey-Fuller (ADF) tests fail to reject the null hypothesis of unit root on levels, whereas differences appear to be stationary, so that the ex-ante hypothesis of non-stationarity of price level time series seems to be plausible. The next step is to evaluate co-integration rank in order to confirm that the proposed VECM approach can be applied; for this, we use the trace test as introduced in Johansen (1991). While assessing the co-integration relationships for possible lags up to level 6 (with or without trend in VAR), one notable feature are quite strong seasonal effects; without seasonal dummies, the trace test indicates no co-integration up to level 4 (without trend in VAR). However, it should be noted that inclusion of exogenous variables into the test, i.e. seasonal dummies, makes the interpretation of critical values rather difficult. Nevertheless, adjusting for seasonality greatly increases the significance of co-integration relation; all of the examined cases then indicate at least one co-integrating equation (see Table 2 for test statistics of the final model).

For the sake of sound interpretability of the results and greatest parsimony possible, we have chosen the setup with one lag and without trend term in VAR, that was not found statistically significant. Moreover, due to a rather small number of observations, models with larger number of lags are starting to exhibit unstable behaviour which interpretation would be difficult.

Short run dynamics

After determining the long-run co-integrating relations, the second step will be to examine how the variables behave in the short term. As stated in earlier sections, the model in (3) without sufficient restrictions does not provide any information about short-term dynamics, including matrices B_0, Λ_p, or determining how fast the particular variable approaches the equilibrium which is described by the term α in model (4).

Therefore, we need to impose $n*(n - 1)/2$ restrictions in total, which should be in principle guided by economic theory (in our setup 3 restrictions). We decided not to interfere with the long run determinants of the variables and therefore we chose only to apply restrictions on contemporaneous behaviour of the variables. For this purpose, in order to identify the matrix B_0 in model (3), the first two restrictions were set so that price of emission permits does not contemporaneously affect coal price and vice versa. The third restriction abandons instantaneous response of the electricity price with respect to emission permit price, therefore assuming adaptive behaviour in this respect.

For determining how a particular shock to a given variable propagates through the model, we utilized the commonly used impulse response function, measuring dynamic response of electricity price to 1 EUR increase of emission permits and coal, respectively. To calculate confidence intervals, we use 95% Hall percentile with 500 bootstrap replications.

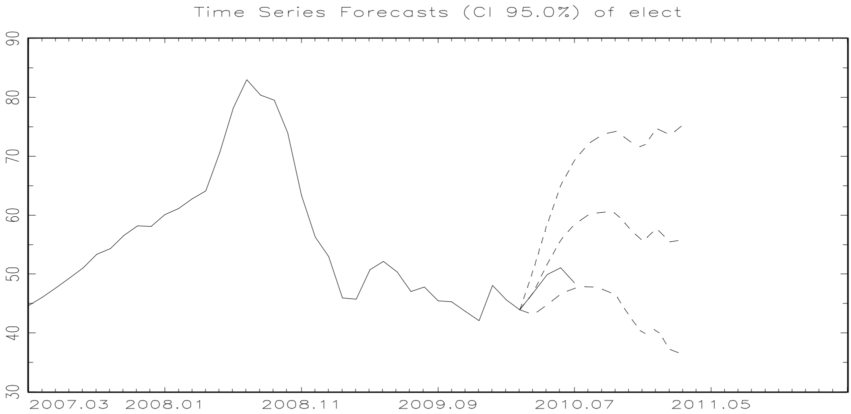
3 The results

The results of long-term co-integration estimates are reported in Table 1. All coefficients are statistically significant, which implies that both price of emission permits and coal are crucial to define the level to which electricity price is attracted in the long term. We can also see that all estimates have expected signs. The coefficients themselves can be interpreted as price elasticities, implying that a 1% increase in price of emission permit price would be, in equilibrium, associated with an 1.2% increase in electricity price. Similarly, an increase in coal prices by 1% in equilibrium would raise electricity price by 0.17%. In other words, if we assume that there is going to be an increase in emissions permits price form e.g. €30/tCO^2 to €35/tCO^2, i.e. by 17%, the model calculates the increase in electricity price by 20.4%. Shrot term predictions about electricity prices can be seen in Figure 2.

Table 1: Cointegrating vector estimates (model with 1 lag)

	$1p_{electricity}$	$-1.201\ p_{EUA}$	$-0.172\ p_{coal}$	-20.958
p-value	[...]	[0.000]	[0.019]	[0.000]
t-value	{...}	{-3.518}	{-2.355}	{-4.704}

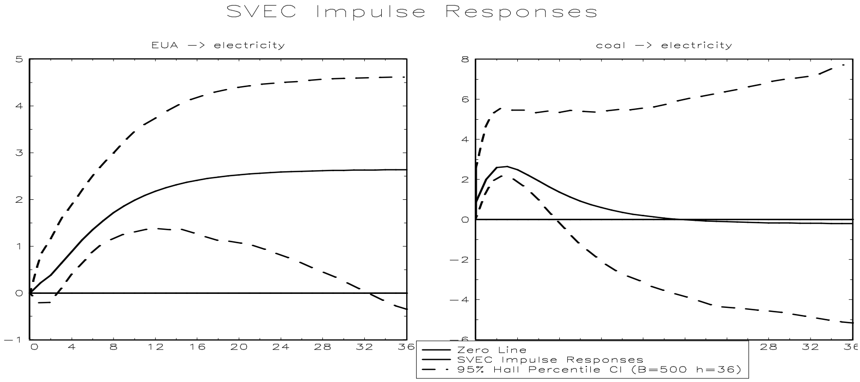
Figure 2: Prediction of the electricity price



Source: Simulation of the data in econometric package EViews 7

Turning to short-run dynamics, Figure 2 presents impulse response functions of 1 EUR price increase shock of emission permits and coal to electricity price. We can see that the increase of emission permit price has a slower onset, but is more persistent than the resulting increase of coal price. The latter peaks rather quickly after three months and then fades away. However, since the underlying time series of the used data is quite short, the plotted 95% confidence intervals show that the margin of error is relatively large in both cases and any resulting conclusions should be then taken with due consideration.

Figure 2: Impulse response functions (model with 1 lag)



Source: Simulation of the data in econometric package EViews 7

Economic Interpretation

We used the structural co-integrated VAR model to demonstrate the relationship between electricity prices and EU ETS allowances scheme within conditions of Czech electric energy market. The model has confirmed importance of the EU ETS system introduction as a strong transparent, environmental and market based instrument. In the Czech reality the model gives us clear evidence of the strong mutual interdependence of the three variables while the impact of the price of allowance on the electricity price. Thus we can conclude that the carbon pricing is significant and seriously perceived by all stakeholders.

On the other hand, from a perspective of the EU climate change policy, the European Trading Scheme was meant as a main tool to introduce a system that enables the inclusion of externalities coming from burning of the fossil fuels into the price of final output on the “polluter pays” principle. As we can read from the first results this might not have been fulfilled as the ETS has passed an increased costs burden from electricity producers to final electricity consumers, i.e. according to a “consumer pays” principle. As we can see once again on the Czech example, there is a plausible option that allowances trading may have significant impacts on consumers through the increased electricity prices and some kind of regulation or compensation at national level may be needed.

At the same time the introduction of the ETS highlighted the issue of so-called "carbon leakage". This finding holds true namely within the "new" EU Member States (based on the fact that the industrial and power generation base of the Czech Republic is very similar to other countries from the Central and Eastern Europe) were the above described transmission caused increased energy prices for a number of energy intensive industries. Due to the high interdependency of allowance price and electricity price, sharp increase in the former leading to even sharper increase in the latter will bring about significant indirect costs. Unlike other sectors, affected sectors cannot take the advantage of allowances auctioning and trading in order to compensate for the expected losses and government action may be needed. This slightly disconcerting fact might even double in future with the introduction of the third phase of the ETS when the allocation of allowances for free is going to be gradually replaced by allowances auctioning.

Conclusions

Following the model outputs we can conclude that: *both price of emission permits and coal are crucial to define the level to which electricity price is attracted in the long term* and we are able to calculate price elasticities between the variables. To be specific, *calculated price elasticities imply that a 1% increase in the emission permit price would be, in equilibrium, associated with 1.2% increase in the electricity price and similarly, an increase in coal prices by 1% in equilibrium would raise electricity price by 0.17%.* Based on this fact and pointing at the current imperfect allocation of emission allowances, major presumption is resulting from model output – *a dependence of electricity prices on emission allowances will be stronger* after a suppression of EA allocations and a commencement of 100% auctioning of EA within the EU ETS system.

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Annex

Table 2: Test statistics (model with 1 lag)

Johansen trace test	likelihood ratio	p-value
r = 0	44.54	[0.0030]
r = 1	9.57	[0.6860]
r = 2	2.87	[0.6135]
Portmanteau test (up to 10 lags)	adj. test statistics	p-value
	117.7909	[0.0024]
ARCH-LM test (up to 10 lags)	test statistics	p-value
e1	9.0023	[0.5319]
e2	9.1292	[0.5199]
e3	7.2074	[0.7057]
Jarque-Bera test	test statistics	p-value
e1	2.9243	[0.2317]
e2	0.0166	[0.9917]
e3	0.0714	[0.9649]