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Application of an Error Correction Model in Assessment and Forecasting of Energy Consumption in the European Union

(Recommended by Prof. A. Katkow)

In the following framework, efforts of building a model of energy consumption with regard to basic macroeconomic factors such as gross domestic product (GDP), consumer price index (CPI), and demographic variables, have been undertaken. Above-mentioned model, thanks to an error correction mechanism enables to indicate short- and long-term relations between analyzed variables.The spatial and time sample which was chosen for the research, includes data from 1980 – 2005 from the European Union countries. The application of such cross sample and decomposition of absolute term, enables to indicate certain general regularities in analyzed phenomenon, and also typical of particular countries. From empirical point of view, the created model can be used in preparation of simulations and forecasts with planned energy consumption on the national and international level.

Предпринята попытка построения модели потребления энергии с учетом макроэкономических факторов, таких как ВВП, индекс цен потребителя, и демографических данных. Предлагаемая модель позволяет с помощью механизма коррекции ошибок определить кратко- и долгосрочные отношения между анализируемыми переменными. Использована пространственно-временная выборка данных с 1980 по 2005 г. по странам Европейского Союза. Применение такой перекрестной выборки и разбиение временного периода позволяет определить некоторые общие закономерности анализируемых явлений, а также закономерности, типичные для определенных стран. Созданная модель может быть использована для подготовки процедур моделирования и прогнозирования планируемого энергопотребления на национальном и международном уровнях.

K e y w o r d s: model of energy consumption, error correction model, European Union, GDP, energy market.

Introduction. The creation of a uniform power market in Europe is currently in a transition phase — there are no longer separate national markets, but it still is not a homogenous European Union market. Regional markets play a more and more important role, which is often perceived as a transitory step towards the creation of a uniform European market. On the one hand, they extend the scope of national markets and increase the number of participants, but on the other hand, there is a fear that the present situation will inhibit the process of creation of a common, uniform market [1]. In reference to these information it seems the legitimate building of econometric model illustrating the consumption of electric energy in dependence on the indicated determinant.

The situation on the power market of individual European countries is diversified, which results from the nature of economic development, the number of inhabitants, climate, as well as different strategies of investing in energy sources [2].

The European power market — basic European community documents. The restructuring of the energy industry sector in Europe has been carried out for at least twenty years. In the first years of liberalization the scientific and regulatory circles were mainly interested in short-term effectiveness and competitiveness of companies from this sector. The need to determine long-term effectiveness was first noticed in the countries that were the first to liberalize the power market and to complete the first investment cycle in new circumstances, i.e., in England and Wales. Other power markets are just getting closer to the stage of complete liberation of the power market and an increase in investment risk related to it. Such a situation is currently observable on the most liberalized markets, e.g. in Spain, Germany and the Scandinavian countries.

Numerous documents of the European Commission, which are secondary sources of legislation, provide for possibilities to achieve EU strategic goals by way of achieving partial goals. Directives form the core of regulation, in particular with respect to the power generation sector. The relevant major directives are as follows [3]:

Directive on uniform rules of an internal electric energy market (2003/54/EC).

Directive on uniform rules of an internal natural gas market (2003/55/EC).

Directive on integrated prevention to pollution and control thereof (96/91/EC).

Directive on reduction of emissions from large incineration objects (2001/80/EC).

Directive on national limits of pollution emissions (2001/87/EC).

Directive on promotion of renewable sources of energy (2001/77/EC).

Directive on energy parameters of buildings (2002/91/EC).

Directive on promotion of electric energy generated in combination with heat generation (2004/8/EC).

Directive on actions to secure supplies of electric energy (2005/89/EC).

Directive on efficiency of ultimate use of energy (2006/32/EC).

Other relevant EU documents should also be mentioned [4]:

regulation on conditions applicable to access to cross-border exchange of electric energy (1228/2003/EC),

regulation establishing general rules of providing support to trans-European power grids (807/2004/EC),

decision on a set of guidelines for trans-European grids (1229/2003/EC), decision approving a long-term program of actions in the energy field Intelligent energy — Europe 2003—2006, (1230/2003/EC).

However, these are the so-called white books that are documents formulating strategic goals of the Community and individual Member States. White books are prepared on the basis of sectoral documents — green books, covering specialist fragments of integration within the EU and prepared General Directorates of the Commission or initiated by a commissioner.

With an energy white book in the offing, mention should be made of two green books, published by the General Directorate of Energy and Transportation. The first of them (of 2000) has a characteristic sub-heading: Towards a European security strategy of energy supplies. The most recent document of that rank — the green book of 2006 — expands the scope of discussion, signalling as the area of interest a strategy promoting balanced, competitive and secure energy.

Basing on the book, the current situation in the sector of energy may be characterised as follows.

Investments are needed urgently. In Europe alone satisfaction of demand for energy and replacement of ageing infrastructure will require investments of one trillion euro over the next 20 years.

Our dependence on imports has been growing. Unless we make energy from internal sources more competitive, then over the next 20 or 30 years about 70% of EU demand for energy will be covered with imports as opposed to 50% nowadays.

Reserves are concentrated in few countries. Now about one half of EU gas consumption is covered with supplies from three countries (Russia, Norway and Algeria). If the existing trends continue, gas imports will grow by 80% over the next 25 years.

Global demand for energy has been growing. World demand for energy — and CO_2 emissions — are expected to grow by 2030 by about 60 %. Global oil consumption is to grow by 20% at an expected annual rate of 1.6% annually.

The crude oil and gas prices have been growing. Over the last two years, the prices have almost doubled in the EU, similarly to electric energy prices. That may result in larger savings in energy consumption and more innovation.

Europe has not yet developed fully competitive internal energy markets. Only when such markets exist, EU citizens can enjoy the benefits from secure energy supplies and lower prices. To achieve that, it is necessary to develop cross-border connections, to develop and apply an effective legal framework as well as strict observance of EU rules of competition [4].

The attempt to construct the econometric model of electric energy consumption in this relationship was undertaken for European countries in the presented paper. When the information available on the formation of the phenomenon examined in a particular population is too scarce, one may expand it by the information on the same phenomenon for another population of a similar nature [5]. Such test would be cross-sectional in this case (the same variables for various objects, e.g. countries) within the same time unit or cross-sectional-time when the data are additionally related to several periods.

Space-time models. A typical method of using the space-time models is the single-equation, single-factor econometric model estimated in virtue of panel data, in the following form [6]: $y_{it} = \alpha + X_{it}^T \beta + u_{it}$, for $i = 1, ..., N$, $t = 1, ..., T$, where i — means an object (e. g. a country); t — time (e. g. years); XT_{it} —vector of observations on explanatory variables with K coordinates; α — absolute and invariable term in time and space; u_{it} — random component divided into two groups, $u_{it} = \mu t + v_{it}$; μt — reflects the non-observable and regression effect, not included in the equation and resulting from affiliation with the ith group; v_{it} — the remaining part of the random component.

In case the quantity of the objects is large, the application of the above methods is disputable as it requires the inclusion of additional artificial variables in the regression equation, which in consequence means the loss of degrees of freedom. Furthermore, when the number of observations for the data possessed does not grow in time, then estimator α and estimator μ will become incompatible. We solve the problem assuming that μ_i is a random variable, for example: $u_j = Z_\mu \mu_j + v_j$. In this case we encounter a model with decomposition of the random component. We may similarly proceed in case of a two-factor model, where

$$u_j = Z_\mu \mu_j + Z_\lambda \lambda + v_i.$$

The balanced data obtained permit, in addition to the said decomposition of the random component of the absolute term, to differentiate the structural parameter values for the individual variables in the test [7]. It is assumed that the parameter value is composed of the value typical of all the objects and the value characteristic of the individual object: $Y_i = X_i \beta_i + \xi_i$. Therefore, if $\beta_i = \beta + v_i$, then $Y_i = X_i \beta_i + (\xi_i + X_i v_i) = X_i \beta + w_i$.

The methods used in the estimation process are similar to those of the random component decomposition. Such methods, in addition to the selection of start levels of a particular phenomenon, permit to specify the individual characteristics of the particular objects grouped in the test. In our case, due to the vast complexity of calculations and, most of all, the problems resulting from having a non-balanced test, this method cannot be used.

In modeling with the use of space-time data, due to the differentiation of artificial variables responsible for the effects specific to individual objects, a series of tests is applied to check the total significance thereof. The most popular ones are: Chow's F-test, the Breusch-Pagan Lagrange multiplier test, the Hausman test.

There are two options to be applied in case of the data we have:

to build a model based on a mixed test (space-time), non-balanced (where the length of time series varies from object to object);

to build a model based on a balanced test — supplementing the data by the sectional method or by means of estimated trend equations.

Principally, it frequently appears that the parameters being the fragments of an absolute term decomposed are in some cases statistically insignificant. In such situation we replace the significant parameters with zero-one variables and proceed as in case of typical econometric models.

If the data for which a long-term influence of explanatory variables on explained variable is assumed were available, the error-correction model as an isomorphic form of autoregression model was used to illustrate this influence in the paper [8]. The simplest form of this model is as follows:

$$\Delta y_t = \alpha_0 + \beta_0 \Delta x_t + (\alpha_0 3 - 1)(y_{t-1} - \delta_1 x_{t-1}) + \xi_t .$$

In this model β_0 is a short-term multiplier indicating short-term flexibility of y in relation to x, when both explanatory variables and explained variable are expressed in logarithms. However, in this case, δ parameter reflects the long-term flexibility of y relation to x. The difference $(y_{t-1} - \delta_0 - \delta_1 x_{t-1})$ constitutes an equilibrium error which was made in the earlier period and is called an error-correction component [9]. This error is a correcting factor in the model and it acts as an explanatory variable. Another advantageous feature of the error-correction model is the use of increments eliminating the random component autocorrelation phenomenon and limiting the apparent regression phenomenon.

The presented sample consists of 29 European countries (EU + Norway and Iceland). Regarding to the lack of data from Malta, Bulgaria, and Romania — to short time series — the sample was restricted to 26 countries. Therefore, the estimation was associated with spatial and time sample for 26 objects with 9 periods of time series. The sample was balanced. The form of this model is as follows:

$$\Delta Kon_{it} = \alpha_{i0} + (\alpha_1 - 1)(Kon_{t-1} - \delta_1 Pep_{t-1} - \delta_2 Inf_{t-1} - \delta_3 Gdp_{t-1}) +$$
$$+ \gamma_1 \Delta Pep - \gamma_{2\Delta} Inf + \gamma_3 Gdp + \xi_{it},$$

where Kon_{it} — Electricity Consumption in billion kilowatt-hours in a given period t for a given country i (Figures 1 and 2); Gdp_{ti} — value of GDP in EUR stable prices from year 2000 for the ith country in period t; Pep_{it} — the number of people in thousands in a given period t for a given country i; Inf_{it} — inflation in percent in a given period t for a given country i.

Empirical results. As a result of estimation, the parameters' estimates prove significant short-term relationships between energy consumption, and GDP [10, 11], (CPI) and population level. Moreover, the autoregressive long-term

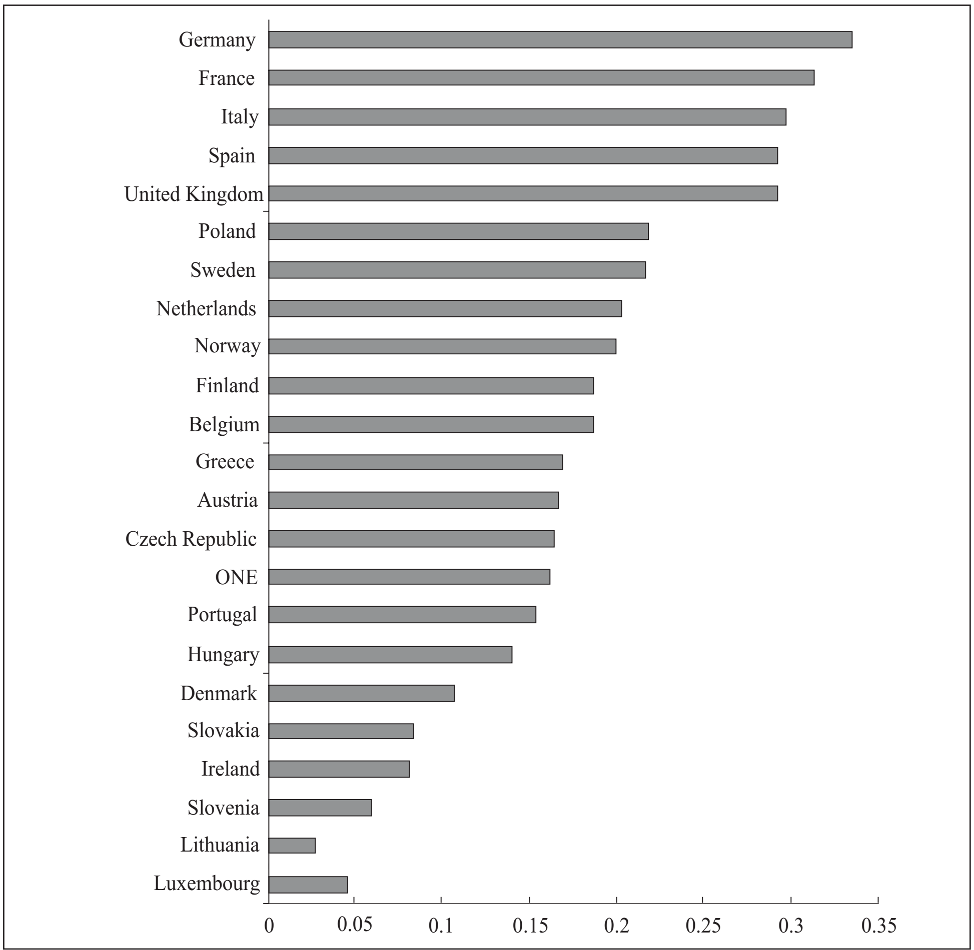

Fig. 1. Absolute term values characteristic of individual states in the 1st model of electrical energy consumption

relationship appeared to be significant. In this case, we can indicate very high consumption elasticity with regard to potential demand represented by the number of citizens

$$\Delta Kon_{it} = \alpha_{i0} + (0.923-1)(Kon_{t-1} - 0.361 Gdp_{t-1}) + 2.613\,\Delta Pep + 0.082\,\Delta Gdp + \xi_{it}.$$
$$\qquad (0.019) \qquad\qquad (0.005) \qquad\quad (0.787) \qquad (0.056)$$

The increase of the number of citizens by 1 % can cause — assuming other factors unchanged — an increase in energy consumption by 2.558%. The positive correlation between elasticity of consumption with regard to GDP is ex-

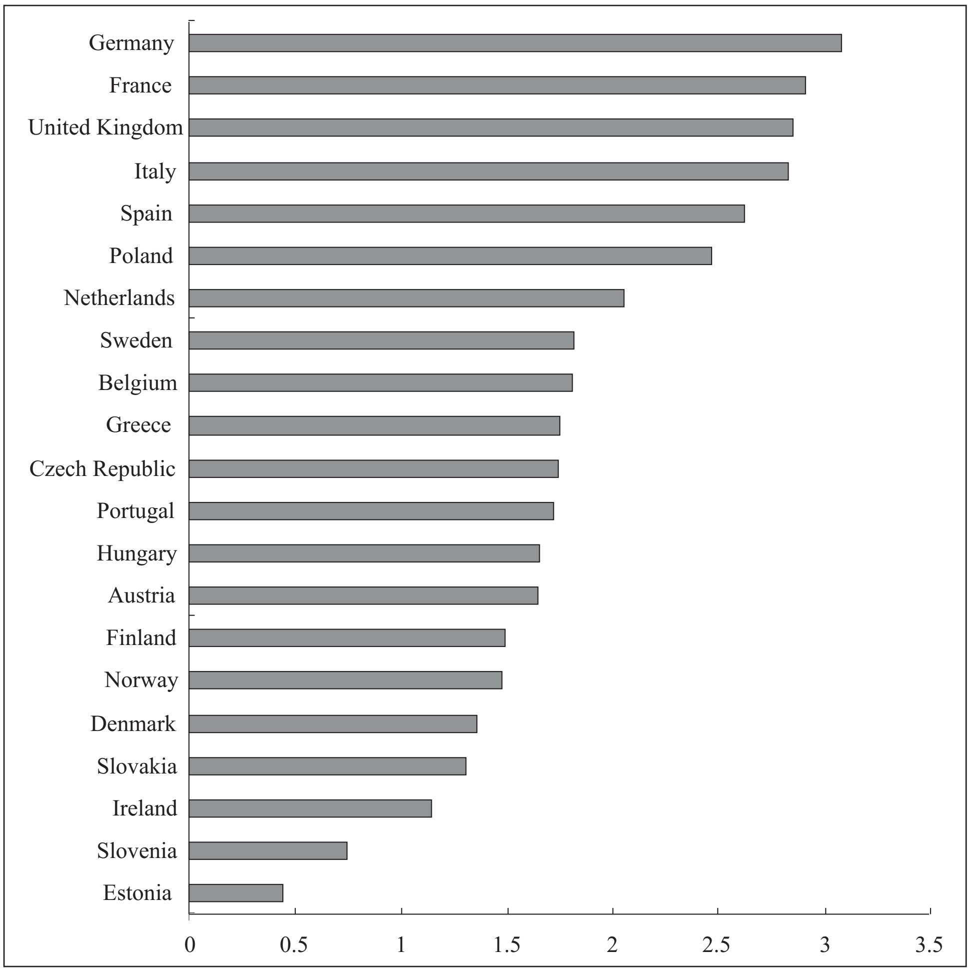

Fig. 2. Absolute term values characteristic of individual states in the 2nd model of electrical energy consumption

plainable, however quite visible positive correlation with regard to CPI level seems to be surprising. It would mean that together with inflation growth, the energy consumption also experiences a significant rise. It may be the case that in this situation some important factors, which determine consumption, are omitted or wrongly aggregated. It is namely connected with unselected export value. Obviously, the growth of inflation indicates usually a growth of export. In favourable conditions, this growth results in an increase of production — as a reaction to activation of market demand — and increase of energy consumption. On the other hand, the inflation influence exceeds three times the influence of GDP (the significance is confirmed on the level of relevance equal to 0.075), which indicates that energy consumption is rather dependent on financial policy than on business policy. All these factors indicate a fast and short-term relation. Therefore, we experience a very sensitive energy market, which is reacting almost immediately. It is possible to find market aspects in the trade of energy. Decomposition of absolute term enables to identify interactions between indicated variables typical of 22 countries. Considering multiplicative character of absolute terms in the exponent function, we may discuss a kind of intensification or reduction of influence of particular determinants on individual.

It seems to be helpful to divide the countries into few groups — similar especially in "stronger" groups. The strongest indicator of determinants' influence that shapes the consumption has been noticed in Germany. This group includes also France, Italy, and Great Britain — which is natural because of economic potential, but also Spain which is a kind of surprise. Other group includes the Nordic countries, Belgium, Netherlands, and Poland. The weakest — negative indicator was fixed for Luxembourg, which is probably associated with weak comparability of data in this country.

If these determinants are analyzed in a comprehensive way, the intensity with regard to potential economies of scale should be considered [11]. In short-term perspective, it goes to 3.048 % — mainly because of elasticity with regard to the number of citizens that is in reality a relatively constant number — especially in the case of European countries. Decomposed absolute terms in practice make the value more real. Therefore, we experience an effect on the level of 0.89 — 1.02 for the first group, 0.57 — 0.66 for the second, etc.

What is worth mentioning, certain regularity may be observed. Performed calculations (with the use of Pearson's correlation coefficient) indicate a very strong, positive correlation between decomposed absolute terms and average consumption of energy in a particular country. It proves the importance of indicator, which in fact is an indicator of intensity of energy consumption. With regard to wealth of every country measured by GDP value an opposite — however not so strong, but still significant linear dependence — negative on the level of 0.46 is observed. Therefore, we can conclude that together with the increase of wealth, intensity of energy consumption decreases. It is probably associated not with absolute declines, but relative ones generated by the use of economical technologies in more wealthy countries. Rich people understand and can afford savings. Moreover, it should be emphasized that modern — very developed economies — base their activity on services — rather than manufacturing. Services are certainly less energy consuming in comparison with manufacturing.

Decomposition of absolute term is performed by dividing it into as many parts as the amount of used objects. If any of them is insignificant, there is an additional absolute term implemented, which is representing all objects.

As a result, we obtain estimates which are characteristic of significant objects and a general estimate of absolute term «ONE».

The adjustment of presented model is very low — $R2$ = 0.27 (F = 2.64), however statistically significant. Unfortunately, rejection of hypothesis concerning the existence of autocorrelation is also difficult. In this situation — after additional analysis of entry data and model residuals, we observed, that the majority of non-standard observations concerns Lithuania and Latvia. What is more, during estimation it has become clear that decomposed absolute terms, which are insignificant, concern smaller countries — Luxembourg, Cyprus, and Iceland. Based on this information, the model has been rebuilt and as a result, the database includes 21 countries. Subsequently, during estimation of the model with error correction mechanism and decomposition of the absolute term, the model encompassing all 21 significant absolute terms and four relatively significant estimations of structural parameters has been obtained. It was only one parameter that was problematic — the one that was positioned at a variable responsible for short-term elasticity with regard to inflation — 0.11 relevance level. The subsequent estimation — with exclusion of this variable — gave fully satisfactory results. The adjustment of the model on the level of 0.57 — considering the fact that it is the error correction model — seems to be fully acceptable. Moreover, the first order coefficient of residuals' autocorrelation close to 0.11 — confirms the relevance of using this method.

In contrast to the previous model, this one confirmed the long-term influence of the number of citizens on energy consumption, and simultaneously denied the short-term influence. It was only GDP in short term, which has occurred to be a significant factor in creating energy consumption.

$$\Delta Kon_{it} = \alpha_{i0} + \underset{(0.030)}{(0.833-1)}\,(Kon_{t-1} + \underset{(0.155)}{2.79}Pep_{t-1}) + \underset{(0.038)}{0.218}\,\Delta Gdp + \xi_{it}.$$

It is worth noticing that we experience a kind of overcalibration. Namely, the values of structural parameters in this case have been reduced in comparison with the previous model, where the values of decomposed absolute term have increased. The conclusion is that, for the same entry data, energy consumption will be much higher for Germany or France, in comparison not only with Czech Republic or Slovenia — which has much lower economic potential — but also with regard to Finland or Norway where energy consumption indicators are twice lower.

Conclusions. The model indicates clearly that energy consumption is correlated with economic growth and the population number. These two determinants are found out to be significant, but GDP level is a stronger factor in a short term, whereas the population number, which is in a short-term horizon a relatively constant value, occurs to be relevant only in a long term. It is worth to remember that on the other hand, GDP indirectly depends on the increase of energy consumption, which stimulates economic growth — therefore we experience a feedback. In the case of particular countries, these determinants have influence on a certain consumption level adequate to the level of economic development. The described model enables to identify these relations and can be used as a helpful instrument in forecasting a demand for electric energy.

Здійснено спробу побудувати модель споживання енергії з урахуванням макроекономічних факторів, таких як ВВП, індекс цін споживача, та демографічних даних. Запропонована модель дозволяє за допомогою механізму виправлення похибок визначити коротко- і довгострокові стосунки між змінними, що аналізуються. Використано просторово-часову вибірку даних з 1980 по 2005 р. по країнам Європейського Союзу. Застосування такої перехресної вибірки та розкладання часового періоду дозволяє визначити деякі загальні закономірності явища, що аналізується, а також закономірності, типові для визначених країн. Розроблену модель можна використовувати для підготовки процедур моделювання та прогнозування енергоспоживання, що планується, на національному та міжнародному рівнях.

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