International Journal of Research in Business Studies and Management
Volume 2, Issue 2, February 2015, PP 38- 45
ISSN 2394-5923 (Print) & ISSN 2394-5931 (Online)

Increasing Energy Efficiency in the Post-Communist East-Central Europe – A Critical View

Tekla Sebestyén Szép[1], Zoltán Nagy[2]

[1]*Institute of World and Regional Economics, Faculty of Economics, University of Miskolc, Miskolc, Hungary, (Assistant Lecturer)*
[2]*Institute of World and Regional Economics, Faculty of Economics, University of Miskolc, Miskolc, Hungary (Associate Professor)*

ABSTRACT

Energy efficiency measures are affected by many factors such as the economic structure, the technology applied, and the price of energy. But there is growing interest in the question of why energy efficiency improvements do not result in the expected energy consumption reduction. It is indispensable to know accurately and to forecast the degree of the rebound effect for designing the appropriate national strategies. In this study we examine the rebound effect in the household sector of East-Central Europe (which we define as consisting of the Czech Republic, Poland, Hungary, Slovakia and Slovenia), analyzing the heating, water heating and the total final energy consumption, from 1990 to 2009. Our findings show that the rebound effect is a real phenomenon in East-Central Europe.

Keywords: Energy efficiency, East-Central Europe, energy consumption, energy saving, rebound effect.

INTRODUCTION

The effectiveness of energy efficiency measures is influenced by many factors, such as economic structure, the applied technology, the energy price, etc. There is growing interest in a relatively hidden factor to explain why the energy efficiency improvements do not result in the expected energy consumption reduction. One reason is that the calculated (potential) energy savings are overestimated, because consumer behaviour is not taken into consideration (Haas et al. 1998). Another reason is the rebound effect, whose history started in 1865 with a book by Jevons (1866) called The Coal Question.

The most comprehensive study on this topic was made by the UK Energy Research Centre (UKERC) in 2007. According to its researchers (including Sorrell, Dimitropoulos, and Barker), in the historical view the improvement of the gross inland consumption of energy divided by GDP (i.e. the energy intensity) is due to the fact that the economic structure has significantly changed and the quality of energy used has improved, not because of technological developments (Sorrell 2007). According to Sorrell, "the rebound effect is an umbrella term for a variety of mechanisms that reduce the potential energy savings from improved energy efficiency" (Sorrell, Dimitropoulos and Sommerville 2009, 1457). Even the smallest increase in the demand for energy services reduces the energy savings resulting from the growth of energy efficiency (Sorrell, Dimitropoulos and Sommerville 2009). For example, a customer who buys a more economical car (more efficient, lower petrol consumption) decides to use it more frequently because of the lower operating costs per kilometre. Another typical example is related to the household sector: the heating temperature will increase as a result of the reduction of heating costs per m2 (e.g. from upgrading the thermal insulation of a house), or even the heating period will be longer.

The phenomenon can be classified in many ways. Two types of rebound effect are known: direct and indirect. As a direct effect, any efficiency improvement in energy supply reduces its price, which leads to the increase of demand for that service. The indirect rebound effect comes from the substitutability of goods: the price decrease of energy leads to the rearrangement among the groups of goods consumed by a consumer. For instance, the thermal insulation of a house leads to a reduction in

***Address for correspondence:**

regtekla@uni-miskolc.hu

heating costs; the savings achieved in this way will be spent on holiday by a given family which, in turn, will increase the consumption of kerosene or other fuel.

While the direct rebound effect can be relatively easily estimated, the measure of the indirect rebound effect is more complex, and existing estimates are limited. In spite of this, in the last three years researchers have attempted to expand these analyses (such as Chitnis et al. 2013; Wei 2010; Yu, Zhang and Fujiwara 2013).

The size of the rebound effect is influenced by many factors, such as the price elasticity, the energy intensity of the sector, the time elapsed after energy efficiency improvements, consumer attitudes, the income level of consumers and the substitution of the energy. Hertwich (2005) distinguishes three main types with regard to size: a weak effect occurs if the effectiveness is below expectations; with a strong effect the expected amount of energy saving is not realized; and if the energy consumption increases after an energy efficiency improvement this is called a backfire affect.

Opinions are diverse about the degree of the rebound effect, the main reason being that "its measurement is very complex, different methodologies lead to various results" (Panyi, 2009, p. 2). Some (such as Hanley et al. 2009) believe the rebound effect can be negligible, it is significant only in the long run, while according to others both in the short run and in the long run it is significant, and some views have emerged (such as Wei 2010) arguing for its short time importance. That is, a rebound effect of 20% means that 20% of the potential energy savings have been lost.

There are two possibilities for measuring the rebound effect: the first is a simple estimation by which we examine how much the demand for energy supply was before and after the energy efficiency innovation. The methodological elaboration of these measurements is very soft because they try to draw conclusions only from a before-and-after comparison.

There are many other different kinds of methods: calculating elasticity, general equilibrium models, input-output models, life-cycle and econometric analysis. For the latter we use secondary data to estimate the price elasticity of energy demand in different aggregation stages (economic sector, region, country). In this case the data can be varied: panel data, cross-sectional and time series data. The most popular econometric methods are the Ordinary Least Squares (OLS), the Two Stage Least Squares (2SLS), the Three Stage Least Squares (3SLS), Vector Autoregressive (VAR) methods, as well as Vector Error Correction Models (VECM).

PROPOSED METHODOLOGY AND DISCUSSION

The relationship of energy consumption and energy efficiency is most often described with Multivariate Linear Regression Models, which are typically estimated with the Ordinary Least Squares method. The general form of it is:

$$Y_t = \beta_1 + \beta_2 X_{t2} + \cdots + \beta_k X_{tk} + u_t \qquad (1)$$

where Yt is the dependent variable in time period t, Xtk is the independent variable k in time period t and t=1…n, k=1…n, βk is the coefficient, and ut is the residual term.

In multivariate linear regression models a dependent variable is examined through many independent variables and we assume a linear relationship (and the normality of the observations). The Ordinary Least Squares models minimize the sum of the square of the residual terms, which means that "this method minimizes the sum of squared vertical distances between the observed responses in the dataset and the responses predicted by the linear approximation." (Sajtos and Mitev 2007, 215).

In our analysis we pay great attention to checking the conditions, as summarized in Table 1. The first step is the test for stationarity. A time series is not stationary if the mean and the variance change over time (Maddala 2004; Wadud, Graham, Noland 2009a; Wadud, Graham, Noland 2009b). Most time series are not stationary, but the differentiation of them are that. We examine this condition with the Augmented Dickey-Fuller, DF-GLS and the KPSS test.

We use the coefficient of determination (denoted R2) to measure how well the observed outcomes are replicated by the model, i.e., what proportion of total variation of the dependent variable is explained by the independent variables (Ezekiel and Fox 1970). The F-probe measures the goodness of fit and we measure the relevance of the variables with t-statistics (using 5 % significance level). We evaluate the homoscedasticity with the White and Breusch-Pagan tests, and the autocorrelation is checked by the Breusch-Godfrey test (the null hypothesis is that there is no disturbing autocorrelation). The variance inflation factor (VIF) was appropriate to check the condition of multicollinearity. We tested the model specification with the Ramsey RESET-test (the null hypothesis is that the model is adequate, so correctly specified). The final condition refers to the residual terms: we tested the normality of the distribution graphically.

Table1. *Conditions of the OLS models*

Variable	Condition	Problem	Test applied
Conditions of dependent and independent variables			
Dependent and independent variable	Linearity	Non-linear connection	Scatterplots
Dependent and independent variable	Independence from each other	Multicollinearity	VIF indicator
Dependent and independent variable	Stationarity	The time series variables are non-stationary	ADF test, ADF-GLS-test, KPSS test
Conditions of residual terms			
Residual terms	Normal distribution	Not normal distribution	Graphical normality test
Residual terms	Not correlated	Autocorrelation	Breusch-Godfrey test
Deviation of residual terms depending on the independent variable	Not correlated (homoscedasticity)	Heteroscedasticity	White test, Breusch-Pagan test

Source: *own compilation on the basis of Sajtos and Mitev, 2007, p. 217*

The empirical analysis of the energy consumption of the households uses the following basic equations (Freire-González, 2010; Haas and Biermayr, 2000; Haas et al. 1998):

$$lnE_t = C + \alpha lnP_t + \beta lnY_t + \gamma lnHDD_t(+\delta lnA_{Nt} + \varepsilon lnDB_t + \theta lnE_{t-1}) \quad (2)$$

where ln is the natural logarithm of the variables, C is the constant, α, β, γ, δ, ε, θ are the coefficients, E is the energy use, P is the energy price, Y is the income, and HDD means the number of heating degree days per year (this latter variable is used by the analysis of the household heating). Haas et al. (1998) use the AN variable (average floor area of dwellings, m2) and DB variable (number of dwellings). In all cases the researchers include the first order lag of energy consumption Et-1, which makes the model dynamic.

In our models we use the logarithmic form of all variables, so the results are elastic, which measures the percentage changes of the dependent variables with regard to one percentage change of the independent variables. We build the models using this basic equation. We assume the symmetry reaction of the households for the changes in energy costs and energy price, meaning that the changes in energy consumption (the reaction of the households) are the same when the energy prices (or energy costs) either increase or decrease by one unit.

Database

We carried out calculations for the Czech Republic, Poland, Hungary, Slovakia and Slovenia for the household sector. Due to lack of data we could not carry out an analysis for Slovenia's heating, and for Poland and Slovenia's water heating. The examined time period is 1990-2009, and the data sources are the Worldbank, Eurostat and Enerdata Odyssee databases.

Table 2 shows the applied variables and their abbreviations (blue is for the main indicators which show the size of the rebound effect). We integrate into our models the crude oil prices since the price of energy is an extremely important indicator for analyzing the energy demand, but there is no data about the gas and electricity prices for household consumers from 1990-1999 (just from 2000). We make a correlation analysis for the gas and electricity prices for household consumers and the inflation adjusted crude oil prices. There is a medium strong correlation for each country, so the inflation adjusted crude oil prices can be perfectly substituted. Another reason is that according to the literature (such as Hertwich, 2005) the crude oil prices have to be considered because whether the prices are in an increasing and decreasing period can also affect the results (Haas et al. 1998).

Table2. *The applied variables of the OLS models*

Abbreviations	Data	Role of the variable in the model
FCspaceheatC	Final consumption of residential for space heating with climatic corrections (Mtoe)*	Dependent variable
Usefulea	Unit consumption per m2 for space heating with climatic corrections (koe/m2)*	Independent variable
Fcwaterheati	Final consumption of households for water heating (Mtoe)*	Dependent variable
UCHotwaterP	Unit consumption of hot water per dwelling (toe/dw)*	Independent variable
FinConsCC	Final consumption of residential with climatic corrections (Mtoe)*	Dependent variable
UCPERdw	Unit consumption per dwelling with climatic corrections (toe/dw)*	Independent variable
AreaDW	Floor area of dwellings (average) (m2) *	Independent variable
DD	Degree-days*	Independent variable
NUhouseholds	Total stock of dwellings (k)*	Independent variable
HouseFCEpe	Household final consumption expenditure per capita (constant 2000 US$) **	Independent variable
Oilprice	Annual average domestic crude oil prices (U.S. average, (in $/bbl.))***	Independent variable

Note: **: Source - Odyssee database; **: Source – Worldbank; ***: Source - McMahon database (2013)*

Source: *own compilation*

The indicator of household income is significant in energetic analysis. Since income data is also lacking (available only starting from 2005 in the Eurostat database), we used the household final consumption expenditure per capita as a proxy variable (this is available from 1990). According to the Worldbank the household final consumption expenditure per capita is the market value of all goods and services, including durable products (such as cars, washing machines, and home computers), purchased by households. This indicator is also applied by Haas et al. (1998) and Schipper and Grubb (2000), justified by the lack of more specific data.

The final consumption of residential with climatic corrections is the final consumption of the residential building corrected by the square root of the heating degree days using the Werner method. Thus the final consumption of residential for space heating with climatic corrections is corrected by the number of heating days. The final consumption is the difference between domestic consumption and the consumption in energy transformations, and the losses involved. Final consumption measures the needs of the final consumers of the country. Final consumption is broken down into several groups with regard to the final consumption purpose: heating, water heating, cooking, lighting and the energy consumption of other household appliances.

EXPERIMENTAL RESULTS

We integrated into the models all of the variables in Table 2 and we left the insignificant indicators using the Stepwise model reduction method (at 5% significance). These insignificant variables are signed with a horizontal line in Table 3, Table 4 and Table 5. Because of the strict character limits we avoid from the interpretation of the indicators - we concentrate on the calculation of the rebound effect.

Table3. *The OLS model for space heating*

	CZ	HU	PL	SK
konstans tag	-19.029 (-6.924) [0.000]	-0.231 (-3.418) [0.004]	2.426 (2.275) [0.039]	0.535 (169.7) [0.000]
AreaDW	-	-	-14.795 (-3.811) [0.002]	-2.407 (-8.593) [0.000]

DD	-	-	-0.237 (-1.781) [0.097]	-
Usefulea	0.817 (8.241) [0.000]	0.96 (43.31) [0.000]*	0.623 (8.639) [0.000]	1.048 (110.5) [0.000]*
NUhouseholds	2.176 (7.08) [0.000]	-	-	-
HouseFCEpe	-	0.029 (3.489) [0.003]	-	-
Oilprice	-	-	-	-
FCspacehe_1	0.169 (2.938) [0.0102]	-	0.256 (2.465) [0.027]	-
R2	0.939	0.992	0.943	0.999
F-probe	76.754 [0.000]	1040.63 [0.000]	57.979 [0.000]	6102.438 [0.000]
Homoscedasticity	✓	✓	✓	✓
Autocorrelation	✓	✓	✓	✓
VIF	✓	✓	✓	✓

Notes: *variable is the FC space heatgC; the t-statistic ( ); the p-value [ ]*

**: Instead of "Unit consumption per m2 for space heating with climatic corrections (koe/m2)", here the variable is the "Unit consumption per dwelling for space heating with climatic corrections (toe/dwelling)"*

Source: *own compilation*

According to the results of the Table 3 in case of the Czech Republic we calculate the rebound effect on the following: the coefficient of the variable "Unit consumption per m2 for space heating with climatic corrections (koe/m2)" is 0,817. It means if the unit consumption per m2 for space heating with climatic corrections of the households increase 1%, the final consumption of residential for space heating with climatic corrections increases 0,817%. In our case we suppose an energy efficiency improvement, so if the unit consumption per m2 for space heating decrease 1%, the final consumption of residential for space heating with climatic corrections decreases 0,817%. The size of the rebound effect with regard this train of thought is 1-0,817=0,183, so exactly 18,3%. It can be stated after an energy efficiency improvement the unit consumption per m2 for space heating decreases 10%, the aggregate final consumption for space heating decrease with "only" 8,17%. The difference is the loss or with other words it is the rebound effect.

Table4. *The OLS-model for water heating*

	CZ	HU
konstans	0.89 (2.68) [0.016]	-0.193 (-2.587) [0.02]
Oilprice	-	-
DD	-0.109 (-2.67) [0.017]	-
NUhouseholds	-	-
AreaDW	-	-
HouseFCEper	-	0.025 (2.655) [0.017]
UCHotwaterP	0.958 (11.65) [0.000]	0.978 (23.17) [0.000]
Fcwaterheati _1	-	-
R2	0.895	0.971
F-probe	68.504 [0.000]	271.915 [0.000]
Homoscedasticity	✓	✓
Autocorrelation	✓	✓
VIF	✓	✓

Notes: *The dependent variable is the Fc water heati; the t-statistic ( ); the p-value [ ]*

The next calculation refers to the water heating. Because of the lack of data the analysis can be implemented only for Hungary and the Czech Republic. The starting models fulfil al off the requirements of the OLS-method. The constant and the coefficients are significant. The value of F-statistics is acceptable. The value of R2 is near to 1.0, it is over the value 0, 85. There is no multi co linearity and the residual terms are homoscedastic and are not auto correlated, so the coefficients can be interpreted. According to the Ramsey RESET test the models are correctly specified. (Table 4)

Table5. *The OLS-model for final consumption of residential*

	CZ	HU	PL	SK	SLO
konstans	-6.412 (-7.092) [0.000]	-10.55 (-19.51) [0.000]	2.675 (138.1) [0.000]	0.512 (104) [0.000]	-
UCPERdw	0.859 (11.88) [0.000]	0.889 (38.22) [0.000]	0.821 (15.74) [0.000]	1.056 (83.66) [0.000]	0.249 (11.34) [0.000]
Nuhousehold	0.909 (8.498) [0.000]	1.442 (22.08) [0.000]	-		-
Oilprice	-	0.01 (1.945) [0.071]	-		0.101 (2.291) [0.036]
DD	-	-	-		-
AreaDW	-	-	-10.036 (-4.751) [0.000]	-2.524 (-8.408) [0.000]	-
HouseFCEper		-	-	-	-
FinConsCC_1	0.115 (2.615) [0.019]	-	-	-	-
R2	0.96	0.993	0.956	0.997	0.901
F-probe	121.16 [0.000]	714.66 [0.000]	173.03 [0.000]	3518.647 [0.000]	72.96 [0.000]
Homoscedasticity	✓	✓	✓	✓	✓
Autocorrelation	✓	✓	✓	✓	✓
VIF	✓	✓	✓	✓	✓

Notes: *dependent variable is the FinConsCC; the t-statistic ( ); the p-value [ ]*

Source: *own compilation*

These analysis are made for the total final energy consumption of the households, which shows the reaction of the households for the potential costs decline thanks for the energy efficiency improvements. In these cases the models fulfil all of the conditions mentioned above. (Table 5)

Table6. *The average rebound effect in East-Central Europe for the household sector.*

	Heating	Water heating	Total energy consumption
Czech Republic	18.3%	4.2%	14.1%
Hungary	4%	2.2%	11.1%
Slovakia	0%	-	0%
Slovenia	-	-	75.1%
Poland	37.7%	-	17.9%

Source: *own compilation*

Table 6 shows the average rebound effect in East-Central Europe for the household sector. Our results vary, but the size of the rebound effect is far from the previous results (such as Sorrell, Herring etc.) found in the literature. The rebound effect is seen in every country except for Slovakia. For residential heating, the size of the rebound effect is the largest in Poland (near to 40%), and the smallest in Hungary (4%). For the water heating the effect is quite low, under 5%. We analyze the total energy consumption of the households with regard to the energy consumption per household. This amount is between 10% and 20% in Hungary, the Czech Republic and Poland, while in Slovenia it is more than 70%, which is a really high value. The rebound effect is under 100% in every case (in one case it is even 0%), which means that energy efficiency improvements are not unnecessary; they contribute to reducing the energy consumption.

CONCLUSION

It can be stated that the rebound effect is a real phenomenon in East-Central Europe. The size of the rebound effect is significant in the household sector of the Czech Republic, Slovakia, Slovenia and Hungary and it varies with regard to household activities (heating and water heating). Furthermore, the contribution of energy efficiency improvements to energy conservation is lower than expected. For the reduction of energy consumption and for environmental protection the energy efficiency improvements alone are not the most appropriate solution. In parallel we have to aim for energy savings and to restrain energy consumption.

These results have a practical importance: in Hungary the 2nd National Energy Efficiency Action Plan of Hungary prescribes 21 PJ energy savings in the household sector per year. If this is carried out then we predict that 11.1% of it, or 2,331 PJ, would be lost due to the rebound effect. Such losses must be taken into consideration when forming energy policy.

ACKNOWLEDGEMENT

The described work was carried out as part of the TÁMOP-4.2.1.B-10/2/KONV-2010-0001 project in the framework of the New Hungarian Development Plan. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

REFERENCES

[1] 2nd National Energy Efficiency Action Plan of Hungary until 2016 with an outlook to 2020. Ministry of National Development, Budapest 73 p. downloaded: September 2012 http://www.buildup.eu/sites/default/files/content/HU%20-%20Energy%20Efficiency%20Action%20Plan%20EN.pdf

[2] Chitnis, M., Sorrell, S., Druckman, A., Firth, S. K., Jackson, T. 2013: Turning lights into flights: Estimating direct and indirect rebound effects for UK households. Energy Policy 55. pp.234-250 DOI:10.1016/j.enpol.2012.12.008

[3] Eurostat 2013: Database http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

[4] Ezekiel, M., Fox, K. A. 1970: Correlation and regression analysis. (in Hungarian: Korreláció és regresszióanalízis) Közgazdasági és Jogi Publisher 594 p.

[5] Freire-González, J. 2010: Empirical evidence of direct rebound effect in Catalonia. Energy Policy 38. pp.2309-2314 DOI:10.1016/j.enpol.2009.12.018

[6] Haas, R., Biermayr, P., Zoechling, J., Auer, H. 1998: Impacts on electricity consumption of household appliances in Austria: a comparison of time series and cross-section analyses. Energy Policy Vol. 26 Issue 13. pp.1031-1040

[7] Haas, R.,Biermayr, P. 2000: The rebound effect for space heating-Empirical evidence from Austria. Energy Policy 28. pp.403-410

[8] Hanley, N., McGregor, P., Swales, J. K., Turner, K. 2009: Do increases in energy efficiency improve environmental quality and sustainability? Ecological Economics 68. pp.692-709 DOI: 10.1016/j.ecolecon.2008.06.004

[9] Herring, H., Roy, R. 2007: Technological innovation, energy efficient design and the rebound effect. Technovation 27. pp.194-203 DOI: 10.1016/j.technovation.2006.11.004

[10] Herring, H. 2008: Definition and Implications of the Rebound Effect. http://www.eoearth.org/article/Rebound_effect downloaded: July 2011.

[11] Hertwich, E. G. 2005: Consumption and the rebound effect. Journal of Industrial Ecology, Vol. 9., No.1., http://www.score-network.org/files//333_3.pdf downloaded: July 2011. pp.85-98

[12] Jevons, W. S. 1866: The Coal Question; An Inquiry concerning the Progress of the Nation, and the Probable Exhaustion of our Coal-mines. London, Macmillan and Co., 2nd edition http://oll.libertyfund.org/?option=com_staticxt&staticfile=show.php%3Ftitle=317&Itemid=27 downloaded: June 2012.

[13] Maddala, G. S. 2004: Introduction to Econometrics. (in Hungarian: Bevezetés az ökonometriába) National Publisher, Budapest 704 p.

[14] Odyssee (Enerdata) 2012: Database on energy efficiency indicators. downloaded: February 2012. http://odyssee.enerdata.net/ nrd_web/site/

[15] Panyi, M. 2009: The goodwill can lead to climate hell. (in Hungarian: A jószándék klímapokolba vihet) http://kitekinto.hu/hatter/2009/07/26/a_ joszandek_klimapokolba_vihet&lap=1 3 p.

[16] Sajtos, L., Mitev, A. 2007: Handbook for data analysis and research with SPSS. (in Hungarian: SPSS kutatási és adatelemzési kézikönyv) Alinea Publisher: Budapest.

[17] Schipper, L., Grubb, M. 2000: On the rebound? Feedback between energy intensities and energy uses in IEA countries. Energy Policy 28. pp.367-388

[18] Sorrell, S. 2007: The Rebound Effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency. UK Energy Research Centre. http://www.ukerc.ac.uk/support/tiki-index.php?page=ReboundEffect

[19] Sorrell, S., Dimitropoulos, J., Sommerville, M. 2009: Empirical estimates of the direct rebound effect: A review. Energy Policy 37. pp.1356-1371 DOI: 10.1016/j.enpol.2008.11.026

[20] Wadud, Z., Graham, D. J., Noland, R. B. 2009a: Modelling fuel demand for different socio-economic groups. Applied Energy 86. pp.2740-2749 DOI: 10.1016/j.apenergy.2009.04.011

[21] Wadud, Z., Graham, D. J., Noland, R. B. 2009b: A cointegration analysis of gasoline demand in the United States. Applied Economics pp.3327-3336. DOI: 10.1080/00036840701477306.

[22] Wei, T. 2010: A general equilibrium view of global rebound effects. Energy Economics 32. pp.661-672 DOI: 10.1016/j.eneco.2009.09.002

[23] Worldbank 2013: Database - World Development Indicators

[24] Yu, B., Zhang, J., Fujiwara, A. 2013: Evaluating the direct and indirect rebound effects in household energy consumption behaviour: A case study of Beijing. Energy Policy 57. pp.441-453 DOI: 10.1016/j.enpol.2013.02.024

AUTHORS' BIOGRAPHY

Tekla Sebestyén Szép is an economist and she works at the University of Miskolc as assistant lecturer. Her research field is mainly the energy economics, with special regard to the energy efficiency, rebound effect, and lately the sustainable energy development and the energy convergence. The methods used include econometric analysis, index decomposition analysis, Sigma, Beta and Gamma convergence calculations.

Zoltán Nagy is an economist specialized in international economics and teacher of geography and history. His research topic is the social geography, regional economics, urban competitiveness and the urban energy use. The methods used include spatial econometric analysis, factor and cluster analysis and other statistical methods.