Peter Hostak[1], Jaroslav Holomek[2], Martina Klierova[3]

ENERGY INTENSITY AND CONVERGENCE OF ECONOMIC PERFORMANCE OF THE EUROPEAN UNION COUNTRIES [*]

The study examines efficiency of the energy consumption within the context of regional development of the European Union countries. More specifically it presents and discusses regional disparity in economic output and energy intensity and examines the relationship between convergence of economic performance and convergence of energy intensity indicators.

Keywords: *energy intensity; regional development; sustainable economic growth; regional disparities.*

JEL classification: O13; R11; Q43.

Петер Хоштак, Ярослав Холомєк, Мартіна Клієрова

ЕНЕРГОІНТЕНСИВНІСТЬ ТА ЗБЛИЖЕННЯ ЕКОНОМІЧНИХ ПОКАЗНИКІВ КРАЇН ЄВРОСОЮЗУ

У статті досліджено ефективність споживання енергії в контексті регіонального розвитку Європейського Союзу. Проаналізовано регіональні дисбаланси за рівнем економічного розвитку та рівнем споживання енергії. Пояснено взаємозв'язок між зближенням економічних показників країн регіону та зближенням показників їх енергоінтенсивності.

Ключові слова: *енергоінтенсивність; регіональний розвиток; стійке економічне зростання; регіональні дисбаланси.*

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Петер Хоштак, Ярослав Холомек, Мартина Клиерова

ЭНЕРГОИНТЕНСИВНОСТЬ И СБЛИЖЕНИЕ ЭКОНОМИЧЕСКИХ ПОКАЗАТЕЛЕЙ СТРАН ЕВРОСОЮЗА

В статье исследована эффективность потребления энергии в контексте регионального развития Европейского Союза. Проанализированы региональные дисбалансы по уровню экономического развития и уровню потребления энергии. Объяснена взаимосвязь между сближением экономических показателей стран региона и сближением их показателей энергоинтенсивности.

Ключевые слова: *энергоинтенсивность; региональное развитие; устойчивый экономический рост; региональные дисбалансы.*

Introduction. Europe's economic growth over the last 30 years has lagged in comparison with other advanced economies and improving Europe's growth potential is crucial (Schindler et al., 2014). Much of the relative decline has been explained by the weak total factor productivity growth and inefficient use of resources. This study focuses on the efficiency of energy consumption within the context of regional development.

Energy is an essential factor of economic development even though economic theory recognizes only 3 primary factors of production: land, labor and capital.

[1] Alexander Dubcek University of Trencin, Slovakia.
[2] Alexander Dubcek University of Trencin, Slovakia.
[3] Alexander Dubcek University of Trencin, Slovakia.
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Energy is considered to be the secondary production factor as it is obtained from land with the help of labor and capital. Yet, as pointed out in (Obabi and Korcek, 2014) modern society is dependent on energy sources that are an indispensable factor in ensuring the production of products and services. There is an increasing awareness of the fact that natural resources are not "readily available", as it was assumed in traditional economic models.

Investigation of causal relationships between energy consumption and economic growth is systematically examined in a seminal paper by J. Kraft and A. Kraft (1978) who found evidence for causality running from GNP to energy consumption in the United States, using data for the period 1947–1974. As points out by J. Asafu-Adjaye (2000) the direction of causation between energy consumption and economic growth has significant policy implications. If, causality runs from income to energy, it may be implied that energy conservation policies may be implemented with little adverse or no effects on economic growth. In the case of negative causality running from employment to energy, energy conservation policy would result in higher employment. On the other hand, if unidirectional causality runs from energy consumption to income, reducing energy consumption could have adverse impact on economic growth.

Consequently it is essential to develop economic models that adequately reflect growing importance of finite energy resources in economic growth. Energy efficiency has recently attracted a great deal of attention in public debate, focusing on the question of how to meet environmental objectives with respect to climate change mitigation and how to enhance energy security in a sustainable way. However, as much as there seems to be consensus that there exists an energy efficiency gap (observed actually realized levels of energy efficiency differ from the optimal cost-minimizing level of energy efficiency), the measurement or assessment of the cost/benefit of energy investments remains notoriously challenging (Allcott and Greenstone, 2012).

It is also important to understand efficiency implications in the context of energy security in terms of individual economies as well as in terms of broader transnational alliances so that it is possible to promote measures aimed at securing stable access to energy resources. Currently, energy sources availability is determined by a complex system of global markets, multinational network of transit systems, interests of a small group of dominant energy suppliers, new technologies, geopolitical situation and financial markets development.

It should be noted that the EU is increasingly dependent on energy imports and the degree of this dependence can be characterized as the worst in its history. Modern European society begins to approach its energy ceiling and possibilities for increasing the energy supply are very limited. The share of renewable energy in the overall energy consumption should be driven by the reduction of final consumption and not by the quantitative growth of energy production from renewable sources.

This study contributes to the efforts to develop a general framework for analyzing the welfare impact of energy investments at the macrolevel by examining the relationship between regional development and energy efficiency.

Problem statement and research objectives. The goal of this study is to evaluate the trends in the efficiency of energy consumption in the EU in the context of cohesion policy aiming at convergence of economic performance of individual Member

States. It is not obvious what the impact of regional development on energy efficiency is – economic growth increases tendency to consume energy, on the other hand, economic development might also generate resources to invest into measures improving energy efficiency. To better understand the impact of these two conflicting forces we examine time series trends in regional disparities with respect to economic performance and energy efficiency of individual Member States; as well as the correlation of the examined empirical proxies. Lastly, we use logistic regression analysis to investigate the relation between the propensity of an underperforming region to converge towards EU energy efficiency standards and recent developments of its economic performance.

Economic performance. Consistent with other regional development studies (Workie, 2004; Workie, 2006; Haviernikova and Jansky, 2014) we use gross domestic product (GDP) per capita as a proxy for economic performance of a region. It reflects the market value of all final goods and services produced in a region during the reporting period over one year. In order to eliminate the possibility that price movements inflate observed growth rate we use real GDP per capita as reported by the Eurostat.

Energy intensity. This study uses energy intensity indicator as a measure of energy efficiency. Energy intensity is defined as the ratio between gross inland consumption of energy and GDP calculated for a calendar year. The advantage of energy intensity indicator is its ability to reflect to what extent there is a decoupling between energy consumption and economic growth. Decoupling of energy consumption from economic growth may result from reducing demand for energy services, or more efficient use of energy (thereby using less energy per unit of economic output), or a combination of the two. This measure therefore contrasts the measure that reflects consumption of energy against measure of economic output.

Regional disparities. Examination of regional development dynamics is a relatively challenging statistical task as there is not a single universal indicator able to comprehensively capture the degree of regional development. There exists a wide range of tools and the choice of a statistical indicator must reflect the objectives of specific empirical analysis, territorial structure as well as primary data availability. Static and dynamic tools represent two basic approaches to measuring regional development and disparities. Static tools measure regional disparities at a certain date while dynamic tools are used to evaluate historical trends in time series. Primary focus of this study is on a year-to-year comparison of the selected indicators of regional disparities and energy efficiency and therefore we use static tool, more specifically Gini coefficient. Consistent with the "Regions at Glance" database maintained by the OECD we use unweighted Gini coefficient defined as:

$$GINI = \frac{2}{N-1}\sum_{i=1}^{N-1}\left|F_i - Q_i\right|, \quad \text{where } F_i = \frac{i}{N} \text{ and } Q_i = \frac{\sum_{j=1}^{i} y_j}{\sum_{i=1}^{n} y_i} \tag{1}$$

and y_i is the value of GDP per capita in region j when ranked from low (y_1) to high (y_N) among all regions within a country. The coefficient ranges between 0 (perfect equality: y is the same in all regions) and 1 (perfect inequality: y is nil in all regions except one).

Data. The study uses the data assembled and disseminated by the Eurostat, the statistical office of the European Union, for the time period 1995 through 2012. In terms of territorial levels the study is conducted at the national level which corresponds to the first level of the Nomenclature of Territorial Units for Statistics standard and it includes data for all 28 member countries (EU28) including the newest EU member – Croatia.

Key research findings. Consistent with prior studies (Haviernikova, 2014; Ivanova et al., 2015; Kordos, 2014; Kordos and Karbach, 2014), Table 1 illustrates that regional disparities in the EU are high and as such they necessitate corrective actions in order to ensure harmonious economic development and improvement of living standards across the continent.

The EU28 experienced, since 1995 till 2007, a period of economic growth with real GDP per capita increasing by 30.7%. The financial crisis of 2008 ended the period of sustained, though modest, economic growth and resulted in two years of recession followed by rather timid recovery. Consequently real GDP per capita in 2012 remained 2.5% below the level reported in 2007. Yet, the pace of growth varied greatly across regions – while Latvia and Lithuania enjoyed growth in excess of 160% over the period from 1995 to 2012, Italy reported the growth of mere 4.1%. Luxembourg has strengthened its position of the most developed region with real GDP per capita that greatly exceeds the EU28 average (by the factor of 2.68 in 2012). At the opposite end of the spectrum is the least developed and largely rural Bulgaria with real GDP per capita of 15.9% from the EU28 average. The range of real GDP per capita measure increased from 44,000 EUR in 2003 to 58,900 EUR in 2012, i.e., the difference between the most and the least developed regions has increased by 33.8%. Nevertheless, the value of Gini coefficient decreased from 0.40 in 1999 to 0.36 in 2012 indicating a slight decrease in regional disparities across all EU regions. This is primarily due to rapid economic growth in the region of Central and Eastern European countries during the post-accession period.

Table 2 reports the values of energy intensity measure. At the EU28 level the measure of regional energy intensity decreased by 20.2% from 1995 till 2007 as economic growth significantly outpaced minor increase in energy consumption (energy consumption has increased over that period by 7.9%). Energy intensity in the period 2008–2012 decreased by additional 5.7% over the level reported in 2007 reflecting economic stagnation accompanied by 6.7% decrease in energy consumption, i.e. EU28 in this period managed to decouple its economic performance from energy consumption in absolute terms. It should be noted that energy intensity varies significantly across regions. The economically weakest Bulgaria is also the country with the highest energy intensity, in 2012 Bulgaria needed 700 kg of oil equivalents in order to generate 1,000 EUR of GDP. This is a major (48%) improvement since 1995 but this underdeveloped region is only slowly converging towards energy efficiency level typical for the EU28. While Denmark and Ireland succeeded to develop highly performing economies while maintaining their status of the countries with the lowest energy intensity in the EU (in 2012 they needed less than 90 kg of oil equivalents in order to generate 1,000 EUR of GDP).

Table 1. **Economic performance (real GDP per capita),** *authors' calculations and* Eurostat

	1995	1997	1999	2001	2003	2005	2007	2008	2009	2010	2011	2012
EU28 (EUR)	18,200	19,000	20,000	21,100	21,600	22,400	23,800	23,700	22,600	23,000	23,300	23,200
EU28 (% change)		*4.4*	*5.3*	*5.5*	*2.4*	*3.7*	*3.0*	*-0.4*	*-4.6*	*1.8*	*1.3*	*-0.4*
Max (EUR)	46,100	48,300	54,300	58,900	60,900	65,000	70,400	68,700	63,700	64,500	64,200	62,600
Min (EUR)	2,100	1,900	2,100	2,300	2,600	3,000	3,400	3,700	3,500	3,500	3,700	3,700
GINI		**0.39**	**0.40**	**0.40**	**0.39**	**0.38**	**0.37**	**0.37**	**0.37**	**0.37**	**0.36**	**0.36**

Table 2. **Energy intensity (energy consumption in kg of oil equivalent per 1,000 EUR of GDP),** *authors' calculations and* Eurostat

	1995	1997	1999	2001	2003	2005	2007	2008	2009	2010	2011	2012
EU28	190.3	186.5	175.9	170.9	169.2	163.9	151.9	151.0	148.9	151.6	144.0	143.2
EU28 (% change)		*-2.0*	*-5.7*	*-2.9*	*-1.0*	*-3.1*	*-4.6*	*-0.6*	*-1.3*	*1.8*	*-5.0*	*-0.6*
Max	1,810	1,319	1,085	1,040	942	849	760	712	661	669	705	670
Min	119.5	119.4	108.0	103.3	101.2	92.4	88.6	89.3	89.5	92.5	83.7	82.8
GINI	**0.46**	**0.41**	**0.38**	**0.37**	**0.35**	**0.33**	**0.32**	**0.31**	**0.31**	**0.31**	**0.32**	**0.31**

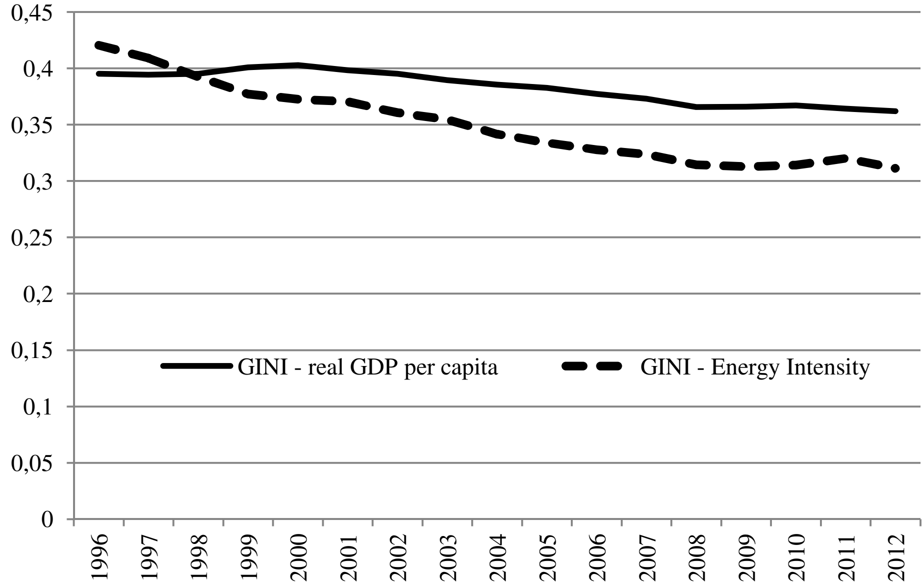

Figure 1. **Regional disparities (Gini coefficient),** *authors'*

The range of regional energy intensity measure in Table 2 decreased from 1691 kg / 1000 EUR in 1995 to 587 kg / 1000 EUR, i.e., the difference between the most and the least energy efficient region has decreased by almost two thirds. Gini coefficient confirms a significant decrease in regional disparities as its value decreased from .46 in 1995 to 0.31 in 2012. Nevertheless, energy intensity disparities remain relatively high and have not decreased much since 2008.

Figure 1 contrasts measure of regional disparities in terms of economic performance (Gini coefficient – real GDP per capita) against measure of regional disparities in terms of energy efficiency (Gini coefficient – Energy intensity). Both indicators follow a similar pattern: over the examined period there is some evidence of convergence but its pace is halted by the recession of 2008. Pearson correlation coefficient for these two measures over the period 1995 to 2012 is high (the value of 0.86) and statistically significant (p-value of less than 0.0001).

Panel A of Table 3 reports Pearson correlations between the variable capturing economic performance of a region (real GDP per capita) and the variable reflecting energy efficiency (Energy intensity) for the sample of 476 country-year observations. The reported values confirm a strong negative and statistically significant correlation between economic development of a region and energy intensity – regions with high real GDP per capita typically consumer lower amount of oil equivalents in order to generate 1000 EUR of GDP. This relationship remains statistically significant over the whole examined period even though the magnitude of correlation has slightly decreased from -0.71 in 1995 to -0.68 in 2012. This indicates that economic growth not only stimulates demand for energy consumption but also facilitates investments into a wiser, more productive use of resources.

Table 3. **Correlation of economic performance and energy intensity,** *authors' calculations and* Eurostat

Year	Panel A: Real GDP per capita & Energy intensity		Panel B: Real GDP per capita change & Energy intensity change	
	Correlation coefficient	*p-value*	*Correlation coefficient*	*p-value*
1996	-0.70	*<.0001*	-0.27	*0.1804*
1997	-0.71	*<.0001*	0.23	*0.2528*
1998	-0.72	*<.0001*	0.29	*0.1399*
1999	-0.72	*<.0001*	0.35	*0.0735*
2000	-0.71	*<.0001*	0.28	*0.1622*
2001	-0.71	*<.0001*	0.04	*0.8544*
2002	-0.71	*<.0001*	0.07	*0.745*
2003	-0.71	*<.0001*	-0.21	*0.2875*
2004	-0.70	*<.0001*	0.43	*0.0244*
2005	-0.69	*<.0001*	-0.04	*0.8463*
2006	-0.68	*<.0001*	0.18	*0.3722*
2007	-0.68	*<.0001*	0.06	*0.7818*
2008	-0.69	*<.0001*	-0.33	*0.0913*
2009	-0.72	*<.0001*	-0.23	*0.2448*
2010	-0.69	*<.0001*	0.09	*0.6612*
2011	-0.68	*<.0001*	-0.40	*0.0406*
2012	-0.68	*<.0001*	-0.45	*0.0174*
1996–2012	-0.66	*<.0001*	-0.07	*0.1347*

Panel B of Table 3 reports the variables capturing changes in economic performance of a region (year-to-year change in real GDP per capita) and changes in energy efficiency (year-to-year change in energy intensity) for the sample of 476 country-year observations. Consistent with the results reported in Panel A, correlation coefficient for the whole sample is negative but not statistically significant (the p-value of 0.13), i.e., this result indicates that increase in economic performance in terms of GDP per capita is associated with energy intensity decrease. It should be noted that examination of correlation coefficients on the annual basis is inconclusive – one plausible explanation is that the increase in economic strength and improvements in energy efficiency are not necessarily realized contemporaneously.

Table 4. **Logistic regression – regional development convergence and energy intensity,** *authors'*

		(Sample N=281)		
Parameter	**Predicted Sign**	**Estimate**	**Wald Chi-Square**	**Pr > ChiSq**
Intercept	??	0.7678	34.4785	<.0001
GDPconv	+	0.000671	3.8521	0.0497
Percent Concordant			**53.6**	
Percent Disconcordant			**38.5**	
Percent Concordant			**8.3**	

Table 4 provides results for the empirical test that examines the relationship between the convergence in terms of economic performance and the propensity of a country to improve its energy efficiency. We use logistic regression analysis to estimate the probability that the country converges towards the EU28 energy intensity standard as a function of its convergence towards the EU28 GDP per capita standard. The dependent variable *D* is equal to 1 if year-to-year change in the difference between energy intensity of a country and energy intensity of the EU28 is negative, and 0 otherwise. The results we present are based on the following model specification:

$$\log_{it}(D) \equiv \alpha + \beta_1 GDPconv_{i,t}, \quad (2)$$

where α is the intercept; *GDPconv* is the year-to-year change in the difference between real GDP per capita of a country and real GDP per capita of the EU 28. Positive value indicates that underperforming country is converging towards EU29 standards. This analysis is conducted on a sub-sample of countries with energy intensity higher (i.e. less efficient) than the EU28 standards. This yields 281 country-year observations for the period of 1996 through 2012. The results of this analysis suggest that the propensity to converge towards the EU28 energy intensity standards increases with the convergence in economic performance of a country as reflected in real GDP per capita. This support the assumption that regional development convergence goes hand in hand with improved energy efficiency and not the other way around.

Conclusions. Economic growth and energy consumption are interconnected. Historically, economic growth led to higher energy consumption, thus increasing the pressure of energy production and consumption on the environment. More efficient energy is therefore essential in order to decouple energy-consumption from economic growth either in relative terms (i.e. energy consumption grows but more slowly than the economy) or preferable in absolute terms (energy consumption is stable or decreases while GDP grows). This study examines the trends in measures of economic development and energy efficiency of the EU members over the period of 1995 through 2012. The study documents progress achieved over the period 1995–2012 and also presents evidence that regional development disparities as well as regional energy efficiency disparities in the EU remain high. The results of our empirical analysis are consistent with the conjecture that economic growth accelerates energy efficiency investments – more developed countries tend to operate with lower energy intensity and the likelihood that underperforming country converges towards the EU28 energy intensity standards increases with the level of its economic development.

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