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SUSTAINABLE DEVELOPMENT OF POLAND AND EUROPE – SPATIOTEMPORAL ANALYSIS AND SPATIAL EKC MODELS

Abstract. The aim of this paper is the presentation of the level of economic and sustainable development realization in Poland and other European Countries. In this article there were applied selected methods of spatial concentration and spatial econometrics models. Analysis concerns air degradation as one of the most priority issue. In this paper there were used spatial concentration measurements: spatial Gini index and Locality Quotient. There were also verified Environmental Kuznets Curve hypothesis for European Countries for such air indicators per capita as: SO_2, CO_2, NO, CO and GHG. The EKC hypothesis were examined by Spatial Lag and Spatial Error Models. Data includes years from 1990 to 2006.

Key words: Sustainable Development, air quality, indicators of Sustainable Development, spatial Gini index, Locality Quotient, spatial models, Spatial Environmental Kuznets Curve.

1. INTRODUCTION

This paper provides a comparative analysis of economic growth, environmental degradation (emphasize the problem of air quality) and sustainable development in EU. There were applied selected methods of spatial concentration and models of spatial econometrics. One of the main objectives of this paper is measuring and presenting the relation between economic development and environmental degradation across Europe. Secondly, showing the spatial dependence among European countries. Finally, proving the hypothesis of spatial EKC (Environment Kuznets Curve) models. With the object to execute all this papers' assumptions there were used spatial econometrics models and spatial concentration measurements, such as: Locality Quotient, spatial Gini index. The analysis is based on selected indicators of sustainable development. Data base includes years from 1990 to 2006. Beyond spatiotemporal comparison analysis, this study

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proves the EKC hypothesis in EU for some indicators of air degradation. Practicing some econometrics methods: Spatial Lag Model and Spatial Error Models the EKC was examined for selected indicators per capita: SO_2, CO_2, NO, CO, GHG. The second part of this paper presents main principles and specifications of sustainable development in UE. The third section displays the relationship between the air quality problems and economic activities. The fourth section characterizes database and discusses the spatial concentration measures and econometric issues involved to be used in the study. The fifth section presents the empirical results of practicing spatial concentration using Location Quotient, spatial Gini index, spatial econometrics estimations. The sixth section brings some final comments.

2. SUSTAINABLE DEVELOPMENT IN POLAND AND EUROPE

Sustainable development has been defined in many ways but the most frequently quoted definition is from *Our Common Future*, also known as the *Brundtland Report*:[1] "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within two key concepts of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs." Sustainable development has been a fundamental objective of the European Union since 1997. Effective responses require international co-operation and solidarity. The strategy sets overall aims (general environmental) and concretes actions on seven key priority challenges until 2010.[2] The main framework, elaborated by the Polish Government is the "Sustainable Development Strategy for Poland up to 2025" (*Polska 2025*). It has not been institutionalized by law, but the *legal basis* is provided by the Constitution from 1997. Article 5 lays down that "The Republic of Poland provides for the protection of the environment, while pursuing the principle of sustainable development". However, many significant environmental improvements have been achieved however, Poland still has a high potential in this field, especially in the area of air quality.

[1] World Commission on Environment and Development, *Our common future,* Oxford Uni Press, 1987 p. 43.

[2] The site of: http://ec.europa.eu/environment/eussd/, the last entrance data: 23/05/2008, time 13:39.

3. ECONOMIC GROWTH & AIR INTEGRATION

In order to make improvements in the air quality, the amount of pollutants must be measured by selected indicators and quantitative methods of calculation. They provide benchmarks for policy performance, set a framework for reporting to a wider stakeholder community on the benefits (and costs) of policy, and permit targets for policy to be set.[3] Conducting comparative analysis, developing new methods of measurement is crucial for monitoring integration processes and harmonized methodology.

4. METHODOLOGY AND DATA

This part of research provides the spatial comparative analysis based on selected characteristics of the sample. In the second section there is verified EKC hypothesis for selected air pollution indicators. The estimation relates to specified EKC Spatial Autoregressive (SAR) and Spatial Error (SEM) models.[4]Combining the result from both parts of research there are drawn some conclusions. Recently, one of the measure of spatial concentration is the Location Quotient (LQ), also known as the Hoover-Balassa coefficient[5]:

$$LQ = \frac{Y_{ij} / Y_j}{Y_i / Y} \tag{1}$$

where:
Y_{ij} – the amount of the air pollutant j in the country i; Y_j – the whole amount of this air pollutant j in all Countries (32 EU countries); Y_i – total level of air emissions in the country i; Y – whole amount of air emissions in examined countries;

Spatial concentration of the air pollutant over Europe is also measured by the Gini index for spatial data (locational Gini), as follows:

[3]Hertin J., Berkhout F., Moll S., Schepelmann P., *Indicators for Monitoring Integration of Environment and Sustainable Development in Enterprise Policy*, UK 2001.

[4]In this publication two types of models were chosen in the way of selection. These models gave significant results of estimations. There are many other types of spatial models, see: Anselin L., (2001a), *Spatial Econometrics*, [w:] B. Baltagi (red.), *A Companion to Theoretical Econometrics*, Oxford: Basil Blackwell.

[5]Krugman P. (1991b), *Increasing Returns and Economic Geography*. *Journal of Political Economy* 99.3, s. 483–499.

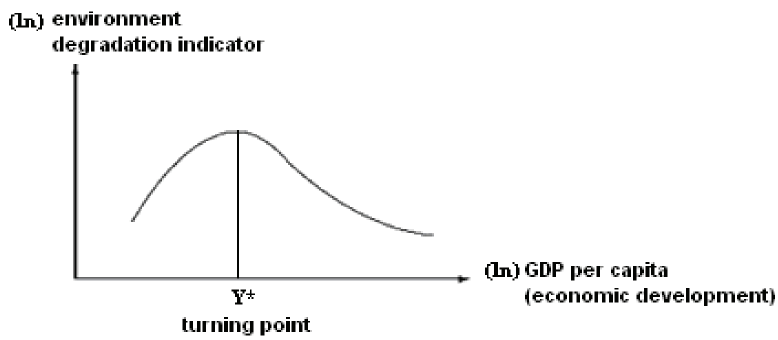
$$G = \frac{\Delta}{4\overline{LQ_i}} \tag{2}$$

where:

$$\Delta = \frac{1}{R(R-1)} \sum_{i=1}^{R} \sum_{m=1}^{R} \left| LQ_i - LQ_m \right| \tag{3}$$

where: LQ_i – Lorenz curve index (Location Quotient) in location i, $\overline{LQ_i}$ - mean, $\overline{LQ_i} = \sum_{i=1}^{R} \frac{LQ_i}{R}$, R – number of regions, i and m – two different regions;

Gini equals zero when an air pollutant is allocated across space in exactly the same way as total air pollutions. Index equals 0.5 when an air emission is concentrated in a single location. LQ displays in which region the concentration of concrete substance is the highest. Whereas, EKC is a hypothesized relationship between various indicators of environmental degradation and income per capita (graph 1).



Turing point Y*: $\exp\left(\frac{-\beta_1}{2\beta_2}\right)$, where β_1 & β_2 – estimated coefficients, ln – indicates natural logarithms.

Graph 1. Environmental Kuznets Curve

Source: own work.

The EKC hypothesis assumes that in the early stages of economic growth degradation and pollution increases. Beyond some level of income per capita the trend reverses. This implies that the environmental impact indicator is an inverted U-shaped function of income per capita. The KC is named for Kuznets (1955) who hypothesized that income inequality first rises and then falls as economic development proceeds. The EKC concept emerged in the early 1990s with Grossman and Krueger's (1991) path-breaking study of the potential impacts of NAFTA and the concept's popularization through the 1992 World Bank Development Report (IBRD, 1992). If the EKC hypothesis were true, then rather than being a threat to the environment economic growth would be the means to eventual environmental improvement. If there were no change in the structure or technology of the economy, pure growth in the scale of the economy would result in growth in pollution and other environmental impacts[6].

EKC transformed into econometrics equation is as follows (4). Typically, the logarithm of the indicator is modeled as a quadratic function of the logarithm of income. The use of logarithms is theoretically preferable because as income goes to infinity, the estimation in levels predicts that pollution goes to minus infinity, whereas when the logarithm of pollution goes to minus infinity, pollution approaches zero (Cole, 1997). This is an important theoretical point as emissions and GDP cannot be negative.

$$\ln(E/L)_{it} = \beta_0 + \beta_1 \ln(GDP/L)_{it} + \beta_2 (\ln(GDP/L))_{it}^{\ 2} + \sum_{j=1}^{k} \beta_j X_{ijt} + \varepsilon,^{7} \quad (4)$$

where:
$\ln(E/L)_{it}$ – air emissions per capita in country i, in time t, $\ln(GDP/L_{it})$ – nominal GDP per capita in PPS in region i, time t, X_{ijt} – additional variables, *ln* – indicates natural logarithms;

Significant developments, fall into a new wave in the investigation of environment-development relations using decomposition analysis and efficient frontier methods (cubic and spatial). In this paper, the results shows that spatial dependence between countries exists, and it is truly important aspect of modeling. Location and distance are important forces of spatial spillovers of air pollutions and GDP. Empirical studies of EKC have been already using the SAR or SEM models (Kakamu 2006, Kakamu, Polasek&Wago 2007).

1. SAR model:

$$\ln(E/L)_{it} = \rho \mathbf{W} \ln(E/L)_{it} + \beta_0 + \beta_1 \ln(GDP/L)_{it} + \\ + \beta_2 (\ln(GDP/L))_{it}^{\ 2} + \varepsilon_{it} \quad (5)$$

[6]Stern D., *The Rise and Fall of the Environmental Kuznets Curve*, World Development Vol. 32, No. 8, p. 1419–1439, 2004, p. 1420–1422.

[7] To prove the EKC for concrete indicator, the β_1,β_2 coefficients must be statistically significant and negative, Common M., Stagl S., *Ecological Economics. An Introduction*, Cambridge University Press, UK, 2005, For some pollutants there where constructed the spatial EKC with tripled GDP indicator.

where: $\varepsilon : \mathrm{N}(0,\sigma^2\mathbf{I})$

2.SEM model[8]:

$$\ln(E/L)_{it} = \beta_0 + \beta_1 \ln(GDP/L)_{it} + \beta_2 (\ln(GDP/L))_{it}{}^2 + \lambda \mathbf{W}\varepsilon_{it} + \xi_{it} \tag{6}$$

where: $\xi : \mathrm{N}(0,\sigma^2\mathbf{I})$.

In this paper, these methods of spatial econometrics were used to estimate and verify EKC in EU for five air pollutants, as a total national emissions in thousands of tons per capita, in country *i* of: SO_2 – sulfur dioxide, *NO* – nitro oxides, *CO* – carbon dioxides, CO_2 – carbon monoxide, *GHG*– green house gases; There was constructed the spatial weights matrix **W** – rook contiguity.[9]The estimation method – ML; The cross-section analysis includes 32 European Regions over the 1990 – 2006. Meanwhile, the sample covers only those countries that have data available from national European datasets (Eurostat and OECD databank).

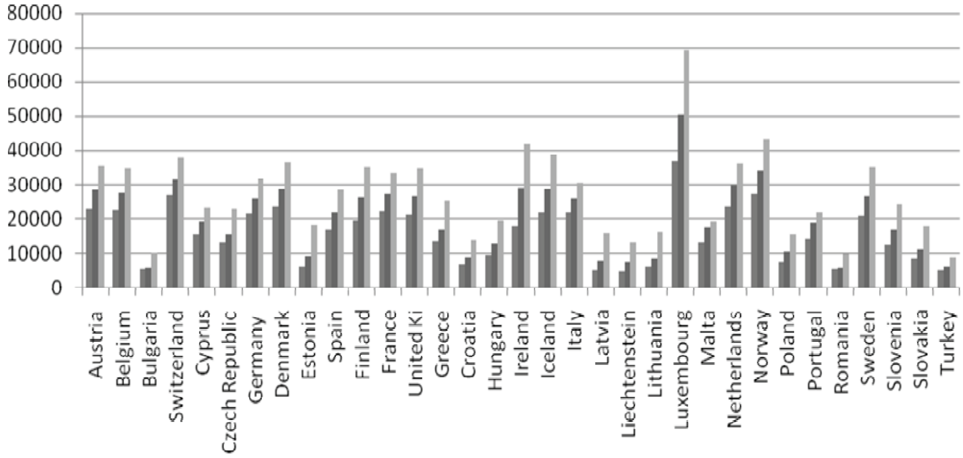
5. EMPIRICAL RESULTS & INTERPRETATION

Gross Domestic Product (GDP) per capita is widely assumed to be an indicator of a country's level of development. There are some disproportions in GDP across Europe from 1990 to 2006 (graph 2).

Luxemburg and Liechtenstein have the highest level of GDP per capita. It implicates that these countries might be the most economically developed. On the other hand, Bulgaria and Romania have the lowest level of GDP. Poland is rather in the end of ranking (Nominal GDP/capita): in 1990 it peaks 6115, in 1995 it accounts 7600, in 2000 it is 10772 and in year 2006 = 15444. After a slowdown of the economic growth, Poland's economy has shown symptoms of a revival since the second half of 2002. In 2006, was observed a progressive increase of the growth rate. In the first quarter, as compared to the previous year, GDP increased by 2.3%, in the second quarter by 3.9%, in the third by 4.0% and in the fourth quarter, the growth reached 4.7%. As a result, in 2006 the growth of the GDP amounted to 3.8% (comparing to 1.0% in 2000 and to 1.4% in 2002).

[8]The original spatial models are presented in: Anselin L., *Spatial Econometrics: Methods and Models*, Kluwer Academic, 1988 Dordrecht. these models where modified to theme requirements.

[9] The order of contiguity is 4- the choice of weight matrix was only the author's proposition.



Note: *be* Belgium, *bg* Bulgaria, *cz* Czech Republic, *dk* Denmark, *de* Germany, *ee* Estonia, *ie* Ireland, *gr* Greece, *es* Spain, *fr* France, *it* Italy, *cy* Cyprus, *lv* Latvia, *lt* Lithuania, *le* Luxembourg, *hu* Hungary, *mt* Malta, *nl* Netherlands, *at* Austria, *pl* Poland, *pt* Portugal, *ro* Romania, *si* Slovenia, *sk* Slovakia, *fi* Finland, *se* Sweden, *uk* United Kingdom, *hr* Croatia, *tr* Turkey, *li* Liechtenstein, *no* Norway, *ch* Switzerland.

Graph 2. Nominal GDP per capita in EU, in PPS, 1995, 2000, 2006 [10]

Source: own studies, EUROSTAT; OECD national accounts; national statistics; Consensus Economics.

The driving forces behind air pollution are directly associated with human activity. Energy consumption, industrial activities, transport demand and agriculture husbandry are the specific forces most directly linked to air emissions. The development of these driving forces determines the potential scale of air pollutions[11]. However, it will also vary depending on technical and social changes developed in response to air quality and emission abatement legislation[12]. Most Countries have made a good progress in reduction of SO_2. Only in Greece, Lithuania, Romania and Switzerland there have been observed an increase of the pollutant[13]. Poland has achieved decrease of 19% in 2006 due to 2000. Despite the efforts, Polands' atmospheric emissions of SO_2 and particulates remain very high compared with European Countries. To display the regional differences (spatial concentration) in time there are presented LQ and Gini values of SO_2 in years: 1990, 1995, 2000, 2006 (table 1).

[10]European Community, *Measuring progress towards a more sustainable Europe*, Monitoring report of the EU sustainable development strategy, Luxemburg, 2007.

[11] The quantity of air pollution comparing between European Countries one may see on EUROSTAT website.

[12] EEA Report No 2/2007, *Air pollution in Europe 1990–2004*, Copenhagen, 2007.

[13] http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode= ten00067 &plugin=1, last entering: 30.05.2009.

Table 1. Location Quotients of spatial concentration, SO2, 1990, 1995, 2000, 2006

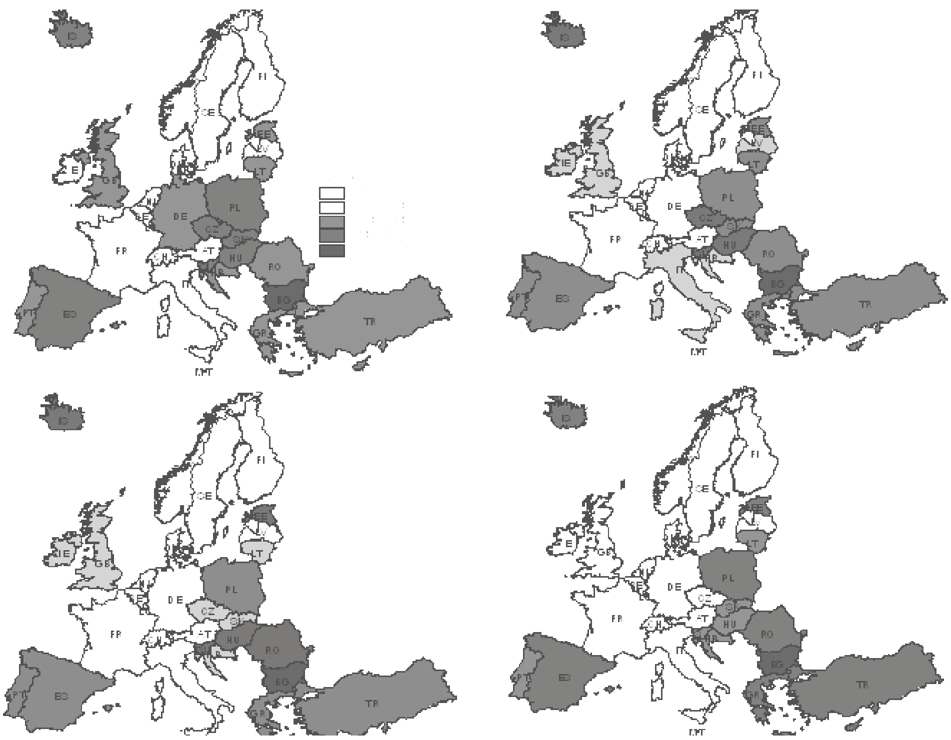
Country	LQ 1990	Country	LQ 1995	Country	LQ 2000	Country	LQ 2006
li	0.26	*li*	0.10	*li*	0.09	*lu*	0.09
ch	0.43	*ch*	0.16	*lu*	0.14	*li*	0.11
nl	0.49	*nl*	0.18	*nl*	0.16	*at*	0.14
at	0.50	*at*	0.18	*ch*	0.16	*lv*	0.15
no	0.57	*no*	0.21	*at*	0.18	*dk*	0.16
lu	0.62	*lu*	0.27	*dk*	0.20	*nl*	0.19
se	0.81	*se*	0.29	*no*	0.23	*ch*	0.21
fr	1.27	*fi*	0.41	*de*	0.29	*no*	0.25
be	1.35	*de*	0.48	*se*	0.31	*se*	0.31
dk	1.39	*fr*	0.53	*lv*	0.43	*de*	0.32
ie	1.78	*be*	0.53	*fi*	0.48	*fi*	0.44
it	1.87	*dk*	0.54	*fr*	0.50	*fr*	0.50
fi	1.98	*it*	0.75	*be*	0.54	*it*	0.50
lv	2.02	*ie*	0.82	*it*	0.63	*ie*	0.57
de	2.35	*uk*	1.00	*cz*	0.83	*be*	0.62
tr	2.39	*hr*	1.04	*uk*	0.83	*uk*	0.63
it	2.42	*lv*	1.14	*ie*	0.91	*cz*	0.80
gr	2.50	*lt*	1.29	*lt*	1.01	*hu*	0.89
uk	2.58	*tr*	1.37	*hr*	1.18	*sk*	1.01
hr	2.84	*sk*	1.41	*sk*	1.20	*lt*	1.08
pt	2.87	*pt*	1.43	*pt*	1.70	*si*	1.11
ro	2.87	*ro*	1.46	*gr*	1.75	*hr*	1.12
cy	3.33	*gr*	1.47	*es*	1.76	*pt*	1.53
ee	3.54	*pl*	1.63	*pl*	1.77	*pl*	1.78
pl	3.78	*ee*	1.70	*tr*	2.18	*es*	1.83
sk	3.85	*es*	1.72	*si*	2.39	*ee*	2.01
is	3.90	*cy*	1.88	*ee*	2.39	*gr*	2.28
es	4.05	*si*	2.03	*ro*	2.39	*cy*	2.34
cz	5.21	*cz*	2.16	*cy*	2.83	*tr*	2.36
hu	5.51	*is*	2.23	*hu*	2.86	*mt*	2.56
si	5.68	*hu*	2.68	*is*	2.89	*ro*	2.60
mt	7.93	*mt*	3.61	*mt*	4.45	*is*	3.01
bg	9.20	*bg*	5.02	*bg*	6.45	*bg*	7.25
Mean of LQ	2.79	***Mean of LQ***	1.26	***Mean of LQ***	1.40	***Mean of LQ***	1.23
GINI	**0.18**	***GINI***	**0.20**	***GINI***	**0.24**	***GINI***	**0.24**

Source: own studies based on EUROSTAT [14].

LQ calculations introduce changes in concentration of SO_2 among EU in each year. It is pointed that Bulgaria cumulates the largest quantities of this air pollutant. The Liechtenstein has become the country where the concentration of

[14]The table has been inserted here as an example of the LQ calculations. For other air pollutants tables would not be placed as it would take a lot of space. To gain the tables please contact the author: Antczak (family name: Wiszniewska) Elzbieta: wiszniewska@uni.lodz.pl.

SO_2 is the lowest, Poland has improved air quality. Furthermore. Gini index values from 0.18 in 1990 through 0.20 in 1995, 0.24 in 2000 to 0.24 in 2006. It indicates that the average quantity and the level of concentration of SO_2 emissions is stable in time over Europe. On the other hand, it means that there are Countries where SO_2 emission is more aggregated than in others (graph 4: quite large level of concentration). It shows which Country has a significant impact on total emission of SO_2 in Europe (dark color).



Graph 4. Location Quotient of SO_2 in each country in 1990, 1995, 2000, 2006[15]

Source: own studie,. based on table 1.

In 1990 the spatial variability of SO_2 emission is also not strong (Gini = 0.18), with LQs ranking from 0.26 to 9.2 (table 1, graph 4). Maximum value of 9.2 (Bulgaria) means that the share of sulfur dioxide is 820 percent greater in this area than in EU as a whole (mean of LQ = 2.79). The value of LQs: in Malta

[15] It is an example of the graph – to gain the rest of graphs concerning NO, CO, CO_2 and GHG indicators please contact: wiszniewska@uni.lodz.pl. (Wiszniewska-Antczak Elżbieta).

(7.93), Slovenia (5.68), Hungary (5.51) means that the share of SO_2 in these locations adequately: 693%, 468% and 451% is higher than on the average in EU. Minimum value of 0.26 (Liechtenstein) means that the share of sulfur dioxide emission is 74 percent lower in this area than in Europe. The value of LQs: in Switzerland (0.43), Netherlands (0.49), Austria (0.5) implies that the share of SO_2 in these areas is accordingly: 57%, 51% and 50% lower than on the average in EU. The level of LQ in Poland achieved 3.78 – it is 278 percent greater than in EU overall. In 2006 the situation is nearly the same as in previous periods, with LQs ranking from 0.09 to 7.25 (graph 4). Maximum value of 7.25 (Bulgaria) means that the share of sulfur dioxide emission is 625 percent greater in this area than in EU as a whole (the mean value of LQ, LQ = 1.23). The values of LQs: in Iceland (3.01), Romania (2.6), Malta (2.56) mean that the share of SO_2 in these locations adequately: 201%, 160%, 156% higher than on the average in EU. The minimum value of 0.09 (Luxemburg) means that the share of sulfur dioxide emission is 91 percent lower in this area than in EU as a whole. The level of LQ in Poland achieved 1.78 – it is 78 percent greater than in EU overall (it has increased). The LQs values of concentration are higher in these years.

In Europe. *nitrogen oxides (NO_x)* pollute air as a result of road traffic and energy production. Higher levels of NO generally occur in areas with heavy traffic congestion. Apart from giving rise to acid rain and other air pollutants, current levels of NO affect our health. Most of countries have made good progress in reduction of NO since 1990. However, there are some, where the level of emission increased (Bulgaria, Austria, Spain, Portugal, Turkey). In Poland there was also increase from 1995, which achieved 6% in 2006 in comparison to 2000. Anthropogenic NO_x emissions originate in Poland mostly from energy combustion in stationary and mobile sources, Emissions from industrial processes have also major importance. LQ calculations display changes in concentration of NO among EU in each years. It is pointed that Iceland concentrates the largest quantities of this air pollutant in all years (LQ = 2.66). In 1990 Luxemburg, Estonia, Romania, Bulgaria have become countries where the concentration of NO is the lowest (LQ from 0.26 – 0.67). In 2006 Luxemburg, Liechtenstein, Germany and Netherlands have the lowest level of NO concentration. Poland has worsen air quality in this area. The level of LQ in Poland in 1990 achieved 0.90, 1995 – it is 0.89, 2000 – 0.85 and in 2006 it has achieved the level of 0.98 and is still increasing. Furthermore, the value of Gini index indicates that the concentration of NO has risen from 0.088 in 1990 through 0.085 in 1995 and 0.082 in 2000 to 0.099 in 2006. It determines that the average quantity and concentration of NO emissions have increased in time. On the other hand, it means that there are countries where emission of NO is more aggregated than in other Regions.

Carbon monoxide (CO) is a component of motor vehicle exhaust, which contributes about 56% of all CO emissions nationwide. Other non-road engines and vehicles (such as construction equipment and boats) contribute about 22% of CO production. Most of countries have reduced emissions of CO since 1990. There are Countries, where the level of CO emission increased (Bulgaria, Latvia, Malta, Romania, Slovenia). In Poland there was decrease which achieved 19% in 2006 in comparison to 2000, LQ calculations display changes in concentration of CO among EU in years 1990, 1995, 2000 and 2006. Latvia concentrates the largest quantities of this air pollutant (Turkey in 1990). In 1990 Romania, Slovenia, Czech Republic and Netherlands become Countries where the concentration of CO was the lowest (LQ 0.28 – 0.42). In 2006 Ireland, Netherlands, UK, Czech Republic and Luxemburg had the lowest level of CO concentration. Poland also has already improved the air quality in this area. Gini index indicates that the concentration of this pollutant has risen from 0.099 in 1990 through 0.096 in 1995, 0.11 in 2000 to 0.12 in 2006. However, it is seen that the concentration of CO in 1990 – 2006 is slowly increasing. It means that the responsibility for CO air degradation bear less countries.

The quantity of carbon dioxides emissions *per capita* show significant differences across the EU Member States. There is a dissimilarity of a factor between Coutreis with lowest emissions *per capita* in 2006 (Latvia, Lithuania, Romania and Turkey) and those with highest *per capita* emissions (Luxembourg and Estonia). The CO_2 emissions declined by 11.7% (1.4 tons *per capita*). The main decrease occurred particularly in 1995. Between 2000 and 2006 the level of CO_2 showed no change within the EU.[16] Conversely, in most of countries there was rise of CO_2 emission since 1990 to 2006 (Austria, Cyprus, Denmark, Spain, Finland, Greece, Croatia, Ireland, Iceland, Italy, Malta, Norway. Portugal, Slovenia, Turkey). In Poland there was not an increase in 2006 due to 1990, rather decrease, but insignificant. However, there was fall in 2006 to year 2000 which only achieved about 0.8%. Poland is the world's eighth largest producer of coal and emissions which are predominantly from coal burning: 71% in 2006. LQ calculations display changes in concentration of CO_2 among EU in years 1990, 1995, 2000 and 2006. In 1990 Luxemburg, Liechtenstein and Estonia concentrated large quantities of this air pollutant (LQ ranges from 1.11 – 1.18). In 1990, Iceland and Ireland have become Countries where the concentration was the lowest. In 2006 the highest level of CO_2 achieved Luxemburg. Liechtenstein. Germany (LQ: 1.06 – 1.10). One reason for the high *per capita* emissions could be 'fuel tourism' (fuel bought in Luxembourg by people living in border regions of other countries and truck drivers, because of lower fuel taxes), which the

[16] EEA Report, *Greenhouse gas emission trends and projections in Europe 2007. Tracking progress towards Kyoto targets*, No 5/2007 p 19.

country estimates to be responsible for about 40% of its total CO_2. The lowest level of CO_2 has been noticed in Latvia, Lithuania, Ireland, Romania, Iceland (LQ: 0.75 – 0.85). Poland has improved air quality in this issue. The value of Gini index indicates that the concentration of this pollutant has dropped from 0.023 in 1990 through 0.023 in 2000 to 0.02 in 2006. It determines that the average quantity and concentration of CO_2 emissions decreased in time. On the other hand, it means that concentration of CO_2 emissions is not aggregated in one country.

Greenhouse gases (GHG) are essential to maintaining the current temperature of the Earth. In order, Earth's most abundant greenhouse gases are: water vapor, carbon dioxide, methane, nitrous oxide, ozone, CFCs. Fears are that if people keep producing such gases at increasing rates, the results will be negative in nature. These changes to the environment will most likely cause negative effects on society. such as lower health and decreasing economic development.[17] Poland's GHG emissions level was 24% lower in 2006 due to 2000. Main factors for decreasing emissions with regard to base year (1990) was the decline of energy inefficient heavy industry and the overall restructuring of the economy in the late 1980s and early 1990s. The notable exception was transport (especially road transport) where emissions increased. Between 2000 and 2006 (about 26%), process related emissions from metal and energy production.[18]There are Countries, where the level of GHG emission increased (Cyprus, Spain, Luxemburg, Malta, Portugal, Turkey). The spatial distribution of GHG in years 1990 – 2006 show that the GHG concentration in Europe is still not stable. In 1990 Ireland and Iceland were Countries where the concentration of GHG was the largest (LQ ranges from 1.72 – 1.97). In this year Luxemburg has become the Country where the concentration was the lowest. In 2006 the highest level of GHG emission achieved Lithuania, Ireland, Romania, Latvia and Iceland (LQ: 1.64 – 2.19). The lowest level of GHG has been noticed in Liechtenstein and Luxemburg (LQ: 0.53 – 0.68). Gini index indicates that the concentration of GHG changed over the years 1990 – 2006. The concentration of this pollutant has not displayed any clearly noticed tendency. In 1990 Spatial Gini approximated 0.08, in 1995 = 0.083, in 2000 = 0.09 and in 2006 it has dropped to 0.08. However, it might stand that the level of GHG emission is not easily predictable.

It is well known that regional data cannot be regarded as independently generated because of the presence of spatial similarities among neighboring regions (Anselin, Bera, 1998). None growth of the country. neither economic nor envi-

[17] Hopwood N., Cohen J., *Green gases and society*, Department of Geological Sciences, University of Michigan, US, 1998.

[18] EEA Report, *Greenhouse gas emission trends and projections in Europe 2007. Tracking progress towards Kyoto targets,* No 5/2007 – Country profile.

ronmental (sustainable) can exists without any impact of regions situated closely. The second part of empirical research evidences about significance of spatial effects in regional development and also human activities on air quality.

In tables 2,3 & 4 there are results of estimation of spatial EKC models among EU over 1990 – 2006. The hypothesis assumes that economic growth influences the environmental quality (including spatial dependence as a meaningful aspect in regional analysis). The results are drown from estimation of different types of EKC – there are traditional spatial EKC with lagged dependent variable, "pure spatial EKC" – without any additional variables, inverted spatial EKC – it means exactly U shape, other spatial models (with tripled GDP variable) and non - spatial EKC. Table 2 presents the results of EKC estimations in spatial aspects over 1990 – 1995 for each pollutant.

Table 2. Spatial EKC models – results of estimation, European Countries, 1995

Model	**1**		**2**	**3**		**4**		**5**
Variable	**$\ln(SO_2/L_i)$**		**$\ln(NO/L_i)$**	**$\ln(CO/L_i)$**		**$\ln(CO_2/L_i)$**		**$\ln(GHG/L)$**
$\ln(GDP_i)$	39.2 ***	16.1***	X	-9.64***	-11.2***	181***	181.3**	0.0007***
$(\ln(GDP_i))^2$	**-2.1*****	**-0.85*****	X	0.52***	0.62***	**-19.3*****	**-19.3****	X
Constant	**-190.9 *****	**-84.3*****	X	35.4***	44.6***	**-567*****	**-572****	-0.005**
W_dependence Variable	0.23 ***	0.29***	X	0.05***	X	X	X	0.27**
Lambda (λ)	X	X	X	X	0.95***	-0.68***	X	X
Lag (5 years) dependent variable	X	0.88***	X	X	0.35***	0.38***	0.32***	X
$(\ln(GDP_i))^3$	X	X	X	X	X	0.69***	0.68**	X
Breusch-Pagan	4.62	1.56	X	1.56	1.28	2.41	5.3	1.45
Likelihood Ratio Test	4.4***	3.3***	X	3.72 ***	5.26***	1.96 **	X	1.6**
R^2	0.31	0.78	X	0.31	0.44	0.49	0.47	0.23
Moran's I	0.31	0.13	X	0.07	0.16	-0.06	X	0.12
Turning point (PPS/capita)	**11309**	**12973**	X	10607	8369	1)12185 2) 19573	1) 11409 2) 18770	X

Note: *** the estimate is statistically significant at the 5 percent level; Number of observations: 32;

Source: own calculations in GeoDa and STIS [19].

Concerning the results of estimation in table 2 it is clear that in years 1990 - 1995 "the pure spatial EKC" and traditional spatial EKC with lagged dependent variable hypothesis were proved regarding to SO_2. It means that: β_1 & β_2 coefficients are negative and statistically significant; the environmental impact indicator is an inverted U-shaped function of income per capita; location and distance are important forces of spatial spillovers of air pollutions and GDP; the coeffi-

[19] More about Moran statistic in publication: Anselin L., *Spatial Econometrics: Methods and Models*, Kluwer Academic, 1988 Dordrecht.

cients on the spatial lag is highly significant, lagged dependent variable (SO_2 lagged 5 years) is positive and highly significant.

In *SO_2 EKC SAR* model the spatial lag term of SO_2 reflects the spatial dependence inherent in the sample data. measuring the average influence on observations by their neighboring observations. It has "a positive effect" – it reflects in this case that one Country conduces to higher level of SO_2 emission to its Neighbors. The significant lagged variable (from 1990) also evidences about the negative influence of pollutants from previous 5 years. SO_2 – "pure EKC" - 11309 PPS/capita (Hungary/Slovenia) and 12973PPS/capita (Slovenia/Czech Republic) - spatial EKC with lagged dependent variable means that from these levels of GDP per capita the air degradation by SO_2 decreases. The turning point, considering the influence of lagged dependent variable, is higher (12973$/capita) in lagged EKC than in ordinary spatial EKC. It might mean that the Country needs greater level of development to reduce the SO_2 emission. As it seen the impact of pollutant from previous term is significant (the turning point is rising its value). The Countries having been in turning point were in 1995 at a such level of development that did not damage air by SO_2. Poland in 1990 - 1995 did not gain the turning point. The positive Moran' I value means that the spatial dependence exists and caused gathering Countries with similar level of pollution.

CO – the hypothesis of "exactly U shape spatial EKC" and spatial EKC with lagged dependent variable mean that from turning points (levels of GDP per capita) the economic development provides to increase of CO. The levels of GDP per capita in EKC without CO from 1990 achieves 10607 PPS/capita (Hungary/Slovenia) and in case of EKC with lagged CO from 1990 gains 8369 PPS/capita (Poland/Slovakia). It indicates that these countries development cause the rise of CO from these levels of GDPs. Moreover, the quantity of CO pollutions from previous years evidences that the Country started to damage air from lower level of development (the GDP/capita is lower than in EKC without lagged CO). The positive Moran's I value in CO case is parallel to interpretation of Moran's statistics value in model with SO_2 dependent variable. CO_2 – in this case the hypothesis of spatial cubic EKC was proved. It means that there were two turnings points. The first 12185PPS/capita indicates that from this peak the development of the Country did not negatively affected air (Slovenia). On the other hand, there was the second peak 19573 PPS/capita from which the Country's development (Finland) started to pollute air with CO_2 again. In this EKC case the influence of lagged CO_2 (from 1990) is highly significant. The negative Morans' values are also statistically significant and this evidence that there is no tendency in clustering among Countries, Poland, in 1990 – 1995 did not gain even the first turning point, it meant that the development of Polish economy was degrading European air. In Poland, where power generation was based largely on the burning of coal, the atmosphere became heavily polluted. Closing the existing technical gaps between harvesting, processing and consuming natural resources, leading to waste, high costs and low quality of production can lead to economic benefits.

In table 3 there are the results of EKC estimations from years 1995–2000. It is presented that the spatial EKC hypothesis is proved in cases of three indicators.

Table 3. Spatial EKC models results of estimation, European Countries, 2000

Model	**1**	**2**	**3**	**4**	**5**
Variable	**ln(SO_2/L_i)**	**ln(NO/L_i)**	**ln(CO/L_i)**	**ln(CO_2/L_i)**	**ln(GHG/L)**
ln(GDP_i)	23.9***	0.65***	5.11***	2.5***	0.38***
(ln(GDP_i))^2	**-1.24*** **	**-0.023*** **	**-0.27*** **	**-0.12** **	X
Constant	**-124.7 *** **	**-5.26*** **	**-26.5*** **	**-13.3*** **	-10.5***
W_dependence Variable	X	X	X	X	0.07***
Lambda (λ)	**0.96*** **	**0.87*** **	**0.64*** **	X	X
Lag (5 years) dependent variable	X	0.69***	0.8***	0.86***	X
(ln(GDP_i))^3	X	X	X	X	X
Breusch-Pagan	4.62	0.7	0.11	1.3	0.005
Likelihood Ratio Test	6.02***	3.03***	2.55***	X	2.65**
R^2	0.55	0.88	0.77	0.94	0.30
Moran's I	0.24	0.12	0.16	X	0.05
Turning point (PPS/capita)	**15323**	**13702**	**12874**	**33412**	X

Note: *** the estimate is statistically significant at the 5 percent level; Number of observations: 32.

Source: own calculations in GeoDa and STIS.

Concerning the results of estimation (table 3) it is clear that in years 1995 - 2000 the estimation of "pure EKC model" confirms the hypothesis in SO_2 case. "Traditional spatial EKC with lagged dependent variable" hypothesis are proved regarding to NO and CO. Spatial EKC concerning CO_2 and GHG indicators does not exists. In GHG spatial model evidences the tendency that the increase of GDP per capita causes the increase of the GHG level. Due to SO_2, NO, CO the proved spatial EKC hypothesis it means that: β_1 & β_2 coefficients are negative and statistically significant; the environmental impact indicator is an inverted U-shaped function of income per capita; location and distance are important forces of spatial spillovers of air pollutions and GDP; the coefficients on the spatial lag is highly significant; lagged dependent variables (lagged 5 years) are positive and highly significant;

The effect of spatial EKC has occurred in 2000 regarding to NO variable. In SO_2 EKC SEM model the turning point it is at the level of 15323PPS/capita (Hungary/Czech Republic). From this level of GDP air degradation by SO_2 decreases. Poland in 1995 - 2000 did not gain the turning point. The positive Moran' I value means that the spatial dependence exists and caused gathering Countries with similar level of pollution. Due to NO – SEM model with the lagged dependent variable (NO from 1995) indicates the turning point at 13702PPS/capita (Hungary). It is also seen that the influence of lagged dependent variable is significant. Poland in 1995 - 2000 did not gain the turning point. The interpretation of positive Moran's I value in NO case (1995 – 2000) is parallel to Moran's statistics value in model with SO_2 dependent variable. CO – SEM model indicates the turning point at 12874PPS/capita (Hungary). It is also seen that Poland in 1995 - 2000 did not gain the turning point. The interpretation of positive Moran's I value in CO case (1995 – 2000) is parallel to Moran's statistics value in model with SO_2 and NO dependent variable.

In table 4 there are the results of spatial EKC estimations over the 2000 – 2006. It is seen that spatial EKC hypothesis is proved due to NO indicator.

Table 4. Spatial EKC models – results of estimation, European Countries, 2000–2006

Model	**1**	**2**		**3**	**4**		**5**
Variable	**ln(SO_2/L_i)**	***ln*(NO/L_i)**		**ln(CO/L_i)**	**ln(CO_2/L_i)**		**ln(GHG/L)**
ln(GDP_i)	X	33.3***	30.1***	X	-0.05***	2.43***	X
(ln(GDP_i))^2	X	**-1.67***	**-1.54***	X	0.002***	**-0.25***	X
Constant	X	**-176.4***	**-147.1***	X	0.23***	**-7.99***	X
W_dependence Variable	X	X	X	X	-0.23***	X	X
Lambda (λ)	X	0.7***	0.66***	X	X	X	X
Lag (5 years) dependent variable	X	X	0.97***	X	1.04***	X	X
(ln(GDP_i))^3	X	X	X	X	X	**0.008***	X
Breusch-Pagan	X	1.36	2.5	X	1.25	1.6	X
Likelihood Ratio Test	X	3.99***	1.97**	X	13.3***	X	X
R^2	X	0.47	0.62	X	0.97	0.68	X
Moran's I	X	0.22	0.1	X	0.1	X	X
Turning point (Euro/capita)	X	**17549**	**21377**	X	26834	X	X

Note: *** the estimate is statistically significant at the 5 percent level; Number of observations: 32;

Source: own calculations in GeoDa and STIS.

In NO EKC Spatial Error models there is the significant lagged variable (from 2000) and it evidences about the negative influence of pollutant from previous years. NO – "pure EKC" with turning point at 17549 PPS/capita (Poland/Slovakia) and spatial EKC with lagged dependent variable at 21377 PPS/capita (Hungary/Portugal/Czech Republic) - mean that from these levels of GDP the air degradation by NO decreases. The turning point, considering the influence of lagged dependent variable is higher (21377$/capita) in lagged EKC than in ordinary spatial EKC. It might mean that the Country needs greater level of development to reduce the NO emission. As it seen the impact of pollutant from previous term is significant (the turning point is rising). Poland in 2000 - 2006 did not gain the turning point (15444PPS/capita). The positive Moran' I value (table 4) means that the spatial dependence exists and caused gathering Countries with similar level of pollution. The significant spatial NO dependence among Countries confirms fact that NO can be transported across long distances. The hypothesis of spatial EKC in NO case occurs not before 2000. It could be relative to more and more intensified usage of cars as the possibility for humans to move flexibly from place to place. Transport cross-boundary areas sensitive to pollution from neighboring countries, which also damage those countries' natural environment.[20]

Poland till 2006 is still before the turning points in relation to EU. However, the Country is close to this peak. Poland is just at the beginning of improving its economy. In general, the result of analysis displays that the EU has made significant progress in combating air pollution. On the other hand, there are substantial differences between countries and regions not only when it comes to the causes of air pollution but also in terms resources to address the challenges. National capacity tackle air pollution as the one of the most extreme importance among sustainable development goals. From the analysis it is also seen that the value of Moran's I statistics is decreasing what indicates that the spatial dependence is weaker. At the same time, the influences of spatial degrading air by pollutants is lower.

6. CONCLUSIONS

The results of research present that the EU Countries tend to sustain their developments in the range of air protection. The emissions, in the most of cases are being reduced. Moreover. the economic development (GDP) in years 1990–2006 in case of SO_2 and NO has not caused environmental degradation but even some improvements. On the other hand, there is also still warning signal about

[20] The Surface Transportation Policy Project , *Clearing the Air*, (2003-08-19). Retrieved on [[2007-04-26]].

increasing trends of some climate indicators (CO, CO_2, GHG). It should be emphasized that the spatial dependence among region exists. Some Countries are still the leaders of air emissions (especially in SO_2 and NO). With regard to this fact their paths of development (unsustainable) is hazardous to theirs or neighboring environment. The only way of pursuing a better quality of life for present, future generations and protecting environment is to sustain Countries' development. Poland has achieved considerable reductions in major air emissions over the past 10 years (improvements of monitoring network for air pollution, interregional cooperation and economy transformation). Many significant environmental progress has been achieved. However, Poland still has a high potential in this field.

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ZRÓWNOWAŻONY ROZWÓJ POLSKI I EUROPY – ANALIZA PRZESTRZENNO-CZASOWA I PRZESTRZENNE MODELE EKC

Celem niniejszej publikacji jest prezentacja poziomu realizacji zrównoważonego rozwoju, w zakresie degradacji powietrza w Polsce i innych Krajach Europy. W opracowaniu zastosowano mierniki koncentracji przestrzennej: indeks przestrzennej krzywej Lorenza (współczynnik lokalizacji), przestrzenny współczynnik Giniego oraz przestrzenne modele ekonometryczne oparte na hipotezie Środowiskowej Krzywej Kuznetsa (EKC). Dokonano weryfikacji hipotez EKC w odniesieniu do analizowanych krajów Europy dla wybranych wskaźników środowiskowych - degradacji powietrza na osobę: SO_2, CO_2, NO, CO i GHG. W tym celu wykorzystano przestrzenne modele błędu i opóźnienia przestrzennego. Analiza dotyczyła lat 1990 – 2006.

Słowa kluczowe: Zrównoważony rozwój, jakość powietrza, wskaźniki środowiskowe, wskaźnik przestrzennej koncentracji Giniego, współczynnik lokalizacji, przestrzenne modele ekonometryczne, przestrzenna Środowiskowa Krzywa Kuznetsa.