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Spatiotemporal analysis of sustainable development in Poland and in Other European Union Countries Economic Growth & Air Quality

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Abstract

The aim of this paper is to present levels of economic growth, environmental degradation and sustainable development in Poland and other EU countries, applying selected methods of spatial concentration and models of spatial econometrics. The analysis concerns mainly the air degradation as one of the most priority issue. Despite the noticeable improvement of air quality, Poland still has a high potential in this field. At EU and Member State levels, and within individual cities and regions, most policy-makers now appreciate the need to reconcile the triple objectives of wealth creation, social cohesion and environmental protection. Many even understand that win-win solutions are possible. However, it is crucial to measure the level of eco-growth due to implement these principles to local development strategies more efficiently. Moreover, the aspect of spatiality is one of the most important tool for environmental management as well as for the state's policy of regionalization. In case of realizing assumptions of this article there were used spatial concentration measurement, such as: spatial Lorenz curve, Locality Quotient, spatial Gini index and spatial econometrics models. The analysis is based on selected indicators of sustainable development. Data base includes time period from 1995 to 2006. Beyond spatiotemporal comparison analysis, this study proves the EKC (Environment Kuznets Curve) hypothesis in EU and Poland for some indicators of environment degradation. Practicing some econometrics methods: Spatial Lag Model and Spatial Error Model the EKC was examined for selected indicators (per capita: SO₂, CO₂, NO, CO). Is it true that economic growth brings improvement of environment air quality at different levels of development process ?

Key words: Sustainable Development, environment degradation, air quality, indicators of Sustainable development, spatial concentration, spatial Gini index, Locality Quotient, Lorenz Curve, spatial econometrics, Spatial Lag Model, Environmental Kuznets Curve, Spatial EKC;

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Introduction

Poland's accession to the European Union in May 2004 has been one of the most important events for Polish development (also in the matter of the sustainable growth). Moreover, Poland, as a Member of Community, is now more aware of its spatial, economic and ecological dependence than it used to be before.

Poland is a moderately developed country, but among the poorest countries within the enlarged European Union: with its gross domestic product per capita, in terms of purchasing power parity, about 50% of the EU-25 average, and at the same time with the lowest in the Community level of employment for working age people (53.7%) and the highest unemployment rate (13.8% - in 2006). Any activities, any actions in process of building up common welfare and sustain development are based on regional cooperation. Consequently, economic growth should not be a cause of soil, water or air degradations. Most dangerous are air pollutions which cause premature deaths by the millions, and severe health impacts such as aggravation of asthma and certain heart and lung diseases. They also damage the environment through acidification of natural soil and water ecosystems. Finally, contaminated air is the reason of land degradation, damage to agricultural crops and corrosion of materials and cultural heritage. In Poland, the massive industrialization – with regard to coal extraction, steel and iron, petrochemical plants or energy generation - came at the expense of the environment, leading to high rates of air, water and soil pollution. Therefore, the issue of air protection is one of the main priority of Poland and European countries' development strategies.

This paper provides a comparative analysis of economic growth, environmental degradation (emphasize the problem of air quality) and sustainable development in Poland and other EU countries. There were applied selected methods of spatial concentration and models of spatial econometrics. The research is concentrated on the problem of air degradation as one of the most priority issue. Therefore, one of the main objectives of this paper is measuring and presenting the relation between economical development and this environmental degradation across EU countries. Secondly, to show the spatial dependence among European countries. Finally, to prove the EKC hypothesis.

Despite a significant improvement of air quality, Poland still has a high potential in this field. At EU and Member State levels, and within individual cities and regions, most policy-makers now appreciate the need to reconcile the triple objectives of wealth creation, social cohesion and environmental protection. Many even understand that win-win solutions are possible. However, it is crucial to measure the level of eco-growth due to implement these principles to local development strategies more efficiently. The measurement of sustainable development is therefore of crucial importance. Methods of estimating progress towards sustainable growth are still being improved. Considering spatial aspect it is one of the most important issue for environmental management as well as for the state's policy of regionalization. Taking above assumption into account there were used spatial econometrics models and spatial concentration measurements, such as: spatial Lorenz curve, Locality Quotient, spatial Gini index. The analysis is based on selected indicators of sustainable development. Data base contains the period of time from 1995 to 2006. Beyond spatiotemporal comparison analysis, this study proves the EKC (Environment Kuznets Curve) hypothesis in EU and Poland for some indicators of environment degradation. Practicing some econometrics methods: Spatial Lag Model and Spatial Error Models the EKC was examined that for selected indicators (per capita: SO₂, CO₂, NO, CO). All in all it appears that economic growth brings improvement of environment air quality but at different levels of development process.

The paper is organized as follows. The second part presents main principles and specifications of sustainable development in Poland and in European Union as a whole. 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 Lorenz, Location Quotient, spatial Gini and draws from econometrics estimations, all concerns the field of economic development and air degradation in EU. The sixth section brings some final comments, suggestions for policies and further research.

Sustainable development in Poland and European Union

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*.² "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." The European Commission is firmly committed to sustainable development, honouring the obligations made at the 1992 Rio Earth Summit.³

Furthermore, sustainable development has been a fundamental objective of the European Union since 1997. It was enshrined as article 2 of the Treaty. It is supposed to underpin all EU policies and actions as an over-arching principle.⁴ Effective responses require international co-operation and solidarity. The strategy sets overall aims and concrete actions for seven key priority challenges, for the coming period until 2010. Many of them are predominantly environmental: climate change and clean energy, sustainable transport, sustainable consumption & production, conservation and management of natural resources, public health, social inclusion, demography and migration, global poverty and sustainable development challenges.⁵ Promoting coherence between all European Union policies and coherence between local, regional, national and global actions development is the main issue in order to enhance their contribution to sustainable and in cooperation among EU countries (also Poland).

The main framework, elaborated by the Polish Government is the "Sustainable Development Strategy for Poland up to 2025" (*Polska 2025*). It is a *multidimensional strategy* and the focal point for other plans, programs and strategies. The Strategy was adopted on the 26th of July 2000 by the Council of Ministers. 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". *Polska 2025* is an overarching strategy, that aims at creating the structural frame and direction of development for other national and regional strategies or plans such as: Second National Environmental Policy (from 2000), Strategy of Public Finances and the Economic Development in Poland 2000-2010, National Strategy of Regional Development 2000-2006, Concept of the Spatial Management of the Country, National Strategy of Employment Growth and Development of Human Resources, A National Strategy for the Conservation and Sustainable Use of Biological Diversity – Together with an Action Program (from 2003), National Strategy of Environment Protection 2007-2013, Polish Energy

² World Commission on Environment and Development (WCED), *Our common future*, Oxford University Press, 1987 p. 43.

³ European Community, *Measuring progress towards a more sustainable Europe*, Monitoring report of the EU sustainable development strategy, Luxembourg 2007.

⁴ Commission of the European Communities, *On the review of the Sustainable Development Strategy*, A platform for action, Brussels 2005.

⁵ The site of: <http://ec.europa.eu/environment/eussd/>, the last entrance data: 23/05/2008, time 13:39.

Policy up to the Year 2020, Polish Climate Policy up to the Year 2020 (from 2003, Strategy of Sustainable Development of Production and Consumption. All the strategies shall agree with *Polska 2025*. Therefore, sector policy plans are best understood as a detailed version and clarification of the aims, rules and measures set up in the strategy.⁶ Although many actions are taken to better integrate environmental and economic decisions. Also significant environmental improvements have been achieved Poland still has a high potential in this field, especially in the area of air quality.⁷ Rising industrial and energy production, the burning of fossil fuels and the dramatic rise in traffic on our roads all contribute to air pollution in our towns and cities which, in turn, can lead to serious health problems. For example, air pollution is increasingly being cited as the main cause of lung conditions such as asthma. Therefore, Poland has placed high priority on controlling air quality.

Economic growth & air degradation

On our planet, clean air is the most important natural resources on which all life depends. However, our atmosphere is also in the front line for receiving environmental pollution. The amounts and types of emissions change every year.⁸ These changes are caused by changes in the nations' economy, industrial activity, technology improvements, traffic, and by many other factors. Air pollution regulations and emission controls also have an effect. The issue of air quality is now a major concern for many European countries. It is also one of the areas in which the European Union has been most active. Since the early 1970s, the EU has been working to improve air quality by controlling emissions of harmful substances into the atmosphere, improving fuel quality, and by integrating environmental protection requirements into the transport and energy sectors: through EC legislation, through work at international level to reduce cross-border pollution, through co-operation with sectors responsible for air pollution, through national, regional authorities and through research. As the result of EU legislation, much progress has been made in tackling air pollutants such as sulfur dioxide, lead, nitrogen oxides, carbon monoxide and benzene. However, despite a reduction in some harmful emissions, air quality continues to cause problems.

The issue of air protection is also one of the main case in Polish national policies. Air pollution problems have been clearly identified. The relationship between this problems and economic activities has been analyzed, and priorities, goals and targets - some of them quantitative - have been defined at the highest government level and have received public support. Beyond these intentions, Poland has achieved considerable reductions in major air emissions notably from the power sector and industry. Political and economic transformation that has taken place since 1990, caused the national emissions to drop much below Poland's target under the Kyoto Protocol. Over the years 1988–2004, emissions decreased by as much as 32% below the base year. This reduction has been achieved by implementing a package of policies and measures primarily leading to the improvement of energy efficiency and

⁶R. Zieschank, Poland Case Study, Analysis of National Strategies for Sustainable Development, Berlin 2004, p. 4 - 8.

⁷Poland was the 102nd country in OECD ranking of Environmental Sustainable Index Report (2005) on 146 members, Yale Center for Environmental Law & Policy, *2005 Environmental Sustainable Index Report*, Yale 2005, p. 5.

⁸Major primary pollutants produced by human activity include: sulfur oxides especially sulfur dioxide are emitted from burning of coal and oil. Nitrogen oxides especially nitrogen dioxide are emitted from high temperature combustion. Can be seen as the brown haze dome above or plume downwind of cities. Carbon monoxide is colourless, odourless, non-irritating but very poisonous gas. It is a product by incomplete combustion of fuel such as natural gas, coal or wood. Vehicular exhaust is a major source of carbon monoxide. Carbon dioxide, a greenhouse gas emitted from combustion: From Wikipedia, the free encyclopedia, on 24 May 2008 at 12:55.

restructuring of fuel consumption.⁹ Despite these efforts, Poland's atmospheric emissions of pollutants such as SO₂ and particulates, as well as CO₂, remain very high compared with European Union countries. Local air quality remains poor in many urban areas. Although emissions from power plants and industry have decreased, those from district heating plants and residential coal combustion have not fallen significantly. In addition, motor vehicles are creating a growing share of urban air pollution problems. Poland's legal framework for managing air pollution is complex and unwieldy for stationary sources, and is only being introduced and needs further development for mobile sources. In this case, finding a benchmark or the border form which countries start to lead appropriate sustainable policies. One policy proposed by economists is to allow countries to economically grow out of environmentally damaging activity. Looking at countries with already large economies it is seen that environmental regulation such as emissions standards, extensive recycling programs, and limited timber harvesting oblige them to invest in air protection. The economists supporting a policy that initially allows for environmental degradation assert that if a country can achieve sufficient economic growth in a short period of time then perhaps environmental damage should be tolerated. In Poland special attention will be paid to legislation instruments, introduction and enforcement of proper economic mechanisms strengthening air protection and foreign policy aiming at increasing foreign assistance for this objective (National Ecological Policy).

In order to make improvements in the air quality, the amount of pollutants in the air must be measured by applying selected indicators and quantitative methods of calculation. Indicators of a sustainable community point to areas where the links between the economy, environment and society are weak. They allow to see where the problem areas are and help show the way to fix these problems. Policy indicators are one way of ensuring that sustainability issues are being consistently and transparently considered right across public policy. 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.¹⁰ What is more, there is a necessity for identifying indicators that can support the formulation of an integration strategy and monitor the integration of environment and sustainable development into enterprise policy. Conducting comparative analysis, developing new methods of measurement is crucial for monitoring integration processes and harmonized methodology.

Methodology and data

This first part of research provides to 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 Lag and Spatial Error models. Combining the result from both parts of research there are drawn some crucial conclusions.

Recently, one of the modern used measure of spatial concentration is the Location Quotient (LQ), also known as the Hoover-Balassa coefficient:

$$LQ = \frac{Y_{ij} / Y_j}{Y_i / Y} \quad (1)^{11}$$

⁹ Ministry of Environment, *Poland's National Climate Strategy*, Warsaw 2004, p. 1.

¹⁰ Hertin J., Berkhout F., Moll S., Schepelmann P., *Indicators for Monitoring Integration of Environment and Sustainable Development in Enterprise Policy*, UK 2001.

¹¹ Combes P.P., Mayer T., Thisse J. F., *Economie géographique: L'intégration des régions et des nations (Broché)*, Economica, Paris, 2006.

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 gas air emissions in the country i ;

Y – overall amount of air emissions in examined countries;

Spatial concentration of the air pollutant overall Europe is also measured by the Lorenz curve and the Gini index for spatial data, as follows:

$$G = \frac{\Delta}{4L\bar{Q}_i} \quad (2)$$

where:

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

LQ_i – Lorenz curve index (Location Quotient) of location i ,

$L\bar{Q}_i$ - mean, $L\bar{Q}_i = \sum_{i=1}^R \frac{LQ_i}{R}$,

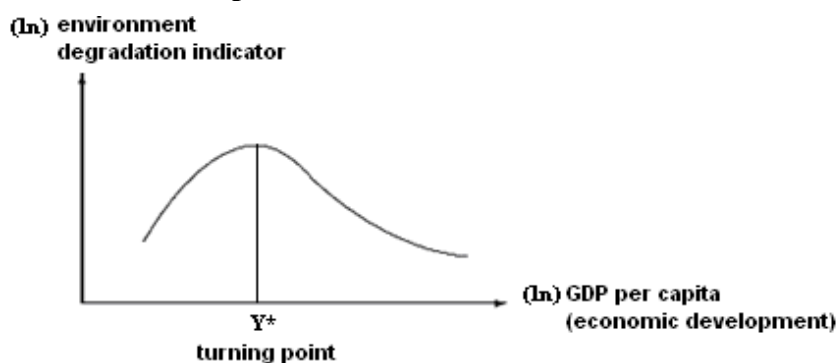
R – number of regions,

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 one when an air emission is concentrated in a single location. LQ displays in which region the concentration of concrete substance is the highest. Furthermore, constructing the Lorenz curve, it is important to remember that values of LQs (referring to each country) should be ranked and sorted in the increasing order. Afterwards, there are calculated aggregated values of: Y_{ij}/Y_j and Y_i/Y . The Lorenz curve is associated with the Gini coefficient. LQ across regions in ascending order and plots cumulated values of Y_{ij}/Y_j on the vertical axis against cumulated values of Y_i/Y on the horizontal. The Gini is equal to the area between the Lorenz curve and the 45° line. The implied null hypothesis for both indices is that each location should just be a scaled version of the average “representative” EU region.

Whereas, the Environmental Kuznets Curve (EKC) is a hypothesized relationship between various indicators of environmental degradation and income per capita (graph 1).

Graph 1. Environmental Kuznets Curve



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

Source: own work.

The hypothesis of EKC assumes that in the early stages of economic growth degradation and pollution increase. Beyond some level of income per capita, which will vary for different indicators, the trend reverses, so that at high income levels economic growth

leads to environmental improvement. This implies that the environmental impact indicator is an inverted U-shaped function of income per capita.

The EKC 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, as claimed by the environmental movement and associated scientists in the past (e.g., Meadows, Meadows, Randers, Behrens, 1972), economic growth would be the means to eventual environmental improvement. This change in thinking was already underway in the emerging idea of sustainable economic development promulgated by the World Commission on Environment and Development (1987) in *Our Common Future*. 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. This is called the scale effect. The traditional view that economic development and environmental quality are conflicting goals reflects the scale effect alone. Proponents of the EKC hypothesis argue that structure, changes in technology, as well as underlying causes such as environmental regulation, awareness, and education, which can only have an effect via the proximate variables.¹² Generally, there are two primary explanations for the proposed shape of the EKC. The first examines the history of developed countries and the paths they took to achieve development. The second reflects the changing preference for environmental quality as incomes rise.

Historically, all developed countries' economies were originally based upon agriculture, a state that produced little environmental damage. Their economies later switched to a much more environmentally damaging state that focused on industry and manufacturing. Finally, upon switching from heavy industry to the now-prevalent service-based economies the levels of environmentally damage fell in most developed countries. Two main factors lead to environmental damage that occurs during industrialization. First, the harmful by-products of production damage the environment. High levels of pollution and water contamination accompany the expansion of industry. The next stage of development saw industrial nations switching to service-based economies, a trend that all global GDP leaders tend towards. During this phase the income threshold of for the EKCs for certain substances appear to have been reached. Service-based economies are able to avoid many of the most environmentally damaging economic activities. Also, highly resource-dependant production is cut significantly which reduces the impacts of resource input and harmful emissions. Environmental impacts also fall as a result of improved technology discovered in developed countries. In some cases technology leads to a more efficient use of inputs. Other technological advancements make it possible to restrict the harmful effects that economic activity have on the environment.

The second reason that a high-income level can reduce environmental damage is by altering the demand for environmental quality. Known as the "income effect", sufficiently high GDP per capita often leads individuals to place environmental quality above additional economic growth. The aggregation of these individual preferences plays an integral role in determining the income threshold.

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.

¹² Stern D., *The Rise and Fall of the Environmental Kuznets Curve*, World Development Vol. 32, No. 8, p. 1419–1439, 2004, p. 1420 – 1422.

$$\ln(E/L_{it}) = \beta_0 + \beta_1 \ln(GDP/L_{it}) + \beta_2 (\ln(GDP/L_{it}))^2 + \sum_{j=1}^k \beta_j X_{ijt} + \varepsilon,^{13} \quad (4)$$

where:

$\ln(E/L_{it})$ – air emissions (SO₂, NO, CO₂, CO) per capita in country i , in time t ,

$\ln(GDP/L_{it})$ – GDP per capita in Purchasing Power Standards in region i , time t ,

X_{ijt} – additional variables,

\ln - indicates natural logarithms;

Usually the models is estimated with panel data. 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 (playing an essential role in processes of sustainable development, and development at all). Empirical studies of EKC have been already using the Spatial Lag or Spatial Error models (Kim, Phipps and Anselin (2003), Kakamu (2006), Kakamu, Polasek and Wago (2007) and so on):

1. Spatial Lag (SL) Model :

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

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

\mathbf{W} – spatial weights matrix;

2. Spatial Error (SE) Model:

$$\ln(E/L_{it}) = \beta_0 + \beta_1 \ln(GDP/L_{it}) + \beta_2 (\ln(GDP/L_{it}))^2 + \lambda \mathbf{W} \varepsilon + \xi \quad (6)$$

where: $\xi : N(0, \sigma^2 \mathbf{I})$.¹⁴

However, there are few simulation studies practicing spatial econometrics. In this paper, these methods of spatial econometrics (1,2) were used to estimate and verify EKC in EU countries and Poland voivodeships for four air pollutants:

SO_2/L_i – total national emissions of sulfur dioxide, thousands of tons per capita, in country i ,

NO/L_i – total national emissions of nitro oxides (including emissions of NO_x from road vehicles), thousands of tons per capita, in country i ,

CO_2/L_i – total national emissions of carbon dioxides, thousands of tons per capita, country i ,

CO/L_i – total national emissions of carbon monoxide thousands of tons per capita in country i ;

There was constructed the spatial weights matrix – rook contiguity (the order of contiguity is 4). The estimation method – OLS;

The cross-section analysis includes 32 European regions: Belgium (be), Bulgaria (bg), Czech Republic (cz), Denmark (dk), Germany (de), Estonia (ee), Ireland (ie), Greece (gr), Spain (es), France (fr), Italy (it), Cyprus (cy), Latvia (lv), Lithuania (lt), Luxembourg (lu), Hungary (hu), Malta (mt), Netherlands (nl), Austria (at), Poland (pl), Portugal (pt), Romania (ro), Slovenia (si), Slovakia (sk), Finland (fi), Sweden (se), United Kingdom (uk), Croatia (hr), Turkey (tr), Liechtenstein (li), Norway (no) and Switzerland (ch). Over the 1995 – 2005 period. The selection of regions aimed at a spatial system with areas of comparable size and, as far as possible, the application of functional regions (Island was

¹³ To prove the EKC for concrete indicator, the β_1, β_2 coefficients must be statistically significant and negative.

¹⁴ 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.

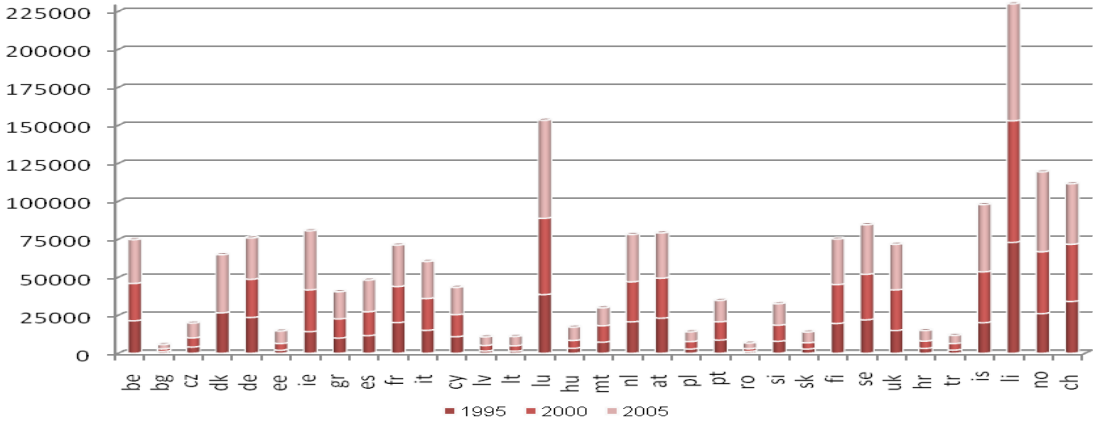
excluded due to large distance from others). Due to data restrictions the sample covers only those countries that have data available from national European datasets. Belarus, Macedonia, Bosna and Herzegovina, Russia are not considered because of a lack of regional data. Regional data on SO₂, NO, CO₂, CO, population and GDP were collected from the Eurostat Regional. For some regions the missing observations were taken from the OECD databank.

The state of the environment, currently, does not differ to a significant degree from the one observed in the developed countries. A positive effect is the constant growth of the protected areas in our country – between 1990 and 2004 this area has grown 1.7 times. At the same time, by becoming the EU member, Poland began to develop the European Natura 2000 network of protected areas, which covers a significant part of the area already under protection.¹⁵

Empirical results & interpretation

Gross domestic product (GDP) is the standard measure of a countries total economic activity. GDP per capita is widely assumed to be a good indicator of a country’s level of development. In the second half of the 1990s, the performance of the EU-27 economy was relatively positive, with a growth rate of GDP per inhabitant in 2000 at more than 3 %. Overall, the dispersion rate of GDP per capita in the EU-27 decreased between 2001 and 2004. After a decline from 2000 to 2005, investment as a percentage of GDP is nearly back to its 2000 level (graph 2).¹⁶

Graph 2. GDP per capita in EU, in PPS, 1995, 2000, 2005



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, *lu* 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.

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

There are some disproportions in GDP per capita across EU regions from 1990 to 2005 time period. From the graph, it is clear that 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 in EU. Poland is rather in the end of ranking. (GDP/capita (Euro/capita): in 1995 it accounts 2200, in 2000 it is 4900 and in year 2005 = 6400). After a slowdown of the economic growth, Poland's economy has shown symptoms of a revival since the second half of 2002. In 2005, a progressive increase of the growth rate was observed. In the first quarter, as compared to the the previous year, GDP increased by 2.3%, in the second quarter by 3.9%, in the third by

¹⁵ Zieschank R., Environmental Policy Research Centre, Poland Case Study, *Analysis of National Strategies for Sustainable Development*, June 2004, Brelin.

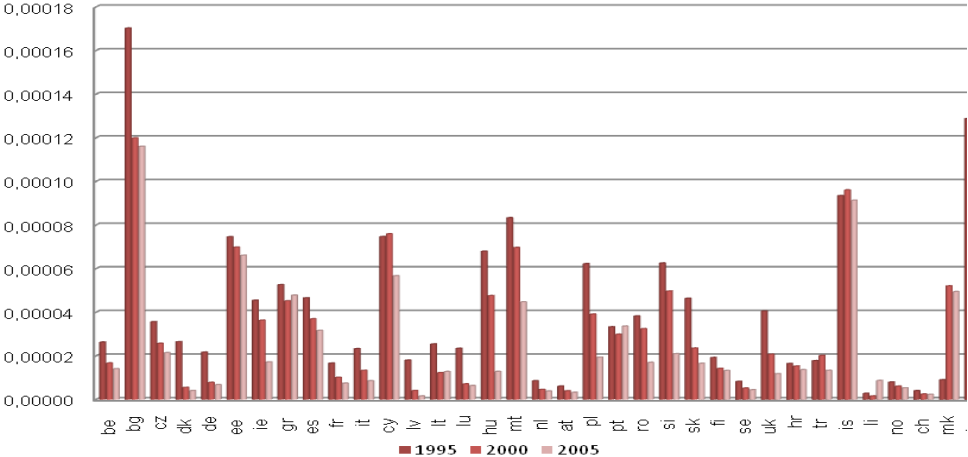
¹⁶ European Community, *Measuring progress towards a more sustainable Europe*, Monitoring report of the EU sustainable development strategy, Luxemburg, 2007.

4.0% and in the fourth quarter, the growth reached 4.7%. As a result, in 2005 the growth of the Gross Domestic Product amounted to 3.8% (as compared to 1.0% in 2000 and to 1.4% in 2002). Moreover, the sector of market services plays an increasingly positive role in the economic growth. Meanwhile, the role of industry and construction varies and is positive or negative, depending on the current phase of the cycle and external factors. Poland is a moderately developed country, but among the poorest countries within the enlarged European Union: with its gross domestic product per capita, in terms of purchasing power parity, about 50% of the EU-25 average, and at the same time with the lowest in the Community level of employment for working age people (53.7%) and the highest unemployment rate (13.8% - in 2006). Italy is in the middle. Graph 1 also presents which regions are still in developing process.

Comparing countries' GDP per capita is the most common approach to assessing their level of economic development. To measure the level of environment degradation there were used indicators of air pollutions, adhered to indicators of sustainable development: SO₂, NO, CO, CO₂. 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. However, it will also vary depending on technical and social changes developed in response to air quality and emission abatement legislation.¹⁷

In European Regions, man-made contributions are of the greatest concern of contributing to environmental levels of sulfur dioxide. These include the use of sulfur-containing fossil fuels for domestic heating and for power generation. In 1995 – 2005 the use of high-sulfur coal for domestic heating has declined in many European countries. Power generation is now the predominant SO₂ emission source.¹⁸ This effects in continued reduction in levels of sulfur dioxide in examined countries - 35 (graph 3).

Graph 3. Total national emissions of SO₂ per capita in EU, 1995, 2000, 2005



Source: own studies, Eurostat.

Most of countries have made a good progress in reduction of SO₂ since 1995. Only in four countries (Greece, Portugal, Liechtenstein, Italy) there have been observed an increase of the pollutant. Poland has achieved decrease of 49 percent in 2005 due to 2000. Although emissions from power plants and industry have decreased, those from district heating plants and residential coal combustion have not fallen significantly. Despite these efforts, Polands' atmospheric emissions of SO₂ and particulates remain very high compared with European

¹⁷ EEA Report No 2/2007, *Air pollution in Europe 1990–2004*, Copenhagen, 2007.

¹⁸ www.euro.who.int/document/aicq/7_4sulfurdioxide.pdf.

Union countries. In Italy there was an average rise of 4 percent during 5 years. To display the regional differences (spatial concentration) in time there are presented the Lorenz Curve and Gini values of SO₂ in years: 1995, 2000, 2005 (table 1).

Table 1. Location Quotients & Gini index of spatial concentration, SO₂, 1995, 2000, 2005

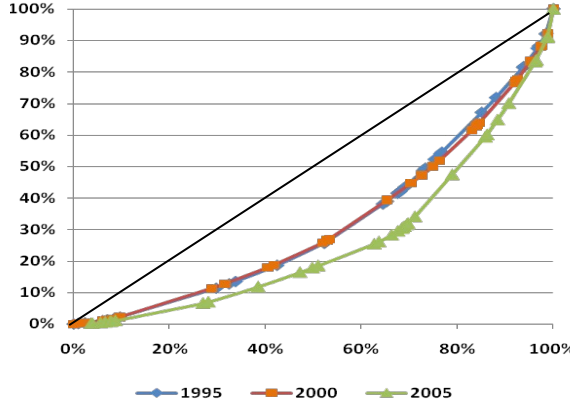
EU Member	LQ 1995	EU Member	LQ 2000	EU Member	LQ 2005
Liechtenstein	0.09	Liechtenstein	0.09	Netherlands	0.05
Switzerland	0.15	Switzerland	0.15	Liechtenstein	0.10
Austria	0.18	Austria	0.17	Luxembourg	0.12
Netherlands	0.18	Netherlands	0.18	Austria	0.15
Norway	0.21	Norway	0.20	Switzerland	0.18
Luxembourg	0.24	Luxembourg	0.25	Denmark	0.20
Sweden	0.29	Sweden	0.32	Latvia	0.21
Finland	0.40	Finland	0.41	Norway	0.26
Germany	0.46	Germany	0.48	Germany	0.30
Belgium	0.52	Belgium	0.51	Sweden	0.35
Denmark	0.54	France	0.58	Italy	0.47
France	0.59	Macedonia	0.60	France	0.52
Italy	0.71	Denmark	0.62	Belgium	0.55
Macedonia	0.72	Italy	0.69	Finland	0.56
United Kingdom	1.02	Ireland	0.87	United Kingdom	0.59
Ireland	1.09	Croatia	0.97	Ireland	0.70
Bosnia&Herzegovina	1.12	United Kingdom	1.02	Czech Republic	0.81
Croatia	1.16	Turkey	1.08	Hungary	0.97
Latvia	1.24	Bosnia& Herzegovina	1.12	Slovakia	1.04
Slovakia	1.36	Greece	1.25	Macedonia	1.15
Turkey	1.40	Portugal	1.26	Slovenia	1.17
Estonia	1.41	Spain	1.42	Croatia	1.21
Greece	1.47	Slovakia	1.51	Lithuania	1.43
Portugal	1.50	Cyprus	1.55	Portugal	1.47
Lithuania	1.50	Latvia	1.59	Spain	1.72
Poland	1.52	Estonia	1.67	Poland	1.74
Romania	1.58	Poland	1.76	Estonia	1.99
Spain	1.70	Lithuania	1.88	Bosnia&Herzegovina	2.13
Cyprus	1.88	Slovenia	2.00	Greece	2.21
Czech Republic	1.99	Czech Republic	2.05	Turkey	2.41
Slovenia	2.03	Romania	2.19	Cyprus	2.54
Iceland	2.45	Iceland	2.33	Malta	2.76
Hungary	2.73	Hungary	2.88	Romania	3.03
Malta	3.32	Malta	3.20	Iceland	4.26
Bulgaria	5.31	Bulgaria	6.92	Bulgaria	7.49
<i>Mean of LQ</i>	1.26	<i>Mean of LQ</i>	1.31	<i>Mean of LQ</i>	1.34
<i>GINI</i>	0.22	<i>GINI</i>	0.23	<i>GINI</i>	0.27

Source: own studies based on EUROSTAT.

LQ calculations introduce changes in concentration of SO₂ among EU countries in each year. It is pointed that Bulgaria cumulates large quantities of this air pollutant. The Netherlands have become the country where the concentration of SO₂ is the lowest. Poland has improved air quality, alike Italy. Furthermore, Gini index values from 0.22 in 1995 through 0.23 in 2000 to 0.27 in 2005. It indicates that the average quantity and concentration of SO₂ emissions

increased in time overall EU. On the other hand, it means that there are countries where SO₂ emission is more aggregated than in others (graph 4: quite large level of concentration).

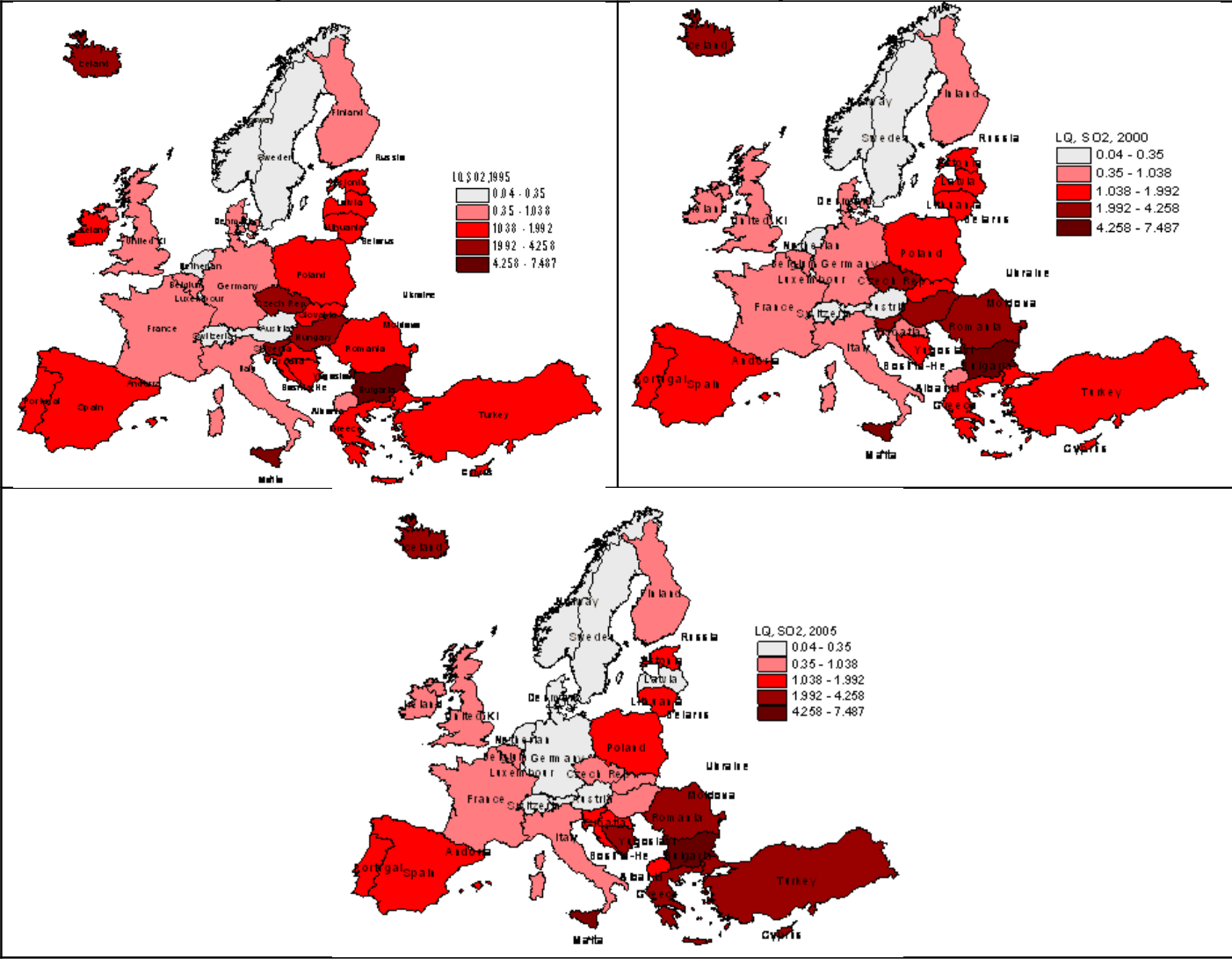
Graph 4. Lorenz Curve for SO₂ emission in each year



Source: own calculation based on aggregated data.

The results of calculations are narrowly presented in graph 5. It shows which country has a significant impact on total emission of SO₂ in Europe.

Graph 5. Location Quotient of SO₂ in each country in 1995, 2000, 2005



Source: own studies, based on table 1.

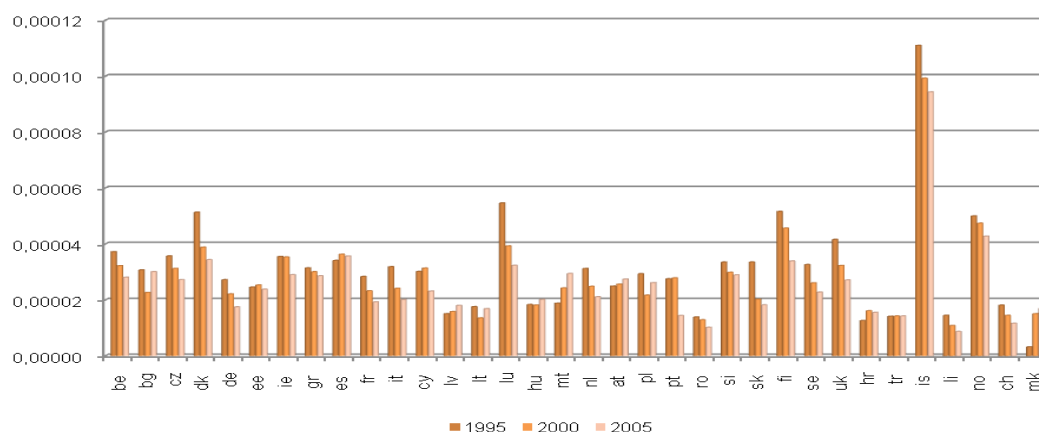
In 1995 the spatial variability of SO₂ emission levels is also not strong (Gini = 0.22), with LQs ranking from 0.09 to 5.31 (graph 5). Maximum value of 5.31 (Bulgaria) means that the share of sulfur dioxide is 431 percent greater in this area than in EU as a whole (mean of EUs LQ = 1.26). The value of LQs: in Malta (3.32), Hungary (2.73), Iceland (2.45), Slovenia (2.03) means that the share of SO₂ in these locations adequately: 232%, 173%, 145% and 103% higher than on the average in EU. Minimum value of 0.09 (Liechtenstein) means that the share of sulfur dioxide emission is 91 percent lower in this area than in EU as a whole. The value of LQs: in Switzerland (0.15), Austria (0.18), Norway (0.18) implies that the share of SO₂ in these areas is accordingly: 85%, 82% and 82% lower than on the average in EU. The level of LQ in Poland achieved 1.52 – it is 52 percent greater than in EU overall. In Italy there is 0.71, so it makes 29 percent lower concentration of SO₂ in this country than in examined EU members.

In 2000 the spatial variability exhibited for the concentration of sulfur emission is not strong (Gini = 0.23), with LQs ranking from 0.04 to 6.92 (graph 5). The maximum value of 6.92 (Bulgaria) means that the share of sulfur dioxide emission is 592 percent greater in this area than in EU as a whole (the mean value of EUs LQ = 1.31). The minimum value of 0.09 (Liechtenstein) 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 is lower than in 1995 and achieved 1.72 – it is 72 percent greater than in EU overall. In Italy there is 0.69, so it makes 31 percent lower concentration of SO₂ in this country than in examined EU members.

In 2005 the situation is nearly the same as in previous periods (Gini = 0.27), with LQs ranking from 0.05 to 7.487 (graph 5). Maximum value of 7.49 (Bulgaria) means that the share of sulfur dioxide emission is 649 percent greater in this area than in EU as a whole (the mean value of LQ, LQ = 1.34). The values of LQs: in Malta (2.76), Turkey (2.41), Iceland (4.26), Cyprus (2.54), Romania (3.03) mean that the share of SO₂ in these locations adequately: 176%, 141%, 326%, 154% and 203% higher than on the average in EU. The minimum value of 0.05 (Netherlands) means that the share of sulfur dioxide emission is 95 percent lower in this area than in EU as a whole. The level of LQ in Poland achieved 1.74 – it is 74 percent greater than in EU overall (it has increased). In Italy there is 0.47, so it makes 53 percent lower concentration of SO₂ in this country than in examined EU members. The LQs values of concentration are higher than in previous years. It is negative trend of SO₂ air polluting (Table 1).

In Europe, nitrogen oxides (NO_x) pollutes the air mainly as a result of road traffic and energy production. Higher levels of NO generally occur in areas with heavy traffic congestion. In cities, 85 to 95 percent of all NO emissions may come from motor vehicle exhaust. Apart from giving rise to acid rain and other air pollutants, current levels of NO may affect our health. Graph 6 shows the level of total NO emissions per capita in each European country over the 1995 – 2005.

Graph 6. Total emissions of NO per capita in European Union, 1995, 2000, 2005



Source: own studies, EUROSTAT;

Most of countries have made good progress in particulate emission reduction of NO since 1995 (Table 2). However, there are some, where the level of emission increased (Bulgaria, Latvia, Lithuania, Hungary, Malta, Turkey, Macedonia). In Poland there was also increase, which achieved 21 percent in 2005 in comparison to 2000 due to the rising number of motor vehicles, creating a growing share of urban air pollution problems. Anthropogenic NO_x emissions originate in Poland mostly from energy combustion in stationary and mobile sources. Emissions from industrial processes (the power plant sector includes the centralized production of electricity and district heat have also major importance. In Italy there were fall of NO (17 percent during 5 years). Table 2 presents the Lorenz Curve and Gini values of spatial NO concentration in years: 1995, 2000, 2005.

Table 2. Lorenz Curve elements and Gini of spatial concentration, NO, 1995, 2000, 2005

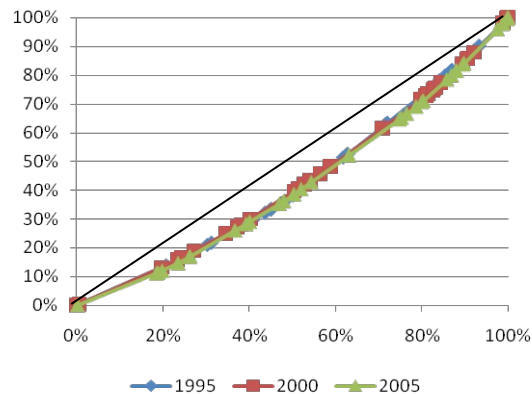
EU Member	LQ 1995	EU Member	LQ 2000	EU Member	LQ 2005
Estonia	0.54	Liechtenstein	0.50	Luxembourg	0.37
Liechtenstein	0.57	Luxembourg	0.63	Liechtenstein	0.46
Luxembourg	0.65	Estonia	0.66	Germany	0.61
Germany	0.67	Germany	0.67	Estonia	0.65
Romania	0.67	Netherlands	0.76	Switzerland	0.69
Netherlands	0.78	Switzerland	0.76	Netherlands	0.72
Czech Republic	0.78	Czech Republic	0.80	Czech Republic	0.81
Switzerland	0.80	Poland	0.81	Cyprus	0.81
Poland	0.83	Belgium	0.86	Italy	0.87
Austria	0.85	Slovakia	0.89	Belgium	0.87
Belgium	0.85	Romania	0.95	Slovakia	0.90
Hungary	0.86	Italy	0.95	Poland	0.91
Cyprus	0.89	Ireland	0.96	Ireland	0.93
Bosnia and Herzegovina	0.89	Austria	1.00	Romania	1.02
Ireland	0.99	Hungary	1.00	Austria	1.04
Greece	1.02	Greece	1.01	Greece	1.04
Croatia	1.03	Bosnia and Herzegovina	1.01	France	1.07
Bulgaria	1.11	Cyprus	1.01	United Kingdom	1.07
Italy	1.14	United Kingdom	1.11	Croatia	1.09
Slovakia	1.14	France	1.11	Finland	1.14
Malta	1.15	Bulgaria	1.15	Bosnia and Herzegovina	1.15

France	1.18	Croatia	1.18	Hungary	1.20
Latvia	1.21	Malta	1.20	Slovenia	1.27
Lithuania	1.21	Denmark	1.26	Turkey	1.34
United Kingdom	1.22	Lithuania	1.26	Denmark	1.34
Denmark	1.23	Slovenia	1.26	Sweden	1.42
Finland	1.25	Finland	1.33	Malta	1.43
Slovenia	1.27	Turkey	1.36	Portugal	1.48
Turkey	1.29	Sweden	1.39	Lithuania	1.48
Sweden	1.35	Macedonia	1.43	Spain	1.52
Portugal	1.44	Portugal	1.43	Bulgaria	1.53
Spain	1.45	Spain	1.52	Macedonia	1.62
Macedonia	1.55	Norway	1.64	Norway	1.67
Norway	1.57	Latvia	1.66	Latvia	1.93
Iceland	3.39	Iceland	3.20	Iceland	3.46
<i>Mean of LQ</i>	1.11	<i>Mean of LQ</i>	1.14	<i>Mean of LQ</i>	1.17
<i>GINI</i>	0.099	<i>GINI</i>	0.098	<i>GINI</i>	0.114

Source: own studies based on EUROSTAT.

LQ calculations display changes in concentration of NO among EU countries in each years. It is pointed that Iceland concentrates large quantities of this air pollutant. Luxemburg, Estonia, Liechtenstein have become countries where the concentration of NO is the lowest. Poland has worsen in air quality in this area. Italy just the opposite. Furthermore, the value of Gini index indicates that the concentration of nitrogen oxide has risen from 0.099 in 1995 through 0.098 in 2000 to 0.11 in 2005 (graph 7). It determines that the average quantity and concentration of NO emissions has increased in time. On the other hand, it means that there are countries where emission of NO is more aggregated than in other.

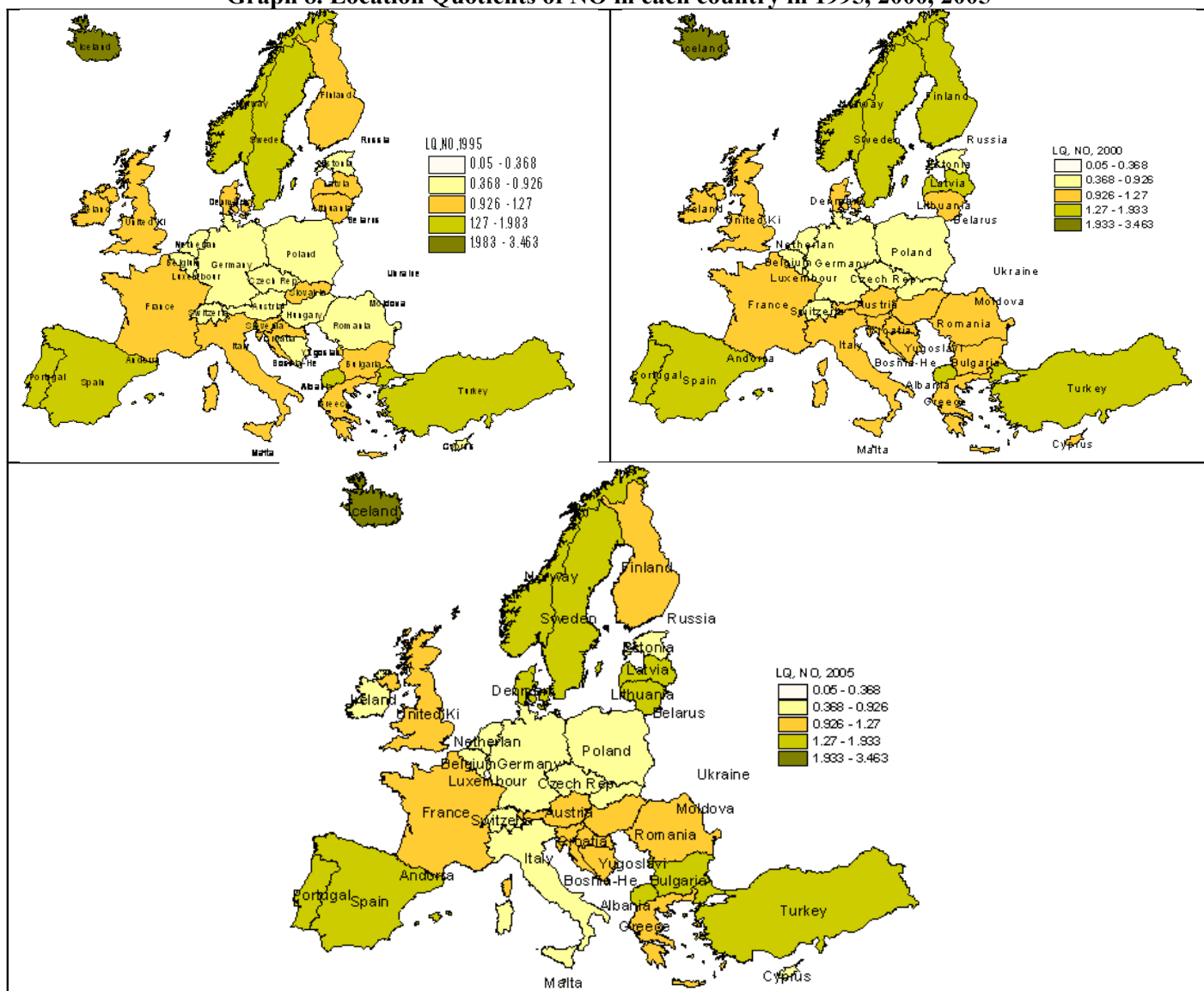
Graph 7. Lorenz Curve for NO emission in each year



Source: own calculation based on aggregated data.

In more details, the results of calculations are presented in graph 8.

Graph 8. Location Quotients of NO in each country in 1995, 2000, 2005



Source: own studies, based on table 2.

In 1995 the spatial concentration of nitrogen oxides emission is weak (Gini = 0.09, table 2). LQs rank from 0.5 to 3.39 (Graph 8). The maximum value of LQ 3.39 (in Iceland) means that the share of nitrogen oxides emission is 239 percent is greater in this area than in EU as a whole (the mean value of LQ in EU approximates 1.11). The minimum values of 0.54 (in Estonia) and 0.57 in Liechtenstein mean that the share of nitrogen monoxide emission is adequately 66 percent and 63 percent lower in this area than in EU as a whole. The level of LQ in Poland achieved 0.83 – it is 17 percent lower than in EU overall. In Italy there is 1.14, so it makes 14 percent greater concentration of NO in this country than in examined EU members.

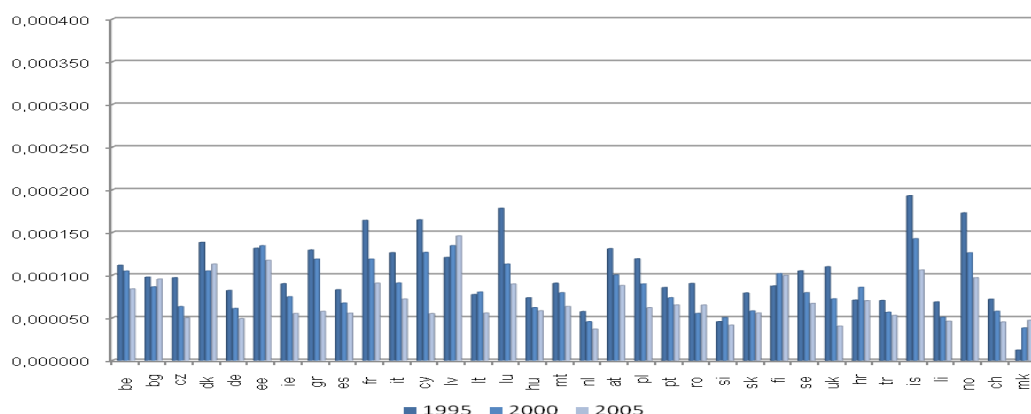
In 2000 the spatial concentration of nitrogen oxides emission ranks from 0.5 to 3.2 (Graph 8). The maximum value of 3.20 (again in Iceland) means that the share of nitrogen oxides emission is 220 percent greater in this area than in EU as a whole (the mean value of LQ in EU approximates 1.14). The minimum value of 0.5 in Liechtenstein. The level of LQ in

Poland achieved 0.81 – it is 19 percent lower than in EU overall. In Italy there is 0.95, so it makes 5 percent lower concentration of NO in this country than in examined EU members.

In 2005 the spatial variability exhibited for the concentration of nitrogen oxides emission is also rather weak (Gini = 0.1, Table 2), with LQs ranking from 0.37 to 3.46 (graph 8). The maximum value of 3.46 (again in Iceland, the mean value of LQ in EU approximates 1.17). The minimum values of 0.37 (in Luxemburg) and 0.46 in Liechtenstein mean that the share of nitrogen monoxide emission is adequately 63 percent and 54 percent lower in this area than in EU as a whole (the values of concentration are lower than in previous years, it is a good trend of NO air polluting, Table 2). The level of LQ in Poland achieved 0.91 – it is 9 percent lower than in EU overall (still increasing). In Italy there is 0.87, so it makes 14 percent greater concentration of NO in this country than in examined EU members (rising tendency).

Carbon monoxide (CO) is a colorless, odorless gas that is formed when carbon in fuel is not burned completely. It is a component of motor vehicle exhaust, which contributes about 56 percent of all CO emissions nationwide. Other non-road engines and vehicles (such as construction equipment and boats) contribute about 22 percent of all CO emissions nationwide. Other sources of CO emissions include industrial processes (such as metals processing and chemical manufacturing), residential wood burning, and natural sources such as forest fires. The highest levels of CO in the outside air typically occur during the colder months of the year when inversion conditions are more frequent. The air pollution becomes trapped near the ground beneath a layer of warm air. Most of countries have reduced emissions of CO since 1995 (graph 9).

Graph 9. Total emissions of CO per capita in European Union, 1995, 2000, 2005



Source: own studies, EUROSTAT;

However, there are some, where the level of emission has increased (Bulgaria, Denmark, Latvia, Romania, Macedonia). In Poland there was a fall 31 percent in 2005 due to 2000. In Italy there were also decrease of 31 percent during 5 years. Table 3 shows the Lorenz Curve and Gini values of spatial NO concentration in years: 1995, 2000, 2005.

Table 3. Lorenz Curve elements & Gini of spatial concentration, CO, 1995, 2000, 2005

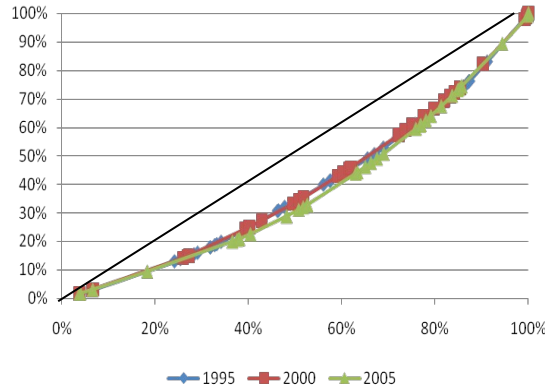
EU Member	LQ 1995	EU Member	LQ 2000	EU Member	LQ 2005
Netherlands	0.40	Netherlands	0.43	Netherlands	0.43
Slovenia	0.48	Czech Republic	0.50	Luxembourg	0.44
Germany	0.56	Luxembourg	0.56	Czech Republic	0.51
Finland	0.59	Germany	0.57	United Kingdom	0.54
Czech Republic	0.59	Ireland	0.63	Germany	0.58
Ireland	0.70	Slovenia	0.66	Ireland	0.60
Belgium	0.71	Liechtenstein	0.73	Slovenia	0.62

Liechtenstein	0.75	United Kingdom	0.77	Cyprus	0.66
Slovakia	0.75	Slovakia	0.79	Greece	0.71
Estonia	0.80	Belgium	0.87	Spain	0.80
Switzerland	0.88	Spain	0.87	Liechtenstein	0.83
United Kingdom	0.90	Finland	0.92	Belgium	0.89
Luxembourg	0.92	Switzerland	0.95	Switzerland	0.91
Denmark	0.92	Poland	1.04	Slovakia	0.93
Poland	0.94	Denmark	1.05	Malta	1.03
Hungary	0.96	Hungary	1.07	Italy	1.06
Macedonia	0.97	Estonia	1.09	Estonia	1.09
Bosnia and Herzegovina	0.97	Italy	1.12	Austria	1.13
Spain	0.98	Macedonia	1.13	Finland	1.14
Bulgaria	0.99	Portugal	1.17	Hungary	1.18
Greece	1.18	Austria	1.22	Portugal	1.19
Romania	1.21	Malta	1.22	Poland	1.27
Sweden	1.21	Greece	1.24	Norway	1.28
Austria	1.24	Bosnia and Herzegovina	1.24	Macedonia	1.39
Portugal	1.25	Romania	1.26	Sweden	1.42
Italy	1.26	Cyprus	1.27	Denmark	1.50
Cyprus	1.35	Sweden	1.32	Bosnia and Herzegovina	1.54
Malta	1.39	Norway	1.36	Romania	1.57
Lithuania	1.48	Bulgaria	1.37	Bulgaria	1.65
Norway	1.51	Iceland	1.43	Lithuania	1.66
Croatia	1.61	Turkey	1.68	Croatia	1.67
Iceland	1.64	France	1.77	Iceland	1.69
Turkey	1.79	Croatia	1.94	France	1.70
France	1.90	Lithuania	2.32	Turkey	1.81
Latvia	2.70	Latvia	4.39	Latvia	5.33
<i>Mean of LQ</i>	1.10	<i>Mean of LQ</i>	1.20	<i>Mean of LQ</i>	1.22
<i>GINI</i>	0.12	<i>GINI</i>	0.13	<i>GINI</i>	0.15

Source: own study based on EUROSTAT.

LQ calculations display changes in concentration of CO among EU countries in years 1995, 2000 and 2005. It is clear, from the table, that Latvia concentrates the largest quantities of this air pollutant. Luxemburg, Netherlands, Czech Republic have become countries where the concentration of CO is the lowest. Poland has already worsen air quality in this area. Italy just the opposite. Furthermore, the value of Gini index indicates that the concentration of this pollutant has risen from 0.12 in 1995 through 0.13 in 2000 to 0.15 in 2005 (graph 9). It determines that the average quantity and concentration of CO emissions increased in time. On the other hand, it means that there are only sparse countries where emission of CO is more aggregated than in others (graph 10).

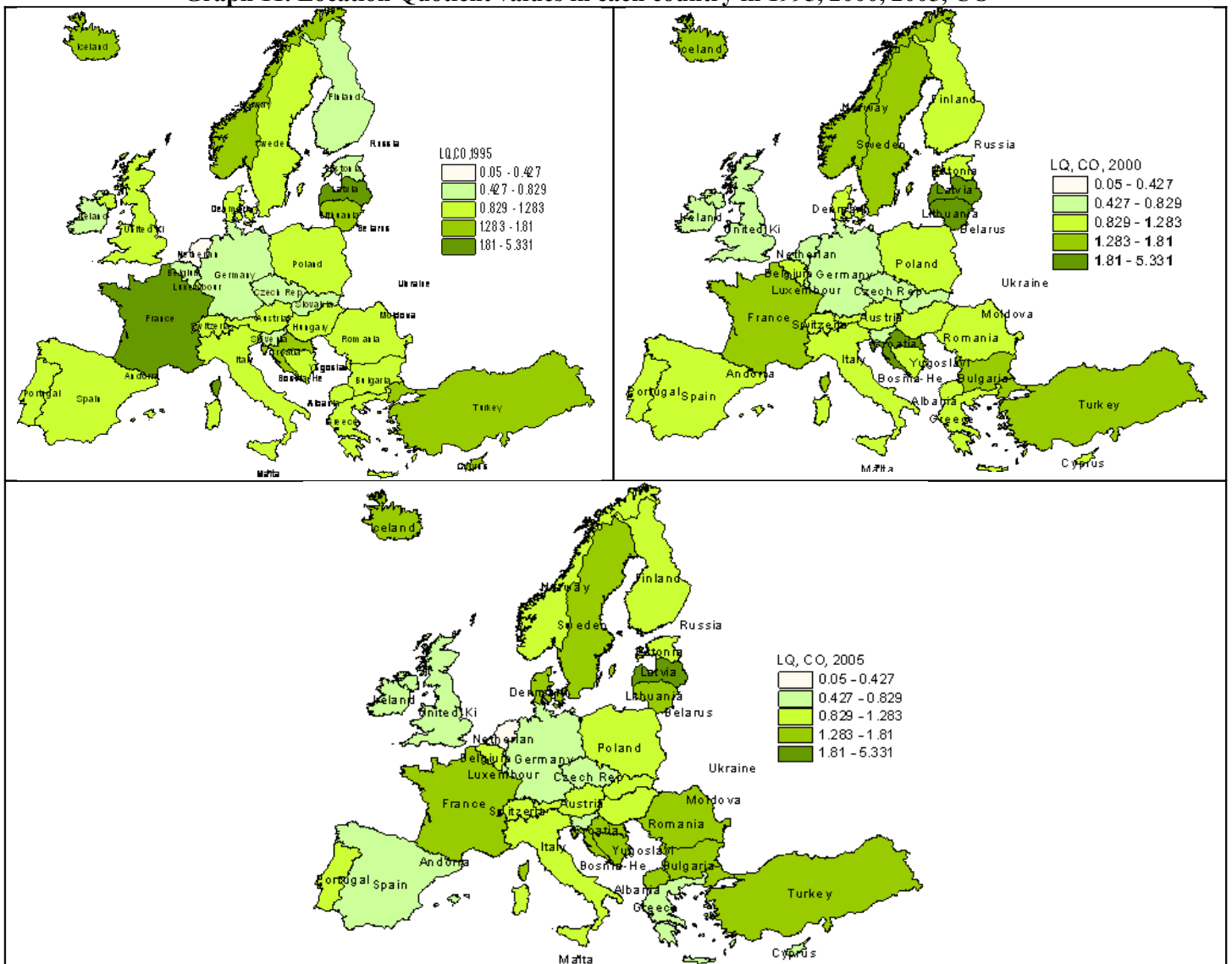
Graph 10. Lorenz Curve for CO emission in each year



Source: own calculation based on aggregated data.

The results, in more details, of calculations are presented in graph 11.

Graph 11. Location Quotient values in each country in 1995, 2000, 2005, CO



Source: own studies, based on table 3.

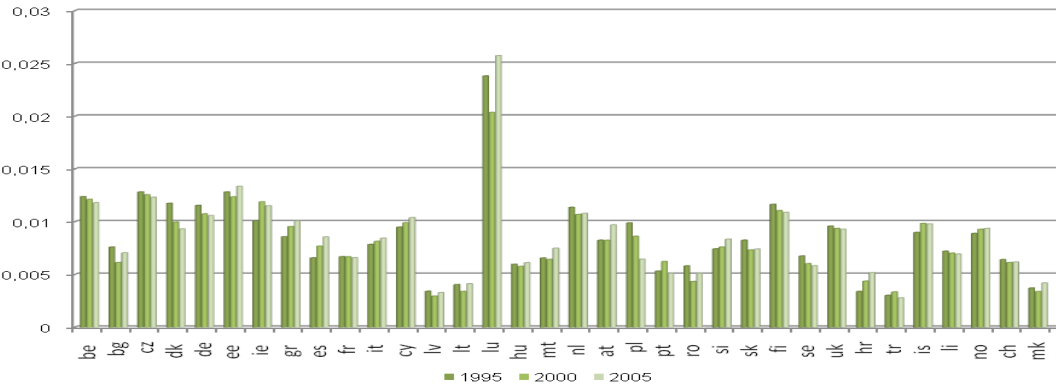
In 1995 the spatial variability exhibited for the concentration of carbon monoxides emission is rather weak (Gini = 0.13, table 3), with LQs ranking from 0.4 to 2.70 (Graph 11). The

maximum value of 2.70 (in Latvia) means that the share of carbon monoxide emission is 170 percent greater in this area than in EU as a whole (the mean value of LQ in EU approximates 1.20). The minimum values of 0.4 (in Netherlands) means that the share of carbon monoxide emission is adequately 60 percent lower in this area than in EU as a whole. The level of LQ in Poland achieved 0.94 – it is 6 percent lower than in EU overall. In Italy there is 1.26, so it makes 26 percent greater concentration of CO in this country than in examined EU members. In 2000 the spatial concentration of carbon monoxides emission ranks from 0.43 to 4.39 (Graph 11). The maximum value of 4.39 (in Latvia, the mean value of LQ in EU approximates 1.20). The minimum value of 0.43 in Netherlands. The level of LQ in Poland is 4 percent lower than in EU overall. In Italy there 12 percent higher concentration of CO than in examined EU members.

In 2005 the spatial variability exhibited for the concentration of carbon monoxide emission is also rather weak (Gini = 0.15, Table 3). The maximum value of 5.33 (again in Latvia) The minimum values of 0.43 (in Netherlands) and 0.44 in Luxemburg mean that the share of carbon monoxide emission is adequately 57 percent and 56 percent lower in this area than in EU as a whole (the values of concentration are nearly the same further to previous years, Table 3). The level of LQ in Poland achieved 1.27. In Italy there is 1.06.

The quantity of carbon dioxides emissions *per capita* show significant differences across the EU Member States (graph 12). There is a dissimilarity of a factor between the Member States with lowest emissions *per capita* (Latvia, Lithuania, Portugal and Sweden), and those with highest *per capita* emissions (Luxembourg and Estonia). CO₂ emissions declined by 11.7 % (1.4 tons *per capita*). The main decrease occurred particularly in 1995. Between 2000 and 2005, *per capita* emissions showed no overall change within the EU.¹⁹

Graph 12. Total emissions of CO₂ per capita in European Union, 1995, 2000, 2005



Source: own studies, EUROSTAT;

Conversely, in most of countries there were rise of CO₂ emissions since 1995. (Bulgaria, Estonia, Greece, Spain, Cyprus, Latvia, Lithuania, Luxemburg, Hungary, Malta, Austria, Romania, Slovenia, Croatia, Norway, Macedonia). In Poland there was also increase, which achieved apx. 21 percent in 2005 due to 2000. Poland is the world's eighth largest producer of coal and emissions which are predominantly from coal burning: 71% in 2005 In Italy there was decrease of 17 percent during 5 years (table 4).

¹⁹ EEA Report, *Greenhouse gas emission trends and projections in Europe 200. Tracking progress towards Kyoto targets*, No 5/2007 p 19.

Table 4. Lorenz Curve elements & Gini of spatial concentration, CO₂, 1995, 2000, 2005

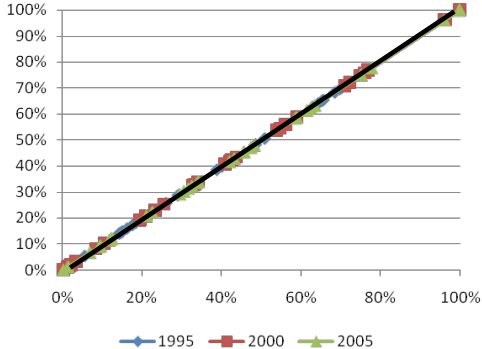
EU Member	LQ 1995	EU Member	LQ 2000	EU Member	LQ.2005
Latvia	0.98	Latvia	0.96	Latvia	0.96
Iceland	0.98	Bulgaria	0.97	Bulgaria	0.98
Bulgaria	0.98	Lithuania	0.98	Iceland	0.98
Malta	0.98	Iceland	0.98	Turkey	0.99
Turkey	0.99	Malta	0.99	Romania	0.99
France	0.99	Croatia	0.99	Lithuania	0.99
Lithuania	0.99	Hungary	0.99	Bosnia and Herzegovina	0.99
Croatia	0.99	Turkey	0.99	Croatia	0.99
Cyprus	0.99	Romania	0.99	Malta	0.99
Portugal	0.99	France	0.99	Macedonia	0.99
Hungary	0.99	Cyprus	0.99	France	1.00
Norway	0.99	Portugal	1.00	Portugal	1.00
Greece	1.00	Greece	1.00	Poland	1.00
Spain	1.00	Bosnia and Herzegovina	1.00	Denmark	1.00
Romania	1.00	Poland	1.00	Sweden	1.00
Italy	1.00	Estonia	1.00	Norway	1.00
Sweden	1.00	Norway	1.00	Hungary	1.00
Poland	1.00	Spain	1.00	Estonia	1.00
Macedonia	1.00	Sweden	1.00	Spain	1.00
Bosnia and Herzegovina	1.00	Slovenia	1.00	Finland	1.00
United Kingdom	1.00	Macedonia	1.00	Greece	1.00
Austria	1.00	Denmark	1.00	Cyprus	1.00
Slovakia	1.00	Italy	1.00	Austria	1.00
Slovenia	1.00	Slovakia	1.00	Slovakia	1.00
Czech Republic	1.00	Austria	1.00	Italy	1.00
Denmark	1.00	Czech Republic	1.00	Slovenia	1.00
Estonia	1.00	United Kingdom	1.00	Belgium	1.00
Ireland	1.00	Finland	1.00	Switzerland	1.00
Luxembourg	1.01	Belgium	1.00	Ireland	1.00
Switzerland	1.01	Ireland	1.00	United Kingdom	1.00
Belgium	1.01	Switzerland	1.00	Liechtenstein	1.00
Finland	1.01	Germany	1.01	Czech Republic	1.00
Liechtenstein	1.01	Liechtenstein	1.01	Germany	1.01
Germany	1.01	Luxembourg	1.01	Netherlands	1.01
Netherlands	1.01	Netherlands	1.01	Luxembourg	1.01
<i>Mean of LQ</i>	1.00	<i>Mean of LQ</i>	1.00	<i>Mean of LQ</i>	1.00
<i>GINI</i>	0.002	<i>GINI</i>	0.003	<i>GINI</i>	0.002

Source: own study based on EUROSTAT.

LQ calculations display changes in concentration of CO₂ among EU countries in years 1995, 2000 and 2005. It is pointed that the Netherlands and Luxemburg concentrate large quantities of this air pollutant. One reason for the high *per capita* emissions could be 'fuel tourism' (fuel bought in Luxemburg by people living in border regions of other countries and truck drivers, because of lower fuel taxes), which the country estimates to be responsible for about 40% of its total greenhouse). Latvia, Iceland, Bulgaria have become countries where the concentration is the lowest. Poland has improved air quality in this issue. Italy just the opposite. Furthermore, the value of Gini index indicates that the concentration of this pollutant has dropped from 0.002 in 1995 through 0.003 in 2000 to 0.002 in 2005 (table 4). It determines that the average quantity and concentration of CO₂ emissions decreased in time.

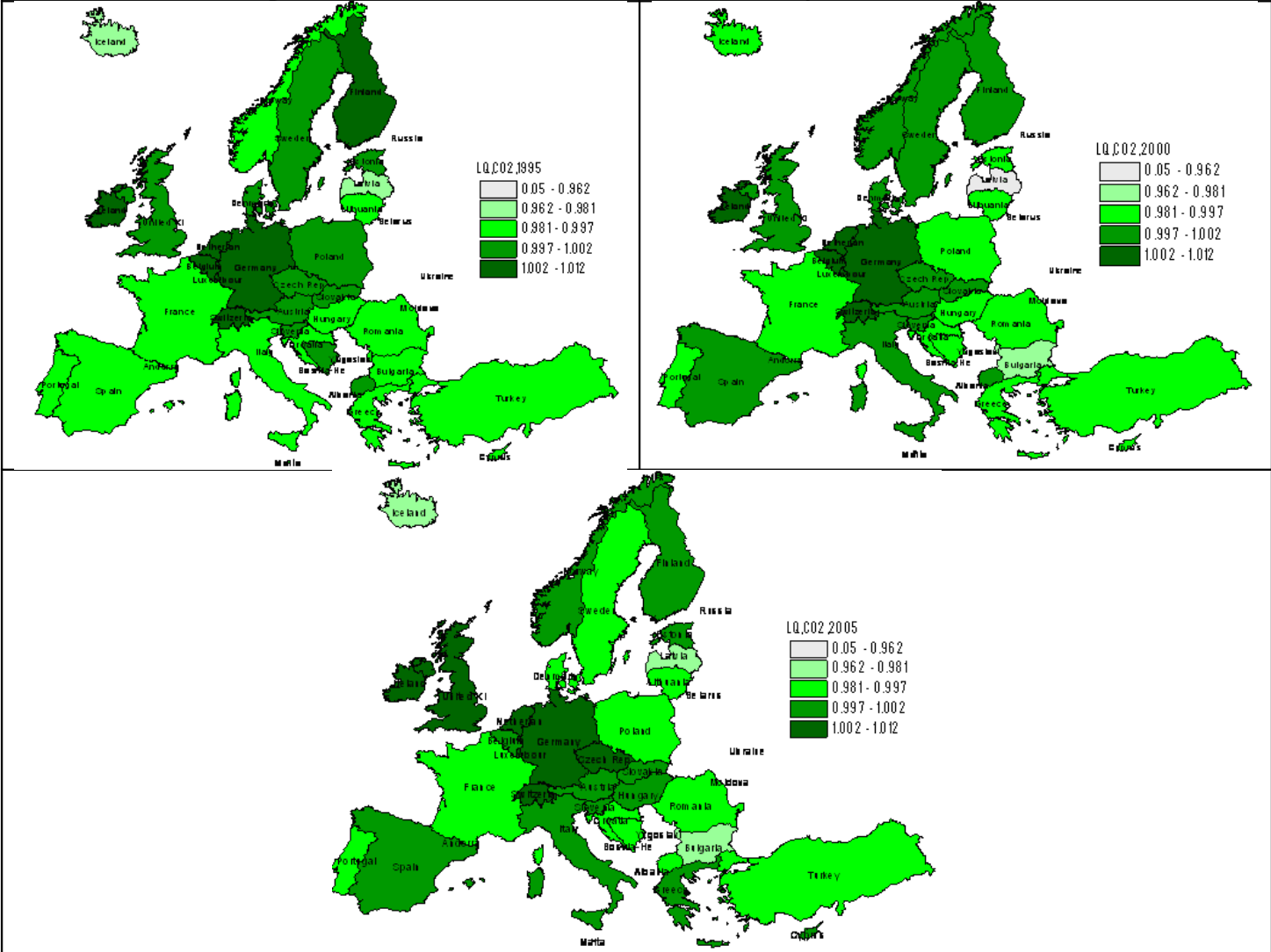
On the other hand, it means that concentration of CO₂ emissions is not aggregated in one country (graph 13).

Graph 13. Lorenz Curve for CO₂ emission in each year



Source: own calculation based on aggregated data.
The results, in more details, of calculations are presented in graph 14.

Graph 14. Location Quotient CO₂ in each country in 1995, 2000, 2005



Source: own studies, based on table 4.

In 1995 the spatial concentration of carbon dioxides emission is regularly distributed (Gini = 0.002, table 4), with LQs ranking from 0.98 to 1.01 (Graph 14). The maximum value of 1.01

(in Netherlands) means that the share of carbon dioxide emission is 1 percent greater in this area than in EU as a whole (the mean value of LQ in EU approximates 1.00). The minimum values of 0.98 (in Latvia) means that the share of carbon dioxide emission is adequately 2 percent lower in this area than in EU as a whole. The level of LQ in Poland achieved 1.00 – it is the same as in EU overall. In Italy is identically (1.00). In 2000 the spatial concentration is nearly at the same level. In 2005 the spatial variability exhibited for the concentration of carbon dioxide emission is also regularly spaced (Gini = 0.002, Table 4), with LQs ranking from 0.96 to 1.01 (graph 14). The maximum value of 1.01 (Luxemburg) means that the share of carbon monoxide is only 1 percent greater in this area than in EU as a whole (the mean value of LQ in EU approximates 1.01). The minimum values of 0.96 (Latvia) means that the share of carbon dioxide emission is adequately 4 percent lower in this area than in EU as a whole (the values of concentration are the same further to previous years, Table 4). The level of LQ in Poland achieved 1.00 – it is the same as in EU overall. In Italy is identically (1.00).

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 environmental (sustainable) can exists without any impact of regions situated closely. Spatial aspects (including local community planning, voivod planning and concepts for country planning, spatial dependence) are the most important tools for environmental management as well as for the state's policy of regionalisation (matching each area's development with its varied specificity). The second part of empirical research provides about significance of spatial effects in regional development and also human activities on air quality. The first section of calculations provides information about the quality of air in European countries. Taking into consideration these principles there was conducted estimation of spatial EKC. Making the use of research results one can find answers to issues:

1. of spatial dependence among examined countries;
2. if economic development causes air degradation;
3. if there are some countries where the levels of emissions are relatively high and additionally, the spatial aspect is significant, so we can than suppose that they damage air in neighboring countries;
4. which regions require prompt pro – ecological activities;
5. about the level of GDP from which occurs environment improvement;

In tables 5,6 & 7 there are results of spatial estimation of EKC model for EU, conducting that economic growth has influences the environmental quality but including spatial dependence as a meaningful aspect in regional analysis.

Table 5. Spatial EKC models – results of estimation, EU countries, 2000

Model Variable	1	2	3	4
	$\ln(SO_2/L_i)$	$\ln(NO/L_i)$	$\ln(CO/L_i)$	$\ln(CO_2/L_i)$
$\ln(GDP_i)$	4.9 ***	2.9 ***	X	X
$(\ln(GDP_i))^2$	-0.30 ***	-0.14 ***	X	X
Constant	-29.4 ***	-24.6 ***	X	X
W dependence Variable	0.07 ***	X	X	X
Lambda (λ)	X	-0.96 ***	X	X
Breusch-Pagan	4.68 *** (heterosk.)	5.19 *** (heterosk.)	X	X
Likelihood Ratio Test	4.25 ***	4.9 ***	X	X
R ²	0.53	0.44	X	X
Moran's I ²⁰	0.27	- 0.20	0.07	-0.015
Turning point (Euro/capita)	7 522	31 481	X	X

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

Source: own calculations in GeoDa.

Table 6. Spatial EKC models results of estimation, EU countries, 2005

Model Variable	1	2	3	4
	$\ln(SO_2/L_i)$	$\ln(NO/L_i)$	$\ln(CO/L_i)$	$\ln(CO_2/L_i)$
$\ln(GDP_i)$	4.12 ***	3.09 ***	X	X
$(\ln(GDP_i))^2$	-0.26 ***	-0.15 ***	X	X
Constant	-26.13 ***	-26.01 ***	X	X
W dependence Variable	0.07 ***	X	X	X
Lambda (λ)	X	-1.11 ***	X	X
Breusch-Pagan	4.26 *** (heterosk.)	7.28 *** (heterosk.)	X	X
Likelihood Ratio Test	3.69 ***	11.82 ***	X	X
R ²	0.48	0.50	X	X
Moran's I	0.18	- 0.29	0.05	-0.012
Turning point (Euro/capita)	6 300	29 733	X	X

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

Source: own calculations in GeoDa.

Concerning the results of estimation in tables 5 & 6, it is clear that in year 2000 and 2005 the spatial EKC hypothesis regarding to SO₂ and NO are proved. Actually, it means that:

1. β_1 & β_2 coefficients are negative and statistically significant;
2. the environmental impact indicator is an inverted U-shaped function of income per capita;
3. location and distance are important forces of spatial spillovers of air pollutions and GDP; the coefficients on the spatial lag and spatial error terms are highly significant.

In SO₂ EKC Spatial Lag model the spatial lag term of sulfur dioxide W_LNSO2/L reflects the spatial dependence inherent in the sample data, measuring the average influence on observations by their neighboring observations. It has a positive effect in both periods of time.

In NO Spatial Error model the coefficient on the spatially correlated errors (LAMBDA) is added as an additional indicator. It has a negative effect.

Turning points and Moran's I value:

1.SO₂; 6 300 Euro per capita in 2005 and 7 522 in 2000, it means that from these levels of GDP per capita the air degradation by SO₂ decreases. There is also general falling trend in sulfur dioxide emissions in EU countries. It could be results of pro-ecological activities in this area, such as: installing pollution control equipment at coal-fired power plants, reducing pollution from industrial processing facilities, reducing the average sulfur content of fuels burned, and using cleaner fuels like natural gas for residential and commercial heat.

The level of GDP per capita (6 300 Euro) is adequate in 2005 to Lithuania, Poland and Croatia. It indicates that these countries are at a such level of development that does not damage air by SO₂.

Moran' I value: it is clearly seen (tables: 5& 6) that the value of spatial dependence decreases in time. I may proceed from the fact that level of SO₂ emissions decreases too.

2.NO; 29 733 Euro per capita in 2005 and 31481 in 2000, it means that from this level of GDP per capita the economic development provides to decrease of NO. There is also general falling trend in NO emissions in EU countries. It could be the result of pro-ecological activities in this area, for instance: fitting catalytic converters to cars.

The level of GDP per capita is adequate to Ireland, Sweden, Denmark. It indicates that these countries development does not cause the rise of NO.

Moran' I value (tables: 5&6) shows that the value of spatial dependence increases in time. NO can be transported long distances. It could be relative to usage of cars as the possibility

²⁰ More about Moran statistic in publication: Anselin L., *Spatial Econometrics: Methods and Models*, Kluwer Academic, 1988 Dordrecht.

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. The areas suffer from the growing international transportation which is, on the other hand, an important part of international co-operation in environmental protection. Accordingly, it becomes a major contributor to air pollution in most industrialised nations.²¹

As the result of EU legislation, much progress has been made in tackling air pollutants. However, in countries, such as Poland, where power generation was based largely on the burning of coal, the atmosphere became heavily polluted. At the same time, there is common ground between a sustainable development policy and the economic interest of the country. 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. The results of estimations show that the EKC hypothesis is proved in case of three indicators in Poland in 2005 (table 7).

Table 7. Spatial EKC models results of estimation, Poland, 2005²²

Model Variable	1	2	3	4
	$\ln(SO_2/L_i)$	$\ln(NO/L_i)$	$\ln(CO/L_i)$	$\ln(CO_2/L_i)$
$\ln(GDP_i)$	2.83 ***	0.87 ***	X	1.24 ***
$(\ln(GDP_i))^2$	-0.01 ***	-0.004 ***	X	- 0.006 ***
Constant	-156.41 ***	-49.54 ***	X	- 66.5 ***
W dependence Variable	X	0.64 ***	X	0.67
Lambda (λ)	0.64	X	X	X
Breusch-Pagan	1.00*** (heterosk.)	1.24 *** (heterosk.)	X	1.1 (homosk.)
Likelihood Ratio Test	3.72 ***	- 4.22 ***	X	4.67
R ²	0.59	0.45	X	0.53
Moran's I ²³	0.31	0.35	X	- 0.13
Turning point (Euro/capita)	8 102	4 846	X	2 153

Note: *** the estimate is statistically significant at the 5 percent level; Number of observations: 16;
Source: own calculations in GeoDa.

Table 7 shows that in year 2000 and 2005 the spatial EKC hypothesis regarding to SO₂, NO and CO₂ are proved:

1. β_1 & β_2 coefficients are negative and statistically significant;
2. the environmental impact indicator is an inverted U-shaped function of income per capita;
3. location and distance are important forces of spatial spillovers of air pollutions and GDP; the coefficients on the spatial lag and spatial error terms are highly significant.

In SO₂ EKC Spatial Error model the spatial error term of the coefficient on the spatially correlated errors (LAMBDA) is added as an additional indicator. It has a positive effect.

In NO and CO₂ Spatial Lag model coefficients are added as an additional indicators. The spatial dependence inherent in the sample data, measuring the average influence on observations by their neighboring observations. It has a positive effect.

Turning points and Moran's I value:

1. SO₂; 8 102 Euro per capita in 2005. It means that from this level of GDP per capita the SO₂ air degradation decreases. There is also general falling trend in sulfur dioxide emissions in EU countries. It could be results of ecological activities in this area: reducing the energy intensity

²¹ The Surface Transportation Policy Project , *Clearing the Air*, (2003-08-19). Retrieved on [[2007-04-26]].

²² In Poland there are 16 voivodships (NUTS 2): zachodnio – pomorskie, dolnośląskie, kujawsko – pomorskie, warmińsko – mazurskie, łódzkie, mazowieckie, śląskie, pomorskie, podlaskie, wielkopolskie, małopolskie, lubuskie, lubelskie, podkarpackie, świętokrzyskie, opolskie;

²³ More about Moran statistic In publication: Anselin L., *Spatial Econometrics: Methods and Models*, Kluwer Academic, 1988 Dordrecht.

and material intensity of production processes, introducing changes in the system of financing environmental activity, and adjusting protective standards to those of the European Union.

Moran' I value: it clearly seen (table 7) that the value of spatial dependence is positive. I may proceed from fact that level of SO₂ emissions decreases too.

2. NO; 4846 Euro per capita in 2005. It means that from this level of GDP per capita the economic development causes the decrease of air pollution by NO. There is also general failing trend in NO in Poland. It could be the result of ecological activities in this area, such as: applying methods which means that low-emission burners issues giving the possibility to the reduction on the level of the minimum of the 30% , the regulation of processes of burning; Moran' I value: it clearly seen (table 7) that the value of spatial dependence is positive.

3.CO₂; 2153 Euro per capita in 2005. It means that from this level of GDP per capita the economic development in Poland causes the decrease of CO₂. The general failing trend in CO₂ in Poland. It could be the result of pro-ecological activities in this area, such as: deep technological modernizations of manufacturing devices in professional energetic;

Moran' I value: it clearly seen (table 7) that the value of spatial dependence is positive.

In general, the result of analysis displays that the EU (including Poland) has made significant progress in combating air pollution. However, 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. Developing countries are in urgent need of improved quality of life, infrastructure and services to the fast growing urban population, also due to the spatial dependence. National capacity tackle air pollution as the one of the most extreme importance among sustainable development goals.

Summary

Poland has placed high priority on controlling air pollution. Air pollution problems have been clearly identified, the relationship between the problems and economic activities has been examined, and priorities, goals and targets have been defined at the highest government level and have received public support. Beyond these intentions, Poland has achieved considerable reductions in major air emissions over the past 10 years, notably from the power sector and industry. A mix of regulatory and economic instruments have contributed to this achievement. However the amount of allocated financial resources for environmental protection decreased (in 2000 it was 0.78% of GDP, 2005 it used to be only 0.43%). The monitoring network for air pollution has been improved in recent years through efforts at both the national and voivodship levels and greater co-ordination between environmental and health authorities. All the results from analysis point that the European Union countries trend to sustain their developments in the range of air protection. The emissions in the most of cases are being reduced. The standards from the Access Treaty are implemented to regional policies and lasting collaboration between countries, that includes the spatial aspects of planning. According to its long-term perspective, sustainable development is perceived of as a *process* that allows for a gradual balancing of growth, social cohesion and environmental protection. The overall strategy aims at not disturbing the country's efforts to catch-up with the industrialized countries. As a country we have still multitude to work out. For the longer term, we have to ensure that sectoral air pollution reduction plans are formulated with participation from relevant ministries, enterprises, EUs strategies specifying intermediate and final target levels for emissions, emphasizing energy efficiency and the introduction of clean technology. Generally, A significant progress has been achieved in environmental protection over the last dozen years or so. The negative pressure of the economy on the environment has declined by reducing the energy intensity and material intensity of production processes, introducing changes in the system of financing environmental activity, and adjusting protective standards

to those of the European Union. The state of the environment, currently, does not differ to a significant degree from the one observed in the developed countries.

In relation to the results of research, it was found that economic development in case of SO₂ and NO determines variety of environmental investments rather than degradation over the 1995 – 2005 time period. On the other hand, there is also still warning signal about increasing trends of some climate indicators (CO, CO₂). It should be emphasized that the spatial dependence among region exists and some countries are still the leaders of air emissions (especially in SO₂ and NO). With regard to this fact their paths of development (unsustainable) is hazardous to theirs or neighboring environment. However, mankind needs clean air. Clean air is as important for human health and well-being and the environment as are clean water or safe food. The only way of pursuing a better quality of life for present, future generations and protecting environment is to sustain countries' development. Good governance, appropriate administrative, economic and legal frameworks, a knowledge-based approach in which education plays a key role for reaching sustainable development goals. The additional research in this area (having spatial panel model in mind) could be conducted to provide some essential conclusions and tips for further pro-ecological activities.

According to conclusions above, it is crucial to implement the principle that sustainable development is maintaining a delicate balance between the human need to improve lifestyle and feeling of well-being on one hand, and preserving natural resources and ecosystems, on which we and future generations depend.

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