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DEGRADATION OF AIR VS. QUALITY OF LIFE – SPATIAL PANEL ANALYSIS

1. INTRODUCTION

The main purpose of this paper is to identify and analyse a spatio-temporal relationship between excessive air pollution and the quality of life (well-being, the cost of living). The analysis was performed using spatial panel models. The following research hypotheses were examined:

– the quality of life depends on the quality of air,
– excessive air pollution has a negative impact on the broadly understood quality of life and raises the cost of living,
– spatial interactions among European countries exist and have a significant impact on well-being, the cost of living and quality of air[1],
– spatial panel data models reflect analysed relationships more precisely than their classic equivalents.

The study concerned 32 European countries over a period of 20 years (1990–2009[2]).

In order to test the above hypotheses, one should be aware of multi-directional relationships among human activity, degradation of air and its influence on the quality of life, state of health and cost of living. A decline in life expectancy could result from a health state deterioration. The reduced quality of health results in higher costs of treatment. All those factors impair the quality of life (the level of well-being) and increase the cost of living. Moreover, air pollution leads to considerable ecological and economic damage. Main consequences of excessive air emissions are, among others, smog, acid rain and climate change.[3] Atmosphere degradation is an effect of broadly understood *unsustainable development*. The reduced quality of air results in the impaired quality of life (e.g. well-being, health) and the rising cost of living. The whole

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[1] E.g. *EU's 7th Environment Action Programme*, Board of Strategic Advisers to the Prime Minister of Poland (2009), *Poland 2030. Development challenges – report summary*, Warsaw. http://ec.europa.eu/governance/impact/planned_ia/docs/2012_env_013_7th_environmental_action_programme_en.pdf, date of entrance: 10th of June 2012.

[2] The lack of air emission data does not allow to extend the research period beyond 2009.

[3] www.intechopen.com/books/the-impact-of-air-pollution-on-health-economy-environment-and-agricultural-sources, date of the last entrance: 1st of June 2012.

system of relationships forms a vicious circle. Those multi-directional relationships keep changing over time and as a result of spatial interactions. Furthermore, as countries and regions are not isolated islands in space, they are vulnerable to the influence of other units.[4] While time-series show one-way relationships, spatial data usually reveal multi-directional ones. To further improve the quality of air, many different kinds of policies and measures need to be adopted. On the other hand, more and more advanced statistical methods and modern information technology can detect previously unknown spatio-temporal links between exposure to air pollution and health effects. To save the European environment (air), and thus economic activity and the high quality of life, global cooperation is required. The cooperation and multi-directional relationships are regulated by targets and objectives of European and local strategies. The creation and implementation of measures relevant to sustainable development predetermine the effective implementation of the concept at each level of governance. Much, although not all, is understood about individual aspects involved in local air pollution and global climate change. Only an integrated perspective that brings together the relevant aspects can provide comprehensive and accurate knowledge of the current state and likely future development. The measurement of progress towards sustainable development is an integral part of the EU.

2. DATABASE AND METHODS OF ANALYSIS

The multi-directional relationships are constantly changing over time and as a result of spatial interactions. One way of verifying, testing and demonstrating a relationship between the quality of air and the quality of life is to apply selected quantitative methods. In this article, the following measures are used: Table 1 – SO_2, NO_x, CO, CO_2, GHG – total yearly emissions of sulphur dioxide, nitrogen oxides, carbon monoxide, carbon dioxide, greenhouse gases in thousands of tonnes *per capita*, *AIRQ* – a synthetic measure of gaseous pollution in thousands of tonnes *per capita*, *HDI* – Human Development Index, *GDP* – Gross Domestic Product *per capita* in PPS, *COSTS* – index of the cost of living based on the *GDP* and life expectancy. Those indices were applied to find out to what extent poor quality of air adversely affects widely understood well-being in 32 European countries from 1990 to 2009. Data sources: Eurostat, UN data, OECD, EEA, WHO.

Table 1. Characteristics of variables, number of observations in the panel n = 640, i= 32, t = 20

	SO_2	*NOx*	*CO*	CO_2	*GHG*	*AIRQ*	*HDI*	*GDP*	*COSTS*
AT	0.000005	0.000026	0.000115	0.0085	0.0019	0.0009	0.921	28161	358.96
BE	0.000021	0.000031	0.000098	0.0119	0.0021	0.0012	0.929	27296	348.77
BG	0.000156	0.000027	0.000079	0.0071	0.0024	0.0010	0.808	7400	102.17

[4] According to W.R. Tobler's first law "Everything is related to everything else, but near things are more related than distant things" (Tobler 1970, pp. 234–240).

	SO_2	*NOx*	*CO*	CO_2	*GHG*	*AIRQ*	*HDI*	*GDP*	*COSTS*
CH	0.000003	0.000016	0.000060	0.0062	0.0011	0.0006	0.890	32024	399.30
CY	0.000062	0.000028	0.000109	0.0096	0.0023	0.0011	0.892	19788	250.77
CZ	0.000066	0.000035	0.000075	0.0128	0.0019	0.0012	0.866	16692	222.48
DE	0.000018	0.000023	0.000071	0.0111	0.0019	0.0011	0.935	26064	333.25
DK	0.000016	0.000043	0.000117	0.0109	0.0027	0.0013	0.877	28449	369.20
EE	0.000085	0.000028	0.000136	0.0144	0.0012	0.0011	0.887	11180	155.89
ES	0.000038	0.000033	0.000071	0.0071	0.0017	0.0008	0.923	22072	277.11
FI	0.000021	0.000046	0.000099	0.0118	0.0025	0.0012	0.915	25887	331.39
FR	0.000013	0.000025	0.000127	0.0066	0.0025	0.0010	0.917	26574	334.51
GB	0.000028	0.000034	0.000083	0.0094	0.0022	0.0011	0.879	26539	338.97
GR	0.000048	0.000030	0.000104	0.0091	0.0021	0.0010	0.916	18534	235.29
HR	0.000018	0.000015	0.000076	0.0045	0.0016	0.0007	0.869	10657	142.52
HU	0.000048	0.000019	0.000066	0.0060	0.0018	0.0008	0.884	13601	188.44
IE	0.000033	0.000032	0.000076	0.0106	0.0060	0.0021	0.867	27833	357.07
IT	0.000016	0.000026	0.000096	0.0080	0.0014	0.0008	0.908	25347	317.46
LV	0.000013	0.000017	0.000131	0.0039	0.0016	0.0006	0.849	9570	135.90
LI	0.000002	0.000011	0.000056	0.0066	0.0008	0.0006	0.877	7909	98.94
LT	0.000023	0.000020	0.000082	0.0047	0.0024	0.0009	0.885	10740	150.14
LU	0.000016	0.000043	0.000197	0.0246	0.0028	0.0019	0.923	52234	666.28
MT	0.000070	0.000029	0.000091	0.0064	0.0009	0.0006	0.881	16857	215.10
NL	0.000006	0.000026	0.000048	0.0108	0.0028	0.0013	0.865	29377	372.13
NO	0.000007	0.000046	0.000134	0.0091	0.0026	0.0012	0.893	33437	422.22
PL	0.000049	0.000025	0.000116	0.0091	0.0016	0.0009	0.857	10916	147.30
PT	0.000026	0.000026	0.000072	0.0056	0.0017	0.0008	0.919	18039	234.03
RO	0.000036	0.000015	0.000076	0.0053	0.0021	0.0008	0.858	7579	105.74
SE	0.000007	0.000027	0.000084	0.0062	0.0017	0.0008	0.921	26750	334.37
SI	0.000051	0.000030	0.000047	0.0078	0.0019	0.0009	0.841	17467	227.82
SK	0.000037	0.000025	0.000065	0.0081	0.0017	0.0009	0.801	12832	174.16
TU	0.000018	0.000013	0.000056	0.0032	0.0008	0.0004	0.842	6475	92.33
$\bar{\bar{x}}$	0.000033	0.000027	0.000091	0.0087	0.0020	0.0009	0.884	20446	263.75
max	0.000156	0.000046	0.000197	0.0246	0.0060	0.0021	0.935	52234	666.28
min	0.000002	0.000011	0.000047	0.0032	0.0008	0.0004	0.801	6475	92.33
V	94	34	35	46	46	39	4	49	47

Note: *n* – number of observations, *i* – number of objects, *t* – number of periods, $\bar{\bar{x}}$ – mean of variables' means, max – maximum value of mean values, min – minimum value of mean values, V – variability coefficient in %, AT – Austria, BE – Belgium, BG – Bulgaria, CH – Switzerland, CZ – the Czech Republic, CY – Cyprus, DE – Germany, DK – Denmark, EE – Estonia, ES – Spain, FI – Finland, FR – France, GB – United Kingdom, GR – Greece, HR – Croatia, HU – Hungary, IE – Ireland, IT – Italy, LV–Latvia, LI – Liechtenstein, LT – Lithuania, LU– Luxembourg, MT – Malta, NL – the Netherlands, NO – Norway, PL – Poland, PT – Portugal, RO – Romania, SE – Sweden, SI – Slovenia, SK – Slovakia, TU – Turkey).

Source: developed by author, using STATA 11.

The values of measures contained in Table 1 informally express the connection between the level of development and quality of air. They indicate that economic growth degrades the environment. One could expect developed and wealthy countries to pollute the air less than the "poorer" ones. However, it is otherwise[5]. The estimated econometric models use *HDI* and *COSTS* as dependent variables, while all the gaseous pollutants and *AIRQ* aggregate measure were chosen as a set of explanatory variables. The *HDI* and *GDP* express the quality of life (well-being, prosperity). The *COSTS* index represents the cost of living. Because of their quantitative character, the indicators present progress in meeting objectives of sustainable and eco-development.[6] One of the goals of the analysis is to test the hypothesis about spatial interactions. Accordingly, it was necessary to design indicators capable of identifying the cost of living and state of air in particular countries.

AIRQ – air quality. The *AIRQ* synthetic measure shows the quality of air. It was built using calculated values of Moran's *I* statistics[7]. The indicator consists of the weighted volumes of particular pollutants (SO_2, NO_x, CO, CO_2, GHG). The weights were assigned according to the average values and numbers of statistically significant Moran's *I* statistics for particular air indicators (see: formula[8]):

$$AIRQ = 0{,}15SO_2 + 0{,}3NO_x + 0{,}25CO + 0{,}05CO_2 + 0{,}25GHG .$$

The main reasons for conducting the diverse panel analysis for particular air pollutants as an explanatory variable were as follows:

- emissions of each pollutant lead to different consequences,
- there are various sources of emissions, which results in specific ways of neutralizing them,
- it is possible to identify diverse profiles and economic considerations of a country,
- it is possible to reduce each of the emissions in a specific strategic way,
- it is possible to identify countries that are considered main polluters in respect of specific substances.

HDI, COSTS – socio-economic well-being and the cost of living. Among the aims of this paper is to verify the direction and strength of a relationship between the state of air, quality of life (well-being) and cost of living. Therefore, *HDI* values were collected. However, the *HDI* formula has been subject to fre-

5 About the empirical spatio-temporal research on different types of the Environmental Kuznets Curve in the EU (e.g. Antczak, Suchecka 2011, pp. 21–44; Antczak, 2011, pp. 167–177; Antczak 2012).

6 The choice of explanatory variables was supported by both theoretical and technical reasons (e.g. Pearson's linear correlation coefficients, unit roots by the Levin-Lin-Chu test. Tables with calculations of results are available by e-mail: wiszniewska@uni.lodz.pl (for a detailed discussion of the tests' properties see e.g. Levin, Lin, Chu, 2002, pp. 1–24; Kluth 2007 pp. 307–314).

7 More about Moran's *I* statistics – see: e.g. Suchecki B. (ed.) et al. (2010), *Ekonometria przestrzenna. Metody i modele analizy danych przestrzennych*, Beck.

8 The construction of the *AIRQ* formula: Antczak E., Suchecka J. (2011), *Spatial autoregressive panel data models applied*…op.cit., p. 370; however, the weights changed due to extended sample.

quent changes.[9] Hence, the authors estimated the 1990-2009 *HDI* values on their own in accordance with the UNDP's methodology.

In order to measure the cost of living, an additional index was introduced: *COSTS*: *COSTS*=*GDP*/*LE*, where: *GDP* – Gross Domestic Product *per capita* in PPS, *LE* – life expectancy of women and men at birth. That index expresses the cost of one year of living (in PPS *per capita per year*). Thus, a further econometric analysis allows to verify whether excessive air pollution increases the cost of living (e.g. raises expenditures on healthcare, prevention or treatment of allergies, expenditures on leisure outside the city) and the scale of that increase. Relationships among air degradation, the quality of life and cost of living take place in both time and space. Hence, volumes of the analysed phenomena in one country influence the range of those phenomena in neighbouring regions (in accordance with the implemented spatial weights matrix).[10]

Spatial panel data models. Spatial econometrics has been an ongoing research field. Recently, it has been extended to panel data settings (e.g. Kapoor, Kelejian, Prucha 2007; Elhorst 2009; Baltagi, Liu 2011). Spatial panel data models allow to study cross-sectional dependence as well as state dependence. They also enable researchers to control for unknown heterogeneity. In this paper, spatial panel models were used to identify the multi-dimensional relationships among the state of well-being, the cost of living and the quality of air in the selected European countries from 1990 to 2009. Spatial panel data models also allow to analyse spatial autocorrelation. This paper applied four types of spatial panels: SAR-FEM, SE-FEM, SAR-REM, SE-REM.[11] The process of estimation used the "splm" toolbox in R Cran (Millo, Piras 2012, pp.1–2).

3. RESULTS OF ANALYSIS

The first part of this section presents results of verifying the following hypotheses:

– the quality of life depends on the quality of air,
– excessively polluted air has a negative impact on the broadly understood quality of life and raises the cost of living,
– spatial interactions between European countries exist and have a significant impact on the well-being, cost of living and quality of air,
– spatial panel data models reflect the analysed relationships more precisely than classic methods.

The confirmation of the formulated hypotheses (from 1) to 4)) means the acceptance of models with negative and statistically significant coefficients

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9 The origins of the *HDI* are found in UNDP reports: http://www.un.org/, (23rd of May 2012).
10 Values of Moran's *I* for *GDP*, *HDI*, *COSTS*, *AIRQ*, *LE* in selected years proved "the spatial hypothesis"; available by e-mail: wiszniewska@uni.lodz.pl.
11 More about spatial panel data models in e.g. Suchecki B. (ed.) (2012), *Ekonometria przestrzenna II. Modele zaawansowane*, BECK, Warsaw.

at the pollutant variables in the case of: *lGDP*, *lHDI* as dependent variables (*YES* answers). A positive and statistically significant coefficient at a selected pollutant variable results in accepting the hypothesis of raising the cost of living. More precisely, it means rejecting the hypothesis (expressed as *NO* answers in Table 2).

Table 2. Verification of the main hypotheses based on spatial panel data models for each pollutant and each measure of the quality of life[12]

Details	***lSO_2***	***lNO_x***	***lCO***	***lCO_2***	***lGHG***	***lAIR***
			lGDP			
SAR-FEM	YES	NO	YES	NO	NO	NO
SE-FEM	NO	NO	NO	NO	NO	NO
SAR-REM	YES	NO	YES	NO	NO	NO
SE-REM	YES	NO	YES	NO	NO	NO
			lHDI			
SAR-FEM	YES	YES	YES	NO	NO	NO
SE-FEM	YES	NO	NO	NO	NO	NO
SAR-REM	YES	YES	YES	NO	NO	NO
SE-REM	YES	NO	YES	NO	NO	YES
			lCOSTS			
SAR-FEM	NO	NO	NO	YES	YES	YES
SE-FEM	NO	YES	NO	YES	YES	YES
SAR-REM	NO	NO	NO	YES	YES	YES
SE-REM	NO	YES	NO	YES	YES	YES

Note: SAR-FEM: Spatial Autoregressive Fixed Effects Model, SE-FEM: Spatial Error Fixed Effects Model, SAR-REM: Spatial Autoregressive Random Effects Model, SE-REM: Spatial Error Random Effects Model.

Source: calculations by author, in R Cran.

Potentially, models for all *YES* answers could be constructed. However, estimation results of models[13]:

- showing the negative impact of air pollution on the level of socio-economic well-being (Table 3),
- presenting the relationship between air degradation and the cost of living (Table 4),
- were chosen for final interpretation.

Well-being-dependent variable lHDI. The results in Table 3 consider the relationship between the quality of air (sulphur dioxides in thousands of tonnes *per capita*) and *HDI* as an index of the socio-economic state of well-being.

[12] All variables were transformed into logarithms and then used in the econometric analysis.

[13] The proper and interesting results of the conducted analyses provide directions for further research. Author/s will continue the spatial modelling of relationships between air degradation and the quality of life (well-being). One of the initial parts of future research will consist in estimating other spatial panel data models with *YES* answers (based on suggestions of Table 2).

Sulphur dioxides are a group of highly reactive gases: they form acid rain, smog[14], cause health problems[15] and considerable damage to materials.[16] These pollutants can accelerate the corrosion of metals, leather, paper, foods and building materials (Gillette 1975). All negative phenomena connected with SO_2 emissions are costly and dangerous. Table 3 presents estimation results of the spatial panel analysis of SO_2 emissions' impact on the *HDI* level.

Table 3. Spatial panel data models for *lHDI* and lSO_2

$lHDI_{it} = const + \alpha_i + \alpha_1 lSO_{2it} + u_{it}$ **FEM (1)**				
parameter	*value*	*t-Student*	*Standard error*	*p-value*
exp(*const*)	0.54	– 42.4	0.01	0.000
α_1	– 0.05	– 33.8	0.001	0.000
exp(α_i)	AT=0.52, BE=0.57, BG= 0.54, **CH=0.5**, **CY=0.58**, CZ=0.55, DE=0.57, DK=0.52, **EE=0.58, ES=0.58**, FI=0.56, FR=0.55, GB=0.54**, GR=0.58**, HR=0.52, HU=0.55, IE=0.54, IT=0.55, **LV=0.5**, **LI=0.49**, LT=0.54, LU=0.55, MT=0.57, **NL=0.5**, NO=0.52, PL=0.55, PT=0.57, RO=0.54, SE=0.54, SI=0.52, **SK=0.5**, TU=0.52;			
R^2=0.86	*within* = 0.65	*between* = 0.09	*overall* = 0.22	
Chow's test of fixed effects significance: *F**(1, 607) =1.47 , *F*=1142, *F*>*F**; Residuals normality: Chi-squared=26.8, with *p-value*=0.01; Residuals stationarity: Levin-Lin-Chu, without trend H_1: – 3.89(0.000), with trend H_1: -3.55 (0.000); Test of panel effects: *rho*=0.87 > 0; *F*(31, 607) = 93.17, *corr* (lSO_2; α_i)= – 0.57, prob=0.000, FEM more effective than REM;				
$lHDI_{it} = const + \alpha_i + \alpha_1 lSO_{2it} + \alpha_2 \rho l\mathbf{W}HDI_{it} + u_{it}$ **SAR-FEM (2)**				
parameter	*Value*	*t-Student*	*Standard error*	*p-value*
exp(const)	0.87	– 19.2	0.001	0.000
α_1	– 0.01	– 10.5	0.001	0.000
ρ	0.80	41.9	0.02	0.000
α_i	**AT=0.91, BE=0.91**, BG=0.89, CH=0.83, **CY=0.91,** CZ=0.87, **DE=0.91**, DK=0.84, EE=0.89, ES=0.89, FI=0.90, FR=0.89, GB=0.86, **GR=0.92,** HR=0.87, HU=0.90, IE=0.84, IT=0.90, LV=0.82, LI=0.83, LT=0.89, LU=0.90, MT=0.89, NL=0.83, NO=0.86, PL=0.86, PT=0.90, RO=0.87, SE=0.90, SI=0.84, **SK=0.80**, TU=0.84;			
R^2=0.93;	*within* = 0.65	*between* = 0.09	*overall* = 0.22	
Chow's test for fixed effects significance *F**(31, 588) = 1.47, *F*=27.1, *F*>*F**; Residuals normality: Shapiro-Wilk, *W* = 0.99, *p-value* = 0.08; Residuals stationarity: Levin-Lin-Chu, without trend H_1: – 4.38 (0.000), with trend H_1: – 6.05 (0.000)				
Chow's test of spatial effects: $\boldsymbol{F_{SAR\text{-}FEM} > F^*}$**, 270>3.52**, SAR-FEM better than FEM and SE-FEM, *p-value* =0.05, *F* (2,19)				

Note: the results of SE-FE and RE models: wiszniewska@uni.lodz.pl, *l*-logarithm.

Source: developed by author, using R Cran, STATA 11 and Gretl.

Finally, the results of spatial analysis were compared with those of classic ones (Table 3.):

- a 1% increase in SO_2 causes an average decline of 0.05% in *HDI*, α_1= – 0.05, ceteris paribus;

[14] www.publicsmog.org/ the last entrance: 26th of May 2012.
[15] www.who.int/mediacentre/factsheets/fs313/en/, the last entrance: 26th of May 2012.
[16] Bensalah N. (ed.) (2012), *Pitting Corrosion*, InTech, Crotaria, the last entrance: 26th of May 2012: www.intechopen.com/books/pitting-corrosion.

– between 1990 and 2009, CY, EE, ES, GR showed the highest levels of well-being (*HDI*) adjusted by volumes of SO_2 emission (α_{CY}=0.58, α_{EE}=0.58, α_{ES}=0.58, α_{GR}=0.58), while LI, LV, SK, CH, NL represented the lowest *HDI* group in respect of SO_2 (α_{LI}=0.49, $\alpha_{LV}=\alpha_{SK}=\alpha_{CH}=\alpha_{NL}$=0.5);

– all the estimated coefficients are statistically significant at the level of less than 1% of confidence, Chow's test indicates the significance of fixed effects, residuals are stationary but the distribution is different than the normal one, Hausman's test indicates that FEM is more effective than REM;

– although the FE model shows the right direction of analysis, some results of FEM are NOT essentially correct (values of fixed effects).

– Interpretation of spatial FEM (SAR-FEM)-model (2) results (Table 3):

– a 1% increase in SO_2 causes an average decline of 0.01% in *HDI* (α_1= – 0.01), ceteris paribus;

– spatial interactions exist and are positive (ρ=0.8). Interregional relationships (according to the assumed spatial weights matrix) cause a rise in *HDI* in neighbouring countries of 0.8% on average Moreover, there are groups of regions with similar levels of analysed phenomena in Europe;

– between 1990 and 2009, AT, BE, CY, DE, GR showed the highest levels of well-being adjusted by volumes of SO_2 ($\alpha_{AT}=\alpha_{BE}=\alpha_{CY}=\alpha_{DE}$=0.91, α_{GR}=0.92), while SK showed the lowest *HDI* in respect of SO_2 (α_{SK}=0.8);

– coefficients: statistically significant at the level of less than 1% of confidence;

– Chow's test indicates the significance of fixed effects, residuals are stationary, distribution is normal at the level of 10% confidence;

– Chow's test indicates that SAR-FEM (2) is better than FEM (1) and SE-FEM; the results of SAR-FEM are essentially correct;

– both the models: FEM (1) and SAR-FEM (2) prove the hypothesis of the negative impact of emissions on well-being. However, the statistically significant spatial element in the SAR-FEM allows for some specifications;

– spatial interactions intensify the negative influence of SO_2 on *HDI* (from – 0.05 to – 0.01, growth at about 80%). Interregional interactions make the analysed influence stronger;

– values of *const* increased (79%), the share of each country in the general value of *HDI* increased and, in some cases, changed considerably, e.g. α_{AT}=0.52, spatial α_{AT}=0.91: about 75% stronger, α_{SK}=0.5, spatial α_{SK}=0.8: about 60% stronger. The level of *HDI* increased (in respect of higher SO_2). At the same time, there is a positive ρ coefficient in *SAR-FEM*;

– emissions rise within the *HDI* (well-being);

– higher level of *HDI* does not lead to an increase in SO_2: the environment is not among luxury goods;

– positive spatial interactions diversify the countries in respect of well-being: divergence processes;

– SAR-FEMs reflect the analysed relationships more precisely than FEMs: R^2, *Chow's* test for spatial effects, residuals' normality.

The cost of living. Cleaner air should be linked to a longer life expectancy (i.e. the cost of living should be lower). Table 4 shows the results of an econometric analysis considering the influence of air pollution on the cost of living.

Table 4. Spatial panel data models for *lCOSTS* and *lAIRQ*

$lCOSTS_{it} = const + \alpha_i + \alpha_1 lAIRQ_{it} + u_{it}$ **FEM (3)**				
parameter	*value*	*t-Student*	*Standard error*	*p-value*
exp(*const*)	11.13	4.1	0.59	0.000
α_1	**– 0.43**	– 5.1	0.09	0.000
exp(α_i)	AT=17.52, BE=18.59, BG=4.09, CH=16.29, CY=12.91, CZ=11.8, DE=16.99, DK=20.47, EE=7.42, ES=12.52, FI=18.07, FR=16.87, GB=17.2, GR=11.61, HR=5.63, HU=8.32, **IE=23.27**, IT=14.37, LV=5.18, **LI=3.44**, LT=6.7, **LU=43.22**, MT=8.47, NL=20.5, NO=22.3, PL=6.78, PT=10.33, RO=4.66, SE=14.76, SI=10.55, SK=7.85, **TU=3.06**;			
R^2=0,76	*within* = 0,04	*between* = 0,36	*overall* = 0,20	
Chow's test of fixed effects significance: $F^*(1, 607)$ =1.47 , F=45.3, $F>F^*$; Residuals normality: Chi–squared= 6.71, with *p-value* = 0.04; Residuals stationarity: Levin-Lin-Chu, without trend H_1: – 3.33 (0.001), with trend H_1: – 4.06 (0.000); Test of panel effects: rho = 0.82 > 0; F(31, 607) = 45.9, *corr* (*lAIR*; α_i) = – 0.69, prob=0.000, *FEM* more effective than *REM*				
$lCOSTS_{it} = const + \alpha_i + \alpha_1 lAIRQ_{it} + \alpha_2 \rho l\mathbf{W}COSTS_{it} + u_{it}$ **SAR-FEM (4)**				
parameter	*value*	*t-Student*	*Standard error*	*p-value*
exp(const)	4.01	6.5	0.21	0.000
α_1	0.13	4.1	0.03	0.000
ρ	0.91	71.4	0.01	0.000
Exp(α_i)	AT=4.01, BE=4.67, BG=2.34 CH=2.17, **CY=6.89**, CZ=4.09, DE=4.47, DK=3.9, EE=2.59, ES=3.16, **FI=6.17**, FR=4.57, GB=3.53, **GR=6.11**, HR=2.92, HU=4.57, IE=3.56, **IT=6.23**, LV=2.36, **LI=1.14**, LT=3.19, **LU=8.09**, MT=4.57, NL=4.02, **NO=7.03**, PL=3.1, PT=2.97, RO=2.59, SE=5.59, SI=4.57, SK=4.02, TU=2.54;			
R^2=0.98; Chow's test for fixed effects significance $F^*(31, 588)$ = 1.47, F=5.65, $F>F^*$; Residuals normality: Shapiro-Wilk, W = 0.93, *p-value* = 0.08; Residuals stationarity: Levin-Lin-Chu, without trend H_1: – 3.52 (0.000), with trend H_1: – 8.54(0.000)				
Chow's test of spatial effects: $\boldsymbol{F_{SAR\text{-}FEM} > F^*}$**, 56.5>3.52**, SAR-FEM better than FEM and SE-FEM, *p-value* =0.05, F (2,19)				

NOTE: *l*-logarithm; Spatial random effects models were also estimated. However, tests indicated that FEMs are more effective than REMs. Therefore, the main analysis considers the results of FEMs estimations The results of modelling SE-FE and classic RE models: wiszniewska@uni.lodz.pl.

Source: developed by author, using R Cran, STATA 11 and Gretl.

Interpretation of Classic FEM – model (3) results (Table 4):

– a 1% increase in *AIRQ* causes an average decline of 0.43% in *the cost of living* (α_1= – 0.43), the value of this coefficient is not essentially correct; this proves the imperfection of the classic model;

– between 1990 and 2009, LU, IE showed the highest levels of *COSTS* adjusted by volumes of *AIRQ* (α_{LU}=43.22, α_{IE}=23.27), while LI, TU – the lowest *COSTS* in respect of air pollution (α_{LI}=3.44, α_{TU}=3.08);

– all coefficients are statistically significant at the level of less than 1% of confidence, Chow's test indicates the significance of fixed effects, residuals are stationary but the distribution is different from the normal one, Hausman's test indicates that FEM is more effective than REM;

– the results of FEM are NOT essentially correct (the direction of influence).

Interpretation of spatial FEM (SAR-FEM)-model (4) results (Table 4):

– a 1% increase in *AIRQ*: an increase in *COSTS* (α_1= 0.13), ceteris paribus;

– spatial interactions among regions exist and are positive (ρ=0.91). That means that interregional dependences (according to the assumed spatial weights matrix) cause a rise in the cost of living in neighbouring countries by 0.91% on average. Moreover, there are groups of regions with similar levels of the analysed phenomena. The cost of living is higher due to e.g. health problems;

– between 1990 and 2009, LU showed the highest levels of the cost of living adjusted by volumes of emissions (α_{LU}=8.09), while LI showed the lowest *COSTS* in respect of air pollution (α_{LI}=1.14);

– all coefficients are statistically significant at the level of less than 1% of confidence, Chow's test indicated the significance of fixed effects, residuals are stationary, distribution is normal; Chow's test: SAR-FEM better than FEM and SE-FEM;

– results of SAR-FEM are essentially correct (as opposed to FEM).

Interpretation of SAR-FEM vs. FEM results (Table 4):

Only the SAR-FE spatial model proves the hypothesis of *AIRQ's* impact on *COSTS*:

– spatial interactions cause an essentially correct direction between air quality and the cost of living;

– in the SAR model, emissions of AIRQ cause a rise in COSTS (α_1=0,13); in FEM, an increase in AIRQ causes a decrease in COSTS (α_1= – 0.43);

– introducing the spatial factor makes the model rational;

– the values of *const* and the standard errors of all the coefficients decrease and their significance increases in SAR-FEM rather than in FEM;

– the share of each country in the general value of COSTS decreases and, in some cases, changes considerably, e.g. α_{LU}=43.22, spatial α_{AT}=8.09: at about 81%, α_{LI}=3.44, spatial α_{LI}=1.14: at about 67%. The results of the spatial model indicate that there is no leading country but the cost of living is spread among more regions. It is the effect of the increasing level of air emissions and cost of living. At the same time, in *SAR-FEM*, there is a positive ρ coefficient,

– the higher level of air degradation leads to the higher cost of living: the lower quality of health: making each year of life more expensive;

– positive spatial interactions diversify the countries in respect of the cost of living: divergence processes;

– spatial panel models reflect the analysed relationships more precisely than classic methods: R^2, *Chow's* test for spatial effects, higher significance.

– Generally, the spatial models proved the formulated hypothesis and seemed to be more effective than classic FEMs. However, the analysed phenomena are becoming more and more complex and thus require further research.

4. SUMMARY AND DIRECTIONS OF FURTHER RESEARCH

The results of this spatial analysis emphasize the significance of the spatio-temporal correlation among excessive air pollution, the quality of life and cost of living. Spatial panel models confirm the research hypotheses. Specifically, estimation results indicate that polluted air has a negative impact on the broadly understood quality of life. Moreover, air degradation raises the cost of living.

The SAR-FEMs show that spatial interactions among European countries exist and have a significant impact on well-being, the cost of living and quality of air. In Europe, there are regions where the quality of life and well-being are high. It translates into the lower quality of environment. It entails higher costs of a year of living.

Finally, the environment, air in this case, is not among luxury goods that are worth investing in. The monitoring of how those relationships interfere with achieving sustainable development is important for assessing whether territorial units develop as planned.[17] Spatial panel data models constitute an essential element of modelling spatio-temporal relationships in the system of: air quality – economic activity – life quality. This research shows that spatial tools reflect the analysed relationships correctly and more precisely than their classic equivalents. This analysis does not exhaust the subject. Therefore, there are some directions of further research:

- dividing countries into homogeneous groups considering, e.g. the level of the quality of life, air pollution, economic development,
- constructing other synthetic indices of air, life quality, eco-development,
- examining direct relationships among air, health quality, life expectancy,
- taking into account more explanatory variables,
- examining the impact of other environmental factors on the widely understood quality of life,
- application of advanced spatial FE and RE models,
- considering the dynamics of phenomena,
- introducing different types of the spatial weights matrix to models.

A very important aspect of the struggle against environmental degradation is ecological awareness and education. Every person undertaking economic activity should do that considering the well-being and quality of life of future gen-

[17] Institute of Meterology and Water Manangement (2009), *Wpływ zmian klimatu na środowisko, gospodarkę i społeczeństwo*, Project: Climate, http://klimat.imgw.pl/wp-content/uploads/2010/09/zad.4.r2009web.pdf, date of entrance: 10th of June 2012.

erations. Environmentally-aware people treat the environment as one of luxury goods that deserves investment.

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Elżbieta Antczak

DEGRADATION OF AIR AND QUALITY OF LIFE – SPATIAL PANEL ANALYSIS

The main purpose of the paper is to identify and analyse a correlation between excessive air pollution, well-being and the cost of living. The analysis was performed using spatial panel models. Two research hypotheses were confirmed. One assumed a negative impact of excessive air degradation on the level of socio-economic development. The other concerned an increase in the cost of living due to air pollution. 32 selected European countries were studied from 1990 to 2009.

The level of socio-economic well-being was expressed by measures of the *GDP per capita* and *HDI*. The cost of living was presented by means of a measure designed by the author – *COSTS*. Air quality was expressed in terms of SO_2, *CO*, NO_x, *GHG*, CO_2 and a constructed synthetic measure – *AIRQ*.

DEGRADACJA POWIETRZA A JAKOŚĆ ŻYCIA – PRZESTRZENNA ANALIZA PANELOWA

Głównym celem publikacji jest identyfikacja i analiza zależności pomiędzy nadmiernym zanieczyszczeniem powietrza a poziomem jakości życia (dobrobytem społeczno-ekonomicznym, kosztami życia). Analizę przeprowadzono z zastosowaniem przestrzennych modeli panelowych. Weryfikacji poddano dwie hipotezy badawcze. Jedna zakłada negatywny wpływ nadmiernej degradacji powietrza na poziom dobrobytu społeczno-ekonomicznego. Druga mówi o wzroście kosztów życia z powodu zanieczyszczeń atmosfery. Badanie dotyczyło wybranych 32. państw Europy i okresu czasowego od 1990 do 2009 roku. Poziom jakości życia wyrażony został: *PKB per capita*, indeksem *HDI* oraz skonstruowanym miernikiem *COSTS*. Jakość powietrza wyrażono w: SO_2, *GHG*, CO_2 oraz skonstruowanym miernikiem syntetycznym *AIRQ*.