ACTA UNIVERSITATIS LODZIENSIS
FOLIA OECONOMICA 292, 2013
https://doi.org/10.18778/0208-6018.292.11

Renata Jaworska[*]

APPLICATION OF MIMIC MODEL TO CONSTRUCTION OF ENVIRONMENTAL PRESSURE INDEX

1. INTRODUCTION

A range of environmental problems now affect our whole world. As globalization continues and the earth's natural processes change local problems into international issues. Pressure on environment is more and more. It comes from different sectors, depending on the resource that is having an influence on.

Governments are under greater than ever pressure from international bodies and non-governmental organizations to reduce their emitting activities and define an environmentally friendly economic growth plans. These increasing international concerns require an index that allows evaluating the environmental performance of countries over time. Empirical researchers may be also interested in such an environmental performance measures for various cross-country analyses.

The main aim of this paper is calculating an actually index of environmental pressure and providing a ranking for 33 European countries from 2009. Other specific goals of our research are: appraisal of spatial diversity the environmental pressure across the Europe. Cause-effect analysis of the environmental determinants in European countries, using MIMIC model.

The most of the surveys, which explain the relationship between air pollution and economic, political and social impacts, are based on individual indicators. Those approach only allow to explain the effects of the variables of interest on one indicator of environmental pressure.

In our studies, the specific measure of environmental pressure, using Multiple Indicators Multiple Causes (MIMIC) model, will be created[1]. The MIMIC model, a particular form of structural equation models, can analyze relationships between latent variables and their indicators.

[*] M.A., Department of Spatial Econometrics, University of Lodz.

[1] This problem has also been discussed by Andreas Buehn from Utrecht School of Economics (2009) in an application of the MIMIC model to calculate Environmental Pressure Index for 122 countries all over the World.

2. THEORETICAL ASSUMPTIONS AND METHODS

The theoretical and analytical background for the study of environmental pressure in the literature is the theory of the Environmental Kuznets Curve (EKC)[2]. The Environmental Kuznets Curve hypothesis states the relationship between various indicators of environmental degradation and income per capita. It may be graphically represented by an inverted-U curve. The shape of this curve implies that high income leads to greater degradation, up to a turn point at which incremental increases in income cause the curve to begin to slope downwards, implying upgrading in the quality of the environment.

In the early phase of economic growth, degradation and pollution increase, but beyond some level of the income per capita, which can be vary for different indicators, the trend reverses, so that at high income levels economic growth leads to environmental improvement. Typically, the logarithm of the indicator is modeled as a quadratic function of the logarithm of income (Stern 2004, p. 1419). To construct Environmental pressure index it was used a particular form of Structural Equation Modeling that's called Multiple Indicators Multiple Causes Model. Generally SEM allows to estimate caused-effect relationship between a lot of observed variable as well as latent variable, which can't be measured directly. SEM is a combination of two methods: path analysis and confirmatory factor analysis. The first one is a form of graphical representation of a model. One of the easiest ways to explain SEM is to a draw a diagram of it, referred to as path diagram. Such a diagram is equivalent to a set of equations defining a model and is typically used as an alternative way of presenting a model scheme. Observed and latent variables are represented in path diagrams by two distinct graphical symbols. Squares or rectangles are used for observed variables, and circles or ellipses are employed for latent variables. The main focus of this approach is relationships between latent and observed variables. They are represented graphically in a path diagram by one-way and two-way arrows. The first one signal that the variable at the end of the arrow is explained in the model by the variable at the beginning of the arrow. Two-way arrows are used to represent covariation between two variables (Raykov, Marcoulides 2006, pp. 8–12).

Confirmatory factor analysis determines whether the hypothesized structure provides a good fit to the data, or in other words, that a relationship between the observed variables and their underlying latent, constructs exist.

Some of the paths shown in the diagram are labeled with the number "1". This means that those paths' coefficients have fixed values set to 1.00. These fixed values are included by obligation: they set the scale of measurement for the latent factors and residuals. Alternatively, it can be set the variances of the factors to 1.00 to obtain totally standardized solutions. In this study it has been

---

[2] The EKC is named for Kuznets (1955) who hypothesized that income inequality first rises and then falls as economic development proceeds.

investigated a particular alternative of a SEM with one latent endogenous variable which is environmental pressure. This so-called MIMIC model (Jöreskog, Goldberger, 1975) allows us to analyze the relationship between environmental pressure and its determinants. The key benefit of the MIMIC approach is that it allows taking into account more than one measure of environmental pressure at a time. Generally a MIMIC model consists of two parts (Jöreskog, Goldberger, 1975):

– The structural equation submodel:

$$\eta_1 = \mathbf{\Gamma x} + \zeta_1, \tag{1}$$

where: η- latent variable, index of environmental pressure, $\boldsymbol{x} = (x_1, x_2 \ldots, x_q)$ is a q vector and each x_i is a potential cause of η, $\boldsymbol{\Gamma}$- vector of coefficients in the structural model describing the "causal" relationships between environmental degradation and its causes;

– Measurement submodel:

$$y = \mathbf{\Delta}\eta_1 + \varepsilon, \tag{2}$$

where: $\boldsymbol{y} = (y_1, y_{2,\ldots,} y_p)$, vector of indicators of environmental pressure, $\varepsilon = (\varepsilon_1, \varepsilon_{2\ldots,} \varepsilon_p)$, vector of disturbances, $\boldsymbol{\Delta}$ - vector of regression coefficients.

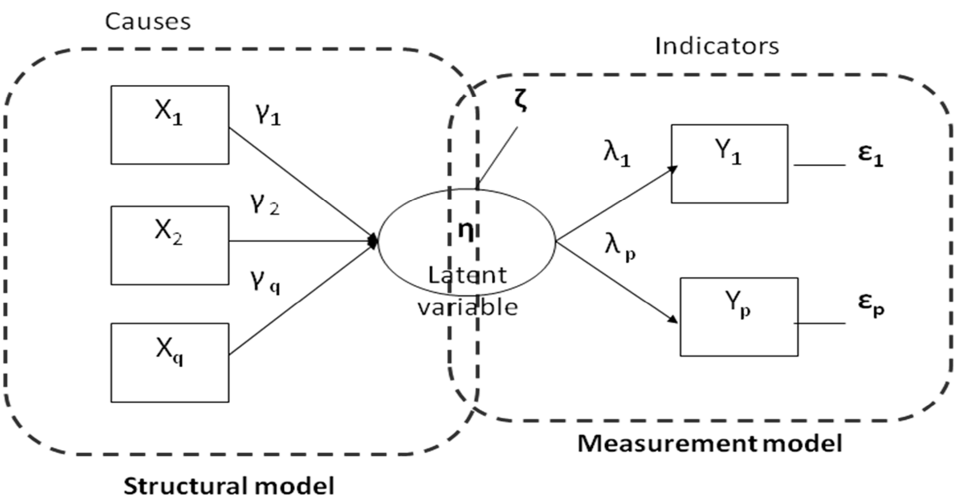

Figure1. Path diagram of simple MIMIC Model

Source: developed by the author based on (Farzanegan, Buehn, 2009).

3. DATA SET

The Data have obtained for 33 European countries from 2009. There are the most actual data that it was available for all variables. The data derived from World Databank[3], Eurostat[4] and some political indicators from United Nation site[5]. All of variables are expressed as rates of intensity.

Causes of environmental pressure have been divided into three groups: economic, demographic, governance factors. Potential economic variables are: log of GDP per capita,squared log of GDP per capita, industry value added (% of GDP), electricity production from coal sources (% of total electricity production), energy efficiency (log of GDP per unit of energy). Demographic causes can be: rural population and working population. And governance factor: instability index and corruption index (Table 1). As a potential indicators, according to EKC, there are taking into consideration 3 indicators of air pollution. The first one carbon dioxide emissions per capita as a global air pollution, sulfur oxides emissions per capita and nitrogen oxides per capita as a local air pollution (Table 1).

Table 1. Specification of the model

Name	**Variable**	**Expectation correlation**
Causes		
GDP_log	Log of GDP per capita in US$	+
GDP2_log	Squared log of GDP per capita in US$	–
IND	Industry, value added (% of GDP)	+
ENERGY_log	Energy efficiency (Log of GDP per unit of energy)	–
COAL_ EL	Electricity production from coal sources (% of total electricity production)	+
RURAL	Rural population (% of total population)	–
WORK	Population ages 15-64 (% of total population)	+
INSABIL	Political Instability index, higher values higher instability (values 1-10)	+
CORRUP	Corruption index, higher index values indicate less corruption (values 1-10)	–
Indicators		
CO_2_log	Log of carbon dioxide emissions per capita (in tonnes)	+
SO_log	Log of sulfur oxides emissions per capita (in kg)	+
NO_log	Log of Nitrogen oxides emissions per capita (in kg)	+

Source: developed by the author.

To depict a relation resulting from EKC approach, there are shown two main variables on Fig. 2and Fig. 3. Presented maps show value of two observed variables used in the model: GDP per capita as indicator variable and carbon dioxide per capita as causal variable. When we compare these two maps, we can

[3] databank.worldbank.org.
[4] ec.europa.eu/Eurostat.
[5] mdgs.un.org.

see that countries with higher values of GDP have higher values of emission CO_2. But for example Sweden is opposite to this. It can be explicated that Sweden has crossed a turning point on the EKC curve. Accordingly higher values of GDP cause less emissions of CO_2.

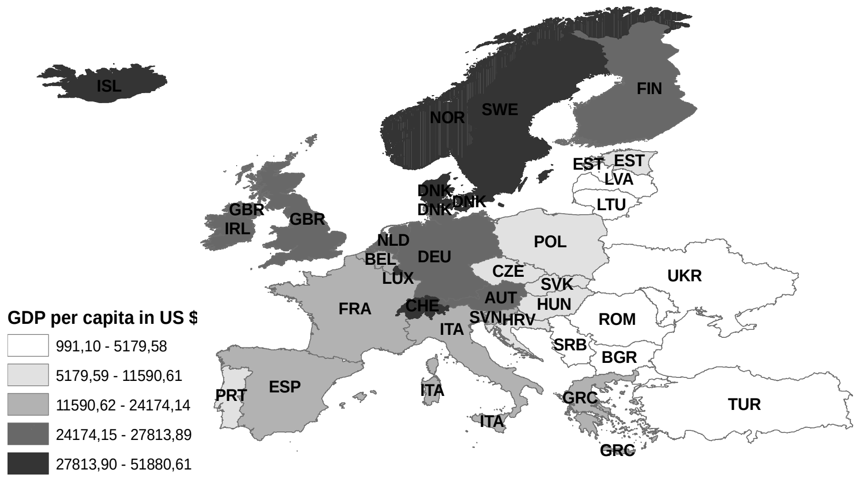

Figure 2. GDP per capita in European countries in US $

Source: developed by the author using ArcMap.

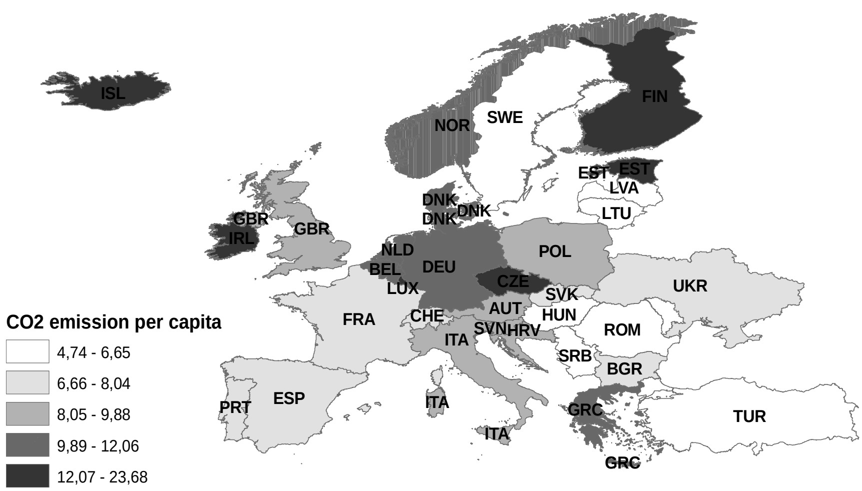

Figure 3. CO2 emissions in European countries in tonnes per capita

Source: developed by the author using ArcMap.

4. RESULTS OF THE SURVEY

The most common method of an estimation in SEM is Maximum Likelihood method. The goal of the estimation procedure is to find values for the parameters and covariances that produce and estimate for model's covariance matrix that is as close as possible to the sample covariance matrix **S** for the observed causes and indicators. The estimation procedure deriving the parameters minimizes the following fitting function (Bollen 1989, p. 135):

$$F_{ML} = \log\left|\hat{\Sigma}\right| + tr\left(S\hat{\Sigma}^{-1}\right) - \log\left|S\right| - \left(p+q\right). \tag{3}$$

Table 2. Regression coefficients of the estimated MIMIC model

			Estimates	S.E.	C.R.	p	Label
EPI	←	GDP2_log	– 0.095	0.015	– 6.380	***	par_1
EPI	←	ENERGY_log	– 0.591	0.097	– 6.101	***	par_2
EPI	←	COAL_EL	0.002	0.001	2.363	0.018	par_3
EPI	←	CORRUP	– 0.037	0.017	– 2.175	0.030	par_4
EPI	←	GDP_log	1.500				
EPI	←	INSTABIL	– 0.011	0.017	– 0.622	0.534	par_5
CO_2_log	←	EPI	1.000				
NO_log	←	EPI	1.002	0.183	5.471	***	par_6

*** p-value< 0.001.

Source: developed by the author using SPSS AMOS 19.0.

Table 2 reports result of a MIMIC model estimation. This is the best specification for a proposed model. With the exception of variable called instability, all other parameters are statistically significant with significance level equal 0.05. It can't be seen results for GDP parameter because of the constrain that is used to confirm EKC assumption. Besides CO_2 parameter had to be normalized to a value 1, what it is caused by a confirmatory factor analysis. To calculate EPI index they are needed standardized coefficients, so Figure 4 shows a path diagram of estimated model with standardized coefficients.

Only one variable isn't statistically significant. Altogether, five variables turned out to be significant causes, among them are variables describing economic and political conditions. We can find a significant positive correlation for the GDP per capita and a significant negative correlation for its squared term confirming the EKC hypothesis. Energy efficiency is negatively correlated to environmental pressure, while the correlation of the electricity production from a coal is as expected positive. In addition, interesting is a fact that political situation influences on environmental pressure.

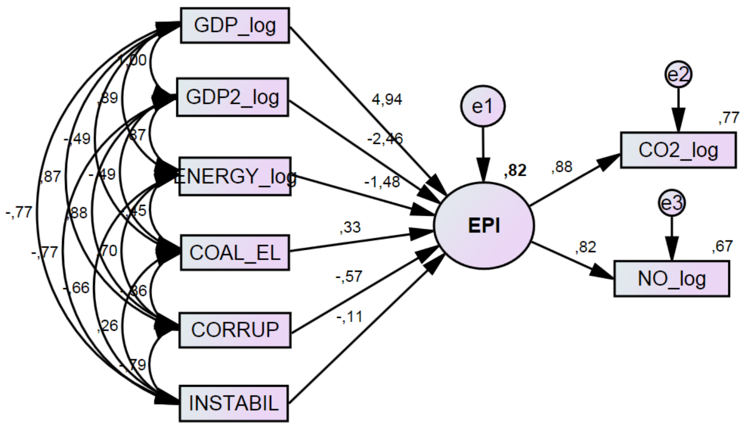

Figure 4. Path diagram of MIMIC model with standardized coefficients

Source: developed by the author using SPSS AMOS 19.0.

Summing up, we might conclude that all significant causes have the expected sign.

Table 3. Theoretic goodness-of-fit measures of MIMIC models

Measure	Good fit	Description
Chi-square	$p > 0.05$	The chi-squared test indicates the difference between observed and expected covariance matrices. Sensitive on sample size (Bollen 1989, pp. 263–266).
X^2/df	< 5	Chi-square ratio to degrees of freedom (Wheaton 1977).
RMR	< 0.08	Root Mean Square Residual, the square root of the discrepancy between the sample covariance matrix and the model covariance matrix (Jöreskog, Sorbom 1981, p. 41, 1989 p. 44).
GFI	> 0.95	Goodness of Fit Index, a measure of fit between the hypothesized model and the observed covariance matrix (McDonald 1999, p. 84).
AGFI	> 0.95	Adjusted Goodness of Fit Index, corrects the GFI, which is affected by the number of indicators of each latent variable (McDonald 1999, p. 84).
AIC	Smaller values better fit	Information-theoretic measures are intended for model comparisons and not for the evaluation of an isolated model (Akaike, 1987, pp. 317–332, Schwarz, 1978).
BIC	Smaller values better fit	

Source: developed by the author.

Various goodness-of-fit measures are available to examine the validity and reliability of the estimated MIMIC models. The most popular is chi-square ratio. The chi-square statistic tests the specification of the model against the alternative that the covariance matrix of the observed variables is unconstrained. Here, smaller values indicate a better fit. But it's sensitive on a sample size. Others alternative measures can be: GFI and AGFI, which show how closely the reproduced covariance matrix is to the covariance matrix of the observed causes and indicators taking the model's complexity into account. Besides there is a Root Mean Square Residual and Information-theoretic measures.

According to obtained goodness-of-fit measures it is claimed that the MIMIC model of environmental pressure fits the data very well. It is caused by low value of RMR and high value of GFI. Chi-square statistic it wasn't taken into consideration because of too small sample. The equation's form after estimation is as fallow below:

$$\begin{aligned} EPI &= 4{,}94*GDP\_log - 2{,}46*GDP2\_log - 1{,}48*ENERGY\_log \\ &+ 0{,}33*COAL\_EL - 0{,}57*CORRUP. \end{aligned} \tag{4}$$

From theoretical point of view, economic factor (GDP) has the strongest impact on environment status. It confirms EKC hypothesis, which tells about relationship between economic development and environmental status in countries. The next fairly strong determinant of environment status is energy efficiency. Higher energy efficiency means less pressure on environment. The scores shows how important is saving energy for clean air. Other two factors of environmental pressure are electricity from coal sources and political index of corruption. Outside of GDP per capita, energy efficiency is the second reason differential the environmental pressure across the European countries.

Should be added that environmental status is measure by air pollution (CO_2 emission and NO emission). There are the most frequently used environmental indicators.

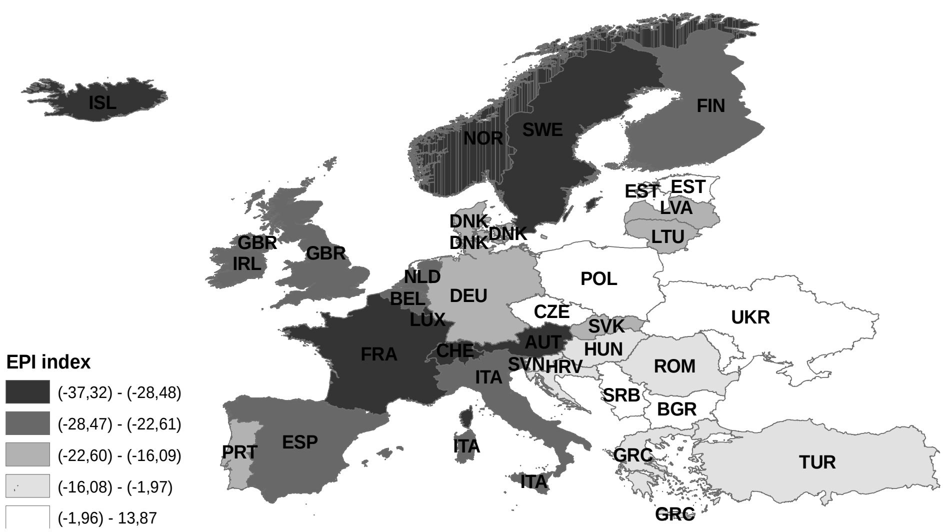

Figure 5. Values of EPI index across European countries

Source: developed by the author using ArcMap.

The Figure 5 (above) presents a drawn map with values of environmental pressure index across European countries. Higher value of the index indicate higher the environmental pressure in a country.

According to this index, the country with the lowest level of environmental degradation is Luxemburg fallowed by Norway, Switzerland, Iceland and Austria. The highest level of environmental pressure have: Poland, Estonia and Serbia. The ranking of the countries is not amazing. Generally, highly developed countries of Western and North Europe have the lowest environmental pressure, except for Denmark and Deutschland. These countries characterized by high GDP per capita present medium, not small, environmental pressure.

5. CONCLUSION

As a consequence, results have been obtained that made it possible to put forward the following conclusions. The most important causes of environmental pressure in European countries have turned out: GDP per capita, energy efficiency, electricity production from coal sources, corruption. It confirmed EKC hypothesis, which assumes an impact of economic development on the environment.

The ranking of the countries is a little surprising, because not all highly developed countries of Western and North Europe have the lowest environmental pressure. It is caused by some differential determinants like energy efficiency or energy from coal sources. Therefore, Denmark and Deutschland have included only in third position group of countries according to the environmental pressure. On the other hand, France for example has reached a very good position in the ranking, because of small percentage of production energy from coal sources (most of the energy in this country is produced by nuclear power plants).

We found that the MIMIC model is a good alternative way of many solutions for presentation of a synthetic measure which is EPI index. But the main advantage of this tool is possibility of analyzing relationships between environmental causes and indicators simultaneously at a time. Results of the survey should be treated cautiously because the study is based on a few chosen variables, that data were available for.

REFERENCES

Akaike H. (1987), *Factor analysis and AIC.Psychometrika*. No. 52.

Bollen K.A. (1989), *Structural Equations with latent variables*. New York: Wiley.

Buehn A., Farzanegan, M.R. (2009), *Environmental Pressure Index: Evidence from a Structural Model*. The electronic version of the publication is under review: http://www.eea-esem.com/EEA-ESEM/2011/m/viewpaper.asp?pid=1139 *(access 01.06.2012)*

Biswas A.K., Farzanegan, M.R, Thum, M. (2011), *Pollution, Shadow Economy and Corruption: Theory and Evidence,* CESifo Working Paper No. 3630.

Jöreskog K.G.,Sorbom, D. (1981), LISREL V: Analysis of Linear Structural Relationships by Maximum Likelihood and Least Square Methods. (Research Report 81-8). Uppsala, Sweden: University of Uppsala, Department of Statistics.
Jöreskog K.G., Goldberger, A.S. (1975), *Estimation of a model with multiple indicators and multiple causes of a single latent variable,* Journal of the American Statistical Association, 70 (351).
Jöreskog K.G.,Sorbom, D. (1989), *LISREL VII: A guide to program and applications,* SPSS Inc.: Chicago, Illinois.
Konarski R., (2009), *Modelowanie równań strukturalnych,* Warszawa: PWN.
McDonald R.P. (1999), *Test theory: A unified treatment,* Mahwah, N.J.: LEA.
Raykov T., Marcoulides, G.A. (2006), *A first course in Structural Equation Modeling,* Mahwah, New Jersey: Lawrence Erlbaum Associates.
Stern D., (2004), *The rise and fall of the environmental Kuznets Curve*.World Development Vol. 32, No. 8.
Wheaton B., Muthen, B., Alwin, D., Summers, G., (1977), *Assesing reliability and stability in panel models,* W: D.R. Heise (ed.) Sociological Methodology 1977. San Francisco: Jossey-Bass.
databank.worldbank.org (access 01.06.2012)
ec.europa.eu/eurostat (access 01.06.2012)
mdgs.un.org (access 01.06.2012)

Renata Jaworska

APPLICATION OF MIMIC MODEL TO CONSTRUCTION OF ENVIRONMENTAL PRESSURE INDEX

The article aims at estimating the environmental pressure index and provide a ranking for selected European countries with the use of a Multiple Indicators Multiple Causes (MIMIC) model. The MIMIC model is a special form of Structural Equation Modeling able to estimate models with latent variables. This type of model is used to derive information about the relationship between cause and indicator variables and a latent variable, here the index of environmental pressure, from covariance structures. This research analyzes an influence of some causes like GDP per capita, energy efficiency, industrial production, urbanization and working age population as well as the produced electricity from coal sources on the environment. The main indicators of the environmental pressure are CO2 and SO2 emissions per capita.

The index of environmental pressure is finally arrived at with the use of statistically significant causes affecting the quality of the environment. The results of this paper will allow to create a ranking of European countries according to the environmental level. It can be a source of important information for UE environmental policy and for all governments, which closely monitor the environmental performance of individual Member States.

ZASTOSOWANIE MODELU MIMIC DO BUDOWY INDEKSU ODDZIAŁYWANIA NA ŚRODOWISKO

Celem artykułu jest oszacowanie indeksu oddziaływania na środowisko w wybranych krajach Unii Europejskiej z wykorzystaniem modelu MIMIC (Multiple Indicators Multiple Causes). Modele MIMIC należące do klasy modeli równań strukturalnych (SEM), pozwalają na estymację modeli ze zmienną ukrytą. Ten typ modeli pozwala na badanie zależności pomiędzy wskaźnikami pełniącymi rolę przyczyn i skutków oraz zmienną nieobserwowalną, tutaj indeksem oddziaływania

na środowisko. W niniejszym badaniu analizie poddany zostanie wpływ takich czynników jak PKB pre capita, efektywność energetyczna, produkcja przemysłu, stopień urbanizacji czy produkcja energii z konwencjonalnych źródeł energii na stan środowiska. Głównymi wskaźnikami mierzącymi stan środowiska są emisja dwutlenku węgla i emisja dwutlenku siarki.

W rezultacie indeks oddziaływania na środowisko utworzą istotne statystycznie wskaźniki wpływające na jakość środowiska. Wyniki badania pozwolą utworzyć ranking krajów Unii Europejskiej ze względu na jakość środowiska. Poza tym mogą stanowić cenne wskazówki w prowadzeniu polityki środowiskowej w UE oraz poszczególnych krajach członkowskich.