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The sustainable development modeling and mechanisms of its implementation on regional level

This paper deals with modeling the relationship between emissions and such influencing factors as per capita income and climate conditions. It is found that automobile emissions follow EKC pattern, that is relationships between per capita income and pollution are inverted U-shape. The overall pollution does not show bell-shaped relationships, and growing steadily together with per capita income. In terms of sustainable economics it means that Ukraine is on yet on the path of sustainable development due to overall pollution, which is constantly increasing.

Keywords: sustainable development, environmental Kuznets curve, "income-pollution" relationships, economic mechanism.

Introduction

There is an old debate about the relationships between economic growth and the environmental quality. One of an ambiguous questions of an Environmental Economics is how to treat the increase in countries well being. That is we need to clarify whether economic growth positively or negatively influences the environmental quality. The recent studies conducted in the area of Environmental Economics suggest inverted U-shape relationship between pollution and per capita income. *The sustainable economic development is achieved when economic growth is associated with decline in the total level of pollution, and there are available resources for future generations to meet their own needs. The first problem about the relations and of economic growth and pollution is discussed in this paper.* The bell-shaped link between pollution and income is known as *Environmental Kuznets Curve (EKC)*; after Simon Kuznets, who in 1955 showed that at the early stages of a country's development the gap between poor and rich increases, while later when the country becomes wealthier the inequality gap decreases. The EKC pattern suggest that on the first stages of country's development there is a negative link between pollution and growth, but later when people become wealthier more attention is paid to the pollution, and as a result environmental quality improves. The EKC relationship may be simply described as inverted parabola. The particular interest of such kind of the relationship is the *turning (break) point*, that is the amount of income per capita when the pollution starts to decline.

The structure of the paper is as follows. First, we provide the literature review on the topic. Second, we present methodology and describe the data used. Third, the empirical model is estimated and EKC results are analyzed from the sustainability point of view.

In 1995, Grossman and Krueger [1] on the basis of cross-country analysis introduced the inverted *U-shape* relationship between pollution and per capita income. In their seminal work, Grossman and Krueger tested different pollutants and found that in countries with low GDP per capita concentration of dangerous chemical substances initially increased but then, after some specific level of income (which was different for different pollutants), concentration was

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decreasing. The form of the relationship between pollution and income was found exactly inverted U –shape. The authors estimated *break points* for per capita income (measure of people well-being when pollution starts to decline), and found that they were at the level of $4,772-$5,965 (in 1990 prices).

Panayotou [2] summarized 30 published articles and working papers on the EKC, of which 27 were cross-country analysis, and the EKC hypothesis was confirmed for SO2, NO_x, and suspended particulate matters.

In the early EKC studies little attention was paid to the properties of the data and methodological issues that could explain the pollution-income relationship. Also the cross-country analysis was widely criticized for the lack of theoretical background at international level. That is why the late 1990s brought some new developments into the treatment of the EKC, and inverted *U-shape* relationship was tested at the regional level – within boundaries of some specific countries.

The dependent variable pollution is usually presented as concentrations or emissions. The concentrations of chemical substances are measured in mg/m^3, while emissions are measured in tons (kilograms). It appears to be that the obtained results were not the same for different types of measurement (concentration vs. emission). For example, the estimated break points of per capita income were lower for concentrations as compared to emissions. In some cases, these discrepancies in break points were very significant. For example, Panaytou used concentrations in his study on sulfur dioxide pollution and estimated a *break point* as $3,137 (in 1990 prices) while Stern and Common used emissions and ended up with $101,166 (in 1990 prices USD).It appears to be that for the same specification of the model, but with different data sets, the break points differ because of the difference in coefficients. One of the hypotheses behind the concentration model to exhibit lower break points is the omission of weather *conditions*.

The bell-shaped relationship between pollution and income can be explained under several assumptions. Thus, starting the bulk of EKC assumptions the Lopes [3], wrote that EKC can be observed only due to *nonhomothetic preferences* of economic agents. Under the homothetic individual preferences, an increase in income leads to higher consumption, which causes higher pollution. Individuals with nonhomothetic preferences along with rising income may desire less consumption and pollution, depending upon relative risk aversion between consumption and environmental safety. Another theoretical approach that explains the shape of the EKC assumes that environment is a *luxury good*. It implies that if income increases by 1%, the demand for safe environment increases by more that 1%, but empirical studies conducted in this area, for example McConnell [4] showed some inconsistencies regarding luxury good explanation of EKC. Thus, the Environment in the EU countries is considered to be a normal good with income elasticity of demand a little higher than one.

Finishing the theory of EKC we present the work done by *Jaeger and Kolpin* [5], which deals with environmental quality and income per capita. Their theoretical model is not described in full amount; we just say that using above mentioned assumptions *Jaeger and Kolpin* [5] constructed the theoretical framework and it was shown that the link between population and environment is also inverted U-shape. As for the income-pollution, the main finding of the article was formulated as follows: "During the early phase of growth, environmental quality will decline with increases in the derived demand for waste disposal and extractive service. Consumption will increase and environmental quality will decline. Beyond some point, however, rising per capita income and the higher relative scarcity of environmental quality will shift the allocation in such a way that environmental quality improves". Furthermore it was shown that marginal substitution between income and pollution increases as income rises. The income-pollution relationship described by Beckerman [6] shows that the best way to improve environment is to become rich. Summarizing the theoretical background we state that using the set of assumptions it's possible to construct theoretical framework that explains the "bell-shaped relationship" between pollution and income.

With respect to empirical work much of attention has been paid to the Grossman and Krueger [1] study, which started the EKC studies in environmental economics. Grossman and Krueger estimate the reduced form equation for pollution which is dependent variable with the present and lagged values of GDP per capita as explanatory variables. The data for the study was taken from the GEMS/Air project, and the number of cities in different countries varied from 7 cities in 4 countries to 47 cities in 28 countries. Grossman and Krueger consider that the main advantage of the reduced form (which they used in their paper) is that it allows estimating net effect of per capita income on pollution. Second advantage of reduced form approach is that it does not depend on legal regulations and the state of technology.

Their estimation model is.

$$Y_{it} = \beta_1 G_{it} + \beta_2 G^2{}_{it} + \beta_3 G^3{}_{it} + \beta_4 \overline{G_{it}} + \beta_5 \overline{G^2{}_{it}} + \beta_6 \overline{G^3_{it}} + X_{it}\beta_7 + \varepsilon_{it} \quad (1)$$

where Y_{it} – is a measure of water or air pollution in station *i* in year *t*

G_{it} – is a GDP per capita in a year *t* in the country where the station *i* is located

$\overline{G_{it_{it}}}$ – average GDP per capita over the period of 3 years.

X_{it} – vector of other covariates

ε_{it} – error term

Grossman and Kruger suggest using median values of air pollution during some specific year in all observed situations. For the water pollution, the authors suggest using mean values of pollution. GDP estimates were taken from the World Bank estimates.

A three year lag was included in order to approximate hypothesis of permanent income. Moreover, the authors assume that lagged values of GDP per capita also have significant influence on the level of pollution. Cubic parameters are considered to be flexible enough to describe the various relationships between pollution and GDP. It was found by Grossman and Krueger (1995) that for small levels of incomes there was a positive correlation between income and pollution, but for higher levels of income relationship was negative.

In Grossman and Krueger model, location of a station (rural or urban area), and the nature of the land used nearby the station (industrial, commercial, residential or unknown) are treated as dummy variables. Population density of a city and character of a city (how far it is from sea side, reflecting absorbing properties of the atmosphere) are also included into the model.

Cramer [7] analyzes the relationship between population growth and local air pollution. Error term in his model reflected unobservable factors such as culture, local values, and technological changes. Cramer [7] uses logarithmic Cobb-Douglass production function to explain the pollution on cross-country level. The estimated model is as follows:

$$\ln I = \beta_0 + \beta_1 \ln(P') + \beta_2 \ln(A') + \beta_3 \ln(R') + \varepsilon_t \qquad (2)$$

where *lnI* – trends in county's emissions;
LnP – growth rate of population;
LnA – trend in per capita income;
LnR – trend in regulated technology (amount of money spend by local government on environmentally clean technology)

Cramer claims that countries with higher per capita income growth, experience slower population growth, and as a result, lower pollution. Large population growth is associated with higher increase in emission, so the coefficient β_2 is positive.

Below we provide critique of cross-country analysis and present argumentation for the estimation of EKC on individual country level. The cross-country approach was criticized by Egli [8], who favored the EKC at a single country level. The main critique of the cross-country analysis is that the estimated coefficients are uniform for all countries. This is questionable since different countries do not follow the same pattern in their development. The research was continued by Matthew Cole [9] who criticized the cross-country approach of the EKC estimation as well. In his paper, it was stated that *"*It's unrealistic to believe that the shape of the relationship between income and pollution will be the same for each country. Given the differences in Economies, political Structures, geography, cultural and climate that exist across countries there is no reason to believe that the same income-pollution relationship will be experienced by, for example, countries as diverse as Switzerland and Cameroon".

Other critique of cross-country approach is given in Cole .In order to control for each country's specific features, the random coefficient approach in estimation was used by Cole. Cole [9] used different intercepts, but the same slopes for different countries. Random coefficient approach was applied to a sample of OECD countries, and the EKC relationship was tested for three pollutants, namely SO_2 NO_x and CO_2. The results supported the inverted U-shape curve. However, high sensitivity of the results to the sample size suggests that there is no common EKC for the sample of OECD countries.

In addition to that, when Vincent [10] estimated the EKC for Malaysia, and found the results to be in contradiction with the cross-country analysis. Predicted break points for the country like Malaysia on the basis of a cross-country approach were inconsistent with a single country analysis approach.

Vincent [10] states that the cross-country analysis "may simply reflect the juxtaposition of positive relationship between pollution and income in developing countries with a fundamentally different negative one in developed countries, not a single relationship that applies to both categories of countries". At a cross-country level, the EKC is not necessarily shows the link between income and pollution. It may be the case, as Vincent argues, that rich countries just transfer production to poorer countries, and the EKC is just a statistical artifact. Moreover, studies done by List and Millimet [11] for the United States showed that each state had its own break point. The fact, that states in the US are more homogeneous among each other than different countries in a sample provides support for the idea about impossibility of applying single model for all countries. As a result, the use of the EKC at the cross-country level is inconsistent due to violation of the assumption of heterogeneous growth pattern amongst different countries.

Perman and Stern [12] used data for 74 countries on sulfur dioxide pollution over the period of thirty years. The data set was tested for cointegration of income per capita and pollution. Estimation showed that for many countries panel series were integrated. As a result, Perman and Stern concluded: "Results of the panel cointegration statistics are mixed. Even if there is cointegration in the panel, many of the individual EKC functions are U-shape or monotonic in income. There is no cointegration vector common to all countries. The results show that the EKC may be a problematic concept, as simple global EKC models are misspesified". We use this conclusion as an additional argument in favor of estimating the income-pollution relationship at the regional level or within boundaries of one specific country. As an intermediate conclusion, *all above mentioned arguments suggest that the EKC may exist only at a country level. This study will test this assumption on the basis of estimation of the EKC for Ukraine using data at regional level.* It is also possible to claim the above mentioned arguments can be used in order to show that EKC will not exist on country level, rather on regional, e.g. each region has its own EKC. One possible explanation of EKC on cross-country level is that rich countries transfer their production to poor ones;[13, p.152] we cannot use that argument within one country, because of the uniqueness of legislation (human rights, freedoms). For example, if firm A transfer its dirty production from one region to other (assume more poor), the firm will gain on wages, but lose on transportation cost, plus payment to the government for the pollution are the same as in previous region. So it is impossible reduce cost on pollution within one country, except adopting more environmentally friendly production process, or transfer production to more poor countries, as for Ukraine we don't have poorer neighbors. In that sense the arguments against EKC on cross-country level cannot be apply for our research, and if EKC originates in Ukraine it be due to some technological changes or through the impact of authorities, which is exactly the point we want to estimate within Ukraine

The main research questions of the paper

The sustainable economic development is achieved when economic growth is associated with decline in the total level of pollution, and there are available resources for future generations to meet their own needs. We are discussing and modeling sustainable development framework for Ukraine in terms of "income- pollution" relationships. The main research question is whether liberal mechanisms of economic growth are sufficient to guarantee sustainable development of Ukraine.

Descriptive statistics and methodology

The data set used in this study consists of three blocks: (i) income block, (ii) pollution block, and (ii) meteorological block.

The Income block includes data on 25 regions. Basic variables in the income block are average annual wages in regions and per capita income. Data for per-capita income and wages is taken from the Ukrainian Statistical Year Books. On average, each region is represented by two cities.

In addition to that, for the regions, we consider total *employment* and also total capital assets in each region.

The pollution block consists of *emissions*. Emissions are measured in tons. Emissions of pollutants are not measured individually like concentrations, but reported separately by each firm. Based on this information, the Statistical Committee calculates emissions for the whole region and/or for some big cities. Emissions are presented as quantities of pollutants emitted by transport and by stationary polluters (firms). The sum of transport pollution and pollution from stationary polluters represents the vector of overall pollution in a region or city.

The meteorological block is presented by such indicators as the number of days in a year with *smog, precipitations, winds, and annual average temperature*. Based on these indicators, a vector of climate variables was constructed which includes: percentage of days with smog, winds, precipitation during a year; average temperature. All these indicators are given at the regional level.

The regional data is presented by their own emissions, climate variables, and income variables. The entire data set is constructed for the period of *nine* years 1998-2006, which gives us 225 observations on each indicator at the at the regional level.

The methodological part is devoted to emissions as a dependent variable. The data set is associated with new assumptions to be tested. One of the hypotheses to be tested (except major EKC) is that vector of climate variables (VCV) has no significant influence on emissions. To test this hypothesis, the following model is proposed (quadratic and linear forms are tested):

$$E_{it} = \beta_0 + \beta_1 Y_{it} + \beta_2 Y_2^2{}_{it} + \beta_4 T_{it} + \beta_5 W_{it} + \beta_6 R_{it} + \beta_7 S_{it} + \varepsilon_{it} \qquad (3)$$

where E_{it} – stands for pollution in a city *i* in year *t*, *Y* stands for per capita income in each particular region, *T* – is average annual temperature in each region *i, W* – is the percentage of days in the year with wind in each particular region, *R* – is the percentage of days in the year with precipitation in the region, *S* – is the percentage of days in the year with smog in each region. In general, model (1) is restricted in a sense that we have a single intercept for all regions.

According to that assumption, within one country the pollution would be the same if all economic and climate factors were equal. That assumption can be overcome by incorporating dummy variables for all but one region, which is a control unit. The EKC hypothesis is confirmed if $\beta_1 > 0$, $\beta_2 < 0$. This would result in an inverse quadratic relationship between income and pollution. We expect that the vector of climate variables will be *insignificant*, and as a result, do not include it in the above equation.

In literature review, we mentioned that additional explanatory variables used in estimation of the pollution-income relationship vary significantly from model to model. The most widely used additional variables are imports/exports, trade share, government expenditures on air quality protection, environmental legislation, property rights, and some others. All these factors are not used in our models. They do not cause the omitted variables bias because previous studies that did use these factors were either cross-country or single country analysis with pooled data, and they did not consider regions separately. In our models we assume that those additional variables (legislation, property rights, government, and trade) are not varying in cities with time and they are removed by random (fixed) effect estimations.

The relationship between pollution and income based on instrumental variable approach can be specified as follows

$$E_{it} = \beta_0 + \beta_1 \hat{Y}_{it} + \beta_2 \hat{Y}^2_{2it} + \beta_3 \hat{Y}^3_{it} + \beta_4 T_{it} + \beta_5 W_{it} + \beta_6 R_{it} + \beta_7 S_{it} + \varepsilon_{it} \qquad (4)$$

In which $\hat{Y}_{it}$ is the predicted value of capital for each particular city, which comes from the following regression:

Once the value of capital $\hat{Y}_{it}$ is obtained through the instrumented income with capital; it can be substituted into equations (2) and in order to estimate the true influence of per-capita income on pollution

As a conclusion to the methodological part we summarize the specification of models to be used in further research. The first model to be estimated is random and fixed effect estimations. The specific choice between consistent fixed effect models vs. efficient random effect model will be done with *Hausman specification test*. The second model is an instrumental variable approach that is measure the influence of per capita income on pollution under the assumptions that income is itself influenced by pollution.

Description and discussion of the results

The regression describes the relationships between overall pollution and per capita income. Overall emissions are the sum of emissions from stationary points (firms) and automobile emissions. Our results suggest that overall pollution measured in tons increases monotonically with an increase in income, and there is no EKC pattern observed in this specification. The test on serial correlation was not rejected; however, the model adjusted for autocorrelation showed the same pattern. First step in the instrumental variable approach is to find an instrument for the income, in our case we chose assets per capita in regions (results are in table 1).

Table 1 – Assets per capita in regions

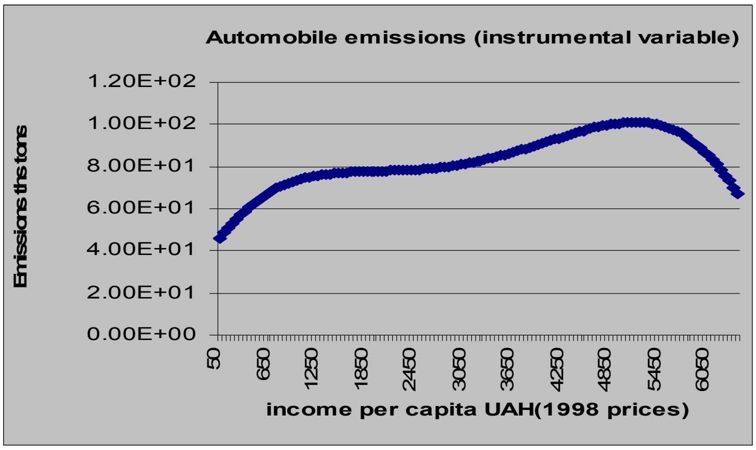
(1)	(2)	(3)	(4)	(4)
	overallpoll	overallpoll	overallpoll	overallpol
incomhat	0.022 (0.032)**	-0.035 (0.003)***	0.083 (0.000)***	-0.031 (0.564)
inchat2		.0000102 (0.000)***	-.0000413 (0.000)***	.0000383 (0.278)
inchat3			6.26e-09 (0.000)***	-1.54e-08 (0.101)
inchat4				2.00e-12 (0.021)**
y1999	-11.971 (0.080)*	-6.265 (0.304)	-11.113 (0.050)*	-9.297 (0.100)
...	rest	year	dummies	...
y2006	-22.001 (0.335)	-5.998 (0.768)	8.599 (0.648)	4.811 (0.796)
Constant	198.217 (0.000)***	248.211 (0.000)***	189.192 (0.000)***	239.006 (0.000)***
Observations	225	225	225	225
Number of id	25	25	25	25
R-squared	0.222	0.392	0.491	0.505

*p values significant * 10%; ** 5%; *** 1%*

Before discussing the results, first it is needed to explain the variables that are used within our framework. Then we represent the time dummies and city dummies.

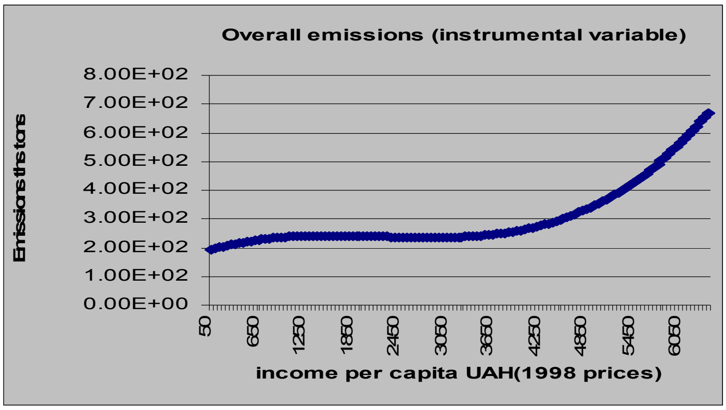
Next step is re-estimation of the emission-income relationship with new instruments. It appears to be that automobile emissions as well as stationary emissions exhibit an increasing pattern using different specifications of income (linear, quadratic, and cubic). However, we also tried a new specification of the EKC by adding *incomehat* in fourth power since under certain values of parameters it can also produce the inverted U-shape relationship. *Incomehat*- is an instrument which is received with assets per capita.

Automobile pollution showed the inverted relationship with respect to income, and the obtained pattern is presented on graph 1.



Graph 1. The behaviour of automobile emissions modelled with instrumental income

From graph 1, we can expect that automobile emissions should decrease pretty soon. The estimated break point is at level UAN5280 in 1998 prices. Next step was to model the overall pollution with instrumented income in fourth power. However, results from regression analysis did not support the EKC hypothesis as seen below.



Graph 2. The behaviour of overall pollution under the instrumental variable approach specified with forth power income link.

It turns out that different specifications of the overall pollution failed to exhibit the EKC pattern, and there are no vivid arguments to speak about sustainable pattern of economic development. Therefore, only automobile emissions alone exhibit such a pattern.

The overall emission pattern did not decrease during the 1998-2006; on the contrary the emissions were increasing, which may suggest about the development of new chemical and metallurgical industries. We assume that economic recuperation of Ukraine starting from 1999 increased pollution in terms of one pollutants (CO2, dust, CO and some others), and possibly slow down the in terms of others (SO2, dust, NO2). Actually it's very difficult to compare the concentrations and emissions, because data for the concentrations is measured exactly in the cities, while emissions are from firms that belong to some specific city, but they are not necessary to be within the city (usually outside). The most series drawback of EKC modeling is lack of explanatory power when curve crosses the horizontal axe [14, p.63]. However we don't work on those scales, because due to the general econometric principles the explanatory power of model is reduced in case of increasing predicting intervals much more beyond available data.

Conclusions

The pollution-income relationship was specified in the usual way as quadratic relationship. The emission data set failed to support the usual form of EKC, however showed a sustainable plateau in pollution in the range of UAN 1000-15000 (in 2007 prices). It suggests that the automobile pollution should start to decline in Ukraine beyond income level of UAH15000. The quantity of cars increased significantly through the whole territory of Ukraine in 1998-2006, while the emissions are almost on the same level, which means that the quality of cars in terms of pollution improved. In terms of sustainable economics it means that Ukraine is on yet on the path of sustainable development due to overall pollution, which is constantly increasing. If we look at economic growth as liberal mechanism of sustainable development, it is possible to claim that pollution will not be fully alleviated only through the economic achievements. The recommendations for the future research are to look at the influence of certain economic instruments and to introduce them into "income-pollution" models.

1. *Grossman G.* Economic Growth and the Environment / Alan Krueger, Gene Grossman // Quarterly Journal of Economics, 1995. – Vol. 110. – P. 353–377.
2. *Panayotou T.* Economic Growth and the environment / Theodore Panayotou : [Електронний ресурс]. – Harvard University. 2000. – Working paper № 56. – Режим доступу : http://www.cid.harvard.edu/cidwp/pdf/056.pdf.
3. *Lopez R.* The environment as a factor of production: The Effect of Economic Growth on the trade Liberalization / Ramon Lopez // Journal of Environmental Economics and Management. – 1994. – Vol. 27. – P. 163–184.
4. *McConnell K.* Income and demand for environmental quality / Kenneth McConnell // Environment and development Economics. – 1997. – Vol. 2. – P. 383–400.
5. *Jaeger W.* Economic growth and Environmental Resource Allocation / Jaeger William, Kolpin Van / [Електронний ресурс]. – Economics Department of Williams College, 2001. – Режим доступу : http://www.williams.edu/Economics/wp/Jaeger_growth.pdf.
6. *Beckerman W.* Economic growth and the Environment: Whose growth! Who's Environment? / Wilfred Beckerman / World Development. 1992. – Vol. 20. – P. 481–496.
7. *Cramer J. C.* Population Growth and Local Air Pollution: Methods, Models, and Research / James Cramer // Population and development review, – 2002. – Vol. 28. – P. 31–45.
8. *Egli H.* The Environmental Kuznets Curve – evidence from Time Series Data for Germany [Електронний ресурс] / Hannes Egli // WIF institute of economic research. Working paper 03/28. – 2004. – Режим доступу :

http://www.cer.ethz.ch/research/wp_03_28.pdf.
9. *Cole M.* Re-examining the pollution-income relationship: a random coefficients approach [Електронний ресурс] / Matthew Cole // Economics Bulletin, 2005. – Vol. 14. – №. 1. – P. 1–7. – Режим доступу : http://economicsbulletin.vanderbilt.edu/2005/volume14/EB-05N50001A.pdf.
10. *Vincent Jeffrey.* Testing for Environmental Kuznets Curves within a developing country / Jeffrey Vincent // Environment and Developmental Economics. – 1997. – Vol. 2. – P. 417–433.
11. *Millimet D.* The Environmental Kuznets Curve: Real progress or misspesified models? [Електронний ресурс] / Millimet Daniel, List John, Stengos Thanasis // The review of Economics and Statistics. – November 2003. – Vol. 85. – №. 4. – P. 1038–1047. – Режим доступу : http://www.economics.uoguelph.ca/Research /DisPapers/2002_13.pdf.
12. *Perman R.* The Environmental Kuznets Curve: implications of non-stationarity [Електронний ресурс] / Roger Perman, David Stern // Working paper 9901. The Australian National University. 1999. – Режим доступу : http://een.anu.edu.au/download_files/eep9901.pdf.
13. *Бобылев С. Н.* Взаимосвязь между уровнем благосостояния и устойчивым развитием. Кривая Кузнеца / Сергей Николаевич Бобылев // Социально-экономический потенциал устойчивого развития: учебник ; под. ред. проф. Л. Хенса и проф. Л. Мельника. – Сумы : ИТД «Университетская книга» 2007. – Разд. 5. – С. 134–159.
14. *Телиженко А. М.* Экономика чистого воздуха: международное управление : монография / Александр Михайлович Телиженко. – Сумы : ИТД «Университетская книга», 2001. – 326 с.

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Еколого-економічне моделювання сталого розвитку та механізми його впровадження на регіональному рівні

В даній статті досліджуються та моделюються зв'язки між емісіями забруднюючих речовин та доходами на душу населення. Значна увага приділена прогнозуванню рівню достатку населення коли забруднення повинно почати спадати. Головним результатом роботи, проведеного за допомогою екологічної кривої Кузнеця, є те, що емісії від стаціонарних джерел слідують оберненій U-подібній формі зв'язків з доходами, а емісії від стаціонарних джерел демонструють зростаючий тренд разом зі зростанням доходів на душу населення. З точки зору економіки сталого розвитку Україна, ще не перейшла на шлях стійкості, так як рівень загальний рівень забруднення зростає і спрогнозувати точку переходу на даному етапі досить складно.

Ключові слова: сталий розвиток, екологічна крива Кузнеця, модель «доходи-забруднення», економічний механізм.