THE ENVIRONMENTAL KUZNETS CURVE: EVIDENCE FROM UKRAINE

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Abstract

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In this study, influence of per capita income on pollution is modeled with the help of the Environmental Kuznets Curve (EKC). The EKC pattern suggests an inverted U–shape relationship between per capita income and pollution. Starting at low levels of income, pollution increases along with income, but when income is large enough pollution starts to decline. The main finding of this study is that Ukraine follows the EKC pattern for some pollutants such as SO2, NO2, IZA while there is an increasing pattern for such pollutants as dust and CO2. For pollutants exhibiting the inverted U-shape relationship, we have estimated break points, and they appeared to be in the range $2000-$5000 in 2007 prices. The main prediction of the found EKC relationship is that the levels of SO2 and NO2 should start to decrease on the whole territory of Ukraine in the nearest future while the levels of CO2 and DUST are going to increase.

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C h a p t e r 1

INTRODUCTION

The relationship between economic growth and pollution has been a focus of research by economists for many years. There are two basic competing views with respect to this relationship: the first one states that economic growth is harmful to the environment due to ineffective use of recourses, while the second one states that technological process and economic growth improve environmental quality. The initial debate between the two approaches has been mainly on theoretical grounds because of the lack of indicators to reflect environmental quality. Starting in the 1990s, the ambient concentrations of harmful ingredients became the most widely used approximation of environmental quality.

In 1995, Grossman and Krueger (1995) on the basis of cross-country analysis introduced the idea of an inverted *U-shape* relationship between pollution and per capita income. Due to the form of the relationship the curve was named the 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 then when the country becomes wealthier the inequality gap decreases. Simone Borghesi (1999) argues: "It was probably Panayotou who first coined the term Environmental Kuznets Curve"

In their seminal work, Grossman and Krueger (1995) 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 decreasing.* The form of the relationship between pollution and income was found to be an 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 (2000) summarized 30 articles and working papers on the EKC, of which 27 were dedicated to 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 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, together within development of theoretical background for individual country EKC.

The main objective of this study is estimation of the functional form of the EKC for different air pollutants in Ukraine. We want to see whether or not Ukraine follows developed and developing countries that do exhibit the EKC relationship. If Ukraine shows EKC pattern, the other interesting and important step is estimation of break points that is such levels of per capita income, when pollution will start to decrease. The break point analysis can suggest us time when pollution will start to decrease.

As a matter of fact, regions in Ukraine differ in terms of GDP per capita and regional levels of pollution which may show that regions "choose" appropriate levels of pollution on their own. In order to estimate EKC for Ukraine we are using Ukrainian regional data on pollution concentrations, climate variables and income variables.

With the development of research on the EKC, measurement of pollution was subdivided into two categories: *ambient concentration of pollutants and emissions per capita*. Ambient concentrations are measured in milligram per cubic meter while emissions are measured in tons (kilogram's) per capita. It happened 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 (1993) used concentrations in his study on sulfur dioxide pollution and estimated a *break point* at $3,137 (in 1990 prices) while Stern and Common (2001) used emissions and ended up with $101,166 (in 1990 prices USD). For the same specification of the model, but with different data sets, the estimated break points differ because of the difference in estimated coefficients. One of the hypotheses behind the concentration model to exhibit lower break points is the omission of weather *conditions*. We will explain the influence of weather on concentrations below.

Using *concentrations of pollutants* as a dependent variable, we are going to include such variable as per capita income, and some new factors that were not tested yet as independent variables. These new factors are: atmospheric precipitation, the number of days with low and strong wind, percentage of days with smog and average temperature. According to the methodology of the Ukrainian Central Geophysical Observatory weather (climate) conditions have strong influence on the concentrations of pollution in particular region at a given point in time. For example, higher winds reduce observed concentrations; fog makes chemical substances to hang in the air. An atmospheric precipitation makes chemical substances fall down to the ground, and that is why concentrations observed are smaller on those days. If we add these new variables to the model by introducing the so-called Vector of Climate-Related Variables (VCV), it will be possible to test whether this vector affects on the level of pollution. Evaluation of climate condition impacts on per capita income can be a valuable by-product of this study in addition to the Ukrainian EKC. It could be done by estimating the per-capita income equation with usual factors such as capital and labour plus some additional factors such as VCV which shows how climate influences per-capita income.

The effect of weather condition can be an omitted factor, which leads to the difference in the results. First of all, not taking into account weather conditions leads to the *measurement error* of concentration. Meteorological stations measure biased concentrations of pollutants at a specific time and place. As a result, standard errors become larger, and even if coefficients are still unbiased, they are inefficient due to narrower confidence intervals. Second, there could be an omitted *variable bias* in the case if weather conditions are correlated with per capita income. The novelty of our approach will be shown in detail in methodological part where the influence of weather conditions on per capita income will be described, and the choice of a suitable model will be discussed.

The study is structured in the following way. First, we provide literature review, where the theoretical EKC background and different country studies are discussed. Second, we give data description and provide methodology that is used. Third, the results are presented, that are followed by the broad discussion. Finally, we aim directions for the further research and present conclusions of our study.

C h a p t e r 2

LITERATURE REVIEW

The structure of this literature review is as follows. In the first section, we provide theoretical background and assumptions behind the EKC. Second section presents a review of the literature on pollution-income relationship within a cross-country approach. Third section provides critique of the cross-country analysis and presents a review of the literature on pollution-income relationship within one country (regional level).

2.1. Theoretical background behind EKC studies

The bell-shaped relationship between pollution and income can be explained by several assumptions. According to Lopes (1994) 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. Continuing the series of EKC assumptions, Dasgupta and Laplante (2002) proposed to consider following assumptions to explain the "bell-shaped" relationship between income and pollution:

1) with rising income, marginal propensity to consume should decline or at least be constant;
2) marginal disutility of polluted environment should increase
3) marginal economic cost of pollution should increase

These assumptions are quite reasonable and little critique followed.

Having above mentioned assumptions in a mind, several theories appeared to explain the income–pollution relationship. First, the study done by de Bruyan and Ecins (1997) suggested subdividing pollution into two effects: *technical and composition*. The technical effect is associated with the use of more productive technology, less harmful inputs, and more environmentally friendly equipment. All of these are possible only along with an increasing per capita income. However, at early stages of a country's development, the technical effect brings negative impact on environmental quality due to intensive exploitation of the resources. The composition effect explains the EKC hypothesis from a structural standpoint. In the process of development, when nations become richer share of industrial sector diminishes relative to the service sector. New industrial sectors appear within an economy, which are less environmentally damaging.

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 (1997), showed that 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* (2001), 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* (2001) constructed the theoretical framework, which explains the inverted U-shape relationship. The problem was presented as

$$\max U(c,e)$$
$$\text{s.t.}(\text{c,e}) \in P$$

where *c, e, p* are consumption, environmental quality and production possibility set respectively. It was stated that inverted U-shape curve is observed in central planning and Pareto efficient economies. Theoretically 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 (1992) 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.

2.2. Cross-countries analysis of EKC

The following part of the literature review is devoted to empirical testing of the EKC on a cross-country level. Literature review in this section starts from cross-country analysis approach and conducted in the following way: first, the data properties are described in every cited paper, and than, some econometric models and main findings are discussed. We provide two models in that section just to show which specification of EKC were used in a cross-country analysis.

With respect to empirical work much of attention has been paid to the Grossman and Krueger (1995) study, which started the EKC studies in Environmental Economics. Grossman and Krueger (1995) 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 (1995) consider that the main advantage of the reduced form (which they used in their paper) is that it allows estimating the 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.

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

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 Krueger (1995) 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 Kruger (1995) 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 (2002) 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 (2002) uses logarithmic Cobb-Douglass production function to explain the pollution on cross-country level. The estimated model is as follows:

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

Where *lnI* trends in county's emissions;

LnP growth rate of population

LnA- trend in per capita income;

*Ln*R -trend in regulated technology (amount of money spend by local government on environmentally clean technology)

Cramer (2002) finds 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.

Harbaugh and Levinson (2000) in their study used the model developed by Grossman and Krueger (1995) to analyze sensitivity of the

EKC with respect to different specifications of the model and additional data. The authors used 2,381 observations on sulfur dioxide in 72 cities. The data was taken from the GEMS/Air project for more than 40 countries. The main finding of the study is that estimation of the break point was very sensitive to the changes in data.

We have shown above the early development of EKC studies and the first models that started income-pollution modeling within EKC approach. However, along with first testing of EKC on cross-country level the critique of approach also increased. Next we show the main arguments against EKC on international level and present argumentation for the estimation of EKC on individual country level.

The cross-country approach was criticized by Egli (2004), 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 (2005) 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".*

Cole (2005) tested the cross-country EKC approach and in order to control for each country's specific features, the random coefficient approach in estimation was used. Cole (2005) 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 (1997) 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 (1997) 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 necessary present a global link between income and pollution. It may be the case, as Vincent (1997) argues, that *rich countries just transfer production* to poorer countries, and the EKC is just a statistical artifact.

Perman and Stern (1999) 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. We cannot use that argument within one country, because of the it is difficult to transfer dirty productions from one region to the other due to the uniqueness of legislation (human rights, freedoms) within one country. 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 the payment to the government for the pollution are the same as in previous region (uniqueness of legislation). So it is difficult 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 (except Moldova, which is too small). In that sense the arguments against EKC on cross-country level cannot be apply for our research, and if EKC originates in Ukraine it is due to some technological changes or through the impact of authorities, which is exactly the point we want to estimate within Ukraine.

2.3. Individual country analysis of pollution- income relations

Next let us take a look at some country specific studies, below we provide very detailed information for the each country EKC researches. A very detailed insight on EKC at individual country level is needed because later we compare Ukrainian income-pollution relations with other countries. *Special attention we pay to the studies done for the developing and transition countries, because they are very close to Ukraine in terms of economic development. Those important studies are presented by De Groot et al. (2002), Gallanger (2005).*

David Giles and Carl Mosk (2003) tested the existence of the EKC in *New Zealand* for such specific pollutant as enteric methane. Their data set covered period of more than a century, from 1895 to 1996. Technically traditional regression models and nonlinear regression estimations (fuzzy regressions) were used. All of the models supported the EKC hypothesis for CH_4. Break points were estimated at the level of $7000-7500 for different specifications of parametric models, and $8000 for the "fuzzy regression". All results are comparable with the earlier results obtained from the cross-country analysis. Moreover it happened to be that cross-country prediction of CH4 for New Zealand coincides within single country analysis. Major finding of this study is that economic growth improves air quality (Giles, Mosk 2003). The coincidence of cross-country analysis and single country could happen for some particular pollutants and countries, but in general it is rather exception than a rule.

Roca (2003) estimated the EKC on the basis of 16-year dataset for *Spain* (1980-1996). The following chemical substances were used: carbon dioxide (CO_2), methane (CH_4), nitrous dioxide (N_2O), sulfur dioxide (SO_2), nitrogen oxide (NO_x). Trend representation of pollution showed growing tendencies for all pollutants but SO_2. Based on his results, Roka concluded that only SO_2 could follow the EKC hypothesis. In his study, Roca (2003) tested econometric model with squared and cubed per capita GDP, and found "that model does not satisfy minimum econometric claims for Spanish data". Log-log regression of all but SO_2 pollutants, on income per capita showed positive correlation. Roca used his findings of positive correlation between pollution and income as argument against the EKC. In addition, List and Millimet (2002) suggested different EKC curves for different countries. Their findings can be applied to explain the Spanish phenomenon: a country might have not achieved its peak to combat pollution. Roca (2003) notes that Spain is one of the most polluted countries in the EU with the "dirtiest production". However, the increasing trends in pollution do not dismiss the EKC. They only show the uniqueness in the development of each country, and it is reasonable to assume that in the nearest future situation in Spain might improve.

American scholars Millet and List (2002) used the *U.S.* state level data on sulfur dioxide and nitrogen oxides in terms of concentrations to test the inverted U-shape relationship. They found that the data followed the EKC assumptions at the country level, and their tests suggested a semi-parametric specification of the EKC. Millimet D. and List J. (2002) made a thorough research for the US on "test the appropriateness of the traditional parametric regression specification of EKC against semi parametric partly linear regression model (PLR model)." The authors claimed that they had a proper data set for NO_x and SO_2 at state level starting from 1924 up to 1994. The advantage of such data is that the data covers long period, and it is more precise then cross-country analysis data. As a result, there was a greater possibility that such data would capture the whole Kuznets Curve. Parametric regression results of different model specification (cubic, squared) supported the hypothesis of inverted U-shape relationship between income and pollution for both NO_x and $SO_{2.}$ Coefficients of income terms were significant at 99% confidence interval; moreover they were jointly significant at 99% confidence interval too. The EKC was also estimated for the shorter period of 1985-1994. The results showed that coefficients of income were significant for $SO_{2,}$ but not for $NO_{x.}$ The study done by List and Millimet showed that short term model did not capture the whole EKC. Parametric estimation showed the EKC to be monotonic function with a break at the level of $13000- $20000. Semi parametric estimation results were much more optimistic, and emissions declined when income per capita was about $7000-$9000. The problem with PLR approach is that researchers "failed to reject the assumption of no serial correlation in the model" (Millimet D and List J, 2002)". As a separate problem, Millimet and List estimated the EKC for separate states - nine states for SO_2 and nine for $NO_{x.}$ Semiparametric approach showed the inverted U-shape relationship. Parametric curves for NO_x in Alabama, Georgia, Iowa, Ohio and South Carolina area were almost horizontal, while semiparametric approach suggested the U-shape structure.

Egli (2004) estimated two different econometric models of the EKC for *Germany*. The first one was traditional, incorporating income per capita, and it's square and cubed terms. The other one was the error correction model. The estimated model showed serial correlation, and that is why the GLS procedure was performed. Egli (2004) found that incorporating cubed term changed the sign of the coefficient of the income for some pollutants. The reduced form model with only squared terms of income per capita showed the inverted U-shape relationship, and it should be mentioned that all, but NO_x coefficients were insignificant. Egli (2004) found that error correction model had more explanatory power and more clearly supported the hypothesis of the inverted U-Shape relationship. Thus, it was found for Germany that "coefficients of error correction term are all significant and as expected negative. These results can be interpreted in the sense that changes in income have an influence only through the second channel. Therefore, even there is no direct influence through the first channel; the significant results of the second channel suggest EKC for tested pollutants Egli (2004)".

Grafton, Day (2002) tested the income-pollution relationship on *Canadian* data. They used data on CO2, CO, SO2 and TSP (total suspended particular matters). Grafton and Day used log-log model to test the environmental degradation, including squared and cubic terms. The authors were not able to reject the hypothesis of no serial correlation for all pollutants but CO2, which could suggest omitting important factors in the model. Analyzing series properties of the data it was found that there could be a spurious regression between income per capita and pollution. Test for unit root revealed non-stationarity of the data. In addition, the Engel-Granger test showed no cointegration vectors between the tested variables.

Grafton and Day (2002) used a VAR approach to test for the causality. Bidirectional properties of data were found. Sensitivity of causality significantly depended on lag length. For the longest lag (6 lags) causality was accepted at a 95% confidence interval. Other important finding of the study is that there was no long run relationship between income and pollution in Canada.

Studies devoted to the estimation of the pollution-income relationship at the individual country level were usually performed for the *developed countries*, and the *developing countries* were not tested. Main reasons for that were the data suitability, and availability of economic institutions willing to perform such analysis. *The studies presented below by De Groot et al. (2002), Gallanger (2005), are very important because they are done for the countries which are comparable with Ukraine in terms of GDP and economic development. Later we use EKC break points for developing countries and compare them with Ukrainian ones.*

A study by De Groot et al. (2002) shed some light on developing countries, particularly *China*. China is a developing country, and also could be considered as transition economy. The data set for China consisted of several parts: waste, water pollutants, solid pollutants, SO_2 and industrial gas, waste gas. Data was taken from the Chinese statistical yearbooks for the period of 16 years (1982-1997). One peculiarity of the data is that Chinese statistics does not provide data on CO_2 and NO_2. Serious analysis of regional disparities was performed before econometric modeling. It appears that the Coastal areas and South were developing at much faster rates than the inland and North of China (12% vs. 6%). Northern regions in China are mainly agricultural, and they contribute only small share to GDP (de Groot et al 2002). Econometrically the model was specified in such a way that allowed intercepts to change from region to region, but slope coefficients of the GDP per capita were the same. That could be done under the assumption of similar development of pollution trends in the regions when income increases. The main finding of this study is that China failed to support the EKC hypothesis, but still they found a linear relationship between income and pollution (increase in per capita income is associated with decline in pollution). Waste water analysis showed a downward sloping monotonic pattern. Possible explanation by de Groot et al (2002) is that initially water was already heavily polluted, endangering the human lives, and there was no other way out as to only improve the quality of water. For the solid waste emissions, situation was the same: No inverted U-shape relationship was observed. Instead only linear coefficients were significant, showing negative correlations. Emissions per gross regional product decreased as people became richer. The model for the waste gas in levels showed the inverted U-shape relationship but per capita terms as well as relative to GRP terms were monotonically increasing.

Gallanger (2005) conducted a comprehensive analysis of income-environmental quality relationship for *Mexico*. Cross-country analysis suggests that break points for pollution occur at the level of per capital income of $5,000-$15,000. It appears to be that the per capita income of $5,000 was associated with the year of 1995 when Mexico started to liberate its economy. So, as argued in the paper, *"Mexico is a pure laboratory for estimation of EKC relationship*". The econometric modeling of income-pollution relationship did not find any bell-shaped relationship. Instead the environmental quality was deteriorating with respect to income. Gallanger (2005) tested the assumption of Mexico being a "pollution heaven". The main hypothesis was associated with NAFTA: Due to trade liberalization the US transferred its "dirty" production to Mexico. However, the "pollution heaven" hypothesis appeared to be wrong. The share of industrial output in Mexico's manufacturing was decreasing from 1988 to 1998. It was found that at the beginning of the period the share of dirty industry accounted for 30.1%, while at the end - 26.5% of production. The decreased share of dirty industries is explained by the fact that Mexico is "abundant in unskilled labor". The unskilled labor factor promotes the development of assembly lines rather than manufacturing plants. One of possible ways of Mexico's development is restructuring in favor of big international corporations. Gallanger (2005) conducted a study on predicting the "break point" in pollution in Mexico using the abatement cost for air pollution, pollution growth rates, and expected growth rates. Three critical break points in income per capita were considered - $7500, $10000, and $15000. The expected break years in pollution were identified as 2028, 2057, and 2097. In addition, Gallanger estimated the damage before a break point under the 3% interest rate. They are US$79 billion, US$105 billion, and US$119 billion respectively for each critical point. It was also mentioned that those estimates are not precise, but still the trade-off between pollution and growth is possible in the future due to the fact that pollution damage may constitute from 1/3 to 3/5 of Mexico's current GDP.

All above mentioned studies support the hypothesis that economic growth is linked to pollution, but do not support the reverse link. Bellow we give arguments in favor of *negative influence of pollution on economic growth.* The fact that not only income influences pollution but the opposite is also true can be found in some studies. De Bryan (2002) claims that *"Environmental degradation not only reduces the productivity of workers and man made capital, it also reduces natural resources as inputs"*. Barbier (1994) also claimed that decrease in environmental quality has negative influence on production and well-being of individuals.

Melnik (2006) described the influence of environmental degradation on efficiency of economic system. The environmental degradation causes loses in agricultural and forest industries; causes corrosion of industrial equipment; stipulates loses related to the worsening of workers health status, and higher mortality rates. Overall bad environmental quality stipulates such expenditures as:

- Additional expenditures on conditioners, filters in order to protect people from dangerous chemical substances
- Additional expenses to protect equipment, (the use of anticorrosion metals); selection of more resistible agricultural plants. The last factor includes costs on R&D due to the fact that more "stable" agricultural plants are associated with genetic engineering
- Additional cost to compensate for the reduction in productivity (costs of labor flow, medical insurance, the use of mineral fertilizers, etc.).

It is also necessary to mention that opportunity costs are rarely taken into consideration. Due to degradation of the environment some sensitive production should be reduced (usually agricultural products and some manufacturing products). In fact, the highest opportunity costs arise due to closing of such industries as recreation and tourism. In general, pollution as a negative externality reveals itself through such channels as

1) Underproduction of goods and services (health problems, additional machine servicing)
2) Reduction in productivity and quality of goods and services. Acid rains destroy agricultural plants, kill fish and generally negatively influence on farming Melnik (2006)

Ming–Feng Hung and Daigee Show (2004) applied new methodology to examine the EKC hypothesis for Taiwan. Both authors suggest that it is more appropriate from a theoretical point of view to use simultaneous equation method (SEM) to estimate income-pollution relationship. The main critique of the reduced form specification of the EKC is that there was no feedback from pollution to economic growth, and what is more important, pollution was considered as "outcome of economic growth". The Hausman test was used to clarify the hypothesis of simultaneous equation, and the results supported the SEM. Ming–Feng Hung and Daigee Show (2004) claim that previous estimation was biased due to the omission of important factors. The basic idea of the paper is that income influences pollution, and, in turn, pollution influences income.

Ming–Feng Hung and Daigee Show (2004) worked with elasticities, and income-pollution relationship was specified in quadratic form. The income equation was a modified version of the Cobb-Douglas production function (which is also log-log). The dependent variable was log of per capita income, and the independent variables were air pollution, man-made capital, raw labor, local government expenditures. In their model, *"pollution plays surrogate variable representing the aggregate effects of those direct and indirect forces of production"*. The main findings of the Ming–Feng Hung and Daigee Show (2004) are confirmation of the EKC hypothesis for NO_2 and SO_2. The break points were estimated at levels of $12,800 and $6,833 for both pollutants respectively. *The influence of pollution on income* (second equation of SEM) turned out to be insignificant. The last results were expected by assumption for several reasons. First of all, increased pollution usually means increased production. Second, increased pollution causes more ecological projects to be implemented, plus stricter ecological standards, which reduces production. The two affects offset each other showing insignificant coefficients of the income-pollution model.

As a conclusion for the literature review we say that a lot of papers were already published devoted to the EKC on the cross-country level or single country analysis for developed countries, but little work was done for developing countries, as a single country analysis. More over cross-county approach or single country analysis that use concentration as dependent variable have not taken into consideration the influence of weather conditions. The impact of VCV may be a significant factor determines the concentration of pollutants in some specific territory. In the next sections we proceed with estimations of EKC for Ukraine and compare our findings with studies done on individual country level, especially with those that related to developing and transition countries.

C h a p t e r 3

DATA DESCRIPTION

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

The Income block includes data at two levels – a city level (50 big Ukrainian cities), and regional level (25 oblasts). The basic variable in the income block is per capita income in regions. Data about per-capita income is taken from the Ukrainian Statistical Year Books. On average, each region is represented by two cities. However, there are some exceptions: data on pollution is better represented in eastern part of Ukraine where population density is higher and mining industries are better developed. Thus, Donetsk and Lugansk regions are represented by seven and five cities respectively, Kyiv and Dnipropetrovs'k regions are represented by four and three cities respectively, the rest regions are represented by one, two, or three cities. The per capita income in each region is attributed to 1-3 big cities in this region, and the same is done with respect to wages. There are 25 annual observations on per capita income (one region is one observation), which are subscripted accordingly for all 50 cities in each region. On average, regional per capita income is attributed to two cities. Unfortunately, per-capita income at the city level is not published in the Ukrainian Statistical Year Books.

In addition to that, for the cities, the data on total *population* and capital assets (measured in billions of hryvnas) has been collected. For the regions, we consider also total *population* total capital assets in each region.

The pollution block consists of *concentrations and emissions*. Concentrations are measured in mg/m^3 while emissions in thousands of tons. The data set includes concentrations of such pollutants as CO_2, NO_2, SO_2, *dust and IAP* *(index of air pollution)*. Construction of IAP is discussed later in methodology. The *concentration* data is presented at the city level as annual concentration of pollution in the air. As for the regions, the concentration of pollution in the air is calculated as average of several cities in a region. In fact, regional concentrations are not much different from any city's concentration within the region. The city level annual concentration data on 50 Ukrainian cities is based on observations from 162 meteorological stations of the Central Geophysical Observatory with annual data from 1994-2006 and 1997-2006 depending on a pollutant. We use aggregate concentration data prepared by the Central Observatory and it is complete for both cities and regions.

The data on emissions at both levels - regions and cities - is taken from the statistical yearbooks "Environment of Ukraine". Emissions of pollutants are not measured individually like concentrations, but reported separately by each firm to the local government authority, which makes some aggregation (district, town) and sends it to the State Statistical Committee. 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 regional *emission data* set is complete while the city emission data set is not. The city level emission data is represented only by emissions from stationary points.

The meteorological block is represented by such indicators as the number of days in a year with *smog, precipitations, winds, and annual average temperature*. Additionally to that the information on the Wind Roses in all of 50 cities is also available. 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 city level. However, we also use these indicators as representation of weather condition for the region as a whole. The approach is as follows: we take 2-3 big cities in a region and calculate the average for to each climate variable. It appears to be that regional average is not much different from any city in that region.

The city level data and regional data are presented by their own concentrations (*CO_2, NO_2, SO_2, and dust*), emissions, climate variables, and income variables. The entire data set is constructed for the period of *nine* years 1998-2006 for 50 big Ukrainian cities and other data set for 25 regions, which gives us 450 observations on each indicator at the city level and 225 at the regional level. Below we present some variable description from Appendix A

Variable	Obs	Mean	Std. Dev.	Min	Max
id	450	25.5	14.44693	1	50
year	450	2002	2.584863	1998	2006
income	450	2642.933	1255.397	778	6197.845
inc2	450	8557615	8690842	605284	3.84e+07
inc3	450	3.32e+10	5.25e+10	4.71e+08	2.38e+11
inc4	450	1.49e+14	3.12e+14	3.66e+11	1.48e+15
wage	450	246.0162	104.2545	90	518.1035
wage2	450	71368.8	60032.64	8100	268431.2
wage3	450	2.37e+07	2.94e+07	729000	1.39e+08
populth	450	367.80 67	443.3788	13	2718
assets	450	11359.21	14820.08	351.1552	100847.9
ass2	450	3.48e+08	1.03e+09	123310	1.02e+10
ass3	450	1.80e+13	8.08e+13	4.33e+07	1.03e+15
so2	450	.0274667	.0328631	.01	.4
no2	450	.0481111	.0245899	.01	.17
co2	450	1.946022	1.040624	.01	5
dust	450	.1565556	.0909289	.01	.5
iza	450	8.879489	5.065898	1.49	26.1
smog	450	3.374444	3.296937	0	19
precip	450	35.97122	14.8889	3.29	63.84
nowind	450	22.98356	16.02662	1	74
wind	450	77.01644	16.02662	26	99
temperature	450	10.06289	8.355576	6.5	97
smogdays	450	12.31676	12.03383	0	69.35
precipitdays	450	131.2956	54.34567	12	233
winddays	450	281.11	58.49715	94.9	361.35
alchev	450	.02	.1401558	0	1
armyan	450	.02	.1401558	0	1
bilats	450	.02	.1401558	0	1
brov	450	.02	.1401558	0	1
vinn	450	.02	.1401558	0	1
resr city dummies…………………….					
yalta	450	.02	.1401558	0	1
y1998	450	.1111111	.3146195	0	1
y1999	450	.1111111	.3146195	0	1
rest year dummies	…………………	……………	…………………	……………………	…………………… …

```
y2006 |       450    .1111111    .3146195          0          1
```

Id – identidification variable (for cities 50 overall)

Year-variable for the year 1998- 2006

Income- per capita income in each city respectively

Inc2, inc3, - squared and cubic per capita incomes

Populth-population in the each city respectively

Assets-main assets in each city respectively (capital - measured in Hryvnas, according to Ukrstatbooks.)

so2, no2, co2, dust - concentration of pollutants in each city respectively

smog, precip, wind, temperature- quantity of days in a year with smog (fogs), precipitations (rain or snow), wind(more than 1m/c), and average annual temperature in each city respectively

IZA (IAP) - *Index of Aggregate air Pollution* in each city (it resembles principal component analysis, when from many variables one is constructed), more deeply IAP is considered in methodological part. From now instead of calling this index IAP, in this study we use IZA which is a well established term of the Ukrainian Central Geophysical Observatory.

Alchev, armyan, bilats…yalta - are dummy variables for each of 50 cities.

Lnincome, lnasset... – are natural logarithms of some variables

asper is assets per capita in each particular city in real values

We also have a data set on the locations of all metrological stations at the city map for each of 50 cities. The information about the main polluting firms (specifically which firm causes which pollution in each city respectively) is also available. Our data is not completely full because concentrations in the city are influenced by many other things such as structure of the city, locations of high buildings (indirectly influences through winds), level of innovations etc. But still our data is rich enough to make the EKC research for Ukraine.

Chapter 4

METHODOLOGY

It is necessary to start with some definitions of our dependent variable – pollution

Maximum Permissible Dose (MPD) is such concentration of a substance in any medium (water, air, ground, meals) that during long period of time does not cause health problems for human beings.

The most frequently used method for the MPD is day-average, which produces concentration in mg/m^3. All air pollutants are subdivided into 4 classes according to their influence:

Class 1 - extremely dangerous (benzaperin, lead)

Class 2 - highly dangerous (nitric oxide, phenol)

Class 3 - relatively dangerous (dust, sulphur dioxide)

Class 4 - not very dangerous (carbon dioxide, ammonia)

Table1. *Maximum Permissible Dose of pollution and class of dangerousness*

Pollutant	**MPD (day-average)**	**Class**
Dust	0.15	3
Ammonia	0.04	4
Mercury	0.0003	1
Carbon dioxide	3	4
Sulphur dioxide	0.05	3

* according to Melnik (2006) p.217

The quality of air is acceptable if the following inequality holds

$$C_i \leq MPD_i \qquad (1a)$$

where C_i is the existing concentration of a pollutant, mg/m^{3,} MPD_i is its maximum permissible dose.

Atmospheric pollution is a special case because of the so-called additive affect. Additive effect is associated with a situation when several pollutants together are much more dangerous than the sum of these pollutants based on their individual MPDs. This effect is reflected by the following formula:

$$\frac{C_1}{MPD_1} + \frac{C_2}{MPD_2} + ... + \frac{C_n}{MPD_n} \leq 1 \qquad (1b)$$

For comparison of air quality in different cities (territories), integral indicator of pollution is used – the Index of Air Pollution (IZA).

$$IZA = \sum_{i=1}^{n} \left(\frac{C_i}{MPD_i}\right)^{K_i} \qquad (2)$$

where K_i is coefficient defined with respect to a pollutant's class. Values of K_i are given below:

Table 2. The relationship between pollution class and coefficient of adjustment in IZA (according to Central Geophysical Observatory (CGO) Ukraine)

Pollution class	Coefficient of adjustment (K_i)
1	1.7
2	1.3
3	1
4	0.85

* according to Melnik (2006) p.218

Table 3. The Environmental standards for day-average MPD in different countries (according to CGO Ukraine)

Country	SO_2	NO_2	CO_2	Dust
Ukraine	0.05	0.04	3	0.15
Japan	0.12	0.08	12.5	0.1
Australia	0.2	0.1	7	0.12
Switzerland	0.1	0.08	8	0.15

Germany	0.14	0.08	10	0.15
Canada	0.12	0.16	…	0.2

* according to Melnik (2006) p.218

According to above mentioned table3, we can't judge about the strictness of pollution legislation in different countries, because each country could have different decision rule (most often it is *1a* or/and *1b*). The formula (1b) could vary the right hand side, and as the result the strictness of legislation is not obvious from it. The table3 itself is given as additional information for considering.

Basic model that we are going to test is taken from Egli (2004), who tested the EKC hypothesis for Germany using pooled data. Egli (2004) found a reduced form model with only squared terms for income that underlies the inverted U-shape relationship.

He used the following specification:

$$E_t = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_4 IS_t + \beta_5 I_t + \beta_6 D_t + \varepsilon_t \qquad (3)$$

Where, *E*- pollution indicator for the Germany, *Y* stands for per capita income, *IS* – industry's share in GDP, *I* - sum of imports and exports from pollution intensive production relative to GDP, *D* is the reunification dummy for Germany. Egli states that because of time series data two econometric problems may arise: serial correlation and non-stationarity. Therefore, he proposed the use of GLS estimates to control for serial correlation in time series analysis. If two or more time series are non-stationary, they can be regressed on each other only if the series are integrated of the same order. The process is known as cointegration. The main critique of the aggregate country data is lack of data range; Egli (2004) had 33 observations starting from 1966 to 1999.

In our model, the pollution-income relationship is based on theory using available data. Due to the fact that we have a panel data for 50 big Ukrainian cities (450 observations) and another data set for all 25 regions (225 observations), the model (3) will be changed slightly and expanded. In order not to generate confusion in the description of the methodology, further we are going to use only "city level", but in the description of the results we will distinguish between the city and regional levels.

The main model that we are estimating in our study is:

$$P_{it} = \beta_0 + \beta_1 Y_{it} + \beta_2 Y_{2\ it}^2 + \beta_4 T_{it} + \beta_5 W_{it} + \beta_6 R_{it} + \beta_7 S_{it} + \varepsilon_{it} \qquad (4)$$

where P_{it} stands for concentrations of pollution (SO2, NO2, CO2, dust) and IZA in a city *i* in year *t*, *Y* stands for per capita income in each particular city, *T* - is average annual temperature in each city *i, W* – is the percentage of days in the year with wind in each particular city, R - is the percentage of days in the year with precipitation in the city, *S* – is the percentage of days in the year with smog in each city. In general, model (4) is restricted in a sense that we have a single intercept for all cities. 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 city, 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.

Climate variables such as precipitation, wind, temperature, and smog have strong influence on *concentration* of pollution in the air, but not on the *emissions.* The expected signs are as follows: β_5, which shows marginal impact of wind, should be negative, because stronger winds reduce concentration of chemicals in the air; β_6, which shows marginal impact of precipitation, is also expected to be negative, because more rain and snow only increase the quality of air; β_7, which shows marginal impact of smog, is expected to be positive because in such a case particles of a harmful ingredient stay in the air and do not fall on the ground. As for the β_4, which is marginal impact of temperature, the sign is unclear a priori. We expect that it could be insignificant in influencing pollution; actually there is no theory behind the influence of temperature on concentrations of chemicals. We also may assume that higher temperature could increase evaporation of chemicals from wastes or garbage (if they are outside the plant), but wastes are usually more or less well utilized in special storage places that the outside temperature has no influence on them.

As for the dependent variable, we are going to use both - concentration and emissions. It is also important to know whether general ecological situation in a city improves or not. For that purpose, the IZA is used. We expect the IZA to be correlated with income and maybe with the Vector of Climate Variables (VCV) since weather conditions have different impacts on different types of pollutants. The influence of the VCV on the IZA is difficult to predict, because the IZA in each city has different structure and weights of pollution classes (see table above), and, as a result, the impact of weather is often ambiguous. For example, precipitation eliminates dust more quickly from air than CO2 or NO2 because dust has larger particles, and rain more effectively purifies atmosphere. On the other hand, wind reduces concentration of CO2 and NO2 in the air much quicker because these chemicals are smaller in both size and mass, and they are easier transferred by the wind out of a city. That is why it is difficult to predict theoretically the impact of the VCV on the IZA since it depends on the structure of the IZA. In fact, our data set includes only the IZA but its structure in each particular city is unknown, equal IZA doesn't not mean the equality of concentrations of some specific pollutants in cities. For example, in 2006 according to IZA Odessa was the most polluted city in Ukraine, due to only one extremely dangerous pollutant – benzapiren, the rest of the pollutants in Odessa were below Ukrainian average. So IZA is used as aggregate indicator of environmental quality, however the influence of VCV on it is unknown. The IZA is calculated by the Central Geophysical Observatory using *up to 60 pollutants* as components of the index.

In our literature review, we found that climate variables were not included in models tested previously for the EKC. Based on our analysis of the existing literature, we hypothesize here that previous models suffer from omitted variable bias. In order to test it, we need to estimate model (4) (of course, taking care for potential multicollinearity), and if any of the coefficients $\beta_4, \beta_5, \beta_6, \ \beta_7$ is significant, the hypothesis about omitted variable should be accepted. The test of the VCV significance is the test of joint significance of climate variables in the models. We test the hypothesis of omitted variable bias only for the models that have *concentration* as a dependent variable. As for the *emissions,* there is no theory behind influence of climate variables on pollution.

The major bulk of models on EKC estimations are run as lin-lin model, however some authors use log-log specification, when they work under the assumptions of income endogeneity in pollution equation. According to the existing theory, there is an inverse relationship between pollution and income that goes both ways. The reasoning behind the statement "higher income reduces pollution" has been already explained. On the other hand, according to Ming-Feng Hung and Daigee-Shaw (2004), pollution reduces income due to such factors as *"the loss of days due to health problems, the corrosion of industrial equipment due to polluted air or water, and product voided because of being polluted"*. Using this statement, Ming-Feng Hung and Daigee-Shaw (2004) specified a simultaneous equations model in the following form:

$$\ln P_{it} = \mu_t + \gamma_1 \ln Y_{it} + \gamma_2 (\ln Y_{it})^2 + \omega \ln X_{it} + \varepsilon_{it} \tag{5a}$$

$$\ln Y_{it} = \alpha_t + \beta_1 \ln P_{it} + \beta_2 \ln K_{it} + \beta_3 \ln L_{it} + \\ + \beta_4 \ln H_{it} + \beta_5 \ln G_{it} + e_{it} \tag{5b}$$

The first equation represents the pollution equation and P is the indicator of pollution in air basin i in year t, Y is per capita income in air basin i in year t. Therefore, income has direct and indirect impact on pollution, and for this reason, others variables were organized in vector X, which included *"population density, number of specialists involved in air quality protection within government and air inspection rates on stationary and mobile sources in Taiwan regions"*

The second equation is the modified Cobb-Douglas production function. Where P_{it} is pollution, K_{it} - capital, L_{it} - employment, H_{it} - human capital, G_{it} - are government expenditures, all of them are given in year t in region i respectively

The model that can be used in this study can be presented as follows:

$$\ln SO2_{it} = \alpha_0 + \alpha_1 \ln Y_{it} + \alpha_2 (\ln Y_{it})^2 + \alpha_3 \ln W_{it} + \\ + \alpha_4 \ln R_{it} + \alpha_5 \ln S_{it} + \alpha_6 \ln T + \varepsilon_{it} \tag{6a}$$

$$\ln Y_{it} = \gamma_0 + \gamma_1 \ln SO2_{it} + \gamma_2 \ln K_{it} + \gamma_3 \ln population + \gamma_4 \ln NO2_{it} + \\ + \gamma_5 \ln CO2_{it} + \gamma_6 \ln dust_{it} + e_{it} \tag{6b}$$

Equation (6a) is very much like equation (4) for panel data estimation of the pollution-income relationship. The only difference is that we added the Vector of Climate Variables in log-log model for pollution. The income-pollution equation (6b) is extended form of the Cobb-Douglas production function, but in addition to endogenous SO2, as in (5b) we bring *new exogenous* variables – NO2, CO2, dust. As far as we know such models (with VCV and "new exogenous") were not tested yet, and some critique is needed to improve it. The main critique of equation (6b) is that it could suffer omitted variable bias, because few explanatory factors are included into the model (actually because we have data only on capital and population). Other possible drawback of Simultaneous equation model is that equation (6b) could suffer *multicollinearity problem*, because CO2, NO2, dust, SO2 are often emitted from the same source, and as a result they are not independent. We still will proceed with multicollinearity, because in other way it will be necessary to estimate the system of 5 simultaneous equation (for each pollutant), which will definitely will not be estimated because condition of identification are violated. So we specify system of simultaneous equation for each pollutant separately (that is we have 5 different systems each of them has two equations) In equations (6a), (6b) we have specified the pollution equation for SO2; in the similar way we are going to test the influence of income per capita on other pollutants (NO2, CO2, dust), so the three more simultaneous systems are considered. We have two proceed in such way (introduce not one SEM with 5 equations, but 5 systems of simultaneous equations in two equations each), because in opposite way we can not estimate simultaneity.

Estimation of simultaneous equations is based on some theoretical background, and as such, can better capture the pollution-income relationship. One of the drawbacks of the model is that the system can be undetermined if there is a statistically significant link between income per capita and the vector of climate variables. Nonetheless, simultaneous equations should be constructed based on theory, and only then the order of the simultaneous equations should be define for identification purposes.

The order condition for identification is

$$Def.1: \qquad K - k \geq m - 1 \qquad (7a)$$

$$Def.2: \qquad (M - m) + (K - k) \geq (M - 1) \qquad (7b)$$

where, ***M*** – the number of endogenous variables in the model, ***m*** – the number if endogenous variables in a given equation, ***K*** – the number of predetermined variables in the model, ***k*** – the number if predetermined variables in a given equation.

In the case when income is determined by all climate and pollution variables or

$$\ln Y_{it} = \delta_0 + \delta_1 \ln SO2_{it} + \delta_2 \ln NO2 + \delta_3 \ln dust + \delta_4 \ln CO2 + \\ + \delta_5 \ln W_{it} + \delta_6 \ln R_{it} + \delta_7 \ln S_{it} + \delta_8 \ln T + \delta_9 \ln K + \delta_9 \ln population + \tau_{it} \qquad (8)$$

The only instrumental variable for income in equation (6a) is capital, K, because all other variables are in equation (6b). As for the equation (6b) it can't be identified under assumption that per capita income is determined by equation (8), because order condition of identification (7a) is not satisfied. The theoretical background behind equation (8) is as follow.

A study done by Chimeli (2002) indicates that weather is an important factor in corn production. Suman Jain (2007) finds that climate variables are important determinants of net-farm revenues. Jeffrey Sachs (2003) showed a significant influence of geography on per capita income on the basis of cross-country analysis. Deschenes (2004) estimated the reduced value of agricultural lands due to climate changes. Helmy (2007) found a link between climate changes and efficiency of Egyptian economy, and it was proposed for Egypt to implement better technology and more irrigation. All of the above studies show that there could be a significant correlation between income per capita and weather conditions for some specific agricultural regions. The most serious critique in this approach is that weather conditions are not that important for industrialized or service economies. However, study done by Sorenson (2002) deals with seasonal forecasting of Monthly Hotel Night in Denmark, and one of the influencing factors was weather (climate index), which included indicators of Sun activity, rain, humidity, and temperature. The study done by Sorenson (2002) showed that all indicators except rain were statistically significant and were influencing tourism in Denmark. This result shows that even in developed countries weather conditions are important in determining the per capita income.

In the case when income is modeled as proposed in equation (8) the equation (6a) is not identifiable. SEM model is very restrictive and require a very rich data set, our data does not allow us to estimate SEM properly. One possible econometric solution is the instrumental variable approach (we use that approach as approximation of SEM).

The relationship between pollution and income based on instrumental variable (*K* is an instrument for *Y*) approach can be specified as follows.

The new instrument for Y is $\hat{Y}_{it}$, which is obtained from regression (8), and predicted value of per capita income can be substituted into equations (4) and (6a) in order to estimate the true influence of per-capita income on pollution.

The models to be estimated with instrumental variables are:

$$\begin{aligned} \ln P_{it} &= \alpha_0 + \alpha_1 \ln \hat{Y}_{it} + \alpha_2 (\ln \hat{Y}_{it})^2 + \alpha_3 \ln W_{it} + \\ &+ \alpha_4 \ln R_{it} + \alpha_5 \ln S_{it} + \alpha_5 \ln T_{it} + e_{it} \end{aligned}, \qquad (9)$$

$$P_{it} = \beta_0 + \beta_1 \hat{Y}_{it} + \beta_2 \hat{Y}^2_{2it} + \beta_4 T_{it} + \beta_5 W_{it} + \beta_6 R_{it} + \beta_7 S_{it} + \varepsilon_{it} \qquad (10)$$

The equation (9) models the log-log relationship between pollution and income, while equation (10) uses usual specification of the Environmental Kuznets Curve, which is lin-lin model. In both specifications $\hat{Y}_{it}$ is the predicted value of income per capita for each particular city, $\hat{Y}_{it}$ comes from the regression (8). The predicted income per capita value from (8) is, logarithmic so in order to get $\hat{Y}$ we make it exponential.

All previously discussed models were dealing with *concentration* as the dependent variable. The rest part of the methodology will be devoted to *emissions* as the dependent variable. A new data set is associated with new assumptions to be tested. One of the hypotheses to be tested is that vector of climate variables (VCV) has no significant influence on emissions. For the emission we also test for the EKC hypothesis, and additionally we want to see the VCV influence on pollution under emission data set.

The linear and quadratic models are also proposed to test the EKC within emission data set. Three different models to estimation are proposed. A priory we don't know which of them suits better to emissions

$$E_{it} = \beta_0 + \beta_1 Y_{it} + \beta_2 Y_{2\ it}^2 + \beta_4 T_{it} + \beta_5 W_{it} + \beta_6 R_{it} + \beta_7 S_{it} + \beta_8 K + \varepsilon_{it} \quad (11a)$$

$$E_{it} = \mu_0 + \mu_1 Y_{it} + \mu_2 T_{it} + \mu_3 W_{it} + \mu_4 R_{it} + \mu_5 S_{it} + \mu_6 K + \nu_{it} \quad (11b)$$

$$\begin{aligned} \ln E_{it} &= \eta_0 + \eta_1 \ln Y_{it} + \eta_2 \ln Y_{2\ it}^2 + \eta_4 \ln T_{it} + \eta_5 \ln W_{it} + \\ &+ \eta_6 \ln R_{it} + \eta_7 \ln S_{it} + \eta_8 \ln K + \varsigma_{it} \end{aligned} \quad (11c)$$

where E_{it} - emissions. Other variables are the same: per-capita income, temperature, wind, precipitation, smog and capital. We expect that the VCV will be *insignificant*, and as a result, do not include it in the above equation.

As a conclusion to the methodological part, let us summarize specifications of the models to be used in empirical research. The first models to be estimated are Random and Fixed effect estimations. Specific choice between consistent fixed effect models vs. efficient random effect model will be done on the basis of the *Hausman specification test*. For the second model (Simultaneous Equations Model),we use simplification and run models with instrumented variables .

To conclude the methodology, we use Egli (2004) model as a basic to estimation of EKC for Ukraine, and the model that we derive out of it is the main in our study. The hypothesis of SEM is approximated with instrumental approach, when we estimate only the pollution equation.

Chapter 5

ESTIMATION RESULTS

This description includes two sets of results: (i) the one associated with pollution expressed as concentrations (a city level analysis), and (ii) another one associated with pollution in terms of emissions (a regional level analysis). First, we run linear regressions and show that the linear model is misspesified. Second, we provide the description of the basic model that contains only income as a major explanatory variable and pollution in terms of concentrations. Next we add the vector of climate variables (VCV) to see whether the VCV coefficients are significant or not. Then we compare the obtained break points in these two models of the EKC. After that, we test the hypothesis of the EKC on the basis of simultaneous equations model. In the latter, *income* is influenced by the key factors such as assets per capita, the VCV and pollutants; in turn, *pollution* is determined by the VCV and income. *Finally, we discuss the obtained results in terms of break point analysis.*

The results of the "emissions" set are presented as follows. First, we discuss results of the EKC specification for pollution by transport, then stationary pollution and the overall pollution which is the sum of the previous two (overall pollution = stationary plus transport). Finally, we look at region specific results - OLS with dummies.

5.1. Description of the results based on concentrations

Bellow we present results of the EKC estimation when only linear terms of income are used in the model. Similar analysis was performed by De Groot at al. (2002) when the EKC hypothesis was tested for China. De Groot at al (2002) did not find the EKC for China, but linear specification of the pollution-income relationship produced negative correlation between pollution and income.

Table 1. The results of EKC regressions with ***linear*** income variables + VCV

(1)	(2)	(3)	(4)	(5)	(6)
	so2	no2	co2	dust	IZA
income	-4.25e-06 (0.000)***	-2.62e-06 (0.091)*	.0002283 (0.002)***	.0000409 (0.000)***	-.0003163 (0.309)
smog	0.000 (0.793)	-0.001 (0.111)	-0.001 (0.947)	0.002 (0.194)	0.008 (0.909)
precip	0.000 (0.613)	0.000 (0.558)	-0.004 (0.402)	-0.000 (0.814)	-0.014 (0.467)
wind	-.000168 (0.196)	-.0000234 (0.802)	-0.005 (0.280)	-.0003135 (0.356)	0.037 (0.051)*
temperature	0.000 (0.875)	0.000 (0.618)	0.005 (0.230)	-0.000 (0.378)	0.026 (0.106)
y1999-y2006	…	…	…	…	…
Constant	.0274029 (0.000)***	0.054 (0.000)***	2.167 (0.000)***	0.117 (0.000)***	6.720 (0.000)***
R-sq overall	8	2	10	10	2

In our study for Ukraine, we observe a negative and significant correlation between pollution and income for SO2, NO2, and the IZA. The income-pollution relationship is positive and significant at 99% confidence interval for CO2 and dust. The impacts of other explanatory variables are the same: once again effect of wind is negative, however insignificant. The results that are obtained for the CO2 are in accordance with the theory (Grossman and Krueger (1995), Stern (2003)), that is concentrations of CO_2 are increasing together with rise in per capita income.

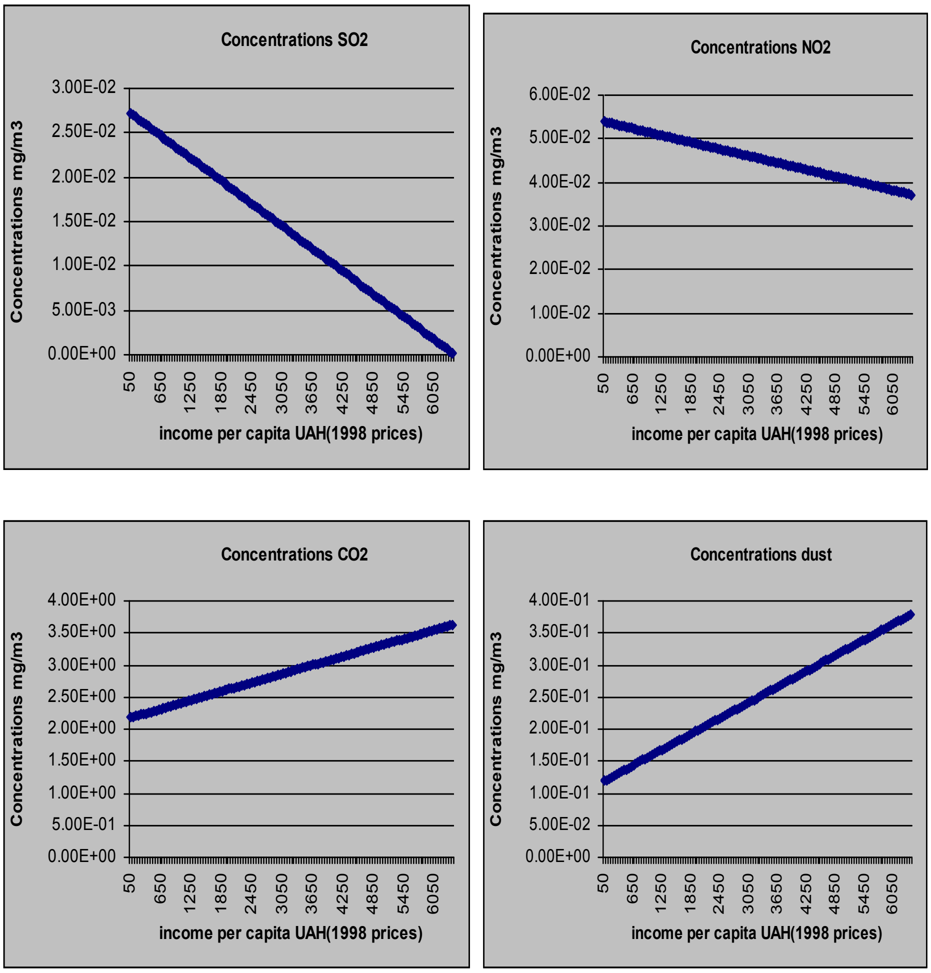


Figure 1. Linear relationship between concentrations of the pollutants and per capita incomes

The scaling of all graphs on horizontal axe represent the maximum income per capita among 50 cities in Ukraine in 2006 (we use real prices of 1998). That is in 2006 Kyiv has UAH 6200 in real money as per capita income. It seen from the graph on SO_2, that in the nearest future when all other cities will achieve the Kyiv 2006 income per capita, the concentration of SO_2 should become zero. However significance of EKC model may suggest that linear model is misspesified.

We proceed with description of the results of the standard EKC specification, in which only income is a major explanatory variable. The Hausman specification test showed that it was appropriate to use the *efficient random effect* rather than fixed effect (the test itself is presented in appendix B). The following table shows the results obtained under the assumption that the VCV and pollution have no influence on per capita income (no endogeneity assumption).

Table 2. The results of EKC regressions only with income variables

(1)	(2)	(3)	(4)	(5)	(6)
	so2	no2	co2	dust	iza
Income	.000013 (0.009)***	8.06e-06 (0.208)	.0001782 (0.551)	.000016 (0.498)	0.003 (0.012)**
inc2	-1.89e-09 (0.000)***	-1.07e-09 (0.082)*	6.38e-09 (0.826)	2.46e-09 (0.278)	-3.37e-07 (0.006)***
y1999	-0.002 (0.765)	0.001 (0.809)	-0.217 (0.093)*	-0.004 (0.646)	2.230 (0.000)***
..rest seven year dummies..					
Constant	0.003 (0.758)	0.039 (0.000)***	1.780 (0.000)***	0.126 (0.000)***	4.811 (0.007)***
Observations	450	450	450	450	450
Number of id	50	50	50	50	50
R-sq overall%	20	4	3	9	12

p values in parentheses* significant at 10%; **significant at 5%; ***significant at 1%

From table 2, it is seen that SO2 pollution follows the inverted U-shaped EKC pattern at 99% confidence interval while NO2 pollution follows the EKC pattern at 90% confidence interval. The obtained results for the other pollutants (CO2 and dust) show an increasing pattern, however, all coefficients are statistically insignificant. As for the year dummies some studies do include it, some studies do not include year dummies. We think that econometrically it is more proper to work with time dummies, because they could grasp some year specific changes on the whole territory of Ukraine. With time dummies we control equal change of some parameter in whole Ukraine within one year. The low R^2 suggest about high variability in data and maybe omission of some influencing factors.

There are some rather unexpected results associated with the Index of Aggregate Pollution. Format of the IZA was discussed in methodological part of this study. Generally speaking composition of the IZA is based on the Principal Component Analysis when a set of pollutants is converted into one aggregate index (the index is not a weighted arithmetic or geometric average, the construction of index was discussed in the methodological part). Each pollutant contributes its own share to the IZA according to its dangerousness. According to the Environmental Economics theory, some pollutants do exhibit the EKC pattern, and pollution eventually declines over time with an increase in income. However, other pollutants according to Grossman and Krueger (1995), Stern(2003) such as CO2, CO grow steadily with an increase in income, our findings also supports those arguments. Based on this understanding, we expected that the IZA would be insignificant. However, the IZA pattern turned to follow the inverted U-shaped pattern. Moreover, it is significant at 99% confidence interval, so may be the due to the fact that share of CO2 is not so big in index (CO2 is not relatively dangerous)

The focus of any EKC research is on the break point at which pollution begins to decline with an increase in income per capita. Below we present results and break points for all pollutants that follow theoretical EKC pattern. The results are taken from table 1.

$$SO2 = .000013 * \text{income} - 1.89e\text{-}09 * \text{income}^2,$$

The break point is **3440** UAN in 1998 prices or **9288** UAN in 2007 prices.

$$NO2 = 0.039 + 8.06e\text{-}06 * \text{income} - 1.07e\text{-}09 * \text{income}^2,$$

The break point is **3770** UAN in 1998 price or **10217** UAN in 2007 prices.

$$IZA=4.811+0.003*income-3.37e-07*income^2,$$

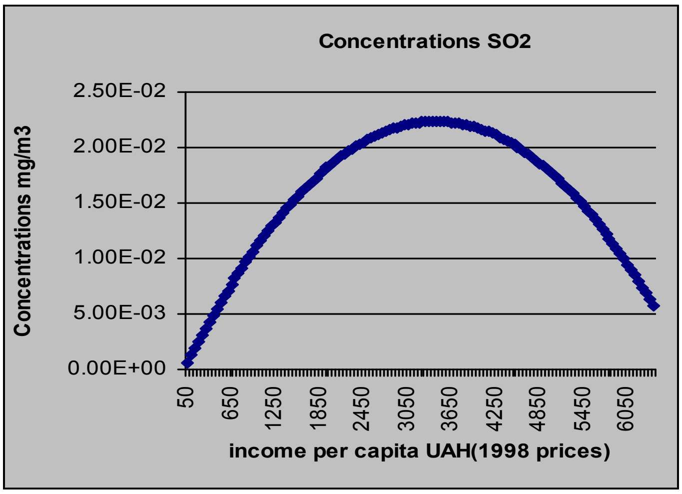
The break point is **4450** UAN in 1998 price or **12059** UAN in 2007 prices

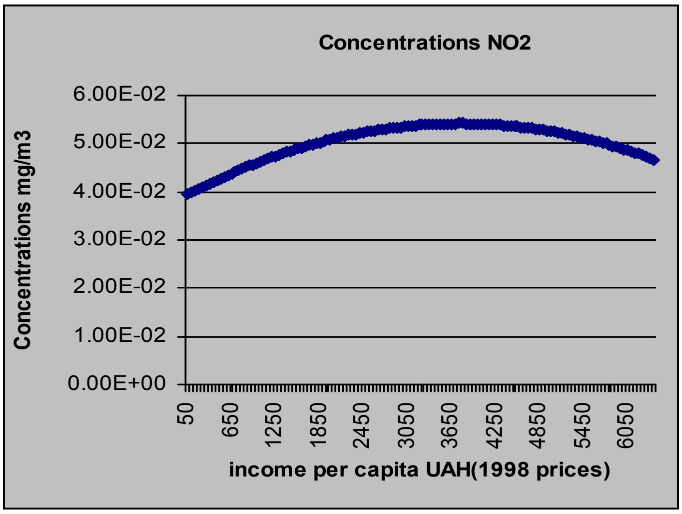
Our sample range on per capita income is between 1000 and 6000 UAH in 1998 prices. The 1000 means the poorest city in 1998 and 6000 UAH means the richest city in 2006 (all in 1998 prices)

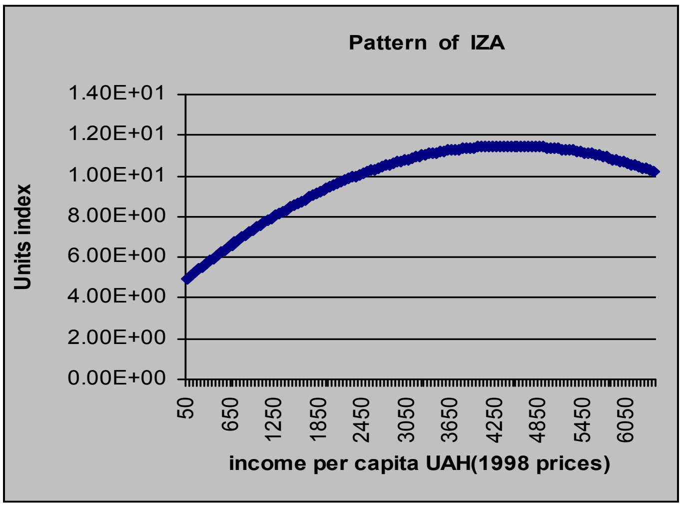
In order to perform comparison analysis, we calculated the cumulative index of inflation in Ukraine for the period of ten years. The cumulative index of inflation during the 1998-2007 period was defined as 271 %.(Ukrstat.gov.ua).

Here we do not define the level of income at which pollution equals zero (the point when the EKC curve crosses the horizontal axis). However, in Appendix A (data description) we show that maximum level of income in real terms prices of 1998 is 6197.845 UAN (it is for Kyiv in 2006), and the rest of cities are lagging.

Below we present the EKC for SO2, NO2, and IZA







Figures 2. The EKC specifications of SO2, NO2, and IZA

Since we use the same scale, the break points can be compared. The most recent break point is for the SO2 pollution, and it is associated with the income per capita equal to UAN 3440. In turn, NO2 pollution is associated with 3770 UAN, and the IZA is associated with 4450 UAN (all monetary values are given in 1998 prices).

From our city data set we found that almost all cities reached break points at 3440 UAN while the richest, big cities such as Kyiv, Donetsk, Dnipropetrovsk, Slovyansk, Kremenchyk and some other cities produced the value of income UAN 4500 in 2006 (1998 prices). ***According to our***

results on the basis of the IZA, a decrease in pollution is expected in the nearest future, specifically in the period of 2008-2010 on the whole territory of Ukraine. Some regions have already crossed the threshold but the majority are not (so we expect that in 3-7 years the majority of cities will cross the threshold.) but before the majority of regions will cross the threshold the pollution will increase, that's why we give such a broad prediction 3-7 years for Environmental situation to improve. This prediction is based on the EKC modelling of the pollution-income relationship that assumes no serious macroeconomic shocks implying that per capita income will be growing steadily in all Ukrainian regions.

Next we look at the EKC relationship with the VCV added to our regressions (see Table2).

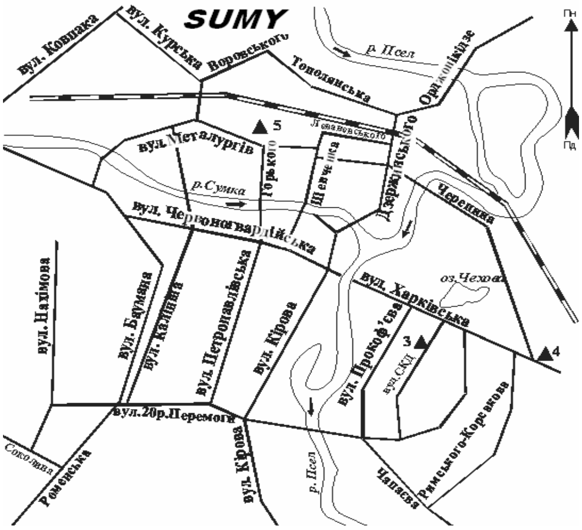
Table 3. The results of EKC regressions with income variables + VCV

(1)	(2)	(3)	(4)	(5)	(6)
	so2	no2	co2	dust	iza
income	.000013 (0.010)**	7.57e-06 (0.248)	.0000894 (0.753)	.0000176 (0.459)	0.003 (0.040)**
inc2	-1.89e-09 (0.000)***	-1.01e-09 (0.107)	1.43e-08 (0.611)	2.30e-09 (0.314)	-2.94e-07 (0.019)**
smog	.0001437 (0.801)	-0.001 (0.106)	-0.001 (0.944)	0.002 (0.183)	0.006 (0.937)
precip	0.000 (0.783)	0.000 (0.540)	-0.004 (0.413)	-0.000 (0.783)	-0.013 (0.491)
wind	-.0001246 (0.335)	-1.01e-09 (0.786)	-0.005 (0.287)	-.0003044 (0.370)	0.035 (0.060)*
temperature	-0.000 (0.813)	0.000 (0.816)	0.005 (0.210)	-0.000 (0.478)	0.020 (0.224)
Constant	0.012 (0.409)	0.042 (0.000)***	2.332 (0.000)***	0.146 (0.001)***	3.050 (0.192)
y1999-y2006 dummies	…	…	…	…	…
Constant	0.012 (0.409)	0.042 (0.000)***	2.332 (0.000)***	0.146 (0.001)***	3.050 (0.192)
R-sq overall	21	3	11	11	9

p values in parentheses*significant at 10%; **significant at 5%; ***significant at 1%

The above table shows that influence of wind as predicted is negative, however, insignificant at 10% level of significance, except for the IZA regression. Impact of smog is positive in some regressions but negative in others. It is also insignificant at 10% level of significance. Influence of precipitations in all these models is insignificant; and same is true for temperature.

The re-estimated break points for SO2, NO2, and the IZA do not change significantly when the VCV is present in the model. We found that the new break point for SO2 is at 3430 UAN level of income vs. 3440 UAN in the model without the VCV. The new break point for the NO2 is associated with 3750 UAN vs. 3770 UAN in the previous model. The new break point for the IZA is 5100 UAN vs. 4450 UAN in the previous model. The difference of 600 UAN is not a big one since annual real income per capita on average increases by 500 UAN over time(in real 1998 prices). So the issues of VCV are not a big problem if you add dummy variables for the years. When we run a regression without time dummies the VCV was still insignificant but the signs are correct. We think that insignificance arise due to the yearly aggregation of VCV parameters, and maybe due to the not proper use of information about the wind. That is we control for the strong and small winds, but we do not consider the direction of wind. For example, we have the map of city Sumy, all dirty manufactures, and we know the yearly wind rose in the city, but what we do not know is the location of the polluting industries on the map of the city (east, west, north, south or their combinations).



On both graphs UP is NORTH

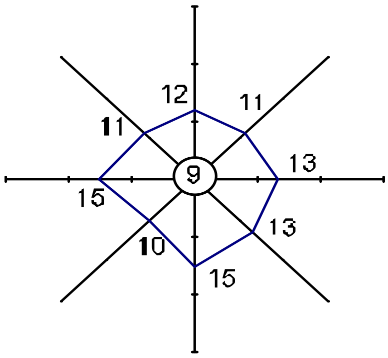


Figure 3.Map of city Sumy (with metrological stations marked as triangular) and wind rose of city Sumy.

We see that for Sumy the wind factor may even not important; because through year distribution of wind direction is almost the stable (there are no predominant winds). But we can not say it with respect to other cities. Below we provide some graphs on the direction of winds (Wind Rose) in some other cities.

They are Uzhgorod, Cherkassy, and Donetsk respectively.

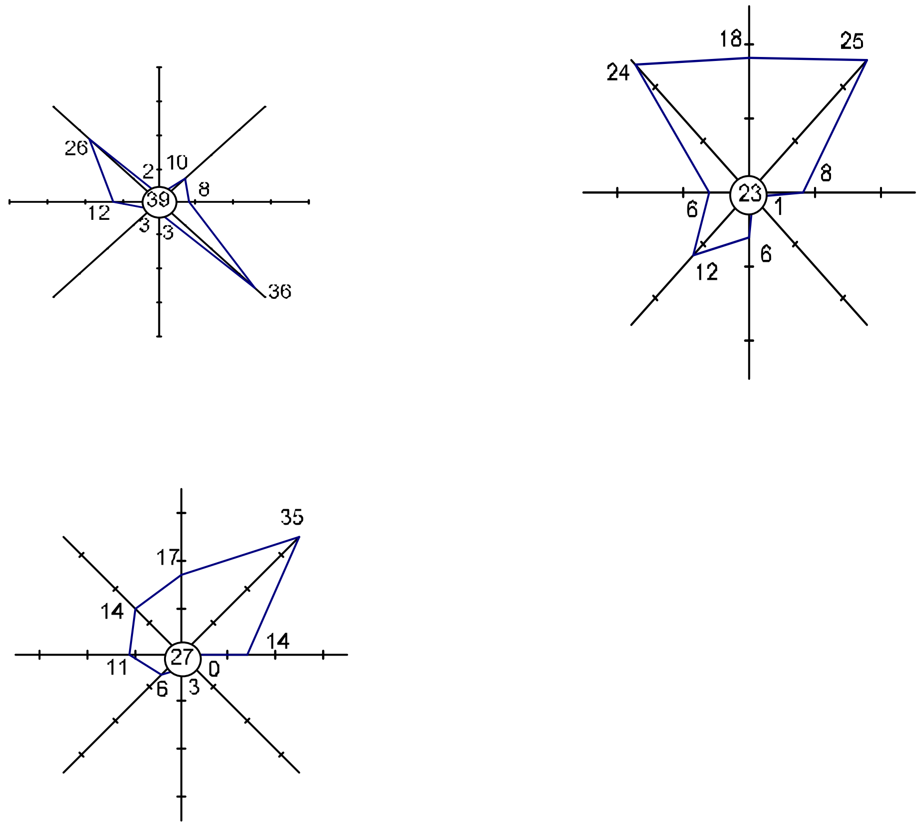


Figure4. The annual wind Roses of Uzhgorod, Cherkassy, and Donetsk

So from the pictures above it is very clear that location of the polluting manufacture is important, as well as the location of metrological stations which measure the concentrations is also important.

In our research we have a complete data on all city maps (with locations of metrological stations), complete data on wind Rose in each city, and complete data on all polluting businesses in each city respectively (overall again all is for 50 Ukrainian cities). What we don't know is the location of those polluting industries on the each city map. So we can't get more precise results on VCV without knowing the location of business in each city respectively.

When we run regressions for EKC with VCV we found correct but insignificant influence of wind on concentrations, if it was possible to consider the locations of both stations and polluting industries, together with Wind Rose in each city the results could be much more reliable, and maybe the significance would increase.

The test for serial correlation is presented in Appendix C. We failed to reject the hypothesis of no serial correlation, and that is why the model was re-estimated in order to control for the serial correlation within PANEL DATA.

Table 4. The results of EKC regressions with income variables + VCV (corrected for autocorrelation)

(1)	(2)	(3)	(4)	(5)	(6)
	SO2	NO2	CO2	dust	iza
income	.0000127 (0.080)*	.0000143 (0.035)**	.0001732 (0.567)	6.16e-06 (0.806)	.0028133 (0.040)**
inc2	-1.82e-09 (0.003)***	-1.56e-09 (0.021)**	6.00e-09 (0.850)	3.06e-09 (0.222)	-2.83e-07 (0.038)**
Smog	-.0001684 (0.777)	-0.001 (0.035)**	-0.001 (0.931)	0.001 (0.460)	0.016 (0.805)
precip	0.000 (0.766)	0.000 (0.449)	-0.002 (0.532)	-0.000 (0.857)	-0.001 (0.939)
Wind	-.0001282 (0.393)	0.000 (0.897)	-0.006 (0.219)	-0.000 (0.688)	0.041 (0.036)**
temperature	0.000 (0.897)	0.000 (0.633)	-0.001 (0.822)	-0.000 (0.800)	0.013 (0.328)
Constant	0.017 (0.324)	0.030 (0.012)**	2.314 (0.000)***	0.150 (0.001)***	1.991 (0.407)
Observations	450	450	450	450	450
Number of id	50	50	50	50	50
R-sq overall%	20	8	11	10	9

Here we discuss the corrected results only in terms of break points for models that exhibit the EKC. The break points were estimated for per capita income in UAN 1998 prices at the levels of 3490 UAN, 4580 UAN, and 4970 UAN for SO2, NO2, and the IZA respectively. These results are not much different from the previously calculated break points. In terms of time difference, it is not longer than two years (except for NO2). The results obtained for NO2 corrected for autocorrelation differ significantly. Break point without the VCV was estimated at the level of 3770 UAN and the new one (corrected for autocorrelation) at the level of 4580 UAN (see the graph below)

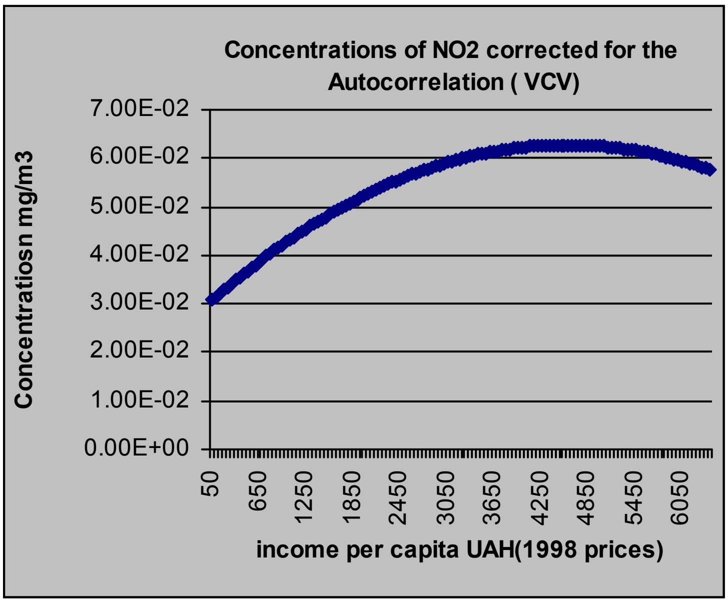


Figure 5. The EKC specification of NO2 concentrations with VCV and corrected for the serial correlation.

We see that VCV does not change much the break points (which are important for the study). So basically we have to admit there is no omitted variable bias in terms of VCV for the country such as Ukraine. If in some specific year in Ukraine there was increase in temperature or change in some other VCV indicator the year dummy variable captures the effect.

The test for the Heteroscedasticity was not rejected, and we run FGLS regressions for our panel data (All tests are in Appendix M). Bellow we present results from xtgls estimation procedure, one interesting fact is that many of VCV factors are significant however the year dummy become insignificant.

The above analysis was performed under assumption that income was *not influenced by the VCV and by pollutants*. Now we address the EKC issue under the assumption that the VCV and pollution influence per capita income as well. That is we use instrumental variable approach discusses in the Methodological part.

The earlier studies that considered climate variables in estimation of the income-pollution relationship were cited in methodological part, and they are Chimeli (2002), Jeffrey Sachs (2003), Helmy (2007), Deschenes (2004), Suman Jain (2007).

In order to estimate the income regression we use Ming-Feng Hung and Daigee-Shaw (2004) specification of the relationship in a form of equation (5a). This is a Cobb-Douglas production function of some specific form. The model that we use for estimation is also a modified Cobb-Douglas production function. The income equation is presented in the log-log form to work with elasticities (equation 8) as follows:

$$\ln Y_{it} = \delta_0 + \delta_1 \ln SO2_{it} + \delta_2 \ln NO2 + \delta_3 \ln dust + \delta_4 \ln CO2 + \\ + \delta_5 \ln W_{it} + \delta_6 \ln R_{it} + \delta_7 \ln S_{it} + \delta_8 \ln T + \delta_9 \ln K + \tau_{it}$$

Table 5. the Estimation of the income equation.

```
Random-effects GLS regression      Number of obs =   450
Group variable (i): id             Number of groups = 50
R-sq:  within  = 0.9761            Obs per group: min= 9
       between = 0.5484            avg = 9.0
       overall = 0.7136            max = 9
Random effects u_i ~ Gaussian      Wald chi2(17) =121.26
corr(u_i, X) = 0 (assumed)         Prob > chi2 =  0.0000
```

lnincome	Coef.	Std. Err.	z	P>|z|
lnasper	.1865378	.0402924	4.63	0.00 0
lnso2	-.0171741	.008438	-2.04	0.042
lnno2	-.0038037	.0123876	-0.31	0.759
lnco2	.0000327	.0034426	0.01	0.992

lndust	.0206264	.0076958	2.68	0.007
lnsmog	.008492	.0085451	0.99	0.320
lnwind	.0405543	.0336635	1.20	0.228
lntemp	.0444326	.0164784	2.70	0.007
y2006	1.07048	.0202728	52.80	0.000
_cons	6.295135	.2219335	28 .36	0.000

Rest year dummies can be found in Appendix D.

The Cobb-Douglas specification of the income equation explains 71% variability in statistical income. Variable ***asper*** stands for assets per capita in each particular city in real values adjusted for inflation over study period. As seen from the above regression, income is correlated with both the VCV and concentration of pollutants. Economic theory states that pollution negatively influences per capita income. However, in our regression we found that SO2 was negatively correlated with income while dust was positively correlated (both SO2 and dust are significant at 5% level of significance). The VCV is significant in terms of ***Wind*** and ***Temperature*** factors. Both wind and temperature positively affect income: temperature is significant at 1% level of significance while wind is not statistically significant. The above regression supports the fact that southern Ukraine (Donetsk, ARK, Odessa) is richer not only due to its well-developed manufacturing sector but also due to some favourable climate conditions. Apparently this is due to tourism since all of these regions are located close to seas, and, as a result, average annual temperatures are higher.

According to the above mentioned arguments the fact that pollution and the VCV influence per capita income, we are not able to estimate the System of Simultaneous equations (6a) and (6b) since equation (6b) cannot be identifiable. In table 5 we showed that income is itself is influenced by VCV and pollution, so the pollution equation itself can be estimated only with SEM or instrumental variable approach. To overcome identification problem, we use instrumental variable approach. First, we estimate equation (8), which is given in table 5, and then we use the fitted values of income from that equation to estimate the pollution equation (9)

We have done the 2 step GLS estimation procedure, because in our case it is impossible to use *xt ivreg* (automatic instrumental variables), because we have Squared income, which can not be instrumented automatically, we have done it on manual base. The Stata output is presented in the Appendix F.

As the results of the table above suggest only dust follows the expected EKC pattern under the assumption of the Simultaneous Equation Model. The EKC relationship is as follow

Dust= -0.588+ 0.001*income -5.29e-08*income^2

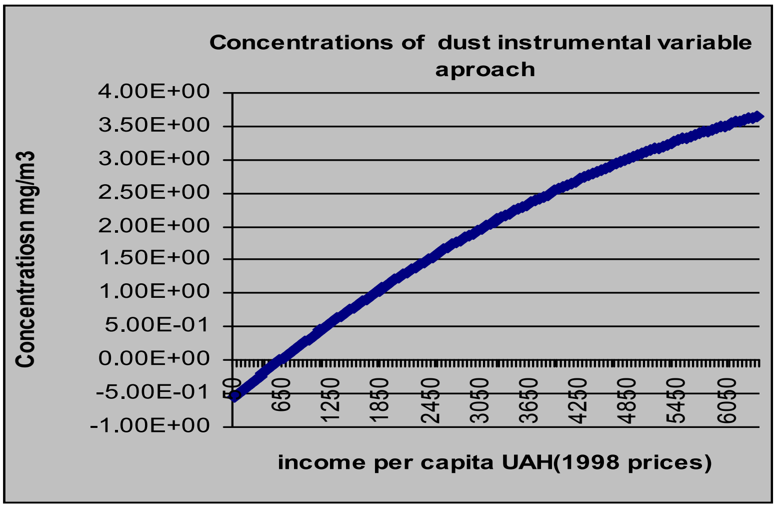


Figure 6. The EKC specifications of dust concentrations (instrumental variable approach)

The dust pattern using the instrumental variable approach is presented on the same scale as our previous models for SO2, the IZA, and NO2. Break point for *dust* was estimated at the level of 9450 UAN in 1998 prices which is 25510 UAN in 2007 prices. Such a level of per capita income has not been reached by any city in Ukraine. Therefore, the expected break point for dust is suspicious. When we correct for autocorrelation in the regression with instrumental variable (see table 6), the results for SO2 and NO2 become insignificant, however, results for dust are still significant. The new break point in real terms of 1998 prices is 8278 UAN. The corrected for autocorrelation results are given in Appendix F.

There are two alternative ways of estimating the panel data in Stata: First, using option ***xtreg*** command; second, estimation of the usual regression with dummies for each region but one. The results are the same only when the option ***xtreg*** is estimated for the *fixed effect* (the fact that those two options are identical is described in appendices G1 and G2). Bellow we present results of estimation of the usual regression with dummies. This really contradicts to the previous statements that random effects are better, but what we need is to see the relative pollution of each city in comparison to control. Alchevsk 1998 was chosen to be a control city. We can see that dummies for other cities are negative and are almost all significant. It means that Alchevsk is one of the most polluted cities in Ukraine. This is obviously due to many metallurgical enterprises located there. As for the EKC pattern, it is not observed. However, earlier we have performed a Hausman specification test in favour of random effect estimation (all of the regressions above). The regional concentration analysis may be used only to see the influence of each specific city dummy, when the Hausman test favours random rather than fixed effect. The regression results are presented in Appendix G1.

The reason that we include the city specific regression output in the text is that we want to compare different regions in terms of pollution through the city dummies. The only two cities: Gorlivka and Dniprodzerginsk are dirtier than the control city Alchevsk.

In this paper we used different models for the EKC specification, they are linear and logarithmic, and also both vary in terms of VCV (include/not include), autocorrelation (corrected/not corrected), assumptions of simultaneity (instrumental/not instrumental approach). All those specifications have shown some EKC patterns, with corresponding break points.

Below we unite all break points from different models and present them in a single table.

Table 6. The EKC **break points** from the different model specifications (in 2007 prices)

	SO2	NO2	IZA	Dust
Models without VCV	**9322.4**	**10216.7**	**12059.5**	**na**
Models corrected for autcorr (without VCV)	**9455.19**	**12419.93**	**13470.04064**	**na**
Models with VCV	**9295.3**	**na**	**14097.42**	**na**
Models with VCV correct for autorr	**9457.9**	**12419.93**	**13468.7**	**na**
Models with instrumen approach	**na**	**na**	**na**	**25614.92**
Models with instrument approach correct for autocorr	**na**	**na**	**na**	**22433.775**

The table above represents EKC break points for the different concentration of the pollutants under the different specifications of the pollution income relationship. The usual specification of the model we correct for the autocorrelation, than estimate break point with VCV, and also correct for the autocorrelation. The last specification is within instrumental variables corrected and not corrected for the autocorrelation. The main finding is that the beak point incomes per capita are not far away from the today's levels, and in the nearest future we expect the Environmental situation will improve in Ukraine.

5.2. Description of the results based on the emissions of pollution

In Appendix H, we present *output* regression results from overall pollution regressed on per capita income and the VCV. Here we discuss only overall emission which is the sum of emissions from stationary points (firms) and automobile transport 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.

Now we address the problems of endogeneity and use instrumental approach to address the issue. There is a significant correlation between income per capita and emissions as shown in table 7.

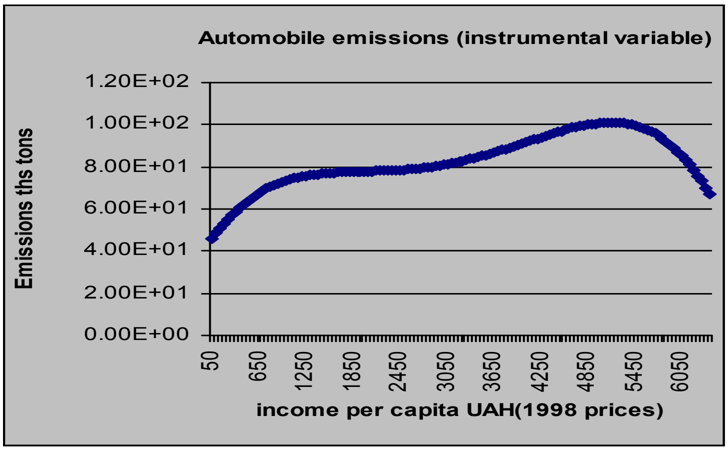
Table7.Modeling the income relationship with emission

	(1)	(2)	(3)	(4)	(6)
	income	income	income	income	income
assetsmln	0.022 (0.000)***	0.021 (0.000)***	0.021 (0.000)***	0.021 (0.000)***	
asper					47.377 (0.000)***
overallpoll			6.289 (0.000)***		6.021 (0.000)***
pollutavtom	3.703 (0.177)	5.721 (0.051)*		5.721 (0.051)*	
pollutionstati	7.014 (0.000)***				
precip	-3.131 (0.327)				
wind	-1.739 (0.732)	3.661 (0.501)	0.285 (0.952)	3.661 (0.501)	1.072 (0.811)
temperature	3.431 (0.407)	3.111 (0.489)	3.038 (0.461)	3.111 (0.489)	5.627 (0.148)
donetsk				-441.308 (0.640)	-6,836.031 (0.000)***
Constant	-10,719.569 (0.000)***	-441.308 (0.640)	-10,332.374 (0.000)***		
ark	10,749.077 (0.000)***	33.927 (0.938)	9,956.041 (0.000)***	-407.381 (0.519)	-1,337.596 (0.008)***

vinnit	10,644.164 (0.000)***	215.376 (0.653)	9,870.040 (0.000)***	-225.932 (0.722)	-1,151.475 (0.025)**
dnipro	5,332.589 (0.000)***	226.638 (0.305)	4,875.359 (0.000)***	-214.671 (0.800)	-5,847.833 (0.000)***
	Rest cities in	Appendix J			
chernigiv	11,329.659 (0.000)***	561.922 (0.309)	10,542.050 (0.000)***	120.614 (0.823)	-707.650 (0.104)
y1999	282.477 (0.004)***	283.146 (0.008)***	298.267 (0.002)***	283.146 (0.008)***	417.735 (0.000)***
y2006	2,212.481 (0.000)***	2,384.545 (0.000)***	2,221.490 (0.000)***	2,384.545 (0.000)***	2,493.874 (0.000)***
Constant	-10,719.569 (0.000)***	-441.308 (0.640)	-10,332.374 (0.000)***		
Observations	225	225	225	225	225
R-squared	0.925	0.911	0.924	0.983	0.98

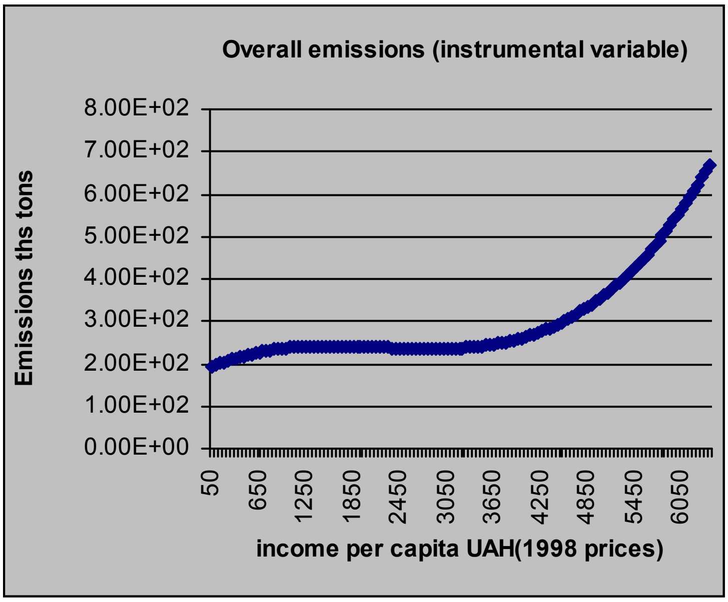
We have also tested the influence of emissions on per capita income with dummy variables that reflect all regions in Ukraine. The model uses Donetsk 1998 as a control city for the first two specifications, and no intercept is assumed. In table 8 results of these regressions are presented. The main finding is that *assets,* and assets per capita (*asper),* automobile pollution and overall pollution variables have positive and significant impact on per capita income. In addition to that the explanatory power of emissions regressions is high - between 0.91 and 0.98.

According to the above presented discussion, income is correlated with both types of emissions – mobile (automobile) and stationary. Again, because of endogeneity problem, we use the instrumental variable approach in order to more carefully estimate the emissions equation. The first step is estimation of instruments for income variable. We use equation (6) from table (7) as a basic equation for instrumented income, and then we use the fitted values of income which is *incomehat.* Next step is re-estimation of the emission-income relationship with new instruments. The results of the instrumental variable approach are given in Appendix K. 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. Estimation results were strikingly similar to the previous. Automobile pollution showed the inverted relationship with respect to income, and the obtained pattern is presented on graph 7

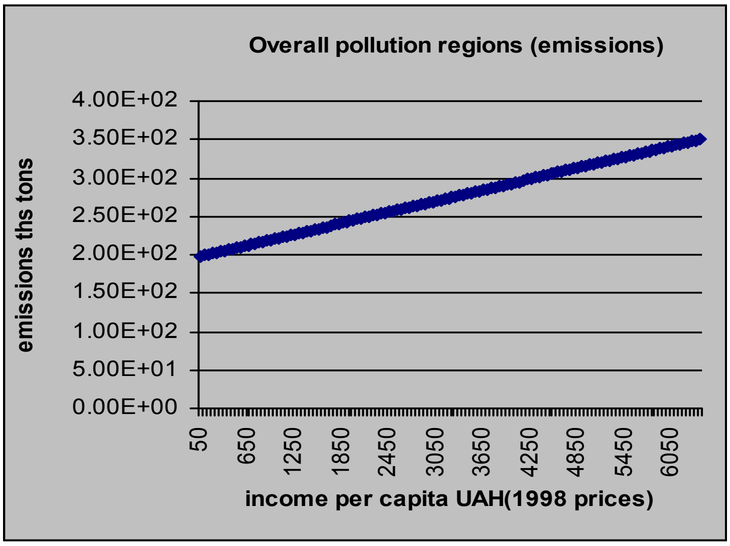


Graph 7. The behaviour of automobile emissions modelled with instrumental income.

From graph 7, we can expect that automobile emissions should decrease pretty soon. 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.



The linear spesificating of overall emissions is as follows.



Graph 8. The behaviour of overall pollution under the instrumental variable approach and usual linear relationship.

It turns out that different specifications of the overall pollution failed to exhibit the EKC pattern. Therefore, only automobile emissions alone exhibit such a pattern as seen on graph 7.

Actually we can't compare two data sets (concentrations vs. emissions) because of the different measure of pollution. The problem is that emissions are not just kilograms of CO2, NO2, dust, etc, but also production wastes released into the atmosphere are also added to emissions. The other reason of incomparability of two data sets is that regions and big cities in the regions are not the same things. Big cities are usually richer that small cities and purchasing more cars and those cars are very likely to be expensive ones, which are often more or less environmentally friendly. That is situation in big can be improved even to that factor. Than second-hand cars are often resale at rural areas and small sites, so the overall regional emissions (sum of big and small cities and villages) increase, while big sites are very likely to become purer. On that ground the results of concentration block and emission blocks are treated separately.

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 main finding from the regional analysis is that the automobile emissions were like a plateau with different per capita incomes. 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.

Conclusions

Influence of per capita income on pollution is modeled with the help of the Environmental Kuznets Curve (EKC). The EKC pattern suggests an inverted U–shape relationship between per capita income and pollution. The main finding of our study is that Ukraine follows the EKC pattern for some pollutants such as SO2, NO2, IZA while there is an increasing pattern for other pollutants such as dust, CO2.

The pollution-income relationship was specified in the usual way as quadratic and logarithmic relationship. Both representations were estimated, but only linear relationship showed the EKC pattern (logarithmic model did not support the EKC hypothesis). Inclusion of the Vector of Climate Variables (VCV) into the model did not change much the value of coefficients associated with income. For models exhibiting the inverted U-shape relationship we have estimated break points, and they appeared to be in the range $2000-$5000 in 2007 prices. Our findings are comparable with the earlier studies that estimated beak points at $1000-$80000US. For example, Feng and Show (2004) estimated break point for CO in Taiwan at $6000. According to Egli Hannes (2004), the break point for NOx in Germany was estimated at US$14750 (in 1985 prices), break point for NH3 was at US$17000 (in 1985 prices). List, Millimet al., (2003) performed the EKC modelling for the US, and the estimated break points were at US$5000-20000 (in 1987 prices).

The crucial question that may arise is: Why Ukraine has such small value of break points in comparison with other countries? One possible answer is that oil and natural gas prices are constantly increasing in Ukraine, and Ukrainian businesses are forced to use more energy effective technology which is also more environmentally friendly. Below we provide examples of the largest Ukrainian corporations that started to implement more energy effective equipment according to Rozhin (2007). "Thus "Mariupol Illich Steelworks" in June 2006 started to introduce pulverized coal injection on its blast furnaces. “Yenakievskiy Steelworks” is building coal-dust complex. “Mittal Steel Kryvyi Rih” switches its blast furnaces from gas to coke of higher quality. According to the steel plant announcement it is going to invest 325 million in modernization. It will lead to economy of about 190 thousand cubic meters annually. “Donetsk Steelworks” completely switched from gas to coal-dust fuel. “Alchevsk Steelworks” is going totally invest 1.4 billion dollars over the period of 2007-2010. It is going to decrease gas consumption by 80 percent.“Azot Cherkasy” is investing 400-600 million dollars during the period 2007-2010. The main aim of the program is to cut high energy costs.”

Found values of the break points in Ukraine on the basis of the EKC are smaller than those in developed countries, which may suggest that Ukraine follows its own pattern in economic development.

Our assumption about the omitted variable bias failed to be supported by Ukrainian data on pollution (in terms of concentration). The difference in break points with and without VCV disappears in one or two years.

However, the VCV happened to be important in GLS estimation of the EKC: Wind, smog, and precipitations showed expected results. Random effect showed insignificant influence of the VCV.

The main prediction of our findings based on the EKC is that pollution by SO2 and NO2 should start to decrease in the nearest future, while pollution by CO2 and DUST is going to increase. There is a specific case with dust which failed to support the EKC hypothesis under usual assumption (pollution does not influence per capita income), but showed the inverted U-shape relationship under the instrumental variable approach (break point was at the level of UAN 22433).

The emission data set failed to support the EKC, 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.

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