The Influence of Innovation Activities and Energy Resource Use on the Environmental Situation

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Abstract. *The paper examines the features of the environmental transformation in Ukraine. The results suggest that there is no inverted U-shape relationship between per capita incomes and air emissions (both for pollution per square kilometer and on pollution from stationary sources). However, air emissions from automobile sources show an inverted U-shape relationship. It is essential that expenditures into innovations and innovations products significantly increase all air emissions. Production of innovation goods is also related to the increase in air emission in Ukrainian regions. The reason is that the core of Ukrainian industrial output is related to mining, machine building, metallurgical and chemical production, and whatever innovations are happening with these industries still they would be related to pollution*

Keywords: *environmental and economic development, environmental transformation, environmental Kuznets Curve, economy of Ukraine.*

1 Introduction

The deterioration of the natural environment and reduction ecosystems resilience in Ukraine is mainly related to industrial activity. Among the main sources of environmental pollution are sectors related to the production and processing of non-renewable (raw) types of natural resources.

According to international sustainability indicators, Ukraine occupies last rows of the ranking table, being ahead for some positions in front of African and some Latin countries. For instance, according to the World competitiveness index, Ukraine occupies 70–80th positions among the one hundred and forty participants. The same situation is observed with ecological indicators where Ukraine holds 110–120 position among more than 180 countries participants. The somehow better situation is found with the social dimension of sustainable development, and for example, according to the human development index statistics, Ukraine occupies 80–90 th places (Global Competitiveness, 2018; Environmental, 2019).

In addition, according to official statistics, annual regional innovation expenditures per employer are varying from several USD to half of the thousands.

Objectives: The objective of the paper is to estimate the influence of innovation activities on air emissions and consumption of nonrenewable energy resources in Ukraine.

Practical contribution of research: It is expected to find the relevance of environmental innovation in the structure of all innovation activities in Ukraine and provide relevant policy recommendations for green innovations stimulation in Ukraine. Hypotheses to be tested. Higher relative expenditures for innovations are related to greener regional economic activities. Moreover, it is expected that the growth of per capita incomes would be correlated with the decline of air pollution due to the presence of environmental Kuznets Curve.

The literature review section is divided into two parts. First of all, it is described the innovation activities influence of environmental situations. The second part is devoted to the analysis of per capita incomes on different kinds of pollution.

The innovation-pollution. There is a significant difference between green invention and green innovation, and the first one constitutes the early development of a scientifically or technically new environmentally friendly product or process. The first step of the green invention requires costly research to develop the technical idea with no guaranty that the last one would be sometimes commercialized. The second step is the promotion of green innovation itself and appears only when the new product or process is advertised and started to be available on the market. Most inventions have never been developed into an innovation due to the severe requirements from the market response. Adoption of technical innovation could be a costly procedure since firms have to learn about new technology, purchase new equipment, and frequently adapt it to their particular circumstances (Jaffe, 2004). But it is not enough, and new technology should be pollution reducing one. Within our analysis, we define environmental innovations like (Horbach, 2010) as a product, process, marketing and organizational changes leading to a noticeable reduction of environmental burdens. Development of green innovations and opportunities that industries would have for pollution reduction do not themselves guarantee these technologies will be used. According to Ashford (2003) among the factors that affect the ability and willingness of companies to implement waste reduction measures are the following:

(1the nature of the company's industrial processes;

(2) the size and structure of the company;

(3) technology and information available to the company;

(4) attitudes and opinions that affect company operations;

(5) the economics of waste reduction, and

(6) government regulations.

As for the environmental innovations, they must be environmentally beneficial, and meet a range of other criteria: they should be expectable, it should be possible to fit them into existing processes and in the case of products, and they should meet user requirements in terms of performance characteristics (Kemp, 2000). The classic examples are environmentally friendly shower heads and environmentally improved detergents. The first ones should be comfortable with good stream power and, the second ones should have good washing performance. To be more specific (Kemp, 2000) when the new synthetic detergents were created foam in surface water appeared as an environmental problem. In response to that soap producing companies have developed new environmentally clean processes. Everything has been done without any government regulation. However, there was a definite expectation that there could be some regulation policies in the future. That is in some instances the threat of control may be enough to induce industry to look for greener solutions. The last does not exclude the need for regulation since they are needed for the widespread diffusion of environmental innovation.

Many firms perform some kinds of innovations, but eco-innovators are not significant fraction among them. Jens Horbach, 2010 analyzing Community Innovation Panel (CIS) 2009 measures eco-innovations through the twelve different areas of environmental impacts. Nine of which are environmental process-related impact and include reduced material use per unit of output; reduced energy use per unit of production; reduced CO_2 emissions; reduced emissions of other air pollution; reduced water pollution, decreased soil pollution; reduced noise pollution; replacement of hazardous substances; recycled waste, water, or materials. The rest three areas of environmental impacts are related to after sales use of a product and include reduced energy use; reduced air, water, soil or noise emissions; improved recycling of products after use. Among innovating firms in Germany up 40 percent were implementing to some extend recycled waste, water, or materials (7 percent of firms were considered as high innovators, and 17 were small innovators). As for the reduced energy use per unit of output up to 45 percent of all innovating firms were included (8 percent of firms were considered as high innovators, and 20 were small innovators).

Green innovations are specific kind of innovations, which generally stimulates achieving the next significant advances in pollution reduction. The necessary green innovations should include: (1) the substitution of harmful materials used as inputs, (2) production and/or management processes redesign, and (3) final product reformulation.

In the case of promoting green innovation to combat specific environmental problem (e.g., air pollution) there could appear two market imperfections. First of all, any pollution being a negative externality imposes its costs on surrounding environments and polluter has little interest from a social perspective to reduce those costs. On the other way, green innovation implementation also related to market imperfections since the firm that develops or implements green technology generally creates benefits for others, and there is not much incentive to increase those benefits by more profound promotion of new technologies or process. To summarize (Jaffe, 2004) states that pollution is a negative externality and "invisible hand" of the free market allows too much of it. Technology creates positive externalities, and the same "invisible hand" produces too little of it, since successful innovative firms would capture the only fraction of total rewards, and rest part of overall benefits comes to society. Hence, innovator creates positive externalities in the form of knowledge spillovers for other business and increases consumer surplus due to the use of improved technologies (Jaffe, 2004).

Customer requirements could be another important source of eco-innovations (Horbach, 2010). The last is especially important for products with improved environmental performance. The innovations processes are related to increased material efficiency, reduce energy consumption and waste-producing. The same was found by Kammerer (2009), and empirical evidence provided arguments that customer benefits play a significant role for green innovations as soon as a product delivered added value to the customer. The last was usually transformed into increased demand for the commodity. Such a situation is not typical for the electricity generation industry; however, consumers are ready to pay a premium for organic food or organic baby clothes.

The income-pollution. Several theories appeared to explain the income-pollution relationship. Theoretically, the bell-shaped relationship between pollution and per capita income (which was named an Environmental Kuznets Curve, EKC) can be defined by several assumptions. 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, in the early stages of a country's development, the technical effect brings a negative impact on environmental quality due to the intensive exploitation of the resources. The composition effect explains the EKC hypothesis from a structural standpoint. In the process of development, when nations become a richer share of industrial sector diminishes relative to the service sector. New industrial areas appear within an economy, which are less environmentally damaging (Kubatko, 2008). The work done by Jaeger and Kolpin (2001), constructed the theoretical framework, which explains the inverted U-shape relationship through consumer utility maximization task, where environmental quality is treated as one of the factors. It was stated that an 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) indicates that the best way to improve the environment is to become rich.

2 Methodology

Cramer (2002) used a logarithmic Cobb-Douglass production function to explain the pollution on the cross-country level. The estimated model was as follows:

$$\text{In I} = \beta_0 + \beta_1 \text{ In } (P') + \beta_2 \text{ In } (A') + \beta_3 \text{ In } (R') + \beta_2 + \varepsilon_t,$$

where *lnI* – trends in the county's emissions;

LnP – growth rate of population;

LnA – trend in per capita income;

LnR – trend in regulated technology (amount of money spent by local government on environmentally clean technology)

The error term in the model mentioned above reflected unobservable factors such as culture, local values, and technological changes. Cramer (2002) finds that states with higher levels of GDP per capita do have slower population increment, and finally the lower pollution. Higher rates of population growth are related to the higher increase in emission, and β_2 coefficients are positive. The significant bulk of EKC models are estimated with linear models. While, some authors use logarithmic specification accepting income endogeneity in pollution model. According to the economic theory, there is an inverted U-shape link between pollution and income, which goes from income to pollution. 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*

Table 1 Influence of innovation expenditures on air emission in Ukraine 2006–2013

	(1)	(2)	(3)	(4)
	pollut_per_km2	**pollut_per_km2**	**pollut_stat_th_ton**	**pollut_auto_th_ton**
Income	.0001784 (0.000)***	-0.004 (0.000)***	-0.083 (0.000)***	0.018 (0.002)***
Income squared		1.65e-07 (0.000)***	3.48e-06 (0.000)***	-6.03e-07 (0.009)***
Innovation expenditures	6.13e-07 (0.094)*	7.86e-07 (0.029)**	.00003 (0.002)***	-6.90e-06 (0.099)*
assets (fixed)	.0002592 (0.001)***	.0001311 (0.155)	0.002 (0.272)	0.008 (0.000)***
Nonrenewable resources	0.002 (0.000)***	.0017466 (0.000)***	0.043 (0.000)***	0.002 (0.000)***
y2006		1.155 (0.002)***	19.573 (0.031)**	-10.301 (0.010)***
y2007		3.002 (0.000)***	39.244 (0.003)***	-14.551 (0.003)***
y2008		4.472 (0.000)***	62.670 (0.002)***	-19.338 (0.004)***
y2009		3.084 (0.000)***	38.342 (0.010)**	-4.530 (0.409)
y2010		5.665 (0.000)***	91.388 (0.000)***	-4.251 (0.599)
y2011		6.836 (0.000)***	108.924 (0.001)***	-20.549 (0.048)**
y2012		8.000 (0.000)***	129.841 (0.001)***	-33.377 (0.010)***
y2013		8.605 (0.000)***	143.090 (0.001)***	-35.107 (0.011)**
Constant	-0.800 (0.236)	18.177 (0.000)***	288.543 (0.000)***	-43.737 (0.087)*
Observations	225	225	225	225
Number of id	25	25	25	25

Source: calculated by authors

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:

$$\text{In } P_{it} = \boldsymbol{\mu}_t + \gamma_1 \text{ In } Y_{it} + \gamma_2 (\text{In } Y_{it})^2 + \omega \ln X_{it} + \varepsilon_{it}, \quad (1)$$

$$\text{In } Y_{it} = \alpha_t + \beta_1 \text{ In } P_{it} + \beta_2 \text{ In } K_{it} + \beta_3 \ln L_{it} + \beta_4 \text{ In } H_{it} + \beta_5 \text{ In } G_{it} + e_{it}. \quad (2)$$

The first equation is responsible for the pollution equation. *P* is the environmental indicator *i* in year *t*. *Y* is GDP per capita income in region *i* in year *t*. For that reason, income has both a direct and *indirect influence on pollution. regions"*.

The second equation is the transformed Cobb-Douglas production function. Where P_{it} is pollution, K_{it} – capital, L_{it} – employment, H_{it} – human capital, G_{it} – are government expenditures/costs, which are given in year *t* in regi on *i* respectively.

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 defined for identification purposes.

The order condition for identification is

$$\textit{Def. 1: } K - k \geq m - 1, \quad (3)$$

$$\textit{Def. 2: } (M - m) + (K - k) \geq (M - 1), \quad (4)$$

where, *M* – the number of endogenous variables in the model, *m* – the number of endogenous variables in a given equation, *K* – the number of predetermined variables in the model, *k* – the number of predetermined variables in a given equation. As a conclusion to the methodological part, let's summarize specifications of the models to be used in empirical research. Having a panel data for Ukrainian regions to estimate the income-pollution and innovation-pollution relationships random and fixed effect estimations have to be used. The specific choice between consistent fixed effect models vs. efficient random effect model will be done on the basis of the *Hausman specification test.*

3 Results

The increase of air emissions was observed in 9 regions of the country in 2008-2013 namely in the Vinnitsa region by 16%, Kiev region – 14%, Kharkiv region – 14%, Cherkasy and Kirovohrad regions – 11%, Kherson region – 10% Ternopil region – 3%, Dnipropetrovsk and Lviv regions 1%. As for the absolute magnitude of pollutant emissions into the atmosphere from stationary sources is more than two-thirds of emissions accounted for three regions: prewar Donbass (Donetsk and Lugansk), and Dnepropetrovsk. There are 7.2 tons of air pollution per square kilometer in Ukraine or about 95 kg per capita as an average pollution density from stationary sources. However, some regions, like Donetsk, Dnipropetrovsk, and Luhansk emitted much more emissions exceeding the national average by 5–8 times per 1 square kilometer. The water pollution in Ukraine is caused on 53 percent by electricity generation firms and industrial sphere, by the housing and communal services on 32 percent and 11 percent are due to an agricultural sphere (Environmental, 2007). The regression analysis for pollution being a dependent variable is presented in table 1.

The obtained results (table 1) suggest that there is no inverted U-shape relationship between per capita incomes and air emissions (both for pollution per square kilometer and on pollution from stationary sources). However, air emissions from automobile sources show an inverted U-shape relationship. It is essential that expenditures into innovations and innovations products significantly increase all air emissions. The slope coefficient for innovation expenditures in column 3 suggests that every 100 mln. UAN invested in innovations increase air emissions on three tons in a region. It is not a significant amount since it would be on average 0.15 kilograms per 1 square kilometer per year. That is even the implementation of new technological processes does not reduce air emissions in Ukrainian regions. According to (Jaffe, 2004) environmental impact of social and economic activity is significantly affected by the rate and direction of technological change and technological change itself could either create or mitigate pollution.

The same is true for the regional fixed assets, the more the assets are within the region, the higher the pollution. The reason could be in the classification of innovative expenditures, for example, if the new chemical or metallurgical plant is built, and the last overstrikes efficiency of other already existing plants it could be considered an innovation. Nevertheless, total air emissions would increase. Production of innovation goods is also related to the increase in air emission in Ukrainian regions. The reason is that the core of Ukrainian industrial output is related to mining, machine building, metallurgical and chemical production, and whatever innovations are happening with these industries still they would be related to pollution.

The use of nonrenewable energy resources is correlated with the increase in air emissions, which is theoretically expected. The results suggest that the production of innovative goods is dependent mostly on expenditures for innovation activities, and per every 1 UAH invested there would be 1.12 UAN of innovative products. The influence of fixed capital (as an annual stock) and per capita incomes appeared to be insignificant factors for production of innovative commodities in Ukrainian regions. The increase of per capita incomes does not stimulate the growth of innovation goods production on a regional level in Ukraine. The more the fixed assets are available with the region, the more innovative products are produced.

Many environmental problems in Ukraine have risen from the use of obsolete equipment and morally worn-out technologies. According to the National Institute for Strategic Studies, the usage of worn-out equipment led to vast amounts of industrial waste. Thus, mining wastes contain a significant proportion of useful mineral sources. It is 70% of oil, up to 50% salt, 30% coal, and 25% metal are left in depths after mining is completed (Varnaliy, 2005). Our results are following (Varnaliy, 2005) who performed the environmental analysis for Ukrainian region.

According to the Ashford (1993), having analyzed technological responses of industrial firms to environmental problems it was found that green changes such as input substitution, process redesign, and product reformulations were rare events among other technological responses. One of the possible explanations for slow green changes is that environmental requirements were not stringent enough on their face and/or because there was inadequate enforcement to force technological change. On the example of the US Federal Government's Ashford (1993) shows that waste minimization program was voluntary. As for the governmental regulation of pollution, similar activities (conditions) would promote different technological response depending on the responder. Thus, Ashford (2003) states that the pollution control industry in response to environmental regulation would introduce pollution control devices and the regulated firm would have to change inputs, perform production process improvements. Also regulated firm, like another responder, may add new products if it would have enough time to develop comprehensive strategies and solve tradeoff between achieving quick results and radical change. Depending on the size of the company and its maturity there would be different responses. In general, high outputs and mature sectors would be resistant to change. The last according to Kemp (2000) fits with the Abernathy-Utterback product life cycle model that during the product lifetime the producing industry becomes more rigid and inelastic to changes. On the contrary potential new entrants would demonstrate more innovative responses to environmental regulations.

The presence of environmental policy regulations in Germany is significant for environmental product innovations in several directions like air, water, soil, and noise emissions but not for energy consumption and recycling. That is different areas of environmental impact need different policy approaches and (Horbach, 2010) underlines that industries related to material and energy savings do not require strict regulatory procedures because of their (potential) economic benefits. Also, energy saving benefits are not automatically equally achieved by the firms due to organizational, control and coordination problems.

It is necessary to consider the effectiveness of any regulation policy since according to Kemp (2000) there are few examples of environmental policies that stimulated green innovation. Most often the common compliance industry response is the use of expensive end-of-pipe solutions and incremental process changes offering limited ecological gains.

The environmental impact of environmental innovation is affected by the rate and direction of technological change. New technologies may create or facilitate increased use of nonrenewable energy resources and thus pollution or may mitigate or replace existing polluting inputs or processes (Jaffe, 2004). It is found that the implementation of innovative products and performing different innovation expenditures is related to the increase of nonrenewable energy resources use. And increase in every ten mln. UAH invested in innovation expenditures per year increase annually the use of nonrenewable energy resources on 8.7 mln ton (in terms of oil equivalent) per region. The last suggests the necessity to change the use of innovation expenditures, at last, they should not increase the use of nonrenewable energy resources, on the contrary, the use of renewable resources should be stimulated. It was not estimated the direct effect of an energy price increase on energy resource consumption. However, according to empirical paper Popp (2001) having used energy-related patents as a proxy for energy innovation, it was found that only 30 percent of the overall energy response was related with induced energy innovation, the remaining part of resource was related with high-cost factor substitution. It is seen from the table 3 that starting 2008 year the time dummies become insignificant for the consumption of nonrenewable resources, which could mean that unobservable energy factors price increases were not significant for domestic energy consumption.

The experience of Central and Eastern European countries has many positive examples in reducing energy dependency through energy efficiency, and Poland, Check Republic, Hungary have reduced energy resource consumption from 0.8 kilograms of oil equivalent in 1991 to 0.39 kilogram per one USD of GDP in 2012. The improvement in the energy sphere in the countries mentioned above was achieved due to the development of small-medium scale enterprises

4 Conclusion

The main reason for the slow implementation of the sustainable development concept in Ukraine is the inherited industrial sector from former USSR and related problems of economic restructuring. Also to the relevant causes of environmental issues in Ukraine are attributed rather long-lasting governance loyalties to polluting industries, the absence of appropriate conditions for other economic model building, low level of ecological culture among the population.

Cost savings is considered to be one of the key factors of energy efficiency increase and reduction of material use. Primary gas price fluctuations were not critical for domestic chemical and metallurgical producers, and the GDP growth rates were favorable due to increased demand for steel and chemicals on world markets. However, some Ukrainian corporations started to prepare for possible gas problems several years before the first gas conflict was launched.

References

Ashford, N. (1993). Understanding Technological Responses of Industrial Firms to Environmental Problems: Implications for Government Policy. *Environmental Strategies for Industry*, pp. 277–307.

Beckerman, W. (1992). Economic growth and the Environment: Whose growth! Who's Environment? *World Development,* 20, pp. 481–496.

Cramer, C. (2002). Population Growth and Local Air Pollution: Methods, Models, and Research. *Population and development review,* 28, pp. 31–45.

de Bruyan, S. (1997). Explaining the Environmental Kuznets Curve: structural change and international agreements in reducing sulfur emissions. *Environment and development economics*, 2, pp. 485–504.

United Nations (2007). Environmental performance review series. 196 p.

World Bank (2011). Gross Domestic product. URL: www.worldbank.org.

Horbach, J., Rammer C., and Rennings, K. (2010). Determinants of Eco-innovations by Type of Environmental Impact The Role of Regulatory Push/Pull, Technology Push and Market Pull. *Centre for European economic research Discussion Paper.*

Iemchenko, N. (2012). Formula enerhozberezhennia [Energy saving formula]. URL: http://blog.scm.com.ua/ua/2012/10/19/formula-energozberezhennya.

Jaeger, W., Kolpin, Van (2001). Economic growth and Environmental Resource Allocation.

Adam, J., Lerner, J. and Stern, S. (2004). Innovation Policy and the Economy. *Technology Policy for Energy and the Environment*, 4, pp. 35–68.

Kammerer, D. (2009). The effects of customer benefit and regulation on environmental product innovation. Empirical evidence from appliance manufacturers in Germany. *Ecological Economics*, 68, pp. 2285–2295.

Kemp, R. (2000). Technology and Environmental Policy – Innovation effects of past policies and suggestions for improvement. *Innovation and the Environment*, pp. 35–61.

Kubatko, O.V., Nilova, O.V. (2008). Environmental Kuznets Curve: evidence from Ukrainian data on pollution concentrations. *Mechanism of economic regulation*, 2 (34), pp. 53–67.

Ming – Feng hung and Show, D. (2006). Economic growth and the Environmental Kuznets Curve in Taiwan: A Simultaneity Model Analysis.

Popp, D. (2001). The Effect of New Technology on Energy Consumption. *Resource and Energy Economics*, 23(4), pp. 215–39.

Varnaliy, Z.S. (2005). Regions of Ukraine: problems and perspectives of social and economic development. 498 p.

World Economic Forum (2018). Global Competitiveness Index 4.0. URL: http://reports.weforum.org/global-competitiveness-report-2018/country-economy-profiles/#economy=UKR.

Yale Environmental Center (2019). Environmental Performance Index. URL: https://epi.envirocenter.yale.edu/epi-country-report/UKR.