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Research article

Improved CRA-method in phenomenological approach (on the example of innovative SME and GHG emissions)

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ABSTRACT

Despite the successful experience of highly developed countries, for example, in achieving sustainable development, there is no single recipe. Each country can create its own development scenario or combine existing, which will provide it with positive results. We can determine the best ones using the built rating. To build it, the article proposes an approach consisting of several stages. First, the study determines the relationship between the selected factors and the resulting indicator using a correlation analysis. Then, using the Sturges rule, we determine the range and group the countries in the context of each range (group) in accordance with the level of individual indicators. After, we form groups of countries according to the rating. This approach is entirely shown on the impact of small and medium enterprises' innovation on greenhouse gas emissions. Correlation analysis is often used to determine the relationship between factors and resulting indicators. We have shown that its use without additional processing of input data can lead to false results. Therefore, further in the study show imperfection of "blind" correlation and regression analysis in the phenomenological approach. And in our example, offer an improved technique for processing input data for correlation analysis and changed the ranking of countries.

1. Introduction

The current geopolitical situation requires governments to make decisions that ensure social and environmental development along with economic development. It is almost impossible to continue traditional way of doing business. The reasons for this are the high level of the Earth's interior depletion, the levels of emissions, waste, and environmental pollution. Fortunately, some concepts and approaches can eliminate, and suspend these negative processes. Of course, the Millennium Development Goals and the Global Sustainable Development Goals have identified objectives and indicators that underline trends and outcomes in addressing key social, economic, and environmental issues. Nevertheless, each country chooses independently how to act and what measures and directions will be effective for it. Over the past 20 years, the success of individual countries in various areas shows that the scenarios for its implementation and the tools that were used are different, and the results that have been achieved in terms of sustainable development indicators are impressive. For example, in recent years, the area of organic land in Austria has already exceeded 25% [1], Norway is the leader in the Social Progress Index [2], Singapore and Switzerland take leadership in the Global Innovation Index [3], Germany and the United States Germany are leaders in the production and investment in alternative energy [4].

Many subjective factors, which are inherent in each individual country, influence this state of affairs. However, we believe that there are some general patterns, which allow some countries to be more effective in achieving goals than others.

For example, it is obvious that the level of industrial production and its state (new/old) determines the level of atmospheric pollution, land, and nearby waterways. At the same time, some social factors can influence greenhouse gases (GHG) emissions and pollutants. For example, in our article [5] was performed the first approximation of the impact assessment of economic factors on environmental indicators. In [5] we evaluated the impact of changes in environmental tax rates on pollutants emissions in the oil and gas sector. After in study [6] we described the dependence of the country's economic development and environmental security there. It is shown that there is indeed a relationship between various socio-economic and environmental factors and the level of air pollution. These factors are economic (energy intensity of GDP, consumption of coal and lignite in country), environmental (rent for the natural resources use, total energy consumption), scientific and intellectual (payment for the use of intellectual property, research and

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development costs), social (population density, Human development Index). However, analysing the results in more detail, we found that many factors selected in [6] which are significant for each country, were rejected in the analysis because of the correlation analysis results (CA). For example, indicators that should have had an impact on emissions from a logical point of view, such as the share of renewable energy, transport services (% of import of commercial services), manufacture were rejected. The relationship was not identified or was not considerable. This prompted us to further research and determined the purpose of our present study. And since the issue of emissions is an acute problem for most countries, and with the help of innovations there are prospects for solving them, therefore, we tried to improve the use of CA by the example of determining the impact of innovations on greenhouse gas emissions.

2. Literature review

There are many studies published up to date, which aim to use different approaches to identify the relationships between key socio-economic and environmental factors and on their basis to determine the patterns of the country's development.

The authors [7] carried out a large-scale study of energy consumption impact and economic growth on CO_2 emissions. The relationship between these factors were assessed using regression analysis (joined ordinary least squares regression and fixed effects methods), Granger causality, panel cointegration tests. There were analysed data (1994–2013) from 70 countries. Based on the study, the authors emphasize the importance of low-carbon economy by financing climate projects. This funding refers to the local, national or transnational level, which may be raised from different sources of funding. This will help facilitate the large-scale investment in clean energy needed to reduce emissions of CO_2. But we want to note that for analysis, actual data by country are taken, for example, GDP, and population, available on various statistical sites. The study benefited if such indicators as population density, and GDP per capita were still chosen, which would give a more realistic result, and the indicators would be more comparable.

A few years earlier, studies by [8] explored the dynamic relationships between per capita renewable energy use, agronomic value-added, emissions CO_2, GDP in North African states. In addition, as in [7], using panel cointegration techniques and the Granger causality test, the study presented unidirectional relationships between renewable energy and emissions. The study posted that CO_2 emissions rised because of GDP or energy consumption. So, states of North Africa should use clean renewable energy sources to low carbon emissions.

Also, in the study [9] the relationship between consumption of energy, CO_2 emissions, and economic growth was revealed at the level of one country – Indonesia. In particular, Granger causal tests were performed using time series methods, within which both traditional and additional causal channels were identified. In our opinion, the study would benefit if it were selected from the analysed countries, the leading countries, and their experience in these issues, taking into account other macroeconomic indicators.

Authors [10] established the relationship between efficiency of energy and GHG using panel coherence, causation, and analysis, Fully Modified Ordinary Least Square and The Dynamic Ordinary Least Squares. The study's results are: there is a relationship between energy efficiency and GHG emissions; GHG emissions decrease with increasing energy efficiency. In the study there is data from 29 European countries from 1995 to 2016. A thorough study claimed there is a relationship between the studied indicators in some countries, and in some such a relationship is weak. Looking at the list of these countries, we see that there are contradictions that the group of countries that belong to the highly developed countries includes less developed countries and vice versa, which leads to the need to improve the approach.

The study [11, 12] and [13] are similar. They use data from developed and developing countries to explore factors which have impact on level of green growth. The results state that development of economy is positive for green growth. It was revealed that the influence of these factors is different. It depends on if it is developed or developing countries. So, countries which have different level of development will need separate strategies to gain the Sustainable Development Goals by 2030. We would like to note that this is in line with our assumptions that economic growth should not come at the expense of environmental degradation or public health.

Authors of [14] confirm that growth of economy is the crucial source of CO_2 emissions. The authors propose reducing carbon emissions through economic growth and financing of green technology imports. In addition, the impact of economic growth might be different by region. In the central and western parts of China, authors [15] suggest that economic growth rises carbon emissions when they are below the threshold, but reduces CO_2 emissions when economic growth is above the threshold. In researches [16] and [11] are shown that economic CO_2 emissions in the BRICS countries are exacerbated by economic growth. Analysing these researches, the results of which are significant and logical, we lacked a comparative analysis between the countries selected for analysis or, if this is an association of countries, then with other associations of countries.

In [17] conducted a study taking into account specific factors. This paper aimed to investigate the impact of democracy and renewable energy on CO_2 emissions. It was done for 46 sub-Saharan African countries. They use unbalanced data from 1980 to 2015. Using the instrumental variable of the generalized moment method, the study found that democracy and renewable energy reduce carbon emissions. In addition, foreign direct investment, openness to trade, population, and economic growth have been responsible for sub-Saharan Africa's CO_2. In our opinion, this approach can be recommended for analysis in other countries with appropriate adjustments to the input data.

The authors of [18] developed a probabilistic model for decision-making in the field of sustainable energy transition in the developing countries of South-Eastern Europe. This model was developed using Bayesian networks, as they allow making decisions under conditions of high risk. At the same time, many factors that interact with each other, as well as with the final result are used. The result, in this case, is determined by the two main goals of the transition to sustainable energy of the research object (12 countries of South-Eastern Europe): the share of total energy production which produce by renewable energy sources and the energy intensity of the economy. The period is from 2009 to 2019. The study included 12 indicators.

In study [19] investigated the direction of the causal relationship between renewable electricity generation and economic growth. It was done in a multifactorial context over the period 1990–2017 of the autoregressive distributed lag (A.R.D.L) approach. The study would benefit if [18] and [19] compared the results obtained within the countries under consideration or with some benchmark, a country that is a leader in this field.

The article [20] also investigated long-term and causal relationships between consumption of renewable and non-renewable energy and economic growth. There were used classic and advanced production functions. A comparison was also made between different energy sources to determine which type of energy consumption is more crucial for G7 economic growth over the period 1980–2009. There was applied an autoregressive distributed lag approach to cointegration. The concentrated attention to the existence of a lag in the analysed processes indicates a deep understanding of the economic phenomena' essence. Of course, a gradual change in the structure of energy consumption will not immediately have impact to economic growth.

The causal relationship [21] was investigated between energy production and use, economic performance, and emissions in the BRICS countries. It is believed that the results will serve as guidelines for energy sustainability and environmental security policies in developing countries. The peculiarity is that the article separates renewable and non-renewable energy sources to reveal their clear impact on emissions.

The feasible generalized the least squares (FGLS) and the Panel-Corrected Standard Error (PCSE) estimate for the period 1971–2013 in the BRICS countries are used. The results showed that increased use of renewable energy sources and industrialization improve the ecological fabric of developing countries, while population growth, economic growth, and the use of renewable energy sources increase emissions. Here, we think that there has been economic growth derived from large domestic products with capital; industry value added as a proxy of industrialization. This, in our opinion, is more informative than just GDP and industrial output, but also just the population is taken, and not, for example, population density. Also, fossil fuel use is taken as a proxy for non-renewable energy use (NRE); renewable energy use (REN), and perhaps it was also advisable to take not the natural indicator, but a relative one (for example, the share of NRE and REN, or the ratio of NRE and REN to industrial output, etc.), for more realistic results.

Research [22] used STATA to determine the impact of economic activity on emissions of CO_2 in Malaysia between 1980 and 2011. The aim is to find the relationship between GDP, consumption of energy, foreign investment in CO_2 and international trade, and to investigate the impact that economic expansion has on environmental degradation. The results indicate a relationship between variables such as GDP, energy consumption, foreign trade, and environmental degradation.

In the article [5], the authors assess the effectiveness of environmental taxation in Ukraine in 2013–2017 based on the use of econometric analysis methods, in particular, the construction of an A.R.D.L model. It used to determine how harmful substances emissions influence the atmosphere and factors, such as hydrocarbon production and the rate environmental tax. A boundary testing procedure based on the approach [23] was performed to identify long-term trends between variables. Based on the analysis, it was found that to increase payment pollutant emissions in Ukraine, it is advisable to rise the efficiency of taxes regulation.

In the investigation [24] Burkina Faso, as well as many other African countries, was studied as implemented projects from renewable energy sources (RES) and energy efficiency (EE) registered in the Clean Development Mechanism (CDM). This study aims to determine the impact of these projects on the level of CO_2 emissions and determine their CDM potential by quantifying carbon reductions using approved CDM methodologies tailored to the projects. It would be interesting to compare the results obtained, for example, with other countries or groups of countries, while trying to carefully look at and adjust the incoming data, again in accordance with the macroeconomic indicators of each country and see how much the indicators correlate with each other.

All analysed studies contain the deepest analysis. The approaches used for the calculations are modern, large-scale, however, we assume that the results of the studies would be different if the input data were carefully processed and analysed in the first place, and not only taken from the statistical websites Eurostat, Organization for Economic Co-operation and Development (OECD), the International Energy Agency (IEA) and so on.

That is why, in our opinion, it is advisable to improve the approach to determining the level of various factors influence on individual indicators, according to the results of which to group and form a rating of countries, and accordingly study their experience in achieving high results, in particular in terms of sustainable development indicators. It is important that in addition to analysing the results, it is necessary to rank countries for each of the factors in order to analyse the experience of the best of them and adapt them to other countries.

The purpose of the article is to propose an approach to the formation of the countries' rating by individual factors (in our case, innovation indicators) that affect the level of environmental indicators, and show the imperfection of "blind" correlation and regression analysis (CRA) in the phenomenological approach. Especially pay attention how to go deeper into the input data analysis. And to solve this issue, propose an improved method for processing input data for CRA.

3. Materials and methods

The authors believe that innovations in small and medium-sized businesses (since the share of SMEs in European countries is more than 70%) should be reflected in the environmental indicators of the state, in particular, in emissions of pollutants, in particular, greenhouse gases. Therefore, according to the authors, it is possible to build a rating of states based on the effectiveness of innovation implementation on SMEs and determine the most successful countries. Methods of processing statistical information and statistical data obtained from open sources were used to conduct such research.

3.1. Methods

The general outline of the proposed approach is shown in Figure 1.

At the first stage (items 1–3) of the study, we determine whether there is a relationship between the selected factors and the resulting indicator, its nature, and tightness, based on the determination of correlation coefficients, linear and non-linear (inverse, logarithmic, quadratic, power) functions. We used Microsoft Excel software for our research. We used The CORREL function which returns the correlation coefficient of two cell ranges. We use the correlation coefficient to determine the relationship between two variables. The establishment of relationships between various factors of economic development and parameters characterizing the ecological situation is carried out on the basis of a correlation analysis of statistical data within the framework of the phenomenological approach [25]. This approach is implemented in [6], as noted above:

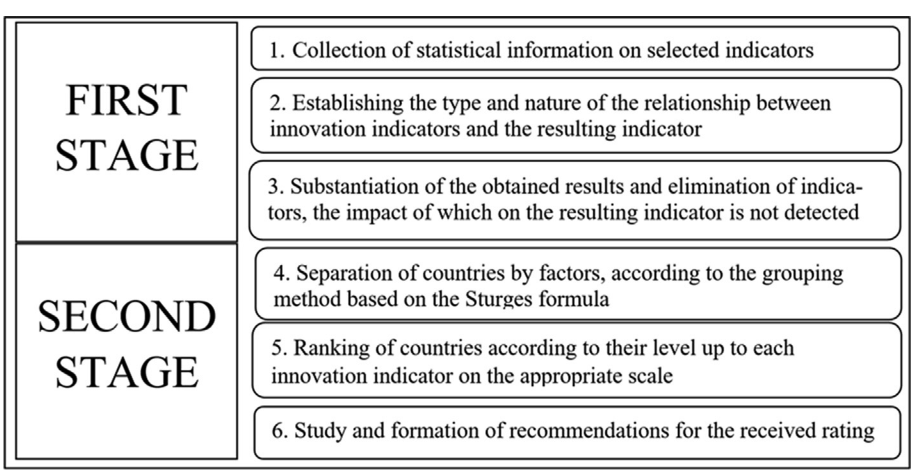

Figure 1. Stages of the approach to assessing the impact of innovations on environmental indicators.

- The absolute values of the correlation coefficients make it possible to assess the level of influence of the selected factors on the results. If the resulting absolute value of the correlation coefficient is less than 0.5, then we assume that the selected factor does not affect the resulting indicator. If this value is greater than 0.5, then we assert that there is a relationship between the factor and the resulting indicator, and then we leave these factors for further analysis.
- In turn, the type of function gives us understanding the nature of the impact: if it is simply linear, then the increase or decrease in the indicator occurs evenly. If it is non-linear, then we get an acceleration or deceleration of the change in the indicator depending on the change in the factor.
- the sign (+ or –) allows us to understand what is the relationship between the change of the factor and the resulting indicator. If we get the value of the correlation coefficient with a minus sign (–), this means that with a decrease in the value of the factor, the resulting indicator will increase and vice versa.

In the second stage, we use the Sturges rule [26], which is an empirical method. It is used in descriptive statistics for determine the number of classes. They must exist in a frequency histogram for classification a dataset representing a sample or population. We use this rule to determine the range and group countries in the context of each range (group) in accordance with the level of individual indicators. When using the Sturges method, we first selected a grouping feature. Then the number of groups and the size of the interval were determined. The next step was to establish a list of indicators that should characterize the selected groups in relation to a specific grouping. Accordingly, we form tables with the grouping results (in our case, contains an example). Then, we rank groups of countries by rating. According to the Sturges rating, each country was in a certain range for the selected indicators (in our case, according to the Innovation Indicators of SMEs). In most cases, if the range is higher, then it is better. In our case, there were 6 ranges for each indicator. And on the basis of this, then they conducted a ranking. If the country is in the highest range (sixth), it gets 6 points for this indicator, if, for example, it is in the third range, it gets 3 points. After summing up all points for all indicators, we find its arithmetic mean and it will be average country rating. Then we make conclusions and recommendations based on the results obtained.

The correctness of the built rating depends on the results obtained in items 1–3 of this approach. Therefore, in this study, we clarify some specific features of the selection and evaluation stage: how adequately the input data is selected, and their relationship is established to continue the study.

3.2. Materials

In our case, as an example of using the approach for the factors which influence was determined, we selected data on innovation indicators from the OECD data based on the OECD National Innovation Statistics Survey 2019 and the Eurostat Community Innovation Survey (CIS-2016), detailed in OECD Innovation Indicators [27] for 2019. Here are the indicators of business innovation in 39 OECD member and partner countries. Given the globalization of markets, innovation and creativity are the determining factors for the success of not only individual enterprises but also national economies. Business innovations have a significant impact on economic decisions, the way they are made, and the timing of their implementation. They ensure the stable growth of their own society, enhance the social impact on society and support the ideas of cross-sectoral partnership. Intensive support for science, last technology,

Table 1. Results of correlation analysis to establish the relationship between factors and GHG emissions excl. LULUCF.

Factors		Function	Correlation coefficient between factors (innovation indicators) and the Total greenhouse gas emissions excluding LULUCF			Accepted/not accepted
Types of innovation:			2016	2017	2018	
R&D active product and/or process innovative firms, as a percentage of product and/or process innovation-active firms (product/process or ongoing/abandoned innovation activities, regardless of organisational or marketing innovation)	X1.13	Quadratic function	0.09	0.09	0.09	Not accepted
Public financial support for innovation activities:						
Firms receiving public support for innovation, as a percentage of product and/or process innovation-active firms (product/process or ongoing/abandoned innovation activities, regardless of organisational or marketing innovation)	X2.1	Inverse	0.632	0.631	0.583	Accepted
Innovation co-operation partners:						
Firms co-operating on innovation activities, as a percentage of product and/or process innovation-active firms (product/process or ongoing/abandoned innovation activities, regardless of organisational or marketing innovation)	X3.1	Power function	0.968	0.967	0.95	Accepted
Firms co-operating on innovation activities with clients (private and/or public sector), as a percentage of product and/or process innovation-active firms (product/process or ongoing/abandoned innovation activities, regardless of organisational or marketing innovation)	X3.3	Quadratic function	0.598	0.594	0.582	Accepted
Firms engaged in national collaboration only, as a percentage of product and/or process innovation-active firms (product/process or ongoing/abandoned innovation activities)	X3.5	Exponential EXP(x)	0.968	0.967	0.970	Accepted
Firms engaged in international collaboration, as a percentage of product and/or process innovation-active firms (product/process or ongoing/abandoned innovation activities, regardless of organisational or marketing innovation)	X3.6	Power function	-0.606	-0.607	-0.618	Accepted
Innovation and participation in international markets:						
Firms operating in international markets, as a percentage of total firms	X5.1	Inverse	0.734	0.734	0.742	Accepted
Innovative firms operating in international markets, as a percentage of total innovative firms	X5.2	Logarithmic	-0.650	-0.653	-0.671	Accepted
Innovative firms not operating in international markets, as a percentage of total innovative firms	X5.3	Power function	0.666	0.663	0.661	Accepted
Product innovative firms operating in international markets, as a percentage of total product innovative firms	X5.4	Inverse	0.667	0.665	0.685	Accepted
Non-innovative firms operating in international markets, as a percentage of non-innovative firms	X5.5	Inverse	0.681	0.678	0.687	Accepted
Innovative firms operating in international markets, as a percentage of total firms	X5.6	Inverse	0.617	0.620	0.633	Accepted

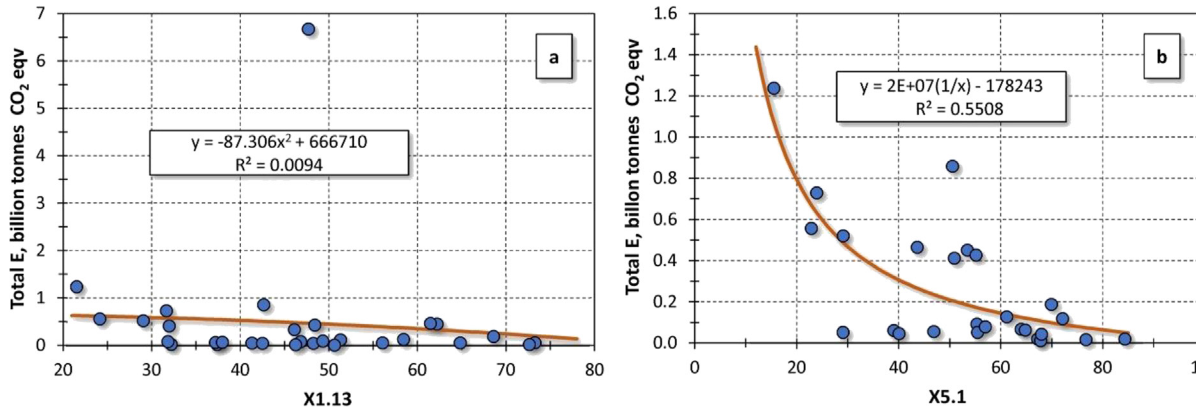

Figure 2. Correlation map for total greenhouse gas emissions excluding LULUCF from X1.13)) (a) and X5.1 (Firms operating in international markets, as a percentage of total firms) (b).

innovation ensures the transition to inclusive and environmentally sustainable economic development. Therefore, indicators of innovativeness at the small and medium-sized enterprises (SMEs) level were chosen for analysis, as we believe that they are the driving force of transformational changes in the economies of all countries. SMEs account for the priority of businesses worldwide and are important for job creation and economic development [28]. Published on January 29, 2020, the Innovation Indicators are based on data collected by national statistical offices. However, this information shows how firms implement new or improved products and business processes; the degree of their novelty and economic significance; investment and joint activities carried out within the framework of these efforts; and the role of markets and special government support in different countries.

We select the number of greenhouse emissions excluding LULUCF (land use, land-use change, and forestry) as the resulting indicator. Because rapid climate change and global warming caused by greenhouse gas emissions is a problem that occurs in today's world due to the burning of fossil fuels [29, 30]. As a consequence, several problems arise at the country level, such as resource depletion, local energy supply, and energy security issues leading to external energy dependency [31, 32]. GHG includes seven gases. They have direct influence on climate change. CO_2 refers to gross direct emissions from fuel combustion only and data are provided by [33]. Total greenhouse emissions excluding LULUCF will be marked with *Total E*.

4. Results and discussion

4.1. An example of a direct application of the approach based on "blind" correlation analysis

In the first step, we selected among all factors those that have an important influence (the absolute value of correlation coefficient >0.5) on the resulting indicator. Indicators that do not have or have a weak relationship with the resulting indicator (the absolute value of correlation coefficient <0.5) are not taken into account at the next step of the study.

According to international methodological standards, the "Oslo Guide" of the OECD [27] defines 4 types of innovation: product, process, marketing, and organizational. For our analysis, we select indicators that are given for SMEs.

The initial data for the calculations were collected in a table in Microsoft Excel. There we calculate the correlation coefficients and

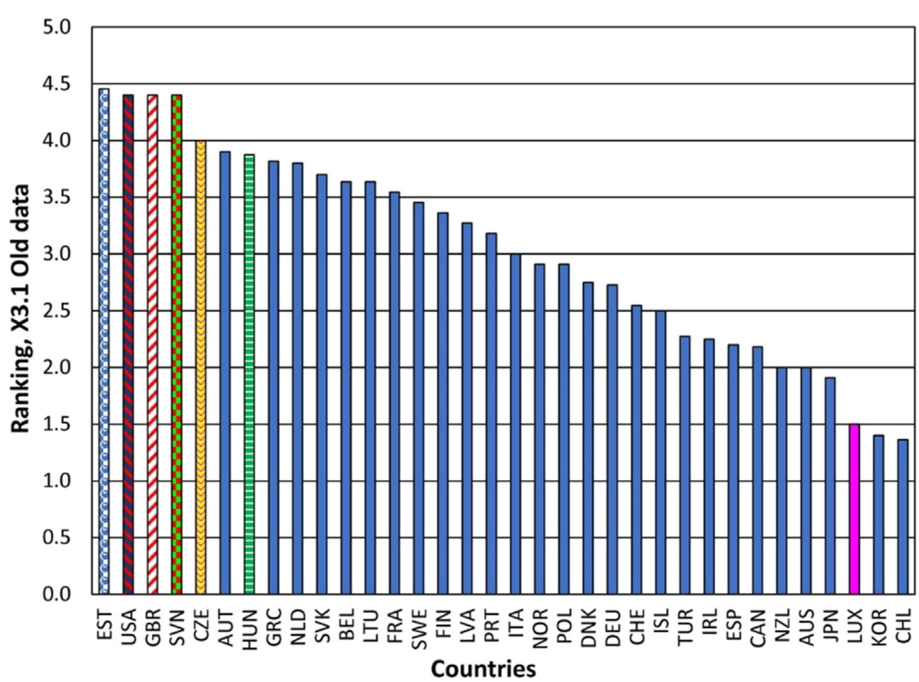

Figure 3. Country ranking on innovative factors influencing greenhouse emissions.

choose the correlation coefficient by the largest modulus using different types of functions for each by the use of CORREL function.

Table 1 presents indicators of innovation in SMEs, which have a strong correlation with the final indicator. And as an example, the coefficient X1.13 is given, as it practically has no correlation with the resulting indicator.

All the indicators of innovations [34] that were analysed are given in Table A1 of Appendix. They are denoted "Xn.m". There is also description all "Xn.m" in Table A1 of Appendix. For the resulting indicator, we have chosen the *Total E*.

To establish the relationship between the factors and the resulting indicator, a correlation analysis was carried out, the results of which are given in Table A1 Appendix. Empty cells in table indicate the absence or low level of a characteristic form of the relationship.

Figure 2a,b provides the examples of weak and good relationships between the factors and the resulting indicator. As one can see in Figure 2a the influence of the factor X1.13 on the volume of GHG emissions, there is practically no correlation: $R^2 = 0.094$ (a correlation coefficient equals (−0.3)).

Figure 2b shows the influence of factor X5.1 on emissions, where a correlation coefficient of (−0.742) is calculated, and a functional dependence curve is plotted accordingly with a fairly high $R^2 = 0.55$.

In Table 1, for five factors, an inverse function is found (X2.2, X5.1, X5.4, X5.5, X5.6), for three (X3.1, X3.6, X5.3) is power, for X3.5 – exponential, for X3.3 it is quadratic, and for X5.2 it is logarithmic. The most significant influence (the absolute value of the correlation coefficient 0.968) has the X3.5 factor (Firms engaged in national collaboration only, as a percentage of product and/or process innovation-active firms (product/process or ongoing/abandoned innovation activities).

Also, we can analyse the "direction" of the factor's influence.

So, due to the increase in the value of the factors X2.2, X3.6, X5.1, X5.2, X5.4, X5.5, and X5.6, the indicator of GHG emissions decreases. This can be confirmed:

X2.2 is SMEs receiving support from government for innovation. Large share of such enterprises indicates the state's interest in introducing innovations. In addition, such SMEs receive support or funding, subsidies or preferential taxation, which stimulates their development.

X3.6 is SMEs involved in international cooperation. Undoubtedly, when there is cooperation not only between companies within the country but also there is cooperation, communication, exchange of innovative experience, ideas and their implementation at the level of two or more countries, that is, a synergistic result of achievement (including the Sustainable Development Goals) that succeeds reach faster.

X5.1 is SMEs are in international markets. Of course, not every enterprise can have access to and operate in international markets. In addition, especially, in recent years, it is not enough to be successful and profitable; often, to enter international markets, it is necessary to be socially and environmentally responsible, which is impossible without the use of advanced technologies and innovations.

X5.2 is Innovative SMEs operating in international markets (percentage of total innovative firms) and X5.6 is Innovative SMEs operating in international markets (percentage of total firms). That is, in both indicators, the numerator is the number of innovative firms in international markets. Unlike the previous indicator X5.1, firms that are immediately identified as innovative are already taken here, their number and share will be less than in the previous case. That is, as in the previous case it is clear that the more innovative firms operate in international markets, the assumption is that they directly or indirectly have a positive impact on the environment and reduce emissions of harmful substances.

X5.4 is share SMEs producing innovative products, which have activities in international markets. Undoubtedly, if the result of the company's work is an innovative product, then often this product can be in its functional purpose to somehow improve the environment, prevent, or determine how to prevent, overcome or solve environmental or social problems.

That is, we confirm that high values of these indicators lead to a decrease in the resulting indicator. This shows that supporting innovation, international activities to promote innovative products and start-up innovative enterprises helps to reduce emissions while working effectively.

An increase in factors X3.1, X3.3, X3.5, and X5.3 leads to an increase in the resulting indicator. And here, analysing the essence of the indicators themselves, the logic of things cannot always explain why their dependence on the resulting indicator is direct. Below we will explain our point of view.

Nevertheless, let us accept the obtained results for the first approach.

Based on the correlation analysis, we will perform the division of countries up to all the factors presented in Table 1, according to the grouping method based on the Sturges formula [26]. This will identify countries that, according to a certain factor, are leaders or outsiders in a certain innovative component.

Table A2 of the Appendix provides a grouping of innovative indicators that affect GHG emissions. The last column shows the average value of GHG emissions for the countries included in the corresponding group. The levels were formed based on the results of grouping up to the Sturges rule. In most cases, there is a direct relationship. Higher values in the range are higher country levels. We distinguish 6 groups for most indicators according to the Sturges rule. If a country, according to a certain innovation indicator, falls into the range with minimum values, then we refer it to a low level; if the values are higher, then we refer it to the group with the level of "high" or "very high", respectively.

Then, in Figure 3, we rank the countries based on their level according to each innovation indicator. If the level is very high, then the country has a rating of 6, if it is low, then a rating of 1. So, we set ratings for all the analysed indicators, and at the end, we calculate the average value according to the received data.

We will rank countries up to their level according to each innovation indicator. The next scale is 1 - low level, 6 - very high-level (Table A3 of the Appendix).

As a result, we consider 5 leaders from this list: Estonia, the USA, Great Britain, Slovenia, Czech Republic, which took the highest rating. Several facts that support to SMEs and their innovative development in these countries at a high level and is the key to an effective environmental policy are given below.

4.1.1. Estonia

According to the Global Innovation Index, Estonia ranked 25th out of 48.28 points out of 100 in 2020 (2019 - 24th place, 49.97 points; 2018 - 24th place, 50.51 points). The Estonian innovation policy was officially launched in 2000 by the discussion of the first version of the Estonia - Land of Knowledge (ECO) strategy for the period 2002–2006. Even then, the experience of Finland and Sweden was taken as a basis, taking into account the special development opportunities of the country, its research potential, and the structure of the national economy, as well as other Estonian development strategies. The two main goals were to update the existing knowledge base and increase the competitiveness of national enterprises. The three key areas of research, development, and innovation in Estonia were:

- user-friendly information technology and the information society development;
- biomedicine;
- material technology.

4.1.2. United Kingdom

The United Kingdom also occupies a high position in the presented ratings. According to the Global Innovation Index, the UK was ranked 4th out of 59.78 points out of 100 in 2020 (2019 - 5th place, 61.30 points, 2018 - 4th place, 60.13 points).

Understanding that SMEs are one of the main engines of a qualitative transformation of the economy, stimulating the development of employment, has become a key factor in forming a strong foundation in the UK for developing an entrepreneurial culture, organizing a dynamic

Table 2. "Controversial" factors based on the results of "blind" correlation analysis.

Factors		Function	Total greenhouse gas emissions excluding LULUCF, thousand tonnes CO_2 equivalent		
Firms co-operating on innovation activities, as a percentage of product and/or process innovation-active firms (product/process or ongoing/ abandoned innovation activities, regardless of organisational or marketing innovation)	X3.1	Power function	0.968	0.967	0.95
Firms co-operating on innovation activities with clients (private and/or public sector), as a percentage of product and/or process innovation-active firms (product/process or ongoing/ abandoned innovation activities, regardless of organisational or marketing innovation)	X3.3	Quadratic function	0.598	0.594	0.582
Firms engaged in national collaboration only, as a percentage of product and/or process innovation-active firms (product/process or ongoing/ abandoned innovation activities)	X3.5	Exponential EXP(x)	0.968	0.967	0.970
Firms operating in international markets, as a percentage of total firms	X5.1	Inverse	0.734	0.734	0.742

start-up market, providing opportunities for SME growth by creating favourable conditions for the short term, lending to businesses and educational activities for state support of small and medium-sized businesses.

To date, four areas for the development of SMEs have been identified in the UK, in particular [35]:

- advising new and existing enterprises;
- financial assistance programs;
- regional assistance programs for small businesses in Scotland, Wales, Northern Ireland;
- programs that stimulate the export activities of small firms.

Also noteworthy is the high level of the SME sector due to the promotion of social entrepreneurship as a form of social innovation in the UK. Government support for social entrepreneurship in the SME sector in the United Kingdom is the highest among European countries, which indicates the recognition of social innovation as an effective tool to help solve social and civic needs and contribute to sustainable (balanced) development of the state.

4.1.3. The USA

The intensification of innovation activities is one of the most important directions of the US state policy to create a scientific and technical basis for the comprehensive development of the country. In order to ensure favourable conditions for the successful operation of SMEs, in 1982 the US Government adopted the Federal Law "On the Development of Innovative Activities in Small Businesses" [36], the main objectives of which are:

- stimulation of technological innovations;
- use of the potential of SMEs for the implementation of federal orders for R&D;
- assistance in attracting talented people to the implementation of technological innovations;
- assistance to the private sector in the commercialization of scientific and technological achievements made under federal orders.

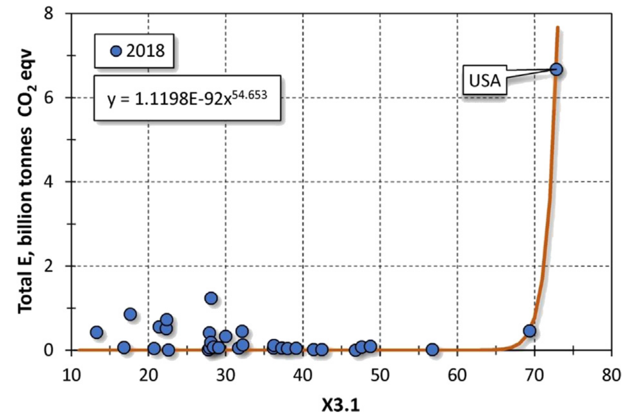

Figure 4. Correlation map for total greenhouse gas emissions excluding LULUCF from X3.1.

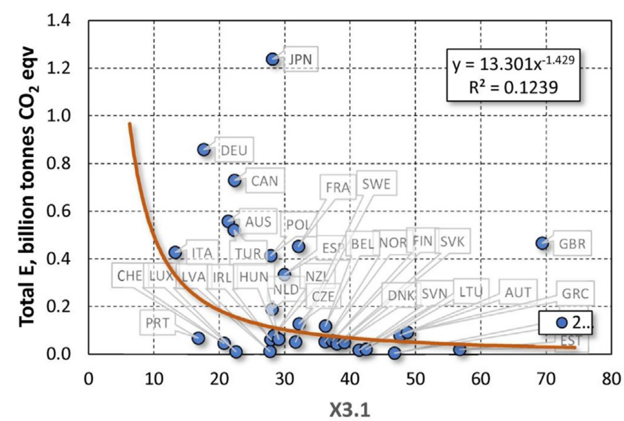

Figure 5. Correlation map for total greenhouse gas emissions excluding LULUCF from X3.1 without the USA.

Many national programs financed from the state budget have been developed, providing innovative SMEs with opportunities to implement their developments. To stimulate innovation at various enterprises, US law provides for the provision of tax incentives, in particular, for the acquisition of documentation, equipment, production of prototypes, testing, and payment for patent services.

The most effective national programs in the US are the Small Business Innovation Research Program (SBIR) and the Small Business Technology Transfer Program (STTR). These programs are coordinated by the US Small Business Administration and provide public funding for research and development on a competitive basis.

4.1.4. Slovenia

In Slovenia, the Ministry of Higher Education, Science and Technology (MHEST) and the Ministry of Economics (ME) support R&D and innovation activities of SMEs through co-financing of R&D projects, investments in innovative research, and research infrastructure, participation in international research networks, and innovation vouchers. In 2009, the measure of R&D co-financing projects was changed. Its goal is to stimulate investment by micro and small enterprises in R&D, new technologies and products. The broader goal is to increase the technological level, value-added and competitiveness of SMEs. Research activities may be carried out within the enterprise or in cooperation with other enterprises and/or public research institutions. Innovation is at the centre of Slovenia's economic life as it is an important component of its ability to remain competitive. Slovenia has a strong R&D focus: it has 4,200 researchers per 1 million people and is the 21st most innovative country in the world. It is also the leader among Central and Eastern Europe (CEE) countries in the number of hidden champions, highly successful innovative SMEs. The investments of Slovenian companies in R&D are average for the EU-28 countries, which leads to the creation of technological products and solutions that are most suitable for future needs. One of the main concerns of SMEs in Slovenia is that SMEs often struggle with the transition of management and development from a "family" or "local" company to a medium or global company with the potential and ambitions of rapid growth.

4.1.5. Czech Republic

Governmental support in the Czech Republic for enterprises and entrepreneurs primarily includes measures to finance development and activities, support for exports, development of entrepreneurial skills and financial literacy of entrepreneurs, research, and development and innovation.

In 2012, the Czech Government adopted the Strategy for Support of Small and Medium- sized Enterprises for 2014–2020 (SME2014+). It is a crucial document for the preparation of the European Union (EU) cohesion policy during the 2014–2020 programming period. These include the Enterprise and Innovation for Competitiveness Operational Program (OPEIC), as well as important national programs to support small and medium-sized businesses.

SME 2014 + support social enterprises and strengthen the education of social entrepreneurs. SMEs 2014 + are implemented through national enterprise support programs, such as the GUARANTEE, ENERG, VADIUM, or Inostart programs; and through OPEIC.

SME2014 + aims to motivate entrepreneurs to use available funding to develop their business through national and EU programs. This includes several instruments, such as state loan guarantees (Czech-Moravian Guarantee and Development Bank), export financing schemes for SMEs (Czech Export Bank) and innovative business (INOSTART program), as well as a program to attract financial resources from the EU Structural Funds OPEIC), which gives SMEs grants, soft loans and guarantees [37].

This is what our approach looks like. According this approach, we proposed and used an example of assessing the impact of innovative indicators on greenhouse gas emissions.

4.2. Improving the approach to the analysis of input data

However, as noted above, the results can differ significantly if the selection and analysis of input parameters are more carefully approached.

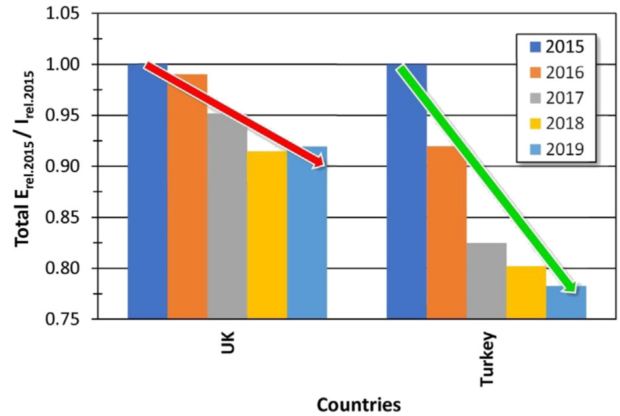

Figure 7. Dynamics of the ratio of relative total GHG emissions to relative Industrial Production Index (level 2015 = 1) in UK and Turkey.

In Table 2, we present the results of the correlation analysis for the factors that we will analyse in more depth. So, if we return to the initial results of the correlation, according to the obtained initial results, an increase in the factors X3.1, X3.3, X3.5, and X5.3 leads to an increase in the resulting indicator - the total amount of greenhouse gas emissions (Table 2).

This, in our opinion, is not entirely logical for all of them. Thus, growth X3.1 is SMEs cooperating in innovation (percentage of firms actively engaged in products or processes innovation) and X3.3 is SMEs cooperating in innovation with customers provokes an increase in emissions. The growth of these indicators and, accordingly, the growth of greenhouse gas emissions is possible if such cooperation leads to the attraction of additional natural material resources or the increase of industrial capacity. On the other hand, if the growth of these indicators (X3.1 and X3.3) is due to intensive factors (results of scientific and technological progress, attracting highly qualified personnel, etc.), it should definitely lead to a reduction in GHG emissions.

The growth of indicators X3.5 and X5.3 can provide the growth of greenhouse gas emissions. It can be logical if we talk about these indicators. X3.5 is share SMEs only participating in national collaboration. This is a direct relationship between this factor and the result, because if SMEs operate in cooperation only within the country, then the standards of this country may be lower than in other countries.

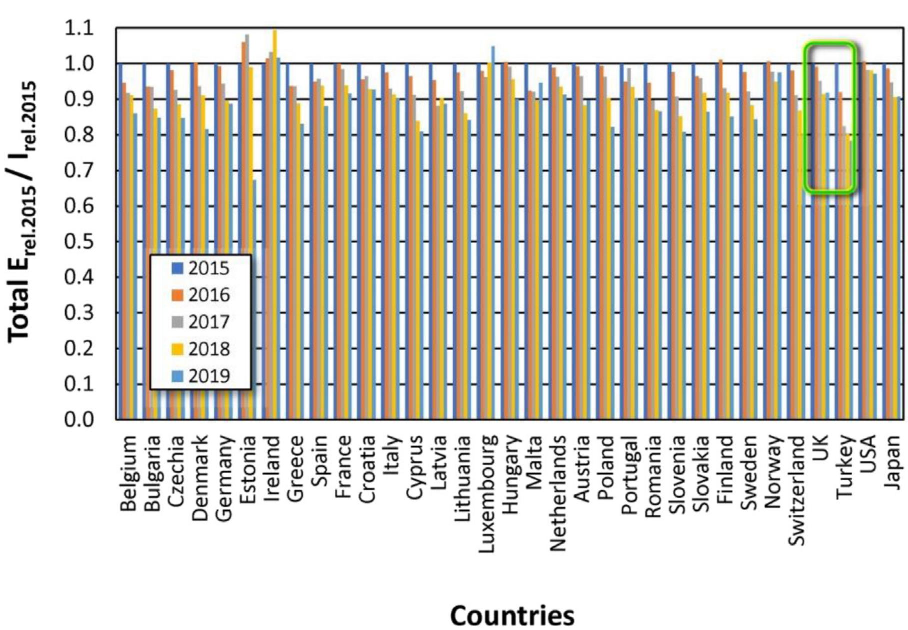

Figure 6. Dynamics of the ratio of relative total GHG emissions to relative Industrial Production Index (level 2015 = 1).

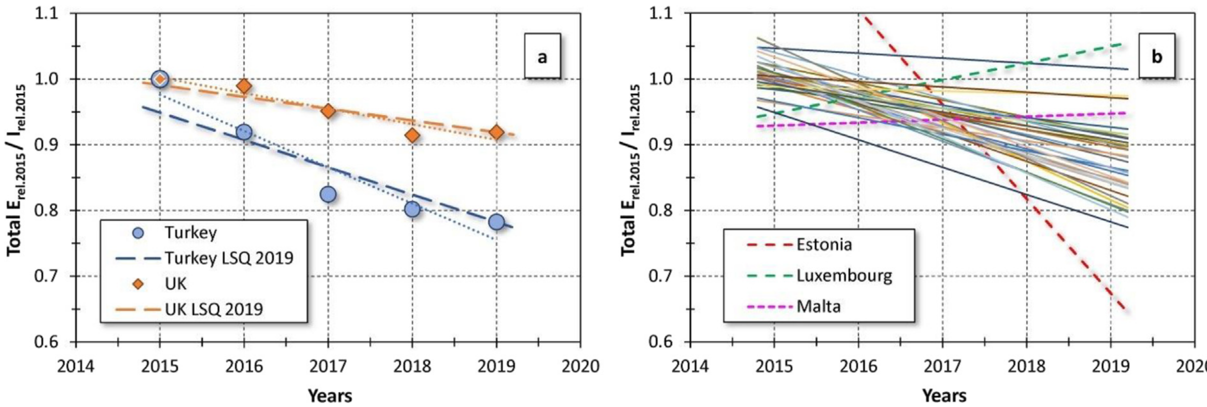

Figure 8. Least-squares trend line of the dynamics the ratio of relative total GHG emissions to relative Industrial Production Index (level 2015 = 1); (a) – Turkey and UK, (b) – all countries studied.

X5.3 is share SMEs not operating in international markets. The growth of this indicator and, accordingly, the growth of greenhouse gas emissions is partly logical. Such behaviour is possible because the innovative firms that do not enter and operate in international markets have "narrow" production places, or their products are not in demand in international markets or do not meet environmental standards.

Let us dwell on these factors in more detail, in particular, on the example of the influence of factor X3.1 on the resulting indicator.

For simplification, we consider only data for 2018 at this stage.

According to the calculations, we found that there is a direct exponential relationship (positive value of the correlation coefficient between X3.1 and the resulting indicator with a high correlation coefficient of 0.95 (Figure 4).

However, as can be seen from Figure 4, the extreme point corresponding to the US values is out of the general trend. Therefore, in the next figure, we will reflect the correlation map without taking into account the values of the US indicators (Figure 5).

As can be seen from Figure 5, with an increase in X3.1, emissions decrease (in contrast to the initial upward trend - Figure 4), which, from our point of view, more correctly reflects the behaviour of this dependence. But, in this case, the obtained value of the coefficient of correlation is low for X3.1: (−0.365). In this regard, this factor should not be taken into account in the analysis because the absolute value of the correlation coefficient $|0.365| < 0.5$. This conclusion is also wrong, because logic dictates that the value of "Firms collaborating in innovation as a percentage of firms actively innovating in products and/or processes" should have a crucial and fundamental influence on the reduction of GHG emissions. Such collaboration and symbiosis of partnership is an effective factor in the sustainability of the eco-socio-economic system of countries.

Despite the low correlation coefficient – (−0.365), one can see that the curve and the points show that the sign has changed, showing us the nature of the changes.

On the other hand, excluding the United States from consideration, as was done above, leads to the need to reject this factor from consideration, since the absolute value of the new correlation coefficient is (0.365), while in our approach, the relationship is considered to be present when the absolute value correlation factor ≥ 0.5.

Thus, this example is a bright demonstration of the fact that it is not always correct to conduct a correlation analysis on the data as is. So, it is not entirely rational to study the relationship in our example X3.1 and the resulting factor, since the number of innovative firms will differ significantly in different countries, because the area of countries, population, production powers are different.

However, excluding such a country as the USA may affect the final results of our study. Therefore, we need to prepare the data form OECD to more correct representation. For this we tried to take not just the input data, but their ratio to some indicator, that allow us to unify them.

In accordance with the above information, try to normalize the input actual data of X3.1 by taking into account such a factor as the population in each country under study. Population normalization is a better approach than just the actual data on the selected factor. In addition to all other influential parameters, the number of firms in a sparsely populated country is highly likely to be smaller than in a large country with many people.

Besides the value of emissions takes as the ratio of *Total E* to the Industrial Production Index. This index expresses the change in the volume of output in countries in such sectors as mining, manufacturing, production, and distribution of electricity, gas, and water. In our opinion, they are fundamental sectors of the economy in the formation of countries' GDP and, in turn, produce the largest amount of emissions.

We will mark the Industrial Production Index with *I*.

We use $Total\ E_{rel.2015}$ to mark the ratio of *Total E* present year to the level of *Total E* in 2015 and $I_{rel.2015}$ to mark the ratio of *I* present year to the level of *I* in 2015. Since in recent years the technologies used in countries are more energy-efficient and resource-saving, the ratio of relative greenhouse gas emission factors to the relative industrial production index decreased from the calculations performed ($Total\ E_{rel.2015}/I_{rel.2015}$). This is a positive development as the amount of GHG per unit of industrial output is decreasing compared to 2015 levels. The authors believe that the rate of change characterizes the quality and effectiveness of measures to implement an energy-efficient policy in business processes.

Figures 6 and 7 present a dynamics the ratio of relative total GHG emissions to relative Industrial Production Index, normalized by year 2015.

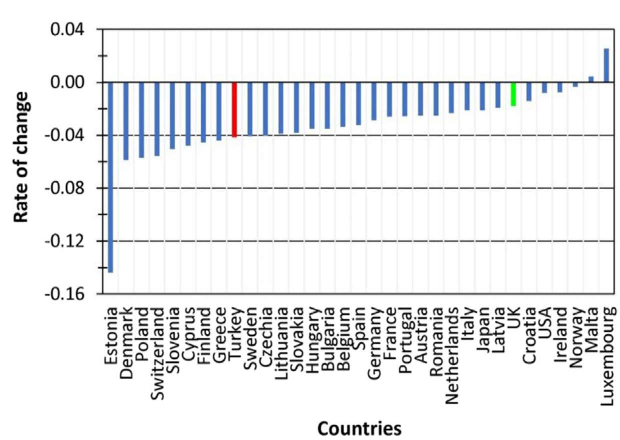

Figure 9. Rate of change the dynamics the ratio of relative total GHG emissions to relative Industrial Production Index (level 2015 = 1).

As can be seen from Figure 6, most countries are characterized by a decrease in the analysed index, which can be considered as a decrease in GHG emissions from industry. A slight increase in this indicator is observed in 2018 in Luxembourg, because in 2018 there was a decrease in the industrial index by 1.1% compared to 2017, while emissions increased by almost 3%. In our opinion, emissions have increased due to other sources of pollution, such as transport. Some countries, including Ireland, Estonia, Finland, and the USA are characterized by growth at the beginning – by years and decrease at the end, which is positive. According to the rate of change, the USA, which is in 2nd place in our ranking of countries (Figure 3) has the lowest rate of decline in the *Total* $E_{rel.2015}/I_{rel.2015}$ indicator (Figure 6). Such a trend in the USA is due to the fact that the volume of emissions during the analysed period did not change significantly. It was approximately at the level of 6,100 million metric tons of CO_2 equivalent each year. The industrial index, after falling by 2% compared to 2015, had a tendency to increase until 2018 and decreased in 2019 by 1% from the level of 2018, similarly in 2019 the emission rate also decreased to the level of 6,000 million metric tons of CO_2 equivalent. One of the reasons is that, between 2000 and 2015, Washington, DC, and 41 states, including Maine and Ohio, managed to reduce their emissions, but nine states, including Nebraska and Montana, increased their emissions. The emission reductions mostly occurred at the end of the 15-year period. That happened due to the impact of the Great Recession and higher gasoline prices, both of which lowered energy consumption.

For a clearer explanation of what the authors mean by the rate of change of the analysed *Total* $E_{rel.2015}/I_{rel.2015}$ parameter, data for Turkey and England are highlighted in the figure with a rectangle, which are further shown on a larger scale in Figure 7.

In Figure 7, we show the indicator change for two countries - the UK and Turkey. In Figure 3, the UK was ranked 3rd, and Turkey was 25th. Figure 7 shows that the indicator that we analyse is decreasing in both countries, which is a positive trend. However, the figure also shows that the rate of decline (shown by the arrows in Figure 7) is much faster in Turkey than in the UK. Finally, the value of the studied indicator is lower in Turkey than in the UK. Therefore, we consider it necessary to study in more depth the rate of decline in the indicator by country.

To do this, using the least-squares method in Figure 8 trend lines are built that pass through the end point (value 2019). The year 2019 was taken as a benchmark, since in 2015 the Global Sustainable Development Goals were adopted, namely goal 13 - combating climate change, including the task of reducing emissions for all countries. Therefore, we believe that starting from 2015 countries are pursuing the goal of reducing emissions.

The rate of change is indicated to us by the slope of the trend line (i.e., the trend coefficient at the argument), which is a quantitative characteristic of the rate of change: the greater its absolute value, the more intense the changes occur.

Figure 8a shows the trend line to the actual data of *Total* $E_{rel.2015}/I_{rel.2015}$ for England and Turkey.

Lines with short dashes show the standard linear trends that Excel builds. Lines with long dashes are modified linear trends passing through the data endpoint (2019). We believe that the construction of such a line reflects a more realistic picture. Since, in 2015, the input data of the analysed indicator and those used for its calculation were different and, accordingly, the situation as of 2015 was different for different countries. And starting from 2015, after the adoption of the Global Sustainable Development Goals and the Paris Climate Agreement, we consider that the course has been taken to reduce emissions, including greenhouse gas emissions.

Comparing Turkey and Great Britain, the differences are clearly visible. In both countries, it can be seen that there is a tendency to decrease the indicator, which is positive. In Great Britain, the rate of decline is less than in Turkey. Turkey managed to reduce emissions starting from 2017 with a constant and significant growth of the industry index (in 2019–113% according to OECD data). In the UK, there has also been a steady reduction in greenhouse gas emissions (a total reduction of 50,000 metric tons of CO_2 equivalent over the period 2015–2019), with the industry index rising by just 6% (according to OECD data).

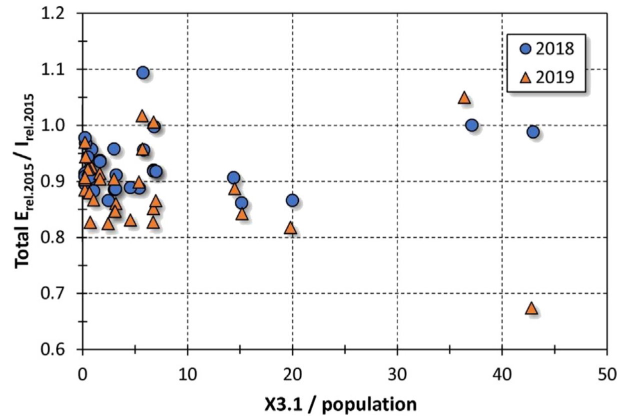

Figure 10. Correlation map for total greenhouse gas emissions excluding LULUCF/Index of production from ratio X3.1 to country's population (mln. people).

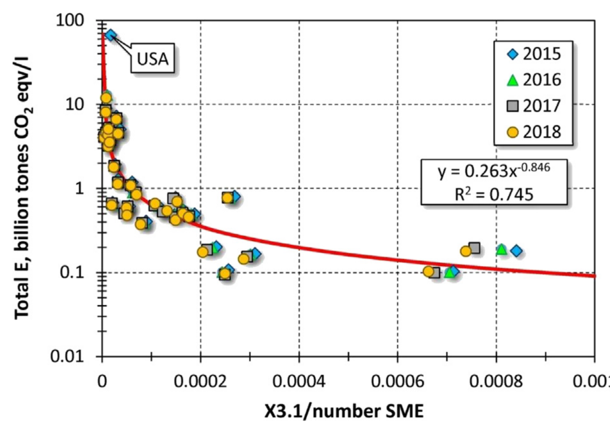

Figure 11. Correlation map for total greenhouse gas emissions excluding LULUCF/Index of production from ratio X3.1 to number SME.

Figure 8(b) shows the trend lines for all countries from Figure 6. Separately, it is seen with a dash-dotted line those edges, which are most pronounced:

- *Estonia* has the largest slope, indicating that in recent years, they have been trying to reduce emissions while trying to generate economic growth due to industrial intensification.
- In turn, *Luxembourg* and *Malta* demonstrate growth rates of the analysed indicator. Up to 2021 SDG Statistical Report for *Malta* we found out an explanation of it. The energy sector is the highest overall contributor to greenhouse gas emissions, by a significant margin other sectors for most of the period 2010–2019.Investment in new generation capacity, fuel switching from fossils to renewable, and alternative sourcing of electricity contribute towards the rapid decrease in emissions observed for the years after 2012. This trend is reversed between 2016 and 2017, as there was a shift back towards local electricity generation as opposed to previous use of the interconnector with mainland Europe's electricity grid. Regarding *Luxembourg*, as stated above, there was an increase in the indicator because despite a slight decline in industrial production, emission indicators were increasing.

A superficial analysis of other countries (solid lines in Figure 8b) also shows that each country has its own rate of change - the slope is different.

In this regard, we are interested in the rating of countries according to the speed of ongoing changes, which is an indirect indicator of the effectiveness of measures to reduce emissions (in our case, on the example of SMEs). Such a rating is shown in Figure 9.

We see that the highest rate of decline is in Estonia, as noted above, which indicates an effective policy in the field of energy efficiency in production and energy saving. The top ten, as we can see, includes small countries, emissions that do not exceed 100 thousand metric tons of CO_2 equivalent and did not decrease significantly during 2015–2019. However, in all countries there was an increase in the industrial index (the least in Greece by 7.1% compared to 2015, the most in Slovenia by 24.4%). The exception is Poland. Its emissions were about 350 thousand metric tons of CO_2 equivalent during 2015–2019, while the growth of the industry index was 20%. Next in the ranking are countries with larger areas. On the one hand, their possibilities are greater, since the availability and quantity of resources are greater. However, they are less flexible and slower in spreading energy-saving measures and innovations in enterprises, as their number is much larger than in smaller countries.

Thus, the analysis and reasoning given above show that the rate of change in the ratio of growth in emissions to growth in the industrial index more correctly reflects the real achievements of countries and is more informative. Therefore, at the next stages of the analysis, we take not just the amount of greenhouse gas emissions, but the indicator of the ratio of emissions growth to the growth of the industry index.

Again, we want to emphasize that population normalization is a better approach than just the actual data on the selected factor. In addition to all other influential parameters, the number of firms in a sparsely populated country is highly likely to be smaller than in a large country with many people. Therefore, similar countries can be compared with each other or brought to some kind of normalized form. So, during a deeper analysis on the example of X3.1, we saw how our results changed if we represent the emission indicator as the ratio of $Total\ E_{rel.2015}$ to $I_{rel.2015}$, and indicator X3.1 (Firms co-operating on innovation activities) is presented as their ratio to the country population (million people).

In this case, according to the results of the correlation analysis for this factor, there is no characteristic form of the relationship (Figure 10). So, for X3.1 in 2018, a power-law form of connection with a low positive coefficient of correlation 0.24 was established, and in 2019 – an exponential form of connection with a negative coefficient of correlation (−0.07). These dependencies are not shown in the figure because the correlation is very weak.

As can be seen, normalization by population did not give the desired effect for generalizing the data. This suggests that another normalization parameter needs to be found. Since we are analysing the impact of individual innovative indicators on emissions, in our opinion, and in our example, we considered not just SMEs co-operating on innovation activities (% product (process) active in innovations firms SME), but took this indicator to the total number of SMEs in the countries under consideration. Again, because of the fact that the number of SMEs in larger countries will be greater, due to a larger territory and greater population density, and vice versa. After normalization we will have a more realistic picture of their activity and level of innovation.

Therefore, in this case, we calculate the impact on emissions per unit of the industry due to the share of innovative SMEs in the total number of SMEs in different countries, which will also balance the data. In this case, we take data for 2015–2018 using the X3.1 factor as an example. We get the following graphical interpretation (Figure 11). It worth to note that Y–axis of Figure 11 is shown in logarithmic format.

The best influence of X on Y is described by dependence in the form of a power function, which has the form:

The coefficient of determination for this function is 0.7446, which means that in 74.46% of cases, a change in X will lead to a change in Y. The value of the correlation coefficient for this function is $\sqrt{0.7446} = \pm 0.8629$, which indicates a fairly high correlation dependence. Since the influence is negative (an increase in X leads to a decrease in Y), the correlation coefficient is negative (has minus sign): (-0.8629).

The value of the order of degree – parameter b in Eq. (1) – is(-0.846). This allows us to conclude that when X changes by 1%, the value of Y will change by (-0.846) %. That is, an increase in the share of SMEs cooperating in innovation by 1% leads to a decrease of 0.846% in emissions per unit of industry.

All countries participate in this distribution, incl. USA, which, in a "blind" correlation analysis, got out of the general trend (Figure 4). In addition, it is obvious that the sign of the correlation coefficient (direction) has changed from (+) - direct influence to (–) - reverse influence, which is natural and understandable.

That is, the contradiction described earlier is removed. Thus, in accordance with current trends, an increase in the indicator X3.1(SMEs cooperating in innovation) involves reducing GHG emissions, due to intensive factors.

In Table 3, one can see how the value of the x3.1 indicator changes when using the approach, and the value of the country's average rating changes accordingly.

Figure 12 shows the new rating of countries with update X3.1.

Figure 12 shows the updated ranking of countries. We built it taking into account the changes obtained as a result of the analysis of the input parameter X3.1. It can be seen that when even one parameter is changed, the rating has changed. In Figure 3, Hungary and Luxembourg are not in the top five. But they hit 5 and 6 in Figure 12. (They are also marked in Figure 3 for the readers' convenience). Also in Figure 12, the US is out of the heel (but marked for comparison), but they are in the top five in Figure 3. Luxembourg, which was in 32nd place, moved to 5th place, Hungary from 7th to 6th, and the USA, which was in 2nd position, moved to 11th place. This is how the ranking of countries has changed as a result when we more truly and carefully approach the assessment of only one factor.

Table 3. Changes in the ranking of countries when x3.1 values change from using the approach.

Country	x2.1	x3.1	x3.1 (new)	x3.3	x3.5	x3.6	x5.1	x5.2	x5.3	x5.4	x5.5	x5.6	Average country rating	Average country rating (with new x3.1)
EST	2	5	6	3	2	6	6	6	1	6	6	6	4.455	4.55
USA	1	6	2	6	6	3	-	-	-	-	-	-	4.400	3.6
GBR	-	6	2	6	5	6	3	4	3	4	3	4	4.400	4
SVN	3	3	5	3	-	6	6	6	1	6	6	4	4.400	4.6
CZE	5	2	2	-	-	-	5	5	2	5	4	4	4.000	4
AUT	-	4	3	3	2	5	4	5	2	5	3	6	3.900	3.8
HUN	4	2	2	2	-	3	5	5	-	5	5	-	3.875	3.875
GRC	3	4	2	4	2	5	4	4	3	4	4	5	3.818	3.636
NLD	5	2	2	1	1	2	5	5	-	6	5	6	3.800	3.8
SVK	2	3	2	3	1	5	5	5	-	5	5	3	3.700	3.6
BEL	3	3	2	1	1	2	6	6	1	6	5	6	3.636	3.54
LTU	2	3	3	2	2	4	5	5	2	5	5	5	3.636	3.63
FRA	6	2	1	2	2	3	4	4	3	5	3	5	3.545	3.45

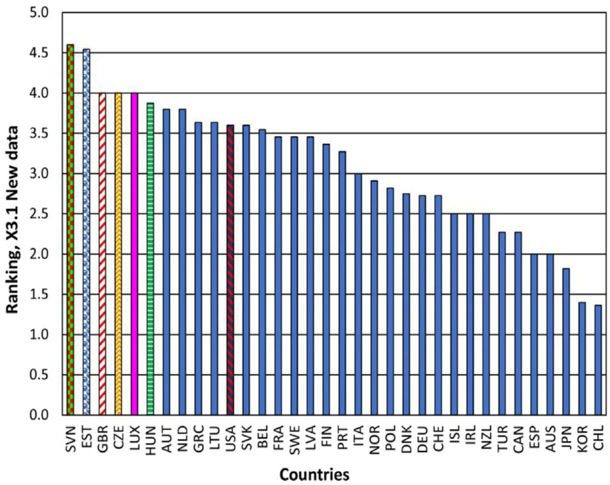

Figure 12. Country ranking with new data of X3.1.

Well, if all the factors are considered in this way, then everything will be completely different. But this is the basis for the next study.

If we compare the obtained research results with the studies that we reviewed in the literature review, we can say that:

1. First of all, we saw that our previous studies were more limited, and we could neglect factors that would have a significant impact on the resulting indicator.
2. Secondly, almost all analysed researches took into account the absolute values of the input parameters, which again will not always give a reliable result, but requires a deeper approach to the selection of input parameters.
3. Comparing with the results of studies given in the Literary Review, it seems to us that our research is larger in scope. We managed to combine the macro situation of countries, their geographical location, population, their environmental policy and the level of innovation development.
4. Well, as you can see, our research is bulky and requires a lot of time to combine blind correlation analysis with the use of a phenomenological approach.

5. Conclusions

Thus, such a deep analysis of each input parameter and its revision through the prism and taking into account macroeconomic indicators for each country will provide more realistic data for the subsequent stages of our approach and in the approaches of other authors, including those considered in the literature review.

The advantage of our research is that it does not require special software, but Microsoft Excel is sufficient. In addition, the method of conducting correlation analysis is quite popular and many scientists already use it in their research, and we only suggest using it more consciously approaching the selection of input parameters. Other stages of the proposed approach are also simple and clear.

Conducting research in recent scientific articles, we used a phenomenological approach and tools of correlation and regression analysis. We noticed that the results of CRA based on the selected input parameters are not always correct. Therefore, based on the proposed approach for assessing the influence of factors on the resulting indicators, it is proposed during the first stages not only not to exclude indicators that did not show a relationship according to the results of the CRA. We recommend that you analyse each factor in such a way as to use the logic and consideration of the "nature" of the factor and its change, for example, according to the input data processing method we have given, following the example of the X3.1 factor. Since this procedure is quite voluminous, we do not present the results of the re-analysis and ranking of countries in this article, but this is the topic of our next study.

Declarations

Author contribution statement

Ivanna Melnychuk: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Yulia Bui: Performed the experiments; Analyzed and interpreted the data.

Serhii Pobihun: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Iryna Hobyr: Wrote the paper; Conceived and designed the experiments.

Oksana Savko: Conceived and designed the experiments; Wrote the paper.

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Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

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