Analyse options for relationship between sustainability development indicators

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Abstract: - The paper focuses to analysis of relation between pollution produced by economic subjects and GDP. It is shown that it is possible to calculate the dependency of pollution on GDP. The method is based on the smoothing of time series of GDP and values of pollution per of GDP It is possible use instead of GDP the Total production, of course. These coefficients are needed when we use Input-Output models in consideration about environmental problems.

Key-Words: -pollution indicator, GDP, linear smoothing, time series.

1. Relation into sustainable development indicators

The links between sustainability indicators are often quite complicated [5,6,10,12,17]. Usually, however, exists between the various indicators of a certain degree of correlation. Within each pillar can be workedwith models for the analysis of different contexts [2]. There are several ways of distribution of indicators of sustainable development. The which the best known is the distribution of the indicators of environmental, economic and social. This classification is very practical because it is relatively easy to assign practically any data to one of the set of indicators. But there are also other approaches, such as capital approach, which divides indicators beneath other criteria[1,16].

This article is focused on a basic breakdown of the usual three pillars of sustainability and analysis of their potential interrelationships, centred on the link between the indicator within the environmental and economic pillars.

However, to balance environmental and economic pillars of sustainability, there is extensive use of apparatus of different kinds of subsidies[14,18].For appropriate analysis it is always difficult to select a sufficient set of indicators that are relevant to the research problem [8,13].

Due to the huge amount of available data, which are assignable to individual pillars, on the order of thousands of time series, it is always necessary for the purpose of concrete researchto define the areas to specific indicators which the research will focus on [9].

Certain tool may represent the fulfillment of the rules for indicators quality, as shown in [9], which can at least disable from the selection time series containing unreliable data, which may adversely affect the results of the research.

This is generally the requirement of materiality, accuracy, transparency of method for obtaining, error-free, representativeness, reliability, transparency, comprehensibility, data should be free of redundancy, measurable and timely.

Some of these requirements are relevant for the analysis and, thus, more attention is paid to a description of their specific binding to the treated topic. The significance is the requirement that the indicators used in this context were significant. Meaning of the indicators can be either specific to the given environmental component (such as an indicator characterizing the quality of the soil can be considered soil quality, or some data how it is used on the selected area, or the percentage of land threatened by erosion, etc.). Other phenomena, such as air quality, may play a role in the broad context of sustainable development [13]. For this broad context of indicators related to air quality were selected for the mutual comparison of indicators related the air quality, and due to other complications, which, as described below, asociated with the acquisition of data for indicators under other pillars, was selected basic as economic indicator the GDP.

Question correctness was treated by selecting of data sources used. It was then verified for used data, how this data was obtained. This is to a certain extent affects the following requirement, because data should not be burdened with significant error. However, he points to data as such, while this requirement determines their explanatory power - that means, what can be from the relevant data expected. Therefore, such a source was used, where it was stated, how the data was obtained. Namely, under what conditions has been made to measurement, using what techniques and with what accuracy. Another requirement of these indicators, which has been verified is that indicators should not be burdened with more significant errors.

Especially in the field of environmental pillar, data are often obtained in the measurement or collection and processing of samples, possibly by research in the relevant area, etc. Whether such samples processed, certified or uncertified laboratory, possible inaccuracies in the results that may be caused by a number of factors can not be excluded. Likewise, the data from the economic and social field may not be entirely accurate, since they can be prepared on the basis of a statistical sample whose selection was not fully representative. That may be, for example data on economic growth whose were gradually refined, and the result may be that instead of the original GDP decline, after refinement to find that there was in the fact a slight increase. Centre for Environment of Charles University even states that in the area of environmental data usually encounter errors very significant.

Therefore, it was necessary to take this risk when selecting data into account and try to eliminate them, because the method used for their evaluation cannot eliminate deviation and would so shift the output values.

Another requirement on the quality of the data is their representativeness. From the description on the one hand must make clear what effect the indicator is monitoring, which in this case is successfully resolved by selecting a convenient base indicators, on the second hand must be selected appropriate scale and timing. As in the case of data for economic pillar of sustainability are usually available data on an annual basis, the environmental data was also monitored on an annual basis. For some indicators may be more or less frequent measurement interval suitable, due to the nature of the observed dependence, which has no emissions linearity during the year due to changes in temperature, the annual interval is the smallest possible, which eliminates this problem. Values or time series, have to be free from redundancy.

In principle, each indicator should bring new information and should not be deducible from other indicators. This requirement is very easy to formulate and understandable. When working with different sets of indicators, however, in their design occurs in practice often a problem of the decision to whether this is already the redundant information or not.Is not easy, because the border between the two indicators is strongly identifiable.

On this issue focuses this article, because it is in the area of sustainability a high rate of correlation of individual time series, both within individual pillars, and between them a common phenomenon. Eg. could be expected that emissions, GDP and employment rate will probably show a similar trend.

This article aims to determine the extent to which this binding is tight and research, if is possible with the knowledge of the development of one indicator, provide the development of the other indicator. This relationship is examined on the basis of selected indicators between environmental and economic pillars. Some additional requirements could not be affected, or are quite general in nature and therefore are not discussed in detail. The penultimate in this listing is a timing requirement. The corresponding values of indicators should be available at the right time. Usually, however, are in many cases the relevant data for social and economic area available not immediately, or if, then are only estimates, but only when it is processed by statistical offices.

So there is a delay with which it is to be calculated. Environmentally oriented technical data whose measurement can be made by the user himself may be on the contrary available immediately, even in real time. Therefore were for the analysis of the relationships between economic and environmental pillars used data that are ordinarily used and for which the above risks are minimal. To a large extent, this problem is solved by setting a time interval of 1 year.

The relationship between economic performance and environmental burden describes the Kuznetsov curve. Works on this topic deals with setting the parameters defined according Kuznetsov curve [11]. Still unresolved question remains, whether the relationship between specific environmental and economic variables cannot be expressed using general mathematical functional dependence. The aim of this paper is to analyze the possibilities for expression of such a functional dependency. For simplicity and brightness of explanation and for the reasons set forth above we consider therefore for air pollution just pollutants mentioned in table 1.

Table 1: Polutants considered for further analysis

TZL	Solids
SO_2	Sulphur dioxide
NO_x	Nitrogen Oxides
CO	Carbon Monoxide

Source: own

Appropriate data timelines used for analysis are taken from Czech environmental air-quality database REZZO 1 to 4 This database is divided into 4 groups of pollution sources (1 - large, 2 - medium, 3 - small) and adds one different category 4 - mobile sources [3]. This is reliable and transparent information source, needed for the analysis in public administration area [7], since they include all emissions produced in the area considered. Data are available in t/year in timelines and shown with the economic indicator in this case, we chose GDP in million CZK (ca. 27 CZK = .1 EUR).

Table 2: The initial data

Year	GDP	Solids	SO_2	NO_x	CO
2000	2 269 695	60 670	224 445	292 849	539 363
2001	2 448 557	62 941	227 105	301 863	538 659
2002	2 567 530	61 824	228 237	288 008	516 688
2003	2 688 107	64 144	222 415	290 279	528 848
2004	2 929 172	60 736	219 163	288 730	509 215
2005	3 116 056	62 328	217 386	291 007	491 209
2006	3 352 599	63 190	210 830	280 120	481 280
2007	3 662 573	62 988	216 545	283 193	435 207
2008	3 848 411	63 729	177 017	264 757	444 720
2009	3 758 979	61 229	174 650	252 005	418 859
2010	3 790 880	62 659	170 323	238 048	398 262
2011	3 823 401	56 966	170 180	225 309	381 912

Source:[3,4]

The production included in GDP calculation includes goods and services produced by resident institutional units during the reporting period in the production process. The term production means an activity carried out under the control and responsibility of an institutional unit that uses inputs of labour, capital, goods and services to produce, individually or collectively for their own final consumption or gross capital generation. So this indicator exactly corresponds to the definition required by theory.

In the table 3 and graph on the Figure. 1we set out the development of the coefficients of pollution per unit of GDP.

Table 3: Ratios of pollution per unit of GDP

Year	Solids	SO_2	NO_x	CO
2000	0,0267305	0,098888	0,129026	0,2376367
2001	0,0257052	0,09275	0,123282	0,2199904
2002	0,0240793	0,088894	0,112173	0,2012393
2003	0,0238621	0,082741	0,107986	0,1967363
2004	0,0207347	0,074821	0,098571	0,1738428
2005	0,0200023	0,069763	0,09339	0,157638
2006	0,0188479	0,062886	0,083553	0,1435542
2007	0,0171977	0,059124	0,077321	0,1188256
2008	0,0165598	0,045997	0,068796	0,1155594
2009	0,0162887	0,046462	0,067041	0,1114289
2010	0,0165288	0,04493	0,062795	0,105058
2011	0,0148992	0,04451	0,058929	0,0998879

Source: own according [3,4]

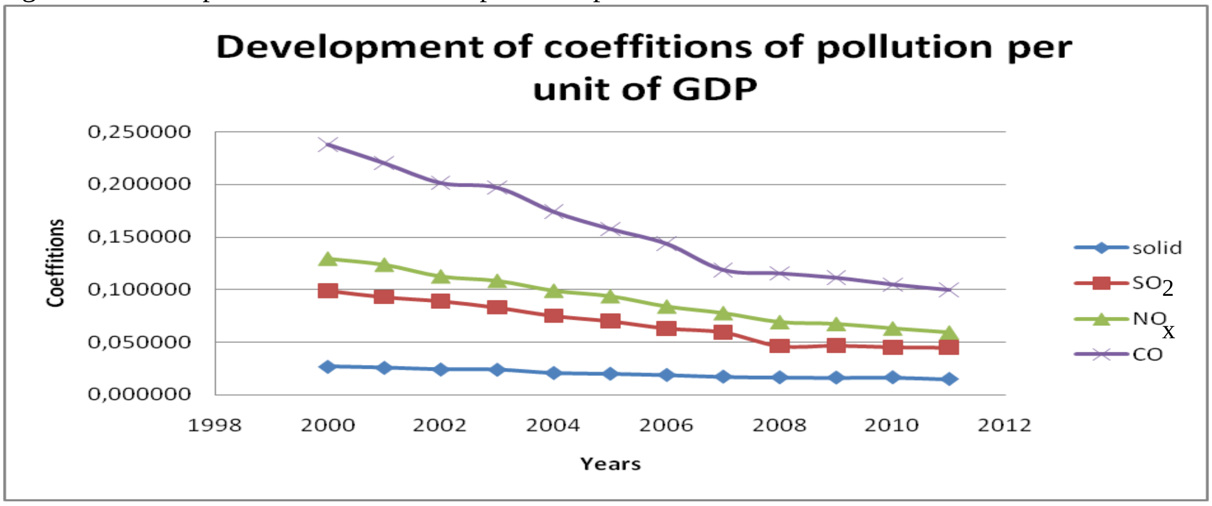
Data listed in Table. 3 are necessary for further calculations, so completely were listed in numerical form. This, however, does not allow easily observe their progress in the time. Therefore, these data are still graphically expressed in the graph of figure 1. There is a noticeable downward trend of production of these pollutants, which is useful information, because the greatest measures to reduce emissions of SO2 and NOx were made in the mid-90th Years of the last century.

Some sources say that since then the situation has again deteriorated.

From the chart it is clearly evident that per unit of GDP, these values are falling, which is much more important than having declined absolutely, as this information may not yet talk much about the actual environmental efficiency of production.

To assess the development is primarily important precisely indication of pollution produced per unit of GDP, which should show a downward trend, as shown in figure 1

Figure. 1. Development of coeffitions of pollution per unit of GDP



Source: own according [3,4]

Because the analysis in the field of public administration and sustainability solutions based on linear models proved [15], was to solve this problem chosen method of linear smoothing. For analysis linear smoothing in time was used.

2. Linear smoothing in time

Let us denote Z as the general type of pollution. The symbol Z will takes following values:

T for pollution solids,

S for pollution caused by sulphur and considered here like SO2 emissions,

N for nitrogen oxide based pollution and considered here like NOx emissions and

C for CO.

GDPisalso referred toH.

Linear smoothing is determined by

$$y = a + bx, \qquad (1)$$

where x denotes time period in form of time cuts from 0 to n; there are integers from zero to11 used, where zero corresponds to the year 2000and 11corresponds to year 2011.

y is the pollution coefficient calculated for each pollutant according Z /GDP,

number of years considered is set to n= 12.

a and b are parameter sobtained by the method of least squares. Analogously, this relationship can be also expressed for GDP, as

$$GDP = a_g + b_g x, \qquad (2)$$

where the subscript g indicates that it is a parameter relative to GDP. By adjusting these two equations for the time it is then possible to express

$$x = \frac{y-a}{b} \qquad (3)$$

and

$$x = \frac{GDP-ag}{bg} \qquad (4)$$

Then can be compared the two relations (3) and (4) because both are equal to time x. This can be then writen:

$$\frac{\mathrm{y-a}}{b} = \frac{\mathrm{GDP-ag}}{bg} \quad (5)$$

Examined is then the relationship between y and H. The expression of this relationship can be obtained from the equation:

$$y = \mathrm{a} + \frac{\mathrm{b}}{bg}(GDP - ag) \quad (6)$$

This equation expresses the relationship between non-recalculated values, ie the relationship between the indicators listed in table 2. To investigate the relationship between the relative indicators are needed to express this equation in terms of GDP. It has then the form:

$$\frac{\mathrm{z}}{GDP} = \mathrm{a} + \frac{\mathrm{b}}{bg}(GDP - ag) \quad (7)$$

By multiplying of this relation by GDP, we obtain:

$$z = \left[\mathrm{a} + \frac{\mathrm{b}}{bg}(GDP - ag)\right] GDP \quad (8)$$

Where z represents the dependence of the examined variables and applies quite generally for any dependency. Similar way are also derived the following calculations for the considered pollutants.

The equation for determiningtheparameters a and b are

$$an + b\sum_{i=1}^{n} x_i = \sum_{i=1}^{n} y_i \quad (9)$$

$$a\sum_{i=1}^{n} x_i + b\sum_{i=1}^{n} x_i^2 = \sum_{i=1}^{n} x_i y_i \quad (10)$$

By solution of these relations, we can express a and b like:

$$b = \frac{\frac{\sum_{i=1}^{n} x_i y_i}{n} - \frac{\sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n \quad n}}{\frac{\sum_{i=1}^{n} x_i^2}{n} - \left(\frac{\sum_{i=1}^{n} x_i}{n}\right)^2} \quad (11)$$

and

$$a = \frac{\sum_{i=1}^{n} y_i}{n} - b\frac{\sum_{i=1}^{n} x_i}{n} \quad (12)$$

From these formulas we get parameters of corresponding relations like:

$$\frac{Z}{HDP} = a_Z + b_Z \mathrm{x} \quad (13)$$

In addition to these relations, we determine these element values of GDP with:

$$GDP = a_H + b_H \mathrm{x}\,. \quad (14)$$

From these relations we can deduce that the x value could be expressed like:

$$x = \frac{1}{b_Z}\left(\frac{Z}{HDP} - a_Z\right) \quad (15)$$

and therefore

$$x = \frac{1}{b_H}(HDP - a_H) \quad (16)$$

So, we obtain

$$\frac{1}{b_H}(HDP - a_H) = \frac{1}{b_Z}\left(\frac{Z}{HDP} - a_Z\right) \quad (17)$$

$$\frac{b_Z}{b_H}(HDP - a_H) = \left(\frac{Z}{HDP} - a_Z\right) \quad (18)$$

$$\frac{b_Z}{b_H}(HDP - a_H) + a_Z = \frac{Z}{HDP} \quad (19)$$

$$\frac{b_Z}{b_H}HDP - \frac{b_Z}{b_H}a_H + a_Z = \frac{Z}{HDP} \quad (20)$$

$$\frac{b_Z}{b_H}HDP + a_Z - \frac{b_Z}{b_H}a_H = \frac{Z}{HDP} \quad (21)$$

After these adjustments, we obtainthe relation of amount of pollution and GDP development as:

$$Z = \frac{b_Z}{b_H}HDP^2 + \left(a_Z - \frac{b_Z}{b_H}a_H\right)HDP \quad (22)$$

This is theoretically derived relationship between GDP and pollution produced, constructed on the basis of mentioned data. It will now be verified for correctness on real data.

2.1 Parameters of linear smoothing

For linear smoothing ratios for each data timeline given in Table 4 were used. These values were calculated by substituting the data of Table 2 (the first line) and 3 (other lines) into equation (11) and (12).

Table 4: Parameters of the linear smoothing

GDP	b	159 965,32
	a	2 308 187,40

T/GDP	b	-0,001103
	a	0,026188

S/GDP	b	-0,005466
	a	0,097709

N/GDP	b	-0,006647
	a	0,126795

C/GDP	b	-0,013158
	a	0,229155

Source: own

Table 5 contains auxiliary indicators for further calculations calculated as mentioned in the table header.

Table 5: Auxiliaryindicators for calculations

	b_Z / b_H	$(b_Z / b_H)\ a_H$	$-(b_Z / b_H)\ a_H + a_Z$
T	-6,89711E-09	-0,01592	0,042108
S	-3,41692E-08	-0,07887	0,176578
N	-4,155E-08	-0,09591	0,222700
C	-8,22582E-08	-0,18987	0,419022

Source: own according [3,4]

2.2 Verification of the correctness of the derived dependence

The following tables and graphs we show the results on the data pollution. Data show how it is possible to obtain from the relative values the absolute pollution data.

2.2.1 Verification of solids

Substituting to formula (22) data from timeline for GDP with parameters for solids, the calculation delivers results mentioned in Table 6. In the first column of the table are listed the values of x corresponding to the years 2000 – 2011, in the second column labelled "solids" are the empirical data, in the third column labelled "solids-calculated" are the values calculated according to the formula (22).

For greater clarity, the values calculated in Table 6 are also graphically represented. Graphic representation of the success of smoothing of the time serine for solids is shown in the graph in figure 2.

Table 6: Statistical and according GDP calculated values for solids by formula (15).

Year = x	Solids	Solids calculated
0	60 670	60 041
1	62 941	61 752
2	61 824	62 645
3	64 144	63 352
4	60 736	64 163
5	62 328	64 240
6	63 190	63 647
7	62 988	61 701
8	63 729	59 899
9	61 229	60 826
10	62 659	60 508
11	56 966	60 170

Source: own, [4]

Graphical representation is necessary here to illustrate the success of time series smoothing. As seen from the graph, the calculated value based on GDP replicates reasonably well empirical data.

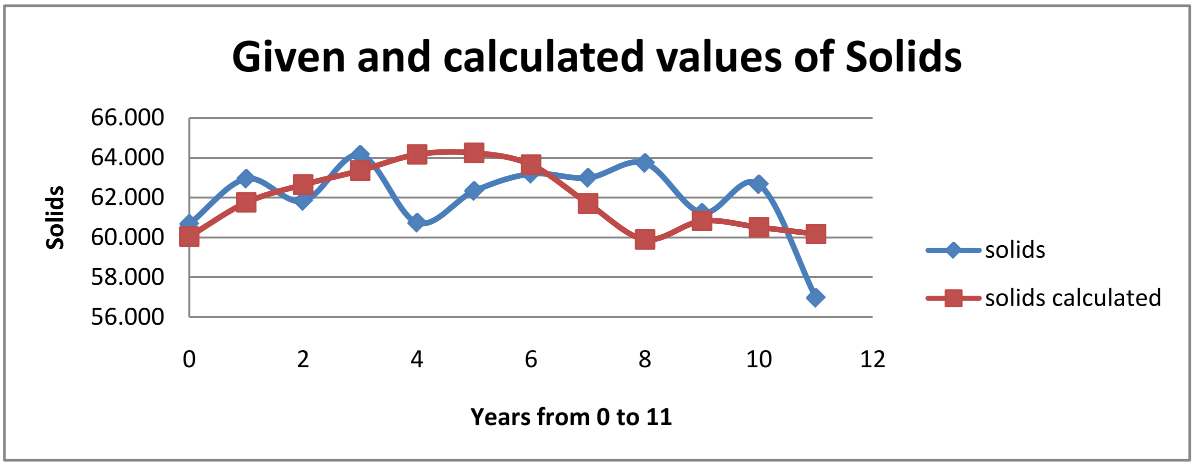


Figure 2: Smoothing of the time serine for solids

Source: own, [4]

As the next pollutant sulphur dioxide was analyzed.

2.2.2 Verification of sulphurdioxide

Substituting to formula (15) data from timeline for GDP with parameters for sulphur dioxide, the calculation delivers results mentioned in Table 7.

Table 7: Statistical and according GDP calculated values for sulphur dioxide by formula (15).

Year = x	SO_2	SO_2calculated
0	224 445	224 756
1	227 105	227 503
2	28 237	228 120
3	222 415	227 758
4	219 163	224 055
5	217 386	218 452
6	210 830	207 937
7	216 545	188 371
8	177 017	173 491
9	174 650	180 946
10	170 323	178 350
11	170 180	175 631

Source: own, [4]

Graphic representation of the success of smoothing of the time serine for sulphur dioxide is shown in the graph in figure 3. Graphical representation is necessary here to illustrate the success of time series smoothing.

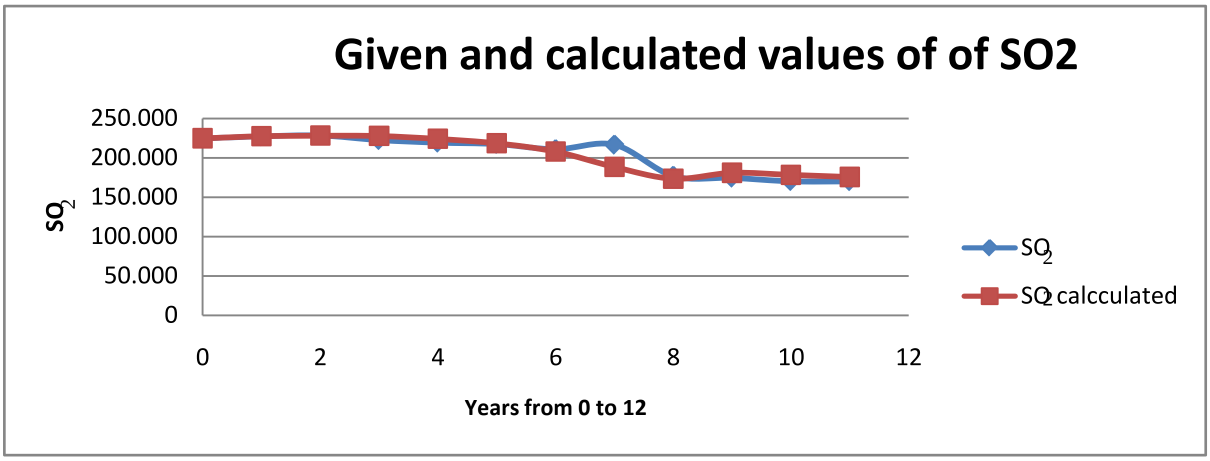


Figure 3:Given and calculated values of SO_2

Source: own, [4]

As the next pollutant nitrogen oxides were analysed.

2.2.3 Verification of nitrogen oxides

Substituting to formula (15) data from timeline for GDP with parameters for nitrogen oxides, the calculation delivers results mentioned in table 8.

Table 8: Statistical and according GDP calculated values for nitrogen oxides by formula (15).

Year = x	NO	NO calculated
0	292 849	291 415
1	301 863	296 183
2	288 008	297 882
3	290 279	298 404
4	288 730	295 825
5	291 007	290 503
6	280 120	279 604
7	283 193	258 284
8	264 757	241 674
9	252 005	250 026
10	238 048	247 123
11	225 309	244 076

Source: own, [4]

Graphic representation of the success of smoothing of the time serine for nitrogen oxides is shown in the graph in figure 4. Graphical representation is necessary here to illustrate the success of time series smoothing.

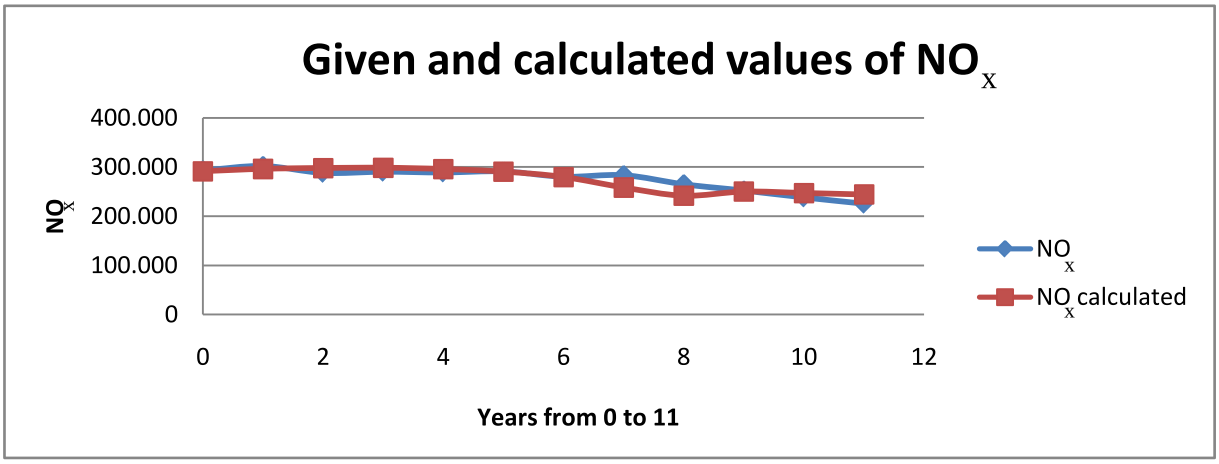


Figure 4: Given and calculated values of nitrogen oxides

Source: own, [4]

As the last pollutant carbon monoxide was analysed.

2.2.4 Verification of Carbon Monoxide

Substituting to formula (15) data from timeline for GDP with parameters for carbon monoxide, the calculation delivers results mentioned in Table 6.

Table 6: Statistical and according GDP calculated values for carbon monoxide by formula (15).

Year = x	CO	CO calculated
0	539 363	527 298
1	538 659	532 826
2	516 688	533 588
3	528 848	531 985
4	509 215	521 608
5	491 209	506 985
6	481 280	480 237
7	435 207	431 251
8	444 720	394 303
9	418 859	412 793
10	398 262	406 348
11	381 912	399 606

Source: own, [4]

Graphic representation of the success of smoothing of the time serine for carbon monoxide is shown in the graph in figure 5. Graphical representation is necessary here to illustrate the success of time series smoothing.

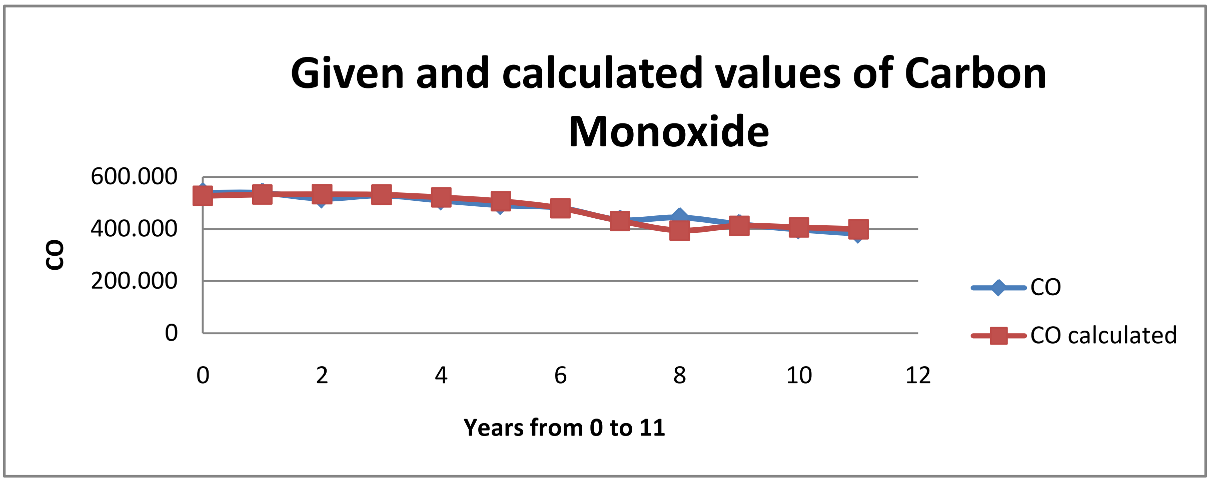


Figure 5: Given and calculated values of carbon monoxide

Source: own, [4]

3 Conclusion

As the graphs shown in Figures 2-5 shows the functional relationship between GDP and emissions produced is very tight. The functional relationship of the formula (15) can accurately calculate the pollutant amount matches the appropriate value of GDP. This demonstrates the relationship between GDP growth and the rate of pollution growth. The proven relationship is consistent with the theory of sustainability, which it supplements.

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