

**POLITECHNIKA WARSZAWSKA**

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**Management of the ecology  
of industry production in the  
mind of the circular economy**

### Hypotheses :

- **Hypothesis 1.** An increase in the level of economic development of countries is accompanied by a change in the level of air pollution and this change may have a certain lag period.
- **Hypothesis 2.** In the post-crisis period, in the countries with different rates of economic growth may observe different rates of air pollution reduction.

## Methods of circular economy :

**Stage 1.** Selection of the initial variables.

**Stage 2.** Verification of the first hypothesis based on the correlation-regression analysis methods

**Stage 3.** Verification of the second hypothesis on the basis of the correlation-regression and cluster analysis methods for the whole array of initial data and within the scope of separate groups of countries, which are similar according to the air pollution (PM 2,5 - mixture of solid and liquid particles) trend and GDP per capita dynamic.

### The global indices and variables



- growth rate of GDP per capita based on constant 2010 U.S. dollars
- GDP per capita growth rate was calculated as a percentage of GDP per capita in pre-crisis 2006

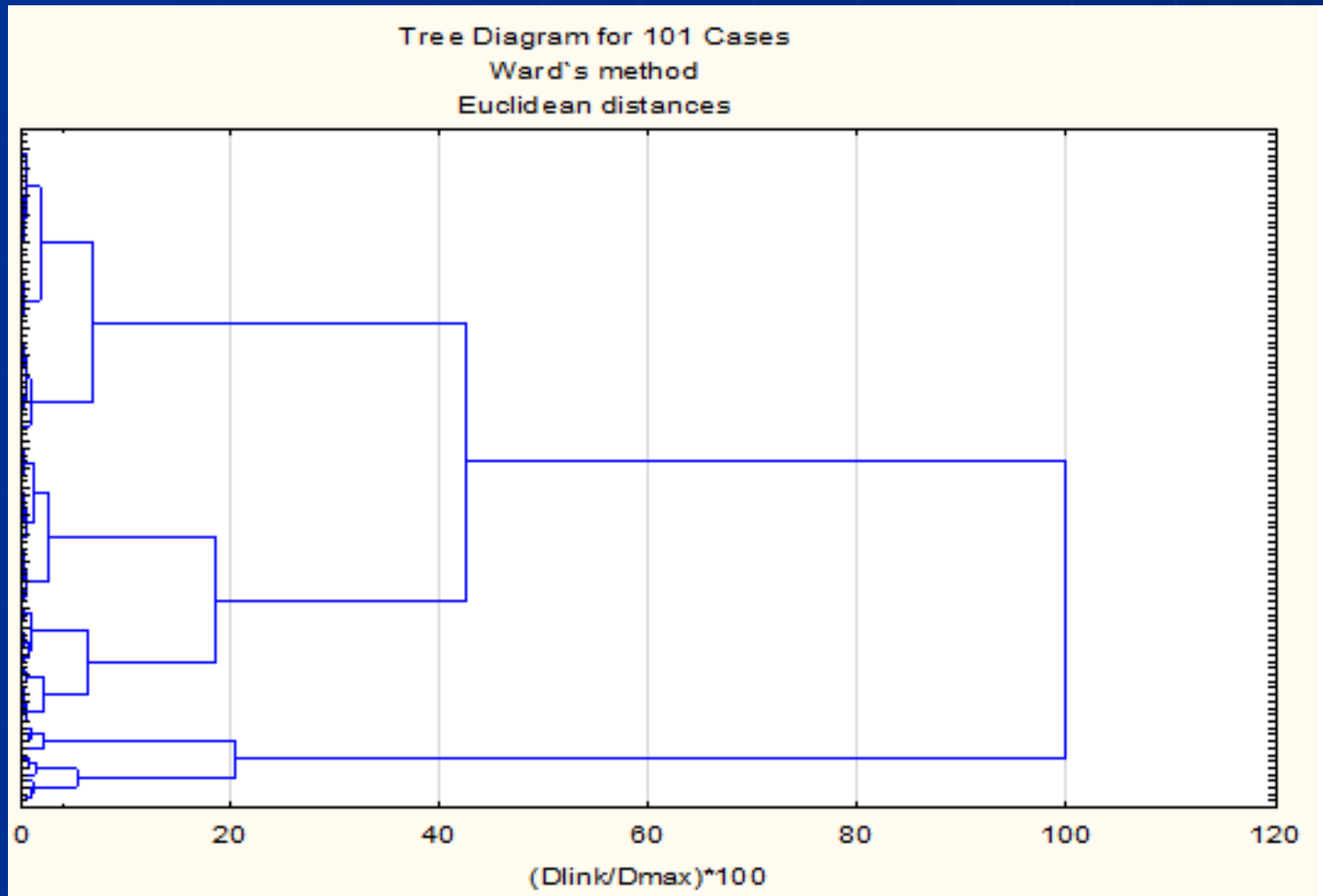


- percent of population living in places where mean annual concentrations of PM2.5 are greater than 25 micrograms per cubic meter
- It is more harmful to human health than other pollutants.

## Methods of circular economy:

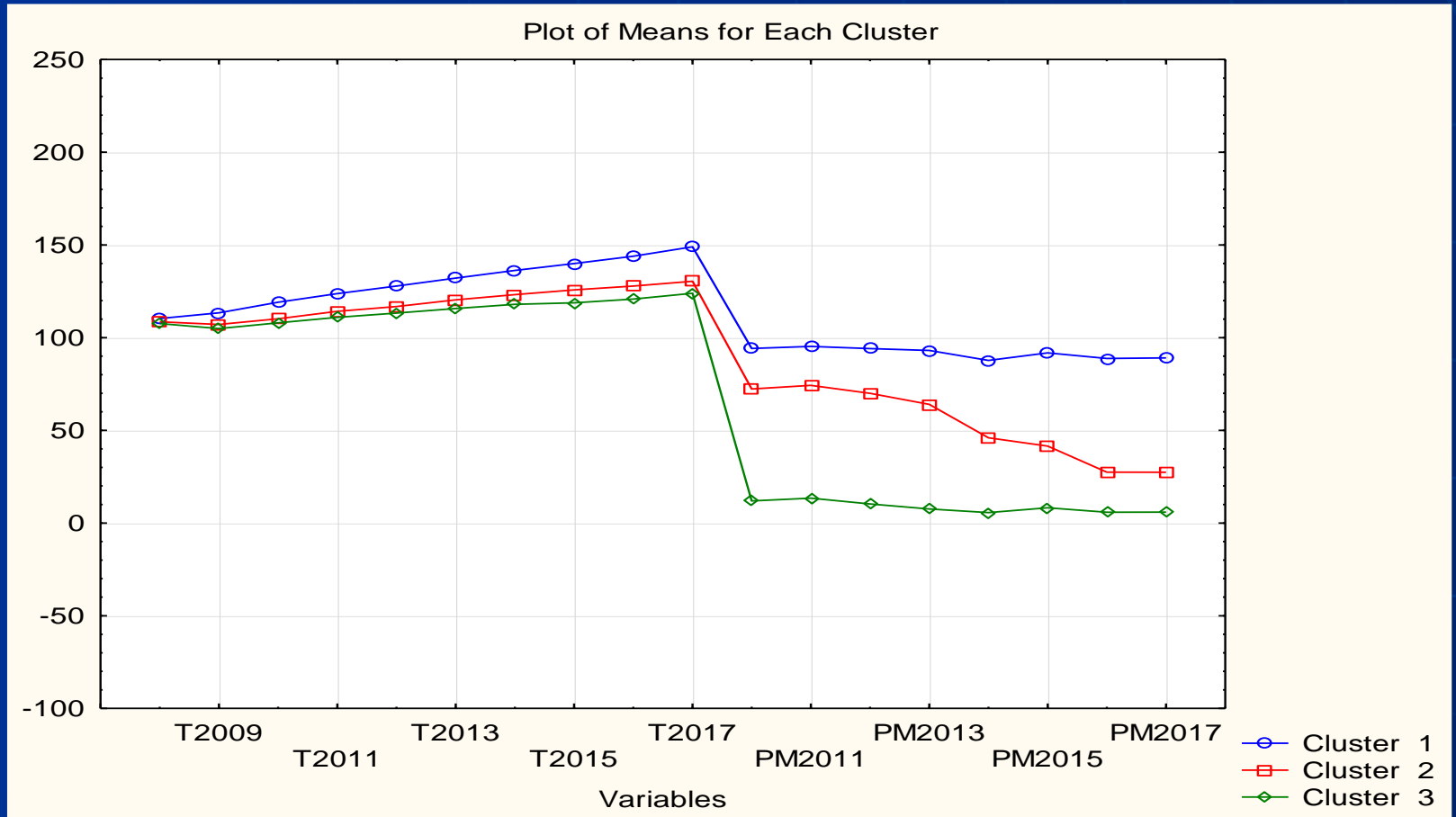
- The objects of research are 101 countries of the world.
- The variables are the data for 2008-2017.
- The countries without sufficient data were excluded from the database.
- The methods of multivariate statistical analysis.
- These statistical methods were implemented with the StatSoft's software package Statistica.

# Results of circular economy:



■ Tree Diagram

# Results of circular economy:



■ Plot of means for each cluster

# Results of circular economy:

## MEMBERS OF CLUSTER NUMBER 1

№	Country	Distance	Correlation coefficient between $PM_t$ and GDP per capita $t$		
			GDP per capita $t-2$	GDP per capita $t-1$	GDP per capita $t$
1	Afghanistan	16,86	-0,3125	-0,2071	-0,0803
2	Armenia	7,35	-0,7989	-0,8986	-0,8510
3	Benin	18,72	0,2707	-0,0357	-0,2179
4	Bhutan	22,92	-0,8710	-0,8773	-0,9479
5	China	42,53	-0,9543	-0,9517	-0,9545
6	Egypt, Arab Rep.	12,47			
7	Ghana	13,22	-0,9066	-0,6157	-0,5139
8	Guinea-Bissau	19,51	0,1586	0,1284	0,2704
9	India	11,28	-0,6252	0,2247	0,4126
10	Iran, Islamic Rep.	19,22	-0,9538	-0,9528	-0,9631
11	Jordan	27,19	0,3012	0,1873	0,1978
12	Cambodia	14,43	0,8483	0,8540	0,8541
13	Korea, Rep.	14,44	-0,9520	-0,9281	-0,9224
14	Lao PDR	25,22	-0,8677	-0,8567	-0,8969
15	Lebanon	16,11	-0,9755	-0,9761	-0,9745
16	Morocco	8,96	-0,4149	-0,9092	-0,9974
17	North Macedonia	11,84	0,7715	0,7263	0,7410
18	Mali	20,29		-0,8639	-0,8889
19	Myanmar	34,15	-0,9218	0,6752	0,5407
20	Mongolia	20,25	-0,8246	-0,8223	-0,8098
21	Nigeria	8,54	0,1655	0,1563	0,1904
22	Nepal	6,15	0,0475	-0,1112	-0,4699
23	Pakistan	18,37	-0,8054	-0,7124	-0,6665
24	West Bank and Gaza	4,62	-0,9191	-0,9521	-0,9828
25	Togo	14,51	-0,9148	-0,9380	-0,7728
26	Thailand	13,01	-0,0811	-0,0876	-0,0988
27	Tajikistan	7,47	-0,9272	-0,8614	-0,8959
28	Turkey	9,16	-0,7768	-0,7454	-0,7600
29	Uzbekistan	18,58	0,9470	0,9879	0,9866
30	Vietnam	10,88	-0,8605	-0,8766	-0,8779
31	Zambia	6,34	-0,9677	-0,9692	-0,9659
Number of maximum values			13	6	12

The first cluster includes 31 countries with the highest rates of economic growth. 61% of countries have a time lag between economic growth and air pollution (42% of countries have a lag of 2 years and 19% – equal to 1 year). Most countries in this cluster have negative correlation coefficients



# Results of circular economy:

## MEMBERS OF CLUSTER NUMBER 2

№	Country	Distance	Correlation coefficient between $PM_t$ and GDP per capita $t$		
			GDP per capita $t-2$	GDP per capita $t-1$	GDP per capita $t$
1	Bosnia and Herzegovina	14,94	-0,8990	-0,9300	-0,9350
2	Belize	23,17	0,1690	0,0570	0,1600
3	Bolivia	9,05	-0,9680	-0,9840	-0,9870
4	Barbados	26,19	0,5920	0,1280	-0,5770
5	Botswana	9,11	-0,7390	-0,7360	-0,7370
6	Chile	7,55	-0,9890	-0,9420	-0,8820
7	Cuba	16,47	-0,9620	-0,9770	-0,9400
8	Georgia	22,48	-0,9120	-0,9220	-0,9040
9	Grenada	20,35	-0,4400	-0,8710	-0,9650
10	Guatemala	15,22	-0,9550	-0,9580	-0,9430
11	Guyana	10,15	-0,9750	-0,9670	-0,9540
12	Honduras	11,82	-0,9260	-0,9080	-0,9070
13	Kenya	13,94	-0,3320	-0,3020	-0,3930
14	Kyrgyz Republic	12,68	-0,7780	-0,9160	-0,9080
15	St. Lucia	24,79	0,1270	0,2190	-0,0080
16	Sri Lanka	28,72	-0,8260	-0,8000	-0,8010
17	Mexico	16,20	-0,8940	-0,8790	-0,9330
18	Montenegro	14,90	-0,7210	-0,7570	-0,7680
19	Malawi	12,31	-0,6220	-0,6070	-0,7060
20	Namibia	15,45	-0,9290	-0,8220	-0,6220
21	Peru	16,46	-0,9930	-0,9630	-0,9490
22	Poland	15,54	-0,9630	-0,9420	-0,8940
23	El Salvador	17,05	-0,9450	-0,9000	-0,9000
24	Serbia	9,97	-0,8680	-0,9170	-0,9080
25	Suriname	14,68	-0,8110	-0,1520	0,5070
26	Turkmenistan	51,33	-0,8950	-0,8940	-0,8930
27	Trinidad and Tobago	19,41	-0,2050	0,2210	0,8150
28	Tanzania	12,75	-0,7300	-0,7070	-0,7210
29	St. Vincent and the Grenadines	23,38	0,0000	-0,6890	-0,9220
30	South Africa	15,41	-0,5400	-0,3890	0,0300
Number of maximum values			15	6	9

The second cluster includes 30 countries with an average GDP growth rates and average air pollution levels

## Results of circular economy:

### MEMBERS OF CLUSTER NUMBER 3

№	Country	Distance	Correlation coefficient between PM <sub>10</sub> and GDP per capita		
			GDP per capita <sup>2</sup>	GDP per capita <sup>1</sup>	GDP per capita <sup>7</sup>
1	Albania	14,0	-0,8337	-0,7651	-0,7297
2	Argentina	4,75	-0,5726	-0,2253	0,7217
3	Australia	7,43	-0,7659	-0,7156	-0,7112
4	Azerbaijan	25,5	-0,6200	-0,4511	-0,4788
5	Bulgaria	9,62	-0,8526	-0,8191	-0,7915
6	Belarus	16,2	-0,9467	-0,8406	-0,5404
7	Brazil	5,51	-0,8608	-0,5715	0,1513
8	Cote d'Ivoire	26,97	0,8705	0,8325	0,7898
9	Colombia	10,33	-0,9726	-0,9714	-0,9443
10	Cyprus	17,08	0,5107	0,4747	0,3337
11	Czech Republic	5,78	-0,4113	-0,7872	-0,7477
12	Germany	7,37	-0,2407	-0,7695	-0,7712
13	Ecuador	5,52	-0,9641	-0,9060	-0,7403
14	Spain	15,54	-0,6278	0,1472	0,6201
15	Guinea	21,17	0,6109	0,5360	0,5855
16	Greece	24,91	0,9426	0,8723	0,6632
17	Croatia	11,70	0,5557	-0,2813	-0,5878
18	Haiti	10,06	-0,0961	-0,7419	-0,3449
19	Hungary	10,64	-0,1798	-0,5763	-0,5606
20	Indonesia	15,44	-0,9716	-0,9665	-0,9609
21	Israel	11,11	-0,9249	-0,9503	-0,9499
22	Italy	17,48	0,6428	0,6146	0,5561
23	Jamaica	16,48	0,8142	0,3301	0,0300
24	Kazakhstan	9,85	-0,8421	-0,8148	-0,7934
25	Latvia	6,91	-0,7541	-0,8256	-0,8110
26	Madagascar	17,19	-0,2323	-0,4323	-0,7534
27	Mozambique	13,62	-0,8904	-0,8739	-0,8265
28	Malaysia	8,40	-0,8056	-0,7510	-0,7604
29	Nicaragua	7,35	-0,9694	-0,9222	-0,9012
30	Philippines	16,10	-0,9556	-0,9679	-0,9676
31	Romania	10,66	-0,2316	-0,5933	-0,6236
32	Russian Federation	3,57	-0,8456	-0,8218	-0,6559
33	Singapore	7,58	-0,2603	-0,4225	-0,4308
34	Sierra Leone	15,57	0,7677	0,5375	-0,2569
35	Slovak Republic	8,35	-0,7319	-0,8281	-0,7507
36	Slovenia	10,96	-0,1461	0,0169	-0,0534
37	Timor-Leste	23,49	-0,4291	-0,3666	-0,3854
38	Ukraine	13,71	-0,1772	-0,2337	0,3106
39	United States	11,12	-0,9240	-0,9643	-0,9606
40	Zimbabwe	12,79	-0,5953	-0,4746	-0,3164
Number of maximum values			25	8	7

The third cluster includes 40 countries with the slowest economic growth and the lowest air pollution .

## Conclusions :

- for most countries the lag in the impact of the economic growth dynamic on the level of air pollution is one-two year. The level of air pollution in 28% of countries changes simultaneously with changes in GDP per capita growth.
- in the post-crisis period, in the countries with high rates of economic growth observe a stable high level of pollution and a slow level of reduction of air pollution rates of air pollution reduction. In the group of countries with low rates of economic development, we also see a very slow decline in pollution. Countries with average GDP per capita growth have the greatest effect with a significant reduction in air pollution.
- ■ Some of the limitations of our research are related to insufficient of the database. Prospects for further studies are related to explore the issues of assessing the influence of pandemic COVID-19 on level of the different groups of countries pollution.

Thank you  
for attention!!!

Дякую  
за увагу !!!