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ENVIRONMENTAL POLICY STRINGENCY AND ITS IMPACT ON AIR POLLUTION IN POLAND

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ABSTRACT: The article aims to assess the level of severity of the environmental policy in Poland compared to the selected EU countries and the impact of this level on the SO_2, NO_X, VOCs, CO_2, and GHG emissions and premature mortality due to exposure to PM2.5. In the research based on OECD and Eurostat data, multiple regression analysis is used. The results of regression analysis do not allow for drawing unequivocal conclusions. The use of one of the selected measures of environmental policy stringency confirms the impact of this stringency on all the studied variables characterising air pollution. In contrast, in the other measure, this relationship was found only for two variables. The reason for different results may be the adoption of different research periods (1990-2012 and 1994-2018) due to the availability of data.

KEYWORDS: environmental policy, air pollution, environmental taxes, expenditures on environmental protection

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Introduction

The environmental policy pursued by individual countries is characterised by various types of instruments used and their motivational power, consisting of smaller or greater financial burdens for companies that damage the environment. The scope and scale of financial support for companies undertaking pro-environmental projects are also different. Different levels of stringency can therefore typify environmental policy. Environmental policy stringency can be defined as 'the strength of the environmental policy signal – the explicit or implicit cost of environmentally harmful behaviour, for example, pollution' (OECD, 2016, p. 3).

The more restrictive the environmental policy instruments that directly increase the costs of environmentally harmful behavior (such as emission standards or taxes), the more stringent environmental policy is. In the case of subsidy instruments (e.g., environmental R&D subsidies, feed-in tariffs for renewable energy) that reward environmentally-friendly behaviour, higher subsidies are interpreted as more stringent environmental policies because they increase the opportunity cost of pollution, thus giving an advantage to "cleaner" activities (Botta, Koźluk, 2014, p. 14).

Researchers in the field of economics are interested in analysing the impact of strict environmental policy on improving the quality of the environment, human health, changes in patterns of trade, foreign direct investment, economic growth, companies competitiveness, or new plant locations (Brunel, Levinson, 2013, p. 6; Jakubów, 2018, p. 10; Kulawik, 2016, p. 3). There is no generally accepted measure of environmental policy severity in the economic literature. Various methods of quantifying this severity are used in research practice what makes it difficult to draw clear conclusions about the effectiveness of environmental policy and its impact on the economy (Caspar, 2014, p. 1; Galeotti et al., 2020, p. 2; Lin et al., 2018, p. 483).

The article aims to assess the level of severity of the environmental policy in Poland compared to the selected EU countries and the impact of this level on sulphur dioxide (SO_2), nitrogen oxides (NO_X), volatile organic compounds (VOCs), carbon dioxide (CO_2), and greenhouse gases (GHG) emissions and premature mortality due to exposure to particulate matters less than 2.5 microns (PM2.5).

Measurement of environmental policy stringency

Assessment of various environmental policy contexts (including stringency) typically involves using a series of tests and analyses usually carried out for many years (Malik, 2012, p. 375). Measuring environmental policy stringency is a challenging task mainly due to the multi-dimensional nature of the policy manifested, among others, by the multitude of instruments used and their design and implementation features. Another problem is the difficulty in correctly assessing the extent to which the expected effects of stricter regulation (e.g. lower pollution level) can be attributed to the stringency of environmental policy and to which to other government economic policies or other country-related variables (OECD, 2016, p.12; Brunel, Levinson, 2013, p. 6-8).

In the literature, various, often overlapping, classifications of environmental policy severity measures are used. For example, Sauter distinguishes four groups of indicators of environmental policy stringency (Sauter, 2014, p. 2-3):

- survey indicators,
- monetary indicators,
- policy specific indicators, and
- performance indicators.

Survey indicators are based on the opinions and perceptions of different respondents (most often managers) regarding the severity of the applied environmental protection instruments in a given state. The main disadvantage of these measures is the subjectivity of the respondents. An example of a measure based on surveys is the indicator of environmental regulatory stringency developed by the World Economic Forum, obtained from Executive Opinion Survey responses.

Monetary indicators may include, e.g. public expenditures for environmental protection, pollution abatement costs, capital expenditures and operating costs in environmental protection activities. Sauter (2014, p. 2) points to companies' difficulties in isolating the costs of pollution abatement from the total costs and the tendency of companies to overstate them as a limitation of the use of these indicators in the assessment of environmental policy strictness.

Policy specific indicators are based on the presence of a particular environmental regulation, the number of adopted or abolished instruments of environmental policy, changes in strictness of regulations or the target group of environmental instruments (Knill et al., 2012, p. 430). Policy specific indicators may refer to the ratification of international treaties in environmental politics, i.e. the severity of a country's environmental policy is determined by the timing or ratification of a specific international agreement on environmental protection (Sauter, 2014, p. 3).

Performance indicators are based on emission, energy consumption or, more generally, environmental performance data. As Sauter (2014, p. 3), rightly points out, by construction these indicators 'quantify the problem environmental policies try to solve and not the stringency of the policies themselves'.

According to Galeotti et al. (2020, p. 2-3) indicators of environmental policy stringency proposed and applied in the literature can be divided into four main categories:

- variables measuring pollution abatement efforts,
- direct assessments of regulations,
- measures based on ambient pollution, emissions, or energy use, and
- composite indexes.

Indicators relating to abatement efforts include measures of both private and public efforts to control pollution. The latter examples are governmental environmental R&D expenditures, revenues from environmental taxes and the implicit tax rate on energy. These indicators measure the commitment of governments to spend public money to support pollution or emissions control. Galeotti et al. (2020, p. 2) notice that private and public types of proxies of environmental policy stringency are generally characterised by very poor country coverage in terms of data availability.

Direct assessments of regulations at the sector or country level are difficult due to multidimensionality and simultaneity of adopted (abolished) environmental policy instruments. Examples of these indicators include using the lead content of gasoline or standardised air quality limits as the measure for overall environmental regulatory severity. Measures based on ambient pollution, emissions, or energy use include information on the level of (or the change in) emissions and energy use at the country or sector level, totally or per capita. Galeotii et al. (2020, p. 3) rightly point out that these indicators can differ across countries for many reasons other than environmental policy stringency, such as, e.g. differences in industrial composition and in the degree of trade openness or changes in factor prices. Composite indexes may be constructed simply from counts of regulations, non-governmental environmental organisations, international treaties signed or based on statistical aggregation techniques using a set of environmental policy indicators.

Another classification of environmental policy stringency indicators can be found in the OECD study (OECD, 2016, p. 10-11), where the following measures are identified:

- measures related to environmental policy instruments, including indicators of the existence of single policies, their levels (e.g. tax rates) or changes as well as composite measures that aggregate selected information on individual instruments,
- measures attempting to capture perceptions of the stringency of environmental policies, based on dedicated survey questionnaires,

- measures relating to changes in agents' behaviour, especially consequences of environmental regulations such as firms' costs, actions and production choices,
- measures relating to changes in environmental outcomes, i.e. the variation in the environmental performance of firms, sectors or countries.

The OECD classification is similar to that given by Sauter (presented above).

Increasingly, in empirical research in the field of economics (e.g. Albrizio et al., 2017; De Santis et al., 2021; Sadik-Zada, Ferrari, 2020; Sterlacchini, 2020; Wang et al., 2019), the composite EPS index (environmental policy stringency index – EPSI) developed by the OECD is used as a measure of the severity of environmental policy. The EPSI is derived by aggregating information on selected environmental policy instruments, primarily related to climate and air pollution. The environmental policy instruments included in the EPSI are divided into:

- market-based instruments (environmental taxes, trading schemes, and feed-in tariffs in renewable energy sources),
- non-market-based instruments (emission standards and renewable energy subsidies).

The EPSI is the arithmetic mean of sub-indices calculated for market and non-market instruments (the market EPSI and the non-market EPSI, respectively). The instruments are scored on a 0-6 scale increasing in stringency. The country scores are then aggregated by instrument type (taxes, trading schemes, emission standards and others), instrument category (market-based and non-market-based) and further on using equal weights at each stage (OECD, 2016, p. 2 and 5). A detailed description of the calculation of the EPSI can be found in the study by Botta and Koźluk (2014).

Research methods

The following measures were selected to assess the level of environmental policy stringency in Poland:

- the OECD EPS index (retrieved from OECD database),
- the share of environmental taxes in the gross domestic product (GDP) (retrieved from OECD database),
- the share of national environmental protection expenditure in GDP (retrieved from Eurostat database).

The OECD database on the EPS index in the UE countries contains data on 19 of them (including also the United Kingdom, which left the EU in 2020). Among these countries, Slovenia was excluded from the analysis due to the too short time series of available data, covering only 2008-2012. The final sample included the following 18 EU states: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Slovak Republic, Spain, Sweden and the UK (hereinafter referred to as 'the EU-18'). The same sample was used in the analysis, taking into account the other two environmental policy stringency measures. The EPS index's available data cover the years 1990-2012 for most countries, and for some countries also the years 2013-2015.

Multiple linear regression was used to analyse the impact of environmental policy stringency on air pollution in Poland. The following were assumed as dependent variables:

- SO_2 emissions (in thous. tonnes),
- NO_x emissions (in thous. tonnes),
- CO_2 emissions (in mln tonnes),
- GHG emissions (in thous. tonnes CO_2 equivalent),
- VOCs emissions (in thous. tonnes),
- mortality due to PM2.5 (per 1 mln inhabitants).

Renewable energy production (REP), expressed in thousand toes, was selected as the control variable. Data on dependent variables and renewable energy production were retrieved from OECD database.

A total of 24 multiple regression models were used in the analysis of the role of environmental policy severity for air pollution, i.e. six each for four independent variables:

- the EPS index (EPSI),
- the market EPS index (MAR_EPSI),
- the non-market EPS index (NMAR_EPSI),
- the share of environmental taxes in GDP (ET).

Due to the availability of data on both independent and dependent variables, the models used include a different analysis period:

- 1990-2012 in models with the variables EPSI, MAR_EPSI and NMAR_EPSI,
- 1994-2018 in models with the variable ET.

Incomplete data on national environmental expenditure made it impossible to use them in regression analysis (table 4).

Results of the research

The level of environmental policy stringency for Poland and the EU-18 in the years 1990-2012, measured using the OECD index, is presented in table 1. The value of Poland's environmental policy stringency index in the analysed period increased from 0.65 to 2.58. There was also an upward trend in all other EU-18 countries. Figure 1 shows the development of the EPSI in Poland and, for example, in Denmark, Finland, France and the UK (for the last two countries, the available OECD data cover the period 1990-2015). In the EU-18 countries, the average EPSI value, amounting to 0.82 in 1990, increased over 23 years to 2.84.

Table 1. Environmental policy stringency index

Year	Poland	EU-18			
		Mean	Standard deviation	Minimum	Maximum
1990	0.65	0.82	0.31	0.35	1.67
1991	0.79	0.94	0.44	0.48	2.13
1992	0.83	1.06	0.48	0.52	2.13
1993	0.88	1.10	0.47	0.52	2.23
1994	0.88	1.14	0.48	0.52	2.23
1995	0.88	1.16	0.48	0.52	1.98
1996	0.88	1.20	0.47	0.52	1.98
1997	0.88	1.23	0.50	0.52	1.98
1998	0.92	1.30	0.56	0.56	2.56
1999	0.92	1.30	0.56	0.52	2.40
2000	0.92	1.43	0.56	0.83	2.60
2001	1.19	1.55	0.54	0.81	2.74
2002	1.19	1.70	0.51	0.85	2.58
2003	1.19	1.87	0.49	1.10	2.54
2004	1.27	2.03	0.52	1.10	2.75
2005	2.13	2.48	0.43	1.78	3.13
2006	2.26	2.66	0.44	1.78	3.28
2007	2.08	2.35	0.42	1.40	2.86
2008	2.26	2.55	0.45	1.53	3.23
2009	2.96	2.94	0.55	2.08	4.07
2010	2.96	2.99	0.54	2.22	4.13
2011	2.96	2.99	0.51	2.27	3.98
2012	2.58	2.84	0.56	2.05	3.85

Source: author's work based on https://stats.oecd.org/viewhtml.aspx?datasetcode=EPS&lang=en [08-01-2021].

In the analysed years 1990-2012, a decrease in the diversity of states' sample in terms of environmental policy stringency can be observed. This is evidenced by the variation coefficients (the ratio of standard deviation to the mean) indicating initially (until 2005) the average variability of this feature's stringency and low variability.

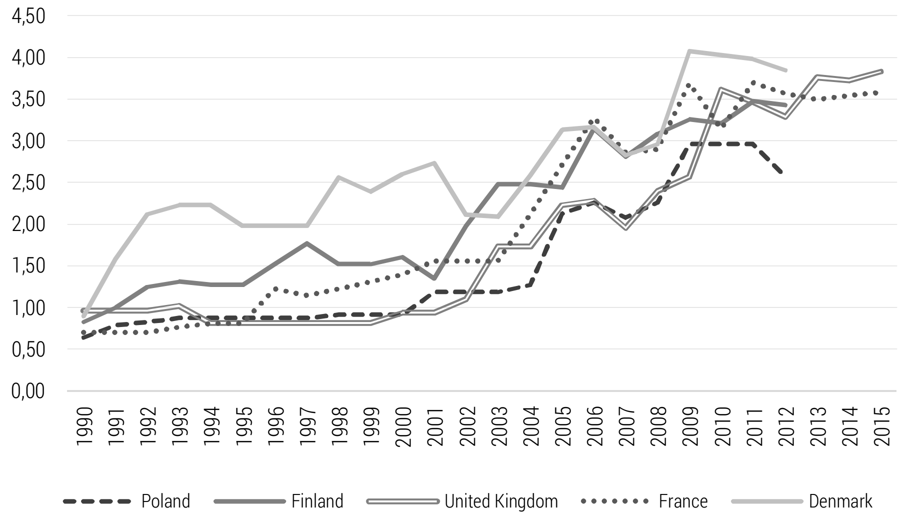

Figure 1. Environmental policy stringency index in Denmark, Finland, France, Poland and the UK

Source: https://stats.oecd.org/viewhtml.aspx?datasetcode=EPS&lang=en [08-01-2021].

According to the EPSI, Denmark can be regarded as the country with the highest environmental policy stringency level. In this country, the difference between this indicator's level at the beginning and at the end of the analysed period is 2.95 (the highest value among the EU-18). Moreover, in terms of the average EPSI level in 1990-2012 (2.61), Denmark is in the first place. Besides in the years 1992-2001, 2005, 2009, and 2011-2012, the maximum values of EPSI in the analysed sample occurred in Denmark. The loosest environmental policy was pursued by Ireland and the Slovak Republic (the average value of the EPSI is 1.24 and 1.25 respectively).

Except for 2009, Poland's level of environmental policy stringency has always been below the EU-18 average. A noticeable increase in this stringency can be noticed after Poland joined the EU.

The stringency level in the analysed European countries is usually lower for market instruments than for non-market environmental policy instruments (table 2). Only for three years (1990, 2008 and 2011), the value of market EPSI of the Polish environmental policy instruments was slightly above the EU-18 average. In the case of non-market instruments, except for 2009-2010, their severity in Poland was lower than the average level in the analysed sample.

Table 2. Market and non-market environmental policy stringency indices

Year	Market EPSI					Non-market EPSI				
	Poland	EU-18				Poland	EU-18			
		Mean	Standard deviation	Min	Max		Mean	Standard deviation	Min	Max
1990	0.42	0.38	0.21	0.08	1.08	0.88	1.26	0.64	0.50	3.00
1991	0.33	0.49	0.37	0.17	1.75	1.25	1.39	0.76	0.50	3.00
1992	0.42	0.62	0.33	0.33	1.33	1.25	1.50	0.77	0.50	3.00
1993	0.50	0.63	0.34	0.33	1.33	1.25	1.56	0.74	0.50	3.13
1994	0.50	0.79	0.47	0.33	1.83	1.25	1.48	0.72	0.50	3.13
1995	0.50	0.84	0.45	0.42	1.83	1.25	1.47	0.63	0.63	2.63
1996	0.50	0.88	0.48	0.33	1.75	1.25	1.52	0.65	0.63	2.63
1997	0.50	0.88	0.50	0.33	1.75	1.25	1.58	0.74	0.63	3.13
1998	0.58	1.02	0.58	0.42	2.00	1.25	1.58	0.74	0.63	3.13
1999	0.58	1.05	0.68	0.42	2.50	1.25	1.55	0.69	0.63	2.63
2000	0.58	1.03	0.70	0.33	2.42	1.25	1.83	0.70	1.00	3.13
2001	1.00	1.20	0.73	0.25	2.60	1.38	1.90	0.68	1.00	3.13
2002	1.00	1.26	0.68	0.33	2.50	1.38	2.15	0.84	1.38	4.00
2003	1.00	1.28	0.59	0.33	2.50	1.38	2.46	0.84	1.38	4.63
2004	1.17	1.30	0.59	0.33	2.50	1.38	2.76	0.89	1.38	4.63
2005	1.63	1.95	0.59	1.05	2.80	2.63	3.00	0.63	2.00	4.63
2006	1.90	2.12	0.70	1.05	3.43	2.63	3.20	0.76	2.00	5.25
2007	1.53	1.59	0.64	0.38	2.60	2.63	3.12	0.87	1.63	5.25
2008	1.90	1.81	0.54	0.92	2.67	2.63	3.28	0.85	1.63	5.25
2009	2.17	2.19	0.57	1.07	3.13	3.75	3.69	0.92	1.75	5.38
2010	2.17	2.29	0.67	1.05	3.98	3.75	3.69	0.94	2.25	5.50
2011	2.17	2.14	0.59	1.12	3.68	3.75	3.84	0.84	2.25	5.38
2012	1.90	1.92	0.57	0.85	3.33	3.25	3.76	0.93	2.25	5.38

Source: author's work based on https://stats.oecd.org/viewhtml.aspx?datasetcode=EPS&lang=en [08-01-2021].

Table 3. Evironmental taxes as a percentage of gross domestic product

Year	Poland	EU-18			
		Mean	Standard deviation	Minimum	Maximum
1994	1.90	2.77	0.57	1.86	4.06
1995	1.73	2.76	0.62	1.73	4.34
1996	1.88	2.83	0.65	1.88	4.57
1997	1.82	2.79	0.66	1.82	4.60
1998	1.84	2.85	0.78	1.84	5.28
1999	2.11	2.88	0.77	2.06	5.37
2000	2.13	2.73	0.67	2.12	5.00
2001	2.10	2.67	0.66	2.01	4.91
2002	2.31	2.72	0.68	2.09	5.10
2003	2.41	2.74	0.63	2.11	4.88
2004	2.57	2.78	0.67	2.08	5.09
2005	2.54	2.75	0.69	2.03	5.07
2006	2.51	2.68	0.68	1.95	4.81
2007	2.60	2.61	0.67	1.90	4.85
2008	2.49	2.52	0.60	1.76	4.32
2009	2.37	2.54	0.54	1.73	4.08
2010	2.39	2.57	0.55	1.76	4.12
2011	2.35	2.60	0.57	1.71	4.14
2012	2.47	2.61	0.61	1.73	4.04
2013	2.33	2.63	0.61	1.97	4.05
2014	2.43	2.60	0.65	1.88	4.02
2015	2.46	2.59	0.66	1.92	3.99
2016	2.53	2.62	0.66	1.86	3.91
2017	2.39	2.56	0.68	1.63	4.04
2018	2.49	2.44	0.84	0.24	3.79

Source: author's work based on https://data.oecd.org/envpolicy/environmental-tax.htm [08-01-2021].

Regarding another measure of the environmental policy stringency, i.e. the share of environmental taxes in GDP, calculated for the years 1994-2018, it should be noted that the EU-18 differentiation in this respect was usually small in that period. The largest share of environmental taxes in GDP was recorded in Denmark (the first place in 1994-2016, the second place in 2017-

2018, behind Greece). At the other extreme, there was Spain, where environmental taxes accounted for the lowest average share of GDP in the EU-18. Moreover, in Spain, there was a minimal size of this share in the analysed EU-18 in 2000-2003 and 2005-2014. Excluding the last year of the analysed period 1994-2018, Poland was always below the EU-18 average (table 3). In the years 1995-1998, Poland was even in the last place among the analysed countries regarding the importance of environmental taxes for GDP. It can be seen that the share of environmental taxes in Poland's GDP was gradually approaching the EU-18 average.

Table 4. National expenditure on environmental protection as a percentage of gross domestic product

States	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Belgium	n/a	n/a	n/a	n/a	n/a	n/a	3.3	3.1	3.1	3.2	n/a
Czech Republic	n/a	n/a	n/a	n/a	n/a	n/a	2.8	2.7	2.7	2.6	n/a
Denmark	2.1	2.2	2.2	2.2	2.2	2.2	2.0	2.2	2.1	2.1	n/a
Germany	n/a	n/a	2.0	2.0	2.1	2.1	2.2	2.1	2.1	2.2	n/a
Ireland	1.6	1.6	1.4	1.3	1.2	1.1	0.9	n/a	0.6	n/a	n/a
Greece	n/a	n/a	n/a	n/a	n/a	n/a	1.4	1.4	1.3	1.3	n/a
Spain	n/a	n/a	1.7	1.7	1.6	1.6	1.6	1.6	1.5	1.5	1.6
France	1.9	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	n/a
Italy	1.7	1.8	1.8	1.7	1.8	1.7	1.6	1.7	1.8	1.7	n/a
Hungary	n/a	n/a	n/a	n/a	n/a	n/a	2.3	2.5	1.8	1.9	n/a
Netherlands	n/a	n/a	n/a	n/a	n/a	2.6	2.7	2.7	2.5	2.5	n/a
Austria	n/a	n/a	n/a	n/a	n/a	n/a	3.1	3.0	3.2	3.2	n/a
Poland	n/a	n/a	1.8	1.8	1.9	1.7	1.8	1.9	2.0	1.9	n/a
Portugal	n/a	n/a	n/a	n/a	n/a	n/a	1.4	1.4	1.2	1.4	n/a
Slovak Republic	1.8	2.3	2.2	1.9	2.0	1.9	1.9	2.3	1.9	1.9	n/a
Finland	n/a	n/a	n/a	n/a	n/a	n/a	1.7	1.8	1.8	1.7	n/a
Sweden	1.7	1.9	1.8	1.9	1.9	1.8	1.8	1.8	1.9	1.8	n/a
United Kingdom	n/a	n/a	1.2	1.2	1.2	1.3	1.3	1.4	1.3	1.3	n/a

Source: https://ec.europa.eu/eurostat/databrowser/view/ten00135/default/map?lang=en [18-02-2021].

Table 4 presents the available Eurostat data on environmental protection expenditure in the EU-18. Much data are missing, which prevents a more in-depth analysis. However, it may be noticed that similarly as in the case of the two other measures discussed above, it is possible to identify countries with both a higher (e.g. Austria, Belgium, Czech Republic, Netherlands) and a lower (Ireland, Portugal, the UK) stringency level than Poland.

Pearson's linear correlation coefficient for two measures of environmental policy severity (the EPSI and ET), calculated for the available data, i.e. 1994-2012, is 0.6875 and statistically significant at the significance level of 0.001. The value of the coefficient indicates a high correlation between the EPSI and ET.

Tables 5-8 show the results of multiple regression for models 1-24. Model 5 and 17 concerning the dependence of VOCs emissions on the EPSI and market EPSI, respectively, and renewable energy production, turned out to be insignificant at the significance level of 0.05. The environmental policy stringency measured with the EPSI has a statistically significant impact (at the level of 0.05) only on the SO_2 emissions in Poland (model 1). Considering the strictness of market-based environmental instruments only (market EPSI), it can be concluded that this variable is a determinant of SO_2 emissions and mortality due to PM2.5 (models 7 and 12, a 0.01 and 0.05 significance level, respectively). The stringency of non-market environmental instruments expressed by the non-market EPSI does not influence air pollutants emissions and mortality due to PM2.5.

According to the results of regression models, including the share of environmental taxes in GDP as a measure of the strictness of the state's environmental policy (models 19-24), the more severe the environmental policy, the lower the emission of SO_2, $NO_{x,}$ CO_2, GHG, VOCs, and mortality due to PM2.5 in Poland (at the significance level of 0.01).

Table 5. Regression results for models 1-6

Specification	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Dependent variable	SO_2 emissions	NO_x emissions	CO_2 emissions	GHG emissions	VOCs emissions	Mortality due to PM2.5
Multiple R	0.8670	0.6137	0.5476	0.5622	0.4725	0.7341
R-squared	0.7517	0.3766	0.2999	0.3161	0.2233	0.5389
Adjusted R-squared	0.7269	0.3143	0.2299	0.2477	0.1457	0.4928
Standard error	315.38	81.01	18.98	22655.79	50.74	66.75
Observations	23	23	23	23	23	23
P-value for F-test	0.0000	0.0088	0.0283	0.0224	0.0798	0.0004
Coefficients						
Const	2684.3***	1071.6***	340,4***	458109.9***	892.3***	1032.6***
EPSI	-332.09**	-24.44	-5,32	-3456.81	-35.96	-36.77
REP	-0.15**	-0.02	-0,0044	-6.7745	0.0021	-0.0231

Source: author's work based on OECD data (https://data.oecd.org/air/air-and-ghg-emissions.htm, https://stats.oecd.org/viewhtml.aspx?datasetcode=EPS&lang=en, https://data.oecd.org/air/air-pollution-effects.htm, https://data.oecd.org/energy/renewable-energy.htm [08-01-2021]).

Table 6. Regression results for models 7-12

Specification	**Model 7**	**Model 8**	**Model 9**	**Model 10**	**Model 11**	**Model 12**
Dependent variable	SO_2 emissions	NO_x emissions	CO_2 emissions	GHG emissions	VOCs emissions	Mortality due to PM2.5
Multiple R	0.9012	0.6704	0.6069	0.6004	0.5512	0.7929
R-squared	0.8123	0.4494	0.3683	0.3604	0.3039	0.6287
Adjusted R-squared	0.7935	0.3944	0.3051	0.2965	0.2342	0.5915
Standard error	274.27	76.14	18.03	21908,94	48.04	59.89
Observations	23	23	23	23	23	23
P-value for F-test	0.0000	0.0025	0.0101	0.0114	0.0267	0.0000
Coefficients						
const	2585.9***	1053.9***	336.6***	454280.6***	881.9***	1014.3***
MAR_EPSI	-0.1064***	-0.0088	-0.0013	-3.2969	0.0068**	-0.0100**
REP	-554.5154*	-76.7631*	-16.4895	-15404.8	-59.0832	-86.9772

Source: author's work based on OECD data (the same as indicated in table 5).

Table 7. Regression results for models 13-18

Specification	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18
Dependent variable	SO_2 emissions	NO_x emissions	CO_2 emissions	GHG emissions	VOCs emissions	Mortality due to PM2.5
Multiple R	0.8468	0.6053	0.5383	0.5629	0.4193	0.7154
R-squared	0.7171	0.3664	0.2897	0.3168	0.1758	0.5119
Adjusted R-squared	0.6888	0.3030	0.2187	0.2485	0.0934	0.4631
Standard error	336.68	81.68	19.12	22642.80	52.27	68.67
Observations	23	23	23	23	23	23
P-value for F-test	0.0000	0.0104	0.0326	0.0221	0.1446	0.0008
Coefficients						
const	2732.7***	1076.8***	341.5***	459050.4***	897.5***	1039.2***
NMAR_EPSI	-165.079	6.071	1.201	3164.113	-18.367	-5.313
REP	-0.205**	-0.036*	-0.007	-9.524*	-0.003	-0.035**

Source: author's work based on OECD data (the same as indicated in table 5).

Table 8. Regression results for models 19-24

Specification	Model 19	Model 20	Model 21	Model 22	Model 23	Model 24
Dependent variable	SO_2 emissions	NO_x emissions	CO_2 emissions	GHG emissions	VOCs emissions	Mortality due to PM2.5
Multiple R	0.9581	0.8234	0.6707	0.6414	0.8469	0.9172
R-squared	0.9180	0.6780	0.4498	0.4114	0.7173	0.8412
Adjusted R-squared	0.9106	0.6488	0.3998	0.3579	0.6916	0.8268
Standard error	155.17	58.24	13.83	15925.18	39.17	35.95
Observations	25	25	25	25	25	25
P-value for F-test	0.0000	0.0000	0.0014	0.0029	0.0000	0.0000
Coefficients						
const	4346.7***	1420.8***	404.5***	519736.5***	1180.3***	1364.6***
ET	-1057.48***	-193.39***	-43.01***	-46116.90***	-113.61***	-195.15***
REP	-0.1334***	-0.0189***	-0.0004	-0.3997	-0.0176***	-0.0178***

Source: author's work based on OECD data (https://data.oecd.org/envpolicy/environmental-tax.htm, https://data.oecd.org/air/air-and-ghg-emissions.htm, https://data.oecd.org/air/air-pollution-effects.htm, https://data.oecd.org/energy/renewable-energy.htm [08-01-2021]).

Conclusions

The conducted analysis of the stringency of the Polish environmental policy on the basis of three selected measures (the EPS index developed by the OECD, the share of environmental taxes in GDP, and the share of national environmental protection expenditure in GDP) allows for the conclusion that, compared to other European Union countries, Poland is a country with a moderate level of environmental policy severity. Except for individual years, the ESP index and the share of environmental taxes in GDP for Poland was lower than the EU-18 average. In the case of the third measure, i.e. the share of national environmental protection expenditure in GDP, although many missing data made it pointless to calculate the mean for the research sample, it is possible to identify countries with both a higher and lower share of environmental expenditure in GDP than Poland. Considering the EPS index, the level of environmental policy stringency in Poland was systematically increasing in the analysed period 1990-2012. This upward trend also occurred in all other analysed EU-18 countries. In the case of the share of environmental taxes in GDP, this indicator's values in 1994-2018 were not subject to clear trends in the EU-18. As for Poland, lower values of this share can be observed at the beginning of the analysed period.

The regression analysis of the dependence of selected variables characterising air pollution in Poland on the level of environmental policy stringency does not allow for drawing unequivocal conclusions. Using the share of environmental taxes in GDP as a measure of this severity, the results of the regression analysis show that the stringency of the environmental policy in Poland has a significant impact on reducing SO_2, NO_x, CO_2, GHG, VOCs emissions and mortality due to PM 2.5. However, in the case of the second measure of environmental policy stringency (EPSI), this relationship was found only for SO_2 emissions (using the total EPSI – taking into account the entire environmental policy) and for SO_2 emissions and mortality due to PM2.5 (using the index taking into account only market-based environmental policy instruments). The results may have been influenced by different analysis periods (1990-2012 vs 1994-2018) due to data availability.

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