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Environmental Taxes in the Member States of the European Union—Trends in Energy Taxes

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Abstract: Environmental taxes, including energy taxes, are applied in all EU Member States. They are considered important instruments in the implementation of the EU energy and climate policies. The main purpose of the research presented in this article is to identify trends in the EU Member States in shaping environmental tax revenues, with particular emphasis on their most important group, i.e., energy taxes. The researchers sought answers to the research question regarding the existence of converging trends in this respect. The "letter values" method was used in the research procedure, which is an extension of the box-plots method. The analysis covered 27 EU Member States. The data used in the research came from the Eurostat database (2009–2020). As a result of the research, it was found that in the EU as a whole, there is a slight downward trend in the share of environmental tax revenues in GDP and the share of environmental tax revenues in total tax revenues, while the share of energy tax revenues in total environmental tax revenues shows a slight upward trend. The decomposition of the research and the conducted comparative analysis, including the determination of specific rankings, showed that both the level and trends in the shaping of the studied variables vary considerably in the individual EU Member States.

Keywords: environmental taxes; energy taxes; tax revenue; letter values

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1. Introduction

Public debate on environmental protection often focuses on the costs associated with measures taken to limit the negative impact of individuals on the environment [1] (pp. 2–3). Even though sustainable development is essential to maintain and improve the quality of life and, in the long run, should lead to limiting the destructive impact of humans on the environment, there is a difference of views on the mechanisms and methods that can be used in this area and the concern about high investment financial means allocated to specific projects [2] (p. 4). The equilibrium between the development in the economic, social, and environmental dimensions, ensured only by the market mechanism, is not possible; hence, the active role of the state in this respect is justified. Fiscal policy plays an important role in the pursuit of sustainable development, especially in the appropriate shaping of income and expenditure instruments. The tax policy pursued in the European Union countries should be highlighted, as it indicates that taxes are effective in supporting sustainable development and a type of self-financing instrument of environmental protection [3] (p. 1). The application of tax mechanisms to protect the environment is also recommended by the OECD by introducing new taxes, restructuring existing ones, or reforming legislation and removing subsidies for environmentally harmful activities [4] (p. 8). Focusing on the pro-environmental goals, it should be noted that their implementation is possible mainly due to the adoption of sustainable taxes [5]. The collected and classified resources from environmental taxes can be used for various purposes. First, they contribute to the increase in budget revenues and, thus, allow the debt to be repaid and the budget deficit to be reduced. Second, these funds may be allocated to tasks related to environmental protection [6] (p. 109), [7] (p. 426).

The concept of environmental taxes was first introduced into the literature by the English economist Pigou in 1920 [8] (p. 93). He made a distinction between the social costs of economic activity and the individual costs of the firm, recorded in the profit and loss account. Pigou noted that the actual social costs of economic activity significantly exceed the cost of production expressed in monetary units [9]. This dependence concerns the creation of external effects of economic activity, such as noise, water, air pollution, etc. These effects were treated by Pigou as the cost of using the "environment" factor by the producer. The resulting cost is usually not included in the firm's account but is passed on to the consumer community—it is subject to the so-called externalization. Externalities reduce the use value of the environment and, thus, limit the possibility for consumers to take advantage of the potential welfare. According to Pigou, the task of the tax is to internalize external costs, that is, assign them to the specific producer that generates them. The tax levied should be equal to the environmental costs of the producer in question. Full internalization would contribute to the fact that a firm's costs would be equated with the social costs of production and would be entirely charged to the account of the direct perpetrator of the cost [10] (pp. 27–28). As stated by Pigou, the tax should play the role of steering consumer demand and shifting their demand from non-organic to organic products. The production of pollution should be accompanied by an assigned price leading to the state of equilibrium if the costs for the environment would be covered by tax revenues [11] (p. 116). The presented solution contributes to limiting the negative impact of external effects on the natural environment [12] (p. 204).

Unfortunately, an attempt to directly implement the tax proposed by Pigou into the tax system encounters very serious problems, related, among others, to difficulties in determining the correct assessment of tax. This is due mainly to technical limitations that make it impossible to accurately estimate external costs, especially expressed in monetary units. In practice, the amount of taxes corresponding to the Pigou concept is sometimes determined by the method of trial and error to find the optimal solution for society [13] (p. 96). Direct application of the tax proposed by Pigou is practically impossible, but it pioneered the trend of creating taxes related to the environment and transferred them to practical grounds.

The studies by international institutions and the available databases, including Eurostat and OECD, frequently use the phrase "environmentally related taxes" concerning taxes that are most often referred to in the literature as ecological. This is the result of some considerations and modifications in the interpretation of these pro-ecological financial instruments. Taxes associated with the environment include all financial burdens related to the environment, borne by households, business entities, and other organizations [14] (p. 2). As defined by the ESA, these taxes are also considered compulsory and unrequited financial charges, whether in cash or in kind, imposed by the general government or certain European Union institutions. In the case of environmental taxes, the tax base is the physical unit of the object or service that has a proven negative impact on the natural environment [15] (p. 9). This can be, for example, the emission of a kilogram of sulfur dioxide into the air, the consumption of a cubic meter of surface water, or a plastic shopping bag.

The cited definitions of the environmental tax are considered binding for the European Union Member States in the reporting obligations for Eurostat under Art. 3 of the Regulation of the European Parliament and of the Council on European environmental economic accounts [16], which imposes on the Member States the obligation to prepare environmental tax accounts and submit reporting data to the European Commission (and consequently to the Eurostat database) [17] (pp. 58–59).

Environmental taxes are considered to be key instruments in the implementation of the EU's energy and climate policy. They are applicable in all EU Member States. Environmental taxes are essential for carrying out the idea of sustainable development [3] (pp. 25–26). By extension, they allow for the collection of funds, encourage activities for environmental protection, and discourage environmentally harmful activities [18] (p. 157). Environmental taxes are introduced in furtherance of ecological plans while meeting the state's fiscal needs is secondary in the case of this type of taxes [10] (p. 25). Their task is to stimulate economic processes in line with the environmental protection policy [18] (p. 157).

On the basis of the Eurostat methodology, using the criterion of the subject of taxation, four groups of taxes related to the environment are distinguished: taxes on energy, taxes on transport, taxes on emissions, and taxes on natural resources [17] (pp. 58–59).

Focusing on environmental taxes, the group of energy taxes should be considered particularly important. As specified by Eurostat [15] (p. 9), the subject matter of energy taxes is:

- energy products for transport purposes: unleaded petrol, leaded petrol, diesel, or other energy products for transport purposes (e.g., LPG, natural gas, kerosene, or fuel oil);
- energy products for stationary purposes: light fuel oil, heavy fuel oil, natural gas, coal, coke, biofuels, electricity consumption and production, district heat consumption and production, and other energy products for stationary use;
- greenhouse gases: carbon content of fuels, emissions of greenhouse gases (including proceeds from emission and permits recorded as taxes in the national accounts).

Energy taxes include taxes on energy production and on energy products used for both transport and stationary purposes. The most important energy products for transport purposes are petrol and diesel. Energy products for stationary use include fuel oils, natural gas, coal, and electricity. Taxes on biofuels and on any other form of energy from renewable sources are included. Taxes on stocks of energy products are also included. Carbon dioxide (CO_2) taxes are included under energy taxes rather than under pollution taxes due to the following reasons. It is often not possible to identify CO2 taxes separately in tax statistics because they are integrated with energy taxes, e.g., via differentiation of mineral oil tax rates according to the carbon content of the fuel. They are partly introduced as a substitute for other energy taxes and the revenue from these taxes can be very large compared with the revenue from pollution taxes. This means that including CO2 taxes with pollution taxes rather than energy taxes would distort both the time series at the national level and international comparisons. If CO_2 taxes are identifiable, these taxes should be reported as a separate category next to the total energy taxes. Taxes on greenhouse gas emissions other than CO_2 should also be included here [15] (p. 13).

From the EU's climate and energy policy perspective, energy is of paramount importance. With this in mind, the main goal of the presented research was to identify trends in the EU Member States in shaping environmental tax revenues, with a focus on their most important group, i.e., energy taxes. The researchers sought answers to the research question regarding the convergent trends in this respect.

As a result of the research, it was found that in the EU as a whole, there is a slight downward trend in the share of environmental tax revenues in GDP and the share of environmental tax revenues in total tax revenues, while the share of energy tax revenues in total environmental tax revenues shows a slight upward trend. The decomposition of the research and the conducted comparative analysis, including the determination of specific rankings, showed that both the level and trends in the shaping of the studied variables vary considerably in the individual EU Member States.

2. Materials and Methods

The research procedure used data covering the following variables: (1) share of environmental tax revenue in GDP, (2) share of environmental tax revenues in total tax revenues, and (3) share of energy tax revenues in environmental tax revenues. The data used in the research procedure came from the Eurostat database. The study was conducted for 27 EU Member States for a period of 12 years, i.e., 2009–2020. The rationale for the research period adopted since 2009 is the fact that this year marked the implementation of the plan known as the "3 × 20" energy and climate package. This plan required EU member states to achieve the following goals by 2020:

- a 20% reduction in greenhouse gas emissions compared with 1990 levels,

- up to a 20% increase in the share of energy consumption from renewable energy sources,
- a 20% increase in energy efficiency to the forecasts for 2020,
- at least a 10% increase in the share of biofuels in the total consumption of transport fuels.

The plan was adopted at the Council meeting on 11 and 12 December 2008, and voted by the European Parliament a week later. The plan was finally introduced in 2009 under the following legal acts:

- Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009, amending Directive 2003/87/EC to improve and extend the Community greenhouse gas emission allowance trading scheme—the so-called EU ETS Directive (European Union Emissions Trading System) [19];
- Decision 2009/406/EC of the European Parliament and of the Council of 23 April 2009, on the efforts made by the Member States to reduce greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments by 2020—the so-called Non-ECJ Decision [20];
- Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009, on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, Euratom, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC, and Regulation (EC) No. 1013/2006—the so-called CCS Directive (Carbon Capture and Storage) [21];
- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009, on the promotion of the use of energy from renewable sources, amending and subsequently repealing Directives 2001/7/EC, and 2003/30/EC—the so-called RES Directive [22].

The legal regulations adopted in 2009 set obligations binding on the Member States in the field of energy and climate, to which the examined environmental taxes, including taxes on energy, are to contribute. The research presented in this article has been completed for 2020, as this is the last year for which a complete data set is available.

For the research procedure, it was assumed that the EU 27 countries form a certain group, which at a given moment may be characterized by a certain empirical probability distribution: (1) the share of environmental tax revenues in GDP, (2) the share of environmental tax revenues in total tax revenues, and (3) the share of energy tax revenues in environmental tax revenues. These variables may vary over time. The "letter values" method was used to synthetically present the studied variables, which is an extension of the box-plots method [23]. In the "letter values" method, the median is determined first (by eliminating 50% of the group that has a greater and lesser value than the median), and then the next "letter values" are calculated, consistently denoting smaller, extreme tail fractions of the surveyed group: lower and upper fourth (quartiles), lower and upper eighth, lower and upper sixteenth, lower and upper thirty-second, etc. [24]. "The letter values are those order statistics having specific depths, defined recursively starting with the median. The depth of the median, d_1, of a sample of size n is $d_1 = (1 + n)/2$; the depths of successive letter values (F = fourths, E = eighths, D = sixteenths, C = thirty-seconds, ...) are defined recursively as $d_i = (1 + \lfloor d_{i-1} \rfloor)/2$." [25]. "Letter value" plots were compiled on the basis of Eurostat data using a solution built into the Palisade Decision Tools 8.2.1 package. The shape of the "letter value plot" depends on the distribution. It is worth distinguishing between the "letter value plot" for uniform and normal distributions (Figure 1).

In addition to the "letter value" method used to identify the trend, the research was extended to establish specific rankings. The rankings made it possible to determine the differentiation of the EU member states in terms of the studied variables. Ranking of countries according to the analyzed variable: (1) the share of environmental tax revenues in GDP, (2) the share of environmental tax revenues in total tax revenues, and (3) the share of energy tax revenues in environmental tax revenues, was prepared on the basis of the weighted average of the variable for the country concerned during the period considered. The examined time series covered 12 periods. It was assumed that the last values are the most important, and the first—the least important. The weighting of 12 for the last values and the weighting of 1 for the first values were adopted, respectively.

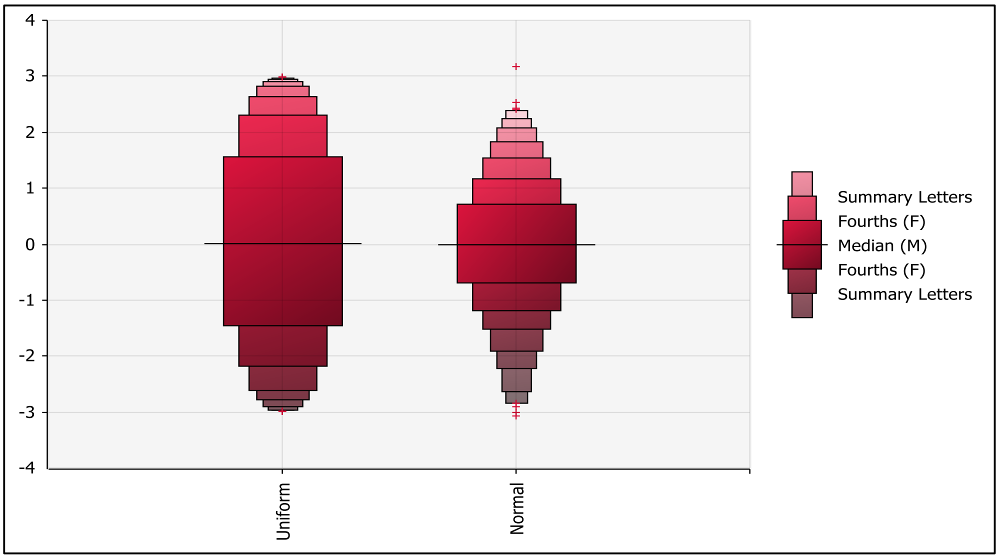


Figure 1. Letter value plot for uniform distribution in the range [−3, +3] and standardized normal distribution (source: own study).

3. Results

In the analyzed period, the share of environmental tax revenues in GDP showed a downward trend. This is confirmed by the change in the median, which increased from 2.52% to 2.64% in 2009–2016, but from 2017 onwards, a decrease to 2.38% in the median share of environmental tax revenues in GDP was observed in 2020. Observing the abscissa behavior, increasingly smaller fractions of the distribution of the share of environmental tax revenues in GDP in a given year, it should be stated that it also confirms the downward trend. Admittedly, the upper quarter of the observations (upper F) did not exceed 3% in 2009–2013, reaching 3.22% in 2016; however, from 2017 onwards, it decreased to 2.99% in 2020. Similar conclusions were drawn from the observation of the upper eighth, sixteenth, and thirty-second parts in the analyzed period (after an increase, a decrease was observed). Observation of the lower cut-off fractions indicates a downward trend in the lower fourth, eighth, sixteenth, and thirty-second upper parts (with a minimum correction in 2013–2015), as are the observations of the extreme values marked with dots in the graph. It is also worth pointing to a noticeable change in the shape of the distribution, which tends to become uniform from a more normal distribution. This means that increasingly more EU 27 countries had values closer to the extreme values of the share of environmental tax revenues in GDP (Figure 2 and Table A2).

It should be noted that the share of environmental tax revenues in GDP in the analyzed period decreased by an average of 0.5 pp in 16 of the EU27 countries. At the same time, it increased in the remaining 11 countries by 0.4 pp, on average. The weighted average ratio in the period under examination was the highest in Greece (3.71%), with an increase from 2.08% in 2009 to 3.77% in 2020. The second country was Denmark (3.68%), where there was a decrease in the discussed ratio from 3.99% to 3.17%. The lowest level of the weighted average ratio was observed for Luxembourg (1.76%) and Spain (1.8%). In Spain, there was an increase in the ratio in the discussed period (by 0.13 pp), and in Luxembourg a decrease (by 0.99 pp). The difference between the largest and the smallest weighted average share of environmental tax revenues in GDP was 1.95 pp. Thus, the considered ratio in Greece was more than twice as high as that in Luxembourg, which indicates its significant differentiation. A detailed ranking of countries is presented in Table 1.

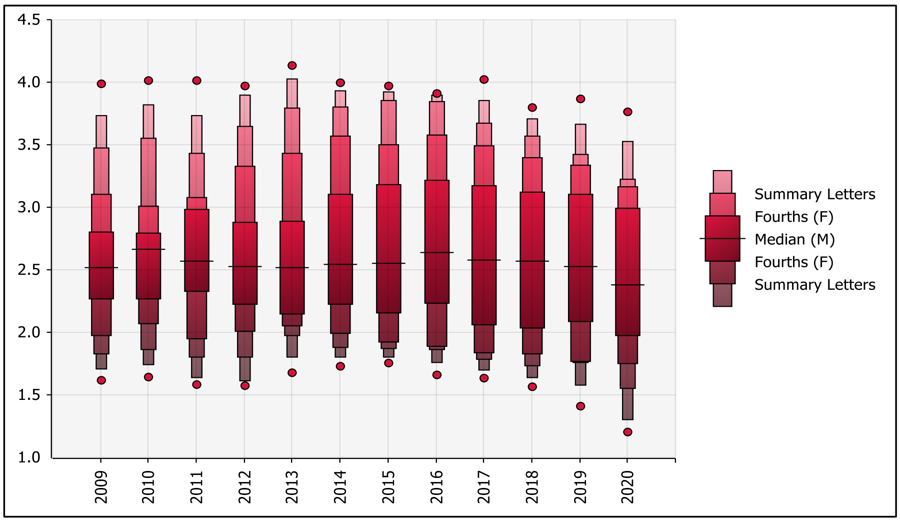


Figure 2. Letter value plot for the share of environmental tax revenues in the GDP of the EU27 in 2009–2020 (source: own study).

Another analyzed variable is the share of environmental tax revenues in total tax revenues. The median share of environmental tax revenues in total tax revenues was 7.05% in 2009. A year later, it increased to 8% and fell to 7.36% in 2011. Then, the median increased to 8.05% in 2014 and stabilized at approximately 8% by 2016. Since 2017, a systematic decline in the median share of environmental tax revenues in total tax revenues was observed to the level of 6.76%. The top quarter of the group (top F) fluctuated at approximately 8.68% (average) in 2009–2014 and increased to 9.04% in 2015. Since 2016, a systematic decline in the upper F letter value to 7.48% in 2020 was observed. At the same time, a systematic decline in the lower F letter value from 6.43% to 5.59% was observed. The area between the lower and upper F letter value narrowed significantly at the end of the period under consideration. The higher share of environmental tax revenues in total tax revenues in 2014–2016 is confirmed by the analysis of the remaining letter values and the extreme values themselves. Their observation also leads to the conclusion that the general trend of the share of environmental tax revenues in total tax revenues in the EU27 in the analyzed period was downward. It is difficult to classify the distribution of the group in particular periods as clearly tending toward uniform or normal (Figure 3 and Table A3).

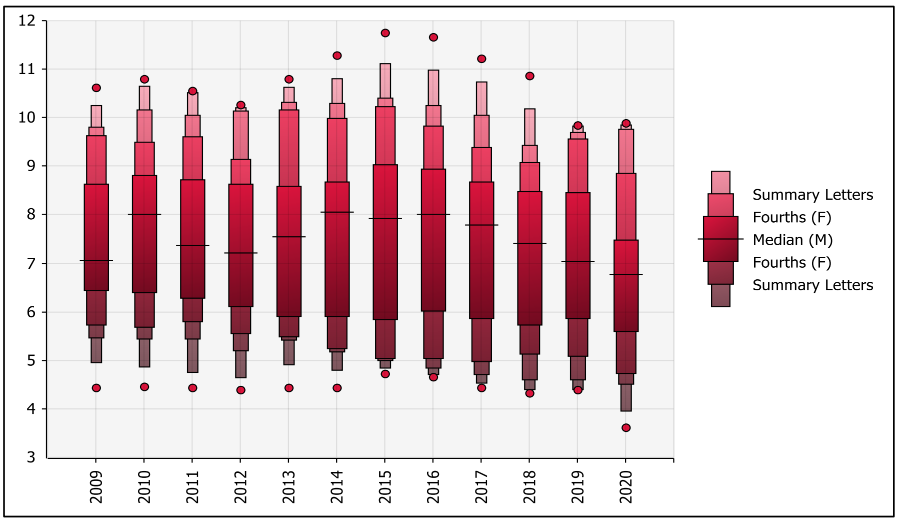


Figure 3. Letter value plot for the share of environmental tax revenues in the total tax revenues of the EU27 in 2009–2020 (source: own study).

Table 1. Ranking of the EU27 based on the criterion of the weighted average level of the share of environmental tax revenues in GDP in 2009–2020 (source: own study).

Country/Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Weigl	Simp	Chart	Change
Greece	2.08	2.67	2.96	3.33	3.66	3.74	3.83	3.81	4.03	3.80	3.87	3.77	**3.71**	**3.46**		**1.69**
Denmark	3.99	4.02	4.02	3.97	4.14	4.00	3.97	3.91	3.67	3.62	3.29	3.17	**3.68**	**3.81**		**−0.82**
Slovenia	3.48	3.61	3.45	3.83	3.92	3.86	3.88	3.88	3.67	3.40	3.34	2.95	**3.54**	**3.61**		**−0.53**
Netherlands	3.47	3.49	3.41	3.24	3.26	3.31	3.32	3.35	3.34	3.34	3.39	3.16	**3.31**	**3.34**		**−0.31**
Italy	2.78	2.78	3.03	3.46	3.43	3.57	3.39	3.51	3.34	3.31	3.25	3.04	**3.30**	**3.24**		**0.26**
Croatia	2.82	3.01	2.65	2.53	2.82	3.14	3.33	3.44	3.47	3.52	3.46	3.28	**3.26**	**3.12**		**0.46**
Latvia	2.64	2.96	3.08	2.99	3.17	3.34	3.50	3.58	3.49	3.37	2.94	3.10	**3.25**	**3.18**		**0.46**
Finland	2.52	2.67	3.00	2.96	2.91	2.88	2.89	3.08	2.96	2.93	2.81	2.75	**2.89**	**2.86**		**0.23**
Bulgaria	2.84	2.75	2.67	2.65	2.86	2.84	2.95	2.98	2.80	2.62	2.99	3.03	**2.86**	**2.83**		**0.19**
Cyprus	2.78	2.75	2.75	2.58	2.72	3.06	3.04	2.93	3.01	2.93	2.54	2.48	**2.79**	**2.80**		**−0.30**
Estonia	2.94	2.93	2.72	2.73	2.56	2.66	2.73	2.97	2.86	2.75	3.21	2.45	**2.79**	**2.79**		**−0.49**
Poland	2.66	2.71	2.63	2.59	2.42	2.58	2.65	2.71	2.68	2.71	2.54	2.55	**2.61**	**2.62**		**−0.11**
Belgium	2.36	2.45	2.57	2.52	2.52	2.54	2.55	2.67	2.70	2.70	2.64	2.54	**2.60**	**2.56**		**0.18**
Malta	3.10	2.80	3.05	2.79	2.59	2.74	2.70	2.64	2.54	2.48	2.46	2.27	**2.57**	**2.68**		**−0.83**
Portugal	2.44	2.43	2.32	2.19	2.20	2.27	2.42	2.58	2.58	2.57	2.53	2.38	**2.44**	**2.41**		**−0.06**
Slovakia	1.97	2.07	2.42	2.38	2.52	2.54	2.50	2.49	2.54	2.46	2.39	2.38	**2.44**	**2.39**		**0.41**
Hungary	2.62	2.64	2.54	2.53	2.43	2.41	2.47	2.53	2.44	2.27	2.26	2.18	**2.38**	**2.44**		**−0.44**
Austria	2.36	2.34	2.42	2.41	2.38	2.39	2.38	2.34	2.39	2.28	2.28	2.10	**2.31**	**2.34**		**−0.26**
France	1.87	1.89	1.92	1.96	2.03	2.03	2.16	2.24	2.31	2.37	2.31	2.18	**2.19**	**2.11**		**0.31**
Sweden	2.75	2.66	2.44	2.40	2.32	2.17	2.15	2.22	2.11	2.09	2.05	2.02	**2.17**	**2.28**		**−0.73**
Romania	1.79	2.11	1.95	2.01	2.06	2.38	2.47	2.40	1.94	1.97	2.12	1.92	**2.11**	**2.09**		**0.13**
Czechia	2.29	2.27	2.33	2.22	2.09	2.12	2.05	2.10	2.01	1.96	2.04	1.93	**2.06**	**2.12**		**−0.36**
Germany	2.26	2.15	2.18	2.12	2.06	1.99	1.92	1.86	1.81	1.77	1.76	1.71	**1.87**	**1.97**		**−0.55**
Lithuania	2.02	1.83	1.68	1.64	1.68	1.73	1.85	1.92	1.91	1.98	1.89	1.93	**1.86**	**1.84**		**−0.09**
Ireland	2.27	2.45	2.45	2.38	2.48	2.40	1.89	1.89	1.76	1.57	1.41	1.21	**1.80**	**2.01**		**−1.06**
Spain	1.62	1.65	1.59	1.58	1.92	1.87	1.93	1.87	1.84	1.83	1.77	1.75	**1.80**	**1.77**		**0.13**
Luxembourg	2.38	2.26	2.30	2.23	2.05	1.89	1.76	1.66	1.64	1.70	1.75	1.39	**1.76**	**1.92**		**−0.99**

The share of environmental tax revenues in total tax revenues decreased in 19 countries in the analyzed period by an average of 1.39 pp. This ratio increased in the remaining 8 countries by an average of 0.73 pp. The highest share of environmental tax revenues in total tax revenues, measured by the weighted average, was observed for Latvia and Bulgaria at the level of 10.69% and 9.84%, respectively. In Latvia, it increased by 0.2 pp, and in Bulgaria, it fell by 0.73 pp. The highest increase in the ratio was observed in Greece from 6.77 to 9.69%, which took 3rd place in the ranking. The lowest level of the weighted average level of the share of environmental tax revenues in total tax revenues was observed in the research conducted for Luxembourg and Germany. It was 4.75% and 4.78%, respectively. In Luxembourg, it dropped by 2.93 pp (the largest decrease in the discussed group of countries) in the analyzed period, and in Germany by 1.58 pp. It should be noted that the difference between the largest and the smallest weighted average share of environmental tax revenues in total tax revenues was 5.94 pp in the studied group of countries. This indicates a large variation in the size of the ratio in question in the Member States of the European Union because, in the country with the highest ratio, it was more than twice as high as in the country with the lowest. A detailed ranking of countries is presented in Table 2.

Table 2. Ranking of the EU27 based on the criterion of the weighted average level of the share of environmental tax revenues in total tax revenues in 2009–2020 (source: own study).

Country/Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Weigl	Simp	Chart	Change
Latvia	9.62	10.47	10.56	10.28	10.81	11.28	11.75	11.66	11.23	10.87	9.58	9.82	**10.69**	**10.66**		**0.20**
Bulgaria	10.62	10.81	10.48	10.15	10.15	9.99	10.23	10.20	9.38	8.81	9.85	9.89	**9.84**	**10.05**		**−0.73**
Greece	6.77	8.26	8.64	9.15	10.20	10.29	10.46	9.82	10.24	9.49	9.79	9.69	**9.76**	**9.40**		**2.92**
Slovenia	9.32	9.49	9.17	10.11	10.45	10.31	10.34	10.31	9.84	9.08	8.93	7.84	**9.45**	**9.60**		**−1.48**
Croatia	7.78	8.41	7.56	7.10	7.78	8.63	9.09	9.29	9.38	9.36	9.20	8.85	**8.84**	**8.54**		**1.07**
Netherlands	9.87	9.83	9.62	9.12	9.05	8.93	8.99	8.73	8.63	8.62	8.64	7.97	**8.73**	**9.00**		**−1.90**
Malta	9.74	9.04	9.61	8.85	8.24	8.70	9.12	8.59	8.40	8.20	8.25	7.66	**8.44**	**8.70**		**−2.08**
Estonia	8.42	8.82	8.65	8.61	8.09	8.27	8.19	8.85	8.71	8.31	9.57	7.20	**8.43**	**8.47**		**−1.22**
Cyprus	8.76	8.67	8.68	8.15	8.56	9.09	9.17	9.05	9.12	8.80	7.37	7.15	**8.41**	**8.55**		**−1.61**
Denmark	8.88	8.92	8.92	8.67	8.95	8.17	8.57	8.55	8.02	8.15	7.04	6.76	**7.98**	**8.30**		**−2.12**
Romania	7.11	8.00	6.89	7.21	7.52	8.66	8.79	9.27	7.78	7.59	8.14	7.30	**7.96**	**7.86**		**0.19**
Italy	6.70	6.73	7.36	8.03	7.93	8.32	7.92	8.33	7.99	7.94	7.70	7.11	**7.79**	**7.67**		**0.41**
Poland	8.50	8.66	8.27	8.06	7.55	8.05	8.17	8.11	7.85	7.70	7.23	7.12	**7.74**	**7.94**		**−1.38**
Ireland	8.05	8.81	8.78	8.43	8.61	8.34	8.15	8.02	7.78	7.01	6.41	6.04	**7.48**	**7.87**		**−2.01**
Slovakia	6.85	7.43	8.35	8.28	8.16	7.98	7.70	7.55	7.51	7.24	6.95	6.81	**7.45**	**7.57**		**−0.04**
Portugal	8.18	8.00	7.20	6.91	6.49	6.65	7.03	7.59	7.56	7.41	7.33	6.76	**7.17**	**7.26**		**−1.42**
Finland	6.19	6.57	7.18	6.98	6.71	6.62	6.65	7.05	6.90	6.92	6.63	6.52	**6.76**	**6.74**		**0.33**
Lithuania	6.68	6.46	6.20	6.09	6.23	6.31	6.40	6.48	6.49	6.58	6.23	6.26	**6.36**	**6.37**		**−0.42**
Hungary	6.74	7.17	7.00	6.49	6.32	6.26	6.37	6.47	6.43	6.16	6.22	6.01	**6.33**	**6.47**		**−0.73**
Czechia	7.05	6.89	6.85	6.43	5.99	6.21	5.98	5.99	5.67	5.44	5.67	5.35	**5.85**	**6.13**		**−1.70**
Belgium	5.46	5.61	5.80	5.56	5.48	5.57	5.66	6.03	6.02	6.02	6.07	5.82	**5.85**	**5.76**		**0.36**
Austria	5.73	5.68	5.87	5.75	5.58	5.59	5.51	5.61	5.71	5.39	5.35	5.00	**5.47**	**5.56**		**−0.73**
Spain	5.45	5.25	5.08	4.88	5.80	5.52	5.70	5.54	5.42	5.28	5.09	4.74	**5.28**	**5.31**		**−0.71**
Sweden	6.30	6.21	5.81	5.69	5.46	5.16	5.05	5.03	4.80	4.76	4.79	4.73	**5.04**	**5.32**		**−1.57**
France	4.43	4.47	4.43	4.40	4.45	4.45	4.73	4.91	4.98	5.13	5.10	4.78	**4.81**	**4.69**		**0.35**
Germany	5.85	5.77	5.78	5.53	5.36	5.20	4.95	4.76	4.61	4.45	4.39	4.27	**4.78**	**5.08**		**−1.58**
Luxembourg	6.55	6.32	6.34	6.12	5.66	5.23	5.05	4.67	4.45	4.33	4.42	3.62	**4.75**	**5.23**		**−2.93**

The key component of environmental taxes is energy taxes; hence, on the basis of the adopted research objective, the trend of the share of energy tax revenues in environmental taxes revenues was subjected to a detailed analysis. The median of the variable increased in the analyzed period from 78.94% to 80.27%. The upper and lower F letter values increased—in the upper case, from 85.05% to 88.09%. However, in the case of the lower one, from

64.52% to 72.45%. The spread decreased from 20.53 pp up to 15.64 pp. The central part between the upper and lower F letter value moved up. The upper E letter value increased from 89.53% to 91.52%. The lower one changed from 58.69% to 57.61%, after an initial increase. The spread between the upper and lower E letter value increased from 30.84 pp up to 33.91 pp. Observing the changes in the distribution, it should be noted that there is increasing right-handedness, which also confirms the increase in the share of energy tax revenues in environmental tax revenues in the analyzed period in the examined group (Figure 4 and Table A4).

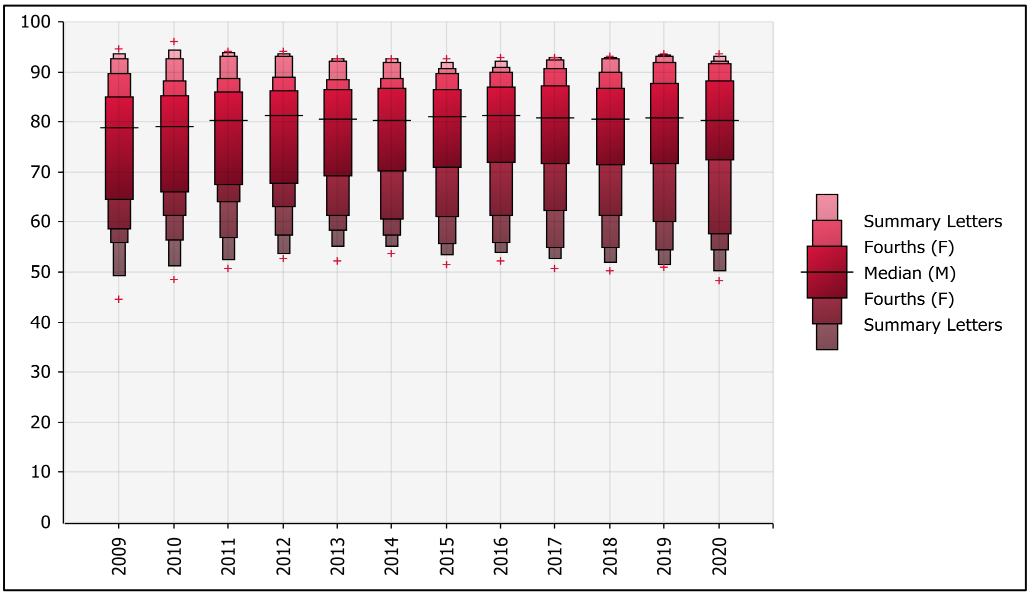
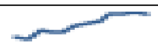
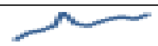
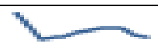
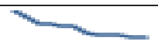
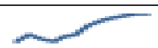
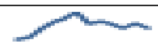
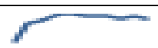
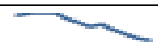
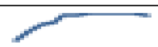
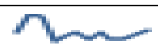
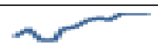
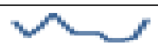
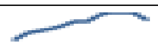
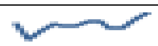
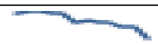
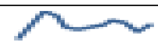
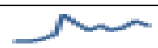
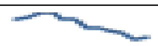


Figure 4. Letter value plot for the share of energy tax revenues in the environmental tax revenues of the EU27 in 2009–2020 (source: own study).

The share of energy tax revenues in environmental tax revenues (Table 3) increased in 19 of the 27 EU countries during the analyzed period, on average by 4.8 pp. In the remaining 8 countries, it decreased, on average, by 4.6 pp, while the difference between the largest and the smallest weighted average share of energy tax revenues in environmental tax revenues was as high as 42.16 pp; thus, the largest analyzed ratio was significantly higher than the smallest—1.8 times. The highest weighted average share of energy tax revenue in environmental tax revenue was observed in the Czech Republic. It was 93.06%. It increased by 0.72 pp over the period considered. Luxembourg was the second country in the ranking, with a weighted average share of energy tax revenues in environmental tax revenues equal to 92.13%. However, in Luxembourg, there was a decrease. The highest increase in the share of energy tax revenues in environmental tax revenues was observed in Cyprus, from 58.69% to 77.51% (by 18.82 pp).

The lowest share of energy tax revenue in environmental tax revenue was observed in Malta and Denmark. The weighted average level of this share amounted to 50.90% and 55.03%, respectively. In Denmark, the share of energy tax revenues in environmental tax revenues decreased by 5.83 pp. In Malta, it increased by 3.64 pp. The largest decrease was observed in Austria—from 65.75% to 57.61%.

Table 3. Ranking of the EU27 based on the criterion of the weighted average level of the share of energy tax revenues in environmental tax revenues in 2009–2020 (source: own study).

Country/Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Weigl	Simp	Chart	Change
Czechia	92.84	92.66	92.94	92.86	92.66	92.72	92.53	92.94	92.93	93.03	93.61	93.55	**93.06**	**92.94**		**0.72**
Luxembourg	92.14	92.61	93.35	93.21	92.47	92.28	91.18	91.27	91.85	92.50	92.79	91.61	**92.13**	**92.27**		**−0.53**
Lithuania	94.54	96.10	94.21	94.13	91.56	91.58	90.08	90.55	90.65	89.95	90.82	90.04	**91.06**	**92.02**		**−4.50**
Romania	84.87	84.33	87.34	86.33	86.18	88.75	89.59	89.93	92.64	92.80	93.18	92.43	**90.60**	**89.03**		**7.56**
Estonia	85.58	87.80	87.12	88.31	86.86	87.00	87.28	87.92	88.03	87.98	91.85	91.52	**88.81**	**88.11**		**5.94**
Slovakia	84.95	86.57	88.30	88.52	87.70	87.65	88.22	87.84	88.28	88.14	88.34	89.68	**88.28**	**87.85**		**4.73**
Bulgaria	87.85	88.13	88.71	88.97	87.81	87.55	88.20	87.34	87.23	85.98	88.46	88.33	**87.75**	**87.88**		**0.48**
Poland	83.11	84.22	84.74	85.91	88.39	86.23	85.64	86.50	87.03	87.49	87.02	87.86	**86.79**	**86.18**		**4.75**
Latvia	89.53	86.05	82.36	82.95	82.97	84.18	84.42	85.17	85.16	85.02	83.53	83.07	**84.17**	**84.53**		**−6.46**
Slovenia	84.02	84.40	83.92	85.45	84.34	84.21	84.21	84.85	84.60	83.68	82.72	80.59	**83.55**	**83.92**		**−3.43**
Germany	85.14	84.58	83.98	83.83	83.68	83.70	83.05	82.83	83.00	82.83	82.75	82.82	**83.15**	**83.52**		**−2.32**
Spain	81.17	81.61	81.79	81.33	82.22	83.25	83.52	82.73	82.79	82.69	82.10	81.83	**82.42**	**82.25**		**0.66**
France	77.94	79.14	78.52	77.94	79.05	79.25	81.21	82.48	82.98	83.51	83.85	83.92	**81.97**	**80.81**		**5.98**
Italy	78.94	79.08	80.24	81.39	81.56	82.42	81.06	81.36	80.81	80.46	80.83	80.27	**80.87**	**80.70**		**1.33**
Greece	63.29	74.51	76.18	78.99	80.64	80.25	79.69	79.12	79.80	78.41	78.69	77.51	**78.59**	**77.26**		**14.22**
Sweden	80.73	81.40	81.26	81.32	80.23	79.39	78.24	78.65	77.73	76.51	75.75	75.13	**77.77**	**78.86**		**−5.60**
Cyprus	58.69	65.87	70.39	72.28	77.73	77.76	78.72	78.83	78.98	79.14	78.94	77.51	**77.29**	**74.57**		**18.82**
Hungary	76.22	78.65	78.18	74.87	75.53	76.01	75.30	76.07	75.08	75.03	75.79	76.42	**75.82**	**76.10**		**0.20**
Croatia	69.16	71.56	68.09	68.28	71.59	72.73	74.91	75.43	74.65	77.02	76.76	76.70	**74.60**	**73.07**		**7.54**
Portugal	75.28	72.83	74.42	76.84	75.34	73.21	73.32	73.29	72.06	72.08	72.34	75.51	**73.57**	**73.88**		**0.23**
Belgium	61.81	64.03	64.79	65.98	66.06	67.76	68.40	70.47	71.16	71.01	70.97	68.62	**69.00**	**67.59**		**6.81**
Finland	67.64	64.25	66.07	67.36	66.77	67.16	68.11	67.85	66.55	66.66	68.53	69.77	**67.65**	**67.23**		**2.13**
Austria	65.75	66.33	66.68	65.63	65.93	63.00	63.59	63.03	62.63	61.31	61.34	57.61	**62.32**	**63.57**		**−8.13**
Ireland	58.94	61.42	64.03	63.12	61.22	60.64	61.14	61.27	62.27	62.04	60.06	61.51	**61.46**	**61.47**		**2.58**
Netherlands	53.71	53.83	53.98	54.84	58.41	56.75	55.78	56.25	55.58	55.98	57.28	56.58	**56.22**	**55.75**		**2.88**
Denmark	58.05	58.81	59.84	60.18	58.28	58.06	55.53	55.44	54.40	53.91	51.71	52.22	**55.03**	**56.37**		**−5.83**
Malta	44.66	48.64	50.81	52.77	52.30	53.64	51.59	52.33	50.83	50.27	51.05	48.30	**50.90**	**50.60**		**3.64**

4. Discussion

The conducted research confirmed that environmental taxes constitute an important element in the tax systems of all EU Member States. This is also evidenced by the studies of other authors carried out in 1991–2021, using various variables. A summary of selected studies from this period is presented in Table A1 [26–77]. Since the introduction of environmental taxes to the literature by Pigou in 1920, many authors have presented papers describing various instruments of tax impact on the behavior of entrepreneurs and consumers, including Goulder [63], Kirchgassner, Muller, Savioz [78], and Stern [79]. An example of one of the most interesting concepts for the application of environmental taxes is the so-called standard emission tax proposed by W. J. Baumol and W. E. Oates [80], [81] (p. 239).

As part of the literature review, attention is also drawn to studies on the impact of environmental taxes on reducing environmental degradation, presented, among others, by Lee and Roland-Holst [69], Morley [61], Miller and Vela [71], and Haites [72]. In turn, studies conducted in recent years by Bashir, MA, Shahbaz, Jiao [44], Ulucak R., Danish K., Kassouri Y. [47], Shahzad [46], Akkaya, Hepsag [48], Esen, Dündar [49], Sarıgül, Topçu [50], and Wolde-Rufael, Mulat-Weldemeskel [51] have concerned the relationship of environmental taxes and carbon dioxide emissions and greenhouse gases. For example, studies by Sen and Vollebergh [39] and Hashmi and Alam [41] indicated that energy taxes can reduce greenhouse gas emissions and energy consumption. The discrepancies and ambiguities in the results of these studies were noted by, among others, Gerlagh and Lise [31], Loganathan et al. [33], and Radulescu et al. [36].

Liobikienè et al. [43] conducted a study in the EU28 countries on the relationship between energy tax and greenhouse gas emissions, renewable energy consumption, fossil energy consumption, and energy intensity, proving that environmental taxes did not reduce greenhouse gas emissions. On the other hand, González-Sánchez and Martína-Ortega [45] demonstrated that greenhouse gas emissions in the EU28 decreased, but other policy instruments mitigating the increases in emissions contributed to the reduction of greenhouse gas emissions to a greater extent than taxes on coal.

Research by Ignjatijević, Đorđević [62], Morley, Abdullah [61], Pautrel [60], Leiter, Parolini, Winner [59], Ricci [58], Andersen [57], Myles [56], and others indicated that there is a relation between the amount of environmental taxes and the GDP value. For example, Ignjatijević, Đorđević [62] analyzed the relationship between economic growth and environmental performance, aiming to emphasize the areas that were under constrain as well as the areas that are positively affected by economic growth. The authors investigated the Environmental Performance Index during the period 2010–2018. The findings revealed that environmental policy directly and positively influences economic performance by improving environmental conditions. However, the authors feared that the demands of the green economy already create high costs and that its benefits will be materialized in the long term. Finally, we note sustainable business operations—the green economy requires timely harmonization in order to fulfill the goals of environmental protection.

At this point, it is also worth mentioning the publications of Dulebenets [73], Tran, Mao, Siebers [74], Rengs, Scholz-Wäckerle, and van den Bergh [75], presenting the impact of taxes on carbon dioxide emissions on the activities of enterprises as well as employment and innovation. Some authors also proved the relationship between the occurrence of environmental taxes and the level of welfare in many countries, for example, Goulder [63], Patuelli, Nijkamp, Pels [64], Anger, Bohringer, Loschel [65], Gago, Labandeira, López-Otero [66], Freire-Gonzalez [67], and Kuralbayeva [68].

In our research, we searched for trends in the EU Member States in the shaping of environmental tax revenues, with particular emphasis on their most important group, i.e., energy taxes. On the basis of our research, it should be concluded that in the EU27, there is a significant variation in (1) the share of environmental tax revenues in GDP, (2) the share of environmental tax revenues in total tax revenues, and (3) the share of energy tax revenues in environmental tax revenues. We have identified that while (1) the share of environmental tax revenue in GDP and (2) the share of environmental tax revenue in total tax revenue is on a downward trend, (3) the share of energy tax revenue in environmental tax revenue has a slight upward trend. The rationale for the downward trend in 2016–2020 for (1) the share of environmental tax revenues in GDP and (2) the share of environmental tax revenues in total tax revenues are the provisions of the Paris Agreement ratified by the EU and applied to international law on 4 November 2016, which was the result of the United Nations Climate Change Conference, COP21, in the French capital, held on 30 November–12 December 2015. The most important agreement was to limit the global temperature rise to below 2 degrees Celsius above the pre-industrial level and to make efforts not to exceed the temperature increase of 1.5 degrees Celsius [82]. To achieve these goals, all countries have committed themselves to present a specific joint action plan [18]. Developed countries have committed themselves to providing financial support to developing countries by providing them with USD 100 billion annually for investments aimed at reducing carbon dioxide emissions [83]. As a consequence, the EU Member States achieved the assumed environmental objectives quite quickly, which contributed to the decrease of the analyzed ratios: (1) the share of environmental tax revenues in GDP and (2) the share of environmental tax revenues in tax revenues. On the other hand, there were countries with a low level of economic development aimed at improving the ratios over a longer period and consistently taxing activities negatively affecting the environment, which increased by the analyzed shares.

The observed relation allows for the formulation of specific conclusions regarding the importance of environmental taxes in the EU Member States in the future. On the one hand, the overall downtrend is expected to continue. If the energy and climate goals set by the EU in the next 30 years are achieved, the tax base of environmental taxes will decrease, and, thus, their fiscal significance will decrease. However, this prediction is debatable considering the unprecedented energy crisis in 2022 caused by Russia's aggression against Ukraine. In some EU Member States, it caused a departure from the processes of decarbonization of the economy, and it is also difficult to determine for how long. Consequently, the upward trend in energy tax revenues may continue and even strengthen. On the other hand, the importance of environmental tax revenues, apart from the tax base, is determined by their structure. Thus, by making appropriate changes in the structure of the applicable taxes or by introducing new taxes, it is possible to cause an upward trend in the total environmental tax revenues. Environmental taxes are expected to play a major role in the transition to a climate-neutral economy by the EU by 2050. In our opinion, the growing importance of environmental taxes requires not only corrections of the applicable solutions but also permanent tax reform. We recognized the desirable ecological tax reform in all EU Member States, and at the same time, we noted that it will be, if it is undertaken, a difficult, long-term process. The question of the harmonization of this reform in the EU remains open, as it is not favored by, among others, the significant differentiation in the meaning of environmental taxes in individual countries identified in our research.

It should be noted that different research methods were used in all the other authors' studies mentioned. Research on environmental taxes is often conducted using an international comparative analysis based on ratios, such as in the works of Mełecki [14], Rubio, Rubio, Moreno [76], Delgado, Freire-González, and Presno [77].

For example, Delgado, Freire-González, and Presno [77] studied the evolution of total environmental taxation and its two main subcategories, energy and transport taxes, as a percentage of GDP and as a share of total taxation in the EU, through a club convergence analysis of the period 1995–2016. From the GDP perspective, the results showed three groups of countries or clubs for the total environmental taxation and only two clubs for the two other categories analyzed. Considering the taxation structure perspective, two clusters emerge for the total environmental taxes, three for the energy case and only one for the transport taxation, denoting overall convergence in this case. These results indicated a high grade of convergence in environmental taxation in the EU.

Considering the complexity of the research problem, a comparative assessment based on the nominal value of environmental tax revenues is difficult. Therefore, it seems more reliable to use relative measures – this is also the approach we used in our research. In the reports of international institutions and scientific studies, the ratios presenting environmental tax revenues expressed as a percentage of total tax revenues and/or environmental tax revenues to GDP are most often used for this purpose. Studies also use a ratio showing the amount of environmental tax income per capita [15,84]. To make international comparisons, the structure of environmental tax revenues is often used based on separate generic groups, such as energy, transport, environmental pollution, and natural resources. Very often, in the reports of international institutions, the generic groups of "environmental pollution" and "natural resources" are treated as one whole. The classification of a given tax into the appropriate generic group is determined by its subject of taxation. In some cases, it is not clear-cut and requires verification, and the final decision is made by the statistical office of a given country. Moreover, certain general rules also apply in this respect [14] (p. 2).

In our research, to synthetically present the studied variables, we used the "letter values" method, which is an extension of the box-plots method. The application of this method allowed for the assessment of the importance of environmental tax revenues, including energy taxes in the EU27, and a detailed assessment of changes in the surveyed group over time. Conclusions obtained through the assessment of "letter value plots" were then confirmed by examining the absolute changes of individual variables taken into account in the research procedure. The originality of our research should be emphasized. This is evidenced by the fact that so far, no other authors have used the "letter values" method to assess trends in the EU Member States in shaping environmental tax revenues, with particular emphasis on energy taxes. At the same time, we hope to contribute to the dissemination of this relatively new method in research involving international comparative analyses.

In addition, the research results obtained by us imply further research. It is very important to undertake research aimed at establishing the cause-and-effect relations between public revenues from individual environmental taxes and the non-fiscal functions assigned to them. The significant differentiation in the EU27 in the level and trends of the studied variables, as identified by us, indicates that these relations are complex. At the same time, a new research question arises: to what extent are these relations a derivative of the limitation of factors with a negative impact on the environment by individual countries, and to what extent are they determined by the construction of specific environmental taxes? It would also be particularly important to study the effectiveness of environmental taxes in contributing to the achievement of specific EU climate and energy goals. We also hope that the results of our research will prove useful to the governments, not only in the EU Member States but also in other countries that construct tax systems. At the present time, it is not possible to change taxes in a given country without simultaneous analysis of taxes applied in other countries. The international context is very important due to the phenomenon of international tax competition. The experience of the other countries may be an inspiration for developing domestic solutions. This applies to environmental taxes, which are "young" taxes. It should be stated that they are at the stage of being shaped as a specific category of taxes, and at this stage, it is necessary to conduct international comparative analyzes.

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Appendix A

Table A1. Selected research on environmental taxes (1991–2021) (source: own study).

Reserach	Authors	Year	Journal	Title
Environmental taxes and CO_2	Repetto R., Dower R., Jenkins J., Geoghegan R.	1992	World Resource Institute	Green fees: how a tax shift can work for the environment and the economy
	Grubb M., Edmonds P., Brink M., Morrison J.	1993	Annual Review of Energy and the Environment	The cost of limiting fossil-fuel CO_2 emissions
	Nordhaus W.	1993	American Economic Review	Optimal greenhouse gas reductions and tax policy in the 'DICE' model
	Oates W. E.	1993	Southern Economic Journal	Green taxes: can we protect the environment and improve the tax system at the same time?
	Tamura H., Nakanishi R., Hatono I., Umano M.	1996	IFAC Proceedings Volumes	Is environmental tax effective for total emission control of carbon dioxide? systems analysis of an environmental-economic model
	Gerlagh R., Lise W.	2005	Ecological Economics	Carbon taxes: A drop in the ocean, or a drop that erodes the stone? The effect of carbon taxes on technological change
	Meng S., Siriwardana M., McNeill J.	2013	Environmental and Resource Economics	The environmental and economic impact of the carbon tax in Australia
	Loganathan, N., Shahbaz, M., Taha, R.	2014	MPRA Paper	The effect of green taxation and economic growth on environment hazards: the case of Malaysia
	Filipović S., Golušin M.	2015	Journal of Cleaner Production	Environmental taxation policy in the EU—new methodology approach
	Sasmaz M. U.	2016	Global Journal on Humanites & Social Sciences	Validity of double dividend hypothesis in EU-15 countries
	Radulescu M., Sinisi C. I., Popescu C., Iacob S. E.	2017	Sustainability	Environmental tax policy in Romania in the context of the EU: double dividend theory
	Aydin C., Esen Ö.	2018	Journal of Environmental Planning and Management	Reducing CO_2 emissions in the EU member states: Do environmental taxes work?
	Lin B., Jia Z.	2018	Energy	The energy, environmental and economic impacts of carbon tax rate and taxation industry: a CGE based study in China
	Sen S., Vollebergh H.	2018	Journal of Environmental Economics and Management	The effectiveness of taxing the carbon content of energy consumption
	Timilsinas G. R.	2018	Development Research Group, Working Paper Series	Where is the carbon tax after thirty years of research?
	Hashmi R., Alam K.	2019	Journal of Cleaner Production	Dynamic relationship among environmental regulation, innovation, CO_2 emissions, population, and economic growth in OECD countries: a panel investigation
	He P., Chen L., Zou X., Li S., Shen H., Jian J.	2019	Sustainability	Energy taxes, carbon dioxide emissions, energy consumption and economic consequences: a comparative study of nordic and G7 countries
	Liobikienè G., Butkus M., Matuzevičitè K.	2019	Resources	The contribution of energy taxes to climate change policy in the European Union
	Bashir M. F., MA B., Shahbaz M., Jiao Z.	2020	Plos One	The nexus between environmental tax and carbon emissions with the rolesOf environmental technology and financial development
	González-Sánchez M., Martín-Ortega J. L	2020	Sustainability	Greenhouse gas emissions growth in Europe: a comparative analysis of determinants
	Shahzad U.	2020	Environmental Scienceand Pollution Research	Environmental taxes, energy consumption, and environmental quality: theoretical survey with policy implications
	Ulucak R., Danish K., Kassouri Y.	2020	Sustainable Development	An assessment of the environmental sustainability corridor: investigating the non-linear effects of environmental taxation on CO2 emissions
	Akkaya Ş., Hepsag A.	2021	Environmental Science and Pollution Research	Does fuel tax decrease carbon dioxide emissions in Turkey? Evidence from an asymmetric nonlinear cointegration test and error correction model
	Esen Ö., Dündar M.	2021	Journal of Emergy Economies and Policy	Do energy taxes reduce the carbon footprint? Evidence from Turkey
	Sarıgül S. S., Topçu A. B.	2021	International Journal of Business & Economic Studies	The impact of environmental taxes on carbon dioxide emissions in Turkey
	Wolde-Rufael Y., Mulat-Weldemeskel E.	2021	Environmental Scienceand Pollution Research	Do environmental taxes and environmental stringency policies reduce CO_2 emissions? Evidence from 7 emerging economies
	Rybak A., Joostberens J., Manowska A., Pielot J.	2022	Energies	The Impact of Environmental Taxes on the Level of Greenhouse Gas Emissions in Poland and Sweden

Table A1. *Cont.*

Reserach	Authors	Year	Journal	Title
	Pearce D.	1991	Economic Journal	The role of carbon taxes in adjusting to global warming
	Bovenberg A, de Mooij R.	1997	Journal of Public Economics	Environmental tax reform and endogenous growth
	Fisher E.O., van Marrewijk C.	1998	Journal of International Trade & Economic Development	Pollution and economic growth
	Myles G.	2000	Fiscal Studies	Taxation and Economic Growth
	Andersen M.S.	2007	National Environment Research Institute	Carbon-energy taxation contributed to economic growth
	Ricci F.	2007	Ecological Economics	Channels of transmission of environmental policy to economic growth
Environmental taxes and PKB	Leiter A.M, Parolini A., Winner H.	2009	Faculty of Economics and Statsitics University of Innsbruck Working Papers	Environmental regulation and investment: evidence from european industries
	Pautrel X.	2009	Ecological Economics	Pollution and life expectancy: How environmental policy can promote growth
	Morley B. Abdullah S.	2010	Bath Economics Research Papers	Environmental taxes and economic growth: evidence from panel causality tests
	Ignjatijević S., Đorđević D.	2020	Menadzment Finansije i Pravo	Determining relationship between economic growth and environmental protection
	Goulder L. H.	1995	International Tax and Public Finance	Environmental taxation and the 'Double Dividend': A reader's guide
	Patuelli R., Nijkamp P., Pels E.	2005	Ecological Economics	Environmental tax reforms and the double dividend: A meta-analytical performance assessment
	Anger N., Bohringer C., Loschel A.	2010	Ecological Economics	Paying the piper to call the tune? A metaregression analysis of the double-dividend hypothesis
Environmental taxes and welfare	Gago A., Labandeira X., López-Otero X.	2014	Hacienda Pública EspañolaReview of Public Economics	A panorama on energy taxes and green tax reforms
	Freire-Gonzalez J.	2018	Journal of Policy Modelling	Environmental taxation and the double dividend hypothesis in CGE modelling literature: A critical review
	Kuralbayeva K.	2019	Environmental and Resource Economics	Environmental taxation, employment and public spending in developing countries
	Lee H., Roland-Holst D.	1997	Journal of Development Economics	The environment and welfare implications of trade and tax policy
	Morley B.	2012	Applied Economics Letters	Empirical evidence on the effectiveness of environmental taxes
Environmental impact of taxes	Miller S., Vela M. A.	2018	Inter-American DevelopmentBank Working Paper Series	Are environmentally related taxes effective?
	Haites E.	2018	Climate Policy	Carbon taxes and greenhouse gas emissions trading systems: what have we learned?
	Dulebenets M.A.	2018	International Journal of TransportationScience and Technology	Green vessel scheduling in liner shipping: modeling carbon dioxide emission costs in sea and at ports of call
Impact of taxes on CO_2 Emission on enterprises	Tran T.H., Mao Y., Siebers P.O.	2019	Sustainability	Optimising decarbonisation investment for firms towards environmental sustainability
	Rengs B., Scholz-Wäckerle M. and van den Bergh J.	2020	Journal of Economic Behavior & Organization	Evolutionary macroeconomic assessment of employment and innovationimpacts of climate policy packages
	Małecki P.	2016	Optimum	Podatki ekologiczne w Polsce na tle innych krajów Unii Europejskiej
Environmental taxes-international comparative analyses	Rubio E. V., Rubio J. M. Q., Moreno V. M.	2017	Revista de Economía Mundial	Environmental fiscal effort: spatial convergence within economic policy on taxation
	Delgado F. J., Freire-González J., Presno M. J.	2022	Economic Analysis and Policy	Environmental taxation in the European Union: Are there common trends?

Table A2. Letter values—share of environmental tax revenues in the GDP of the EU27 in 2009–2020 (source: own study).

Measure	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Minimum	1.62	1.65	1.59	1.58	1.68	1.73	1.76	1.66	1.64	1.57	1.41	1.21
Maximum	3.99	4.02	4.02	3.97	4.14	4.00	3.97	3.91	4.03	3.80	3.87	3.77
Mean	**2.56**	**2.61**	**2.61**	**2.60**	**2.64**	**2.68**	**2.69**	**2.72**	**2.66**	**2.60**	**2.57**	**2.43**
90% CI	**±0.1778**	**±0.1757**	**±0.1776**	**±0.1928**	**±0.2036**	**±0.2084**	**±0.2154**	**±0.2197**	**±0.2207**	**±0.2110**	**±0.2067**	**±0.2025**
Mode	2.36	2.45	2.42	2.38	2.06	2.54	2.47	2.63	2.54	2.93	2.54	1.93
Median	**2.52**	**2.66**	**2.57**	**2.53**	**2.52**	**2.54**	**2.55**	**2.64**	**2.58**	**2.57**	**2.53**	**2.38**
Std Dev	0.54	0.54	0.54	0.59	0.62	0.64	0.66	0.67	0.67	0.64	0.63	0.62
Skewness	0.67	0.68	0.41	0.63	0.89	0.56	0.47	0.29	0.29	0.22	0.20	0.10
Kurtosis	3.74	3.95	3.73	3.34	3.29	2.44	2.24	2.05	2.11	1.98	2.24	2.61
Values	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
Errors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Filtered	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M upper	**2.52**	**2.66**	**2.57**	**2.53**	**2.52**	**2.54**	**2.55**	**2.64**	**2.58**	**2.57**	**2.53**	**2.38**
M lower	**2.52**	**2.66**	**2.57**	**2.53**	**2.52**	**2.54**	**2.55**	**2.64**	**2.58**	**2.57**	**2.53**	**2.38**
M spread	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F upper	**2.80**	**2.79**	**2.98**	**2.88**	**2.89**	**3.10**	**3.18**	**3.22**	**3.18**	**3.12**	**3.10**	**2.99**
F lower	**2.27**	**2.27**	**2.33**	**2.23**	**2.15**	**2.22**	**2.16**	**2.23**	**2.06**	**2.04**	**2.09**	**1.98**
F spread	0.54	0.53	0.66	0.65	0.74	0.88	1.03	0.99	1.12	1.09	1.02	1.02
E upper	3.10	3.01	3.08	3.33	3.43	3.57	3.50	3.58	3.49	3.40	3.34	3.16
E lower	1.97	2.07	1.95	2.01	2.05	1.99	1.92	1.89	1.84	1.83	1.77	1.75
E spread	1.13	0.94	1.13	1.32	1.38	1.58	1.58	1.69	1.65	1.57	1.57	1.41
D upper	3.48	3.55	3.43	3.65	3.79	3.80	3.86	3.85	3.67	3.57	3.43	3.23
D lower	1.83	1.86	1.80	1.80	1.98	1.88	1.87	1.87	1.79	1.74	1.76	1.55
D spread	1.65	1.69	1.63	1.85	1.82	1.92	1.99	1.98	1.89	1.84	1.67	1.68
C upper	3.74	3.82	3.74	3.90	4.03	3.93	3.93	3.90	3.85	3.71	3.67	3.53
C lower	1.71	1.74	1.64	1.61	1.80	1.80	1.81	1.76	1.70	1.64	1.58	1.30
C spread	2.03	2.08	2.10	2.29	2.23	2.13	2.12	2.14	2.15	2.08	2.09	2.23
Outliers	2	2	2	2	2	2	2	2	2	2	2	2

Table A3. Letter values—the share of environmental tax revenues in the total tax revenues of the EU27 in 2009–2020 (source: own study).

Measure	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Minimum	4.43	4.47	4.43	4.40	4.45	4.45	4.73	4.67	4.45	4.33	4.39	3.62
Maximum	10.62	10.81	10.56	10.28	10.81	11.28	11.75	11.66	11.23	10.87	9.85	9.89
Mean	**7.47**	**7.66**	**7.60**	**7.45**	**7.47**	**7.55**	**7.62**	**7.65**	**7.44**	**7.22**	**7.11**	**6.71**
90% CI	**±0.5192**	**±0.5423**	**±0.5365**	**±0.5421**	**±0.5801**	**±0.6110**	**±0.6396**	**±0.6282**	**±0.6021**	**±0.5651**	**±0.5619**	**±0.5451**
Mode	6.74	8.00	5.83	10.18	5.57	8.66	5.05	4.78	7.78	5.27	5.18	6.76
Median	**7.05**	**8.00**	**7.36**	**7.21**	**7.55**	**8.05**	**7.92**	**8.02**	**7.78**	**7.41**	**7.04**	**6.76**
Std Dev	1.58	1.65	1.64	1.65	1.77	1.86	1.95	1.92	1.84	1.72	1.71	1.66
Skewness	0.22	0.01	0.03	0.03	0.28	0.13	0.21	0.05	0.05	-0.01	0.10	0.26
Kurtosis	2.25	2.22	2.21	2.06	2.10	2.03	2.12	2.15	2.23	2.25	1.90	2.69
Values	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
Errors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Filtered	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M upper	**7.05**	**8.00**	**7.36**	**7.21**	**7.55**	**8.05**	**7.92**	**8.02**	**7.78**	**7.41**	**7.04**	**6.76**
M lower	**7.05**	**8.00**	**7.36**	**7.21**	**7.55**	**8.05**	**7.92**	**8.02**	**7.78**	**7.41**	**7.04**	**6.76**
M spread	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F upper	**8.63**	**8.82**	**8.73**	**8.64**	**8.59**	**8.68**	**9.04**	**8.95**	**8.67**	**8.47**	**8.45**	**7.48**
F lower	**6.43**	**6.39**	**6.27**	**6.11**	**5.90**	**5.90**	**5.84**	**6.01**	**5.87**	**5.73**	**5.87**	**5.59**
F spread	2.21	2.43	2.46	2.54	2.69	2.78	3.20	2.94	2.81	2.74	2.58	1.90
E upper	9.62	9.49	9.61	9.15	10.15	9.99	10.23	9.82	9.38	9.08	9.57	8.85
E lower	5.73	5.68	5.80	5.56	5.48	5.23	5.05	5.03	4.98	5.13	5.09	4.74
E spread	3.89	3.81	3.81	3.59	4.67	4.76	5.18	4.79	4.40	3.95	4.48	4.11
D upper	9.81	10.15	10.05	10.13	10.33	10.30	10.40	10.26	10.04	9.43	9.69	9.76
D lower	5.46	5.43	5.43	5.21	5.41	5.18	5.00	4.84	4.71	4.61	4.61	4.50
D spread	4.35	4.72	4.62	4.93	4.92	5.12	5.40	5.42	5.34	4.82	5.08	5.26
C upper	10.25	10.64	10.52	10.22	10.63	10.80	11.11	10.99	10.74	10.18	9.82	9.86
C lower	4.94	4.86	4.76	4.64	4.91	4.81	4.84	4.72	4.53	4.39	4.41	3.95
C spread	5.31	5.78	5.77	5.58	5.73	5.99	6.27	6.27	6.21	5.79	5.42	5.91
Outliers	2	2	2	2	2	2	2	2	2	2	2	2

Table A4. Letter values—the share of energy tax revenues in environmental tax revenues of the EU27 in 2009–2020 (source: own study).

Measure	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Minimum	44.66	48.64	50.81	52.77	52.30	53.64	51.59	52.33	50.83	50.27	51.05	48.30
Maximum	94.54	96.10	94.21	94.13	92.66	92.72	92.53	92.94	92.93	93.03	93.61	93.56
Mean	**75.43**	**76.64**	**77.12**	**77.54**	**77.68**	**77.67**	**77.58**	**77.84**	**77.77**	**77.61**	**77.82**	**77.44**
90% CI	**±4.403**	**±4.102**	**±3.918**	**±3.849**	**±3.734**	**±3.782**	**±3.851**	**±3.840**	**±3.991**	**±4.018**	**±4.122**	**±4.202**
Mode	84.99	87.50	93.50	88.60	87.97	83.71	83.59	88.56	92.47	92.78	83.00	76.88
Median	**78.94**	**79.14**	**80.24**	**81.32**	**80.64**	**80.25**	**81.06**	**81.36**	**80.81**	**80.46**	**80.83**	**80.27**
Std Dev	13.43	12.51	11.95	11.74	11.39	11.54	11.75	11.72	12.18	12.26	12.57	12.82
Skewness	−0.56	−0.57	−0.58	−0.56	−0.71	−0.70	−0.85	−0.85	−0.82	−0.82	−0.78	−0.84
Kurtosis	2.37	2.50	2.53	2.39	2.52	2.39	2.72	2.72	2.73	2.77	2.74	2.88
Values	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
Errors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Filtered	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M upper	**78.94**	**79.14**	**80.24**	**81.32**	**80.64**	**80.25**	**81.06**	**81.36**	**80.81**	**80.46**	**80.83**	**80.27**
M lower	**78.94**	**79.14**	**80.24**	**81.32**	**80.64**	**80.25**	**81.06**	**81.36**	**80.81**	**80.46**	**80.83**	**80.27**
M spread	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F upper	**85.05**	**85.32**	**85.93**	**86.12**	**86.52**	**86.62**	**86.46**	**86.92**	**87.13**	**86.73**	**87.68**	**88.09**
F lower	**64.52**	**66.10**	**67.39**	**67.82**	**69.18**	**70.24**	**70.86**	**71.88**	**71.61**	**71.54**	**71.65**	**72.45**
F spread	20.53	19.22	18.54	18.30	17.34	16.37	15.60	15.04	15.52	15.19	16.03	15.64
E upper	**89.53**	**88.13**	**88.71**	**88.97**	**88.39**	**88.75**	**89.59**	**89.93**	**90.65**	**89.95**	**91.85**	**91.52**
E lower	**58.69**	**61.42**	**64.03**	**63.12**	**61.22**	**60.64**	**61.14**	**61.27**	**62.27**	**61.31**	**60.06**	**57.61**
E spread	30.84	26.71	24.68	25.84	27.18	28.11	28.46	28.67	28.39	28.64	31.79	33.91
D upper	92.49	92.64	93.15	93.04	92.01	91.93	90.63	90.91	92.25	92.65	92.99	92.02
D lower	55.88	56.32	56.91	57.51	58.35	57.41	55.66	55.85	54.99	54.95	54.50	54.40
D spread	36.61	36.32	36.24	35.52	33.67	34.52	34.97	35.06	37.26	37.70	38.49	37.62
C upper	93.69	94.38	93.78	93.67	92.56	92.50	91.85	92.10	92.79	92.92	93.40	92.99
C lower	49.18	51.24	52.40	53.81	55.29	55.20	53.56	53.88	52.62	52.09	51.38	50.26
C spread	44.50	43.15	41.38	39.86	37.28	37.30	38.30	38.22	40.17	40.83	42.02	42.73
Outliers	2	2	2	2	2	2	2	2	2	2	2	2

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