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Does Environmental Tax Affect Energy Efficiency? An Empirical Study of Energy Efficiency in OECD Countries Based on DEA and Logit Model

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Abstract: OECD countries are the largest energy consuming economies in the world, improving energy efficiency and reducing pollution emissions is one of the important goals of the environmental tax policies of OECD countries. Based on the total factor energy efficiency index, this paper establishes an epsilon based measure-data envelopment analysis (EBM-DEA) model to measure the energy efficiency levels of 32 OECD countries during 1995–2016 when undesired outputs are included and not included. The effect of environmental factors on energy efficiency evaluation is compared by efficiency analysis and projection value analysis. On this basis, a Panel Logit model was established to empirically examine the impact of energy taxes on energy efficiency in 32 OECD countries. This paper finds that undesired output has a large impact on the energy efficiency level of OECD countries. Measuring energy efficiency levels without considering undesired outputs tends to lead to overestimation of the energy efficiency level of environmentally friendly countries and underestimate the energy efficiency level of countries that value environmental protection. The collection of energy tax has an important impact on energy consumption efficiency. Without considering the unexpected output, the energy tax has a significant impact on improving the efficiency of coal energy consumption. When considering the unexpected output, the energy tax has a significant impact on improving the efficiency of oil energy consumption. Regardless of the expected output or not, the energy tax has a positive effect on improving the efficiency of natural gas energy consumption. The experimental results also show that the energy structure and energy price have a negative impact on energy efficiency, while the progress of environmental protection technology and industrial structure have a positive impact on energy efficiency. Energy taxes have a "double dividend". This paper argues that when evaluating a country's energy efficiency, it should consider the undesired output factors of environmental constraints; governments should pay attention to the role of energy taxes in improving energy efficiency, improve the energy tax system, optimize industrial structure upgrades, stabilize energy prices and support the development of environmental technologies and improve energy efficiency.

Keywords: energy efficiency; energy tax; DEA model; logit model

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1. Introduction

Since the industrialization process has accelerated, the large-scale exploitation of coal, oil and natural gas has provided cheap power for economic development. At the same time, unreasonable energy use has also produced serious negative externalities, resulting in global climate change, environmental pollution and ecological damage. Sustainable use of energy is critical to a country's economic development, environmental protection and social stability. With the deepening of industrialization and the increasing demand for energy, the contradiction between energy supply and demand in the world has become increasingly acute and the strategic demand for energy innovation and development has been increasing. Governments have raised their energy strategies to national strategies. The United States is vigorously developing shale gas and implementing the "energy efficiency double plan" to increase energy self-sufficiency. Japan has canceled the "zero-nuclear power" plan internally and carried out energy diplomacy. The European Union (EU) has developed a strategy to develop new energy vehicles to implement clean energy. At present, the energy problems of various countries are facing the red line of ecological protection, the multiple constraints of the energy security red line and the bottom line of economic growth. Under the dual pressures of economy and environment, improving energy efficiency has become the first breakthrough to solve the energy problem. According to statistics from BP Petroleum, the OECD countries have been the world's largest economy since the 20th century, and their primary energy consumption accounts for about 60% of global energy consumption. BP predicts that while the global energy demand model is undergoing an energy transition and developing countries are strengthening their role as a major market for energy consumption, the OECD remains the world's largest energy-consuming economy for the next 20 years (see Figure 1). At the same time, the primary energy consumption of developing countries represented by India and China will continue to increase, and the actual demand for improving energy efficiency will continue to increase. From the perspective of OECD countries, it is necessary to study ways to address the bottlenecks encountered in the process of energy efficiency not only for the current OECD countries, but also for China, India and other countries with high energy consumption.

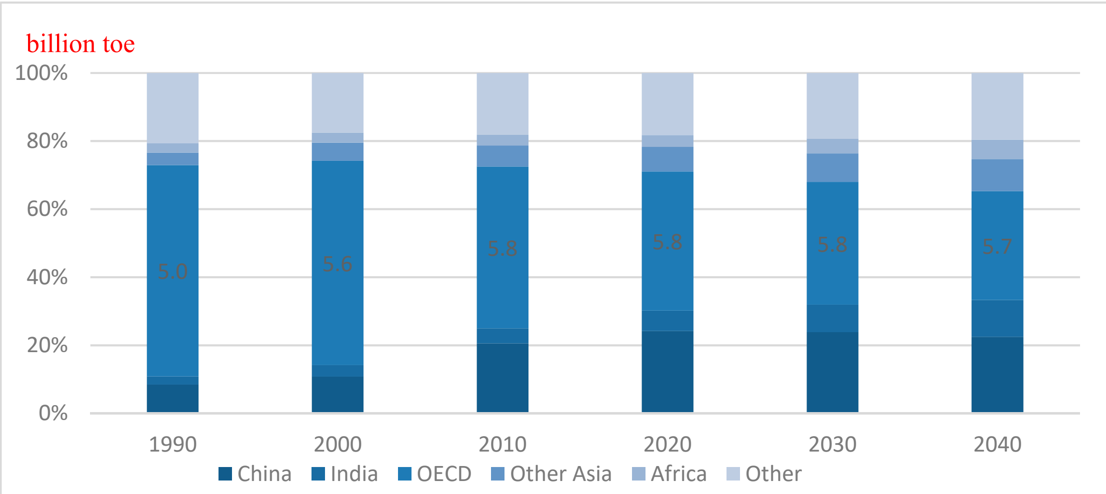

Figure 1. Primary energy consumption by region.

With environmental and ecological problems becoming more serious, in 1972, the United Nations Environment Program held a meeting on human environment in Stockholm, which first raised development and environmental issues and adopted the Declaration on the Human Environment. In 1987, the World Commission on Environment and Development published a report on Our Common Future, which recognized the principles of sustainable development that concern environmental protection. Strengthening environmental protection and using tax enforcement measures to control global environmental degradation have gradually become the core issues in the study of sustainable development of the world economy. In 1920, the British modern economist and founder of welfare economics, Pigou published the book "Welfare Economics", and began to systematically study the theoretical issues of environment and taxation, and first proposed that "the government use tax policy to regulate environmental pollution behavior". Since the concept of environmental tax has been proposed, as one of the means to control environmental pollution, environmental tax has received increasing attention from governments. The OECD countries are the earliest countries in the world to levy environmental taxes. From the 1970s to the early 1980s, based on the principle of "polluter pays", their member states successively formulated and implemented a series of legal systems related to environmental taxation. The polluters afford the cost of monitoring the sewage discharge, and the types mainly include user fees and special-purpose charges, which constitute the prototype of the early environmental tax. From the 1980s to the mid-1990s, the types of environmental taxes were increasing, and taxes such as sewage tax, product tax, energy tax, carbon dioxide tax, and sulfur dioxide tax began to appear. The mid-1990s was a period of rapid development of environmental taxes in order to implement sustainable development strategies. OECD countries have implemented fiscal and taxation policies that are conducive to environmental protection, and many countries have also implemented comprehensive environmental tax reforms. With the improvement of the environmental tax system, the proportion of environmental taxes in total tax revenue has gradually increased. Since the beginning of the 21st century, the proportion of environmental taxes and total taxes in Iceland, South Korea, Lithuania, Turkey and other countries has even exceeded 10%. The environmental taxes collected during this period mainly include energy tax, vehicle traffic tax, carbon tax, resource tax, pollution tax, etc. Among them, energy tax accounted for the largest proportion, almost reaching more than 70% of the total environmental tax (see Figure 2). The taxation of the energy tax is mainly for various energy products (fossil fuels and electricity), products for transportation (gasoline and diesel), and all taxes related to carbon dioxide. Energy taxes account for such a high proportion in environmental taxes, and they have gradually attracted the attention of the academic community. It is a common goal of governments to formulate an effective energy tax system that suits the national conditions.

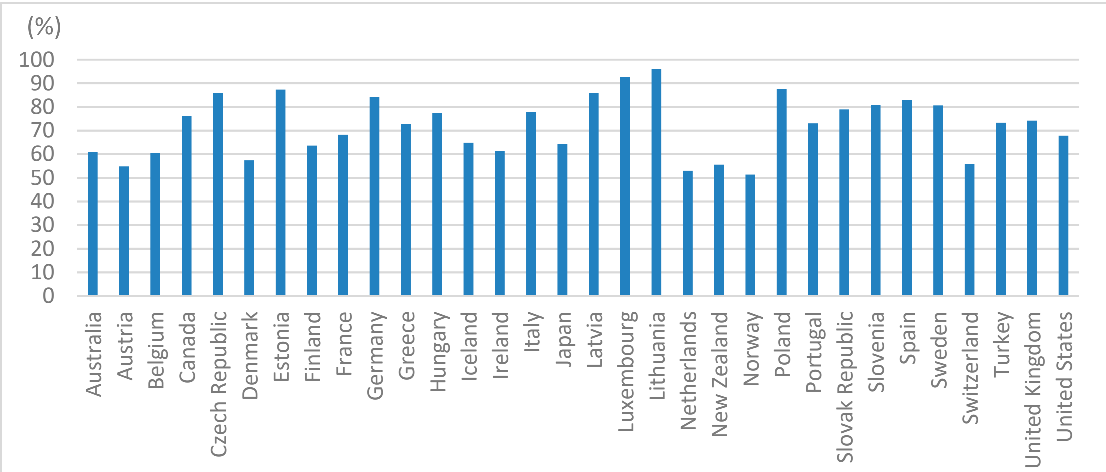

Figure 2. Share of energy tax in total environmental tax.

One of the important goals of environmental tax policies in OECD countries is to save energy and reduce emissions, improve energy efficiency and reduce unit energy consumption. The improvement of energy efficiency is of vital importance to economic development. Improving energy efficiency is the core and key to building a conservation-oriented society and reducing social energy consumption. The improvement of energy efficiency can increase the total output of the whole society while reducing the total amount of social energy consumption. However, due to the rebound effect of energy consumption, technological progress has reduced the relative effective using price of energy services while improving energy efficiency. Stimulating more energy usage will "eat away" energy saved by energy efficiency. As a result, the value of energy consumption reduction may be lower than expected. If a certain proportion of energy taxes are imposed on energy at this time, and indirectly increase the effective use price of energy, it can effectively encourage households and enterprises to consider the environmental externalities of energy conversion and usage. It is possible to further reduce social energy consumption on the basis of basically not affecting the total output of society, while achieving low input and high output. Jaume Freire-González and Ignasi Puig-Ventosa [1] applied a dynamic and computable general equilibrium model and conduct a case study in Spain, they find that only taxes on coal, oil and natural gas power can have a better impact on the environment and economy. Pearce, D (1991) [2] proposed the "double dividend" theory of environmental tax when studying the carbon tax reform. The theory holds that the introduction of environmental taxes will bring two bonuses. The first dividend is "green dividend", which means that the introduction of environmental taxes can effectively suppress pollutant emissions, thereby improving environmental quality; the second dividend is "blue dividend", which means that increased environmental tax revenue can be transferred through tax burden. Reduce the tax burden of tax-distorting taxes such as income tax and capital tax, promote employment and improve economic growth efficiency. In the case of comprehensive measurement of energy efficiency by economic efficiency and environmental efficiency, the larger the GDP, the less environmental pollution emissions and the higher the energy efficiency. According to the double dividend theory of environmental taxes, the levy of energy tax has the dual functions of energy saving and emission reduction and promoting development, that is, indirectly improving energy efficiency. Therefore, studying the relationship between energy tax and energy efficiency and exploring whether energy tax can improve energy efficiency is an important test for whether the energy tax of OECD countries has a double dividend, and is also an important test for the realization of the environmental tax policy objectives of OECD countries. The formulation of the future energy strategy of OECD countries, the design of energy taxation system and the improvement of environmental tax system have important guiding significance, and also have reference and reference significance for the formulation of energy and taxation policies in non-OECD countries.

In this paper, the energy efficiency value analysis and projection value analysis of OECD countries are carried out by using the method of total factor index measurement. From the perspective of input-output variables, it is found that OECD countries need to pay attention to improving energy efficiency. By studying the relationship between energy tax and energy efficiency and testing the effect of energy tax dividends in OECD countries, this paper starts from the industrial structure, technological progress and energy prices to find ways to improve energy efficiency in OECD countries. This paper argues that when evaluating a country's energy efficiency, the environmental related undesired output factors of constraints should be taken into account. Governments should pay attention to the role of energy taxes in improving energy efficiency, improve the energy tax system, optimize industrial structure upgrades, stabilize energy prices and support the development of environmental technologies and improve energy efficiency.

The rest parts of this article are arranged as follows: the second part of the paper is a review of the previous literature, the third part is the data and model introduction, the fourth part shows the empirical results and analysis, the fifth part summarizes.

2. Literature Review

In the current research on energy efficiency, the selection of energy efficiency measurement indicators and the choice of measurement methods are two key issues. In terms of index selection, some scholars use the ratio of economic output to energy input in the production process (single factor energy efficiency) as a measure of energy efficiency. The single factor energy efficiency index accurately measures the size of economic output under the same energy input; the calculation process is simple, the operation method is relatively simple, and the index decomposition can be performed, which is conducive to further analyze the marginal impact of different factors (such as industrial structure, technological progress, etc.) on energy efficiency. However, this index only simply examines the proportional relationship between energy input and output, ignoring the mutual substitution of different input factors and the influence of various "non-efficiency" factors on energy input, which may amplify the role of energy input to some extent. Vlahinić-Dizdarević and Šegota (2012) [3] established CCR-DEA multi-input model to study energy efficiency changes in the EU economies during the period 2000–2010 and analyzed efficiency in producing GDP of three inputs including capital stock, labor and energy consumption. Their results confirm that the traditional one-factor energy efficiency indicators are too simple and may be misleading. In view of this, some scholars recommend the use of total factor energy efficiency indicators (Hu and Wang (2006) [4]). Because this indicator not only considers the energy input problem in the specific calculation, but also takes into account the input of other production factors such as capital and labor and comprehensively examines the interaction between the input elements of the economic entity, so the total factor energy efficiency indicator is gradually replaced. The single factor energy efficiency indicator has become the main measurement method for research and evaluation of energy efficiency indicators. Therefore, this paper also uses the total factor energy index to measure energy efficiency. Most of the existing literature on total factor energy efficiency indicators use economic output such as GDP as the only indicator to measure energy efficiency. However, these studies generally ignore the impact of environmental factors on energy efficiency in the process of energy use. Due to current technical conditions, input factors cannot be converted into economic output 100%. Therefore, in the process of energy utilization, some "by-products" will inevitably occur. Most of the previous studies have focused on expected output such as GDP, but have neglected the impact of undesired output such as environmental pollution emissions, which has distorted the evaluation results of energy efficiency to a certain extent, leading to deviations in research on factors affecting energy efficiency. Zhang, Joglekar and Verma [5] proposed that successful environmental sustainability programs aim to achieve both environmental and economic benefits. Benchmarking these initiatives must take into account environmental and economic outcomes. Li et al. [6] found that the non-carcinogenic risk of Hg probably posed adverse health effects in 41, 30 and36% in the surface soil, the moderate soil subsoil, respectively, under a sensitive land scenario. It may pose a risk to receptors living nearby. So, a risk-based integrated risk management policy was proposed with consideration of the cost benefit effect. Besides., Li et al. [7] use a probabilistic integrated ecological risk assessment method (PIERA) to research e distribution, bioavailability and probabilistic integrated ecological risk assessment of heavy metals in sediments from Honghu Lake, the results indicated that Cd mainly originated from both non-point agricultural and industrial pollution sources. Important strategies should be implemented to reduce discharge of industrial wastewater in Honghu Lake watershed and to control agricultural non-point sources, mainly including aquaculture net enclosure culture, chemical fertilizer and pesticide using. At the same time, Li et al. [8] found that with the rapid urbanization, excessive inputs of heavy metals into urban soils owing to their toxicity, persistence and bioaccumulation took place. Pollution characteristics of heavy metals in urban soils has bad effects on people's health and the urban environment. Cheng and Liu [9] find that most previous studies do not consider pollution when measuring energy efficiency, and the results were partially distorted in the environment. They considered the adverse factors under DEA approach, such as wastewater, waste gas and solid waste. They proposed a non-parametric method based on data envelopment analysis (DEA) to measure energy efficiency and concluded the DEA model with bad output as a by-product is more suitable for energy efficiency measurement. Vencheh [10], Bian, Liang, Xu [11] and many other scholars also believe that adding non-expected output to evaluate economic efficiency and environmental efficiency is more objective. Therefore, this paper puts environmental pollution variables into the energy efficiency model when measuring the energy efficiency of OECD countries and studies the energy efficiency under the undesired output including environmental pollution factors and the traditional containing only expected output such as GDP.

Some researchers have looked at the sector that is most in need of energy efficiency from a departmental perspective. Malinauskaite et al. [12] studied the extent to which the energy policies of European countries in specific jurisdictions such as Italy and the UK solved the energy efficiency problem in industry. They believed that more attention should be paid to industrial energy efficiency. Zeng, J.; Liu, Y.; Feiock, R.; Li, F [13] use panel data from 27 provinces and four direct-controlled municipalities over the period from 2003 to 2016. They found that governmental energy control policies (emission reduction policies and renewable energy policies) may lead to large reductions in air pollutant emission. Bretschge and Zurich [14] studied long-term and medium-term energy scarcity and endogenous capital formation and found that energy efficiency depends on the sect oral structure of the economy, and that industrial structure reform is an effective way to promote efficiency and sustainable development. In the study of energy tax and energy efficiency, Conrad K [15] studied the interaction between energy tax and energy price and energy efficiency, as well as the impact of the improvement of energy efficiency on product price, and found that the direct impact of higher energy price on demand can be partially offset by the technology promoting the production of more energy efficiency equipment in the automobile industry. Goulder and Lawrence H [16] quantified the difference in the impact of the energy tax and its income tax alternatives on pollution emissions and found that for each of the eight major air pollutants considered, the energy tax would result in emissions reductions at least nine times greater than those of the income tax alternatives. Guo, J.Y.; Jiang, S.L.; Pang, Y.J. Guo, J.Y.; Jiang, S.L.; Pang, Y.J. [17] analyze the enhancing mechanisms by examining changes in sludge zeta potential, extracellular polymeric substances (EPS), and microstructure. They propose that preparation and application of rice straw biochar (RSB) that modified by AlCl3 can be a feasible way to reduce sludge volume in municipal sewage treatment plants. Therefore, using technology to develop new materials is conducive to improving energy efficiency. Meanwhile they (Guo, J.Y.; Chen, C et al. [18]) explore mechanisms for sludge dewatering among the coagulation−flocculation process. The biopolymer could be an environmentally friendly way to enhance dewatering, the dynamic variation in distribution and composition of EPSs can clarify the dewatering mechanism, and the combined PACl coagulation and biopolymer flocculation may be a promising technology in sludge dewatering in WWTPs. Abolhosseini, Heshmati and Altmann [19] rejected the traditional view that economic growth promotes environmental quality. They found that it is more effective to mitigate environmental degradation through governance parameters rather than economic development, such as environmental technologies and energy tax instruments. Bjorner T B, Jensen H H [20] estimated the energy demand model of industrial enterprises in a large micro-panel database and quantitatively studied the impact of different policy tools, including carbon dioxide tax, on reducing energy consumption. On the basis of the existing research, this paper combines various factors that are considered in the existing research to affect energy efficiency, including energy tax tools, environmental protection technology, industrial structure, energy structure and other variables, and examines the methods to improve energy efficiency in various aspects.

Compared with previous studies, the marginal contribution of this paper is mainly reflected in the following points: First, based on the epsilon based measure-data envelopment analysis (EBM-DEA) model, this paper respectively calculates the energy efficiency without environmental constraints and the energy efficiency with environmental constraints using the total factor index method. The research method overcomes the shortcomings of the traditional performance evaluation method. This paper finds that, when evaluating the energy efficiency of a country or region, non-expectation factors such as environmental pollution should be taken into account. Second, some OECD countries levied environmental taxes earlier in the world. This study covers 32 OECD countries and lasts for 21 years. This paper finds that energy tax has a significant positive effect on improving energy efficiency, which can play a certain inspiring and helpful role for those countries trying to improve their energy efficiency and formulate environmental tax policies. Third, existing studies on the relationship between energy taxes and energy consumption tend to use single energy consumption indicators, emission indicators or economic growth indicators. In this paper, the economic and environmental performance of energy consumption is integrated by using the energy efficiency indicators including the undesired output and efficiency indicators without undesired output when selecting the output variables. Fourth, this paper investigated the relationship between energy tax and energy efficiency in OECD countries through the binary discrete choice Logit model. Logit model can not only predict in the sample, but also predict the data out of sample, which makes the empirical conclusion more reliable.

3. Data, Samples and Models

In order to ensure the principle of homogeneity among the research objects, this paper identifies the research objects as OECD countries. Among the 36 OECD countries, Chile, Israel, South Korea, Mexico lack emission data of nitrogen oxides, sulfur oxides, carbon monoxide and methane, which are not included in the scope of this study. Therefore, the final sample of this study is 32 OECD countries. In view of the original availability of the data, the scope of the study is 1995-2016. This paper is divided into two stages. The first stage is EBM-DEA data envelopment model, which measures the energy efficiency of 32 OECD countries in 1995–2016. The second stage is panel binary discrete choice logistic regression Panel Logit model, which studies the impact of energy tax on energy efficiency. The data in this paper are from OECD database, BP Oil Company Open Data and World Bank database. The data sources and model variables are detailed in Table 1.

Table 1. Variable statistics and data sources.

		Variable	Calculation Method	Data Source
EBM-DEA Model	Input variables	Coal consumption	Million tones oil equivalent	BP Oil Company Open Data
		Oil consumption	Million tonnes	BP Oil Company Open Data
		Gas consumption	Billion cubic meters	BP Oil Company Open Data
		Human resources	Total Labor Force, Millions	World Bank Database
		Capital	Total Capital Formation, Current Millions of Dollars	World Bank Database
	Output variables	Gross Domestic Product	US Dollar, Millions	World Bank Database
		Sulfur Oxides	Tonnes, Thousands	OECD Database
		Nitrogen Oxide	Tonnes, Thousands	OECD Database
		Carbon Monoxide	Tonnes, Thousands	OECD Database
		Carbon Dioxide	Tonnes of CO2 equivalent, Thousands	World Bank Database
		Methane	Tonnes of CO2 equivalent, Thousands	OECD Database
Panel Logit Model	Dependent variable	Energy Efficiency without Unexpected Output-Coal	Target consumption/Actual consumption	DEA model calculation
		Energy Efficiency without Unexpected Output-Oil	Target consumption/Actual consumption	DEA model calculation
		Energy Efficiency without Unexpected Output-Gas	Target consumption/Actual consumption	DEA model calculation
		Energy Efficiency Including Unexpected Output-Coal	Target consumption/Actual consumption	DEA model calculation
		Energy Efficiency Including Unexpected Output-Oil	Target consumption/Actual consumption	DEA model calculation
		Energy Efficiency Including Unexpected Output-Gas	Target consumption/Actual consumption	DEA model calculation
	independent variable	ENE_TAX	Energy Tax/Total Environmental Tax Revenue	OECD Database
		ENE_TAX(GDP)	Energy Tax/GDP	OECD Database
		ENE_TAX (Total)	Energy Tax/ Total Tax Revenue	OECD Database
	Control variable	Energy price	energy CPI	World Bank Database
		Energy structure	Fossil fuel energy consumption /total energy consumption	World Bank Database
		Environmental protection technology	Environmental Protection Technology/Total Technology	OECD Database
		Industrial structure	Industrial added value/GDP	World Bank Database

The DEA method established by Farrell (1957) and Charnes et al. (1978) is a model for calculating the input-output relationship of different decision-making units. The optimal frontier of the sample is constructed by using the actual observation data of the decision unit, and the relative efficiency of the decision unit is evaluated according to the distance between the production point of each decision unit and the optimal frontier surface. Therefore, the measurement process does not need to presuppose the production function form. It avoids the subjective bias of model setting and is more suitable for solving multi-input and multi-output problems. At present, this method has been widely used in energy efficiency research. Combined with the total factor energy efficiency index and the energy efficiency level considering the undesired output, this paper measures the total factor energy efficiency based on the DEA method.

Traditional DEA models can be divided into two categories, one based on radial (Radial) and angled (Oriented) CCR-DEA and BCC-DEA models. However, such models often cannot effectively solve the inefficiency caused by the slack in input and output. Tone (2001) [21] proposed another type of non-radial and non-oriented Slacks-based Measure (SBM) model, which will be non-radial relaxation. The variable is introduced into the objective function, which effectively solves the measurement error caused by radial and angle selection in the previous DEA model. A method for measuring the efficiency of data envelope analysis based on relaxation is proposed. However, this optimization method not only sacrifices the original information of the efficiency front projection value, but more and more empirical studies show that the optimal relaxation zero value and positive value will have a significant impact on the measurement results. Therefore, Tone and Tsutsui (2010) [22] constructed an Epsilon-based Measure (EBM) model combining the advantages of radial DEA and non-radial DEA based on the CCR model and the SBM model, introducing two connection paths. The parameters of the radial and non-radial models effectively overcome the shortcomings of the above two types of DEA models. Therefore, this paper chooses to establish the above EBM-DEA model to specifically measure the total factor energy efficiency in various regions. While producing the expected output (such as GDP), the production process inevitably produces some non-expected output (such as CO_2, CO, SO_2 and other emissions), which requires the construction of a possible production set containing both expected output and non-expected output. According to this demand, this paper adopts the total factor energy efficiency index to calculate the energy efficiency under the condition of more input and more output. Input factors are coal consumption, oil consumption, natural gas consumption, human resources, and capital. In order to study the impact of unexpected factors such as environmental pollution on energy efficiency, we established two DEA models. One is the DEA model with no unexpected output. The output variable of this model is GDP. The other is the DEA model with unexpected and expected outputs, whose variables include emissions of nitrogen oxides, sulfur oxides, carbon monoxide, carbon dioxide, methane and GDP.

There are K$(k = 1, 2, \ldots, k)$ kind of Decision Making Units (DMU), Each DMU has N $(n = 1, 2, \ldots, N)$ kind of inputs and M$(m = 1, 2, \ldots, M)$ kind of outputs. Input matrix and expected output matrix are respectively expressed as: X $= x^{nk}$, $\mathcal{R}^{N\times K}$,Y $= y^{mk}, \mathcal{R}^{M\times K}$ and X > 0, $Y > 0$, expressed as follows:

$$\tau^* = min\left(\theta - \varepsilon\sum_{n=1}^{N}\frac{\omega_n s_n}{x_{no}}\right),\ 0 \le \tau^* \le 1$$

$$\text{s. t.} \sum_{k=1}^{K}\lambda_k x_{nk} + \overline{s_n} = \theta x_{n0}(n = 1, 2, \ldots, N)$$

$$\sum_{k=1}^{K}\lambda_k y_{nk} \ge y_{m0}(m = 1, 2, \ldots, M)$$

$$\lambda_k \ge 0, \overline{s_n} \ge 0$$

The τ^* is for energy efficiency, the closer τ^* is to 1, the more energy efficient it is, λ is the weight vector, the subscript 0 represents each decision unit evaluated by the model. θ is the efficiency of the radial model calculation values, $\overline{s_n}$ is the non-radial slack variable of the input element,ε is the key parameter to combine radial θ and the non-radial slack variable $\overline{s_n}$.

Panel Logit model not only has the advantages of Logit regression model, but also has the advantages of Panel data model. At the same time, time series data and sectional data were used to provide more information and dynamic changes of financial indicators, which improved the regression accuracy of the model. At the same time, since the data selected in this paper is panel data, and the energy efficiency index of the explained variable is a binary selection variable, the statistical models that usually take binary selection variable as the explained variable all choose probit model and logit model. Panel probit model requires that the random error should be normally distributed, while the Panel Logit model does not. Therefore, the Panel Logit model is selected in this paper. In this paper, when building the Logit model, corresponding to the analysis and calculation results of EBM-DEA data envelopment model, the samples that are located in the efficiency frontier are denoted as 1, and the samples that are not in the efficiency frontier are denoted as 0. The Panel Logit model mainly includes fixed effect model and random effect model. Among them, the individual effect of the random effect model is not related to all explanatory variables. Individual effects in fixed-effect models are associated with one or more explanatory variables. The Panel Logit model with individual effect model is shown as follows:

$$y_{it}{}^{*} = \sigma_i + x_{it-1}\beta + \mu_{it}$$

where $y_{it}{}^{*}$ is the individual effect, x_{it-1} is the value in the year t − 1 of countryi,μ_{it} is the random error term. μ_{it} is in dependent of the explanatory variable x_{it-1}, $y_{it}{}^{*}$ is an implicit variable of the observable binary selection variable y_{it}, means the explanatory variables, they are represented by 0 and 1 respectively as follows:

$$y_{it} = \begin{cases} 1(y_{it}{}^{*} = 1) \\ 0(y_{it}{}^{*} < 1) \end{cases}$$

When $y_{it} = 1$, is the country on the data envelope where the energy efficiency value is equal to 1, and t is the year in which the sample on the data envelope is located. When $y_{it} = 0$, is the country that has not reached the sample on the data envelope, the efficiency value < 1, and t is the year in which the sample has not yet reached the data envelope. In this paper, when using logit model, we need to convert the continuous variables of energy efficiency into binary variables. We use the value of energy efficiency greater than 0.5 as the experimental boundary point to distinguish the dependent variables from 0 or 1.

4. Empirical Results and Analysis

In order to analyze the energy efficiency levels of 32 OECD countries and explore the impact of environmental factors on the energy efficiency of OECDs, this paper establishes an EBM-DEA model including undesired outputs and without undesired outputs to measure the energy efficiency of each decision-making unit. The calculation results show the efficiency values of each decision unit and its slack and residual variables. The Efficiency Value Analysis is carried out in turn to obtain the overall level of energy efficiency and individual differences of each decision-making unit, providing information on the horizontal comparison of energy efficiency among countries, and performing Projection Value Analysis to find weak links in countries with low energy efficiency, and improving energy efficiency for the future. The work provides a basis for guiding decision-making, and the Panel Logit model is further explored to further explore the relationship between energy tax and energy efficiency, and to provide further improvement strategies for improving energy efficiency.

4.1. Efficiency Value Analysis

Through the Efficiency Value Analysis, the efficiency value scores of each decision-making unit can be obtained, and the international economic horizontal value comparison analysis is carried out on the energy efficiency value levels of 32 OECD countries, and those efficiency front countries located on the data envelope are found.

To observe more closely the impact of undesired output factors on the energy efficiency levels of countries, Figure 3 shows the comparison of energy efficiency values without undesired outputs and including undesired outputs. It can be seen that when considering the undesired output factors, the energy efficiency levels of Australia, Austria, Germany, Iceland, Japan, Lithuania, Norway, Sweden, Switzerland, and the United Kingdom have increased significantly, indicating that when these countries consume fossil energy, their emission reduction work has also been carried out simultaneously and has achieved benign results, and the assessment of energy efficiency levels without considering environmental undesired factors will lead to underestimation of the energy efficiency levels of these countries. This also includes Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, the Netherlands, New Zealand, Poland, Portugal, Slovak, Slovenia, Spain, USA, etc. Countries' energy efficiency levels without unanticipated outputs are significantly higher than energy efficiency levels that include expected output, and energy efficiency is overestimated when environmental factors are not considered.

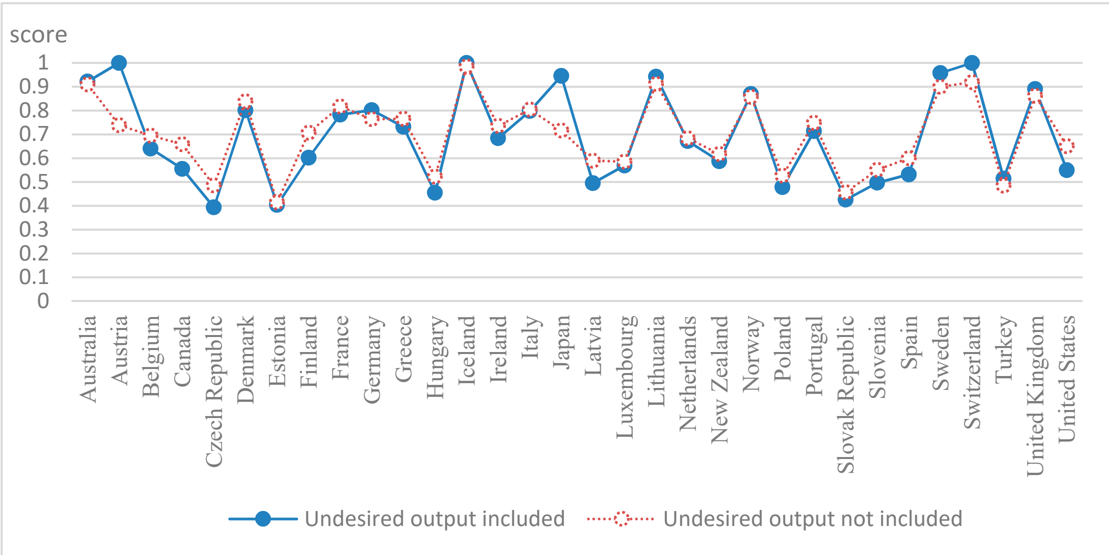

Figure 3. Energy efficiency comparison including undesired outputs.

Therefore, the traditional energy efficiency evaluation method that does not include the expected output value may overestimate the energy efficiency for some countries that do not pay much attention to environmental protection work and underestimate the energy efficiency of countries that have achieved good results in environmental protection work. The result affirms the necessity of incorporating environmental factors in evaluating energy efficiency, and comprehensively evaluates energy efficiency from the economic and environmental perspectives, thereby stimulating the vigorous promotion of energy use and environmental protection in OECD countries.

As mentioned earlier, when using DEA model to study energy efficiency in traditional literature, output variables are usually used such as expected output type of GDP, which may mislead people's assessment of real energy efficiency. From the environmental point of view, the improvement of energy efficiency not only means the increase of GDP per unit input, but also the continuous reduction of environmental pollution emissions such as sulfur dioxide, carbon dioxide, nitrogen oxides, smoke and dust. We call the output of these pollutants "unexpected output". Therefore, only considering the expected output of energy efficiency calculation may make the efficiency value overestimated or underestimated.

As shown in Figure 3, the red dotted line represents the energy efficiency value without considering the unexpected output; the blue solid line represents the energy efficiency value with considering the unexpected output. For example, in Austria and Japan, if the unexpected output is not taken into account, the calculated energy efficiency of these two countries is about 0.7. After considering the unexpected output, we use DEA model to calculate the energy efficiency value. These two countries are about 1 and belong to high efficiency countries. It can be seen that the energy efficiency level of these two countries has been artificially underestimated. After considering the unexpected output, we find that the energy efficiency of these two countries is excellent.

4.2. Projection Value Analysis

Based on the efficiency values of each DMU, the projection value analysis further explores the reason why the efficiency of the decision-making unit that has not reached the efficiency front is low. Due to space limitations, this paper only uses the efficiency values of countries in 2016 to conduct specific projection value analysis, and find ways to improve efficiency values in various countries. Figure 4 presents the 2016 national energy efficiency scores without desired outputs and including desired outputs. In the absence of undesired outputs, eight countries including Australia, Greece, Iceland, Luxembourg, Norway, Sweden, Switzerland and the United Kingdom formed the frontier of the data envelope with an efficiency value score of 1. Other countries have relatively low levels of efficiency, and have not achieved optimal efficiency. In case of including undesired output, 12 countries including Australia, Austria, Greece, Iceland, Italy, Japan, Luxembourg, Norway, Portugal, Sweden, Switzerland and the United Kingdom form the frontier of the data envelope together. Other countries have low relative efficiency levels and have not reached the efficiency front. The projection value analysis will answer the reasons why the above-mentioned countries have not reached the efficiency front, the gap between the above countries and the countries on the envelope, and the improved work direction needed to shorten these gaps.

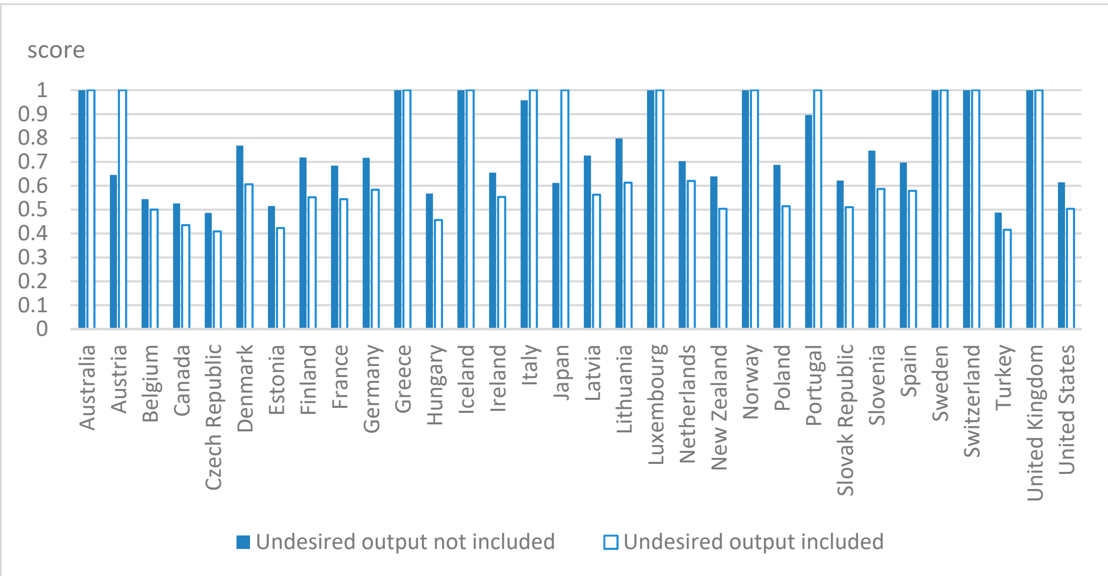

Figure 4. Efficiency value score of Organization for Economic Co-operation and Development countries (OECDs) in 2016.

Table 2 presents the national slack variable S^{-} and the residual variable S^{+} without undesired outputs in 2016. S1+ means "Coal consumption", S2+ means "Oil consumption", S3+ means "Gas consumption", S4+ means "Human resources", S5+ means "capital investment", S6+ means "output variables". It can be seen that reducing energy input is the direction in which most countries will work hard to move toward in the future. From the perspective of input variables, the excessive consumption of coal is a place for improving the efficiency value of countries other than Lithuania that are not on the envelope. These countries need to reduce the amount of coal used and transfer energy demand to clean energy in the future. Excessive oil investment in 12 countries including Belgium, Canada, Estonia, Hungary, Italy, Latvia, Luxembourg, the Netherlands, Slovakia, Slovenia and Spain has affected their energy efficiency further. These countries should reduce oil investment in the future. For Austria, Belgium, Canada, Denmark, Estonia, France, Germany, Hungary, Ireland, Italy, Japan, Latvia, Luxembourg, the Netherlands, New Zealand, Poland, Portugal, Slovak, Slovenia, Spain, Turkey and the United States, the excessive investment in natural gas has had a negative effect on the level of energy efficiency, and these countries should reduce the amount of natural gas used in the future. In terms of human resources investment, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Japan, Latvia, Luxembourg, the Netherlands, New Zealand, Poland, Portugal, Slovakia, Slovenia, Spain, the United Kingdom and the United States, the excessive investment in human resources has affected the further improvement of their energy efficiency levels. These countries should properly control human resources investment in the future. From the perspective of capital investment, Ireland's capital investment has affected its energy efficiency level. In the future development process, Ireland will focus on reducing capital investment while maintaining output levels. From the perspective of output variables, there is no redundancy in the output variables of each country. In general, while maintaining a steady increase in output levels, reducing energy input is the focus of future work for most OECD countries.

Table 2. Slack variables without undesired outputs of OECDs in 2016.

Decision Making Unit	Slack Variable					Residual Variable
	S_1^-	S_2^-	S_3^-	S_4^-	S_5^-	S_1^+
Australia	0.000	0.000	0.000	0.000	0.000	0.000
Austria	−2.453	0.000	−3.732	−1.526	0.000	0.000
Belgium	−1.911	−3.140	−5.873	−1.597	0.000	0.000
Canada	−13.918	−11.977	−66.259	−8.437	0.000	0.000
Czech Republic	−11.090	0.000	0.000	−1.373	0.000	0.000
Denmark	−1.861	0.000	−0.780	−1.038	0.000	0.000
Estonia	−2.921	−0.009	−0.031	−0.420	0.000	0.000
Finland	−3.970	−3.119	0.000	−1.034	0.000	0.000
France	−6.175	0.000	−18.532	−12.405	0.000	0.000
Germany	−70.194	0.000	−46.858	−22.857	0.000	0.000
Greece	0.000	0.000	0.000	0.000	0.000	0.000
Hungary	−1.390	−2.580	−4.113	−2.391	0.000	0.000
Iceland	0.000	0.000	0.000	0.000	0.000	0.000
Ireland	−1.402	0.000	−1.627	0.000	−13369.696	0.000
Italy	−2.046	−2.943	−10.740	−0.867	0.000	0.000
Japan	−99.700	0.000	−50.065	−28.371	0.000	0.000
Latvia	−0.013	−0.410	−0.860	−0.828	0.000	0.000
Luxembourg	−0.052	−1.608	−1.071	−1.050	0.000	0.000
Lithuania	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	−8.909	−1.580	−21.076	−4.603	0.000	0.000
New Zealand	−0.924	0.000	−2.182	−1.119	0.000	0.000
Norway	0.000	0.000	0.000	0.000	0.000	0.000
Poland	−43.906	0.000	−9.158	−12.793	0.000	0.000
Portugal	−1.175	0.000	−1.132	−2.339	0.000	0.000
Slovak Republic	−2.317	−0.409	−0.752	−1.060	0.000	0.000
Slovenia	−1.076	−0.428	−0.159	−0.752	0.000	0.000
Spain	−8.550	−0.897	−8.560	−15.018	0.000	0.000
Sweden	0.000	0.000	0.000	0.000	0.000	0.000
Switzerland	0.000	0.000	0.000	0.000	0.000	0.000
Turkey	−25.096	0.000	−6.734	−12.195	0.000	0.000
United Kingdom	0.000	0.000	0.000	0.000	0.000	0.000
United States	−280.141	0.000	−411.090	−55.094	0.000	0.000

Table 3 presents the national slack variable S^- and the residual variable S^+ including undesired outputs in 2016. It can be concluded that when considering the environmental impact of energy efficiency, reducing energy consumption and reducing various types of gas emissions are the key tasks for OECD countries to improve energy efficiency in the future. From the perspective of input variables, excessive coal investment in Belgium, Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Lithuania, Norway, Portugal, Sweden, Switzerland, and the United States has had a negative impact on national energy efficiency. Excessive oil consumption is a node that needs to be focused on to further improve energy efficiency levels in Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Latvia, Luxembourg, the Netherlands, New Zealand, Poland, Slovenia, and Spain. Excessive natural gas investment in energy efficiency in countries such as Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Latvia, Luxembourg, the Netherlands, New Zealand, Poland, Slovakia, Slovenia, Spain, Turkey, and the United States has negative effects. Further control of fossil energy input and the transfer of energy demand to clean energy are important directions for the improvement of energy work in the countries mentioned above. Excessive human resources investment occupies excess funds and resources, and may even increase energy input, hindering technological progress. As a result, funds and resources for energy efficiency improvement will be reduced, which will have a negative impact on energy efficiency. Excessive human resources investment in Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Latvia, Luxembourg, the Netherlands, New Zealand, Poland, Slovak, New Zealand, Turkey, the United States and other countries have also played a negative energy efficiency role. Excessive capital investment is still an important reason for the energy efficiency level in Ireland. From the perspective of output variables, undesired output is excessive in Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Latvia, Luxembourg, the Netherlands, New Zealand, Poland, Slovakia, Slovenia, Spain, Turkey, the United States, etc. Excessive emissions of nitrogen oxides, sulfur oxides, carbon dioxide, carbon monoxide and methane have a negative impact on the improvement of energy efficiency. The above-mentioned countries should reduce energy consumption, especially fossil energy consumption, while keeping economic output growing steadily, shifting energy demand to clean energy such as renewable energy, and doing a good job of reducing emissions.

Table 3. Slack variables including undesired outputs of OECDs in 2016.

Decision Making Unit	Slack Variable					Residual Variable					
	S_1^-	S_2^-	S_3^-	S_4^-	S_5^-	S_1^+	S_2^+	S_3^+	S_4^+	S_5^+	S_6^+
Australia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Austria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	−1.91	−3.14	−5.87	−1.60	0.00	−1877.56	−20.50	−8333.42	−81.72	−1199.61	0.00
Canada	−13.92	−11.98	−66.26	−8.44	0.00	−21382.73	−820.84	−159181.11	−4001.69	−60806.26	0.00
Czech Republic	−13.06	0.00	−4.39	−3.10	0.00	−3692.89	−101.64	−55901.45	−559.28	−9240.38	0.00
Denmark	−2.03	−3.22	−1.86	−1.00	0.00	−4229.34	−6.18	−18512.78	−175.73	−4776.85	0.00
Estonia	−2.92	−0.01	−0.03	−0.42	0.00	−546.00	−23.99	−13269.96	−89.58	−562.93	0.00
Finland	−4.27	−6.15	−0.92	−1.02	0.00	−3822.93	−38.61	−30951.20	−271.95	−3138.91	0.00
France	−7.55	−38.45	−32.36	−12.30	0.00	−32648.48	−131.69	−167077.46	−1991.28	−38927.21	0.00
Germany	−74.58	−35.72	−60.77	−23.05	0.00	−25983.15	−313.76	−456592.17	−1866.99	−29322.45	0.00
Greece	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hungary	−1.88	−0.87	−6.49	−3.53	0.00	−3126.36	−17.28	−17193.68	−350.54	−5342.00	0.00
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	−1.94	−2.30	−3.28	0.00	−26906.29	−5133.90	−10.81	−19723.31	−25.29	−10397.93	0.00
Italy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Japan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	−0.02	−0.71	−0.99	−0.86	0.00	−1683.89	−3.25	−3463.50	−132.84	−1681.95	0.00
Luxembourg	−0.05	−1.61	−1.07	−1.05	0.00	−2836.03	−12.26	−3657.79	−128.44	−2713.74	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	−9.69	−12.46	−25.80	−4.58	0.00	−4391.22	−12.65	−91506.25	−261.52	−10704.96	0.00
New Zealand	−1.13	−4.46	−3.86	−1.12	0.00	−8210.09	−70.13	−23004.99	−631.50	−32267.21	0.00
Norway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	−47.42	−5.21	−10.65	−15.39	0.00	−16398.81	−677.96	−196408.58	−2132.97	−39254.49	0.00
Portugal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak republic	−2.93	0.00	−3.09	−2.03	0.00	−1381.87	−39.99	−14189.94	−199.65	−2993.19	0.00
Slovenia	−1.08	−0.43	−0.16	−0.75	0.00	−484.54	−8.61	−4164.71	−83.46	−1512.26	0.00
Spain	−9.78	−24.12	−16.73	−15.60	0.00	−10926.97	−225.20	−119694.07	−1222.09	−24237.56	0.00
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	−29.92	0.00	−23.56	−19.01	0.00	−18348.35	−1689.41	−122422.60	−1174.42	−36496.96	0.00
United Kingdom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United States	−280.14	0.00	−411.09	−55.09	0.00	−219419.38	−3171.10	−1671439.35	−36102.14	−394404.39	0.00

4.3. Energy Tax and Energy Efficiency

Table 4 shows the analysis of the relationship between energy tax and energy efficiency by establishing the Panel Logit model. In Table 4, energy structure=ENE_STR, energy price=ENE_P, energy technology=ENE_TECH and industrial structure = IND_STR. Models (1)–(3) are empirical results of the effects of environmental taxes on coal, oil, and natural gas energy efficiency with undesired outputs. Models (4)–(6) are empirical results of the effects of environmental taxes on coal, oil, and natural gas energy efficiency without undesired outputs. The statistical indicators of each model and its information criteria are presented in the lower part of the model results. Each statistical value supports the robustness and applicability of the Logit model established in this paper. In this model, the ratio of the target efficiency value to the actual efficiency value is a measure of the energy efficiency variable. The smaller the ratio, the smaller the actual energy efficiency from the target energy efficiency value, the higher the energy efficiency level. It can be seen from Table 4 that the coefficient between energy tax and coal energy efficiency in model (1) is −0.020, the coefficient is significant at 1% confidence level, energy tax is increased by one unit, and the ratio of target efficiency to actual efficiency is reduced by 0.020, coal energy efficiency indicator increased by 0.020, the same coefficient in model (4) is −0.01 and is not significant. The coefficient between the energy tax and the coal efficiency index in model (2) is −0.018, which is significant at the 1% confidence level. For each unit of energy tax increase, the ratio of petroleum target efficiency value to actual efficiency value is reduced by 0.018 units, the oil energy efficiency is increased by 0.018 units, and the same coefficient in model (5) is 0.005 and is not significant. The coefficient between the energy tax and natural gas efficiency index in model (3) is −0.019, the unit energy tax increases, the ratio of the target efficiency value of natural gas energy consumption to the actual efficiency value decreases by 0.019 units, and the natural gas energy efficiency index increases by 0.019 units., while the same coefficient in model (6) is −0.004 and is not significant. In terms of the impact of energy taxes on energy efficiency, the absolute value of the coefficient and its significance level between energy tax and energy efficiency including undesired outputs are greater than those that do not contain undesired outputs. When studying the effects of energy taxes on energy efficiency, the results of adding environmental factors are even more impressive. It can be seen from Table 4 that the levy of energy tax has an important influence on energy consumption efficiency. Without considering the unexpected output, the energy tax has a significant effect on improving the efficiency of coal energy consumption, and the coefficient is significant at the confidence level of 1%. When considering the unexpected output, the energy tax has a significant effect on improving the efficiency of oil energy consumption, and the coefficient is significant at the confidence level of 10%. Regardless of the expected output or not, the energy tax has a positive effect on improving the efficiency of natural gas energy consumption, although this positive effect is not significant.

From the perspective of the impact of energy structure on energy efficiency, the regression model considering unexpected output shows a significant negative impact between energy structure and energy efficiency of coal, oil and natural gas. Their coefficients are significant at 1% confidence level. Optimizing energy structure plays an important role in improving energy efficiency. This means that in OECD countries, the proportion of fossil energy to total energy has had a significant positive impact on improving the value of fossil energy efficiency in recent decades. As the proportion of fossil energy in the energy structure of OECD member countries declines gradually, OECD member countries should pay more attention to increasing the proportion of renewable energy in total energy consumption and improving the efficiency of overall energy use. Regardless of whether the unexpected output is considered or not, there is a negative relationship between energy price and energy efficiency. Facing the fierce conflict of energy supply and demand worldwide, OECD countries should guarantee domestic energy supply and stabilize energy prices. Considering the unexpected output, there is a significant positive effect between technological progress and energy consumption efficiency of coal and natural gas. Their coefficients are significant at the confidence level of 5% and 1% respectively. Regardless of the unexpected output, there is a significant positive effect between technological progress and coal energy consumption efficiency, and the coefficient is significant at the confidence level of

10%. Technological progress and industrial structure have a positive impact on all energy efficiency, regardless of whether the unexpected output is taken into account. In recent decades, with the development of technology and industrial structure in OECD countries, the ratio of the target efficiency value to the actual efficiency value of fossil energy has been increasing, and the energy efficiency index has been decreasing. Technology and industrial structure are inadequate to improve fossil energy efficiency. Optimizing the industrial structure and supporting the development of environmental protection technology are still the direction of reform for OECD countries in the future.

Table 4. Logit Regression between Energy Tax on Energy Efficiency.

	Including Unexpected Outputs			Without Unexpected Outputs		
	Model (1)	**Model (2)**	**Model (3)**	**Model (4)**	**Model (5)**	**Model (6)**
Dependent variable:	EEC_COAL	EEC_OIL	EEC_GAS	EEN_COAL	EEN_OIL	EEN_GAS
ENE_TAX	−0.020 ***	−0.018 ***	−0.019 ***	−0.001	0.005	−0.004
ENE_STR	−0.009 **	−0.008 **	−0.006	−0.016 ***	−0.023 ***	−0.015 ***
ENE_P	0.004	0.002	0.001	0.004	−0.011	0.009
ENE_TECH	0.068 ***	0.064 ***	0.083 ***	0.041 *	0.091 ***	0.036 *
IND_STR	0.036 ***	0.038 ***	0.023 *	−0.001	0.020	0.007
Mean dependent var	0.397	0.437	0.395	0.315	0.497	0.305
S.E. of regression	0.478	0.487	0.480	0.455	0.483	0.456
Sum squared resid	140.468	145.961	137.029	127.398	143.564	123.561
Log likelihood	−400.276	−411.542	−389.577	−371.851	−406.404	−360.921
Deviance	800.553	823.083	779.153	743.702	812.808	721.843
Avg. log likelihood	−0.646	−0.664	−0.649	−0.600	−0.655	−0.602
S.D. dependent var	0.490	0.496	0.489	0.465	0.500	0.461
Akaike info criterion	1.307	1.344	1.315	1.216	1.327	1.220
Schwarz criterion	1.343	1.379	1.352	1.251	1.363	1.256
Hannan−Quinn criter.	1.321	1.358	1.330	1.230	1.341	1.234
Restr. deviance	832.886	849.664	805.119	772.107	859.477	738.050

***, ** and * indicates 1%, 5% and 10% significance levels, respectively.

To verify the robustness of the results, this paper uses share of energy taxes in total tax revenue or GDP instead of share of energy tax in total environmental tax revenue. The results are shown in Tables 5 and 6. Table 5 shows the analysis of the relationship between energy tax (total tax revenue) and energy efficiency. Table 6 shows the analysis of the relationship between energy tax (GDP) and energy efficiency. The results of ENE_TAX(Total) and ENE_TAX(GDP) are basically consistent with those in Table 4, which shows that the research results in this paper have strong robustness.

In order to make the conclusions of this paper more robust, we use ordinary least square (OLS) regression model to carry out the experiment again, and the results are shown in Table 7. Regardless of whether the unexpected output is considered or not, the energy tax has a positive impact on the energy consumption efficiency of coal, oil and natural gas. Without considering the unexpected output, the positive impact of energy tax on energy consumption efficiency of coal, oil and natural gas is significant at the confidence level of 1%. In the case of unexpected output, the energy tax has an effect on the efficiency of oil energy consumption. This conclusion corroborates the conclusion of the previous logit model.

Table 5. Logit Regression between Energy Tax and Energy Efficiency (Total).

	Including Unexpected Outputs			Without Unexpected Outputs		
	Model (1)	**Model (2)**	**Model (3)**	**Model (4)**	**Model (5)**	**Model (6)**
Dependent variable:	EEC_COAL	EEC_OIL	EEC_GAS	EEN_COAL	EEN_OIL	EEN_GAS
ENE_TAX(Total)	−0.022 **	−0.105 *	−0.028 **	−0.161 ***	−0.006	−0.068
ENE_STR	−0.008 **	−0.018 ***	−0.013 ***	−0.009 **	−0.011	−0.016 ***
ENE_P	−0.004	−0.014	−0.003	−0.005	−0.007	0.002
ENE_TECH	0.039 **	0.028	0.105 ***	0.034 *	0.032	0.022
IND_STR	0.011	0.084 ***	0.009	−0.014	0.133 ***	0.041 ***
Mean dependent var	0.480	0.810	0.572	0.543	0.931	0.594
S.E. of regression	0.498	0.384	0.483	0.493	0.252	0.484
Sum squared resid	152.545	91.022	139.244	149.788	39.226	139.559
Log likelihood	−425.111	−288.409	−395.147	−419.913	−147.519	−394.809
Deviance	850.221	576.817	790.296	839.825	295.039	789.618
Avg. log likelihood	−0.685	−0.464	−0.657	−0.676	−0.238	−0.657
S.D. dependent var	0.500	0.393	0.495	0.499	0.254	0.491
Akaike info criterion	1.385	0.945	1.332	1.368	0.491	1.330
Schwarz criterion	1.421	0.981	1.368	1.404	0.527	1.367
Hannan-Quinn criter.	1.399	0.959	1.346	1.382	0.505	1.345
Restr. deviance	859.882	603.918	820.525	856.360	312.583	811.790

***, ** and * indicates 1%, 5% and 10% significance levels, respectively.

Table 6. Logit Regression between Energy Tax and Energy Efficiency (GDP).

	Including Unexpected Outputs			Without Unexpected Outputs		
	Model (1)	**Model (2)**	**Model (3)**	**Model (4)**	**Model (5)**	**Model (6)**
Dependent variable:	EEC_COAL	EEC_OIL	EEC_GAS	EEN_COAL	EEN_OIL	EEN_GAS
ENE_TAX(GDP)	−0.303 **	−0.232 *	−0.228 *	−0.050	−0.319 **	−0.020
ENE_STR	−0.011 ***	−0.011 ***	−0.009 **	−0.016 ***	−0.024 ***	−0.016 ***
ENE_P	0.001	−0.001	−0.003	0.003	−0.012	0.007
ENE_TECH	0.050 ***	0.045 **	0.062 ***	0.037 *	0.089 ***	0.031
IND_STR	0.017	0.019 *	0.003	−0.005	0.016	−0.000
Mean dependent var	0.398	0.438	0.396	0.316	0.498	0.306
S.E. of regression	0.482	0.491	0.485	0.456	0.482	0.457
Sum squared resid	143.198	148.513	140.031	128.043	142.900	124.328
Log likelihood	−405.836	−417.019	−395.630	−373.225	−405.107	−362.600
Deviance	811.672	834.037	791.259	746.449	810.215	725.200
Avg. log likelihood	−0.654	−0.672	−0.659	−0.601	−0.652	−0.603
S.D. dependent var	0.490	0.497	0.489	0.465	0.500	0.461
Akaike info criterion	1.323	1.359	1.333	1.218	1.321	1.223
Schwarz criterion	1.359	1.395	1.370	1.253	1.356	1.260
Hannan−Quinn criter.	1.337	1.373	1.347	1.232	1.335	1.238
Restr. deviance	834.732	851.317	806.974	774.417	860.874	740.421

***, ** and * indicates 1%, 5% and 10% significance levels, respectively.

Table 7. OLS Regression between Energy Tax and Energy Efficiency.

	Including Unexpected Outputs			Without Unexpected Outputs		
	Model (1)	**Model (2)**	**Model (3)**	**Model (4)**	**Model (5)**	**Model (6)**
Dependent variable:	EEC_COAL	EEC_OIL	EEC_GAS	EEN_COAL	EEN_OIL	EEN_GAS
ENE_TAX	−0.103 ***	−0.141 *	−0.233 ***	−0.066	−0.072	−0.235 ***
ENE_STR	−0.024 **	−0.060 **	−0.078 *	−0.004	−0.024	−0.085
ENE_P	−0.010	0.016	0.033	0.018	0.082	0.020
ENE_TECH	0.050 **	0.081 **	0.024 **	0.090	0.186	0.032
IND_STR	0.454 ***	0.612 ***	0.861 ***	0.393 ***	0.367 **	0.830 ***
Mean dependent var	0.946	0.989	0.937	0.970	0.997	0.929
S.E. of regression	0.140	0.101	0.107	0.159	0.061	0.115
Sum squared resid	4.976	2.746	2.817	4.983	1.138	2.539
Log likelihood	−22.025	−8.736	−11.441	−14.272	−4.701	−10.435
Deviance	44.051	17.473	22.883	28.545	9.402	20.870
Avg. log likelihood	−0.085	−0.032	−0.045	−0.071	−0.015	−0.053
S.D. dependent var	0.226	0.104	0.244	0.171	0.057	0.258
Akaike info criterion	0.208	0.100	0.130	0.192	0.063	0.157
Schwarz criterion	0.276	0.166	0.200	0.274	0.123	0.240
Hannan-Quinn criter.	0.235	0.127	0.158	0.225	0.087	0.190
Restr. deviance	109.038	33.054	119.312	53.958	13.463	101.017

***, ** and * indicates 1%, 5% and 10% significance levels, respectively.

Similar to the logit regression results, the energy structure has a negative impact on the energy consumption efficiency of coal and natural gas, regardless of whether the unexpected output is considered or not. Regardless of whether the unexpected output is considered or not, the energy price has a negative impact on the efficiency of coal, oil and natural gas consumption. Regardless of whether or not the unexpected output is taken into account, energy-related technological progress, industrial structure and energy efficiency have significant positive effects, and their coefficients are significant at the confidence level of 1%. It can be seen that promoting environmental-related technological progress and industrial restructuring will contribute to the continuous improvement of energy efficiency.

This paper uses share of energy taxes in total tax revenue or GDP instead of share of energy tax in total environmental tax revenue. The results are shown in Tables 8 and 9. Table 8 shows the analysis of the relationship between energy tax (total tax revenue) and energy efficiency. Table 9 shows the analysis of the relationship between energy tax (GDP) and energy efficiency. The results of ENE_TAX(Total) and ENE_TAX(GDP) are basically consistent with those in Table 7, which shows that the research results in this paper have strong robustness.

Table 8. OLS Regression between Energy Tax and Energy Efficiency (Total).

	Including Unexpected Outputs			Without Unexpected Outputs		
	Model (1)	**Model (2)**	**Model (3)**	**Model (4)**	**Model (5)**	**Model (6)**
Dependent variable:	EEC_COAL	EEC_OIL	EEC_GAS	EEN_COAL	EEN_OIL	EEN_GAS
ENE_TAX(Total)	−0.007 **	−0.016 ***	−0.011 **	−0.034 ***	−0.024 ***	−0.025 ***
ENE_STR	−0.001 **	0.001 *	−0.000 **	−0.001	0.001	−0.001
ENE_P	−0.001	−0.002	−0.001	−0.000	−0.002 **	−0.001
ENE_TECH	0.015 ***	0.013 ***	0.021 ***	0.013 ***	0.015 ***	0.009 ***
IND_STR	0.016 ***	0.020 ***	0.015 ***	0.013 ***	0.022 ***	0.019 ***
Adjusted R−squared	−0.064	−0.196	−0.015	−0.109	−0.250	0.017
S.E. of regression	0.417	0.268	0.354	0.370	0.217	0.335
Sum squared resid	107.142	44.296	74.573	84.324	29.072	66.745
Log likelihood	−335.558	−61.307	−225.693	−261.196	69.449	−192.367
Durbin-Watson stat	0.559	0.605	0.667	0.870	0.955	1.096
Mean dependent var	0.546	0.774	0.631	0.597	0.857	0.627
S.D. dependent var	0.404	0.245	0.351	0.351	0.194	0.338
Akaike info criterion	1.097	0.214	0.768	0.857	−0.208	0.657
Schwarz criterion	1.132	0.249	0.804	0.893	−0.172	0.693
Hannan-Quinn criter.	1.111	0.227	0.782	0.871	−0.194	0.671

***, ** and * indicates 1%, 5% and 10% significance levels, respectively.

Table 9. OLS Regression between Energy Tax and Energy Efficiency (GDP).

	Including Unexpected Outputs			Without Unexpected Outputs		
	Model (1)	**Model (2)**	**Model (3)**	**Model (4)**	**Model (5)**	**Model (6)**
Dependent variable:	EEC_COAL	EEC_OIL	EEC_GAS	EEN_COAL	EEN_OIL	EEN_GAS
ENE_TAX(GDP)	−0.216 **	−0.204 *	−0.194 *	−0.043	−0.284 **	−0.017
ENE_STR	−0.008 ***	−0.006 ***	−0.005 **	−0.009 ***	−0.019 ***	−0.008 ***
ENE_P	0.002	−0.002	−0.004	0.002	−0.008	0.006
ENE_TECH	0.038 ***	0.039 **	0.048 ***	0.029 *	0.072 ***	0.027
IND_STR	0.009	0.011 *	0.001	−0.003	0.013	−0.002
Mean dependent var	0.598	0.538	0.696	0.516	0.598	0.506
S.E. of regression	0.382	0.391	0.385	0.356	0.382	0.357
Sum squared resid	112.198	116.513	115.031	119.043	126.900	114.328
Log likelihood	−305.432	−317.126	−295.361	−273.612	−315.421	−262.152
Deviance	711.812	734.143	691.621	646.513	710.429	625.164
Avg. log likelihood	−0.592	−0.581	−0.542	−0.581	−0.564	−0.561
S.D. dependent var	0.368	0.387	0.368	0.359	0.462	0.471
Akaike info criterion	1.211	1.341	1.226	1.165	1.261	1.168
Schwarz criterion	1.263	1.371	1.278	1.181	1.261	1.179
Hannan-Quinn criter.	1.267	1.281	1.263	1.185	1.261	1.138
Restr. deviance	742.166	791.316	758.253	682.312	782.153	637.156

***, ** and * indicates 1%, 5% and 10% significance levels, respectively.

5. Conclusions

The research in this paper is divided into two stages. In the first stage, the EBM-DEA model is established to measure the energy efficiency values of OECD countries with undesired outputs and non-expected outputs, and the efficiency of the model is analyzed. Through the analysis of efficiency values, this paper finds that it is necessary to incorporate undesired output factors into the energy efficiency evaluation model. The calculations that do not include unanticipated outputs overestimate the energy efficiency values of some countries that do not pay attention to environmental issues in the energy consumption process, and underestimate the energy efficiency values of some countries that consume fossil energy while taking into account environmental benefits. Through projection value analysis, this paper finds that excessive input of fossil energy is the reason why the efficiency value of DEU that is far behind the data envelope is low when the unexpected output is not included. The excessive input of coal, oil and natural gas and the excessive emission of nitrogen oxides, sulfur oxides, carbon dioxide, carbon monoxide and methane in the process of energy use are the reasons for the low efficiency of countries that fail to reach the data envelope under the condition of including the unexpected output. In order to improve energy efficiency of countries outside the data envelope, it is important to reduce the amount of fossil energy input while maintaining the steady growth of economic efficiency. In the second stage, based on the calculation results of the first stage, the relationship between energy efficiency and energy structure, industrial structure and energy price is studied by establishing the Panel Logit model. The relationship between the variables and the energy efficiency indicators with and without undesired outputs is studied.

Does environmental tax affect the energy environment? The purpose of this paper is to explore the answer to this question. The collection of energy tax has an important impact on energy consumption efficiency. Without considering the unexpected output, the energy tax has a significant impact on improving the efficiency of coal energy consumption. When considering the unexpected output, the energy tax has a significant impact on improving the efficiency of oil energy consumption. Regardless of the expected output, the energy tax has a positive effect on improving the efficiency of natural gas energy consumption. The experimental results also show that the energy structure and energy price have a negative impact on energy efficiency, while the progress of environmental protection technology and industrial structure have a positive impact on energy efficiency. In terms of the empirical results of the model containing undesired output, the research results affirm the positive role of energy tax imposed by OECD countries in improving the efficiency of fossil energy, and affirm the "blue dividend" of promoting economic growth and the "green dividend" of reducing emissions. The empirical results of the model without expected output show that the effect of energy tax on energy efficiency is not obvious. The empirical results also show that the overall energy structure and industrial structure of OECD countries need to be optimized and energy prices need to be further stabilized and controlled in the coming decades. This paper argues that OECD countries should further follow up the implementation and improvement of energy tax policies, continuously optimize the energy structure, industrial structure, stabilize energy prices, and attach importance to the development of environmental technologies.

The development and global dissemination of environment-related technologies are key to achieving the cost efficiency of environmental policy objectives. At present, OECD countries have achieved long-term development of environment-related technologies in air pollution, water pollution, solid waste pollution, soil pollution, climate change and other aspects that may help reduce greenhouse gas (GHG) emissions. In terms of industry, agricultural industry includes livestock breeding, fruit and vegetable planting, fishery, beekeeping, food processing industry and the update and progress of agricultural machinery or equipment. Progress has been made in environmental technologies, including those related to climate change mitigation in the production of consumer goods, mineral processing, oil refining and petrochemical industries, chemical industries and metal processing. In terms of environmental technologies related to energy efficiency, OECD countries' environmental tools cover lighting equipment, heating equipment, ventilation equipment, household appliances, elevators, escalators and pedestrian passageways, general information technology and many other aspects. The goal is to constantly improve the energy efficiency to reduce pollution emissions in the process of technical exploration. The experimental results in this paper validate the conclusions of Mashael, Martin and Alexander [22]. Through case studies of cities, it is proposed that energy strategies of different countries have a positive impact on energy planning and energy efficiency. The study also proposes measures and technologies to improve urban energy efficiency, especially building renovation, which is considered to be the most cost-effective and can significantly reduce energy demand. Decentralized generation and storage technologies, including roof photovoltaics, heat pumps, small gas-fired cogeneration and batteries, also provide ways to reduce emissions and improve long-term energy self-sufficiency. Utilizing municipal waste to generate heat also provides the most cost-effective and low-emission power generation method. The study also suggests that carbon taxes are found to have a significant impact on the absorption of low-emission technologies. The experimental results of this paper are also consistent with the endogenous growth theory proposed by Barbier et al [23]. Endogenous growth theory has re-stimulated people's interest in the role of innovation in determining long-term economic growth. This problem has been the focus of resource economics for many years. The paper therefore demonstrates that endogenous growth can overcome resource scarcity, but the outcome in the long run depends critically on assumptions concerning any constraints imposed by resource availability on the generation of innovation. On 29 January 2019, the OECD announced significant international progress in addressing the tax challenges posed by the digital economy and agreed to continue multilateral efforts to achieve a new consensus-based long-term solution to the tax challenges by 2020. Countries and jurisdictions participating in the OECD/G20 inclusive framework on base erosion and profit shifting (BEPS) will step up their efforts to reach a global solution to the growing debate on how to tax multinationals in a rapidly digitizing economy. To meet the challenge of tax collection and realize the function of tax collection will be a problem to be solved in all OECD countries. However, different countries' energy strategies affect energy efficiency. In the process of simultaneous development of tax means and environmental protection technologies, each country should attach great importance to the development of strategic goals suitable for its energy distribution and industrial distribution.

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