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Regulatory Effect of Improving Environmental Information Disclosure on Environmental Tax: From the Perspectives of Time and Industry Heterogeneity

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ABSTRACT

As a formal means of environmental regulation, environmental tax receives extensive attention from scholars for its emission reduction effect and economic impact. However, few studies have focused on the regulatory effect and impact mechanism of Environmental Information Disclosure (EID) and other informal environmental regulatory methods, especially the heterogeneity of such regulatory effect at the time and industry level. Therefore, based on China input-output tables and pollutant emission data of 139 sectors in 2012, this paper constructed China environmental Computable General Equilibrium (CGE) model for empirical test. Studies have shown that the improvement of EID has a “double dividend” regulatory effect on emission reduction and economic impact of environmental tax, but this effect has obvious time and industry heterogeneity. Specifically, the long-run economic stimulus effect of EID improvement (0.087%) is greater than that of the short-run (0.037%), while the long-run enhanced effect of EID on exhaust emission reduction (SO_2 -0.015%; NO_X -0.014%) is less than that in the short-run (SO_2 -0.081%; NO_X -0.076%). In terms of the comparisons between the two, in the short-run, the enhanced effect of EID on environmental tax’s emission reduction is greater than its effect on economic improvement. While in the long run, the effect on the former is less than its effect on the latter. Meanwhile, the improvement of EID has a weakening effect on reducing wastewater discharge reduction of environmental tax. From the industry perspective, the improvement of EID quality can drive the output growth of the industry in the short run and long run by 64% and 93% respectively. Nonetheless, there exists significant non-uniformity. Among them, production of capital-intensive investment products and its upstream industries have increased emissions when output has expanded significantly, while the output of labor-intensive and export-oriented industries have suffered due to factor prices that have been pushed up. It is worth noting that the improvement of EID quality can stimulate the energy consumption structure to shift from high-emission coal towards clean energy products in the long run. This research can provide references for objectively understanding the complementary role of informal environmental regulation to formal environmental regulation, and promote the construction of a modern environmental governance system with multi-party co-governance.

Keywords: environmental information disclosure (EID); environmental tax; regulatory effect; time and industry heterogeneity; CGE model

1. INTRODUCTION

The ecological environment problems with the rapid economic development become the restrictions of social sustainable development. In order to cope with the increasingly serious environmental pollution problem, China has successively implemented various kinds of environmental regulation means, such as command-and-control, market-based instrument and voluntary approaches (Zhao et al., 2009). According to the different implementation subjects, environmental regulation can be divided into formal regulation led by the government and informal regulation denominated by enterprises and the public (Féres & Reynaud, 2012; Li, 2018). Among them, environmental tax is an important formal regulation method to alleviate

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environmental pollution, and it has been proved to be an effective method not only in theory but also in practice (Ren et al., 2011; Liu et al., 2015; Aubert & Chiroleu-Assouline, 2019). At the same time, departments relevant with ecological protection guide enterprises to raise their awareness of protecting the environment through economic means, and motivate them to participate in environmental protection. For instance, China Securities Regulatory Commission has promulgated the "Administrative Measures on Information Disclosure of Listed Companies", which requires key listed polluters to disclose pollution information and encourages other companies to voluntarily disclose environmental information. The establishment of environmental information disclosure system can encourage enterprises to voluntarily strengthen their investment in environmental protection and thus become a beneficial supplement of formal environmental regulation. Moreover, "the Guidance on the Construction of a Modern Environmental Governance System" also includes the improvement of the legal system and information disclosure of environmental governance as important links in the reconstruction of the environmental governance system. In this context, discussion about the mechanism between environmental tax and EID has practical significance for the formation of multi-party governance model of environment governance.

Environmental tax is a typical formal method of regulating environmental pollution, which attracts wide attention from scholars for its emission reduction effect and economic impact (Patuelli et al., 2005; Lu et al., 2010; Liu and Hu, 2017). Some of studies suggest that environmental taxes will increase production costs and inhibit industrial output while reducing pollutant emissions, but there are still differences on the extent of negative economic impact (Liu and Lv, 2009; Xie et al., 2018; Freire-González, 2018). Huang et al. (2005) argued that the tax on energy and environment could not fundamentally promote the improvement of energy utilization efficiency, but would have a greater negative impact on the macro economy. Nevertheless, Qin et al. (2015) proposed that the environmental tax had a much greater effect on pollutant emission reduction than on economic development. Li and Masui (2019) reached the same conclusion on the basis of dynamic CGE model, namely, the implementation of environmental tax will lead to a substantial reduction of 3.55-7.15% in China's SO_2 emissions by 2030, but the GDP loss will be only 0.1-0.2%. Other scholars suggested that tax rebates could be used to reduce the negative impact of environmental taxes on the economy, and even the "double dividend" effect of emission reduction and economic growth could be realized (Bosquet, 2000; Li and Fu, 2004; Francisco et al., 2005; Ciaschini et al., 2012; Hu et al., 2018). For example, Bowen et al. (2015) used the dynamic CGE model and concluded that if the government employed environmental tax to compensate production tax and corporate income tax, 0.49% and 0.34% of GDP losses could be offset respectively.

As an essential supplement of formal environmental regulation, EID has been proved to have positive impact on pollution emission reduction and firms' production. According to the existing literature, it can be found that EID mainly affects the production of enterprises through two ways. On the one hand, EID promotes technological progress, reduces pollutant emissions by encouraging heavy polluters to actively improve energy efficiency or adopt cleaner production processes, and builds the image of "environmental protection" (Liu et al., 2010; Ren and Hong, 2017; Teng, 2019). Some scholars quantified the enhanced impact on emission reduction. Such as Lin and Xie (2017) found that SO_2 emissions decreases by about 0.03% for every 1% increase in EID quality through the GMM model. Wu (2014) argued that the EID level of listed companies in China's chemical industry was positively correlated with their environmental performance in the short term. On the other hand, EID focuses on reducing financing costs. By reducing risks faced by investors, the cost of equity capital of enterprises can be reduced and further attract investors to increase investment (Marshall et al., 2009; Ye et al., 2015; Li et al., 2017). The research of Fonseka et al. (2019) shows that for every unit increase in EID of Chinese energy enterprises, the equity capital cost decreases by 0.33 units. Meanwhile, active EID can also reduce the information asymmetry and credit mismatch risks between banks and enterprises, therefore reducing the debt financing cost of enterprises (Clarkson et al., 2004; Dhaliwal et al., 2011; Ni and Kong, 2016). Luo et al. (2019) demonstrated that for every unit increase in EID of heavily polluting enterprises, the debt financing cost would be significantly reduced by 0.31%.

However, only few studies discuss the interaction mechanism between informal and formal means of environmental regulation without researching on the regulatory effect of EID on environmental tax. Feres and Reynaud (2012) proposed that informal environmental regulation, especially public pressure, can reinforce the emission reduction effect of formal environmental regulation based on the impact of environmental supervision on industrial enterprises in Brazil. In addition, Xu (2014) illstructed that after the introducing informal environmental regulations, the emission reduction effect of government investment in pollution control on industrial wastewater and SO2 emission intensity would be significantly enhanced. Besides, some studies suggest that the external institutional pressure formed by formal environmental regulations can stimulate polluters to take more active emission reduction measures, so as to improve the pollution control effect of informal environmental regulations (Kathuria, 2007; Jiménez-Parra et al., 2018). Tang and Liu (2019) utilized difference-in-differences and concluded that the enactment of China's Environmental Protection Tax Law had improved the quality of corporate EID obviously. Cole et al. (2005) and Kuang et al. (2017) believe that there is a two-way transmission mechanism between formal and informal environmental regulations, which promote and complement each other. Based on above-mentioned, most of the existing studies are limited to discussing the interaction between the emission reduction effects of informal environmental regulation and formal environmental regulation, and the research on the mechanism of their economic influence is not sufficient.

From the existing literature, we find the following limitations, initially, the studies discuss the strengthen effect of informal regulations on pollutant reduction by formal means, though the interaction in terms of economic impact has not been discussed. It is worth finding whether informal regulation weakens or aggravates the economic cost of formal environmental regulation on pollution emission reduction. Secondly, the enhancing effect of informal regulation on pollutant emission reduction has been researched in current literatures, but the time and industry heterogeneity of such enhancing effect have not analyzed in depth. The characteristics of heterogeneity may lead to differences in the direction and extent of regulatory actions at different stages and in various industries. Thirdly, the literature focuses on the use of econometric methods to analyze the interaction between informal and formal environmental regulations. This partial perspective cannot distinguish between direct and indirect mechanisms, nor can it reveal the difference in transmission mechanism between industries. Additionally, the literature does not directly discuss the regulatory effect of EID on environmental tax. These two tools are the most important means of environmental regulation in China at present, and the chief means of environmental regulation in the construction of modern environmental governance system. It is of great policy significance to directly discuss the interaction and mechanism between the two.

Based on the Computable General Equilibrium (CGE) model, the regulatory effect of EID on environmental tax and its time and industry heterogeneity are compared in this paper. The marginal contributions of the paper are as follows, (1) we clarify the direct impact mechanism of disclosure industry’s EID in different time periods. On account of the mechanism in short-term and long-term, this paper identifies and describes the direct impact path of EID on industries by reducing financing cost in the short term and increasing capital stock in the long term. (2) This article also quantifies the regulatory effect of EID on environmental tax and heterogeneity from perspectives of time and industry. In line with environment module embedded in the general equilibrium model, this paper introduces the path of direct impact of EID and environmental tax, and reveals the difference of regulatory effect of EID on environmental tax in terms of pollution emission and economic impact, as well as the heterogeneity of regulatory effect between short and long term and among industries. (3) It helps to increase the understanding of the complementary role of EID to environmental tax, the complementary role of informal environmental regulation to formal environmental regulation, and provide ideas for improving the corporate responsibility system of environmental governance and building a modern environmental governance system.

2. MATERIALS AND METHODS

Compared with the partial equilibrium model, CGE model is applied to capture the indirect impact mechanism of EID improvements on the macroeconomic, emissions and industries. Chinese environmental CGE model is based on the ORANIG model, which is developed by the Institute of Policy and Management, Chinese Academy of Sciences and the CoPS (Center of Policy Studies) of University of Victoria in Australia. CGE model includes the module of production, investment demands, household consumption, government consumption and export. Then the environment and pollutant emissions accounts are embedded in it.

2.1 Economic module

The economic module mainly includes production, demand and equilibrium. The equation of each part is as follows:

(1) Structure of production. Industry activities mainly include input decision-making and output distribution. The manufacturer chooses its best input to minimize the cost of producing given output, and its output is allocated to the domestic market and export according to the principle of profit maximization. The multi-input nested structure refers to Liu et al. (2015) and Liu & Hu (2017) (see Figure 1). At the top level, commodity composites, a primary-factor composite and energy composites are combined using a Leontief production function. At the second level, each commodity composite is a CES (constant elasticity of substitution) function of a domestic good and the imported equivalent. The primary-factor composite is a CES aggregate of land, capital and labor. The energy composites are divided into coal, oil and gas, coke, electricity, natural gas and refined oil which are also incompletely substituted in the form of a CES function. In addition, each energy composite is the third level of a CES function of a domestic good and the imported equivalent. Equation (1) is the top-level nested function, equation (2-4) is the second-level nested function for intermediate input, primary factors and energy respectively, and equation (5) is the third-level nested function for energy products.

$$X1TOT(i) = \frac{1}{G1(i)} * MIN\left[All, c, COM{:}\ \frac{X1\_S(c,i)}{A1\_S(c,i)}, \frac{FAC(i)}{A1\_F(i)}, \frac{X1\_energy(i)}{A1\_E(i)}\right], COM = \{1, \dots, N\} \quad (1)$$

$$X1\_S(c,i) = CES\left[All, s, SRC{:}\ \frac{X1(c,s,i)}{A1(c,s,i)}\right], SRC = \{dom, imp\} \quad (2)$$

$$FAC(i) = CES\left[\frac{X1LAB(i)}{A1LAB(i)}, \frac{X1CAP(i)}{A1CAP(i)}, \frac{X1LND(i)}{A1LND(i)}\right] \quad (3)$$

$$X1\_energy(i) = CES\left[All, e, ECOM{:}\ \frac{X1energy\_S(e,i)}{A1E\_S(e,i)}\right], ECOM = \{1, \dots, M\} \quad (4)$$

$$X1energy\_S(e,i) = CES\left[All, s, SRC{:}\ \frac{X1energy(e,s,i)}{A1E(e,s,i)}\right], SRC = \{dom, imp\} \quad (5)$$

Where i, c and s are industry, commodity and source respectively. $X1TOT(i)$ is the total output of industry i, $X1\_S(c,i)$ is the intermediate input of product c of industry i, $FAC(i)$ is the primary factor input of industry i, which consists of labor $X1LAB(i)$, capital $X1CAP(i)$ and land $X1LND(i)$. $X1\_energy(i)$ is the energy input of industry i, $G1(i)$ are Hicks-neutral technical-change terms, affecting all inputs equally. $A1\_F(i)$, $A1\_E(i)$ and $A1\_S(c,i)$ are the technical-change terms of primary factors, energy and the commodity c (without distinguishing sources) used in the production of industry i respectively.

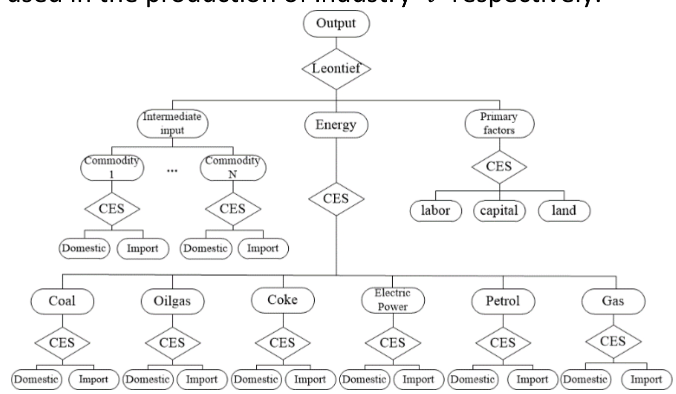

Fig 1 The nested production structure of environmental CGE model

(2) Investment demands. The nesting structure for investment demand is similar to that for production. The manufacturer selects the best investment product portfolio based on the principle of cost minimization to form the current capital required by the industry. The equation is as follows:

$$X2TOT(i) = \frac{1}{G2(i)} * MIN\left[All, c, COM{:}\ \frac{X2\_S(c,i)}{A2\_S(c,i)}\right], COM = \{1, \dots, N\} \quad (6)$$

$$X2\_S(c,i) = CES\left[All, s, SRC{:}\ \frac{X2(c,s,i)}{A2(c,s,i)}\right], SRC = \{dom, imp\} \quad (7)$$

$X2TOT(i)$ is the total amount of investment in industry i, $X2\_S(c,i)$ is the input of investment product c that forms new investment in industry i, $G2(i)$ are neutral technical-change terms, $A2\_S(c,i)$ is the technical-change term of investment product c (without distinguishing the source) used in the investment of industry i.

(3) Household demands. The household consumption module includes household utility function and budget constraints, which satisfies the assumption of utility maximization. Equation (8) is illustrated to maximize the Klein-Rubin (Stone-Geary) non-positional utility function subject to the household budget constraint, and Equation (9) is the linear expenditure system (LES) after solving the problem of utility maximization. Equation (10) means that household consumption of a certain commodity is a CES

function of domestic and imported goods.

$$MAX\ U = \prod_{c=1}^{N}\left[\frac{X3\_S(c)}{Q} - A3SUB(c)\right]^{\beta(c)}$$
$$s.t. \sum_c \frac{X3\_S(c)}{Q} * P3\_S(c) = \frac{Y}{Q} \quad (8)$$

$$X3\_S(c) = X3SUB(c) + \frac{\beta(c)}{P3\_S(c)} * \left[Y - \sum_{c=1}^{n} X3SUB(c) * P3\_S(c)\right] \quad (9)$$

$$X3\_S(c) = CES\left[All, s, SRC: \frac{X3(c,s)}{A3(c,s)}\right], SRC = \{dom, imp\} \quad (10)$$

U is the household utility, Y is the household disposable income, and Q is the number of households. $X3\_S(c)$ is the total consumption of commodity c by households, $X3SUB(c)$ is the subsistence requirements of commodity c, and $P3\_S(c)$ is the purchaser price. $\beta(c)$ is the marginal budget share of commodity c, and $A3SUB(c)$ is the individual household subsistence demands for commodity c. $X3(c,s)$ is the household consumption of commodity c from source s, and $A3(c,s)$ is the marginal propensity to consume.

(4) Export demands. The commodities are classified as tradable and non-tradable. The export demand of non-tradable products is mainly affected by government policy control and has little relationship with their own market prices, while the export demand of tradable products has a reverse relationship with commodity prices. The equation is as follows:

$$X4(c) = F4Q(c)\left[\frac{P4(c)}{PHI * F4P(i)}\right]^{EXP\_E(c)} \quad (11)$$

$X4(c)$ is the export volume of commodity c, $P4(c)$ is the export FOB price in local currency, PHI is the nominal exchange rate under the indirect pricing method, $F4Q(c)$ and $F4P(c)$ allow for horizontal (quantity) and vertical (price) shifts in the demand schedules, $EXP\_E(c)$ is the constant elasticity of export demand.

(5) Equilibrium module. There are three characteristics when the model is in equilibrium: market clearing, zero profit condition for the manufacturer, and balance of payments. Market clearing means that supply and demand are equal both in commodity markets and factor markets. Zero profit, that is, the price accepted by the manufacturer is equal to the cost price, and the purchaser price is equal to the cost price plus taxes and circulation costs in the sales process. Balance of payments includes balance of investment and savings, government payments and international payments. The model is -driven by investment, in which the balance of investment and savings is achieved by adjusting foreign savings.

2.2 Economic Data

Based on the 2012 Input-Output Tables of China published by the National Bureau of Statistics, the database establishment method of 2002 Input-Output Tables of China developed by the CoPS (Horridge and Wittwer, 2008) and the development method of Chinese database in the 9th version of GTAP model (Aguiar et al., 2016) , the database of our CGE model is finally established, which includes 139 sectors (5 sectors of agriculture, forestry, animal husbandry and fishery, 93 sectors of industry, 4 sectors of construction industry, and 37 sectors of service industry), 3 primary factors (labor, capital, land), 6 economic entities (production, investment, household, government, foreign countries, inventory) and 8 types of circulation services (sea transport, air transport, railway, road, pipeline transport, insurance, trade (wholesale and retail), warehouse storage). GEMPACK software is used to complete the whole database establishment (Horridge, 2018). The parameters in our CGE model include substitution elasticity, price elasticity and expenditure elasticity, which are mainly set with reference to the values of China database in the 9th version of GTAP model (Aguiar et al., 2016). Specifically, the elasticity of substitution among the three primary factors is 0.5; the price elasticity of export demand for tradable goods is 4; the range of Armington substitution elasticity between domestic and imported intermediate inputs is 0.9-5.6, with an average value of 2.95; the elasticity of substitution among different energy products is 0.5, and the range of household expenditure elasticity on different commodities is 0.2-2.1, with an average value of 1.05.

2.3 Environmental Module

The pollutant emission module includes two types of exhaust gas (SO2 and NOX) and waste water (COD and NH3). The total emission of exhaust gas is equal to the sum of combustion and process emission. Combustion emission refers to the pollutant gas emission caused by enterprises or residents burning fossil energy in the production or living process. The equation is as follows:

$$BE_{(g,i,e,s)} = a_{(g,i,e,s)} * ED_{(i,e,s)} \quad (12)$$
$$BE_{(g,h,e,s)} = a_{(g,h,e,s)} * ED_{(h,e,s)} \quad (13)$$

Where g is exhaust gas, including SO2 and NOX, i is industry (including 139 sectors), e is energy (including coal, oil and gas, coke, electricity, natural gas and refined oil), s is source (including domestic and imported goods), h is household. $BE_{(g,i,e,s)}$ and $BE_{(g,h,e,s)}$ are exhaust gas g generated by industry i and household h using energy e from source s, $ED_{(i,e,s)}$ and $ED_{(h,e,s)}$ are the demand of industry i and household h for energy e from source s. $a_{(g,i,e,s)}$ and $a_{(g,h,e,s)}$ are the combustion emissions coefficients of industry i and household h.

The process emission of exhaust gas is produced by the enterprise using a particular manufacturing technique. It is generally related to the output of the enterprise. The equation is as follows:

$$PE_{(g,i)} = b_{(g,i)} * Q_i \qquad (14)$$

Where $PE_{(g,i)}$ is the process emission of g generated by industry i, $b_{(g,i)}$ is the process emission coefficient of g generated by industry i, and Q_i is the output of industry i.

The wastewater discharge includes industrial and household process discharge. We assume that the wastewater discharge of a industry is related to its output, while that of a household is related to its consumption. The equation is as follows:

$$PW_{(w,i)} = c_{(w,i)} * Q_i \qquad (15)$$

$$PW_{(w,h)} = c_{(w,h)} * Q_h \qquad (16)$$

Where w is wastewater, including NH3 and COD. $PW_{(w,i)}$ and $PW_{(w,h)}$ are the wastewater discharge volume of industry i and household h, $c_{(w,i)}$ and $c_{(w,h)}$ are the wastewater process discharge coefficients of industry i and household h, Q_i and Q_h are the output of industry i and the consumption of household h.

2.4 Establishment of emission database

The pollutant emission database is based on the 2007 National Non-point Source Pollution Census (hereinafter referred to as Pollution Data), 2013 China Environmental Statistics Yearbook (hereinafter referred to as Environmental Yearbook) and 2012 database of the Institute of Environmental Planning, Ministry of Ecology and Environment. These data have been widely used in research in the field of environmental regulation (Lu et al., 2010; Cao et al., 2013; Jaume, 2017). The above emission data need to be matched with the 139 sectors in the 2012 China input-output tables. The data processing procedure is as follows:

The basic principle of data processing of exhaust gas emission data is to take the emission of each sector in the Environmental Yearbook as the total amount and the proportion of sub-sector emissions as the structure. The equation is as follows:

$$E_i = Q_R * S_i \qquad (17)$$

E_i is the exhaust gas emission of industry i, Q_R is the exhaust gas emission of each sector in the Environmental Yearbook (including 30 industries in 2012) and S_i is the emission structure.

$$S_j^1 = \frac{P_j}{P_J} \quad (j \in J) \qquad (18)$$

$$S_k^2 = \frac{w_k * ED_k}{P_K} \quad (k \in K) \qquad (19)$$

$$S_c^3 = \frac{w_{ave} * ED_c}{P_C} \quad (c \in C) \qquad (20)$$

It should be noted that various emission structures are selected for different industries according to the availability of data. ① S_j^1 is the exhaust gas emission structure of the industrial sector, P_j is the exhaust gas emission of the industrial sub-sector j in the database of the Environmental Planning Institute (including 93 industrial sub-sectors except the construction industry), P_J is the exhaust gas emissions of sector J to which sub-sector j belongs. ② S_k^2 is the exhaust gas emission structure of agriculture, transportation, wholesale and retail and other service industries. w_k is the exhaust gas emission intensity of the sub-sector k in Pollution Data, and ED_k is the total fossil energy input of sub-sector k in 2012, P_K is the exhaust gas emissions of industry K to which sub-sector k belongs. ③ S_c^3 is the exhaust gas emission structure of the construction industry, w_{ave} is the average exhaust emission intensity of all non-construction industries in Pollution Data, ED_c is the total fossil energy input of the sub-sector c of the construction industry in 2012, and P_C is exhaust gas emissions of industry C to which the sub-sector c belongs. Based on the above method, the exhaust gas data of each sector in the 2012 China input-output tables can be obtained. The processing method of wastewater discharge data is similar to that of exhaust gas and the detail is shown in Liu Yu et al. (2020).

3. DESIGN OF SIMULATION SCHEME

3.1 Closure

The short-run and long-run closures are set in order to compare the temporal heterogeneity of the adjustment effect of EID improvement on environmental tax. In the short-run closure, (1) the real wage remains unchanged because of price stickiness, but labor can move freely among sectors and total employment is endogenous. (2) The stock of capital is fixed and cannot flow freely among sectors. This means that the rate of return on investment in each sector is different, so there will be differences in investment in different sectors. (3) Household consumption is determined by income. Government expenditures and technological progress remain unchanged exogenously.

Compared with short-run closure, long-run closure can reflect the impact of capital stock accumulation. In the long-run closure, (1) the total amount of labor remains unchanged, but it can flow freely among various sectors. (2) The stock of capital is endogenous and can also flow freely among sectors. This means that capital has enough time to adjust so that it flows to sectors with a higher rate of return, and ultimately makes the rate of return on investment in each sector equal. At the same time, investment changes with proportion to capital stock. (3) Consumption and government expenditures are endogenous and also change in the same proportion. The trade balance item changes with proportion to GDP. Technological progress remains unchanged exogenously.

3.2 Shocks

Two scenarios are compared to verify the adjustment effect of the improvement of EID quality on environmental tax. Environmental tax (ET) is set as benchmark, and the combination of environmental tax and environmental information disclosure (ETID) is set as policy scenario. There are two reasons for this setting: Firstly, environmental tax is set as benchmark to evaluate the emission reduction and economic impact of levying environmental tax at the current rate. Secondly, by comparing the changes in economic indicators and emission with or without considering EID improvement, the direction and extent of the adjustment effect of EID improvement on environmental tax can be accurately identified.

(1) In the ET scenario, we impose environmental tax on all sectors (except the agricultural sector). Environmental tax is introduced into the CGE model through the ad valorem tax. However, the current tax collection is based on the pollution equivalent value, which is a specific duty. The following formula is used to convert the specific duty to the ad valorem tax:

$$T_g * E_{(g,i,s)} = BT_g * t_{(g,i)} \quad (21)$$

Where g, i and s are pollutant, industry and source respectively. T_g is the specific duty of pollutant g, $E_{(g,i,s)}$ is the emission amount of pollutant g (unit: ton) from source s of industry i, BT_g is the ad valorem tax base of pollutant g and $t_{(g,i)}$ is the ad valorem tax of pollutant g levied on industry i.

The object, coverage, rate of environmental tax should be clarified. ①The current environmental tax laws in China are levied only on enterprises, not on residents. ②At present, Chinese environmental tax doesn't include agriculture in its taxation system. ③Environmental tax at the national level is obtained by a weighted average of provincial environmental tax and the weight is the proportion of the pollutant emissions of each province to the total pollutant emissions of China. After the calculation, the weighted average environmental tax of SO2, NOx, COD and NH3 is 3,248 yuan/ton, 3,460 yuan/ton, 3,953 yuan/ton and 3,098 yuan/ton respectively.

(2) In the ETID scenario, we further introduce the impact of EID on the basis of the ET scenario. As mentioned above, the main impact paths of EID on the disclosure industry include encouraging technological progress (improvements in energy efficiency and process emission parameter) and reducing financing costs. The equation and impact mechanism of the improvement of EID quality on investment are as follows:

$$RORC_i = \frac{PK_i}{\pi_i} - d_i \quad (22)$$

$$RORE_i = RORC_i\left(\frac{KE_i}{KB_i}\right)^{-\beta} \quad (\beta > 0) \quad (23)$$

$$KE_i = KB_i(1 - d_i) + I_i \quad (24)$$

After linearizing the above equation, the relationship between capital growth rate and the rate of return on investment is obtained:

$$KG_i = finv_i + \frac{1}{G*\beta} * \{Q * [RORC_i + fRORC_i] - invslack\} \quad (25)$$

Where i is the heavy polluting industries that disclose environmental information, $RORC_i$ is the current rate of return on investment of the industry i, PK_i is the capital price, π_i is the price of investment goods, d_i is the depreciation rate; $RORE_i$ is the expected rate of return on investment, KE_i is the ending capital stock, KB_i is the beginning capital stock, I_i is the new investment, KG_i is the capital growth rate, G is the ratio of investment to the ending capital stock, and Q is the ratio of the total rate of return on investment ($RORC_i$+d_i) to the net rate of return, $finv_i$ is a preference variable, and $invslack$ is a slack variable. We refer to the ORANIG model (Peter et al., 1982; Horridge, 2000) for parameters: $\frac{1}{G*\beta} = 0.33$, $G = 0.3$, $\beta = 10$, $Q = 2.0$. The exogenous variable $fRORC(i)$ is added to characterize the change of financing cost in short run. If the financing cost decreases, $fRORC(i) > 0$; if the financing cost increases, $fRORC(i) < 0$.

The mechanisms by which the improvement of EID quality affects investment in the short and long run is shown in Figure 2(A) and 2(B). $E0$ is the initial equilibrium point. At this time, the rate of return on investment of industry i is equal to its financing cost. The financing cost of industry i will decrease if it improves EID quality. Then it has the motivation to further expand investment and production capacity. In the short run, the new investment in industry i equals to the level of capital formed in the long run, which just reduces the expected rate of return to the new financing cost $RORE_i^*$. $E1$ is the short-run equilibrium point. In the long run, the actual capital will be accumulated in industry i since investment can be transformed into production capacity, that is, capital stock will increase until the rate of return on investment drops to the new financing cost $RORE_i^*$ and finally a long-run equilibrium point $E2$ is formed.

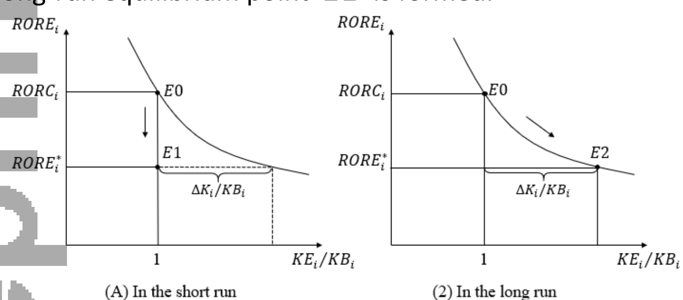

Fig 2 The impact mechanism of EID quality improvement on investment

The empirical results of existing literature about the impact of EID improvements on emission reduction and financing costs are used for shocks. ①According to the Guidelines for Environmental Information Disclosure of Listed Companies published by the Ministry of Environmental Protection, heavily polluting industries mainly include thermal power, iron and steel, cement, electrolytic aluminum, coal, metallurgy, chemical industry, petrochemicals, building materials, papermaking, brewing, pharmaceutical, fermentation, textile, leather and mining. The above 16 industries could be matched with 56 sectors in the 2012 Input-Output Tables of China. ②In terms of the shock of technology, every 1% increase in EID quality will result in a decrease of 0.03% in SO2 and wastewater discharge (Lin & Xie, 2017). Tian et al. (2016) also found that for every 1% increase in EID quality, the emission intensity of COD, NH3 and SO2 would decrease by 0.3%, 0.22% and 0.16%. If energy usage and output remain are unchanged, the rate of change of emissions is equal to that of emission intensity. Therefore, this paper takes an average of 0.1% as the rate of improvement of energy efficiency and process emission coefficient of exhaust gas, and an average of 0.17% and 0.13% as the rate of improvement of process emission coefficient of COD and NH3. Regarding the shock of financing costs, we mainly refer to Shen et al. (2010) and Yuan (2014) which indicated that for every 1% increase in EID quality, financing costs decreased by 0.4%.

4. THEORETICAL MECHANISM

The internal economic framework of the CGE model can be described by a set of equations, which is defined as BOTE analysis. In this paper, it is mainly used to explain the impact mechanism of EID on macroeconomic operations. The equilibrium of the economic module is shown in equation (26-37). Equation (26) is the income method of GDP, including the input of technology, capital and labor; Equation (27) is the expenditure method of GDP, including household consumption, investment, government expenditure and trade balance items. Equation (28) indicates that real wage depends on the marginal return of labor multiplied by technology and the reciprocal of and taxation; Equation (29) also shows the determinants of the rate of return on investment; Equation (32) indicates that the real exchange rate is equal to the ratio of import price to GDP price; Equation (33) shows that terms of trade is equal to the ratio of export prices to import prices; Equation (34-35) shows that in the short-run closure, investment depends on the rate of return on investment and financing costs, and household consumption is equal to the average propensity to consume multiplied by GDP; Equation (36-37) shows that in the long-run closure, investment and capital stock change in the same proportion. Household and government consumption are in a fixed ratio. In addition, exports usually depend on export prices. GDP and the real exchange rate are important factors affecting imports. $\frac{P_{GNE}}{P_{GDP}}$ is the reciprocal of terms of trade. $\frac{P_C}{P_{GNE}}$, $\frac{P_I}{P_{GNE}}$ and $\frac{P_{GDP}}{P_F}$ are all approximately equal to 1.

$$Y = A \cdot F(L, K) \tag{26}$$

$$Y = C + I + G + (X - M) \tag{27}$$

$$\frac{P_L}{P_C} = A \cdot (\frac{1}{T}) \cdot F_L(\frac{K}{L}) \tag{28}$$

$$\frac{P_K}{P_I} = A \cdot (\frac{1}{T}) \cdot F_K(\frac{L}{K}) \tag{29}$$

$$\frac{P_L}{P_F} = \frac{P_L}{P_C} \times \frac{P_C}{P_{GNE}} \times \frac{P_{GNE}}{P_{GDP}} \times \frac{P_{GDP}}{P_F} \tag{30}$$

$$\frac{P_K}{P_F} = \frac{P_K}{P_I} \times \frac{P_I}{P_{GNE}} \times \frac{P_{GNE}}{P_{GDP}} \times \frac{P_{GDP}}{P_F} \tag{31}$$

$$ER_r = \frac{P_M}{P_{GDP}} \quad (32)$$

$$P_{toft} = \frac{P_X}{P_M} \quad (33)$$

$$I = I\left(\frac{P_K}{P_I}, FC\right) \quad (34)$$

$$C = APC \cdot Y \quad (35)$$

$$\frac{I}{K} = R_I \quad (36)$$

$$\frac{C}{G} = R_C \quad (37)$$

In the short run, the improvement of EID quality encourages companies to promote technology (A) in equation (28). Assuming that real wage $(\frac{P_L}{P_C})$ and tax (T) remain unchanged, the marginal return to labor $F_L(\frac{K}{L})$ will decrease to make the right side of equation (28) remain unchanged. Capital stock (K) is fixed, so manufactures can only increase the input of labor (L) to expand total output (Y). It can be seen from equation (29) that the increase in labor (L) input means that the marginal return of capital $F_K(\frac{L}{K})$ and the rate of return on investment $\frac{P_K}{P_I}$ increase. In addition, the improvement of EID quality also reduces the financing cost (FC) in equation (34) and stimulates the increase of investment demands (I). From the expenditure side of GDP, the increase in total income (Y) will drive up household demands (C). Assuming that government expenditure (G) remains unchanged, the term of trade balance (X-M) will fall to maintain balance of payments, which means that ER_r will fall (the exchange rate appreciates), so that GDP price will rise and import demand (M) will increase. The export price in equation (33) will also increase, because the export price and GDP price change in the same direction, which indicates that terms of trade P_{toft} is improved and the export demand (X) decreases. The improvement in terms of trade means that $\frac{P_{GNE}}{P_{GDP}}$ in equations (30) and (31) decreases, and the real price of labor $\frac{P_L}{P_F}$ decreases. However, the return on investment $\frac{P_K}{P_I}$ in equation (31) increases greater than the decline in $\frac{P_{GNE}}{P_{GDP}}$, resulting in an increase in the real price of capital $\frac{P_K}{P_F}$.

In the long run, the improvement of EID quality not only stimulates the technological progress (A) in equation (29), but also makes the return on investment $(\frac{P_K}{P_I})$ decrease. Assuming that tax (T) remains unchanged, the marginal return of capital $F_K(\frac{L}{K})$ will fall. Since labor supply (L) remains unchanged in the long-run, manufactures can only increase the input of capital (K), thereby driving the growth of total output (Y). It can be seen from equation (28) that as the input of capital (K) continues to increase, the marginal return of labor $F_L(\frac{K}{L})$ will rise, which in turn pushes up real wage $(\frac{P_L}{P_C})$. From the expenditure side of GDP, investment (I) and capital stock (K) change in the same proportion, so investment demands (I) increases. At the same time, the term of trade balance (X-M) changes in the same proportion to GDP, so the increase in total income (Y) also increases net exports. This means that the exchange rate in equation (32) depreciates and GDP price drops, thus import demands (M) will decrease. It can be derived that export price in equation (33) also decreases, so terms of trade will deteriorate and export demand (X) will increase. The deterioration in terms of trade means that $\frac{P_{GNE}}{P_{GDP}}$ in equations (30) and (31) increases, thereby raising the real price of labor $\frac{P_L}{P_F}$. However, the return on investment $\frac{P_K}{P_I}$ in equation (31) decreases greater than the increase in $\frac{P_{GNE}}{P_{GDP}}$, resulting in a decrease in the real price of capital $\frac{P_K}{P_F}$.

5. SIMULATION RESULTS AND ANALYSIS

In this paper, the regulatory effect of EID on environmental tax has been analyzed from the perspectives of macro economy, waste water and exhaust emissions, and industrial output changes. The mechanism of EID improvement on emission reduction by environmental tax and on economic cost has two aspects, one is to stimulate enterprises to improve energy efficiency or production process by increasing environmental protection investment, thus it can reduce emissions of waste water and exhaust, and strengthen the effect of environmental tax on emission reductions; however, technology advancement can bring output expansion and emissions increase to some extent. And the other is to reduce financing costs, stimulate enterprise investment and output expansion, so as to offset partial economic losses caused by environmental tax, but it weaken the emission reduction effect of environmental tax. The direction and extent of EID's regulatory effect on environmental tax depends on the joint effect of these two aspects. Overall, the improvement of EID has a positive regulatory effect on environmental tax, which strengthens emission reduction and boost economic growth, while it presents significant temporal heterogeneity. In the long term, the improvement of

EID has a greater stimulus effect on the economy than that in the short term, although the enhanced effect on emission reduction is less than that in the short term. As far as the comparison between the two is concerned, in the short term, EID's stimulus effect on the emission reduction of environmental tax is greater than that on economic improvement, but its enhanced effect on the emission reduction is less than that on the economy in the long term.

5.1 The stimulus effect on macroeconomics

Improving EID quality can reduce the economic loss caused by environmental tax and improve employment, especially its effect on GDP increase in the long-term is more significant. Considering the improvement of EID, the GDP loss caused by environmental tax in the short term is reduced to -0.155%, recovering 0.037%. In the long term, the improvement of EID quality is more significant for the economic boost, and the GDP loss is further reduced to -0.103%, recovering 0.087%. The main reason is the mechanism of EID improvement through two pathways, which are reducing social financing costs and improving energy efficiency and production process. EID encourages enterprises' investment and production, thus it effectively reduces the economic cost of environmental tax. EID makes enterprise investment and production to be stimulated and promotes employment in the short term apparently, and the employment decline shrinks to -0.299%, recovering 0.028%. In the long term, because of the full use of factors of production, assuming that there is no unemployment in the economy, the total amount of employment returns to the level of full employment.

EID improvement will also raise the price of domestic factors of production, which will bring more short-term price pressure. In the short run, the improvement of EID quality will reduce the financing cost of enterprises and stimulate the demand for investment. A large amount of capital flows to the capital-intensive investment goods production industry, raising the price of capital factors. Combined with the expansion of output driven by technological progress, the result is that the price of labor and capital factors rise by 0.068% and 0.143%, respectively, thus driving up the CPI by 0.068%. In the long run, the effect of EID on price rise was reduced to 0.026%, it mainly because the long-term investment will be constantly converted into production capacity, and returns on investment decline, which reduce the price of capital factors by 0.142% and inhibit the CPI rise.

Improving EID can boost domestic demand to a certain extent, which is more effective in driving investment in the long term. In the short term, the improvement of EID quality stimulates the growth of total income, so that the consumption of residents increased by 0.038%. The decrease of financing cost effectively reduces the financial pressure of enterprises, and makes the investment demand increase by 0.138%. In the long term, with the increase of capital accumulation, investment further expands to 0.156%. An increase in investment means a decrease in savings. In order to balance the expenditure-based GDP estimation in Accounting System, household consumption will increase, and government expenditure will grow the same proportion as household consumption that is by 0.023%.

EID has a strong temporal heterogeneity in the adjustment of external demand, and the long-term net export shows the trend of decline first then rises. Import increases by 0.036% and export decreases by 0.117% with the improvement of EID in the short term. This is primarily due to the overall expansion of economic scale, and it directly increases the demand for imports. Nonetheless, because factor price is pushed up, domestic product price rises, international competitiveness weakens, and export falls. Export improves significantly but import declines in the long run, and it is owing to the substantial reduction in the price of capital factors during the long-term improvement of EID, which makes domestic products have more comparative advantages, and the export demand increases by 0.036%. Net exports grow in proportion to GDP, which means a depreciation of the exchange rate and a decline in import demand by 0.037% between the long and short-term.

Tab 1 Comparison between regulatory effect of EID on macro economy in the short-term and long-term (unit: %)

	Short-term			Long-term			Short & Long term (difference)
	ET	ETID	ETID-ET	ET	ETID	ETID-ET	ETID-ET
Real GDP	-0.192	-0.155	0.037	-0.190	-0.103	0.087	0.050
Employment	-0.327	-0.299	0.028	0.000	0.000	0.000	-0.028
Price Level	-0.208	-0.140	0.068	-0.106	-0.080	0.026	-0.042
Price of Labor	-0.208	-0.140	0.068	-0.808	-0.627	0.181	0.113

Price of Capital	-1.033	-0.889	0.143	0.065	-0.077	-0.142	-0.286
Investment Demand	-0.588	-0.450	0.138	-0.428	-0.272	0.156	0.018
Residents' Consumption	-0.170	-0.132	0.038	0.040	0.063	0.023	-0.015
Government Expenditure	0.000	0.000	0.000	0.040	0.063	0.023	0.023
Import	-0.290	-0.254	0.036	-0.090	-0.090	0.000	-0.037
Export	0.277	0.160	-0.117	-0.172	-0.137	0.036	0.152

5.2 Regulatory effect on pollutant discharge

EID's enhanced effect on emission reduction of environmental tax has been weakened in the long term. Compared with the environmental tax scenario, improving EID quality can further reduce the total emissions of SO_2 and NOx by 0.081% and 0.076% in the short term, and reduce the emissions of these two kinds of exhaust by 0.015% and 0.014% in the long term, respectively, with a reduction of 0.066% and 0.061% compared with that in the short-term. This is principally caused by the differences of dominant influential pathways between the short term and long term, the short-term EID improvement of heavy pollution industry improves the energy efficiency of the enterprise and incentives to production process improvement, which acting as the leading path, prompting these sectors' demand for energy such as coal, oil and gas decreases, thus reducing emissions. However, stimulus effect of long-term financing costs decline on the investment and production is more apparent, which results in further economic expansion and causes the increase in emissions. EID has a significant difference in the regulatory direction of industrial and residential exhaust emission, which plays an enhanced role in industrial exhaust emission, while has a weakened role in residential exhaust emission. The increase of residents' exhaust emission is largely caused by the stimulus effect of EID improvement on residents' demand.

It is worthwhile to mention that EID has a certain weakening effect on environmental tax's waste water emission reduction. In the short term, EID slightly increases the total emissions of COD and NH3 by 0.001% and 0.01%, and in the long term, it further increases the emissions of these two kinds of waste water by 0.005% and 0.002%. Similar to the exhaust emission mechanism, EID also has different regulatory directions for industrial and residential waste water discharge. As a result of EID quality improvement, which stimulates the continuous growth of consumer demand, and the increase of residential wastewater discharge is larger than the decrease of industrial wastewater discharge, so the overall wastewater discharge shows an increasing trend1. It can be seen that the increase of residents' emissions is an important factor to weaken the effect of EID on environmental tax emission reduction.

Tab 2 Comparison between regulatory effect of EID on exhaust emission in the short-term and long-term (unit: %)

		Short-term			Long-term			Short & Long term (difference)
		ET	ETID	ETID-ET	ET	ETID	ETID-ET	ETID-ET
SO_2	Total Emission	-1.289	-1.370	-0.081	-1.363	-1.378	-0.015	0.066
	Industrial Emission	-1.381	-1.477	-0.097	-1.481	-1.503	-0.022	0.075
	Residents Emission	-0.246	-0.150	0.096	-0.012	0.050	0.062	-0.034
NOx	Total Emission	-1.024	-1.100	-0.076	-1.097	-1.111	-0.014	0.061
	Industrial Emission	-1.173	-1.159	-0.087	-1.165	-1.186	-0.020	0.066
	Residents Emission	-0.256	-0.157	0.099	-0.016	0.063	0.079	-0.020

Tab 3 Comparison between regulatory effect of EID on waste water emission in the short-term and long-term (unit: %)

		Short-term			Long-term			Short & Long term (difference)
		ET	ETID	ETID-ET	ET	ETID	ETID-ET	ETID-ET
COD	Total Emission	-0.169	-0.169	0.001	-0.006	0.000	0.006	0.005
	Industrial Emission	-0.169	-0.190	-0.020	-0.031	-0.035	-0.004	0.017
	Residents Emission	-0.170	-0.132	0.038	0.039	0.063	0.023	-0.015
NH_3	Total Emission	-0.155	-0.145	0.010	0.013	0.025	0.012	0.002
	Industrial Emission	-0.136	-0.161	-0.025	-0.019	-0.021	-0.001	0.023
	Residents Emission	-0.170	-0.132	0.038	0.039	0.063	0.023	-0.015

5.3 Regulatory effect on industrial output

Improve EID in the short term and long term stimulates the output expansion of heavily polluted industry respectively through investment driven and capital price decline, and through the industrial chain transmission to the upstream and downstream industries has an impact. The improvement of EID in the short term benefited 64% of the industry, with an average output growth of 0.03%. Output in 36% of industries was hurt by rising Labor prices, with output contracting by an average of 0.02%. In the long run, output of 93% industries was improved, and the average output level was further increased by 0.05% compared with that in the short run. Output contracted in just 10 sectors, falling by an average of 0.02%. This is mainly due to the long-term improvement of EID quality, which reduces the capital price of most industries, thus bringing cost advantage to most industries. We according to the output changes direction and the influence mechanism of different industries can be divided into three categories, the first is short term and long term output benefit of industry, the industry mainly includes the capital-intensive investment production and its upstream industries, as well as industry for the residents and government consumption. The second is short-term output is impaired, but the long-term benefit of the industry, including capital intensive energy industry and export-oriented industry. The third category is industries with both short-term and long-term output losses, mainly coal and labor-intensive export-oriented industries, which are analyzed as follows:

(1) Output of the industries that benefit from both short and long term

Short-term investment goods production industry and its upstream are driven by investment demand output expansion, and long-term capital price decline brings cost advantage. This type of industry mainly includes basic chemical raw materials, synthetic materials, non-ferrous metals and their alloys and castings, non-ferrous metal rolling products and other high energy consumption industries. These sectors expanded by 0.04% and 0.13% on average in the short and long term, making them the most profitable sectors. Taking the basic chemical raw material industry as an example, the short-term improvement of EID quality stimulated investment demand, which boosted the output expansion of the housing construction industry by 0.13% (98.9% of the products were used for investment demand), thus increasing the demand for intermediate inputs in the basic chemical raw materials industry, which boosted its output growth by 0.04%. As the industry is capital-intensive, the improvement of EID reduces the financing cost in the long term, making its capital price fall and its output rise by 0.23% in the short term. What needs to be concerned is that the further expansion of output of these energy-intensive industries also brings about the increase of emissions; leading to EID's enhanced effect on environmental tax emission reduction in the long term is less than that in the short term.

The short-term and long-term consumer goods industry benefited from the increase in output by private consumption demand, while the long-term increase in government expenditure boosted the output growth of government service sector. EID quality in the short and long term has stimulated the output expansion of consumer goods industry, such as residential services, water production and supply, catering, dairy products and other industries are mainly used for residents' daily consumption, so the increase in consumer consumption will stimulate the demand for these industries, so as to increase the output of these industries. Assume that government spending in the short term exogenous is changeless, therefore, is mainly used in government consumption industry output growth is very small, and long-term government spending and consumer spending is highly correlated, so the increase of residents' consumption will increase government spending, which makes public facilities management, such as health and education is mainly used in government consumption industry output growth of 0.01% to 0.03%.

(2) Output of the industries that suffer in the short term but gain in the long term

Most of the short-term capital-intensive energy industry output contraction due to the decline in energy demand, long-term capital price decline to a large extent reversed its output damage situation. To be specific, improving EID in the short term increases energy input to a certain extent by stimulating investment and driving output expansion, but on the other hand, the improvement of energy efficiency in heavy polluting industries reduces energy demand. As a result of the leading role in the chain of short-term energy efficiency improvement, the total energy demand eventually fell by 0.37%, which in turn led to a 0.02-0.05% contraction in the output scale of the energy sectors such as power, thermal production and supply. Improving EID in the long term reduces the financing cost of the energy industry, leading to a sharp drop in capital price. As the electricity, thermal production and supply sectors, oil and gas and coking products are capital-intensive, the advantage of lower capital prices has boosted output by 0.05 to 0.19%.

Output in short-term labor-intensive export-oriented industries has been hurt by higher factor prices, while output in most sectors has been improved by lower long-term capital prices. This industry mainly includes footwear, textile, clothing, other electrical machinery and equipment and other industries. For example, textile manufactured goods are labor-intensive, and 51.22% of goods are used to meet export demand. The short-term improvement of EID pushed up the CPI, making the nominal labor price rise, which in turn led to the price rise of intermediate input cotton, chemical fibre textile and printing and dyeing finishing products industry, which restrained the export demand and led to the output decline of the industry by 0.04%. The long-term improvement of EID quality has reversed the situation of damaged output of textile manufactured goods industry, mainly because the improvement of EID has led to a sharp decline in the capital price of the industry, and then stimulated export demand through low export price, so that its output expanded by 0.1%.

(3) Output of the industries that suffer in both short and long term

The short-term energy demand reduction leads to the output contraction of coal mining products industry, and the long-term price substitution effect makes the output of this industry continue to decline, becoming the most damaged industry. In the short term, EID can encourage heavy pollution industries to improve energy efficiency, and thus reduce energy demand, which inhibits the expansion of output of coal mining and processing products industry, making its output decrease by 0.12%. Under the long-term impact of EID improvement, the capital price of coal mining products industry has also decreased, but the price of its products has decreased by a small margin (-0.04%) compared with other energy industries, which has prompted the energy demand to shift from high-emission coal mining products industry to other low-emission energy industries. In addition, energy efficiency in the downstream power and thermal production and supply sectors of coal mining products improved by 0.1%, reducing the demand for coal mining products. Although the energy efficiency of the coal mining products industry also improved by 0.1%, resulting in some expansion of its output, the total reduction of coal demand in the downstream industry was greater than the output expansion caused by the improvement of energy efficiency in the coal mining products industry, resulting in a reduction of 0.04% in the output of the coal mining products industry.

A small number of labor-intensive export-oriented industries, whose output suffers in the short term, continue to suffer in the long run because of further increases in labor prices. For sports, fish, and communications equipment, radio and television equipment and radar and accessory equipment such as environmental information disclosure of the industry, in the short term labor prices pushed up the production cost of these industries, the fall of prices in the long term capital is far less than the increase in price labor, leading to the decline in exports and output contraction industry. Aquatic products processing industry belongs to the environmental information disclosure of heavy pollution industry, improve the quality of EID, short-term pushing up labor costs, making the industry output fell by 0.03%, and improve the quality of EID, for a long time although largely lower prices for the industry's capital, but also further pushed up the price of labor, cause the prices of the upstream industry of fish, raised the aquatic products industry in the middle of the input costs, and product prices also dampened demand for exports, its output further reduce 0.01%.

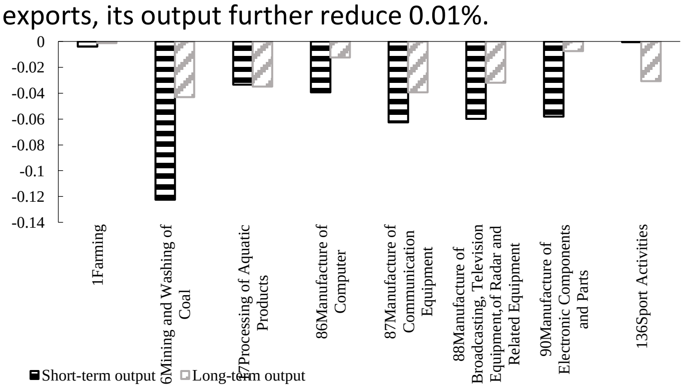

Fig 3 Output of Industries that suffer in both short and long term (unit: %)

6. CONCLUSIONS AND POLICY IMPLICATIONS

Our results show that EID has a “double dividend” effect of strengthening emission reduction and improving economy on environmental tax, but the adjustment effect has obvious time heterogeneity. Specifically, the long-run economic stimulus effect of EID improvement (0.087%) is greater than that of the short-run (0.037%), while the long-run enhanced effect of EID on exhaust gas emission reduction (SO_2 -0.015%；

NOX -0.014%) is less than that in the short-run (SO_2 -0.081%；NOX -0.076%). As far as the comparison between the two is concerned, the strengthening effect of EID on environmental tax's emission reduction is greater than its effect on economic improvement in the short run. While in the long run, the effect on the former is less than its effect on the latter. In addition, EID has a weakening effect on wastewater discharge reduction of environmental tax, which is mainly caused by the expansion of household demands.

It is noteworthy that the improvement of EID can curb energy consumption in the short run by encouraging energy efficiency improvement and promoting the transformation of energy demand from coal with high-emission to other energy products in the long run, so as to help change the energy consumption structure. Our results show that EID improvement can effectively reduce pollutants and promote energy saving in the short run. While it can boost the output expansion of the energy industry and promote the low-carbon economy in the long run, which confirms the "double dividend" effect of EID from the perspective of energy transformation.

The impact of EID improvement has obvious industry heterogeneity. The output expansion of investment goods production industry and its upstream is the most obvious, and the output of industries mainly for household and government consumption has also been achieved, but some industries will also be negatively affected in terms of emission reduction or output. The upstream of investment oriented industries such as basic chemical raw materials is characterized by high energy consumption and high emission, which means that the improvement of EID will not only boost the output of these industries, but also increase their emissions. A few labor-intensive and export-oriented industries, such as aquatic products, are damaged in the short run due to the rising primary factor prices, and aggravated in the long run by the continuous rise of labor price. Based on the above conclusions, this paper proposes the following policy implications:

(1) Enterprises should be encouraged to disclose environmental information and strengthen the responsibility of market entities in the environmental governance system. EID has a positive adjustment effect of strengthening emission reduction and stimulating economic growth on environmental tax. Therefore, it is necessary to establish and improve information disclosure system of heavily polluting enterprises, continuously improve relevant regulations, and formulate standards of pollutant discharge and environmental monitoring. Pollutant-discharging enterprises should be actively guided to disclose real environmental information such as pollutant names, discharge methods and implementation standards through their websites and other channels.

(2) The establishment of a long-run mechanism for environmental information disclosure of enterprises should be improved to adjust the economic impact of formal environmental regulations. The adjustment effect of EID has different emphasis on environmental tax in different periods. Its strengthening effect on emission reduction is more significant in the short-run, while its economic stimulating effect is more prominent in the long-run. Therefore, in order to make the positive effect of EID improvement in offsetting the economic cost of environmental tax, it is necessary to ensure its continuous operation, insist on supervising the integrity of environmental governance in heavy-polluting industries and strengthen social supervision.

(3) The content for environmental information disclosure of enterprises should be refined to play a role in promoting the transformation of energy structure. EID improvement can drive energy consumption demand from coal with high-emission to other energy products with lower-emission through adjusting energy prices. Therefore, the specific content of energy consumption structure should be added to the environmental information disclosed by enterprises, especially for industries that consume more coal products, so as to effectively promote the transformation of energy consumption structure.

(4) The household consumption sector, in which EID improvement has a negative regulatory effect on emissions reduction, should be regulated. The expansion of household demand has also brought an increase in pollutant emissions, weakening the emission reduction effect of EID. Therefore, effective measures such as energy-saving stoves and clean energy substitution should be actively taken to reduce coal combustion emission. At the same time, the current water fee paid by residents in China have already included the sewage treatment fee, so it can be appropriately increased for areas where household discharge more wastewater.

(5) The labor-intensive and export-oriented industries with shrinking output should be supported in the short run, while more attention should be paid to the emission reduction of energy-intensive industries in the long run. In the short run, most labor-intensive and

export-oriented industries suffer more severely due to higher factor prices, so supportive policies should be introduced for them to optimize their development. EID improvement has also resulted in an increase in pollutant emissions of high-energy-consuming industries, especially in the long-run caused by further expansion of output. Therefore, it is necessary to develop of new technologies of energy-saving and emission-reduction and improve energy efficiency and manufacturing technique in these industries.

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