Application of Mathematical Model in Environmental Degradation Valuation

Yu Zheng[1, a], Zhangshun Liao[1, b], Wenhu Shen[2, c], Kunkun Zhang[3, d], Xiangqi Huang[4, e] and Haodong Li[4, f]

[1]College of Mathematics and Information Science, Guangxi University, Nanning, China

[2]Business College, Southwest University, Chongqing, China

[3]College of Mechanical Engineering, Guangxi University, Nanning, China

[4]College of Resources, Environment and Materials, Guangxi University, Nanning, China

[a]2238585033@qq.com, [b]3317219503@qq.com, [c]1191909953@qq.com, [d]2753209254@qq.com, [e]1434757985@qq.com, [f]1256266734@qq.com

Abstract

With the continuous development of the economy, the environmental degradation caused by human production and living activities and the cost measurement of the governance environment have become more and more a real concern of environmental scientists worldwide. In order to reasonably calculate and analyze the cost of environmental governance and the value of environmental degradation, we have constructed different models for different scales and types of projects, providing different environmental cost and environmental degradation value measurement methods. Firstly, for small-scale community projects, combined with the main types of pollutants and their different molecular structures, the sewage charges imposed by enterprises and the investment costs of environmental protection equipment, and the related environmental costs are divided into the environmental prevention cost to prevent further damage to the environment and the cost of environmental damage caused by the current production of the company's production, through the environmental cost of the nuclear algorithm to construct our final model to assess the potential environmental costs of individual project development. For large-scale national or regional projects, we think that it refers not only to a specific project itself, but to different types of projects. Therefore, its environmental cost measurement cannot be equivalent to a small community project. To calculate the unit governance cost of a region, we have established “virtual governance cost (VGC)” indicator by improving the existing indicators, we can finally get the total cost of the environment of a country or region by summarizing the actual governance costs. For the model we built, we selected relevant data from different projects for case study to test the effectiveness of our model: For small community projects, we selected a thermal power plant, through the relevant financial statements and EPA research data. Bringing our model into account, we can accurately assess the value of environmental damage caused by this project and the value of cost of environmental damage – they together constitute the environmental cost of the project. We highlight the potential impact of industrial industry on environmental degradation by dividing pollution sources into air pollution, water pollution and solid waste pollution. Then we further divided them into different types of pollutants. By calculating the unit cost of disposal, unit storage cost and other related costs, the final actual treatment cost and virtual treatment cost are obtained, which is beneficial to us. The total cost of the environment is measured by human production activities. In addition, we use the quadratic fitting method to predict the default data, bring it into our model for testing, and obtain robust results. Finally, we tested the relevant parameters and performed a sensitivity analysis on our model. Ultimately, we find that environmental costs are closely related to t following factors: pollutant emissions, pollutant removal and pollutant discharge standards. Therefore, we have made our recommendations to project planners and managers to better reduce the loss of environmental pollution and environmental degradation then better cope with their potential impact.

Keywords

VGC, Environmental governance, Model, EPA research data.

1. Introduction

Economic theory often disregards the impact of its decisions on the biosphere or assumes unlimited resources or capacity for its needs. There is a flaw in this viewpoint, and the environment is now facing the consequences. However, whenever humans alter the ecosystem, we potentially limit or remove ecosystem services. The impact of local small-scale changes in land use, such as building a few roads, sewers, bridges, houses, or factories may seem negligible.

We offer a model of accessing the real environmental costs of large national project and another one for small scale community. To begin with, we separately calculate the emission of gases, polluted water and solid waste. And then we access the cost of two kinds of projects that may produce. Last, we would like to explain the implications of our modeling on land use project planners and managers and the change over time.

2. The Description of the Problem

In order to solve the problem of understanding the true economic costs of land use projects when ecosystem services are considered, our ICM team has been hired to create an ecological services valuation model. We are going to develop a model to perform a cost benefit analysis of land use development projects of varying sizes.

Considering that most land use projects do not think of the impact of, or account for changes to, ecosystem services, we decide to make services accounted for in the cost-benefit ratio of a project so as to determine and assess the true and comprehensive valuation of the project. Therefore the problems to be solved as follows:

1. How to put a value on the environmental cost of small community-based land use development projects-taking a thermal power enterprise as an example.

2. How to put a value on the environmental cost of large national land use development projects-taking Guangdong Province, China as an example.

3. How to explain the implications of our modeling on land use project planners and managers and the change over time.

3. Basic Assumption

Our data sources are complete and accurate, because our data come from professional national or local statistical yearbooks, which have high data quality and credibility, and can be used as data sets for our analysis.

Due to large projects in most regions of pollution comes mainly from industry, as a result, we have consider the emphasis of industrial pollution as our model, and the air pollution and water pollution from industry and solid waste pollution are included in the measurement of environmental cost of our model, while ignoring other less pollution types and influencing factors.

We take the time factor into consideration and include it in the analysis of our model, that is, we assume that the socio-economic development of a region will bring about changes in pollutant removal amount and corresponding changes in pollutant discharge, the change may be due to technological progress or people's environmental awareness, We evaluate the value of local environmental degradation due to human production by calculating the cost of virtual governance over time and the actual cost of governance.

4. Glossary

Negative externalities: also called external cost or external uneconomic, refers to the behavior of a person or the behavior of a company that affects other people or enterprises, so that they pay extra costs, but the latter cannot obtain corresponding compensation.

Environmental cost: costs connected with the actual or potential deterioration of natural assets due to economic activities. Such costs can be viewed from two different perspectives, namely as (a) costs caused, that is, costs associated with economic units actually or potentially causing environmental deterioration by their own activities or as costs borne, that is, costs incurred by economic units independently of whether they have actually caused the environmental impacts.

Environmental prevention costs: the costs of activities undertaken to prevent the production of waste.

Environmental damage cost: the cost incurred by repercussions (effects) of direct environmental impacts (for example, from the emission of pollutants) such as the degradation of land or human—made structures and health effects. In environmental accounting, it is part of the costs borne by economic agents.

Ecological service: refers to the substances that can be produced by forests and wetland resources each year and the various ecological services provided, reflecting the flow.

Environmental degradation: refers to the deterioration of the ecological environment, including the depletion of resources such as air, water and soil, the destruction of ecosystems and the extinction of wild animals. Environmental degradation can be defined as harmful or undesired changes or disturbances in the environment.

5. Models

5.1 Analysis and Solving of Situation 1

5.1.1 Model Preparation

Our data comes from the annual financial statements of XX Thermal Power Plant in O City and the relevant research data of the municipal environmental protection bureau.

Assumptions

Due to the actual operation of thermal power enterprises, the maintenance costs of some environmental protection equipment cannot be measured, Our model will use approximate measurement. According to the proportion of the total price of

environmental protection equipment of thermal power enterprises, the proportion of maintenance costs in total equipment costs is approximately 2% to 7%.

In the actual measurement work, it is impossible to dynamically monitor the project and monitor the data anytime and anywhere. For example, the data loss ratio of the incomplete combustion of the boiler (q4) is relatively difficult to obtain and the value is small. Therefore, we also use the approximation method for the calculation of the emission of soot in the environmental cost accounting of thermal power enterprises.

5.1.2 Model Establishment

Step1: In the process of modeling, only the facility design cost and equipment construction cost are included in the accounting of the investment cost of environmental protection equipment for thermal power enterprises. Facilities construction costs include: engineering equipment costs; engineering construction costs; equipment installation costs and loan interest during the equipment cycle.

Model one: Determination of the total amount of smoke pollutant emissions

Thermal power enterprises use coal to generate electricity during the production process. For the modeling of the total emissions of flue gas pollutants, through the chemical reaction equations of various gases in the process, the chemical elements under the current coal combustion are modeled.

emissions of Sulfur dioxide (SO2): Regarding the calculation of the total amount of sulfur dioxide emissions from thermal power enterprises, the most critical variable is the basic sulfur content in the coal combustion process and the overall conversion rate of sulfur dioxide converted into sulfur dioxide during the production process. Due to the difference in the types of boilers and coal preparations of thermal power enterprises, the overall conversion rate will be different. Under normal circumstances, this value is between 75% and 85%, thus obtaining the conversion model formula of sulfur dioxide:

$$G_{SO_2} = \frac{32}{16} * b * S_{ar} * K_{SO_2} * (1 - u_{SO_2})$$

The total coal consumption during coal combustion is:

$$b = \frac{\text{Power generation} \times \text{standard coal consumption rate of Power generation}}{29271.1} \times \text{Raw coal low calorific value}$$

According to the United Nations coal calorific value standards, the standard coal heat value is 7000 kcal / kg. The conversion values for the calorific value unit Cal and Joule include a 20 degree Celsius Cal and a 15 degree Celsius Cal. The value of the former is 4.1816 joules and the latter is 4.1868 joules. Therefore, the standard coal calorific value of thermal power companies includes 29271.2 kJ/kg and 29307.6 kJ/kg. In China's current thermal power companies, the heat generated by coal that is commonly used is 29271.2 kJ/kg. This study will select this value for modeling, and the total amount of coal consumed by the power generation standard during power generation also needs to be measured.

In the same way, it can be concluded that:

emissions of Nitrogen Oxide (NOx) :

$$G_{NO_x} = \frac{30.8}{14} * \mathrm{b} * N_{NO_x} * \frac{K_{NO_X}}{m} * (1 - u_N) = \frac{30.8}{14} \times 875560.12 \times 0.96\% \times \frac{25\%}{80\%} \times (1\text{-}50\%) = 2889.35(tons)$$

$$G_{NO_x} = \frac{30.8}{14} * \mathrm{b} * N_{NO_x} * \frac{K_{NO_X}}{m} * (1 - u_N)$$

Model two: The charge of Pollutant emission:

Modeling the emission charges of thermal pollutants for environmental thermal pollutants as follows:

$$\mathrm{p} = \sum_{i=1}^{n} F_i = \sum_{i=1}^{n} (F_{ei} G_i)$$

Combined with the above derivation, we can obtain the sewage charges generated by each thermal power company when confirming a certain type of pollutants:

$$C_{Mi} = \frac{P}{E} = \sum_{\mathrm{i}=1}^{\mathrm{n}} (F_{\mathrm{ei}} G_{\mathrm{i}}) \ / \mathrm{E_n}$$

The above model can also calculate the environmental damage cost and environmental prevention cost of the thermal power enterprise at the time of each power generation, and calculate the total environmental cost of each thermal power enterprise.

Model three：The investment cost of Environmental protection equipment

The investment cost of environmental protection equipment for thermal power enterprises refers to the cost of the thermal power enterprises to invest in the installation of relevant environmental protection facilities, such as wastewater treatment equipment, dust removal equipment, desulfurization equipment, etc., in order to prevent pollution to the ecological environment.

By modeling the investment cost of environmental protection equipment, we obtain:

$$C_{n-1} = C_1(a_1 i^{n-1} + a_2 i^{n-2} + \cdots + a_n i)$$

In the process of modeling, we calculate the loan interest in the investment cycle of the thermal power enterprise environmental protection equipment into the year in which the environmental cost accounting model is currently constructed. Therefore, the total investment in environmental protection equipment should be the sum of the initial investment in environmental protection facilities and the interest generated during the period:

$$C_{\mathrm{i}} = C_1 + C_{n-1}$$

The final model:

The sum of the environmental prevention cost of the enterprise and the environmental loss cost of the enterprise is the total environmental cost of the enterprise：

$$C_{\mathrm{n}} = C_p + C_Q = \frac{32}{16} * b * S_{ar} * K_{SO_2} * (1-u_{SO_2}) + \frac{30.8}{14} * \mathrm{b} * N_{NO_x} * \frac{K_{NO_X}}{m} * (1-u_N) + \mathrm{C}_1 + C_1(a_1 i^{n-1} + a_2 i^{n-2} + \cdots + a_n i)$$

5.2 Analysis and Solving of Situation 2

5.2.1 Model Preparation

Our data comes from the China Statistical Yearbook and the Guangdong Statistical Yearbook, and incorporates some other relevant statistical bulletins.

We assume that pollutants can be completely removed, that is, as long as a certain amount of money and time are invested, the effects of pollutants can be eliminated, ignoring the possible impact of specific technical limitations on pollutant removal.

The treatment of pollutants has the same marginal cost, that is, the virtual treatment cost calculated from the pollutants that should be eliminated, and the actual treatment costs that have actually removed the pollutants follow the same marginal cost.

5.2.2 Model Establishment

Based on our assumptions and practical application needs, we construct the following model to calculate and represent the monetary value of environmental degradation caused by human project development and production activities, which represents the environmental losses caused by the reduction of ecological services and negative externalities caused by human production activities：

$$EDV = AGC + VGC$$

Among them, the AGC can be obtained by us through the national statistical yearbook data set the corresponding pollution types of industrial pollution control investment to complete the forehead to replace, said it was an area used to remove (and then removed) has a certain pollutants of actual cost .While VGC said one not completely removed by the discharge of pollutants into ecosystems remove them completely should be put into the corresponding cost,

we can use the following formula:

$$VGC_i = \sum_{i=1}^{n} UGC_i * PDL_i$$

In this formula, VGC_i represents the pollutants of virtual management costs, UGC_i represents the pollutants of unit cost of governance, PDL_i represents the kind of pollutant emissions, through calculating the sum of them, we can know that a country or region to pollutant removed the need for additional input all the extra overhead expenses, namely virtual management costs.

Due to the different types of pollution and pollution damage to the environment is different, so we are by the method of classification to the different pollution related costs separately calculated, resulting in a certain country or region governance the true costs of environmental degradation, and to this end, we will calculate the pollution governance cost for the following categories.

- Air Pollution

We mentioned here source of atmospheric pollution is mainly due to the industrial emissions and other pollutants, such as Sulfur dioxide, Nitrogen oxides and industrial dust (smoke), etc., the exhaust gas and pollutants, atmosphere of ecological environment is destroyed, ecosystem degradation in order to accurately calculate the atmospheric pollution, the main related governance cost. Through the design and the establishment of the model, we use the following series of formulas to calculate the atmospheric pollution related costs:

$$OC = \frac{PDL + ROP}{EEG}$$

$$LC = \frac{PDL}{EEG}$$

In these formulas, LC representing all the concentration of the pollutants to the atmosphere of untreated and treated clean (not completely) concentration of pollutants to the atmosphere through the relevant calculation of pollutants concentration, we can accurately get the understanding to a country or region when the concentration of pollutant emission levels by importing and calculating the outlet concentration, then we can get the following formula about the governance efficiency GB:

$$GB = \frac{\mathrm{PDL}(OC - LC)}{PDS(PDL + ROP)}$$

In order to better calculate the governance benefits of atmospheric pollutants, we can determine the level of pollutant emission standards through relevant pollutant emission standards stipulated by laws of different countries, and a constant of content dimension is adopted as the specific value in the formula.

By setting weights for governance benefits and performing weighted calculations, we can get the governance cost coefficient GCC:

$$GCC_i = \frac{GB_i}{\sum_{i=1}^{n} GB_i}$$

In this formula, the treatment cost coefficient representing a certain pollutant represents the treatment benefit of a certain pollutant, and the size of the treatment cost coefficient represents the proportion of the treatment benefit of different pollutants in the total treatment benefit.

Through the calculation of the above relevant quantities, combined with the input costs of relevant pollutant treatments in the current year that have been counted in various countries or regions, we can get the unit treatment cost of each pollutant:

$$UGC = \frac{GCY * GCC}{ROP}$$

In this way, we can obtain the relevant costs for each unit of treatment for each pollutant (note: as mentioned above, we believe that the actual and virtual treatment costs for each pollutant follow the same unit treatment costs, therefore, we will no longer consider the subtle differences between the two due to certain factors).So as to lay a solid foundation for our subsequent calculation and analysis.

Through the above calculation, we can finally summarize the virtual treatment cost of a pollutant:

$$VGC_i = \sum_{i=1}^{n} UGC_i * PDL_i$$

Through this method to calculate the cost of virtual management, refers to remove all the related expenses, discharge of pollutants in the ecosystem already in and remove harmful pollutants with actual governance costs constitute a country or region in the current year because of the total cost of the pollution to environment. Through the above analysis, we successfully build a relevant model to calculate the cost of atmospheric pollution control.

- Water pollution

Water pollution is the water that is degraded or lost by the use of harmful chemicals and pollutes the environment. Acids, alkalis, oxidants in sewage, and compounds such as copper, cadmium, mercury, arsenic, organic poisons such as benzene, dichloromethane and ethylene glycol will poison aquatic organisms and affect drinking water sources and scenic spots. Although wastewater discharge from agriculture can also affect and pollute the water environment, industrial wastewater discharge is still the main source of water pollution. Therefore, our model will focus on the environmental damage caused by industrial water pollution. In the cost-value assessment model, in the estimation of this type of pollution, we still use the modified pollution cost coefficient method similar to the above to estimate the value of the relevant treatment cost of water pollution. Therefore, we will use the definition of import concentration and export concentration. The concentration is adjusted and modified to obtain the inlet concentration of the water pollution and the calculation model of the outlet concentration.

$$OC = \frac{PDL + ROP}{EWW}$$

$$LC = \frac{PDL}{EWW}$$

In the formula, it represents the total amount of wastewater discharge in a certain country or region. By obtaining the above relevant variables, we can obtain a calculation model for the cost of water pollution control by a method and process similar to the calculation of the cost of air pollution of control.

So the total cost of water pollution control in a given country or region can be calculated.

- Solid waste pollution

Solid waste pollution refers to the various wastes that are produced daily in a city, wastes that cannot be discharged into water bodies, and those that cannot be discharged into the atmosphere. Sources include homes (such as homes and public places), businesses (such as shops, restaurants, hotels), and industries (such as factories). This type of waste treatment includes transporting waste incinerators, landfills, and recycling. Different from the above-mentioned air pollution and water pollution, since the solid waste generated by human production and life is not necessarily directly discharged into the ecosystem, people mainly deal with the pollution problems caused by these solid wastes in those three ways: the first is the way of comprehensive utilization of solid waste, such as recycling and recycling, recycling solid waste for people's production and life; the second is to use storage methods to store solid waste in concentrated stacking sites or specialized storage facilities; and the third is to directly treat them, such as landfill or incineration, to minimize the potential environmental impact of solid waste pollution. To this end, in the following analysis, we will separately calculate the amount of solid waste treated by different treatment methods, and calculate the actual pollution of industrial solid waste based on the statistics of industrial solid waste. Actual cost and virtual cost, in our method of calculating cost can be expressed by the

following formula:

$$\mathrm{AGC} = \mathrm{UDC} * \mathrm{DOP} + \mathrm{USC} * \mathrm{CSC}$$

$$\mathrm{VGC} = \mathrm{UDC} * (\mathrm{PDL} + \mathrm{CSC})$$

In this way, we can build a model to calculate the costs associated with managing solid waste pollution.

Finally, by adding the actual treatment costs of the above three pollution types and the virtual treatment costs, we can roughly obtain the total cost of environmental pollution in a certain country or region, so that the value of environmental degradation can be assessed.

6. Sensitivity Analysis

6.1 Sensitivity Analysis of Model One

In our model, different models of different pollutant emissions were constructed. In this process, the efficiency of the pollution control equipment was assumed to be a very fixed value. However, with the continuous advancement of technology, the efficiency of existing pollution treatment equipment will also continue to improve, and the level of pollution control will also be improved.

In our model, if the technological equipment continues to develop, then the degree of coal combustion will increase. When the degree of coal combustion increases by 5%, the total amount of pollutants will decrease by 12%, and the cost of treatment will decrease by 9%. When the overall desulfurization efficiency of the desulfurization equipment reaches 100% (ideal state), the total amount of pollutant discharge is 0, the pollution control has achieved remarkable results, and the environmental cost will be greatly reduced.

6.2 Sensitivity Analysis of Model Two

Sensitivity analysis reflects the degree of influence of the change of variables in the model on the final result of the model. Through the sensitivity analysis of the model, we can know the UGC change of the unit treatment cost when the ROP of the pollutant removal changes by ±5%, so the cost of virtual governance also changed accordingly ∓4.76%. At the same time, we further tested that when the EGG of exhaust emissions was ±5%, there was also a change in governance efficiency of ∓4.76%. Therefore, our model passed the sensitivity analysis, it proves that our model is stable and effective.

7. Promotion of Model

We can collect more extensively relevant environmental data by questionnaires, field research, experiments, environmental monitoring, etc. In addition to it, we will incorporate other factors that may affect environmental costs (such as technological progress) into our model.

Through the reasonable modeling methods, the secondary environmental cost model brought by the project development will be established, which together with the original model constitutes a powerful tool for us to calculate the environmental cost and measure the environmental degradation value.

In the future, we will work together to combine different project types, use reasonable means and appropriate methods to calculate the relevant opportunity cost of project development, and incorporate it into the calculation of the total cost of environmental degradation in our model.

8. Conclusion

Through the two models we have established, we find that environmental costs are closely related to the following factors: pollutant emissions, pollutant removal, and pollutant discharge standards.

However, the degree of damage to the environment and the cost of governance of different scales or types of projects cannot be equal. Therefore, we have designed two different models according to the different characteristics of the project to accurately evaluate the relevant environmental costs caused by the project.

The authority should establish and improve relevant accounting standards and statistical systems for environmental cost measurement as soon as possible, provide more accurate data indicators for environmental protection work. Then establish an effective environmental cost assessment model to monitor environmental damage caused by pollution.

The government is supposed to use the way of Pigovian tax, environmental protection industry subsidies, and open enterprise emissions trading market to better control and reduce environmental costs and negative external losses caused by environmental pollution.

Make reasonable construction and use plans of projects to minimize the environmental costs of human development and production.

References

[1] Seong-Hoon Cho, Roland K. Roberts, Seung Gyu Kim, 2011. Negative externalities on property values resulting from water impairment: The case of the Pigeon River Watershed. Ecological Economics 70 (2011) 2390–2399.

[2] Glossary of Environment Statistics, Studies in Methods, Series F, No. 67, United Nations, New York, 1997. < https://stats.oecd.org/glossary/detail.asp?ID=819>.

[3] “Environmental management accounting” < https: // www. accaglobal. Com /an /en /student / exam-support-resources/fundamentals-exams-study-resources/f5/technical-articles/Env-MA.html .>.

[4] Glossary of Environment Statistics, Studies in Methods, SeriesF, No.67, United Nations, New York, 1997. <https://stats.oecd.org/glossary/detail.asp?ID=530.>.

[5] Robert Costanza, 1997.The value of the world's ecosystem services and natural capital. Nature volume 387, pages253–260 (1997).

[6] Samuel Adams, Edem Kwame Mensah Klobodu, 2018. Financial development and environmental degradation: Does political regime matter? Journal of Cleaner Production 197 (2018) 1472-1479.

[7] Guangdong Statistical Yearbook <http://www.gdstats.gov.cn/tjsj/gdtjnj/>.

[8] China Statistical Yearbook <http://www.stats.gov.cn/tjsj/ndsj/>.

[9] Charles D. Kolstad, 2011. Intermediate Environmental Economics. 2nd. Oxford: Oxford University Press.p111-125.

[10] Robert Costanza, 1997. The value of the world's ecosystem services and natural capital. Nature volume 387, pages253–260 (1997).