A New model on evaluating environmental degradation

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Abstract. Environmental protection has attracted more and more attention in today’s society. Traditionally, most land use projects do not consider the impact of, or account for changes to, ecosystem services. To better evaluate the environmental degradation, we created an ecological services valuation model. Our EDC-GP Model provides a quantitative analysis of Environmental Degradation in different areas. Then apply it to both large national project and small city-based project.

1. Introduction

In today’s society, environmental pollution has become a serious problem. As the lifeblood of national economic development, industry has also greatly increased the burden of environmental governance.

Different from the idea of pollution first and treatment afterwards in the past, what the international community advocates now is pollution treatment at the same time. It means that we have to pay attention to the cost of environmental pollution and the economic construction at the same time.

When we build a factory, although the development of GDP promoted, it discharges the industrial waste water, which pollutes the river; It gives off gases, such as carbon dioxide and sulfur dioxide, which destroy the atmosphere; It also produces a lot of dangerous waste, which causes serious pollution to the soil. At the same time, excessive carbon dioxide emissions aggravate the greenhouse effect, leading to global warming.

Originally, the environmental degradation cost was not considered before, thus the calculated economic cost is not true enough. Therefore, we will focus on the price of environmental degradation cost to accurately grasp the real economic cost. We established an ecological service evaluation model and carried out cost-benefit analysis on land use development projects of different scales.

To specify the cost of environmental degradation, we build a model called EDC-GP Model, which is able to value the cost for both large and small eco-projects. Meanwhile, we create an ecological services valuation model to show the true economical costs of land use projects to large national projects. We would also evaluate the effectiveness of EDC-GP model based on our analyses and model design.
2. Assumptions
2.1 Estimate the cost of environmental degradation by using waste water, waste gas and solid waste as the main factors.
2.2 Contaminants between the various areas will not affect each other when conducting environmental service assessments.
2.3 Various political and economic policies remain unchanged when forecasting the cost of environmental degradation.
2.4 The cost of pollution control is the most relevant to the production of industrial products. The industrial product price index (PPI) is used to convert the environmental degradation costs of various pollution over the years.

3. Nomenclature

| Table 1 Nomenclature |
|----------------------|
| Symbol | Definition |
|  
| $U_{dc}(t)$ | Unit t-year degradation cost |
| $U_{dc}/y(t-1)$ | Unit t-1 year unit degradation cost |
| $PPI/yoy(t)$ | t-year year-on-year PPI index |
| $C_{dc}$ | Current Degradation Cost |
| $CD_{dc}$ | Current Dyes of Degradation Cost |
| $C_{pe}$ | Current pollution emissions |
| $Loss_{t}$ | total annual environmental degradation cost |
| $GDP$ | Gross Domestic Product |
| $aGDP$ | Average Gross Domestic Product |
| $IN_{t}$ | the annual completion of industrial pollution investment |
| $EP_{t}$ | the amount of exports |
| $Im_{t}$ | the amount of imports |
| $u_{t}$ | constant coefficient |
| $INS_{n,t}$ | the proportion of the n-th industries |
| $W_{GDP}$ | worth of gross domestic product |
| $W_{dc}$ | worth of environmental degradation cost |
| $s_{peci}$ | Industrial pollution control completed investment |

4. Model Building

4.1. Step 1: Build a model

4.1.1. Estimate EDC. According to the data in the China Green National Economic Accounting Research Report, the water environmental unit degradation cost caused by water pollution in 2004 was 4.712 yuan per ton, Atmospheric environmental unit degradation cost from air pollution was 4939.3 yuan per ton, while solid sites was 7.07 yuan per ton.

In order to calculate the environmental degradation costs of the three pollution years from 1990 to 2009, it is necessary to determine the current unit degradation cost of the three types of pollution. Since the cost of pollution control is less relevant to the consumer's finished products, the industrial product price index is used to convert the historical years. The cost of environmental degradation in the current pollution period,

$$U_{dc}(t) = U_{dc}/y(t-1) \times PPI/yoy(t)$$

The specific results are shown in Table 1. The data shows that the cost of atmospheric degradation is relatively high, indicating that the degree of atmospheric pollution, human health and quantity is higher than that of water dyeing and solid waste.
On the basis of determining the cost of degrading the location of each dyeing year, according to the annual displacement of each dye, it can be regarded as the current retreat cost, the specific formula:

\[ C_{dc} = C D_{dc} \times C_{pe} \]

According to Table 2, China’s environmental degradation costs continue to increase and the contradictions and conflicts with the situation are becoming more and more clear. Without the price factor, the cost of land degradation in the current period is from 1729.32 billion yuan in 1990 to 5128.67 billion yuan, nearly double the amount. Moreover, from the perspective of the cost of environmental degradation, water-dyeing emissions account for more than 90 % of the emissions of dyes, caused by water dyeing. The cost of degraded environment also accounts for more than 50 % of the cost of degradation; however, the discharge of solid waste is higher than that of airborne matter, but the cost of degraded by solid waste is less than 1 % of the cost of degradation caused by airborne dyeing. Therefore, the current cost of environmental pollution in China is mainly derived from the discharge of water and airborne materials.

Table 2. Cost of Environmental Degradation and Gross Domestic Product in China from 1990 to 2009

| Year | \(W_{dec}\) | \(W_{GDP}\) | \(\ln(W_{dec})\) | \(\ln(W_{GDP})\) |
|------|-----------|-----------|----------------|----------------|
| 1990 | 1729.32   | 18667.8   | 7.455483547   | 9.83455393    |
| 1991 | 1768.85   | 21781.5   | 7.478048997   | 9.98816265    |
| 1992 | 1995.24   | 26933.5   | 7.59818623    | 10.20075479   |
| 1993 | 2517.15   | 33333.9   | 7.80982598    | 10.47259412   |
| 1994 | 3041.05   | 48197.9   | 8.01995813    | 10.76307073   |
| 1995 | 3400.83   | 60793.7   | 8.131774798   | 11.01521444   |
| 1996 | 3509.54   | 71176.6   | 8.073882904   | 11.17291939   |
| 1997 | 2993.11   | 78973     | 8.00406826    | 11.2766813    |
| 1998 | 3135.79   | 84402.3   | 8.05636415    | 11.34334993   |
| 1999 | 3653.84   | 89677.1   | 8.211710965   | 11.40397072   |
| 2000 | 3678.26   | 90214.6   | 8.263141878   | 11.50504046   |
| 2001 | 3794.82   | 109655.2  | 8.2413132     | 11.60596918   |
| 2002 | 3678.66   | 120332.7  | 8.210308334   | 11.6901569    |
| 2003 | 4014.02   | 133822.8  | 8.297546512   | 11.81910637   |
| 2004 | 4380.08   | 168678.3  | 8.386222288   | 11.98216818   |
| 2005 | 5068.29   | 184937.4  | 8.51849618    | 12.12777267   |
| 2006 | 5135.26   | 216614.4  | 8.543903909   | 12.28448818   |
| 2007 | 521A.75   | 269810.3  | 8.699348432    | 12.49058318   |
| 2008 | 5453.39   | 314045.4  | 8.603992713   | 12.65729884   |
| 2009 | 5128.67   | 340596.9  | 8.542601645   | 12.73819067   |

4.1.2. The Definition of EDC-GP Curve. The EDC-GP Curve is a hypothesized relationship between environmental quality and economic development: various indicators of environmental degradation tend to get worse as modern economic growth results until average income reaches a certain point over the course of development. The EDC- GP Curve suggest, in sum, that ‘the solution to pollution is economic growth.’ In general, there is an inverted ‘U’ relationship between EDC and GP.

4.1.3. Fit the EDC-GP Curve. Due to different policy quantities, the position and curvature of the EDC-GP Curve could effect several things. The changes in position causes the displacement of the inflection point which represented the relative level of the income level and initial income level of a country.

Therefore, our reasonable governance policy is: Under the conditions of a certain income level,

Standard 1: Under the condition that the income level of the inflection point is equal, the phase position is closer to the governance policy represented by the negotiator.
As shown in the figure above, under the influence of Policy 2 and Policy 3, EKC graph formed a curve 2 and a curve 3. In this case, Policy 2 is better than Policy 3, because when the income is low, the pollution indicator level of Policy 2 is lower than Policy 3. But when the income is relatively high and even grow up further, the speed that the level decrease of Policy 2 is faster than Policy 3.

Standard 2: Under the condition that the income level of the inflection point is large. The policy is constantly changing with it. As shown in Figure, from the perspective of the positional analysis, Policy1 and Policy2 make the same shaped curve move.

![Figure 1. Comparison of 3 Policies](image)

Here are three different situations:

1. If the country’s initial income is low in the country, both of them would speed up the deterioration of environment. But we could choose Policy 2 at first, as the income increase is the same, follow economic growth along a less polluted path. When the income has risen to the middle level, Policy 1 seems more adaptable than Policy 2, which ensure the promotion of the environment.

2. If the country’s initial income is at a medium level, the result of Policy 2 governance is economic growth while environmental pollution increases further along Curve 2, but Policy 1 is relatively reasonable, which not only ensures economic growth but also further reduces environmental pollution indicators.

3. If the country’s initial income is at a high level, although both Policy 1 and 2 can improve the environment, Policy 1 has the lowest level of environmental pollution at the same rate of growth. It can be seen that under certain conditions, the initial income level of a country plays an important role in the choice of environmental pollution control policies.

4.1.4. The Application of the Model. In order to analyze the path of environmental governance in China at this stage, the model of pollution emission loss established by Cole is used for reference

4.2. Step 2: Evaluate the effectiveness

4.2.1. Large National Project. By consulting the information, we obtained the scatter plots of per capita GDP and per capita SO\textsubscript{2} emission load in China and the United States.

In this graph, CPCGDP means China’s per capita GDP, PSO\textsubscript{2} means per capita SO\textsubscript{2} emission load. Because of the lack of SO\textsubscript{2} emission load in 1996, the curve fluctuates widely. We substitute Industrial SO\textsubscript{2} emissions in 1996 for it. And it doesn’t influence the general trend of the curve.
Figure 2. EDC-GP Curve by Matlab

In this graph, UPGDP means the United States’ per capita GDP, UPPS$_2$ means per capita SO$_2$ emission load.

We compare the EKC graph between China and the United States. We find that China is in the stage of increasing pollution, while the United States has entered the stage of gradual improvement of environmental conditions.

According to the assumption that the EKC graph is in inverted U-shaped relationship, China is in the uplift section on the left side of the EKC graph, while the United States is in the downdraft section on the right side of the EKC graph. It means that the United States is in the environmental quality improvement stage after pollution. It exactly consistent with the fact and prove the validity of our model.

4.2.2. Small city-based Project. For the small city-based project, we collected data of several cities in the east of China, calculated the environmental degradation cost and chose the Entropy Method to compare the ecological service qualities.

The EM is a mathematical method for judging the degree of dispersion of an index. The greater the degree of dispersion of the index, the greater the impact on the comprehensive evaluation.

Four single indicators of industrial waste water discharge, total sulfur dioxide emissions, industrial solid waste production, nitrogen oxide were selected, and the comprehensive evaluation index of environmental pollution was constructed by entropy method. The smaller the indicator value, the lower the emission level of the pollutant, that is, the lower the degree of environmental pollution.

Figure 3. Source: National Bureau of Statistics, National Environmental Statistics Report
Specific steps are as follows:

1. Build raw data matrix

\[ X = \begin{bmatrix}
  x_{11} & \cdots & x_{1,j} \\
  \vdots & \ddots & \vdots \\
  x_{i,1} & \cdots & x_{i,j}
\end{bmatrix} \]

Where \( x_{ij} \) is the \( j \)th indicator value of province \( i \).

2. If there is a negative number in the data, the data needs to be non-negative. In order to avoid the meaninglessness of the logarithm when entropy is sought, data translation is required. For the bigger the better indicator,

\[ x'_{ij} = \frac{x_{ij} - \min(x_{ij}, x_{2j}, \ldots, x_{nj})}{\max(x_{ij}, x_{2j}, \ldots, x_{nj}) - \min(x_{ij}, x_{2j}, \ldots, x_{nj})} + 1, \]

For the smaller the better indicators,

\[ x'_{ij} = \frac{\max(x_{ij}, x_{2j}, \ldots, x_{nj}) - x'_{ij}}{\max(x_{ij}, x_{2j}, \ldots, x_{nj}) - \min(x_{ij}, x_{2j}, \ldots, x_{nj})} + 1, \]

3. Calculate the index weight \( P_{ij} \)

\[ P_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{n} x'_{ij}} \]

4. Calculate the entropy value \( e_j \) of the \( j \)th indicator.

\[ e_j = -k \sum_{i=1}^{n} P_{ij} \ln(P_{ij}) \]

5. Calculate the information utility value of the \( j \)th indicator \( g_j \).

\[ g_j = 1 - e_j \]

6. Calculate weights \( w_j \).

7. Calculate the comprehensive score of each province and city \( S_i \).

\[ S_i = \sum_{j=1}^{m} w_j \times P_{ij} \]
Through calculation, the total amount of industrial waste water discharged by each province, the amount of industrial solid waste generated, the total amount of sulfur dioxide emissions, and the total amount of nitrogen oxide emissions are 12.93%, 13.38%, 59.64%, 14.05%. And the comprehensive index values of environmental pollution in each province and city are shown in the table.

|          | industrial effluent/10^4 ft | SO2/t | nitrogen oxide/t | Industrial waste/10^4 ft | Environmental Assessment Value |
|----------|----------------------------|-------|------------------|--------------------------|--------------------------------|
| Beijing  | 8404                       | 3799  | 15495            | 630.35                   | 9612.71113                     |
| Shanghai | 31586                      | 12661 | 38335            | 1630.48                  | 17238.35192                    |
| Chengdu  | 19304                      | 13985 | 86639            | 1943.2                   | 98355.8856                     |
| Tianjin  | 18197                      | 42323 | 73429            | 1495.44                  | 33074.24967                    |
| Hangzhou | 24550                      | 26497 | 31123            | 369.39                   | 23403.17138                    |
| Nanjing  | 19922                      | 15404 | 46249            | 1995.42                  | 17881.3519                     |
| Shijiazhuang | 7470                | 33252 | 58643            | 1588.37                  | 29249.22921                    |

**Figure 5.** Environmental Valuation of Some Cities in 2017

By using Entropy weight method, we get the quality of ecological services from small to large, that is Chongqing, Tianjin, Shijiazhuang, Hangzhou, Nanjing, Shanghai, Beijing. Beijing, the capital city of China, enjoyed most plentiful resources among the whole country and thus had the best ecological services.

5. Conclusion

All in all, we first establish a model to estimate the cost of environmental degradation. Considering that the cost of environmental degradation is also related to the value of goods in various years, we introduce the PPI to more reasonably estimate the cost of environmental degradation in each year.

In order to assess ecological services, we study the relationship between gross product and environmental degradation costs. According to relevant experts, there is an inverted ‘U’ relationship between gross product and environmental degradation costs.

So we construct the corresponding functional formula and then perform the fitting curve to judge the cost-effectiveness by comparing the differences between the different curves.

Therefore, through our model, we can better assess the real economic cost of land use projects considering ecosystem services, so that policy makers can modify and formulate better economic and political policies to optimize cost-effectiveness.

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