Valuation of Ecosystem Services in China' s Resource-Based Cities: A Meta-Model Perspective–Postprint

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Abstract

Resource-based cities serve as supply bases for basic energy and important raw materials; however, due to resource depletion and lack of coordinated planning, these cities face considerable pressure from economic structural imbalances and severe ecological degradation. Therefore, conducting cost-benefit analysis of the natural environmental economic value in resource-based cities provides valuable guidance for improving human settlements and addressing ecological environmental problems. This study employs a Meta model, from the perspective of urban residents' per-household willingness to pay, to evaluate ecosystem service values in resource-based cities, and utilizes value transfer functions to assess park values. The results indicate that: (1) Values derived from ecosystem service characteristic variables are relatively high and exert significant influence on ecosystem services in resource-based cities. (2) Except for forests, environmental resources characterized by other natural type variables derive relatively lower ecosystem service values. (3) Higher urban resident income correlates with stronger payment capacity; regarding payment instrument selection, people demonstrate a preference for donations and entrance fees. (4) The ecosystem service value of parks ranges from $1790.26\$\times 104 to 31016.00\times\$104$ yuan, arranged sequentially for eastern, central, and western regions. Based on these findings, we propose increasing forest area in resource-based cities, enhancing ecological benefit delivery, improving ecosystem service functions, raising residents' disposable income, and promoting voluntary payment instruments such as donations and entrance fees, thereby continuously improving urban ecosystem service values.

Full Text

Abstract

Resource-based cities serve as critical suppliers of basic energy and important raw materials. However, due to resource depletion and insufficient comprehensive planning, these cities face significant pressures including economic structural imbalances and severe ecological environmental degradation. Conducting cost-benefit analyses of the natural environmental economic value of resource-based cities thus provides important guidance for improving living environments and addressing ecological challenges. This study employs a Meta-analysis model to evaluate ecosystem service values in resource-based cities from the perspective of urban residents' average household willingness-to-pay (WTP). By reviewing relevant literature and establishing a value transfer database, we assess the factors influencing ecosystem service values and apply value transfer functions to evaluate park values.

The results indicate: (1) The value obtained from ecosystem service characteristic variables is relatively high, exerting a significant influence on ecosystem services in resource-based cities. (2) Except for forests, ecosystem service values derived from other natural resource types are relatively low. (3) Higher urban resident income correlates with stronger payment capacity. Regarding payment instruments, people prefer donations and entrance fees over other methods. (4) Park ecosystem service values range from 17.9026 million to 310.16 million yuan, decreasing from eastern to central to western regions. Based on these findings, we recommend increasing forest coverage in resource-based cities, strengthening ecological benefit outputs, improving ecosystem service functions, raising residents' disposable income, and promoting voluntary payment instruments such as donations and entrance fees to continuously enhance urban ecosystem service values.

Keywords: resource-based cities; ecosystem services; value transfer; stated preference approach; Meta-analysis

1 Introduction

Sustainable development of resource-based cities is crucial for China' s energy security, economic structural transformation, and the construction of a resource-saving and environmentally friendly society. However, the long-term resource-dependent economic growth model has generated numerous environmental problems, with air pollution and climate change becoming key constraints on sustainable development in these cities. Consequently, quantifying ecosystem service benefits in resource-based cities has attracted considerable scholarly attention. Accurate assessment of ecosystem service values relates directly to regional ecological security and economic development and has gradually become a research hotspot in ecological economics, environmental ethics, and sustainable development.

From an economic perspective, urban ecosystem services constitute public goods with strong externalities, making their value difficult to assess under existing market conditions and potentially leading to undersupply without policy intervention. For non-use value assessment, the absence of markets and real data prevents price determination based on function, making contingent valuation methods essential for non-market goods valuation. Stated preference methods, including contingent valuation and choice experiments, reveal public preferences for public environmental goods through simulated markets and have been widely applied in valuing scenic areas, urban green spaces, tourism resources, biodiversity, and ecological environments. When detailed ecosystem service valuation for specific regions is infeasible, benefit transfer methods become more reliable. Meta-analysis, a quantitative synthesis approach integrating multiple independent studies, offers the most promising benefit transfer method, enhancing understanding of ecosystem service value estimation validity.

Previous research provides extensive references for evaluating urban ecosystem service values and their influencing factors, yet several gaps remain: (1) Few studies focus on resource-based cities with fragile ecological environments and difficult economic transitions, where low production efficiency, backward technology, and weak resource protection awareness exacerbate overconsumption and destruction. (2) Domestic research predominantly concentrates on single natural resource types, yielding inconsistent conclusions regarding study objects and methodological characteristics. (3) Urban ecosystem service valuation still relies primarily on stated preference methods, whose hypothetical nature introduces biases—including strategic, payment vehicle, and protest biases—that constitute core challenges in applied research.

This study addresses these gaps by examining resource-based cities through Meta-analysis, incorporating multiple natural resource types to analyze influencing factors on ecosystem service values. We assess the applicability and development prospects of value transfer methods for urban ecosystem service valuation in China, providing decision-making support for environmental policy feasibility, ecological protection, natural capital accounting, and ecological compensation.

2 Data and Methods

2.1 Data Collection

Meta-analysis requires valid and comparable existing ecosystem service valuation data. This study collected literature focusing on contingent valuation and choice experiment methods. On December 31, 2020, we searched the China National Knowledge Infrastructure (CNKI) database using keywords including "willingness to pay," "contingent valuation method," and "choice experiment method," combined with resource-based city names. The initial search yielded 1,247 articles. Based on established criteria, we selected literature that: (1) could evaluate urban ecosystem service values; (2) employed contingent valua-

tion or choice experiment methods; (3) had resource-based cities as study areas; and (4) included complete information on WTP, sample size, and publication year.

The final dataset included 47 articles (45 journal articles and 2 master' s theses), comprising 143 sample observations and 104,922 resident WTP samples. The dependent variable in our Meta-analysis is the logarithm of residents' average annual household WTP for urban ecosystem services. Since some survey results reported per capita WTP, we converted these to household WTP by: first adjusting different years' prices to 2019 constant prices using the Consumer Price Index (CPI); second, multiplying per capita WTP by city population; and third, dividing total WTP by the number of households. All data were sourced from the *China City Statistical Yearbook*.

2.2 Meta-Regression Model

2.2.1 Model Specification Explanatory variables include study object and method characteristics, natural type characteristics, and ecosystem service type characteristics. We further refined these based on stated preference method components in urban ecosystem service valuation.

Study Object and Method Characteristics encompass socioeconomic variables, payment vehicles, and research methods. Socioeconomic variables include respondents' income levels, proxied by per capita GDP of resource-based cities due to data availability. Other variables include study area size, payment vehicles (taxes, donations, entrance fees, and other forms), and measurement methods (contingent valuation with payment card, dichotomous choice, or open-ended formats; choice experiments). All variables were dummy-coded with appropriate reference groups.

Natural Type Characteristics were expanded from traditional classifications to include forests, parks, lakes, wetlands, and other natural types, each dummy-coded with "other natural types" as the reference.

Ecosystem Service Type Characteristics follow the Millennium Assessment framework but were adapted for resource-based city particularities. Services include provisioning, climate regulation, biodiversity, and recreation, each dummy-coded based on specific study descriptions.

To better describe relationships between dependent and independent variables, all continuous variables were log-transformed. The Meta-regression model is specified as:

$$\ln(y_i) = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \varepsilon_i$$

where $\ln(y_i)$ is the log of household WTP; i indexes sample observations ($i = 1, 2, ..., 143$); X_{1i} represents study object and method characteristics (per capita GDP, city area, payment vehicles, measurement methods); X_{2i} denotes natural

type characteristics (forest, park, lake, wetland); X_{3i} captures ecosystem service type characteristics (provisioning, regulation, biodiversity, recreation); α is a constant vector; β is a coefficient vector; and ε_i is the error term.

Given potential insufficient variation within single studies, we employed weighted least squares using the inverse square root of sample size as weights to avoid biased estimates.

2.2.2 Validity Testing Meta-analysis requires validity testing when used for benefit transfer, examining consistency between predicted values from the regression model and observed values from empirical studies. Transfer accuracy is typically measured by out-of-sample benefit transfer error (BTE), with smaller errors indicating better validity:

$$\mathrm{BTE} = \frac{|V_{\mathrm{obs}} - V_{\mathrm{pred}}|}{V_{\mathrm{obs}}} \times 100\%$$

where V_{obs} is the observed value from empirical research and V_{pred} is the predicted value from Meta-regression. While no definitive threshold exists, BTEs of 20%-40% are generally considered acceptable. We also conducted paired t-tests to examine whether transfer values significantly differ from sample values (accepting the null hypothesis if $p > 0.05$) and one-sample Kolmogorov-Smirnov tests to verify that distributions of real and predicted values are not significantly different from normal distributions.

3 Results

3.1 Meta-Regression Results

Regression results are presented in . Model 1 is a basic model including study object/method and natural type characteristics. Model 2 extends Model 1 by adding ecosystem service type characteristics. Both models show good fit with R^2 values of 0.705 and 0.728, respectively, and F-statistics passing significance tests. The following interpretation focuses on Model 2.

Study Object and Method Characteristics: Per capita GDP shows a significant positive effect on ecosystem service value—a 1% increase in per capita GDP increases household WTP by 0.705%, indicating ecosystem services are normal goods, consistent with existing research. City area has a negative coefficient, suggesting diminishing marginal returns of natural areas in larger cities, though this parameter is not statistically significant. Regarding payment vehicles, tax payments systematically underestimate ecosystem service value compared to other mechanisms (entrance fees, donations), reducing household WTP by 1.435%. Donations and entrance fees increase WTP by 0.789% and 0.728%, respectively. Among measurement methods, choice experiments yield lower WTP than payment card formats (0.483% reduction), possibly because

choice experiments represent a more advanced method while payment cards are more mature and produce values closer to true values.

Natural Type Characteristics: Wetland natural types significantly reduce household WTP by 0.878%, suggesting wetlands are not preferred payment targets despite their public good characteristics and climate regulation functions. Forest coefficients are positive but not statistically significant, indicating residents value forests for both provisioning and protective services.

Ecosystem Service Type Characteristics: Provisioning services significantly increase household WTP by 1.48%, as they provide direct use values like timber. Other service characteristics are not significant, likely because resource-based cities prioritize basic material needs over other ecosystem services.

3.2 Validity Test Results

Using the BTE formula, the Meta-regression model shows transfer errors ranging from 0.48% to 38.68%, with a mean error of 8.26%—well within acceptable limits and lower than most existing studies. Paired t-test results ($t = 0.713, p > 0.050$) fail to reject the null hypothesis, indicating no significant difference between predicted and observed values. One-sample K-S tests show both real and predicted values follow normal distributions ($p > 0.05$), confirming the model' s statistical validity and suitability for out-of-sample benefit transfer.

3.3 Value Transfer Function Application

Based on Meta-regression results, we assessed ecosystem service values for resource-based cities. Since payment vehicles and research methods cannot be determined for transfer applications, we used mean values. Calculated household WTP was multiplied by the number of households and park area to estimate park ecosystem service values, presented in .

Park ecosystem service values range from 17.9026 million to 310.16 million yuan, with a mean of 97.2644 million yuan. Significant spatial differences exist: eastern, central, and western regions show household WTP of 135.3314 yuan, 92.2509 yuan, and 78.7878 yuan, respectively, confirming that higher-income regions exhibit greater ecosystem service values. Corresponding park values are 310.16 million yuan (east), 179.026 million yuan (central), and 97.2644 million yuan (west).

4 Discussion

The significant positive effect of per capita GDP aligns with economic theory and previous research, indicating that raising resident income is key to enhancing ecosystem service values. Tax payment vehicles significantly reduce WTP, suggesting that constrained payment instruments may exhibit less hypothetical bias than voluntary ones. Residents prefer donations and entrance fees, indicat-

ing government should minimize tax policies when improving urban ecosystem services.

Wetland coefficients are significantly negative, possibly because wetlands' public good characteristics and biodiversity/climate regulation functions are perceived as government responsibilities. Positive forest coefficients reflect forests' dual provisioning and protective values. Among ecosystem services, provisioning services yield higher values, consistent with Yan et al.' s findings, as resource-based cities prioritize basic material needs over other services. The value transfer function application confirms that park values correlate with household WTP, with eastern regions highest and western lowest, reinforcing our core conclusion that higher-income areas generate greater ecosystem service values.

5 Conclusions and Recommendations

5.1 Conclusions

1. **Ecosystem Service Characteristics**: Variables yield high values, with provisioning, climate regulation, and biodiversity services positively affecting ecosystem service values. Provisioning services increase household WTP by 1.48%, while recreation services have a negative but non-significant effect.
2. **Natural Type Characteristics**: Values derived from natural type variables are relatively low. Except for forests, other natural types negatively affect ecosystem service values, with wetlands significantly reducing values.
3. **Income and Payment Effects**: Higher income levels in resource-based cities correlate with stronger WTP and higher ecosystem service values. Compared to taxes, donations and entrance fees yield higher values, while choice experiments produce lower values than payment card methods.
4. **Value Transfer Application**: Applying the value transfer function to assess park ecosystem service values yields estimates ranging from 17.9026 million to 310.16 million yuan (mean: 97.2644 million yuan). Eastern regions show highest values, followed by central and western regions, confirming that higher-income areas generate greater park ecosystem service values.

5.2 Recommendations

Urban natural environments form the foundation of human survival. Resource-based cities, characterized by resource-dependent development models with high-pollution, high-energy-consumption industries, have caused substantial environmental damage. To continuously improve urban environments, ecosystem service values must be assessed and incorporated into markets to guide and encourage ecological investment and protection, thereby forming necessary ecological compensation mechanisms.

Based on our findings, we recommend: (1) Increasing forest coverage in resource-based cities through proper resource protection, development, and utilization; strengthening ecological benefit outputs; improving property rights and ecological compensation systems; and enhancing ecosystem service functions, particularly provisioning, regulation, and biodiversity services. (2) Advancing urban development levels to raise resident incomes. (3) Carefully examining sample sensitivity in benefit assessments and increasing use of voluntary payment instruments like donations and entrance fees to enhance urban ecosystem service values.

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Note: Figure translations are in progress. See original paper for figures.