A study of projects to reduce illegal wildlife trade based on least squares and structural equation modeling approaches

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Abstract. Illegal wildlife trade is a rapidly growing global threat to our environment and biodiversity[1]. Despite the establishment of wildlife protection organizations in various countries to combat this issue, the results have not been significant, and illegal wildlife trade continues to be rampant[2][3]. Urgent action is needed to curb this illegal activity.This paper analyzed the problems identified in the article and proposed the 'Stop Illegal Wildlife Trade' program. This paper evaluated the program's effectiveness using two data-driven methods: least squares (OLS) and structural equation modeling (SEM). The program aims to reduce illegal wildlife trade.

Keywords: Illegal wildlife trade,Least squares,Structural equation modeling.

1. Introduction

Illegal wildlife trade is an environmental crime that aims to enable individuals or groups to make private profit through illegal wildlife trade, and he is considered to be one of the most lucrative illegal activities in the world. A decade ago, the annual value obtained through illegal wildlife trade was in the range of 7-23 billion dollars. The illegal wildlife trade has been growing year after year, lured by huge profits [4].

However, with the proliferation of illegal wildlife trade, the survival of some cherished and protected animals is seriously threatened on the one hand, and the living environment of human beings faces unprecedented challenges on the other. At the same time, the illegal wildlife trade also affects the development of local economies, which has a serious impact on our well-being [5].

Therefore, we urgently need to cooperate with international organizations to create a rational and complete project to curb the growth of illegal wildlife trade, in order to stabilize the diversity of ecosystems and protect the human living environment [5].

2. Basic Modeling Analysis

This chapter uses two data-driven methods, least squares (OLS) and structural equation modeling (SEM), to assess the effectiveness of a comprehensive program to reduce illegal wildlife trade. Least squares is a regression analysis method that finds the best linear relationship between the dependent and independent variables by minimizing the sum of squares of the errors. Structural equation modeling is a multivariate statistical analysis method that allows for high flexibility and explanatory power by simultaneously considering relationships between multiple latent and observed variables, as well as relationships between latent variables. Structural equation modeling consists of two parts: the measurement model and the structural model. The measurement model describes how the latent variables are reflected or measured by the observed variables, and the structural model describes how the latent variables interact with each other or interact.

2.1. Selection of variables

In this paper, based on relevant literature and actual situation, trade size, trade frequency, trade type, trade source, trade destination, trade price, trade profit, trade risk , and trade impact as the main explanatory variables. Illegal wildlife trade is a major problem threatening global biodiversity and ecological security, and an important cause of wildlife extinction and infectious disease outbreaks. China, as the world's largest consumer and transshipment country of illegal wildlife trade

One of the largest consumers and transporters of illegal wildlife trade in the world, China is facing great pressure and challenges in combating and preventing illegal wildlife trade.

Based on the relevant literature and the actual situation, the explanatory variable: the reduction of illegal wildlife trade (REDUCTION) was also identified. As the objective and outcome of the comprehensive project to reduce illegal wildlife trade, the reduction of illegal wildlife trade is an important indicator to measure the effectiveness of the project. Specific variables are defined as shown in Table1. These control variables are possible factors affecting the reduction of illegal wildlife trade and need to be controlled in the regression analysis to eliminate the interference of other variables and improve the accuracy and credibility of the model.

Table 1 Integrated data-driven project variable definitions for reducing illegal wildlife trade

Variable Type	Variable Definition	Variable Name
Explained Variables	Reduction in illegal wildlife trade	Redu
Explanatory variable	Scale of trade	VGen
	Frequency of trade	VPol
	Type of trade	VEdu
	Source of trade	VInc
	Trade destination	VExp
	Trade price	VId
	Trade Profit	VUdn
	Trade Risks	VEg
	Trade Impact	VDc

2.2. Construction of the model

Two empirical methods, least squares and structural equation modeling, were used in this chapter to test the research hypotheses. Least squares is a method of estimating unknown parameters using the principle of minimizing the sum of squared errors. Structural equation modeling is a method that allows for the simultaneous analysis of relationships between multiple latent and observed variables and within latent variables. Structural equation modeling consists of a measurement model and a structural model. The measurement model specifies how the latent variables are characterized or measured by the observed variables, and the structural model specifies how the latent variables interact or influence each other. To evaluate the soundness and validity of structural equation modeling, two assessment criteria, fit metric and path coefficients, are used in this chapter. Fit metric reflect the consistency between the model and the data, and commonly used fit metrics include absolute fit metrics (e.g., x2/df, RMSEA, etc.), incremental fit metric (e.g., NFI, CFI, etc.), and parsimonious fit metric (e.g., AIC, BIC, etc.). Path coefficients reflect the strength and direction of causal relationships between potential variables, and t-tests can be used to determine whether path coefficients are statistically significant.

2.2.1Construction of the least squares model

OLS (Least Squares) is primarily used for parameter estimation in linear regression, with the goal of reducing the response of the model parameters (intercept term and slope) by reducing the difference between the true and predicted values of the variables.

The data in this paper meet the normality, independence, linear correlation, and homoskedasticity required by OLS, and the use of the OLS for fitting is reasonable.

Based on the measurement of the core indicators, a multiple linear regression model was established, and the least squares method was used to estimation, and the formula is as follows:

$$Y_i = \beta 0 + \beta 1Xi1 + \beta 2Xi2 + \cdots + \beta kXik + \mathcal{E}i \quad (1)$$

$$\beta = (XTX) - 1XTY \tag{2}$$

In this equation, Y_i represents the dependent variable value of the ith sample, while X_{ij} represents the value of the jth independent variable (secondary indicator) of the ith sample. The variables n and k represent the number of samples and independent variables, respectively. The regression coefficients are represented by β_0, β_1, ..., β_k, and the random error term is represented by ε_i. The least squares estimator is denoted by the symbol β.

The aim of this paper is to investigate the factors that contribute to the reduction of illegal wildlife trade and propose corresponding measures. To achieve this goal, an appropriate model must be selected, one that can accurately reflect the relationship with the explanatory variables.

To investigate the reduction of global illegal wildlife trade and its influencing factors, this paper utilizes the social network analysis model and linear programming model as the theoretical basis. An index system for risk assessment and intervention strategy development of illegal wildlife trade is constructed based on literature review and data collection. The explanatory variable, Redu, in this section pertains to the reduction of illegal wildlife trade. The explanatory variables include the scale, frequency, type, source, destination, price, profit, risk, and impact of trade. A multiple linear regression model is established as follows:

$$\begin{aligned} Redui = C + \beta 1VGeni + \beta 2Vpoli + \beta 3VEdui + \beta 4VInci + \beta 5VExpi + \beta 6VIdi + \beta 7Vudni \\ + \beta 8VEgi + \beta 5VDci + ui \end{aligned}$$

2.2.2 Structural Equation Modeling for Integrated Data-Driven Projects

1.Structural modeling of integrated data-driven projects

To achieve this, we have developed a structural model that describes the causal relationship between latent variables. Each latent variable is determined based on the above theory, and together they form the set structural model. The equation is formulated as follows:

$$\eta = B\eta + \Gamma\xi + \zeta \tag{3}$$

The vector $\eta = (\eta_1, \eta_2, \dots, \eta_n)$ represents the endogenous latent variables, while $\xi = (\xi_1, \xi_2, \dots, \xi_n)$ represents the exogenous latent variables. The matrix B(m×m) contains the path coefficients of the endogenous latent variables, and the matrix Γ(m×n) contains the path coefficients of the exogenous latent variables.

The residual term vector ξ(m×1) reflects the part of the equation that cannot be explained by η.

2.Measurement modeling for integrated data-driven projects

The measurement model assesses the relationship between the latent variable and its manifest variable. The equation is expressed as follows:

$$y = \Lambda y\eta + \varepsilon yx = \Lambda x\xi + \varepsilon x \tag{4}$$

Measurement models are categorized into two forms: reflective and impact models. The equations for impact measurement models are as follows:

$$\eta = \pi\eta y + \delta\eta\xi = \pi\xi + \delta\xi \tag{5}$$

The equations used to measure the exogenous latent and manifest variables are represented by the expression $x = \Lambda_x\xi + \varepsilon_x$, as shown in the following matrix:

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} \lambda_{11} \\ \lambda_{12} \end{bmatrix}\xi + \begin{bmatrix} \delta_1 \\ \delta_2 \end{bmatrix} \tag{6}$$

The endogenous latent and explicit variables measurement equations are represented by the expression $y = \Lambda y\eta + \varepsilon y$.

2.3. Empirical analysis of an integrated data-driven project model

2.3.1 An empirical analysis of least squares

Using SPSS 27.0 software, we conducted OLS least squares regression analysis.The results of the model fitting operation are shown in the table below(As shown in Table 2).

Table 2 Results of the OLS regression model for the integrated data-driven project to reduce illegal wildlife trade

Variable	Coefficient	StdError	t	RobustPr[b]	VIF
Intercept	-3.8738	0.0928	-4.1273	0.0363*	/
VGen	0.4356	0.0380	2.6482	0.0537*	2.4878
VPol	0.1025	0.0635	4.7647	0.0473*	1.7289
VEdu	0.6370	0.0923	3.9380	0.0052**	1.7283
VInc	0.2451	0.0035	5.8368	0.0402*	1.1627
VExp	0.3957	0.0007	2.4386	0.0009**	2.7253
VId	1.3276	0.0473	2.5434	0.0354*	2.3543
VUdn	1.3438	0.0021	2.7653	0.0153*	2.8675
VEg	0.6297	0.0341	3.5655	0.0432*	2.8641
VDc	1.4376	0.0353	2.6742	0.0198*	2.4632

Note: Coefficient is the coefficient; StdError is the standard deviation of the regression coefficient; VIF is the variance inflation factor; Intercept is the intercept; * is passing the 5% significance level test; ** is passing the 1% significance level test.

2.3.2 An empirical analysis of structural equation modeling

To establish the structural equation model for the comprehensive data-driven program to reduce illegal wildlife trade, we must identify the potential and observed variables, as well as the hypothesized relationships between them. The model includes three latent variables: Monitoring Effect, Cracking Effect, and Reduction. The program's effectiveness in monitoring and analyzing illegal wildlife trade is indicated by MonitoringEffect, while CrackingEffect indicates its effectiveness in cracking down on and punishing illegal wildlife trade. TradeReduction measures the amount of reduction in illegal wildlife trade achieved by the program. It is assumed that both the monitoring effect and the crackdown effect have a positive impact on trade reduction. In other words, the greater the monitoring and crackdown effects, the greater the reduction in trade.

Next, we must specify the observed variables for each latent variable, which are the specific indicators used to measure or reflect the latent variable. We have ten observational variables, with three to four for each latent variable.

The following possible observational variables are provided based on relevant literature and the actual situation:

The observed variables for monitoring effectiveness are:

Coverage (AM): indicates the proportion of areas and species of illegal wildlife trade covered by the project.

Accuracy (AC): indicates the correctness and credibility of the data and information monitored and analyzed by the project.

Timeliness (TR): indicates the speed of updating and transmission of data and information monitored and analyzed by the project Frequency.

The observational variables for combating effects are:

Inputs (PS): indicates the amount of resources invested in the program, such as funds, personnel, technology, partners, etc. and quality.

Audience (AT): the number and proportion of traders, consumers, intermediaries and other participants in the illegal wildlife trade that the program combats and penalizes. AT: The number and proportion of traders, consumers, intermediaries and other participants in the illegal wildlife trade that the project combats and penalizes.

Contents (CI): Indicates the characteristics and indicators of the ways, means, efforts, and effects of the program to combat and punish illegal wildlife trade. Effectiveness of the program.

Form (FO): Indicates the forms, channels, media, carriers and other characteristics and indicators of the illegal wildlife trade that the project combats and punishes.

The observed variables for trade reduction are:

Scale (SH): Indicates the total volume, units, number, weight, etc. of illegal wildlife trade.

Type (TS): Indicates the type, class, breed, species, and other indicators of illegal wildlife trade.

Impact (EX): Indicators of the harm and impact of illegal wildlife trade on biodiversity, ecological safety and public health.

The factor loadings are all greater than 0.6 within the acceptable range. The SMC of the measurement model, i.e., the structural variables

Explanatory power of the model, i.e., the structural variables, are all greater than 0.36, which is within the acceptable range（As shown in Table 3）.

Table 3 Comprehensive data-driven project model fitness indicators for reducing illegal wildlife trade

Statistical Test	Adaptation Recommendations	Test Results	Model Fit Or Not
Chi-square/df	<3	2.481	yes
GFI	>0.9	0.978	yes
AGFI	>0.9	0.964	yes
CFI	>0.9	0.995	yes
RMSEA	<0.08	0.044	yes

Table 3 shows that the measurement model and data adaptation results are satisfactory, and all adaptation indicators meet the recommended values. Finally, all 10 observed variables of the comprehensive data-driven project to reduce illegal wildlife trade are included in the structural equation modeling.

After validating the factor analysis, we established the preliminary structural equation model based on the theoretical assumptions and analyzed the measurement model of each latent variable. We then analyzed the relationship between latent and observed variables using the structural equation model.

Then we perform the calculation of the index. The formula for the calculation is:

$$\overline{\varpi_\iota} = \frac{\sigma_i}{\sum_1^n \sigma_i} \tag{7}$$

The formula for calculating the ACSI index involves using the standardized path coefficient (σ_i) for each observed variable, the number of observed variables (n), and the weights of the observe variable ($\overline{\varpi_\iota}$). The mean value of each observed variable is then weighted using the obtained weights.

$$\text{CSI} = \frac{\sum_{i=1}^{k} \sigma_i \ \bar{y_\iota} - \sum_{i=1}^{k} \sigma_i}{\sum_{i=1}^{k} \sigma_i} \times 100 \tag{8}$$

The weight of the observed variable after normalization is represented by σ_i, while $\bar{y_\iota}$ is what σ_i corresponds to the mean value of the observed variable, and k is the number of observed variables.

The formula was used to calculate the indices of the latent variables and their observed variables in the comprehensive data-driven project model for reducing illegal wildlife trade. The table below shows the indices for each latent variable and its observed variables, calculated using the provided formula(As shown in Table 4).

Table 4 Indices of Latent and Observed Variables for Comprehensive Data-Driven Projects to Reduce Illegal Wildlife Trade

Latent Variable	Latent Variable Index (LVI)	Observational Variables	Observed Variable Index (OVI)
Reducing Illegal Wildlife Trade Integrated data-driven project to reduce illegal wildlife trade Programs	55.860	AC	56.844
		FO	57.644
		TR	52.775
		AT	56.211
		SH	55.467
		AM	56.000
		CI	54.500
		PS	54.000
		EX	56.250
		TS	58.875

The results indicate that the illegal wildlife trade continues to face challenges in reducing its scale and impact. To address these challenges, it is necessary to strengthen monitoring and combat efforts, improve the accuracy and timeliness of data, and protect endangered species and ecological security. This requires better monitoring of sources, destinations, and types of trade. It is important to capitalize on the drawbacks of illegal wildlife trade, such as trade prices, profits, and risks, to increase awareness and resistance among traders and consumers, and to elevate the risk and cost of such trade.

3. Conclusion

The project 'Stop Illegal Wildlife Trade' was analyzed and proposed to reduce illegal wildlife trade for the protection of biodiversity and the environment. The effectiveness of the project was assessed using two data-driven methods: least squares (OLS) and structural equation modeling (SEM). This paper assesses the effectiveness of integrated programs in reducing illegal wildlife trade using two data-driven methods: least squares (OLS) and structural equation modeling (SEM). The feasibility and stability of the project is confirmed, and other necessary factors that drive the project are analyze.

References

[1] Hübschle A,Gore LM.Lessons in resilience from the illegal wildlife trade during COVID-19 lockdowns [J].Science of the Total Environment, 2024, 916 170365-.

[2] Moorhouse T,Elwin A,D'Cruze N.Demand reduction campaigns could reduce the domestic trade in illegal wildlife in Peru [J].Biological Conservation,2024,290 110458-.

[3] Cayle L.Illegal wildlife trade: the critical role of the banking sector in combating money laundering [J].Journal of Money Laundering Control,2023,26 (7): 181-196.

[4] Geoff K ,Anne K S ,Laurie M , et al.Corrigendum: Delineating origins of cheetah cubs in the illegal wildlife trade: improvements based on the use of hair δ18O measurements
[J].Frontiers in Ecology and Evolution,2023,11

[5] P.DUV,Mingxia Z.Illegal wildlife trade in two special economic zones in Laos: Underground–open-sale fluctuations in the Golden Triangle borderlands
[J]. Frontiers in Conservation Science,2022,