

## **A study on the relationship between environment and economy based on the Bayesian statistics——a case study of Gansu province**

Lijun Wang<sup>1</sup>, Yongyu Wang<sup>2</sup>, Dequn Zhou<sup>1</sup>, Peng Zhou<sup>1</sup> and Maoxi Tian<sup>3</sup>

<sup>1</sup> Research Centre for Soft Energy Science, Nanjing University of Aeronautics and Astronautics, Nanjing, China

<sup>2</sup> Research Centre for Quantitative Analysis on Economy Development of Gansu Province, Lanzhou University of Finance and Economics, Lanzhou, China

<sup>3</sup> Department of statistics and Finance, Shihezi University, Wujiaqu, China

<sup>4</sup> Corresponding author: Lijun Wang, e-mail: sdwanglijun@nuaa.edu.cn

### **Abstracts**

The relationship between the environment and economy system is one of the hot spots of academic researches, however, the studies, especially empirical studies mainly focused on the pollution load and economic growth from the perspective of the classical statistics, and seldom considered ecological environment and economic growth based on the Bayesian statistics. Taking Gansu province as an example, based on the index of eco-environmental quality and GDP of Gansu Province from 1980 to 2010, environmental economy model is established from the perspective of Bayesian statistics in this paper: normal regression model. The statistical result shows good estimation performance, and the turning point of the extended EKC appeared earlier than the traditional EKC. Aimed to examine the long-term equilibrium relationship between the systems of environment and economy from the Bayesian perspectives, the time series analysis are carried out, which concluded that: the econometric model mentioned above are not 'spurious regression'. That is, the long-term equilibrium relationship of environment and economy was verified, and the existence of the extended EKC (e-BEKC) was correctly judged.

Key Words: Bayesian statistics, Gibbs sampling, Minnesota prior

### **1. Introduction**

The Environment Kuznets Curve (EKC) can be defined as a theory tool dedicated to the relationship between economic development and environment degradation. Among international EKC studies, representative theoretical ones include economic structure theory by Grossman & Krueger(1995) and Panayotou(2001), environment demand theory by Panayotou, Copeland & Taylor (2004), environment regulation theory by Antweiler (2001) and Copeland & Taylor(2004), and other theories on market mechanism and trade; Empirical studies have basically agreed on the existence of an inverted-U-shaped EKC. However, most studies focused on the relationship between environment pollution and economic growth, few demonstrated the relationship using some separate indicators of eco-environment and growth, and seldom considered the relationship from a comprehensive perspective. Moreover, classical statistics were mainly executed in the empirical studies, and few did that from the perspective of Bayesian statistics.

The EKC that we usually talk about is based on the pollution load, showing that the pollution is aggravated with national income at a low level and vice versa. That is, economy and environment interact through the route: poverty and cleanness—abundance and tidiness—abundance and cleanness, as is shown by Fig. 1. But the pollution indicators fail to provide an overall picture of environment degradation. Eco-environment problems arising from economic development lie not only in pollution, but in ecological destruction, like temperature rise, water environment crisis, grassland deterioration, forest decrease, desert

expansion, soil erosion and species decline.

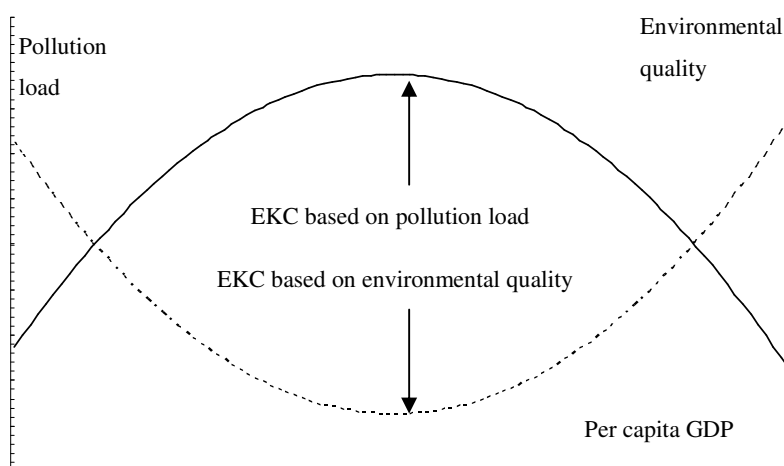


Fig.1 EKC hypothesis based on pollution load and EKC hypothesis based on environmental quality

The mechanism of environment-economy system is given and e-EKC based upon environment quality is proposed. Then the more comprehensive evolution route between economy and environment is: poverty and sound eco-environment abundance and poor eco-environment---abundance and sound eco-environment. Therefore, this paper took into account five environment factors of climate, water, soil, vegetation and environment load to get a comprehensive assessment of eco-environment quality and established an eco-environment quality evaluation system for an extend EKC, also e-EKC, based on environment quality.

Additionally, taking Gansu province as an example, the Bayesian multivariate normal regression model and the Bayesian time series analysis method were introduced in this empirical study, which comprehensively used the model information, data information, and a priori information.

This article consists five sections. The problem of the relationship between economy and environment paper was introduced, and the e-EKC was proposed in section 1; And the mechanism of the economy and environmental system was illustrated in section 2; The extended EKC Model from the perspective of Bayesian statistics perspectives (e-BEKC) was empirically studied in section 3; Finally, the conclusions of the empirical study was given in section 4.

**2. Mechanism analysis of economic development and environmental quality**

This paper improved the existing environment-economy system with the comprehensive ecological environment quality evaluation process, which is shown in figure 2.

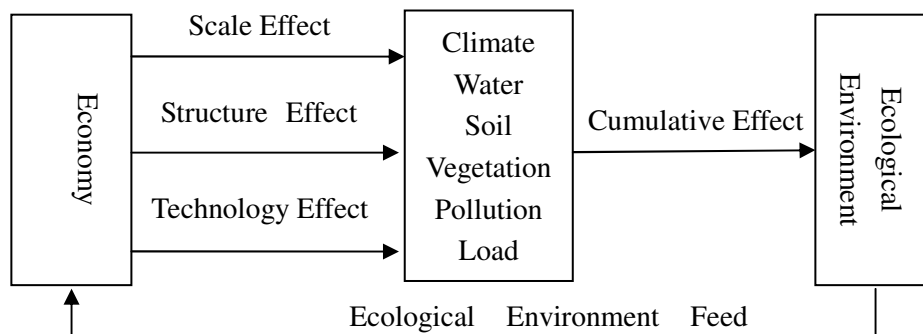


Fig.2 The interaction between the economic system and the environmental system

As shown in figure 2, according to the ecological environment theory, the mechanism of action from the economic system to the environmental system through ecological factors can be summarized as the scale effect, structure effect and technology effect. The scale effect involves the change of the "source" and "sink" of the environmental systems; Structure effect depends on the stage of evolution of industrial structure; Technical effect relies on the technology progress. Simultaneously, the ecological environment imposes negative feed back effect to economy system. Then, taking the Gansu province as an example, the empirical research was conducted by employing "the comprehensive environmental quality index" to explore "EKC" from the perspective of classical statistics and Bayesian statistics respectively to explore based on environmental quality exists.

**3 The extended EKC Model based on Bayesian statistics (e - BEKC Model)**

The purpose of this section is aimed to take Gansu province as a case, using "the comprehensive environmental quality index" instead of "environmental pressure index" and test the existence of the extended EKC. So the index construction and data sources were described briefly first.

**3.1 Index construction and data sources**

The basic idea of analytic hierarchy process (AHP) was employed to construct the comprehensive index. And the goal layer was the ecological environmental quality of Gansu province. The factor layer, of 15 elements, was composed of the climate, water, soil, vegetation, and pollution load. And we set the weights of elements and indicators using the method of expert investigation. For more specific information, one can see Yongyu Wang (2011).

In this section, the data come from *China Environment Yearbook*, *China Water Resources Yearbook*, *China Yearbook of Land and Resources*, *Chinese Forestry Yearbook*, *China Rural Statistical Yearbook*, *Statistical Yearbook of Gansu*, *Gansu Yearbook*, *the New China 60 Years in Gansu*, *the Gansu Agricultural Resources Investigation and Assembly (1986)*, *the Grassland Resources in Gansu Province(1999)*, *Grass Industry Sustainable Development Strategy Research in Gansu Province(2008)*, *Forestry and Scientific Development in Gansu Province (2006)* and including relevant department internal data, at the same time. We selected the six forest resource inventory results for indexes of forest coverage rate. Considering its change trend, we smoothed the data among the period from the base period to reporting period by the average interval development speed.

**3.2 construct extended EKC model based on Bayesian statistics**

Assuming the EKC model that based on Bayesian statistics was a normal regression model, the WinBUGS software was used to estimate the posterior mean of parameters through the Gibbs sampling. In the process of sampling, different initial values and produce three Markov chains were given and 35000 times iterative computation were executed with the 5000 times annealed times..

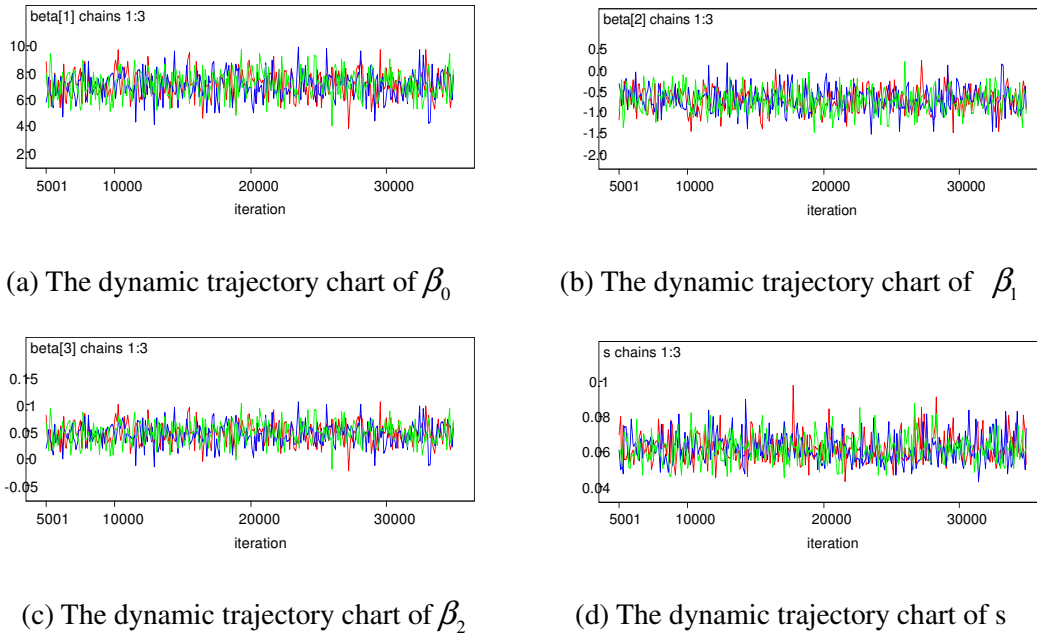


Fig.3 Parameter dynamic trajectory charts of  $\beta$  and s

Figure 3 shows the parameter dynamic trajectory charts of  $\beta$  and s, and the diagnosis graph of GR statistics indicates good parameters convergence. Table 1 shows the exact posteriori estimation results of each parameter. So the e-BEKC Model of Gansu province as follows:

$$\ln NEI = 7.053 - 0.7298 \ln PCGDP + 0.046 \ln PCGDPS \quad (4)$$

Therefore, it could be used to solve the per capita GDP of the “turning point”. The capita GDP is 9512.2268 RMB with 2007 as the base period.

Tab.1 Posteriori estimation results of parameters

Node	Mean	sd	MC error	2.50%	median	97.50%	start	Sample
Beta[1]	7.053	0.9785	3.24E-03	5.127	7.05	8.988	5001	90000
Beta[2]	-0.7298	0.2817	9.35E-04	-1.287	-0.7295	-0.1749	5001	90000
Beta[3]	0.0460	0.0200	6.69E-05	0.0065	0.0460	0.0856	5001	90000
S	0.0618	0.0082	3.21E-05	0.0483	0.061	0.0804	5001	90000

### 3.3 Minnesota under the prior distribution of the Bayesian co-integration analysis

Under assumption of the Minnesota prior, the Bayesian co-integration was tested by using Monte Carlo sampling. The Johansen Bayesian co-integration test results were shown in table 2. According to the results, co-integration rank for  $r = 2$ , i.e. Therefore, there were two co-integration equation. The long-term equilibrium relationship of environment and economy is verified, and the existence of the extended EKC (e-BEKC) was correctly judged.

Tab.2 Results of Johansen Bayesian Cointegration Test

Null Hypothesis Number of Cointegration		Trace Statistics	Trace Statistics 1% Critical Value	Eigenvalue Statistics	$\lambda$ -max Statistics 1% Critical Value
0	$r = 0$	82.446	35.463	57.934	25.865
At least one	$r \leq 1$	24.512	19.935	20.461	18.520
At least tow	$r \leq 2$	4.051	6.635	4.051	6.635

#### 4. Conclusion

We improved the existing research on the relationship between environmental and economic from two aspects: the selection of ecological environmental quality indicators and the introduction of Bayesian statistical method. Then, the EKC based on the ecological environmental quality was proposed, and taking Gansu Province for example, the empirical research was conducted based on classical statistics and Bayesian statistics of environmental economic system.

The empirical studies have shown that the EKC which based on the ecological environment of equality exists. Since the nineties of the last century, the research results of the EKC which based on the pollution load is between the 1000 dollars and tens of thousands dollars. In contrast, the turning point of e-EKC is relatively earlier, which is possibly related to the economic structure of Gansu Province characterized by the status quo of heavy industry. To the contrary, the basic elements of eco-environment were improved substantially, such as vegetation (see also in WANG Yongyu(2011)), and contributed to the early turning point of the e-BEKC.

Gansu province is located in the northwest arid and semiarid areas in China. On the one hand, the GDP is far below the national average level and the economy development task is difficult, on the other hand, the ecological environment is fairly fragile, the environmental protection task would be much challengeable. Therefore, sustainable economic development strategy could be enhanced in Gansu province, which involving introducing advanced technology, improving the efficiency of resource utilization, encouraging recycling economy, developing clean production, exploring new energy, etc. In a word, people should spare no effort to save resources, and protect the environment, to realize the harmonious development of ecology and economy.

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#### Reference

- [1] Antweiler, James & Levinson, Arik. The simple Analysis of the Environmental Kuznets Curve. NBER working paper, Sep. 1998
- [2] Antweiler, Werner., Copeland, Brian R. & Taylor, M. Scott. Is Free Trade Good for the Environment? [J]. The American Economic Review, Sep. 2001, Vol. 91(4): 20-521
- [3] Banbura, M., D. Giannon, & L. Reichlin. Large Bayesian VARs. Journal of Applied Econometrics, 2010, 25: 71-92

- [4] Brain R. Copeland & M. Scott Taylor. Trade, Growth, and the Environment [J]. Journal of Economic Literature, Mar 2004, vol. 42(1): 7-71
- [5] Copeland, Brain R. & Taylor, M. Scott. Trade, Growth, and the Environment [J]. Journal of Economic Literature, Mar 2004, vol. 42(1): 7-71
- [6] Daly, H. E. Beyond growth [M]. Boston, MA: Beacon Press, 1996
- [7] Doan, T., R. Litterman, and C. Sims (1986), 'Forecasting and conditional projection using realistic prior distributions'. *Econometric Reviews* 3, 1-114
- [8] Engle, R F. , Granger, C W J. Co-integration and error Correction: Representation, Estimation and Testing [J]. *Econometrica*, 1987,55(2): 251-276
- [9] Galton, Pearson & the peas. A brief history of linear regression for statistics instruction [J]. *Journal of Statistics Education*, 9(3)
- [10] Gary Koop & Dimitris Korobilis. Bayesian Multivariate Time Series Methods for Empirical Macroeconomics [J], *Foundation and Trends in Econometrics*, 2009, Vol. 3(4): 267-358
- [11] Geman, S. & Geman, D. (1984). Stochastic relaxation, Gibbs distributions and the Bayesian restoration of images [J]. *IEEE Trans. Pattern Anal, Mach. 1986, Intell.*, 6: 721-741
- [12] Gilks, W. Richardson, S. & Spiegelhalter, D. (1996), *Markov Chain Monte Carlo in Practice*, Interdisciplinary Statistics, Chapman & Hall, Suffolk, UK
- [13] Grossman, Gene M. & Krueger, Alan B.. Economic Growth and the Environment [J]. *The Quarterly Journal of Economics*, 1995, Vol. 110(2): 353-377
- [14] Hettige, H., Dasgupta, S. & Wheeler, D. What Improve Environmental compliance? Evidence from Mexico Industry [J]. *Journal of Environmental Economics and Management*, 2000, 39(1): 39-66
- [15] Islam, N., J. Vincent and T. panayotou. Unveiling the Income-environment Relationship: An Exploration into the Determinants of Environmental Quality, Harvard Institute for International Development Discussion Paper, No.701, 1999
- [16] Johansen, S.. Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models [J]. *Econometrica*, 1991, 59: 1551~1580
- [17] Johansen, S. & Katarina Juselius. Maximum Likelihood Estimation and Inference on Cointegration-with application to the demand for money [J]. *Oxford Bulletin of Economics and Statistics*, 1990, 52: 16 9~210
- [18] Lesage, James P.. A Comparison of the Forecasting Ability of ECM and VAR Models [J]. *The Review of Economics and Statistics*, 1990, Vol. 72 (4): 664-671
- [19] Litterman, R. (1986), 'Forecasting with Bayesian vector autoregressions – Five years of experience'. *Journal of Business and Economic Statistics* 4, 25-38
- [20] Panayotou, T. Environment for Growth in Central America: Environmental Management for Sustainability and Competitiveness [M]. Cambridge, MA: Harvard Press, 2001
- [21] Ram's on L'opez & Siddhartha. Corruption, Population, and the Kuznets Environment Curve [J]. *Journal of Environmental Economics and Management*, 40: 137-150
- [22] Tetsuya Tsurumi & Shunsuke Managi. Does Energy Substitution Effect Carbon Dioxide emissions-Income Relationship?[J]. *J. Japanese Int. Economics* 24(2010): 540-551
- [23] Torras. M. & Boyce, J. K. Income, Inequality and Pollution: a Reassessment of the Environmental Kuznets Curve [J]. *Ecological Economics*, 2006, 82(2): 291-310
- [24] WANG Yongyu, WANG Lijun. Evaluation on eco-environmental quality of Gansu Province and its Dynamic Characters[J]. *Journal of Arid Land Resources and Environment*, 2011, 25(5): 41-45
- [25] Zeller A. Bayesian estimation and prediction using asymmetric loss functions [J]. *Journal of American Statistical Association*, 1986, 81(2): 446-451