Environmental Quality Optimization and Fiscal Decentralization: an Expanded Endogenous Growth Model

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Abstract. The research focuses on China's environmental quality and economic system. Using the endogenous growth model and Davoodi & Zou model, a four-sector endogenous growth model with variables of ecological environment and fiscal decentralization is constructed and the static and dynamic panel models are further constructed. The conclusions are as follows: ① Fiscal decentralization and tax burden have non-linear effects on environmental quality; ② Fiscal decentralization and tax burden have a deteriorating effect on environmental quality while the synergy of the two produces a dilution effect that weakens each other; ③ Environmental quality itself has lagged effect. Therefore, it is proposed to coordinate and consist the fiscal decentralization and tax system and cultivate innovation capabilities, reduce unit energy consumption.

1. Introduction
The construction of ecological civilization is crucial for the sustainable development of the Chinese nation. The structure of the paper is as follows. Section 2 presents previous studies on the economic development and environmental quality. A four-sector endogenous growth model is constructed and solved in section 3 and 4. In section 5, the static and dynamic panel models are further constructed. The conclusions and proposals will be carried out in section 6.

2. Literature review
The interaction between economic growth, fiscal decentralization and environmental quality has been deeply studied for a long time. In the 1980s, the endogenous growth theory represented by the Rome’s (1986) [1] knowledge spillover model and the Lucas (1988) [2] labor capital model opened up new ideas for the study. Under this framework, Aghion & Howitt (1998) and Grimaud & Rouge (2005) [3-4] introduced pollution levels into the production function. The research in China on economic-environmental relations under endogenous growth started relatively late. Huang Maoxing et al. (2013) built an environment within the framework of endogenous growth. The five-sector economic growth model of the variable is used to analyze the mechanism of pollution damage, environmental management and economic growth through empirical research, and have made breakthroughs in this field [5]. With regard to the relationship between economic growth and fiscal system, Barro (1990) introduced the private and public sector in the production function [6], and Davoodi & Zou (1998)
further refined public expenditures to form a Davoodi & Zou mathematical model [7]. Chinese scholars form three main existing viewpoints of empirical researches: High fiscal decentralization is not conducive to environmental quality, fiscal decentralization does not have a significant impact on environmental pollution, or there is an inverse U-shaped relationship between them.

The present studies have defects. Firstly, there are few studies that integrate economic, environmental, and fiscal factors into the model. Secondly, the empirical results have no clear consensus. Thus under the model of environmentally constrained growth, the variable is introduced to construct an endogenous growth model with environment quality, economic growth and fiscal decentralization.

3. The extension of endogenous growth model

3.1. Production function.

The endogenous growth model mainly considers four factors: capital K, labor L, work force H, and knowledge A. In the closed economy system, there are four departments which are the intermediate product department, the final product department, the R&D department, and the human capital department. It is also considered that in the total amount of human capital H, H_Y is used for production in the final product department, H_A is used for innovation in the R&D department, and H_H is used for human capital accumulation.

3.1.1. Final product department. According to Peng (2006) [8], introduce the pollution levels z into the production function. z=1 means there is no environmental constraint, at which point the potential maximum yield is obtained; z=0 means that the output is zero when there is no pollution. Then, the fiscal decentralization model of Davoodi & Zou was improved to a central-regional fiscal decentralization model in line with national conditions. The central government's fiscal expenditure was f, and the local government's fiscal expenditure was s. The production function that introduces environmental pollution and fiscal decentralization factors is:

\[ Y = A^{\alpha+\gamma+\eta} H_Y L_f K_f f^\gamma z \]

Among them, \( \alpha, \beta, \gamma, \eta \in (0,\infty) \) and \( \alpha+\beta+\gamma+\eta=1 \).

3.1.2. Intermediate product department. The accumulation of physical capital in the economic system comes from the difference between total output and total consumption. By combining with the influence of government tax factors, the material capital accumulation equation can be recorded as:

\[ K = (1-\tau) Y - C = (1-\tau) A^{\alpha+\beta+\chi+\eta} H_Y L_f K_f f^\gamma z^\delta C \]

\( \tau \) represents tax rate, \( C \) represents the amounts of material products consumed.

3.1.3. R&D department. According to the knowledge spillover model of Romer, the output of the R&D department depends on the human capital stock \( H_A \) used for knowledge innovation and the knowledge stock \( A \). The production function can be expressed as:

\[ \dot{A} = A^{\delta} H_A \]

\( \dot{A} \) is the increase in intellectual capital, \( \delta \in (0,\infty) \) is the production efficiency of R&D department.

3.1.4. Human capital department. According to the human capital model, the human capital sector output depends on the human capital stock \( H_H \) used for its own accumulation, and the accumulation function can be expressed as:

\[ \dot{H} = \delta H_H \]

\( \dot{H} \) is the stock of human capital, \( \delta \in (0,\infty) \) is the production efficiency of human capital department.
3.2. Government Budget Constraint
When the government's revenue and expenditure reach the equilibrium, it must meet the conditions that the tax revenue is equal to the fiscal expenditure. Then the government budget constraint function is:

$$\tau Y = \tau A^{\alpha+\beta} H v L^{\beta} \mathcal{K}^{\gamma} f z s = f + s = g$$

Here, $\tau$ is the tax rate and $g$ is the total expenditure of government.

3.3. Environmental Quality Function
Aghion & Howitt defined the environmental quality $E$ as the difference between the actual value and the upper limit. The environmental quality is affected by two factors: pollution level and environmental self-purification ability. The pollution level $P$ can be expressed as $P(Y, z) = Y \theta$, Where $Y$ is the total output and $z$ is the pollution intensity. $i$ can be understood as the severity of environmental regulation. $\theta$ indicate the environmental self-purification capacity. The equation of environmental quality is:

$$\dot{E} = -Y \theta - \theta E$$

3.4. Utility function for consumers
In order to adhere the idea of sustainable development, and defines the connotation of consumer utility, considering both material consumption and environmental quality factors is needed, according to the equally weighted elasticity utility function, the consumer instantaneous utility function that introduces environmental pollution factors can be expressed as:

$$U(C, E) = \frac{C^{1-\sigma} - (E)^{1+\omega}}{1-\sigma}$$

Among them, $C_t$ and $E_t$ respectively represent the quantity of material products consumed and the environmental quality during $t$ period. The relative risk aversion coefficient $\sigma$ and environmental awareness parameters $\omega$ measure the influence degree of material and environment on utility function, respectively. $U(C, E)$ Represents the instantaneous utility function and its target utility function is:

$$\max \int_{0}^{\infty} U(C, E) e^{-\rho t} dt = \max \int_{0}^{\infty} \left( \frac{C^{1-\sigma} - (E)^{1+\omega}}{1-\sigma} \right) e^{-\rho t} dt$$

4. The equilibrium growth path of model
The decision makers (governments) in the economic system aim at maximizing consumer utility while facing constraints such as environmental quality constraints and fiscal budget constraints, while meeting the conditions for sustainable economic and environmental growth. This dynamic optimization problem can be expressed as:

$$\max_{c, H \alpha, H \tau, z} \int_{0}^{\infty} \left( \frac{C^{1-\sigma} - (E)^{1+\omega}}{1-\sigma} \right) e^{-\rho t} dt$$

s.t. \hspace{1cm} $$Y = A^{\alpha+\beta} H v L^{\beta} \mathcal{K}^{\gamma} f z s z$$

$$K = (1-\tau)Y - C$$

$$\dot{A} = \delta A H$$
\[
\dot{H} = \delta n H_H \\
\dot{E} = -Yz^i - \theta E \\
\alpha + \beta + \gamma + \chi + \eta + \mu = 1 \\
H = H_H + H_A + H_Y \\
\tau Y = f + s = g
\] (5)

And by using the above equations, the Hamilton equation is computed as:

\[
J = C_0^{i-1} - \frac{(-E_0^{i-1})}{1+\omega} + \lambda_1 Y - \lambda_2 H_A A + \lambda_3 H_H H + \lambda_4 ( -Yz^i - \theta E ) \] (6)

Here, the state variables are \(K, A, H, E\); the control variables are \(C, H_A, H_Y, z\); the Hamilton multipliers are \(\lambda_1, \lambda_2, \lambda_3, \lambda_4\). The first-order condition for maximizing the Hamilton function is:

\[
\lambda_3 = C - \frac{1}{1+\omega} \frac{(-E)}{1+\omega} + \lambda_4 \frac{(1-\tau)}{Y} + \lambda_1 \frac{Y}{A} \\
\lambda_2 = C - \frac{1}{1+\omega} \frac{(-E)}{1+\omega} + \lambda_4 \frac{(1-\tau)}{Y} + \lambda_1 \frac{Y}{A} \\
\lambda_1 (1-\tau) = \lambda_4 (1+i) z^i \\
\lambda_4 = \frac{\partial J}{\partial E} = \frac{\partial J}{\partial H} = \frac{\partial J}{\partial A} = \frac{\partial J}{\partial K} = \frac{\partial J}{\partial A}
\] (7)

Taking the first-order condition for the Hamilton multiplier, the Euler equation is:

\[
\dot{\lambda}_1 = \rho \lambda_1 \frac{\partial J}{\partial K} = \rho \lambda_1 - \lambda_4 z^i \frac{Y}{K} \\
\dot{\lambda}_2 = \rho \lambda_2 \frac{\partial J}{\partial A} = \rho \lambda_2 \lambda_1 (1-\tau) ( \alpha + \beta ) \frac{Y}{A} - \lambda_3 H_A A + \lambda_4 ( \alpha + \beta ) \frac{Y}{A} \\
\dot{\lambda}_3 = \rho \lambda_3 \frac{\partial J}{\partial H} = \rho \lambda_2 - \lambda_4 \delta H \\
\dot{\lambda}_4 = \rho \lambda_4 \frac{\partial J}{\partial E} = \rho \lambda_4 (-E) + \lambda_4 \theta
\] (8)

The cross-section conditions are:

\[
\lim_{t \to \infty} \lambda_1 Ke^{\gamma t} = 0 \quad \lim_{t \to \infty} \lambda_2 A e^{\alpha t} = 0 \quad \lim_{t \to \infty} \lambda_3 He^{\mu t} = 0 \quad \lim_{t \to \infty} \lambda_4 E e^{\eta t} = 0
\] (9)

In the optimal path of growth, the system's output \(Y\), consumption \(C\) and capital \(K\) growth rate are balanced, and the three components of human capital \(H\) maintain a consistent growth rate. This article uses \(g_x = \dot{x}/x\) to present the growth rate of any variable \(x\), so there are:

\[
g_Y = g_K = g_C \\
g_H = g_{H_H} = g_{H_A} = g_{H_Y}
\] (10)

The first-order condition is logarithmic and derivatived:

\[
g_{\lambda_1} = -\sigma g_C
\] (11)
\[ g_{\lambda 2} + g_{\lambda} = g_{\lambda 3} \]  
(14)

\[ g_{\lambda 3} = g_{\lambda 1} + g_{\gamma} - g_{H r} \]  
(15)

\[ g_{\lambda 1} = g_{\lambda 4} + i g_{z} \]  
(16)

Combining equations (2-9) with four Euler equations:

\[ g_{\gamma} = (\alpha + \beta) g_{\lambda} + \alpha g_{H r} + \beta g_{L} + \gamma g_{K} + \chi g_{r} + \eta g_{s} + g_{z} \]  
(17)

\[ g_{\varepsilon} = g_{\gamma} + i g_{z} \]  
(18)

\[ g_{\lambda 3} = \rho - \delta_{H} \]  
(19)

\[ \omega g_{\varepsilon} = g_{\lambda 3} \]  
(20)

Combining equations (11-20) with the four Euler equations, the relationship between environmental quality, human capital, and consumption growth on a balanced path is obtained:

\[ g_{c} = -\frac{(\sigma + \omega)}{i(1 + \omega)} g_{c} \]  
(21)

\[ g_{\varepsilon} = \frac{1-\sigma}{1+\omega} g_{c} \]  
(22)

\[ g_{H r} = \delta_{H} + (1-\sigma) g_{c} - \rho \]  
(23)

At the same time, the equation of the growth rate of consumption is:

\[ g_{c} = \frac{\delta_{H}(H_{r}+H_{f}) - \frac{\alpha}{\alpha + \beta} \rho}{1+\frac{\alpha}{\alpha + \beta} - \frac{\sigma + \omega}{i(\alpha + \beta)(1 + \omega)}} \]  
(24)

As one of the key parameters of the model, environmental quality is the focus of this paper. In view of this, combine equations (6) and (24) can obtain the expression (25). Where, \( \zeta = \alpha + \beta + \gamma \)
In order to further clarify the influence mechanism, a first-order partial derivative is obtained for the economic equilibrium growth rate $g$ showed by the equation (24) and the environmental quality $E$ characterized by the equation (25), will get $\frac{\partial g}{\partial \delta_A} > 0$, $\frac{\partial E}{\partial \delta_A} > 0$, $\frac{\partial g}{\partial H_A} > 0$, $\frac{\partial E}{\partial H_A} > 0$. These indicate that the productivity efficiency of the R&D department $\delta_A$ and the human capital stock $H_A$ have positively improved the economic growth and environmental quality through technological innovation, and promoted high-quality environmental build.

In order to reveal the mechanism of the effects of fiscal decentralization and comprehensive tax rate on environmental quality, the first-order partial derivative of equation (25) is:

$$\frac{\partial E}{\partial s/g} < 0.$$ It shows that high fiscal decentralization damages environmental quality improvement, and its theoretical logic can be summarized as “Chinese-style fiscal decentralization”, which drives local governments to pursue GDP growth at the expense of public goods expenditure and sacrificing environmental quality; $\frac{\partial E}{\partial \tau} < 0$. It shows that high regional tax burden leads to the deterioration of environmental quality from the perspectives of vertical tax competition and low-tax innovation incentive effect [9].

5. Empirical Analysis

5.1. Variable selection

5.1.1. Interpreted variable: Environmental Pollution Index (env). The composite index derived from the entropy method of five indicators: industrial wastewater discharge, industrial gas emissions, industrial sulfur dioxide emissions, industrial dust emissions, and industrial solid waste emissions.

5.1.2. Core explanatory variables: fiscal decentralization index (fisde), tax burden index (taxbur), human capital index (hr), and R&D innovation index (rd). Among them, the fiscal decentralization index is obtained by combining the three methods of income decentralization, decentralization of expenditure and fiscal self-environment; the tax burden is based on the treatment of most literature, which is measured by the local fiscal revenue as a percentage of GDP, the human capital index is calculated using the education years method; the patent quantity measure the innovation R&D index.

5.1.3. Control variables: GDP per capita (gdp), industrial structure (indstuc), urbanization rate (urban), foreign direct investment ratio (fdi), energy consumption per unit of GDP (energy), and environmental investment ratio (ecoimpro). Among them, the industrial structure is measured by the proportion of the added value of the regional secondary industry. The proportion of urban permanent residents measures the urbanization rate. The proportion of foreign direct investment refers to the proportion of foreign direct investment in the RMB at the current exchange rate to the regional GDP. The proportion of regional environmental pollution control investment in GDP measures the proportion of investment.
5.2. Model setup
The quality of the ecological environment is affected by multiple factors. Firstly, the static panel model is established and the cross terms and square terms of the core explanatory variables are introduced. Then, the first-order lag term of the explained variables is introduced to establish the dynamic panel model.

Model 1 examines the relationship between environmental pollution and fiscal decentralization, tax burden, etc. Model 2 introduces the interaction term and squared term of fiscal decentralization and tax burden. To further explore the dynamic effects of environmental pollution, model 3 and model 4 of first-order lag dynamic panel data were established. Model 3 and Model 4 adopt the system GMM method and the difference GMM method respectively.

Model 1:
\[ env_{i,t} = \alpha + \beta_1 \cdot fisde_{i,t} + \beta_2 \cdot taxbur_{i,t} + \beta_3 \cdot hr_{i,t} + \beta_4 \cdot rd_{i,t} + \xi X + \epsilon_{i,t} \]
Model 2:
\[ env_{i,t} = \alpha + \beta_1 \cdot fisde_{i,t} + \beta_2 \cdot taxbur_{i,t} + \beta_3 \cdot fisde_{i,t} \cdot taxbur_{i,t} + \xi X + \epsilon_{i,t} \]
Model 3, 4:
\[ env_{i,t} = \alpha + \beta_1 \cdot env_{i,t-1} + \beta_2 \cdot fisde_{i,t} + \beta_3 \cdot taxbur_{i,t} + \beta_4 \cdot fisde_{i,t} \cdot taxbur_{i,t} + \xi X + \epsilon_{i,t} \]

5.3. Data process
The panel data of 30 provincial-level administrative regions in China from 2000 to 2016 (due to the lack of data and incomplete statistics, the empirical analysis does not include the Tibet Autonomous Region, Taiwan Province, Hong Kong and Macao Special Administrative Regions). The data are taken from the China Statistical Yearbook, China Financial Yearbook, China Environmental Statistics Yearbook, and the official website of the National Bureau of Statistics. Relevant data processing and model checking were performed using STATA14.0.

5.4. Analysis outcome
As shown in Table 1, the interaction term and square term of fiscal decentralization and tax burden in Model 2 are significant. Obviously, Model 2 with nonlinear variables is more reasonable. It can be seen that the overall situation in China is: both fiscal decentralization and tax burden significantly aggravated environmental pollution at the 1% significance level. The interaction between the two variables was significantly negative at the 5% significance level, indicating that although fiscal decentralization and tax burden each showed an increasing trend of pollution, both synergy produces mutually diminished pollution dilution effects. At the same time, the square of fiscal decentralization is significantly negative at the 5% significance level, indicating that fiscal decentralization presents a nonlinear pollution effect. R&D expenses and secondary industry ratios are negative at 1% and 5% significance level respectively, indicating that industrially developed and high R&D intensity areas tend to have stronger economic strength and environmental protection, thus significantly improving regional environmental quality. GDP per capita, unit energy consumption and environmental investment ratio are all positive at 1% significance level, indicating that economically developed and high-energy-consuming regions are more likely to sacrifice the environment due to their industrial orientation.

Then, the first-order lag term of environmental pollution level is introduced, and the dynamic panel model is investigated by using system GMM and differential GMM. The study found that the hysteresis terms of both models are significantly positive at the 1% significant level, indicating that the environmental pollution has its own snowball effect. Although the fiscal decentralization, tax burden and their interactions are not completely significant, they show the same increase and synergistic weakening effect under the static panel model; the research and development costs under the system GMM model show significant environmental improvement effects. GDP per capita, unit energy consumption show significant environmental degradation effects. The differential GMM model has
fewer significant variables, but the key variables such as R&D expenses and secondary industry ratios are similar to the previous model.

Table 1. The Panel Model Regression Results

| Coefficient | Static panel model | Dynamic panel model |
|-------------|--------------------|---------------------|
|             | Model 1            | Model 2            | Model 3            | Model 4            |
| L.env       | Fixed effect       | Fixed effect       | System GMM         | Difference GMM     |
|             |                     |                     | 0.5770***          | 0.9190***          |
| fisde       | -0.0013             | 0.0533***           | 0.0226             | 0.0020             |
|             | (-0.46)             | (4.33)              | (1.23)             | (0.08)             |
| taxbur      | 0.0161***           | 0.0603***           | 0.0209             | 0.0617             |
|             | (2.72)              | (2.76)              | (0.53)             | (1.16)             |
| fisde*taxbur| -                   | -0.0013**           | -0.0015**          | -2.00E-04          |
| fisde²      | -                   | -0.0004***          | -0.0001            | -1.64E-05          |
| taxbur²     | -                   | 0.0007              | 0.0020             | 0.0015             |
| hr          | -0.0104             | -0.0063             | -0.0158            | -0.0021            |
|             | (-0.30)             | (-0.19)             | (-0.47)            | (-0.08)            |
| rd          | -0.0936***          | -0.1010***          | -0.0600**          | -0.0176            |
| gdp         | 0.1500***           | 0.1400***           | 0.2000*            | 0.063              |
| gdp²        | 0.0110***           | -0.0033             | -0.0072            | 0.0125             |
|             | (-2.93)             | (-0.68)             | (-0.80)            | (1.29)             |
| instuc      | -0.0032             | -0.0050**           | -0.0004            | -2.20E-03          |
|             | (-1.58)             | (-2.48)             | (-0.11)            | (-0.96)            |
| urban       | 0.0045              | 0.0032              | -0.0082            | 0.0030             |
|             | (1.34)              | (0.97)              | (-1.39)            | (0.57)             |
| fdi         | -0.0127*            | -0.0095             | -0.0105            | -0.0231            |
|             | (-1.83)             | (-1.40)             | (-0.60)            | (1.23)             |
| energy      | 0.1620***           | 0.2020***           | 0.2110*            | 0.1034***          |
| ecoimpro    | 0.0745***           | 0.0646***           | 0.0238             | 0.0031             |
|             | (4.02)              | (3.89)              | (0.87)             | (0.07)             |
| constant    | 3.1450***           | 1.6830***           | 0.9950*            | 0.5470             |
|             | (4.40)              | (4.13)              | (1.87)             | (-1.12)            |
| R-squared   | 0.537               | 0.648               | -                  | -                  |
| wald P value| 0.00                | 0.00                | 0.00               | 0.00               |
| AR(1)P value| -                   | -                   | 0.003              | 0.001              |
| AR(2)P value| -                   | -                   | 0.261              | 0.223              |
| Hansen P value| -                  | -                   | 1.000              | 1.000              |

Note: The value in parentheses is the t-statistic value.
6. Conclusion
Under the framework of integrated endogenous growth model and Davoodi & Zou model, this paper constructs a four-sector endogenous growth model with variables such as ecological environment and fiscal decentralization, and comprehensively examines fiscal decentralization, tax burden, and R&D innovation etc. on China's eco-environmental quality. At the same time, the empirical research is conducted. The results show:

1. Both the fiscal decentralization and the tax burden have deteriorating effect on the regional environmental quality, and the synergy between them produces a dilution effect that weakens each other;
2. Environmental quality has a lagging positive impact on itself.
3. R&D innovation significantly improves the regional environmental quality, and the proportion of unit energy consumption and environmental investment significantly degrades the environmental quality.

Based on the conclusions, the following policy recommendations are proposed: ①In view of the respective intensification and synergistic weakening effect of fiscal decentralization and tax burden. China's fiscal decentralization and taxation should focus on the coordination and consistency of policy orientation, avoiding the blindness and limitations of policymaking, which has a negative impact on environmental quality. ②The snowball effect of environmental quality requires policy development to maintain considerable stability and consistency over a long period. At the same time, vigorously cultivate R&D and innovation capabilities, reduce unit energy consumption, and improve the effectiveness of environmental protection expenditures.

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