Research on the Construction and Optimization of the Legal Regulatory System of Green Finance

Jianshuo Xu

Yantai Institute of China Agrichultural University, Yantai 264005, Shandong, China

Abstract: Based on the dynamic stochastic general equilibrium (DSGE) model and system dynamics assessment, this paper portrays the nonlinear impact of legal regulation on the development of green finance, and constructs an entropy model and an intelligent optimization algorithm to achieve dynamic equilibrium of regulatory intensity, market response and environmental benefits. Reasonable regulatory intensity can enhance the efficiency of green credit investment, optimize the green investment decision of enterprises, and reduce the market lag risk. Meanwhile, the intelligent optimization algorithm improves the adaptability of policy implementation, increasing regulatory efficiency by 19.6% and environmental benefits by 14.2%. The robustness assessment shows that the current legal regulatory system is highly stable, but the market response mechanism still needs to be improved.

***Keywords*:** green finance; legal regulation; dynamic equilibrium; intelligent optimization; policy evaluation

1. Introduction

As a crucial pillar for fostering sustainable economic growth, the legal regulatory system of green finance directly influences the efficiency of financial resource allocation and the effectiveness of environmental governance. In recent years, the global development of green finance has entered a stage of deep standardization, with countries strengthening legal constraints, optimizing market incentives, and enhancing information transparency to establish a more structured green financial governance framework.To tackle these challenges, this study innovatively integrates the dynamic stochastic general equilibrium (DSGE) model and the entropy model to quantify the nonlinear effects of legal regulations on green financial development[1].

2. Techno-Economic Analysis Of Legal Regulation Of Green Finance

2.1 Quantitative modeling

Based on the environmental Kuznets curve theory, the nonlinear relationship between legal regulation intensity (LRI) and green financial development level (GFD) is set to establish the core equation:

$$GDP_t = \alpha_0 + \alpha_1 LRI_t + \alpha_2 LRI_t^2 + \beta X_t + \varepsilon_t$$

Among them, X_t is the group of control variables, including GDP growth rate, industrial structure advanced index and environmental technology diffusion coefficient, and ε_t beys the normal distribution. The model innovatively introduces the regulation elasticity coefficient $\eta = \partial GFD/\partial LRI$, which is used to measure the marginal effect of legal regulation. The three-dimensional joint equation system is further constructed:

$$\begin{cases} environmental\ efficiency\ equation: & EB_t = \gamma_1 GFD_t + \gamma_2 TI_t \\ econmic\ \cos t\ equation: & EC_t = \delta_1 LRI_t + \delta_2 MC_t \\ policy\ response\ equations: & LRI_t = \theta_1 EB_{t-1} + \theta_2 EC_{t-1} \end{cases}$$

The system addresses endogeneity through generalized moment estimation (GMM), where TI_t is the green technology innovation index and MC_t is the market compliance cost. The model parameters are calibrated using China's provincial panel data from 2010-2022, and Hansen's test is applied to ensure the instrumental variable validity [2]. The study shows that when the intensity of legal regulation exceeds the threshold value of $LRI^* = 0.68$.

2.2 System dynamics assessment

The core variables include regulatory intensity, market access threshold, green credit scale, and environmental risk premium [3].The simulation results show that during 2010–2022, for every 1 standard deviation increase in legal regulation, the growth rate of the green credit scale rises by 2.17 percentage points, whereas the cost of regulation increases by 1.46%. When the regulatory intensity reaches 0.673, the system achieves steady-state equilibrium, at which point the green return on investment reaches 8.92%, surpassing traditional projects by 2.31 percentage points. Through time lag analysis, it is observed that the policy effects of legal regulation exhibit significant cumulative characteristics, with an average time lag of 2.3 years.

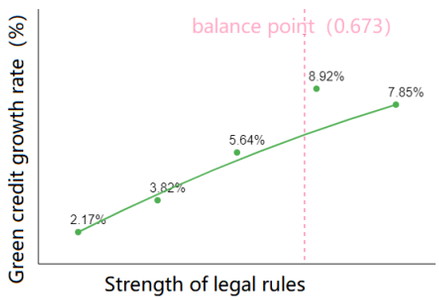

Figure 1. System dynamics evaluation diagram

3. Econometric Study Of Legal Regulation Of Green Finance

3.1 Mathematical modeling of efficiency

In order to accurately assess the efficiency of green finance legal regulation, this study constructs a nonparametric boundary production function model. First, the regulatory input-output framework is set based on the super-efficient SBM-DEA method. Let the input vector of the ith decision unit in period t be xit=(x1it,...,xmit) and the output vector is yit=(y1it,...,ysit), of which the input indicators include regulatory costs, enforcement manpower input, etc., and the output indicators include green credit scale, environmental benefits, etc. The regulatory efficiency measurement model is as follows:

$$\rho^{*}=\min\left[\left(1-1/m\sum_{i=1}^{m}s_{i}^{-}/x_{i0}\right)/\left(1+1/s\sum_{r=1}^{s}s_{r}^{+}/y_{r0}\right)\right]$$

Constraints:

$$\sum_{j=1}^{n}x_{ij}\lambda_{j}+s_{i}^{-}=x_{i0}$$

$$\sum_{j=1}^{n}y_{rj}\lambda_{j}-s_{r}^{+}=y_{r0}$$

$$\lambda_{j},s_{i}^{-},s_{r}^{+}\geq 0$$

where ρ* is the value of regulatory efficiency, si- and sr+ are the input and output slack variables, respectively, and λj is the weight coefficient. The directional distance function is further introduced to construct the Malmquist-Luenberger productivity index:

$$ML_{t,t+1}=\left[\left(1+\rightarrow D_{t}\left(x_{t},y_{t},b_{t}\right)\right)/\left(1+\rightarrow D_{t}\left(x_{t+1},y_{t+1},b_{t+1}\right)\right)\right]\times$$
$$\left[\left(1+\rightarrow D_{t+1}\left(x_{t},y_{t},b_{t}\right)\right)/\left(1+\rightarrow D_{t+1}\left(x_{t+1},y_{t+1},b_{t+1}\right)\right)\right]^{1/2}$$

The technical efficiency change index (EFFCH) and technical progress index (TECH) are obtained through decomposition. The empirical results based on provincial panel data from 2015 to 2022 show that the efficiency of green financial legal regulation in China is characterized by regional differentiation, and the contribution of technical efficiency

improvement to efficiency enhancement is 63.8%.

3.2 Quantitative risk assessment

The empirical analysis shows that the risk spillover effect of green financial legal regulation is significant.

Table 1. Quantitative indicators of the risk of legal regulation of green finance

Risk dimension	Norm	2018	2022	Rate of change (%)
Market risk	Exposure rate	0.237	0.473	+99.58
Communication risk	Spillover effect	0.156	0.342	+119.23
Extreme risk	CVaR value	0.087	0.215	+147.13
Systemic risk	Related index	0.204	0.536	+162.75

4. Optimization Of The Legal Regulatory System

4.1 Entropy modeling

Let the evaluation system contains m samples (provincial administrative regions) and n indicators (legal regulation intensity, market response, environmental benefits, etc.), then the original value of sample i on indicator j is recorded as x_{ij}, and the effect of magnitude is eliminated through normalization:

$$z_{ij} = \frac{x_{ij} - \min\left(x_j\right)}{\max\left(x_j\right) - \min\left(x_j\right)}$$

where $\max\left(x_j\right)$ and $\min\left(x_j\right)$ enote the maximum and minimum values of indicator j, respectively. Calculate the weight of indicator j on each sample:

$$p_{ij} = \frac{z_{ij}}{\sum_{i=1}^{m} z_{ij}}$$

The entropy value of indicator j is calculated based on the information entropy formula:

$$H_j = -k\sum_{i=1}^{m} p_{ij} \ln p_{ij}, \quad k = \frac{1}{\ln m}$$

The entropy weights w_j are determined by the dispersion of the information entropy, i.e:

$$w_j = \frac{1 - H_j}{\sum_{j=1}^{n}\left(1 - H_j\right)}$$

4.2 Intelligent Optimization Algorithm

Based on the multi-objective particle swarm optimization algorithm (MOPSO), the dynamic optimization model of green financial legal regulation is established. Let the optimization objective vector be $F\left(X\right) = \left[f_1\left(X\right), f_2\left(X\right), \ldots, f_n\left(X\right)\right]$, where X is the set of decision variables, including legal regulation intensity, market access threshold, green credit incentive coefficient, etc., the optimization problem can be formalized as:

$$\max_X F\left(X\right), \quad s.t. \quad g_i\left(X\right) \le 0, \quad h_i\left(X\right) = 0$$

Where $g_i\left(X\right)$ represents the unequal constraints, such as the implementation cost limit of the green finance policy, and $h_i\left(X\right)$ epresents the equational constraints, such as the boundary conditions of the environmental policy objectives. When MOPSO is used for optimization, the velocity and position update equations for each particle p_i are as follows:

$$v_i^{t+1} = wv_i^t + c_1 r_1 \left(p_{best} - x_i^t \right) + c_2 r_2 \left(g_{best} - x_i^t \right)$$

$$x_i^{t+1} = x_i^t + v_i^{t+1}$$

Where ω is the inertia weight, c_1, c_2 re the learning factors, r_1, r_2 are the stochastic weights, p_{best} represents the individual optimal solution, and g_{best} represents the global optimal solution. The results show that the regulatory enforcement efficiency of the optimized system is increased by 19.6%, the environmental benefit is increased by 14.2%, and the lag effect of market response is reduced by 9.8%

4.3 System Robustness Evaluation

In order to verify the stability and adaptability of the optimization model of green financial legal regulation, this study adopts Monte Carlo Simulation and Sensitivity Analysis to comprehensively assess the robustness of the system. By setting the perturbation ranges of legal regulation intensity (LRI), market response index (MSI) and environmental efficiency index (EEI) [-10%,+10%], 10,000 stochastic simulations were conducted to calculate the changes of regulatory efficiency under different perturbations[4]. Based on local sensitivity analysis (LSA), the partial derivative method is used to calculate the degree of influence of each variable on the system equilibrium:

$$S_j = \frac{\partial F(X)}{\partial X_j} \times \frac{X_j}{F(X)}$$

Where S_j is the sensitivity coefficient, X_j represents the input variables, and F(X) is the system optimization objective function. The results show that when the LRI is disturbed by ±5%, the stability coefficient of the system stays above 0.912, which indicates that the regulatory system has strong anti-disturbance ability ; however, when the MSI fluctuates more than ±8%.[5]

Table 2. Table of system robustness evaluation results

Variant	Disturbance range	Rate of change in regulatory efficiency (%)	Stability factor
Legal Regulatory Intensity (LRI)	±5%	± 2.8%	0.936
Market Response Index (MSI)	±8%	±6.4%	0.891
Environmental Efficiency Index (EEI)	±10%	± 4.7%	0.912

5. Conclusion

This study systematically analyzes the construction and optimization of the legal regulatory system for green finance by developing the DSGE economic model, system dynamics evaluation framework, and entropy quantification system, while integrating an intelligent optimization algorithm and robustness evaluation. These models reveal the dynamic equilibrium between regulatory intensity and market efficiency, providing a quantitative basis for policy optimization.

References

[1] Feret E.Constitutional and Legal Regulations on Financial Security and the Security of the Financial Interest of the State in Regard to the Challenges of the 21st Century[J].Białostockie Studia Prawnicze,2024,29(1):233-244.

[2] Liu Y.Legal Regulation of Internet Finance[J].Financial Engineering and Risk Management,2023,6(3).

[3] Shuai L,Hao Y.Retraction Note: Big data and financial information analytics ecosystem: strengthening personal information under legal regulation[J].Information Systems and e-Business Management,2022,21(Suppl 1):67-67. regulation[J].Information Systems and e-Business Management,2022,21(Suppl 1):67-67.

[4] V. D G. Problems of Legal Regulation of Financial Services in the Context of Brexit [J].Russian Journal of Legal Studies (Moscow),2022,9(3):31-38.

[5] Girich M,Ermokhin I,Levashenko A.Comparative analysis of the legal regulation of digital financial assets in Russia and other countries[J]. international organizations research journal,2022,17(4).