Digital Finance, Government Policies and ESG Behavior Improvement of Small and Medium Enterprises - Based on Network Game Modeling

Qin Liu [a], Jingwen Yang [*]

School of Entrepreneurship, Wuhan University of Technology, Wuhan, Hubei, 430070, China

[a]liu.qin@whut.edu.cn, [*]17386001280@163.com

Abstract. In order to alleviate the pressure of SMEs' green innovation costs and promote ESG behavior improvement, this study focuses on digital finance and government policies, and constructs a network game model with SMEs, financial institutions and the government as the main bodies. The simulation results show that: the government tax rebate coefficient directly promotes the improvement of SMEs' ESG behavior; the digital penetration rate of financial institutions has a significant contribution to the improvement of SMEs' ESG behavior; and the government's financial support for digital financial institutions also promotes the improvement of SMEs' ESG behavior.

Keywords: digital finance; government policy; ESG behavior; network games.

1 Introduction

With the rising wave of global sustainable development, China's economy is shifting towards high-quality development, and the ESG concept has gradually become popular. The ESG concept requires enterprises to pay more attention to environmental responsibility, social contribution and corporate governance effectiveness in order to realize the double improvement of economic and social benefits. As an important indicator for measuring the effectiveness of high-quality development, ESG performance has also received increasing attention from governments and scholars. ESG performance significantly drives continuous innovation by alleviating financing constraints [1]. Enterprises seeking to improve ESG performance need to invest in green innovation, but its long-term and high-risk nature often leads to investment and financing mismatches [2]. Digital finance, popularized in SMEs, can accurately assess ESG risks, provide green credit and other services, reduce financing difficulties, and accelerate the implementation of green projects[3]. And government policies such as fiscal and tax incentives can effectively mobilize the interaction between financial institutions and enterprises and promote the improvement of corporate ESG behavior [4]. However, few scholars have analyzed the relationship between digital finance, government policies and SMEs' ESG behavior improvement from the perspective of dynamic synergy. Therefore, this study will focus on this and analyze the influence of government tax rebate coefficient, digital

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penetration rate of financial institutions and other factors on SMEs' ESG behavior improvement by constructing a network game model, aiming to reveal how digital finance can help SMEs to overcome the financing difficulties of green transformation and promote them to achieve a higher level of ESG behavior improvement under the guidance of government policies.

2 Game Model Design

2.1 Game Model

Due to the continuous development of information technology, the links between small and medium-sized enterprises are more frequent and gradually show the characteristics of the small world, so this study is more suitable for small world networks. the connectivity of the NW model network is stronger and more in line with the characteristics of real-world network connectivity. Therefore, we choose to adopt the NW small world model [5] as the basis for the construction of enterprise networks. The parameters of the model are defined in Table 1 and the game payment matrix is shown in Table 2.

Table 1. Variable definition

Variable	Defined
C	Green technology R&D costs
α	Green technology R&D risk ratio
M	Low-interest loan amount
h	Probability of obtaining a low-interest loan
Ct	Cost of traditional financial services
Rt	Gains from traditional financial services
b	Digital penetration
E	Amount of government tax revenue
q	Government rebate coefficient
F	Government financial support
R	Enterprise pre-existing earnings

Table 2. Game Payment Matrix

		Company1	
		Improvement	
Company2	No improvement	$R + M * \left\lceil \frac{F(1+b)}{Rt} \right\rceil + E * q - C^*(1+\alpha) - Ct^*(1-b)$	$R + M * \left\lceil \frac{F(1+b)}{Rt} \right\rceil + E * q - C^*(1+\alpha) - Ct^*(1-b)$
		$R + M * \left\lceil \frac{F(1+b)}{Rt} \right\rceil + E * q - C^*(1+\alpha) - Ct^*(1-b)$	$R + M * h - Ct$
		$R + M * h - Ct$	$R + M * h - Ct$
		$R + M * \left\lceil \frac{F(1+b)}{Rt} \right\rceil + E * q - C^*(1+\alpha) - Ct^*(1-b)$	$R + M * h - Ct$

- Hypothesis 1: Game parties include SMEs, financial institutions and government. SMEs: willingness to improve ESG x, vice versa 1-x; financial institutions: digitalized services y, traditional services 1-y; government: positive support z, negative 1-z.
- Hypothesis 2: Both sides are willing to improve ESG behavior, then the gains of both enterprise 1 and enterprise 2 are $R + M * \left\lceil \frac{F(1+b)}{Rt} \right\rceil + E * q - C^*(1+\alpha) - Ct^*(1-b$
- Hypothesis 3: Firm 1 is willing to improve ESG behavior and Firm 2 is not, the payoff to Firm 1 is $R + M * \left\lceil \frac{F(1+b)}{Rt} \right\rceil + E * q - C^*(1+\alpha) - Ct^*(1-b$ and the payoff to Firm 2 is $R + M * h - Ct$
- Hypothesis 4: Firm 1 is unwilling to improve ESG behaviors and Firm 2 is not, then the return for Firm 1 is $R + M * h - Ct$ Firm 2's return is $R + M * \left\lceil \frac{F(1+b)}{Rt} \right\rceil + E * q - C^*(1+\alpha) - Ct^*(1-b$
- Hypothesis 5: Both sides are unwilling to improve ESG behavior, then the gains for both Firm 1 and Firm 2 are $R + M * h - Ct$

2.2 Evolutionary Rules

In this study, we construct a small-world network game model to explore the dynamic evolution mechanism of ESG behavior improvement of manufacturing firms under the guidance of government policies and the support of digital finance. By considering firms as nodes in the network, we show how firms adjust their green technology innovation strategies and ESG performance by considering the key factors of network structure, game time, and payoff function.

To this end, we introduce the Fermi function as a strategy updating rule between nodes, i.e., firms focus on strategy gaming and learning exchanges with their direct competitors, i.e., those firms with direct connecting edges to themselves. In each round of the game process, firm i interacts with all directly connected firms in its neighborhood and aggregates to compute the cumulative gain f(i) for the round. Subsequently, based on the gain obtained, enterprise i will engage in strategy learning with neighboring enterprises with a view to optimizing its own strategy choices. This can be expressed in a mathematical formula as $p = \frac{1}{1+e^{-\beta(\pi_j - \pi_i)}}$

3 Simulation Results Analysis

3.1 Parameter Allocation

We take manufacturing enterprises in the new energy field as an example, set the maximum size of the network to 300 will not be exceeded, combined with the assignment method in the study of Yunxia Cao et al. to the government tax rebate coefficient q, digital penetration rate b, and the government's financial support for financial institutions F for the assignment of [0,1], this paper argues that the initial probability of the

manufacturing enterprises are willing to improve ESG behavioral strategies is 0.1. The model parameter values are set as in Table 3.

Table 3. Parameter settings

Parameters	Value taken	Units
C	0.04	millions
α	0.5	millions
M	0.025	millions
Ct	0.03	millions
Rt	0.036	millions
E	0.003	millions
R	0.07	millions
h	0.45	
q	0.3	
b	0.4	
F	0.6	

Simulation Cases

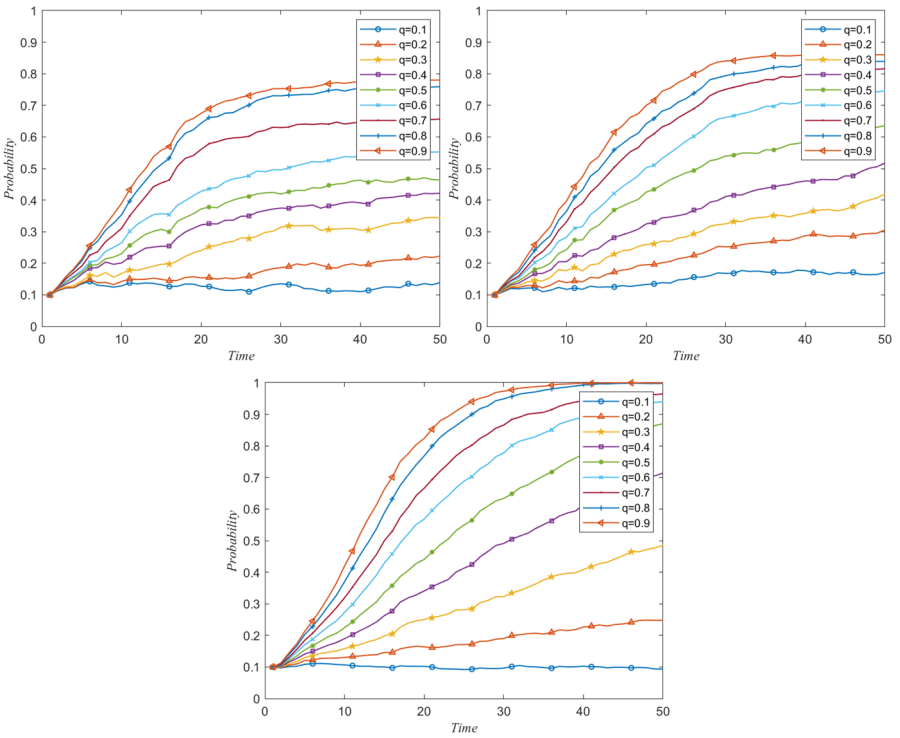

Fig. 1. The effect of government tax rebate coefficient q on ESG behavioral improvement in SMEs.

The figure 1 shows the impact of government tax rebate coefficient q on the improvement of SMEs' ESG behavior, and the continuous improvement of government tax rebate coefficient plays a direct role in promoting the improvement of SMEs' ESG behavior. The government tax rebate as a fiscal means [6], by reducing the tax burden of SMEs, reduce the direct cost risk borne by SMEs to carry out green technological innovation [7], so that the willingness of SMEs to improve their ESG behavior is strengthened, and with the gradual improvement of the benefits of these SMEs, more and more other enterprises will follow and update their own strategies according to the Fermi updating rule. At this time, as the network size continues to expand, the improvement of SMEs' ESG behavior is more and more sensitive to the government tax rebate coefficient, that is to say, as the number of enterprises in the network increases, the proportion of SMEs' ESG behavior improvement under the condition of the same government tax rebate coefficient will also increase.

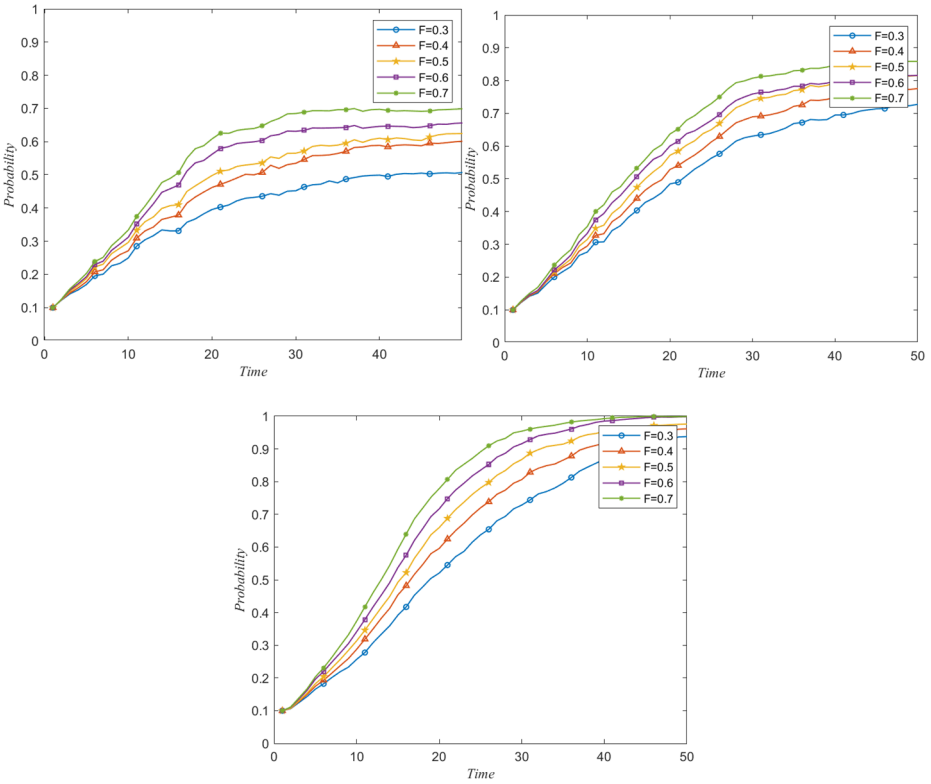

Fig. 2. The Impact of Digital Penetration b on ESG Behavioral Improvement in SMEs.

The figure 2 shows the impact of digital penetration on SMEs' ESG behavior improvement. Compared with traditional financial institutions, the service cost of digital financial institutions is reduced due to the application of digital technology, and SMEs with ESG behavioral improvement are more likely to obtain low-interest loans from

financial institutions due to the easier and more comprehensive access to information by digital financial institutions and the faster identification of potential green technology innovation projects. As the digital penetration rate of financial institutions increases in networks of different sizes, the stronger the digital penetration rate will be on the improvement of SMEs' ESG behaviors.

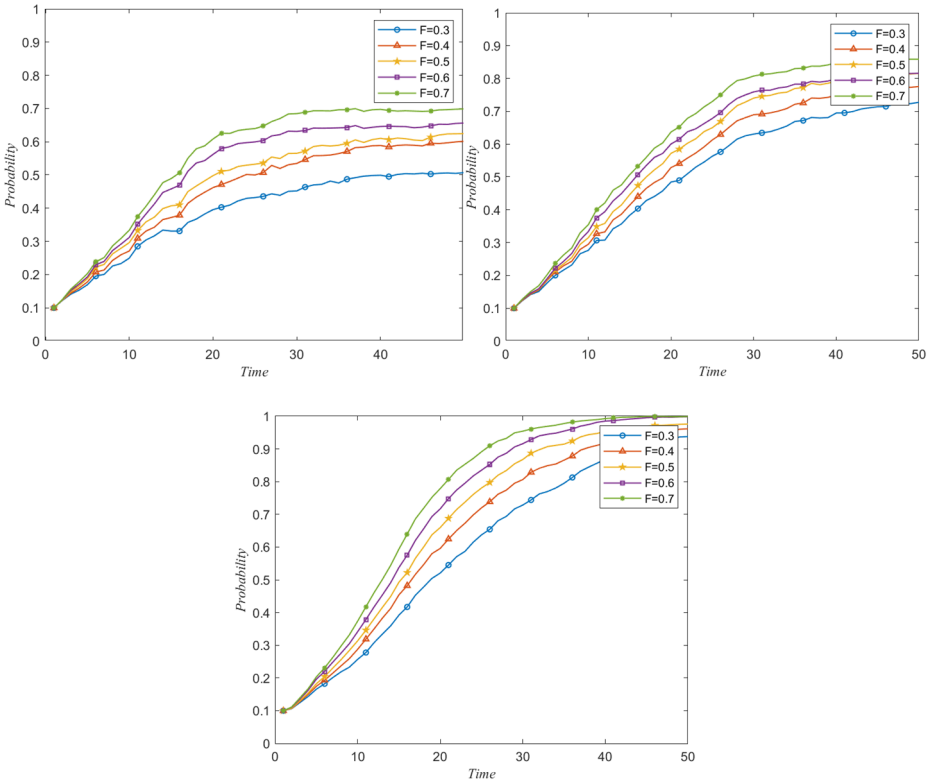

Fig. 3. The Indirect Effect of Government Financial Support on ESG Behavior Improvement in SMEs

The figure 3 shows the indirect impact of the government's financial support F on the behavioral improvement of SMEs. The government's financial support for financial institutions that have carried out digital transformation reduces the service costs of digital financial institutions, prompting digital finance institutions to further promote digital transformation, and according to the previous research: the digital transformation of financial institutions reduces the financing constraints of SMEs, indirectly encouraging SMEs to carry out green technology innovation, which ultimately has an impact on the improvement of SMEs' ESG behavior. With the increasing number of enterprises participating in the game, under the same conditions of government financial support, the willingness of enterprises to improve ESG behavior increases with the continuous expansion of the network.

4 Conclusions

This paper will analyze the relationship between digital finance, government policy and SME ESG behavior improvement from the perspective of network game, and draw the following conclusions:

- The government's tax rebate coefficient has a direct contribution to the ESG behavior improvement of SMEs
- The digital penetration rate of financial institutions has a significant facilitating effect on the ESG behavior improvement of SMEs, and the higher the digital penetration rate of financial institutions, the lower the cost and risk of ESG behavior improvement of SMEs, and the greater the willingness to improve ESG behavior
- The government's financial support for digital financial institutions has a facilitating effect on SMEs' ESG behavior improvement

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