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A Study on the Impact Mechanism of Delayed Retirement on the reen Transformation of Pension Insurance Funds under the Constraint of " Dual Carbon" Targets

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Abstract: Under the dual constraints of my countrys aging population and "dual carbon" targets, exploring how the delayed retirement policy affects the green transformation of pension funds is of great significance for achieving coordinated economic, social, and environmental development. Existing research often discusses delayed retirement and green investment separately, lacking a mechanism test of their intrinsic connection. To fill this gap, this study constructs a comprehensive analytical framework. First, a multi-period difference-in-differences model is used to identify its net effect. Second, a dynamic ESG evaluation system is constructed. Finally, through system dynamics models and Monte Carlo simulations, the emission reduction effects and risk-return profile of green investment are quantified. This study reveals the intrinsic mechanism by which the delayed retirement policy drives green transformation through optimized fund asset allocation. The policy implication is that emphasis should be placed on the synergy between delayed retirement and green finance policies, strengthening ESG guidance and incentives to jointly improve the long-term financial and environmental sustainability of pension funds.

Keywords: Pension insurance fund; Green transition; Difference-in-differences; ESG evaluation system; System dynamics.

1. Introduction

Under the dual constraints of "dual carbon" targets and an aging population, the sustainable development path of Chinas pension insurance system urgently needs innovation. As a key measure to address pension payment pressures, the delayed retirement policys spillover effects, particularly its guiding role in long-term investment strategies for funds, especially in green transformation, are cutting-edge issues in the intersection of public policy and financial research.

Existing research has significant limitations: On the one hand, assessments of delayed retirement policies largely focus on their direct impact on fund financial returns, neglecting their potential optimization function on asset structure. On the other hand, research on green investment in pension funds often remains at the level of advocacy and case analysis, or suffers from difficulties in making precise causal inferences and dynamic measurements due to lagging ESG data and static rating systems. This disconnect between theory and methodology makes it difficult to answer questions such as: Does delayed retirement policy significantly drive the green transformation of funds? Is the impact of improved ESG performance on green investment linear or non-linear? And how significant is the carbon emission reduction effect of green investment?

To address the aforementioned issues, this study employs a composite research methodology integrating quasi-natural experiments, dynamic evaluation, and system simulation. Specifically: First, a multi-period DID model is constructed using the 2018 Ministry of Human Resources and Social Securitys pilot policy on delayed retirement to effectively identify the policys effects. Second, an entropy weight - TOPSIS method with a time decay factor is innovatively introduced to construct a dynamic ESG evaluation system, and panel regression and PVAR models are used to capture the nonlinear and dynamic relationship between ESG scores and green asset allocation. Third, a system dynamics model is used to characterize the feedback loop of "green investment - carbon emission reduction - fund returns," and Monte Carlo simulation is used to assess the probability of achieving emission reduction targets and related risks.

2. Literature Review

2.1. The Development History of Delayed Retirement

On September 13, 2024, the Standing Committee of the National Peoples Congress voted to pass the decision on implementing a gradual delay of the statutory retirement age. Starting from January 1, 2025, China will gradually delay the statutory retirement age of male employees from the original 60 years old to 63 years old over 15 years, and gradually delay the statutory retirement age of female employees from the original 50 years old and 55 years old to 55 years old and 58 years old respectively. Previously, Li Qin and Peng Haoran (2015) defined delayed retirement as: if a man expects to stop working at an age of more than 60 years old, or a woman expects to stop working at an age of more than 55 years old, we consider that the individual is willing to delay retirement [1] . In modern times, Yang Haowen (2024) defines delayed retirement as: in a narrow sense, delayed retirement generally refers to delaying the statutory retirement age; while in a broad sense, delayed retirement includes both the continuation of the inherent career and the diversified "re-employment" of younger elderly people [2] . Hou Huaiyin and Zhang Huiping (2025) pointed out that once the policy was introduced, it triggered a wide range of discussions and research on social issues and fairness issues such as elderly human resources, pensions and retirement benefits, family intergenerational relationships, population aging, and the silver age industry. The research mainly focused on social policy areas such as delayed retirement age, pension and labor system protection, elderly employment and elderly human resource development [3] . Later, Sun Nan (2025) studied that individuals in a healthy working state have better physical and mental health, can maintain higher work efficiency and quality of life, thereby delaying the non-voluntary retirement process caused by health reasons [4] .

2.2. The Green Transformation and Development Process of Pension Insurance Funds

Abroad, Blundell-Wignall et al. (2008) proposed the concept of "sovereign pension funds" (SSRFs), emphasizing their connection with the national social security system. The funds mainly come from the contributions of the insured and have payment requirements, such as the US Federal Social Security Trust Fund [5] . Cao Heng (2022) believes that the pension insurance fund in the narrow sense refers to a special fund composed of government subsidies, employer and individual contributions in a certain proportion, with the purpose of guaranteeing and solving the basic living of the insured after retirement or loss of labor capacity, and is collected and pooled by social security agencies in accordance with relevant laws and regulations [6] . With the aggravation of the aging population problem and the increase in the expenditure pressure of pension insurance fund in China, the sustainable development of the fund faces severe challenges, and the need to realize the preservation and appreciation of pension insurance fund and ensure the maximization of returns is becoming increasingly prominent (Wang Yong, 2025) [7] . Therefore, Jing Peng and Chen Mingjun (2018) pointed out that because green investment projects have advantages such as large market potential, fast value appreciation and high comprehensive benefits, and there is a large financing gap, pension insurance funds in various countries have realized that they should adhere to the green investment orientation [8] . Zou Maolin (2024) also pointed out that Chinas basic pension insurance fund belongs to the social insurance fund. Green investment of the basic pension insurance fund involves both social security and environmental protection. Using budget subsidies to support green investment of the basic pension insurance fund is in line with the direction and goal of general public budget expenditure and is reasonable and legal [9] .

2.3. The Impact and Development of Delayed Retirement on the Green Transformation and Integration of Pension Insurance Funds

The space for reducing pension insurance fees and the balance of fund revenue and expenditure has been increasingly valued by the academic community. Although delayed retirement can improve the situation of pension insurance fund, it is difficult to change the trend of pension insurance revenue not covering expenditure (Yang Yixin and He Wenjiong , 2016) [10] . Therefore, Huang Chunmei and Sun Ziwen (2025) believe that in order to respond to the reform of Chinas pension insurance system and cultivate the concept of active aging and healthy aging, the national pooling of pension insurance fund and the policy of delayed retirement age should be promoted simultaneously, which is intended to effectively alleviate the fiscal expenditure pressure of social pension insurance fund and increase the social labor supply in the long term [11] . Chen Wenhui (2021) also pointed out that the scale of Chinas three major pension pillars exceeds RMB13 trillion and needs to be matched with the green investment cycle [12] . Therefore, Zheng Bingwen proposed the necessity of pension fund as ESG investment subject and emphasized the compatibility of "dual carbon" target with long-term pension fund capital. Zheng Bingwen, Li Chen, and Pang Qian (2022) analyzed international ESG investment strategies (such as negative screening and ESG integration) and proposed a green transformation path for Chinese pension funds [13] . In foreign countries, Friedman, M. (1970). The Social Responsibility of Business is to Increase Its Profits. proposed the view that traditional corporate social responsibility (CSR) conflicts with shareholder interests [14] , which later evolved into the ESG investment paradigm and the Global Sustainable Investment Alliance (GSIA, 2020). Global Sustainable Investment Review. defined seven sustainable investment strategies (such as negative screening and ESG integration), laid the foundation for the green transformation methodology of pension funds, and then proposed that pension funds should incorporate environmental and social risks into asset pricing models through ESG integration strategies to reduce long-term systemic risks [15] . Battiston, S., et al. (2021). Climate Risk and Financial Stability: The Case of Pension Funds. The EU’s Sustainable Financial Disclosure Regulation (SFDR) mandates disclosure of climate risks, which has driven pension funds to increase their ESG investment ratio to 45%. In summary, delayed retirement has prompted pension insurance funds to undergo a green transformation . [16]

3. Research Content

3.1. Studying the impact mechanism of delayed retirement policy on the green transformation of pension insurance fund

Chinas population is aging rapidly, with those aged 60 and above accounting for 19.8% of the total population in 2022. The pension dependency ratio has fallen to 2.8:1, highlighting the pressure on pension fund revenue and expenditure. The delayed retirement policy has significantly improved the green asset allocation of pension funds and promoted carbon emission reduction, thus driving the green transformation of pension funds. Therefore, we examine the long-term impact of policy intervention on fund sustainability, investigating whether the delayed retirement policy has a significant impact on the green transformation of pension funds, and whether there are regional heterogeneities in the policys effects, such as differences between the eastern, central, and western regions.

3.2. The Optimizing Role of ESG Scores in Green Asset Allocation

The 20th National Congress of the Communist Party of China proposed "developing green finance," requiring social security funds to increase the proportion of green investments to 30%. Currently, the green asset allocation ratio is only 12%, necessitating the optimization of the ESG evaluation system to guide investment. Therefore, we construct a dynamic correlation model between ESG scores and green asset allocation, identifying the marginal contribution of ESG three-level indicators to portfolio risk and return, verifying the driving effect of ESG optimization strategies on the green transformation of funds, investigating whether improved ESG scores significantly promote green asset allocation, and how to resolve the contradiction between the lag in traditional ESG ratings and dynamic market feedback. The expected results show that for every 1-point increase in ESG score, the green asset allocation ratio increases by 0.5%-1.2% (non-linear relationship). The Sharpe ratio of high ESG score portfolios is 15% higher than the benchmark portfolio, verifying the existence of a "green premium."

3.3. The emission reduction effect of the proportion of green investment on the carbon footprint of funds

Pension insurance funds need to achieve carbon neutrality by 2035, but their current investment portfolio has a high carbon emission intensity (approximately 1.2 tCO_2/10,000 yuan). Increasing the proportion of green investment is a key emission reduction path, but its feasibility and policy costs need to be quantified. Therefore, we simulate the dynamic impact of increasing the proportion of green investment on the carbon footprint of pension insurance funds, quantify the feasibility of the policy target of emission reduction intensity per unit investment (≥0.5 tCO_2/ 10,000 yuan), verify the emission reduction effect of the low-carbon transition path, and study whether the target of emission reduction intensity per unit investment ≥0.5 tCO_2/ 10,000 yuan is feasible. Furthermore, we investigate whether excessive concentration of green investment will lead to liquidity risks. The expected results show that for every 1% increase in the proportion of green investment, the funds carbon footprint decreases by 0.75 tCO_2/10,000 yuan . When the carbon price exceeds 100 yuan/ton, the emission reduction cost -benefit ratio can reach 1:5.

4. Model Construction

4.1. Verifying the Policy Effects Using the Difference-in-Differences (DID) Model

The core idea of the Difference-in-Differences (DID) model is to infer the net effect of a policy by comparing the differences between the treatment and control groups before and after policy implementation. Its basic logic is that by comparing the changes in the two sets of data before and after policy implementation, the shared time trends and potential interferences of both groups can be effectively controlled, thus making the estimation more accurate. A DID model is constructed to quantify the policy effect:

$$Y_{it} = \beta_0 + \beta_1 \cdot DID_{it} + \gamma X_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

Where Y_{it}represents the pension fund size of province X_{it}i at time t. DID represents the dummy variable for the impact of the delayed retirement policy, treating government policy as a quasi-natural experiment. If a city is a pilot city and has already conducted policy trials, DID is assigned a value of 1; otherwise, it is assigned a value of 0. Other variables affecting the fund size are represented. μ_i Individual fixed effects, δ_t time fixed effects, and ε_{it} random error terms for each province are represented. A multi-period difference-in-differences model is used to quantitatively analyze the impact of the policy on the pension fund size.

4.2. Construction and Measurement of ESG Evaluation System

4.2.1. Construction of ESG Evaluation System

Based on the "Green Investment Guidelines (Trial)" , a three-level indicator system for ESG evaluation of pension insurance funds was constructed . The relevant standards were selected and the results are shown in Table 1.

Table 1. Three-tiered indicator system for ESG evaluation of pension insurance funds

Dimension	Primary indicators	Secondary indicators	Level 3 indicators
environment	carbon emission intensity	Carbon emissions per unit of investment	Total carbon emissions of the investment portfolio
	Green investment ratio	Green bond/stock investment ratio	Green investment coverage
society	Beneficiary group coverage	Increase in replacement rate among low-income groups	The proportion of people employed in green industries
governance	Investment decision transparency	ESG Information Disclosure Completeness	ESG Report Disclosure Score

4.2.2. Entropy Weight -TOPSIS Comprehensive Scoring Method

(1) Data standardization: Range standardization is performed on primary indicators such as carbon emission intensity and the proportion of green investment.

$$x'_{ijk} = \frac{x_{ijk} - \min(x_{jk})}{\max(x_{jk}) - \min(x_{jk})} \quad (2)$$

(2) Entropy weighting method: Calculate the weights of the environment (E), society (S), and governance (G) dimensions (\ omega$_k$), eliminating subjective bias:

$$\omega_k = \frac{1-H_k}{\sum_{k=1}^{3}(1-H_k)} \quad (3)$$

in, $H_k = -\sum_{j=1}^{m_k} p_{ij} \ln p_{ij}$,$p_{ij} = \frac{x'_{ijk}}{\sum_{i=1}^{n} x'_{ijk}}$

4.2.3. Dynamic Model for Green Asset Allocation

Panel regression model

Basic model:

$$GreenAssetRatio_{it} = \alpha_0 + \alpha_1 ES_i + \alpha_2 ES_i^2 + \beta X_{it} + \varepsilon_{it} \quad (4)$$

Key improvements:

Nonlinear effect: ES_i^2The inverted U-shaped relationship between ESG and green configuration is captured by the quadratic term ( ).

Dynamic lag effect: Incorporating the first-order lag term of the ESG score:

$$GreenAssetRatio_{it} = \alpha_0 + \rho GreenAssetRatio_{it-1} + \alpha_1 ES_i + \beta X_{it} + \varepsilon_{it} \quad (5)$$

4.3. Study the emission reduction effect of the proportion of green investment on the carbon footprint of the fund.

4.3.1. Decomposition of research objectives

(1) Core Objectives

The dynamic impact of increasing green investment on the carbon footprint of pension funds was quantified to verify the following hypothesis:

Effectiveness of emission reduction pathways: For every 1 percentage point increase in the proportion of green investment, the funds carbon footprint decreases by ≥0.5 tCO_2/10,000 yuan.

Policy objective feasibility: Feasibility of reducing the funds carbon footprint by 30% by 2035 compared to 2020.

(2) Definition of key variables

Explained variable: Fund carbon footprint ($CarbonFootprint_{it}$)

Key explanatory variable: Percentage of green investment ($GreenRatio_{it}$)

Control variables:

$InvestmentVolume_{it}$:Total annual investment amount of the fund (unit: RMB 10,000).

$EmissionIntensity_{it}$Carbon emission intensity per unit of investment (unit: tCO_2e / 10,000 yuan).

$CarbonPrice_{it}$Carbon market price (unit: yuan / tCO_2e).

4.3.2. Construction of System Dynamics Model

Basic causal feedback loop

Construct a dynamic feedback model that includes variables such as green investment, carbon emissions, and funding gaps:

$$\frac{dCarbonFootprint}{dt} \tag{6}$$

Formula explanation:

The dynamic changes in carbon footprint are driven by two parts:

New carbon emissions: Total investment × (1 - percentage of green investment) × emission intensity per unit of investment.

Carbon offsetting: Emission reductions achieved through carbon trading, green technologies, and other means.

5. Empirical Analysis

5.1. Descriptive Statistics

The data sources selected for this project include the National Bureau of Statistics, the "Statistical Yearbook on Population and Social Security Development" of various provinces, the ESG rating database of the Green Finance Institute of the Central University of Finance and Economics, annual reports of third-party rating organizations, and the carbon emission database of the Green Finance Institute of the Central University of Finance and Economics. Detailed results are shown in Table 2.

Table 2. Experimental Data Results

Variable name	Meaning	Observed values	Average value	Standard deviation	Minimum value	Maximum value
Dummy variable for delayed retirement policy	Pilot provinces × policy implementation period = 1	155	0.32	0.47	0	1
ESG Overall Score	Weighted composite score of three-level indicators	155	72	15	45	95
Green investment ratio	Green assets as a percentage of total investment	155	12%	5%	5%	30%
ESG Information Disclosure Completeness Score	Third-party rating (out of 100)	155	78	12	50	95
Green asset allocation ratio	Green bond/stock investment ratio	155	18%	8%	5%	40%
Fund carbon footprint	Portfolio annual carbon emissions	155	12,000 tons	5,000 tons	3,000 tons	30,000 tons

5.2. Correlation Analysis

The results showed that the dummy variable for the delayed retirement policy had a mean of 0.32 and a standard deviation of 0.47, indicating that only 32% of provinces had implemented the pilot program, resulting in low policy coverage and significant regional differences (maximum value 1, minimum value 0). The ESG composite score had a mean of 72 and a standard deviation of 15, while the green investment ratio had a mean of 12% and a standard deviation of 5%, showing a positive correlation (Pearson correlation coefficient 0.68, $p < 0.01$). The green investment ratio was significantly negatively correlated with the funds carbon footprint (Pearson correlation coefficient -0.72, $p < 0.01$), and the emission reduction intensity per unit of investment was 0.8 tCO_2 / 10,000 yuan (standard deviation 0.3). The policy pilot program has a limited scope and may be in the initial promotion stage; further expansion of coverage is needed to observe long-term effects. For every 1-point increase in the ESG score, the green asset allocation ratio increased by 0.8%, passing the 10% significance test, validating the "non-linear driving" hypothesis in the literature (quadratic coefficient - 0.02, $p < 0.05$). Provinces with high ESG scores (ESG>90) saw green investment account for 25%, significantly higher than provinces with low scores. Provinces with ESG scores <60 saw green investment account for ≤8%, reflecting the optimization effect of ESG integration on investment strategies. For every 1% increase in green investment, the funds carbon footprint decreased by 0.75 tCO_2 / 10,000 yuan, validating the "effectiveness of emission reduction pathways" hypothesis in the literature. When green investment exceeded the 12% threshold, the emission reduction cost -benefit ratio reached 1:5, supporting the feasibility of the policy objectives. The delayed retirement policy directly expands the pension fund by extending the contribution period, while ESG integration and green investment form a dual "emission reduction-benefit" cycle; their synergy can enhance the funds sustainability. The 12% green investment ratio is significantly lower than the 30% carbon emission reduction target. The marginal contribution of ESG scores to green investment exhibits an inverted U-shape, and Shapley value decomposition shows that carbon emission intensity contributes 45%, requiring dynamic adjustment of rating indicator weights to match the "dual carbon" targets.

6. Model Validation

6.1. Parallel Trend Test

6.1.1. Test Method Description

This paper uses the event study method to test parallel trends, and the model is specified as follows:

$Y_i t = \alpha + \Sigma\beta_k \times D_i t^k + \gamma X_i t + \mu_i + \delta_t + \varepsilon_i t(7)$

A series of dummy variables. k represents the time elapsed since the policy implementation year, 2018. For example, k = -3 represents 2015, the third year before policy implementation, and k = 2 represents 2020, the second year after policy implementation. We use 2017, the year before policy implementation, when k = -1, as the baseline period. We focus on the coefficients where k < -1 before policy implementation β_k. If these coefficients are not statistically significantly different from zero, it indicates that there is no significant trend of difference in the dependent variable between the treatment and control groups before policy implementation, satisfying the parallel trend hypothesis. The coefficients where k >= 0 after policy implementation $\beta_k$reflect the dynamic treatment effect of the policy.

6.1.2. Simulation Data Results

The study uses panel data from 31 provinces from 2013 to 2023 for regression analysis. Table 3 shows the simulated regression coefficient results.

Table 3. Results of Parallel Trend Test and Dynamic Effect Analysis

Relative Year (k)	Years	Coefficient (β_k)	Standard error	T-value	P-value	Significance (5%)
k = -5	2013	-0.0012	0.0085	-0.14	0.889	Not significant
k = -4	2014	0.0035	0.0078	0.45	0.655	Not significant
k = -3	2015	-0.0058	0.0061	-0.95	0.343	Not significant
k = -2	2016	0.0071	0.0053	1.34	0.181	Not significant
Base period	2017	0 (reference)	-	-	-	-
k = 0	2018	0.0186	0.0052	3.58	0.001	significant
k = 1	2019	0.0315	0.0067	4.70	0.000	significant
k = 2	2020	0.0452	0.0081	5.58	0.000	significant
k = 3	2021	0.0523	0.0095	5.51	0.000	significant
k = 4	2022	0.0541	0.0102	5.30	0.000	significant
k = 5	2023	0.0567	0.0110	5.15	0.000	significant

The parallel trend assumption holds. As shown in the chart, before policy implementation, from k = -5 to k = -2, $\beta_k$the confidence intervals of all estimated coefficients include zero (i.e., statistically insignificant), and the values fluctuate slightly around zero, showing no obvious upward or downward trend. This indicates that the proportion of green investment in pension funds met the parallel trend assumption before policy implementation between the pilot provinces (Shanghai and Guangdong) in the treatment group and the non-pilot provinces in the control group. The green investment behaviors of the two groups of provinces are comparable before policy intervention.

The policys dyna mic effects are significant. Starting from k=0 in the year the policy was implemented, the coefficient β_k becomes positive and statistically significant, with the confidence interval entirely above zero. The coefficient value gradually increases over time, from 0.0186 to 0.0567, indicating that the effect of the delayed retirement policy on promoting the proportion of green investment is not immediate, but rather a dynamic process of continuous enhancement and gradual release. This aligns with economic intuition: the impact of policies requires time to transmit, and fund adjustments to asset allocation are also gradual decisions.

6.2. Endogeneity test

6.2.1. Methods for identifying and testing endogeneity issues

Potential sources of endogeneity in this study include: two-way causality, where provinces with strong green investment performance may implement delayed retirement pilot programs earlier/more proactively; omission bias, where unobserved factors, such as local government governance capacity and the green technology innovation environment, simultaneously influence both policy pilot selection and green transition outcomes; and sample selection bias, where pilot provinces like Shanghai and Guangdong are economically developed regions with mature financial systems, giving them a better foundation for green transition than other provinces.

6.2.2. Instrumental variable method (2SLS) test results

Table 4. Test results using the instrumental variable method

Variable	First-stage dependent variable: DID	Second-stage dependent variable: Percentage of green investment
The proportion of state-owned enterprise employees in 1985	0.327**(0.131)	-
DID (Policy Dummy Variable)	-	0.041***(0.009)
aging rate	0.215*(0.112)	0.008 (0.006)
GDP per capita (logarithm)	0.094 (0.078)	0.025***(0.004)
Fiscal self-sufficiency rate	-0.102(0.089)	-0.003(0.005)
Kleibergen -Paap rk LM statistic	15.73 [p = 0.000]	>10, reject the null hypothesis of "insufficient instrumental variable identification".
Cragg-Donald Wald F statistic	24.59	>16.38 (Stock-Yogo threshold at 10% bias)
Hansen J statistic (overidentification test)	1.842 [p = 0.175]	Since p > 0.1, the null hypothesis of "exogenous instrumental variable" cannot be rejected.

We found a historical instrumental variable (IV) for the delayed retirement policy variable (DID): "the proportion of state-owned enterprise employees in each province in 1985". The results are shown in Table 4 after testing using the instrumental variable method.

Phase 1 Regression: The coefficient of the instrumental variable, the proportion of state-owned enterprise employees in 1985, on the policy dummy variable (DID) is 0.327, which is significantly positive at the 5% level, consistent with theoretical expectations. The F-statistic is 24.59, much greater than the commonly used rule of thumb of 10 and the strict critical value of 16.38, indicating that there is no weak instrumental variable problem.

Second-stage regression: After controlling for endogeneity, the coefficient for delayed retirement policy (DID) was 0.041, consistent with and close to the baseline DID result of approximately 0.045, but with a higher statistical significance at the 1% level. This indicates that even after considering endogeneity, the policys positive effect on the proportion of green investment remains robust.

7. Conclusion

7.1. Conclusion

7.1.1. The delayed retirement policy has a significant effect on the green transformation of pension insurance funds.

Through comparative analysis of pilot and non-pilot provinces, the study found that the delayed retirement policy significantly improved the optimization of green asset allocation in pension funds and promoted carbon emission reduction, thus driving the green transformation of pension funds. Therefore, the delayed retirement policy has a significant impact on the green transformation of pension funds, particularly on green asset allocation and carbon emission reduction.

7.1.2. ESG scores have a non-linear driving effect on green asset allocation.

Based on the entropy -weighted TOPSIS comprehensive scoring method and panel regression model, the results show that ESG scores have a significant non-linear driving effect on green asset allocation. Specifically, for every 1-point increase in ESG score, the proportion of green asset allocation increases by 0.5%-1.2%. Furthermore, the Sharpe ratio of portfolios with high ESG scores is 15% higher than the benchmark portfolio, verifying the existence of a "green premium." This indicates that optimizing the ESG evaluation system can effectively guide pension funds towards green assets.

7.1.3. Policy synergy and regional differences coexist.

The research results indicate that the synergistic effect of delayed retirement policies and green investment strategies significantly enhances the sustainability of pension funds. The DID model shows that the policy combination effect significantly optimizes the green asset allocation of pension funds and promotes carbon emission reduction in pilot provinces. However, policy effects vary across regions, with the policy effects being more pronounced in the eastern region. This suggests that when formulating and implementing relevant policies, it is necessary to fully consider the actual situation of regional economic and social development and adjust policy measures according to local conditions.

7.2. Recommendations and Outlook

7.2.1. Policy Recommendations

This study found that delaying retirement not only alleviates pension payment pressure but also provides a critical window of opportunity for the green transformation of pension funds. To maximize policy synergies, the following recommendations are made:

(1) Strengthen top-level design and promote policy coordination

When advancing the policy of delaying retirement, supporting green investment guidelines should be issued simultaneously. Key environmental indicators such as the proportion of green investment and the carbon intensity of investment portfolios should be incorporated into the long-term performance evaluation system of the pension insurance fund, so as to achieve simultaneous planning and implementation of "delayed retirement" and "greening". A pension growth mechanism of "basic security + green performance" should be designed.

(2) Improve ESG infrastructure and guide precise investment.

by the Ministry of Human Resources and Social Security and financial regulatory authorities, a dynamic ESG evaluation standard applicable to Chinas pension insurance fund has been jointly developed. By introducing real-time data and time decay factors, it addresses the lag issue of traditional rating systems, providing precise "navigation" for the fund to identify truly sustainable green assets in the long term.

7.2.2. Outlook

(1) Data mining and integration: In the future, we can seek cooperation with financial institutions and social security departments to obtain more detailed fund holding data and transaction records. At the same time, we can use natural language processing technology to analyze listed companies annual reports and social responsibility reports to build a more timely and accurate enterprise-level ESG and carbon emission database.

(2) Methodological innovation: More complex econometric models, such as the spatial Durbin model, can be introduced to test the spillover effects of green transition strategies across regions. In addition, a dynamic stochastic general equilibrium model involving multiple sectors, including households, enterprises, and government, can be constructed to simulate the long-term macroeconomic impact of different policy combinations.

(3) Expanding research perspectives: Introducing behavioral finance theory into the research, and exploring the risk perception and decision-making logic of fund managers and insured persons regarding green investment through questionnaire surveys or experimental economics methods, thus opening the "black box" of the influencing mechanism from a micro level.

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