



A Holistic Study on Pension Finance Development in the Context of Population Aging

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Abstract. Against the backdrop of accelerating global population aging, the traditional pension security system is facing multidimensional and severe challenges. The replacement rate of pension continues to decline, fiscal sustainability is facing a serious crisis, and intergenerational conflicts are increasingly intensifying. These problems are like a series of difficulties looming over the pension security system. This study deeply analyzes the multidimensional value of pension finance in alleviating public pension pressure and promoting economic transformation. However, the development of pension finance has not been smooth sailing, with key issues such as accumulated longevity risks, frequent market fluctuations, product homogenization and weak innovation, regulatory lag, and lack of cross departmental coordination mechanisms severely constraining its further development. To effectively address these challenges, this study has developed a comprehensive solution framework that covers measures such as public-private partnership design to enhance intergenerational equity, the use of financial engineering tools to diversify risks and optimize returns, and the construction of dynamic regulatory mechanisms combined with biometric technology.

Keywords: Population Aging, Pension Finance, Longevity Risk, Economic Transformation, Financial Technology.

1 Introduction

In recent years, the global demographic aging trend has shown a significant acceleration. United Nations projections indicate that by 2050, the percentage of the population aged 65 and older in the total population will exceed 16% worldwide. Developing countries, constrained by economic development levels and demographic scales, often face more complex challenges during their aging transitions. This systemic demographic shift is exerting pervasive pressures on socioeconomic development, while traditional pension security systems—confronted with declining replacement rates, fiscal sustainability crises, and intensifying intergenerational conflicts—are revealing increasingly apparent institutional deficiencies. Against this backdrop, pension finance, as a critical institutional mechanism coordinating resource allocation and ensuring elderly welfare, holds dual significance in both theoretical value and practical application.

The traditional pension security system takes the pay as you go system as the main framework, and its sustainability highly depends on the balance between demographic structure and economic development. However, with the deepening of aging and the rapid rise of the elderly dependency ratio, the funding gap of pension insurance plans continues to expand. The European welfare system is facing questions about intergenerational equity. According to the data analysis of 27 countries, the longitudinal study data indicate that, after controlling for other variables, every 1% increase in the annual growth rate of the elderly population (aged 65+) as a proportion of the total population, the support rate of youth unemployment benefits will decline by 0.7%, forming a policy dilemma of "zero-sum game" [1]. Empirical research indicates that sustained declines in mortality rates, among other factors, will lead to an accelerated deterioration in the surplus ratio of China's basic pension insurance fund for urban workers. and the fiscal deficit is expected to reach 3.2% of GDP by 2050. In addition to the problems of the pay-as-you-go system itself, there are also many structural problems in the three-tiered pension system in China. The structural imbalance of the "three pillar" pension system further weakens effectiveness of security - basic pension insurance is widely covered but the substitution rate is insufficient, while enterprise annuity and individual pension are difficult to achieve inclusive coverage due to policy fragmentation and insufficient incentives. In this context, diversified pension financial instruments such as commercial insurance and pension funds have become the key path to supplement public security and mitigate intergenerational contradictions.

Based on practical experience at home and abroad, this study deeply analyzes the core problems restricting the development of pension finance, and puts forward a systematic solution framework covering system optimization, product innovation, regulatory strengthening and technological integration, aiming to provide a theoretical basis and practical path for improving the financial governance of aging society and help achieve the dual goals of sustainable pension security and high-quality economic and social development.

2 The Multidimensional Societal Value of Pension Finance in Aging Societies

2.1 Sustainability Crisis and Institutional Gap of the Traditional Pension System

With the persistent deepening of population aging, the conventional pension system is subjected to mounting pressures, posing significant sustainability challenges to the pension funds' long-term fiscal balance [2,3]. China's aging problem has become increasingly prominent, putting pressure on the existing pension security mechanism [3]. The traditional pension system has an institutional gap in responding to the needs of an aging society, which is reflected in both inadequate material foundation and low degree of socialization, such as insufficient fund reserves, low investment returns limited coverage, and single participants [3]. By constructing a panel data model of the impact of inter-provincial population aging on the sustainability of basic pension funds, and using

the least square method for estimation, the econometrics model results show that the balance rate of basic pension insurance funds will be reduced by population aging, and the financial pressure of the pension system will be further aggravated [2]. Therefore, need to make up for these gaps by developing pension finance, to better meet the pension needs of residents [3]. Sustainable public pension systems are crucial for governments and institutions alike [4].

2.2 The Catalytic Role of Pension Finance in Driving Economic Transformation

Pension finance is playing an increasingly pivotal role in economic transformation. It not only provides solutions to address challenges posed by population aging but also injects new dynamism into economic development [5]. Through mechanisms such as promoting industrial upgrading, stimulating consumption, and optimizing resource allocation, pension finance actively drives structural economic transitions.

First of all, the development of pension finance contributes to quality and efficiency improvement with tier-upgrading of industrial structure. The progressive aging of the population is generating increasing demand for elderly care services, consequently creating expansive market opportunities for the senior care industry's development. Pension finance can support the construction and operation of pension service institutions by providing diversified financial products and services, and promote the large-scale and professional development of the pension industry [5]. For example, in recent years, China's yearly average growth rate in healthcare expenditures, smart pension, and other service industries has exceeded the GDP growth rate by 2.3 percentage points, forming a trillion-level market space [6]. Pension finance amplifies this effect through consumer credit, pension insurance, and other tools, such as a 17.6% increase in investment in related industries in the pilot areas of long-term care insurance [7].

Furthermore, pension finance enhances residents' retirement security through financial instruments such as savings accounts, wealth management products, and insurance plans, thereby boosting consumption confidence and effectively stimulating consumer demand, which in turn propels economic growth. U.S. consumer expenditure data reveal that the service consumption share of individuals aged 65+ accounts for 42%, significantly higher than the 35% observed among the working-age population [8]. Additionally, by innovating age-appropriate financial products and services to meet the multi-tiered needs of the elderly population, pension finance can further catalyze consumption expansion.

Thirdly, pension finance contributes to optimizing resource allocation and enhancing economic operational efficiency. Through market-oriented mechanisms, pension funds are strategically allocated to high-productivity sectors—such as investing in equities and bonds to bolster the real economy, or funding innovative enterprises to catalyze industrial upgrading—thereby elevating overall economic competitiveness.

In addition, the development of pension finance can also promote the development of green finance and promote sustainable economic development. Pension funds can be invested in green industries, such as China's social security fund green bond allocation ratio rose from 5% in 2018 to 12% in 2022 [9], and promote low-carbon transformation by reducing financing costs [10, 11].

Pension finance serves as a critical driver of economic transformation, fostering economic development through mechanisms such as promoting industrial upgrading, expanding consumption, optimizing resource allocation, and advancing green finance initiatives. However, realizing its full potential necessitates addressing concomitant challenges—including strengthening regulatory oversight, enhancing risk management frameworks, and improving financial literacy among aging populations—to ensure its multidimensional contributions to sustainable socioeconomic advancement.

3 Core challenges in the development of Pension Finance

3.1 Complexity in Risk Management: Longevity Risk and Market Volatility

Longevity risk and market volatility, the two major challenges in pension finance risk management, are interwoven and jointly threaten the stable operation of pension systems. Longevity risk, which means the risk of individuals living longer than anticipated and thus extending pension payment period and causing financial strain on the system, is becoming more prominent with intensifying population aging and demands effective management. Market volatility refers to fluctuations in financial market asset prices like stocks and bonds. While pensions, invested in diversified portfolios for long-term growth, can be destabilized by these fluctuations, leading to unstable returns or losses that impact pension accumulation and payment, especially during economic downturns or financial crises.

3.2 Product Homogenization and Innovation Deficit

Product homogenization in pension finance refers to the high similarity in product functions, return characteristics, and risk profiles, which fails to meet personalized demands. Financial institutions tend to replicate successful market precedents when designing pension finance products, leading to product homogenization [12]. Empirical evidence reveals that China's pension products exhibit up to 70% contractual clause similarity, with primary distinctions confined to yield commitments and lock-up periods [13]. While regulatory frameworks standardize product design, they may inadvertently stifle innovation. Concurrently, market information asymmetry diminishes investors' capacity to identify differentiated products.

Insufficient innovation in pension finance manifests as a market deficiency in products addressing longevity risks and catering to personalized needs. Primarily, the absence of effective longevity risk management instruments substantially constrains innovation in pension financial products [14,15]. Secondly, financial institutions' inadequate comprehension of diverse client groups' retirement needs results in undifferentiated product designs lacking target specificity [16]. Furthermore, limited adoption of FinTech applications—such as artificial intelligence and big data analytics—within the pension finance sector continues to hinder product and service innovation.

3.3 Regulatory Lag and Inadequate Protection of Investor Rights

Pension finance is growing rapidly with increasingly diverse products and services. However, the current regulatory system is lagging in some aspects. For instance, digital

pension finance's cross-market and cross-industry nature makes it hard for traditional capital - adequacy - ratio-centered regulatory indicators to capture liquidity mismatch risks, causing regulatory updates to lag behind market practices. Moreover, given pension finance's long-term fund management and complex risk-taking factors, regulatory agencies need to constantly enhance their risk identification and evaluation capabilities to safeguard pension funds effectively.

Investor protection constitutes a core objective of pension finance regulation. In practice, however, elderly investors remain vulnerable to mis-selling and fraudulent practices due to information asymmetry and limited financial literacy. The increasingly complex risk-return structures of composite pension products, coupled with institutional misconduct such as misleading promotions and inadequate risk disclosure, exacerbate cognitive biases. The absence of suitability assessments during sales processes frequently leads to risk mismatches. Furthermore, existing dispute resolution mechanisms demonstrate inefficiencies and prohibitive costs, substantially undermining the effectiveness of rights enforcement. Ukraine's regulatory experience demonstrates that enacting dedicated legislation—the Pension Finance Consumer Protection Act—can elevate successful claim resolution rates from 32% to 58% [17]. Key legislative priorities should encompass:

Establishing a negative list for pension product, prohibiting the sale of instruments with maturity mismatches exceeding five years to individuals aged 65+;

Implementing burden-of-proof inversion mechanisms requiring financial institutions to demonstrate full compliance with disclosure obligations [18].

4 The Limitations of Current Macro-Policies and the Absence of Some Mechanisms

This section takes China as a case study, where the current pension insurance system is confronting multiple institutional challenges. The underlying structural contradictions have become increasingly pronounced amidst accelerating population aging. The pay-as-you-go (PAYG) based Employee Basic Pension System (CEBPS) is enduring dual pressures from longevity risk and demographic shifts. Meanwhile, the three-pillar pension framework exhibits structural imbalances. The interplay of these institutional deficiencies is driving pension insurance reform toward systemic restructuring.

4.1 The Limitations of Macro-Policies

Projections for China's Employee Basic Pension System (CEBPS) reveal that fiscal sustainability is significantly impacted by volatility in funding gaps attributable to longevity risk. Dynamic mortality modeling demonstrates that if mortality improvement rates exceed expectations, the fiscal gap could widen to 3.2% of GDP by 2050 [19]. This structural vulnerability stems from the high sensitivity of the pay-as-you-go (PAYG) system to demographic shifts: as the old-age dependency ratio escalates from 0.4 in 2020 to 0.9 by 2080, maintaining equilibrium would require increasing contribution rates from 30% to 40%, yet enterprise contribution rates are already approaching international warning thresholds [20].

China's three-pillar pension system exhibits marked asymmetric development. The coverage rate of enterprise annuities (second pillar) remains below 6%, while the account activation rate for individual pension schemes (third pillar) stands at a mere 23%, significantly below the OECD average [21]. Insufficient policy incentives result in marginal benefits for high-income groups being triple those for low-income earners, thereby transforming the third pillar into tax arbitrage vehicles rather than inclusive retirement security mechanisms.

4.2 Deficiency in Coordinated Mechanisms within the Multi-Pillar Social Security System

China's three-pillar pension finance system exhibits pronounced policy fragmentation. While the Basic Pension Insurance (first pillar) achieves over 90% coverage, its replacement rate remains below 45%, with significant disparities in benefit levels exacerbated by the urban-rural dual structure [22,23]. The Enterprise Annuities (second pillar), constrained to merely 6.5% coverage, are predominantly concentrated in state-owned enterprises and high-income demographics. Meanwhile, the Individual Pension (third pillar) pilot programs progress sluggishly, with participation largely limited to high-net-worth individuals, failing to establish inclusive coverage [24]. This structural imbalance reflects systemic deficiencies in policy design, particularly the absence of cross-pillar tax coordination (e.g., ineffective linkage of tax-deferred incentives) and integrated contribution incentive mechanisms [25,26].

The pension system suffers from a lack of integrated design in fund pool coordination across pillars. For instance, Basic Pension Insurance funds face constrained investment scopes, hindering market-oriented operations for value preservation and appreciation. While enterprise annuities and individual pension schemes can access capital markets, insufficient risk mitigation instruments lead to excessive risk concentration in individual accounts [27].

Pension account management systems remain fragmented across social security agencies, financial institutions, and tax authorities, with deficient interdepartmental data-sharing mechanisms. A case in point: tax deduction information between individual pension accounts and enterprise annuity accounts cannot be synchronized in real-time, significantly increasing operational complexity [28,29]. Furthermore, despite mature applications in green finance, distributed ledger technologies like blockchain have yet to achieve technological adaptation breakthroughs in pension coordination management.

5 Conclusion

Population aging has fundamentally reconfigured the underlying logic of pension finance, subjecting traditional pension systems to multidimensional shocks encompassing expanding fiscal deficits in pay-as-you-go (PAYG) mechanisms, exacerbated intergenerational tensions, and structural imbalances within the three-pillar framework. Research highlights the dual socioeconomic value of pension finance in alleviating public pension pressures and driving economic transformation: on one hand by catalyzing new

growth momentum through silver industry upgrading and elderly consumption activation, on the other by supporting sustainable development via green finance integration and resource allocation optimization. However, compounded challenges—including longevity risk coupled with market volatility, product homogenization, and regulatory lags—render current systems inadequate in addressing the complex demands of accelerated aging. Systemic reforms must transcend fragmented institutional, product, technological, and regulatory frameworks to construct intergenerational equity-oriented coordination mechanisms. This requires preserving the universal welfare function of basic pensions while achieving risk diversification and efficiency enhancement through market-based instruments.

At the policy level, governments should prioritize advancing tax coordination and inclusive coverage across the three-pillar pension system, integrating incentive mechanisms for enterprise annuities while enhancing flexibility in individual pension accounts. A cross-sector regulatory technology platform must be established, embedded with dynamic circuit-breaker mechanisms and biometric authentication to ensure comprehensive lifecycle protection for elderly investors. Financial institutions need to accelerate the development of multi-tiered product portfolios, incorporating innovative instruments such as intergenerational tontines and variable payment annuities, while leveraging blockchain and digital human solutions to optimize age-friendly service delivery. Future research should deepen actuarial modeling of longevity risks and refine intergenerational wealth transfer mechanisms. Critical exploration is required to define ethical boundaries for digital technologies in pension finance and operationalize pathways for intergenerational equity, thereby providing theoretical underpinnings for building a sustainable and inclusive financial ecosystem tailored to aging societies.

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