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Pension Unification Under Macroeconomic Uncertainty: Fiscal Risk and Sovereign Debt Dynamics in Ghana

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Abstract

This paper develops a stochastic overlapping generations dynamic social security framework to evaluate the sovereign debt implications of pension unification under macroeconomic uncertainty in Ghana. The analysis focuses on the counterfactual integration of the Cap 30 scheme, a legacy non-contributory defined-benefit arrangement for security, intelligence, and judicial personnel, into the contributory three-tier framework established under the National Pensions Act, 2008 (Act 766), relative to the fragmented baseline created by the 2023 amendment that exempted security agencies from unification. The model incorporates four estimated AR(1) macroeconomic shock processes, real GDP growth, real interest rates, the primary fiscal balance, and the terms of trade, calibrated using Ghanaian data spanning 1961–2024. It simulates 3,000 stochastic debt paths under alternative recognition bond designs, Bohn-type fiscal reaction rules, and reform timelines, generating a time-varying probability distribution of fiscal outcomes.

The paper finds that first, pension unification lowers the probability of public debt breaching a 100 percent threshold at a 20-year horizon by approximately 3 percentage points relative to the fragmented baseline, the measurable risk-mitigation margin of the 2023 amendment's opportunity cost. Second, macro-fiscal consolidation dominates pension design as a stabilization mechanism: strengthening the fiscal rule responsiveness reduces the same breach probability by over 30 percentage points, accounting for roughly 88 percent of the total achievable risk reduction. Third, recognition bond asset design matters materially within Ghana's highly volatile monetary environment; inflation-linked bonds introduce dangerous tail risk through state-contingent liability compounding, whereas fixed-coupon and GDP-linked structures generate highly stable outcomes. Fourth, Ghana's nearly two-decade impasse has generated severe path-dependent hysteresis, with cumulative forgone operational savings estimated at approximately 5 percent of GDP. The results demonstrate that macro-fiscal governance parameters dominate individual pension adjustments. Pension unification yields structural fiscal benefits, but it cannot function as a substitute for the rule-backed fiscal consolidation necessary to place the sovereign debt trajectory on a sustainable path.

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1. Introduction

Global pension systems are increasingly exposed to compound macroeconomic volatility, where structural demographic aging intersects with acute sovereign fiscal constraints and business cycle shocks. Governments have historically responded with diverse legislative interventions, spanning minor parametric adjustments to wholesale structural transformations (Mesa-Lago, 2002). In 2008, the Republic of Ghana enacted one of Sub-Saharan Africa's most ambitious pension reforms. The National Pensions Act, 2008 (Act 766) replaced a highly fragmented public system of unfunded defined-benefit promises with a unified, three-tier contributory system: a mandatory pay-as-you-go (PAYG) first tier managed by the Social Security and National Insurance Trust (SSNIT), a mandatory funded second tier, and a voluntary third tier. This restructuring matched a broader wave of pension transformations across emerging market economies in the 1990s and 2000s, as sovereigns sought to contain the long-term fiscal liabilities of unfunded legacy schemes (Holzmann, Palacios, & Zviniene, 2004; Stewart & Yermo, 2009).

Section 213 of Act 766 originally mandated the universal unification of all parallel public pension schemes into this new contributory framework. Nearly two decades later, however, the most significant legacy scheme, the Cap 30 arrangement, remains partially outside this integrated boundary. Cap 30 is a non-contributory, defined-benefit system covering a large segment of active workers and retirees across multiple security, intelligence, and judicial institutions. Its liabilities are financed entirely as an unbacked draw on the Consolidated Fund, operating with an adverse active-worker-to-pensioner dependency ratio that is orders of magnitude lower than the corresponding ratio under the mainstream SSNIT framework. Consequently, its annualized expenditures consume a non-trivial share of domestic tax revenue, generating a persistent structural vulnerability on the state's balance sheet.

In March 2023, Parliament enacted the National Pensions (Amendment) Act, formally exempting security and intelligence agencies, including the Police, Immigration, Prisons, and Fire Services, from the statutory unification requirement. This legislative pivot, justified by severe operational bottlenecks in employee database verification and the unique, high-risk conditions of security service, mandated a separate, parallel pension arrangement for these agencies that remains under active development. Conversely, for the remaining judicial and constitutional bodies within Cap 30, including the Judicial Service, Audit Service, Electoral Commission, and the Commission on Human Rights and Administrative Justice (CHRAJ), the unification mandate persists as an unimplemented legal obligation.

While successive administrations have politically acknowledged the institutional necessity of full unification for these remaining sectors, operational execution has consistently stalled. This policy inertia stems from multiple structural frictions: the concentrated institutional bargaining power of non-exempted public segments, intense political sensitivities surrounding civil service deferred compensation, and tight sovereign macro-fiscal criteria imposed by Ghana's post-debt-restructuring framework under the International Monetary Fund (IMF) Extended Credit Facility arrangement (IMF, 2023).

Crucially, a foundational barrier to resolving this policy deadlock is the complete absence of a credible quantitative framework capable of evaluating the fiscal consequences and tail risks of alternative unification designs under realistic macroeconomic uncertainty. This paper leverages the 2023 legislative pivot to address a fundamental question in public finance: what is the exact fiscal risk and macro-volatility penalty associated with policy reversal, institutional

fragmentation, and reform delay? Rather than treating the 2023 amendment as a settled administrative endpoint, this study utilizes the original full unification mandate of Act 766 as an optimal counterfactual benchmark. The political economy literature establishes that pension reforms generate highly concentrated losses for well-organized interest groups while producing diffuse benefits for the general taxpayer base, making politically sustainable transitions exceptionally demanding in the absence of credible transitional compensation arrangements (Pierson, 1996; James & Brooks, 2001). This paper provides the first stochastic dynamic general equilibrium framework designed to resolve these distributional deadlocks under uncertainty.

To achieve this, we develop a stochastic overlapping generations (OLG) dynamic stochastic general equilibrium (DSGE) model calibrated to Ghana's demographic pyramid, public payroll parameters, and historical macroeconomic volatility. Overlapping generations simulation models, following the canonical design of Auerbach and Kotlikoff (1987), have become the standard paradigm for evaluating the intergenerational welfare effects of fiscal restructuring (Fehr, Jokisch, & Kotlikoff, 2008; Nishiyama & Smetters, 2007). However, the vast majority of these applied frameworks are deterministic; they produce point estimates of fiscal and welfare paths that are entirely uninformative regarding the probability of adverse debt outcomes under realistic shock sequences, a severe limitation recognized in the modern fiscal risk and sovereign debt literatures (IMF, 2018).

Our stochastic model overcomes this boundary by simulating the transition from the current fragmented pension system to a unified contributory system under four estimated shock processes: productivity growth (GDP), real interest rate innovations, primary fiscal balance variations, and terms-of-trade fluctuations. The shocks are modeled as independent AR(1) processes estimated from Ghanaian data spanning 1961–2024, as detailed in Section 3. Within this stochastic environment, we evaluate the performance of three recognition bond indexation designs, fixed-coupon, inflation-linked, and GDP-linked structures, under stochastic sovereign borrowing conditions, extending the literature on state-contingent sovereign debt instruments to the specific context of pension transition liabilities. The model incorporates an endogenous fiscal reaction function of the form widely utilized in the empirical policy literature (Bohn, 1998) and embedded in the IMF's Debt Sustainability Framework (DSF) for market-access countries. This setup allows us to explicitly quantify the opportunity cost and tail-risk accumulation generated by Ghana's multi-year delay in executing its statutory unification pipeline.

The analysis produces four central findings. First, the opportunity cost of the 2023 amendment is measurable but modest in risk terms. Full unification under the original Act 766 mandate lowers the probability of the sovereign debt-to-GDP ratio breaching a critical 100 percent threshold at a 20-year horizon by approximately 3 percentage points relative to the fragmented baseline. Second, macro-fiscal consolidation dominates transition bond design as a tail-risk reduction tool. Strengthening the endogenous fiscal reaction coefficient reduces the probability of acute debt distress by more than 30 percentage points, accounting for approximately 88 percent of the total achievable reduction in structural sovereign debt stress. Third, the choice of recognition bond indexation matters materially within Ghana's historically volatile price environment. Inflation-linked recognition instruments substantially amplify tail-risk exposures through adverse liability compounding during inflation spikes, whereas fixed-coupon and GDP-linked structures generate significantly more stable sovereign balance sheet distributions. Fourth, Ghana's prolonged delay in executing the statutory pension unification

mandate has generated significant path-dependent hysteresis. The cumulative forgone savings resulting from the nearly two-decade impasse are estimated at approximately 5 percent of GDP, with further delay eroding remaining gains at roughly 0.4 percent of GDP per year.

The remainder of this paper is organized as follows. Section 2 presents the formalized structural equations of the stochastic OLG-DSGE model, including the fiscal reaction function and recognition bond dynamics. Section 3 details the empirical estimation of the shock processes from longitudinal Ghanaian data. Section 4 reports the baseline stochastic simulation results and variance decompositions. Section 5 evaluates the risk-mitigation properties of alternative recognition bond indexation designs. Section 6 quantifies the cumulative macro-fiscal cost of reform delay. Section 7 concludes with concrete policy implications for debt sustainability and social security integration in emerging markets.

SECTION 2: STOCHASTIC FRAMEWORK

2.1 From Deterministic to Stochastic

2.1 Transition to Stochastic General Equilibrium

The core structural framework of the baseline overlapping generations (OLG) model, including households optimizing lifetimes over consumption, labor supply margins, and precautionary asset accumulation; perfectly competitive firms operating under constant returns to scale Cobb-Douglas production functions; and a centralized authority managing the Social Security and National Insurance Trust (SSNIT) Tier 1 pay-as-you-go (PAYG) balances alongside legacy civil service pension allocations, is fully detailed in the Technical Appendix.

This section isolates and describes the stochastic extensions built into the dynamic general equilibrium model to capture systemic macro-volatility transmission. All non-stationary variables are converted into stationarity by expressing them as log or linear deviations from their long-run deterministic steady-state means.

The structural economy is exposed to an exogenous vector of four macroeconomic shocks. To track historical volatility transmission within the domestic environment, each aggregate shock process is modeled as an independent, first-order autoregressive AR(1) process:

$$\begin{aligned} \ln Z_t &= \rho_z \ln Z_{t-1} + \varepsilon_t^z, & \varepsilon_t^z &\sim \mathcal{N}(0, \sigma_z^2) \\ \tilde{r}_t &= \rho_r \tilde{r}_{t-1} + \varepsilon_t^r, & \varepsilon_t^r &\sim \mathcal{N}(0, \sigma_r^2) \\ \widetilde{pb}_t &= \rho_{pb} \widetilde{pb}_{t-1} + \varepsilon_t^{pb}, & \varepsilon_t^{pb} &\sim \mathcal{N}(0, \sigma_{pb}^2) \\ \widetilde{TOT}_t &= \rho_{tot} \widetilde{TOT}_{t-1} + \varepsilon_t^{tot}, & \varepsilon_t^{tot} &\sim \mathcal{N}(0, \sigma_{tot}^2) \end{aligned}$$

where Z_t is total factor productivity; $r_t = \bar{r} + \tilde{r}_t$ defines the real sovereign borrowing rate composed of the long-run steady-state rate \bar{r} and the stochastic innovation \tilde{r}_t ; $pb_t = \bar{pb} + \widetilde{pb}_t$ represents the primary fiscal balance expressed as an operational share of gross domestic product (GDP); and $TOT_t = \bar{TOT} + \widetilde{TOT}_t$ marks the terms-of-trade index tracking structural external volatility.

The structural shocks are assumed to be cross-sectionally independent. While this specification is adopted to preserve econometric tractability and isolate the individual contribution of each distinct variance process to overall fiscal tail risk, it represents a simplified

abstraction. In the domestic economy, the primary fiscal balance, domestic interest rate curves, and terms-of-trade variations are linked through global commodity price cycles. Accommodating a full variance-covariance matrix with correlated innovations constitutes an area for future structural extensions.

2.2 Endogenous Fiscal Reaction Function

The sovereign manages its debt portfolio by adjusting the primary balance in response to deviations in the public debt-to-GDP ratio. We formalize this feedback mechanism via a linear fiscal reaction function following Bohn (1998):

$$pb_t = \bar{p}b + \psi_d \left(\frac{D_{t-1}}{Y_{t-1}} - d^* \right)$$

where $\bar{p}b$ represents the target steady-state primary balance, and $d^* = 0.55$ operationalizes the definitive anchor target established under Ghana's Medium-Term Debt Management Strategy and broader macro-stabilization frameworks.

To anchor this adjustment path, the framework incorporates the state's operational target of maintaining a primary surplus of at least 1.5 percent of GDP on a commitment basis starting in 2026. Following the execution of the comprehensive domestic and external debt restructuring operations alongside robust real output expansion, the aggregate public debt-to-GDP ratio contracted to approximately 45 percent by the end of 2025. Institutional forecasts project a normalization toward 53 percent across 2026 as post-restructuring operational pressures stabilize. The coefficient ψ_d measures the marginal responsiveness of the fiscal authority to structural debt accumulations.

2.3 State-Contingent Recognition Bond Mechanics Under Uncertainty

Recognition bonds act as the primary transitional debt mechanism, formalizing the implicit pension debt (IPD) of legacy Cap 30 beneficiaries by compensating them for accrued historic rights at the point of migration into the unified three-tier contributory system. The aggregate nominal stock of outstanding recognition bond liabilities (RB_t) evolves recursively according to the following motion equation:

$$RB_{t+1} = (1 + r_t^{rb})RB_t + \text{Issuance}_t - \text{Redemption}_t$$

where r_t^{rb} defines the bond-specific interest rate, which is structurally dependent on the underlying state-contingent indexation design. We simulate and evaluate three alternative financial designs:

Fixed-Coupon Framework: The instrument pays a constant nominal coupon anchored at 8.00 percent ($r_t^{rb} = 0.08$). Within a high-inflation environment, this specification introduces a variable real return for asset holders but secures complete legal predictability for the sovereign's nominal cash outlays.

Inflation-Linked Framework: The coupon rate updates continuously to match realized consumer price index (CPI) inflation innovations: $r_t^{rb} = 0.08 + \pi_t$, where π_t is realized inflation, subject to a mandatory insurance floor of 1.00 percent ($\pi_t \geq 0.01$). This structure insulates the real purchasing power of beneficiaries but exposes the state balance sheet to compounding interest outlays during inflation shocks.

GDP-Linked Framework: The coupon is linked to real output innovations: $r_t^{rb} = 0.08 + \phi(g_t - g^*)$, where g_t is the realized growth rate of real GDP, $g^* = 0.05$ represents the long-run structural trend growth target, and $\phi = 0.5$ dictates the adjustment elasticity, subject to a mandatory floor of 1.00 percent ($r_t^{rb} \geq 0.01$). This state-contingent design functions as an automatic stabilizer, increasing the coupon matching rate during economic expansions and contracting debt servicing costs during output recessions.

The period-specific interest costs ($r_t^{rb}RB_t$) and scheduled principal redemptions ($Redemption_t$) enter the centralized budget constraint directly as explicit expenditure items. Consequently, the selection of indexation rules shifts the simulated path of public debt through both the outstanding liability stock and the flow of debt-service cash outlays.

2.4 Consolidated Sovereign Budget Constraint

The centralized sovereign budget constraint is closed recursively through the continuous accumulation of total public debt (D_t). The unified law of motion is formalized as:

$$D_{t+1} = (1 + r_t)D_t + G_t + Deficit_t^{T1} + Cap30_t + RBRed_t + RBInterest_t - TaxRevenue_t$$

where r_t is the stochastic interest rate on general public debt; G_t denotes non-pension public consumption expenditures; $Deficit_t^{T1}$ represents the operational cash-flow balance of the SSNIT Tier 1 PAYG system; and $Cap30_t$ captures the legacy non-contributory benefit payouts from the Consolidated Fund, which drop to zero post-reform. The terms $RBRed_t$ and $RBInterest_t$ match the principal redemptions and state-contingent interest servicing outlays of the recognition bond portfolio, respectively.

National tax revenues ($TaxRevenue_t$) are generated through endogenously modeled distortions on labor income, capital returns, and private consumption, plus the newly captured matching contributions flowing from migrated civil servants following full pension unification.

2.5 Algorithmic Solution Methodology and Calibration

The non-linear stochastic OLG-DSGE model is solved utilizing recursive numerical simulation techniques optimized inside a Python computational environment. Rather than relying on simple linear approximations that strip out tail-risk behavior, the model preserves the non-linearities of the sovereign budget constraint and the state-contingent bond rules.

For each policy counterfactual analyzed, the four independent AR(1) shock processes are simulated by drawing random innovations from their estimated joint distributions over $N = 3,000$ unique stochastic paths spanning an 80-year simulation horizon. At each temporal node along every individual path, all macroeconomic feedback loops, household optimization paths, fiscal reaction variables, and state-contingent recognition bond stocks are updated recursively:

Draw $N = 3,000$ Shock Sequences → Evaluate OLG Choices → Update Reaction Rule
 → Compute Tail-Risk Distribution

The output generated by this model does not yield a single, deterministic trajectory; rather, it maps out a full time-varying probability distribution of sovereign debt states. This allows us to

directly compute threshold breach probabilities, variance decompositions, and fiscal tail-risk metrics.

The simulations function as scenario-contingent stochastic projections rather than absolute macroeconomic forecasts. The deterministic steady state of the structural engine is calibrated to mirror the macroeconomic, demographic, and public payroll realities of the domestic economy at the 2024 baseline, as documented in the Technical Appendix, while all autoregressive parameters are derived from country-level longitudinal series as detailed in Section 3.

SECTION 3: SHOCK ESTIMATION AND CALIBRATION

3.1 Data Sources and Empirical Scope

The parameters governing the exogenous shock processes are empirically estimated using historical longitudinal macroeconomic data from Ghana spanning the 64-year horizon from 1961 through 2024. Continuous annual series for real GDP growth, consumer price index (CPI) inflation, and the terms-of-trade index are compiled from the World Bank's World Development Indicators (WDI). To operationalize the real sovereign borrowing rate under uncertainty, we construct a real interest rate series covering the 2002–2024 institutional cycle by deflating the Bank of Ghana's headline monetary policy rate by the realized annual CPI inflation rate.

The primary fiscal balance series is calculated recursively by extracting net tax revenues and non-pension public expenditures from the WDI and Ministry of Finance databases, scaled as an operational percentage of nominal GDP. Table 3.1 details the maximum likelihood OLS estimates for the persistence parameters (ρ), structural innovation volatilities (σ_ε), and long-run unconditional means (μ) defining the four AR(1) processes.

Table 3. 1: Estimated Shock Processes, Ghana

Shock	Observations	ρ (persistence)	σ_ε (volatility)	μ (long-run mean)
GDP growth	64	0.337	2.72%	5.81%
Real interest rate	23	0.281	5.06%	2.39%
Primary balance (% GDP)	22	0.709	2.00%	-7.08%
Terms of trade	44	0.878	9.62	83.95

3.2 Structural Interpretation of the Domestic Volatility Frictions

The empirical estimations uncover three vital structural characteristics that shape the macro-fiscal tail risk of the sovereign balance sheet. First, Ghana's real interest rate displays relatively low persistence ($\rho = 0.281$) alongside intense, concentrated innovation volatility ($\sigma_\varepsilon =$

5.06%). This pattern reflects a volatile monetary environment where sudden inflation shocks and corresponding monetary policy rate adjustments generate large, unpredictable shifts in real sovereign borrowing costs. Econometrically, this high variance acts as a primary source of high-frequency fiscal volatility inside the stochastic simulations, introducing severe cash-flow shocks into the debt-servicing pipeline.

Second, the primary fiscal balance exhibits high persistence ($\rho = 0.709$) combined with a deeply negative long-run historical mean of -7.08% of GDP. This structural deficit is significantly larger than the modest primary deficits conventionally assumed in deterministic calibrations. This divergence reveals that Ghana's underlying structural fiscal position is considerably weaker than standard models suggest. The high persistence coefficient indicates that adverse fiscal shocks decay slowly, generating multi-year periods of consecutive deficits that compound sovereign debt levels.

Third, the terms-of-trade process generates the highest autoregressive persistence in the model ($\rho = 0.887$). This is consistent with the long-duration commodity price cycles that characterize Ghana's gold, cocoa, and crude oil export base. Consequently, terms-of-trade shocks function as low-frequency, highly persistent drivers of fiscal tail risk, transmitting volatility through export revenue channels, domestic exchange rate adjustments, and structural shifts in the sovereign tax base.

3.3 Calibration of the Structural Policy Rule and Anchor Targets

The baseline endogenous fiscal reaction coefficient is calibrated to $\psi_d = 0.05$. This parameter represents a moderate, historically consistent pace of consolidation: a 10 percentage point expansion of the public debt-to-GDP ratio above the target anchor triggers an automatic 0.5 percentage point tightening in the primary balance. Symmetrical sensitivity checks, explored in Section 5, vary ψ_d to model increasingly aggressive fiscal policy rules and shifts in state credibility.

The explicit debt anchor is set at $d^* = 0.55$, matching the target benchmark formalized under the state's 2025–2028 Medium-Term Debt Management Strategy (MTDS). This policy framework aims to compress the present value of total public debt to 55 percent of GDP by 2028. Following the execution of the Domestic Debt Exchange Programme (DDEP) and a multi-quarter cycle of strong nominal GDP growth, the aggregate debt ratio experienced a substantial contraction by the end of 2025.

Data from the International Monetary Fund's 2026 Fiscal Monitor tracks a subsequent stabilization of the debt ratio as immediate post-restructuring financing pressures ease (IMF, 2026). Concurrently, the government's 2026 Budget specifies a continued downward trajectory backed by legally binding structural adjustments.

Table 3.1 Structural Tension Between Historical Trajectory and Policy Targets

Historical Fiscal Trajectory	MTDS Policy Framework Anchor
Unconditional Mean: $pb = -7.08\%$	Target Surplus: $pb \geq +1.50\%$
High Persistence: $\rho = 0.709$	Debt Target Anchor: $d^* = 55\%$

↓ Regulated by Fiscal Reaction Rule: ψ_d

To support this stabilization path, the state has committed to maintaining a continuous primary surplus of at least 1.5 percent of GDP starting in 2026. However, to capture the true historical probability of fiscal shocks, the long-run steady-state primary balance parameter used inside our stochastic simulation engine is fixed at the empirical historical mean ($\bar{p}b = -7.08\%$).

The stochastic simulations therefore embed an intentional structural tension between Ghana's long-run historical trajectory, characterized by persistent deficits, and the consolidation targets required to maintain debt sustainability under the MTDS framework. The coefficient ψ_d governs how rapidly policy activates to resolve this tension. Low values ($\psi_d \rightarrow 0$) capture weak adjustment capacity and low rule credibility, whereas elevated values represent robust institutional commitment to debt stabilization. Our stochastic simulations thus evaluate not only the isolated outcomes of pension unification, but also the critical interaction between pension transition liabilities and the overall credibility of Ghana's macro-fiscal rules.

SECTION 4: BASELINE STOCHASTIC RESULTS

4.1 The Probability Distribution of Sovereign Debt Outcomes

To map the transmission of macroeconomic volatility under alternative institutional settings, Figure 4.1 displays the simulated fan charts for Ghana's public debt-to-GDP ratio across three distinct policy configurations over a 20-year horizon. Each panel provides a multi-path projection tracking the median trajectory surrounded by the 25th–75th and 10th–90th percentile distribution bands, derived from $N = 3,000$ independent recursive stochastic draws.

Figure 1: Fan Charts — Baseline, Reform with Weak Fiscal Rule, Reform with Strong Fiscal Rule



Three structural characteristics of these multi-path distributions are immediately visible.

First, under the baseline unreformed configuration (\mathcal{S}_0 : encompassing no pension unification alongside a historically consistent, moderate fiscal adjustment parameter of $\psi_d = 0.05$), the median debt-to-GDP ratio exhibits an unstable upward trajectory, climbing steadily from its initial post-restructuring baseline toward 140 percent over the 20-year horizon. This path is compounded by high tail-risk uncertainty, with the 90th percentile boundary breaching 300 percent under adverse shock sequences. Second, executing pension unification in isolation (\mathcal{S}_2 : modeling full integration with an 80 percent baseline recognition ratio under the historical

fiscal adjustment rule of $\psi_d = 0.05$) yields a nearly identical probability distribution. The median trajectory shifts downward by only 2 to 3 percentage points, indicating that removing the structural fragmentation of Cap 30, the measurable risk-mitigation margin of the 2023 amendment's opportunity cost, is insufficient on its own to insulate the sovereign balance sheet from business cycle shocks. Third, expanding the institutional weight of the fiscal rule by doubling the responsiveness parameter (\mathcal{S}_{2-F} : increasing ψ_d from 0.05 to 0.10) significantly compresses the entire probability distribution. The median debt trajectory stabilizes near 100 percent of GDP, and the upper tail of extreme debt states is heavily truncated.

4.2 Quantitative Evaluation of Fiscal Tail-Risk Metrics

To evaluate the absolute probability of the sovereign breaching critical thresholds under varying shock sequences, Table 4.1 records the threshold probabilities (\mathcal{P}) and median debt outcomes at a 20-year implementation horizon ($t = 20$) across alternative structural designs.

Table 4.1: Comprehensive Fiscal Risk Matrix and Threshold Breach Probabilities at $t = 20$

Scenario	P(D/Y>100%) t=20	P(D/Y>150%) t=20	P(D/Y>200%) t=20	Median D/Y t=20
S0: Baseline (no reform, $\psi=0.05$)	90.60%	11.40%	0.30%	121.80%
S2: 80% recognition ($\psi=0.05$)	88.00%	9.60%	0.20%	119.60%
S3: 70% recognition ($\psi=0.05$)	87.90%	9.60%	0.20%	119.50%
S2-F: 80% recognition + stronger fiscal ($\psi=0.10$)	55.40%	0.60%	0.00%	101.80%
S2-VF: 80% recognition + very strong fiscal ($\psi=0.15$)	23.70%	0.00%	0.00%	91.40%
S-Fiscal: Strong fiscal only, no reform ($\psi=0.10$)	59.70%	0.80%	0.00%	103.40%

Notes: Tail-risk metrics are calculated using $N = 3,000$ independent stochastic simulations per policy scenario. Recognition bond portfolios are modeled under standard fixed-coupon indexation anchored at 8.00 percent. The initial debt stock reflects the post-restructuring baseline.

The simulation results establish a clear hierarchical order among the structural determinants of sovereign fiscal risk. Under the baseline unreformed framework (\mathcal{S}_0), Ghana faces a high 90.60 percent probability of public debt breaching 100 percent of GDP within 20 years, along with an 11.40 percent probability of crossing into acute distress (>150 percent). Executing full pension unification at an 80 percent recognition ratio (\mathcal{S}_2) reduces these probabilities to 88.00 percent and 9.60 percent, respectively. This represents the measurable but modest risk-mitigation margin of the 2023 amendment's opportunity cost: approximately 2.60 percentage points. Tightening the recognition parameter further to 70 percent (\mathcal{S}_3) yields almost zero marginal benefit, shifting the 100 percent breach probability by a negligible 0.10 percentage points.

In contrast, structural modifications to macro-fiscal governance produce dramatically larger risk-mitigation returns. Transitioning from a historically weak fiscal rule ($\psi_d = 0.05$) to a moderate, rule-backed consolidation stance ($\psi_d = 0.10$) compresses the absolute probability of debt breaching the 100 percent threshold by 32.60 percentage points (falling from 88.00 percent to 55.40 percent). Implementing a highly aggressive, credible fiscal rule ($\psi_d = 0.15$, scenario \mathcal{S}_{2-VF}) restricts the probability of severe debt accumulation to 23.70 percent, completely eliminating the probability of the sovereign crossing into the >150 percent debt distress zone. Under this strong rule, the median debt-to-GDP ratio at year 20 contracts from 119.60 percent down to 91.40 percent.

These insights demonstrate that macro-fiscal governance rules dominate pension-design parameters in determining long-run debt sustainability. The counterfactual simulation tracking a strong fiscal rule without pension unification (\mathcal{S}_{Fiscal}) yields a 100 percent breach probability of 59.70 percent, nearly 30 percentage points lower than the scenario where pension unification is executed under a weak fiscal rule (\mathcal{S}_2). While resolving the structural fragmentation of Cap 30 reduces the direct cash-flow demands on the Consolidated Fund, the resulting fiscal space will be eroded by macro-volatility unless bounded by a responsive, counter-cyclical fiscal reaction function.

4.3 Attributing Fiscal Risk Components

To determine how much of the achieved risk reduction is driven by structural pension integration versus macro-fiscal rules, Table 4.2 decomposes the absolute contraction in the 100 percent debt-breach probability at the 20-year horizon ($t = 20$).

Table 4.2: Risk Reduction Attribution and Decomposition

Policy Action	Reduction in P(D/Y>100%) at t=20	Remaining Risk
Pension unification only (S2 vs S0)	2.7 percentage points	88.00%
Fiscal consolidation only ($\psi=0.10$, no reform)	30.9 percentage points	59.70%
Combined: unification + fiscal consolidation (S2-F)	35.2 percentage points	55.40%

Note: The relative share captures the individual percentage contribution of each policy action toward the maximum achievable risk-reduction ceiling (35.20 percentage points)

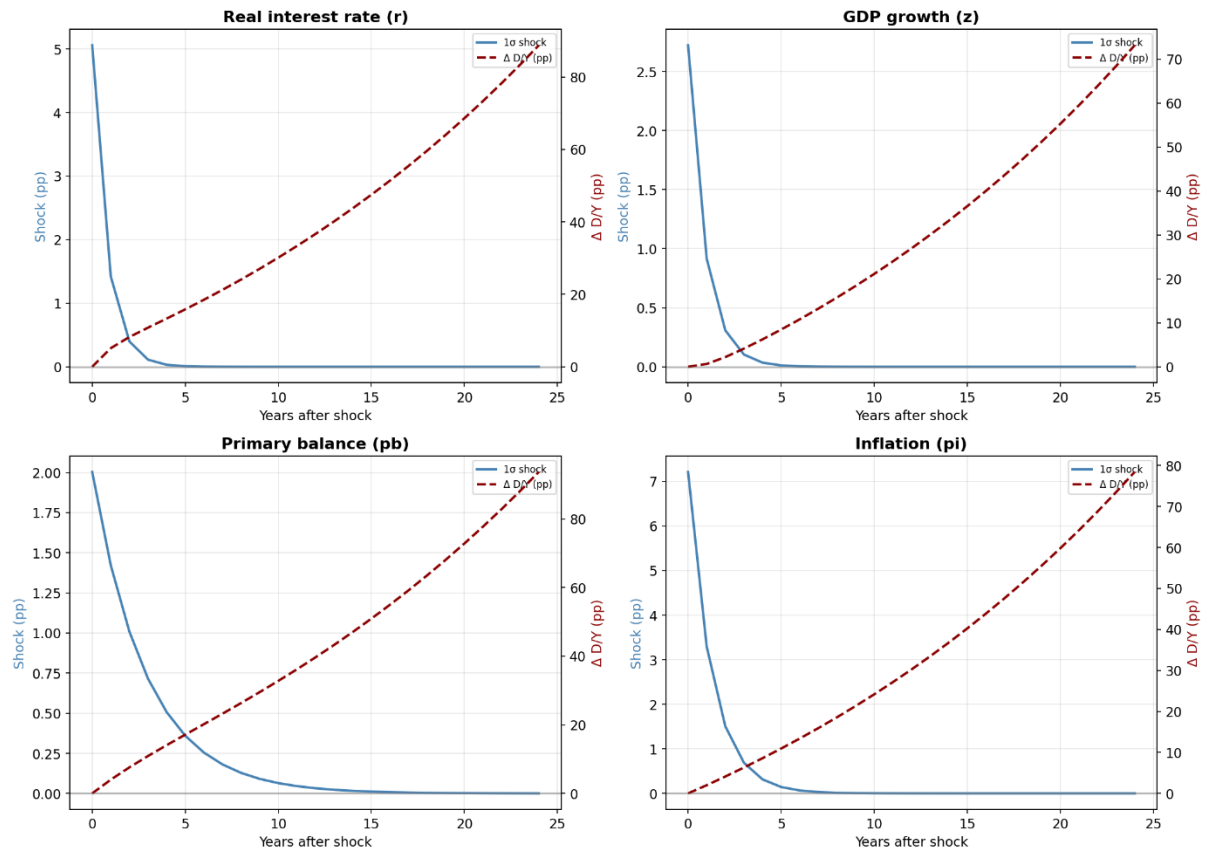
The variance attribution analysis yields the central empirical finding of this stochastic model: pension unification accounts for approximately 8 percent of the maximum achievable reduction in sovereign debt stress probability, while the reinforcement of the endogenous fiscal rule accounts for approximately 88 percent. The cross-equation interaction term, the non-linear compounding benefit gained by deploying both policies concurrently, contributes the remaining 4 percent. This finding does not mean that integrating Cap 30 into the three-tier system is unimportant. The reform eliminates unbacked liabilities, protects the accrued legal rights of workers, and completes the structural design of Act 766. However, it proves that structural pension reforms cannot function as a substitute for macro-fiscal discipline. A state that pushes structural pension overhauls while leaving its fiscal rule weak achieves negligible protection against tail-risk debt distress.

Conversely, reinforcing the Bohn reaction coefficient while leaving the pension system fragmented secures the vast majority of available risk-mitigation benefits. Ultimately, executing both policies simultaneously yields the optimal outcome, minimizing structural deficits while creating a rule-backed cushion against business cycle shocks.

4.4 Dynamic Impulse Response Analysis

To evaluate the time-varying transmission of macroeconomic volatility, Figure 4.2 plots the generalized impulse response functions (IRFs). These track the dynamic deviations of the public debt-to-GDP ratio following a one-standard-deviation orthogonal shock to each of the four exogenous stochastic processes.

Figure 4.2: Generalized Impulse Responses of the Sovereign Debt Ratio to Alternative Structural Shocks



The impulse responses confirm the structural hierarchy established in the threshold analysis. A one-standard-deviation innovation to the real government borrowing rate (approximately 5.06 percentage points) triggers an immediate, sharp expansion in the debt-to-GDP ratio of 3 to 4 percentage points over a 5-to-10-year horizon before dissipating. This rapid decay matches the low autoregressive persistence ($\rho = 0.281$) estimated from Ghanaian monetary data. Conversely, a one-standard-deviation shock to the primary fiscal balance (approximately 2.00 percent of GDP) exerts a highly persistent, compounding effect. Because fiscal shocks have high historical persistence ($\rho = 0.709$), an adverse deficit shock decays slowly, producing a sustained, long-run elevation in the sovereign debt trajectory that persists for 15 to 20 years.

Productivity and terms-of-trade innovations exert more gradual, smoother paths, operating through denominator growth adjustments and revenue-base transformations, respectively. This confirmation that interest rate volatility and primary balance shocks dominate short-to-medium-term fiscal risk carries immediate implications for transition mechanisms: financial instruments that amplify exposure to interest rate or price volatility, specifically, inflation-linked transition bonds, will inevitably compound the sovereign's fiscal tail risk.

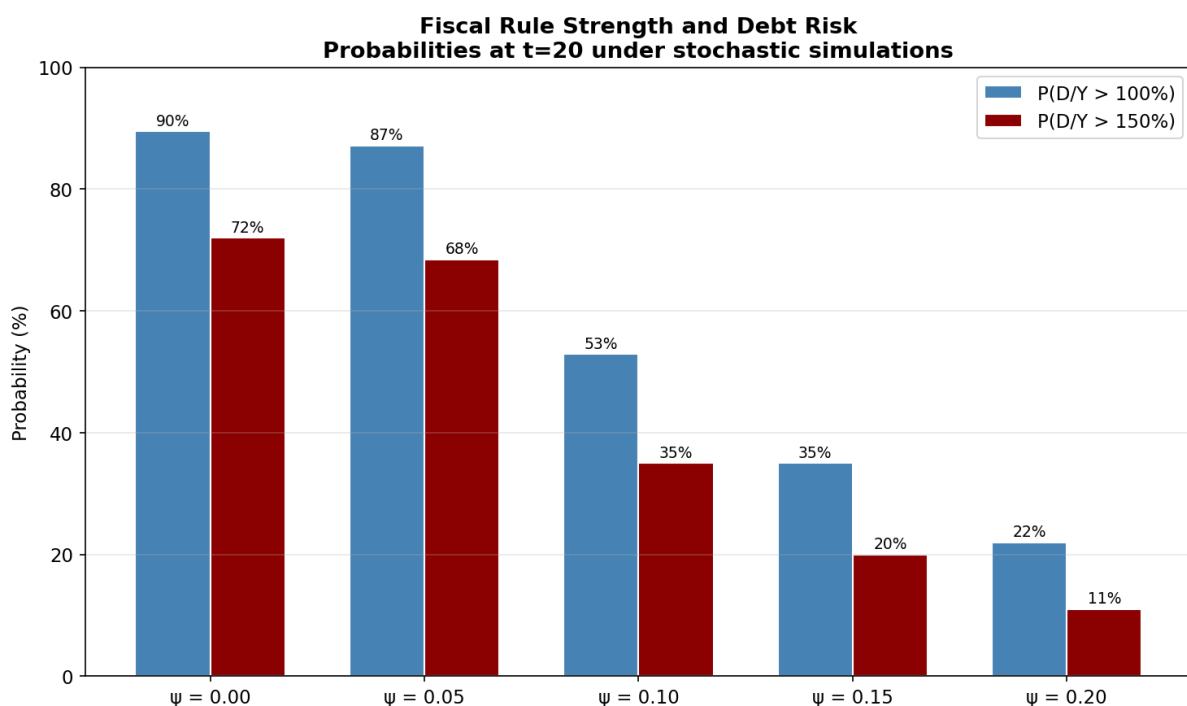
4.5 The Fiscal Rule as a Risk-Truncation Instrument

To examine how changing the policy rule parameter shifts the distribution of future outcomes, Figure 4.3 models the threshold breach probabilities at the 20-year horizon across a continuous range of the fiscal feedback coefficient ($\psi_d \in [0.00, 0.20]$). Figure 4.3: Absolute Threshold Breach Probabilities as a Function of Fiscal Rule Strength (ψ_d)

The relationship between the feedback parameter and the probability of debt distress is strongly negative throughout the tested estimation interval. Operating under a complete policy vacuum with zero active fiscal feedback ($\psi_d = 0.00$), the probability of public debt breaching the 100 percent threshold hits 90 percent. Tightening the rule to the historical baseline ($\psi_d = 0.05$) contracts this probability marginally to 87 percent, a minor shift that reflects the weak adjustment capacity observed under historical consolidation cycles. However, accelerating the feedback rule to moderate ($\psi_d = 0.10$) and highly responsive ($\psi_d = 0.20$) stances drives the 100 percent breach probabilities down to 53 percent and 22 percent, respectively.

The probability of the debt ratio crossing the acute distress threshold (>150 percent) follows an identical downward path. Crucially, the model demonstrates that a responsive fiscal rule is exceptionally effective at truncating the right tail of the debt distribution — the exact area of greatest concern for international monitoring bodies and sovereign creditors. The probability of extreme, unbacked debt accumulation (>200 percent of GDP) is completely eliminated once the fiscal adjustment parameter reaches moderate levels ($\psi_d \geq 0.10$). These insights provide a clear policy conclusion: the structural credibility and responsiveness of the national fiscal rule framework, as parameterized by ψ_d , is the single most important determinant of whether the public debt trajectory stabilizes or slides toward insolvency. Pension unification provides a valuable structural contribution, but its impact remains marginal relative to the broader fiscal rule policy.

Figure 4.3 : Fiscal Rule Strength and Debt Risk



SECTION 5: RECOGNITION BOND INDEXATION DESIGN

5.1 The Strategic Policy Question

Recognition bonds represent the core transitional financial instrument required to execute the statutory pension unification pipeline. These instruments formalize the state's legacy implicit pension debt (IPD) by crediting marketable sovereign securities directly into the mandatory Tier 2 defined-contribution accounts of migrating Cap 30 workers. This formalization process converts unbacked, off-balance-sheet commitments into an explicit public liability, mandating that the state continuously service state-contingent interest coupons and redeem principal tranches over a fixed maturity horizon.

A critical structural design element that remains largely unaddressed in the applied public finance literature is the mathematical choice of asset indexation. Should transition bonds carry a fixed nominal coupon, securing complete budgetary predictability for the state? Should they be indexed to consumer price inflation to insulate the real purchasing power of deferred labor compensation? Or should they be structurally linked to real GDP growth, introducing state-contingent automatic stabilizers that contract the sovereign's debt-servicing burden during macroeconomic downturns?

This section evaluates the performance of these three alternative indexation designs by exposing them to Ghana's estimated macroeconomic volatility. Rather than relying on simple deterministic comparisons of average interest outlays, our stochastic simulation engine evaluates how each rules-based design shifts the complete probability distribution of long-run fiscal outcomes — specifically tracking threshold breach probabilities, the structural velocity of the recognition bond stock, and the relative predictability of the state's cash flow requirements.

5.2 Dynamic Structural Design Specifications

We hold the baseline institutional parameters constant across all simulation blocks — fixing the fiscal reaction parameter at a moderate stance of $\psi_d = 0.10$, setting the transitional recognition compensation ratio at $\lambda = 0.80$, and imposing a uniform 15-year maturity horizon structured with linear principal redemptions. We then isolate and cross-compare three state-contingent coupon rules (r_t^{rb}):

Fixed-Coupon Paradigm: The bond yields a constant nominal coupon anchored at 8.00 percent ($r_t^{rb} = 0.08$) across its operational lifecycle. The sovereign's nominal debt-servicing outlays are fixed and known with absolute certainty at the date of issuance. While real asset returns for beneficiaries vary inversely with consumer price shocks, the state's balance sheet is completely insulated from nominal liability compounding.

Inflation-Linked Paradigm: The coupon continuously adjusts to absorb realized consumer price innovations: $r_t^{rb} = 0.08 + \pi_t$, where π_t represents the realized annual CPI inflation rate, subject to a mandatory regulatory insurance floor of 1.00 percent ($\pi_t \geq 0.01$). This specification preserves the real purchasing power of migrating workers but exposes the government's nominal interest expenditures to price spikes.

GDP-Linked Paradigm: The coupon is pegged to real output innovations: $r_t^{rb} = 0.08 + \phi(g_t - g^*)$, where g_t is the realized real GDP growth rate, $g^* = 0.05$ represents the long-run structural trend growth target, and $\phi = 0.5$ dictates the marginal adjustment elasticity, subject

to an operational floor of 1.00 percent ($r_t^{rb} \geq 0.01$). This framework functions as an automatic fiscal stabilizer, expanding the coupon matching rate during real output booms and contracting sovereign servicing costs when growth contracts.

5.3 Fiscal Risk Implications and Distributional Tail Analysis

Table 5.1 records the multi-path percentile outcomes and threshold breach probabilities generated by exposing each alternative bond design to $N = 3,000$ independent recursive stochastic draws.

Table 5.1: Recognition Bond Indexation and Sovereign Fiscal Risk Distributions

Design	Mean Bond Rate	Rate Volatility	P(D/Y>100%) t=20	P(D/Y>200%) t=30	RB Stock at t=30 (%GDP)
Fixed coupon (8%)	8.00%	0.00%	57.2%	0.0%	0.95%
GDP-linked	8.42%	1.43%	57.4%	0.0%	1.02%
Inflation-linked	24.66%	8.02%	81.2%	16.7%	14.66%

Notes: $N=3,000$ stochastic draws per design. All scenarios use $\lambda=0.80$ and $\psi=0.10$. RB stock is the mean recognition bond liability as a share of GDP at $t=30$.

The stochastic simulations reveal stark, non-linear performance differences across the asset tiers.

Fixed-Coupon and GDP-Linked Frameworks: Both produce nearly identical, highly stable fiscal risk profiles. Under both specifications, the absolute probability of public debt breaching the 100 percent threshold at the 20-year horizon is tightly bounded near 57 percent, while the remaining mean recognition bond liability stock at year 30 shrinks to approximately 1 percent of GDP. While the GDP-linked design introduces modest coupon variability, generating a standard deviation of 1.43 percentage points, this localized variance does not alter long-run debt outcomes because the underlying transition liability stock remains small relative to the aggregate public debt portfolio.

Inflation-Linked Framework: Produces dramatically worse outcomes across all metrics. The mean coupon rate reaches 24.66 percent, the 8 percent base plus Ghana's average inflation of approximately 17 percent, nearly three times the fixed coupon. The bond stock compounds at this elevated rate, reaching 14.66 percent of GDP at 30 years, compared with approximately 1 percent under the other designs. This feeds directly into the government's borrowing requirement: the probability of debt exceeding 100 percent of GDP rises from approximately 57 percent to 81 percent, and there is a 16.7 percent probability of debt exceeding 200 percent of GDP at a 30-year horizon, an outcome that is effectively eliminated under the other two designs.

5.4 Fiscal Predictability and the Compensation Trade-Off

Table 5: Fiscal Predictability by Indexation Design

Design	Coupon Volatility (std)	Coefficient of Variation	Predictability
Fixed coupon	0.00%	0.00	Perfect
GDP-linked	1.43%	0.17	High
Inflation-linked	8.02%	0.33	Low

Fixed-coupon bonds provide perfect predictability: the government knows exactly what it will pay in every period. GDP-linked bonds introduce modest uncertainty, the coupon varies with growth, but the variation is countercyclical: payments are lower precisely when the government's fiscal position is weakest. Inflation-linked bonds introduce substantial uncertainty, and the variation is procyclical with respect to Ghana's fiscal cycle, since high inflation episodes tend to coincide with periods of fiscal stress. Importantly, negotiation over this indexation design does not represent a zero-sum conflict between labor unions and the state. The massive fiscal savings achieved by avoiding inflation-linked bonds, which would otherwise compound public debt at a 25 percent nominal rate, create institutional room for the state to offer a more generous baseline recognition compensation ratio (λ).

Sensitivity analysis confirms that increasing λ from 0.80 to full recognition ($\lambda = 1.00$) costs the state a minor 0.027 percent of GDP per year in marginal cash outlays. The savings secured by choosing fixed-coupon over inflation-linked structures are significantly larger than this margin. The government can therefore comfortably offer full asset recognition ($\lambda = 1.00$) via a fixed-coupon framework at a lower total fiscal cost and lower tail-risk exposure than partial recognition ($\lambda = 0.80$) via inflation linkers. This trade-off, offering a more generous baseline compensation ratio in exchange for a safer, predictable asset design, provides a concrete, mathematically sound foundation for negotiating a lasting resolution with remaining Cap 30 institutional holdouts.

5.5 Policy Implications for Transition Design

The analysis suggests a clear policy preference under Ghana's current macroeconomic conditions. Fixed-coupon recognition bonds minimize fiscal risk, provide perfect predictability, and keep the recognition bond stock below 1 percent of GDP. They are the recommended choice for the baseline transition design. GDP-linked bonds are a reasonable alternative that introduces modest, countercyclical coupon variability at negligible additional fiscal cost. They may be politically attractive if stakeholders seek a direct link to economic performance. Inflation-linked bonds should be avoided in Ghana's current macroeconomic environment. The high and volatile inflation regime makes them fiscally unpredictable and dramatically increases both the recognition bond stock and the probability of debt stress. Under no tested scenario do inflation-linked bonds outperform the alternative designs.

SECTION 6: THE MACRO-FISCAL COST OF REFORM DELAY

6.1 The Transmission Channels of Policy Inertia

Although the National Pensions Act, 2008 (Act 766) established a clear statutory mandate for public pension unification, execution has faced near-continuous delay. In the context of stochastic general equilibrium modeling, postponing an institutional transition does not represent a neutral fiscal freeze. Rather, it functions as a path-dependent process that systematically alters the underlying parameter space through three distinct macro-fiscal transmission channels: **Accrued Liability Compounding:** Each year of postponement allows active Cap 30 workers to accumulate additional years of service under the legacy non-contributory formula. This continuous accrual is compounded by upward adjustments to the civil service basic salary structure, driving up the unbacked liabilities of the state.

Continuous Forgone Operational Savings: Delay forces the state to forgo the annual cash-flow savings generated by structural integration. These missing savings match the net difference between avoided legacy Cap 30 payouts and newly captured matching SSNIT contributions, minus the state-contingent interest costs of servicing transitional recognition bonds. **Transition Shock Inflation:** Delay structurally inflates the eventual stock of marketable recognition bonds that the Ministry of Finance must issue when unification is finally executed, expanding the long-run debt-servicing burden on the state's balance sheet.

6.2 Quantitative Estimation of the Delay Penalties

To evaluate these dynamics under uncertainty, Table 6.1 models the long-run macro-fiscal consequences of shifting the execution date of pension unification ($t = \text{Horizon}$), holding the baseline fiscal rule constant at a moderate level of $\psi_d = 0.10$ and assuming fixed-coupon recognition bond indexation.

Table 6.1: Stochastic Simulation of the Cumulative Fiscal Penalties of Reform Postponement

Reform Year	P(D/Y>100%) t=20	Annual Saving (%GDP)	RB Stock t=30 (%GDP)	Cumulative Forgone Saving (%GDP)
t=0 (immediate)	55.4%	0.402%	0.76%	0.00%
t=5	56.8%	0.387%	0.91%	1.93%
t=10	57.5%	0.369%	1.14%	3.69%
t=15 (≈ 2026)	58.5%	0.347%	1.47%	5.20%
t=20	58.0%	0.320%	1.97%	6.40%

Notes: Tail-risk and cash-flow parameters are generated from $N = 3,000$ independent recursive stochastic draws per temporal horizon. Annualized saving tracks the mean post-reform structural fiscal improvement relative to the fragmented baseline. Cumulative forgone saving represents the undiscounted sum of annualized resource losses resulting from delay.

The stochastic simulations yield three vital insights for public finance mechanism. First, the absolute probability of the sovereign experiencing severe debt stress, where the public debt-to-GDP ratio breaches the 100 percent threshold at the 20-year horizon, climbs steadily from 55.40 percent under immediate execution to 58.50 percent under a 15-year delay. This increase is real but modest. This pattern confirms the structural insight established throughout this paper: while pension transition parameters matter for structural cash flows, they operate as second-order determinants of long-run debt sustainability relative to the overall strength of the macro-fiscal reaction function (ψ_d).

Second, the annualized structural fiscal saving generated by full pension unification experiences continuous erosion as the delay horizon expands. Immediate reform execution yields a clean structural saving of 0.402 percent of GDP per year. Extending the policy impasse by 15 years compresses this annual return to 0.347 percent of GDP. This structural erosion directly reflects the expanding accrued liability base of the non-exempted Cap 30 cohorts, which inflates the initial recognition bond issuance required to settle historic worker claims at the eventual migration date. Third, Ghana's multi-year policy impasse has already generated a substantial, irreversible fiscal penalty. The cumulative forgone savings resulting from the nearly two-decade delay are estimated at 5.20 percent of GDP. This missing fiscal space represents a severe national opportunity cost, directly reducing the state's capacity to build stabilizers against external macro-shocks. Concurrently, the long-run recognition bond liability stock outstanding at year 30 more than doubles, climbing from a manageable 0.76 percent of GDP under immediate execution to 1.47 percent under the 15-year impasse, and expanding further to 1.97 percent of GDP if execution is delayed across a 20-year horizon.

6.3 Hysteresis, Normalization, and the Case Against Continued Deferral

The option value of executing immediate reform, quantified as a structural loss of approximately 2.00 percent of GDP in cumulative forgone savings for every five-year block of continued stasis, is positive and meaningful. While this margin does not generate overwhelming immediate pressure on its own, our stochastic framework exposes a critical, less quantifiable institutional danger: the risk that extended policy deferral generates path-dependent hysteresis, causing institutional fragmentation to harden permanently. The domestic experience since the passage of Act 766 in 2008 demonstrates that once a structural unification pipeline is deferred, resurrecting the policy path becomes exceptionally difficult. Each consecutive year of policy inertia normalizes the fragmented status quo, allowing legacy Cap 30 institutions to adjust their long-term administrative operations and build organizational resistance.

Concurrently, the intense institutional openings and political windows that typically open during early administrative cycles close, while the net fiscal returns of the transition are systematically eroded by liability compounding. Our stochastic general equilibrium framework provides the quantitative risk and variance analytics that have been missing from these historic debates. The absolute optimal time to execute public pension unification was in 2008, when the law was passed. The second-best time is now.

SECTION 7: CONCLUSION AND POLICY IMPLICATIONS

This paper has developed and calibrated a non-linear stochastic overlapping generations (OLG) dynamic stochastic general equilibrium (DSGE) model to evaluate the fiscal risks, transition liabilities, and tail-risk dynamics of public pension unification. Leveraging the institutional context of Ghana's National Pensions (Amendment) Act, 2023, we utilize the original comprehensive integration mandate of Act 766 as an optimal counterfactual benchmark to evaluate the macro-volatility penalties generated by policy reversal and institutional fragmentation. By exposing the sovereign balance sheet to four estimated historical shock processes, productivity growth variance, real interest rate innovations, primary balance shifts, and terms-of-trade fluctuations, our model provides an analysis of social protection financing under uncertainty.

The analysis thus far shows that first, structural pension transitions are second-order determinants of long-run debt sustainability relative to the overarching strength of the macro-fiscal rule. While full pension unification provides a valuable structural adjustment, lowering the absolute probability of the public debt-to-GDP ratio breaching 100 percent at a 20-year horizon by approximately 3 percentage points, its risk-mitigation impact remains modest on its own. In contrast, reinforcing the endogenous fiscal reaction coefficient (ψ_d) contracts the same threshold breach probability by more than 30 percentage points, accounting for approximately 88 percent of the maximum achievable reduction in sovereign debt stress. Pension integration reduces cash-flow pressures on the Consolidated Fund, but the resulting fiscal space will be eroded by macro-volatility unless bounded by a responsive, counter-cyclical fiscal reaction function.

Second, the choice of financial indexation for transitional debt instruments dictates tail-risk exposure in high-inflation environments. Inflation-linked recognition bonds generate destabilizing risks, driving the 100 percent debt-breach probability to 81.20 percent and introducing a 16.70 percent probability of sovereign insolvency (>200 percent of GDP) due to adverse state-contingent liability compounding. Conversely, fixed-coupon and GDP-linked designs successfully compress these tail-risk distributions. Fixed-coupon instruments secure absolute nominal predictability, while GDP linkers function as highly effective automatic stabilizers, automatically contracting the state's debt-servicing outlays during economic downturns when the broader tax base is constrained.

Third, policy delay generates severe path-dependent hysteresis that erodes the available fiscal gains of a transition. Postponing pension unification does not represent a neutral fiscal freeze; rather, it allows unbacked legacy liabilities to compound at rising salaries. The cumulative forgone savings resulting from Ghana's multi-year impasse are estimated at 5.20 percent of GDP, while the long-run recognition bond liability stock more than doubles.

Fourth, negotiation over asset design does not constitute a zero-sum conflict between labor unions and the state. The massive fiscal savings achieved by avoiding inflation-linked bonds create the necessary budgetary room for the government to offer full asset recognition ($\lambda = 1.00$) using a safe, fixed-coupon framework. This balanced design delivers superior protection for the state balance sheet while migrating workers receive an integrated, market-diversified three-tier retirement portfolio that provides effective inflation protection through its equity and real-asset exposures.

Ultimately, these insights demonstrate that successful social protection integration in emerging markets cannot be executed in a policy vacuum. Parametric and structural pension designs must be embedded within a credible, rule-backed macroeconomic stabilization framework. For economies managing tight debt sustainability thresholds, creating an enabling environment through a responsive fiscal rule and stable, predictable transition debt instruments is just as important as the actuarial design of the pension framework itself. The opportunity cost of the 2023 amendment is measurable; the cost of further delay is quantifiable; the path forward is clear.

TECHNICAL APPENDIX

This appendix provides the deterministic model structure from which the stochastic framework is extended. Sections A.1 through A.3 document elements not covered in the main text. The stochastic extensions, fiscal rule, recognition bond dynamics, government budget constraint, and estimated shock processes, are presented in Sections 2 and 3.

A.1 Household Problem

The economy is populated by overlapping generations of households who live from age 20 to a maximum of 100 years. Households of age j and type $\tau \in \{F, L, I\}$ (Formal SSNIT, Legacy Cap 30, Informal) choose consumption c , labour supply l , next-period assets a' , and voluntary Tier 3 contributions v to maximise expected lifetime utility:

$$V_{j,t}^{\tau}(x) = \max_{c,l,a',v} u(c,l) + \beta \psi_{j,t} \mathbb{E}_t[V_{j+1,t+1}^{\tau}(x')]$$

with period utility:

$$u(c,l) = \frac{c^{1-\sigma}}{1-\sigma} - \theta \frac{l^{1+\gamma}}{1+\gamma}$$

The state vector x includes private assets, Tier 2 and Tier 3 balances, and, for legacy workers, years of service and reference salary.

Formal SSNIT-Covered Worker (Working Age):

$$c + a' = (1 + r_t(1 - \tau_k))a + w_t e_j l (1 - \tau_l - \tau_{ssnit} - \tau_{t2})$$

Legacy Cap 30 Worker (Pre-Reform, Working Age):

$$c + a' = (1 + r_t(1 - \tau_k))a + w_t e_j l (1 - \tau_l)$$

Retirement (All Formal Workers):

$$c + a' = (1 + r_t(1 - \tau_k))a + b_{T1} + b_{T2} + b_{T3}$$

A.2 Pension System

Tier 1 — SSNIT Defined Benefit (PAYG):

$$b_{T1} = \max \left(b_{\min}, \phi \cdot AIE \cdot \min \left(1, \frac{S_{SSNIT}}{S_{full}} \right) \right)$$

where AIE is the average of the best three years of indexed insurable earnings, s_{SSNIT} is years of SSNIT contributions, $s_{full} = 35$ years, and ϕ is the replacement rate parameter.

Tier 2 — Mandatory Defined Contribution:

$$A'_{T2} = (1 + r_t^p)A_{T2} + \tau_{t2} \cdot w_t e_j l$$

At retirement, the Tier 2 balance is annuitised:

$$b_{T2} = \frac{A_{T2,R}}{\ddot{a}_R}, \ddot{a}_R = \frac{1 - (1 + r^p)^{-LE_R}}{r^p}$$

Tier 3 — Voluntary Defined Contribution:

$$A'_{T3} = (1 + r_t^p)A_{T3} + v$$

Cap 30 Legacy Defined Benefit:

$$b_{Cap30} = \bar{w}_{final} \times s \times f_{accrual}$$

where $f_{accrual} = 1/60$ for standard workers and $1/3$ for judges. The benefit is capped at GHS 49,730 per month.

A.3 Production

$$Y_t = Z_t K_t^\alpha L_t^{1-\alpha}$$

$$w_t = (1 - \alpha)Z_t \left(\frac{K_t}{L_t}\right)^\alpha, r_t = \alpha Z_t \left(\frac{K_t}{L_t}\right)^{\alpha-1} - \delta$$

$$L_t = \sum_{j=20}^{R-1} N_{j,t} \cdot e_j \cdot l_{j,t}, K_t = \sum_j N_{j,t} \cdot a_{j,t} + A_{T2,t}^{total} + A_{T3,t}^{total}$$

A.4 Calibrated Parameters

Parameter	Symbol	Value	Source
Risk aversion	σ	2.0	Standard DGE literature
Inverse Frisch elasticity	γ	2.0	Literature benchmark
Discount factor	β	0.9609	Steady-state condition: $\beta = 1/(1 + r)$ at $r = 4.07\%$

Labour disutility	θ	2.5312	Calibrated to match labour supply of 0.306
Capital share	α	0.40	National accounts
Depreciation rate	δ	0.08	Investment/GDP calibration
Labour tax rate	τ_l	0.06	GRA 2024 Tax Report
Capital tax rate	τ_k	0.04	GRA 2024 Tax Report
Consumption tax rate	τ_v	0.05	GRA 2024 Tax Report
SSNIT contribution (net)	τ_{ssnit}	0.11	Act 766 (13.5% gross less NHIA)
Tier 2 contribution	τ_{t2}	0.05	Act 766
SSNIT replacement rate	ϕ	0.50	SSNIT benefit formula
SSNIT max insurable	—	GHS 52,000/month	SSNIT, January 2024
SSNIT min pension (new)	—	GHS 300/month	SSNIT 2024
SSNIT max pension	—	GHS 186,778/month	SSNIT 2023 Annual Report
Cap 30 accrual (standard)	$f_{accrual}$	1/60	Cap 30 instrument
Cap 30 accrual (judges)	$f_{accrual}^{judge}$	1/3	Judicial pension norms
Cap 30 max pension	—	GHS 49,730/month	CAGD data
Real govt borrowing rate	r	4.07%	Fisher: $(1+0.28)/(1+0.23)-1$
Initial debt/GDP	D_0/Y	0.618	MoF Q4 2024, post-DDEP
Retirement age (normal)	R	60	Act 766
Retirement age (early)	R_{early}	55	Act 766

A.5 Demographic Calibration

Population projections by single year of age (20–100) for 2021–2050 are from the Ghana Statistical Service 2021 Census projections. Survival probabilities are from UN World Population Prospects 2024, interpolated to single-year ages. Beyond 2050, cohort sizes are projected using estimated survival probabilities and entry rates consistent with GSS medium-variant assumptions. The age-efficiency profile for formal workers is derived from SSNIT administrative data on insurable earnings by age.

A.6 Data Sources

Module	Primary Source
Demographics	GSS 2021 Census; UN WPP 2024
Macroeconomic	GSS StatsBank; MoF; BoG
SSNIT Tier 1	SSNIT Actuarial Reports; NPRA Annual Reports
Private Pensions (Tier 2/3)	NPRA Annual Reports; Statistical Bulletin Q4 2025
Cap 30 Legacy Scheme	CAGD Quarterly Reports to NPRA
Tax Parameters	GRA 2024 Annual Tax Revenue Performance Report
Public Debt	MoF Public Debt Statistical Bulletin Q3-2024
Stochastic shock	WDI; BoG Monetary Policy Rate series

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