BOJ Quantitative Tightening Scenarios: A DSGE Analysis of Financial Conditions and Unconventional Monetary Policy Exit Strategies

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Abstract

A medium-scale New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model is calibrated in this study to the institutional and macro-financial features of the Bank of Japan (BOJ) for assessing exit strategies from Japan's protracted unconventional monetary policy. Research on Japan's quantitative tightening lacks quantitative evidence on how balance-sheet changes transmit to financial conditions. The model encompasses two main components: (i) a distinct BOJ balance-sheet block, and (ii) a financial-conditions transmission channel, which incorporates endogenous corporate credit spreads and term premia. The research applies the counterfactual quantitative tightening (QT) experiment with perfect foresight to quantify how quickly and early it impacts financial stability through balance-sheet reduction. In addition, it affects economic output and inflation rates and modifies the natural interest rate response. The main finding is robust, confirming that all tested scenarios produce the same sequence of results. Front-loaded QT induces large and immediate increases in premia and spreads, resulting in larger declines in output and comparable, contained reductions in inflation compared with accelerated and gradual strategies. The analysis also reveals that the risk premia increase while the short-rate component decreases endogenously because Japan's low-interest-rate regime triggers a protective monetary policy. Subsequently, the robustness and sensitivity tests validate the initial ranking, which shows that financial amplification strength determines the precise amount of real-side costs. The study results show that a state-dependent QT strategy is needed in Japan that incorporates open risk management and spread and premia monitoring to achieve normalization without causing major economic consequences.

Keywords: Quantitative Tightening · Dynamic Stochastic General Equilibrium · Bank of Japan · Financial Conditions · Unconventional Monetary Policy

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1 Introduction

Japan's prolonged and persistent battle against deflation, alongside economic stagnation, since the 1990s guided the Bank of Japan (BOJ) to implement unprecedented unconventional monetary policies, including Quantitative Easing (QE) and Yield Curve Control (YCC) (Aoki & Ueda, 2025; Ferreira-Lopes et al., 2022). The central bank needed to increase its balance sheet size to record-high levels because these policies established a fresh monetary policy transmission system. The Dynamic Stochastic General Equilibrium framework shows that these policies work by creating time-dependent market price distortions that affect price dynamics and risk premium levels. This requires a structural model to connect central bank asset holdings with market equilibrium outcomes (Negro & Schorfheide, 2008; Smets & Wouters, 2007). The implementation of these effective policies faces major obstacles because exit procedures depend on multiple factors, which include market emotions together with legal frameworks and the combination of strict monetary policies and banking system properties (Hayashi & Koeda, 2019; Tanaka, 2022). The central bank encounters difficulties when performing quantitative tightening because it needs to reduce its large asset collection, which controls most of the government bond market (Basu & Wada, 2023; Carriere-Swallow et al., 2025). The research needs direct financial friction modeling because credit spreads form through market equilibrium, which increases market sensitivity to shocks while making it difficult for policymakers to take action (Atenga et al., 2021; Salem et al., 2024).

Research about unconventional monetary policy has produced many studies, yet researchers have developed only limited and insufficient methods to study how the BOJ should exit its current policy while understanding its effects on the economy through a single structural macroeconomic model (Wang, 2021). Research has studied two specific areas, which include DSGE model assessments of BOJ policy through bond-market systems (Basu & Wada, 2023) and statistical methods to measure how quantitative easing affects interest rate differences between short-term and long-term bonds (Sudo & Tanaka, 2021). The current DSGE framework lacks a complete model that includes the BOJ balance sheet as a state variable and shows how financial conditions affect its changes and performs different QT scenarios through proper simulation methods (Hayashi & Koeda, 2019; Wang, 2021). The existing gap represents a major issue because QT operates as an intertemporal policy that depends on expectations, and its results stem from how well markets trust the policy and how shocks affect the system and the relationships between observable data and model components (Herbst & Schorfheide, 2015).

The research establishes a connection between these two fields through its development of a New Keynesian DSGE model, which matches the Japanese economic scale and includes BOJ balance sheet elements and financial market constraints. The model maintains its core New Keynesian microeconomic structure to study how financial instruments from balance sheets affect interest rate behavior and risk assessment, and lending conditions, which subsequently influence inflation rates and output performance through complete market equilibrium (Smets & Wouters, 2007). This research addresses the following questions: (i) How do different quantitative tightening scenarios, which reduce the balance sheet size at different speeds, affect Japanese macroeconomic indicators, such as inflation, output, and interest rate movements? (ii) What is the role of the financial conditions channel, specifically through credit spreads and the bond market, in transmitting the effects of quantitative tightening? (iii) Why does the Bank of Japan need to evaluate all possible exit methods from its prolonged period of unconventional monetary policy, given that each approach creates different trade-offs and potential financial stability risks?

The primary contributions to the existing literature are multifaceted. First, the research begins by developing a DSGE model that includes full BOJ balance sheet dynamics and QT mechanisms to help researchers create relevant policy scenarios (Hayashi & Koeda, 2019). Second, the research conducts financial friction analysis, which shows how balance-sheet policies create financial conditions through credit spread mechanisms that enable QT transmission (Carriere-Swallow et al., 2025). Third, we conduct a quantitative evaluation of possible QT scenarios that affect Japan to create evidence-based normalization methods (Sudo & Tanaka, 2021). The research data support policy suggestions that concentrate on risk administration and economic stability maintenance throughout the extensive process of big balance sheet normalization.

This study develops a medium-scale New Keynesian Dynamic Stochastic General Equilibrium model specifically calibrated to the institutional and macro-financial features of the Bank of Japan. The model contains an explicit BOJ balance-sheet block, which works together with a financial-conditions transmission channel to endogenously determine term premia and corporate credit spreads. It is micro-founded in household and firm optimization and augmented with a detailed representation of the BOJ's balance sheet and endogenous financial conditions. The non-linear system of equations is linearized around its non-stochastic steady state using a first-order Taylor approximation and solved using a perturbation method. The structural parameters receive Bayesian estimation, which unites data-based likelihood with theoretical and empirically based prior distributions.

This research, based on counterfactual quantitative tightening experiments under perfect foresight, shows that front-loaded QT leads to the earliest and most significant increases in term premia and spreads, which results in the biggest output and inflation reductions among all three strategies. The simulation results demonstrate that risk premia rise while the short-rate component decreases endogenously in a low-interest-rate environment. The research confirms the qualitative order of results through robustness tests, which demonstrate how financial amplification affects real-world cost measurement accuracy. The research shows that a state-contingent QT strategy, which expands step by step, will decrease economic volatility when Japan uses monetary policy normalization.

The remainder of this paper is organized as follows. Section 2 reviews previous studies about unorthodox monetary instruments and quantitative tightening through Japanese DSGE models, which analyze how economic balance sheets create market irregularities (Aoki & Ueda, 2025; Basu & Wada, 2023; Wang, 2021). Section 3 explains the theoretical basis that supports our DSGE model. Section 4 explains the data collection process along with measurement equation details and transformation methods. Section 5 outlines the solution and Bayesian estimation strategy employed. The empirical results section of Section 6 presents three main sets of data, which include parameter estimates, impulse response functions, and simulation-based results for quantitative tightening scenarios (Hayashi & Koeda, 2019; Tanaka, 2022). The results from robustness checks and sensitivity analysis appear in Section 7. The last part of Section 8 contains research findings that direct the execution of suggested policies.

2 Literature Review

Major central banks implemented unconventional monetary tools, such as quantitative easing (QE), yield curve control (YCC), and negative interest rate policy (NIRP), during the global financial crisis, which triggered researchers to study monetary policy extensively. The review combines essential theoretical, methodological, and empirical findings that study Japan's monetary policy framework through Dynamic Stochastic General Equilibrium models that analyze unconventional monetary tools, balance sheet management, and financial system responses. The review is organized into four subsections (Sections 2.1–2.4). The first section explains how DSGE models use their fundamental theoretical structure to study non-traditional monetary tools in their analysis. The research investigates which scientific methods scientists use to study policy implementation and exit strategy assessment. The following discussion examines essential transmission channels, which include financial market problems and credit market interest rate differences. The review then identifies unresolved gaps in the literature and positions the present study within this context, before concluding with a transition to the model framework.

2.1 Theoretical and Conceptual Foundations of Unconventional Monetary Policy

The Japanese economy has maintained deflation since the beginning through its implementation of unorthodox monetary tools, which include Quantitative and Qualitative Easing and Yield Curve Control. The economic model DSGE has gained popularity among researchers who analyze these policies according to Aoki and Ueda (2025) and Ferreira-Lopes et al. (2022). The DSGE modeling framework enables researchers to study these policies because it contains three essential components, which include forward-looking decision-making and complete microeconomic structures and policy reliability within a complete economic system (Negro & Schorfheide, 2008; Smets & Wouters, 2007). The system depends on unconventional monetary policy to change market prices across time and risk levels

and market expectations because standard interest rate tools become ineffective when interest rates reach their lowest possible level.

Early DSGE applications to the Japanese economy focused on the effective lower bound problem and examined how monetary policy transmission weakens as nominal interest rates approach zero. The standard New Keynesian model received additional components that explained how central bank asset purchases affect both long-term interest rates and future price expectations. Two channels feature prominently in this literature. The portfolio balance channel shows that asset purchases by central banks decrease the amount of long-term safe assets that private investors can access, thus leading to lower term premia. The signaling channel shows how central bank asset purchases create market expectations about future policy actions, which results in monetary accommodation (Sudo & Tanaka, 2021; Tanaka, 2022).

Research from previous years has developed better analytical methods through studies that show how financial statement management affects government financial performance. The study by Alberola et al. (2023) demonstrates, through DSGE models with government debt sustainability mechanisms, how Japanese asset purchases from its debt-heavy economy affect both home credit access and debt growth. The research shows that balance sheet policies create monetary effects that also depend on how fiscal expectations and debt patterns respond to these policies.

The banking sector and financial intermediaries become part of DSGE frameworks, which provide an enhanced conceptual framework. The economic impact of central bank balance sheet operations emerges from three main channels, which include reserve supply management and its effects on intermediary balance sheets and credit market conditions. Bigio and Sannikov (2021) show that reserve supply creates its own effects on borrowing costs and credit access, which do not depend on short-term policy rate stability. This literature establishes that the central bank balance sheet functions as an independent policy instrument, rather than merely a supplement to interest rate policy. The theoretical work developed multiple concepts that enable researchers to study monetary policy through the analysis of balance sheet normalization as an independent economic factor.

2.2 Empirical DSGE Approaches to Unconventional Monetary Policy

The analysis of unconventional monetary policy and exit strategies now depends on DSGE models because these models enable researchers to study how policy tools affect market expectations and financial sectors through their structural framework. The main empirical method for analyzing Japan's unorthodox monetary actions and their impact on the economy depends on Medium-scale New Keynesian DSGE models.

The research employs a particular methodological framework that creates bond market models and maturity structure models to evaluate how portfolio rebalancing operations impact investment performance. Wang (2021) creates a DSGE model that includes bonds with different maturity dates to study how Japanese asset purchase programs affect bond markets through portfolio adjustments, which lead to extended periods of declining interest rates. Basu and Wada (2023) build upon this method by developing a DSGE model that unites commercial banks with excess reserves and government bonds through direct connections between the central bank and financial intermediaries and the fiscal authority. The research data show that unconventional monetary tools successfully reduced bond market interest rates, which produced better economic results through appropriate financial institution modeling. Sudo and Tanaka (2021) analyze Japanese data through DSGE modeling to show that stock effects from central bank bond holdings generate more impact on long-term yields than flow effects.

The literature on exit strategies and quantitative tightening also relies heavily on structural modeling. Research findings show that monetary policy depends on balance sheet decisions because interest rates have reached their minimum point (Gagnon et al., 2023). Research using DSGE models shows that quantitative tightening produces different macroeconomic results than quantitative easing because expectations, financial stability, and automatic policy rate adjustments affect the study findings (Erceg, 2024). Research using segmented asset markets together with shadow-rate frameworks demonstrates how unconventional monetary tools remove quantitative restrictions that produce changes in financial market conditions (Adrian, 2024; Sims & Wu, 2021).

Research studies validate the results that scientists discovered through their model-based investigations. The research using event-study and announcement-based methods shows that government bond yields increase when governments reduce their balance sheet size, but the effects on other assets and real economic performance remain unknown (Du et al., 2024). The research results demonstrate that DSGE models help analysts understand unconventional monetary policy actions, but the obtained results depend on the model parameters that researchers use.

2.3 Financial Conditions and Monetary Policy Transmission

Financial frictions now represent a fundamental element in DSGE models, which help researchers study how monetary policy affects the economy during times of unorthodox central bank actions. Standard New Keynesian models ignore financial sector weaknesses, which prevents them from showing how credit market problems lead to economic expansion. The credit spread movements serve as the primary channel through which monetary and financial disturbances travel because agency problems, together with collateral constraints and intermediary balance sheet limitations, generate these disturbances (Atenga et al., 2021).

Research indicates that financial market problems increase economic system vulnerability to monetary and fiscal policy adjustments. DSGE models incorporating such frictions exhibit stronger and more persistent responses of output and inflation relative to frictionless benchmarks (Salem et al., 2024). Research shows that business and family financial situations affect monetary policy transmission because their limited access to funding makes monetary policy more effective (Ferreira et al., 2023; Liu et al., 2010). Financial markets maintain their connection to real economic performance through credit spreads, which represent the difference between borrowing costs and risk-free interest rates.

The current DSGE models include financial intermediaries as components to achieve better representation of these economic processes. The models show that interest rate adjustments will lead to major changes in loan expenses because term premia and credit spreads function as automatic price adjustment systems (Bernanke, 1986; Gertler & Karadi, 2015). The ability to set different borrowing and lending rates through extensions shows that spread variations create substantial effects on consumer behavior and investment patterns and inflation patterns (Bigio & Sannikov, 2021; Lee et al., 2021). The research shows that financial conditions serve as the main channel that allows balance sheet normalization to impact macroeconomic performance in countries that have substantial central bank assets.

2.4 Research Gaps and Study Contribution

Despite substantial progress in DSGE modeling of unconventional monetary policy, a significant gap remains in the comprehensive evaluation of exit strategies from the Bank of Japan’s specific policy configuration. Research studies analyze asset purchases and balance sheet policies independently from each other, but they do not develop quantitative tightening models that would work for Japan's long-term low inflation environment and its distinct market characteristics (Alberola et al., 2023; Hayashi & Koeda, 2019; Wang, 2021; Yang et al., 2024). Research about exit strategies tends to ignore the specific institutional elements that exist only in Japan, such as the BOJ controlling most government bond market activity and how central bank balance sheet operations affect monetary conditions.

Research has started to include financial frictions in DSGE models, but scientists have not performed enough quantitative studies about how these frictions affect Japanese balance sheet normalization. The research does not provide sufficient analysis about how endogenous credit spreads affect quantitative tightening transmission when different policy approaches are used (Atenga et al., 2021; Basu & Wada, 2023; Carriere-Swallow et al., 2025; Ferreira et al., 2023; Salem et al., 2024). The research solves these problems through its development of a New Keynesian DSGE model, which operates at a medium scale and specifically targets Japan's economy while using the BOJ balance sheet as a model state variable and financial frictions to create endogenous credit spread dynamics. The framework allows researchers to perform structured counterfactual assessments of different quantitative tightening approaches while they analyze their effects on the economy.

Overall, the review shows that Japan needs to establish a structural system to evaluate its quantitative tightening policies. By synthesizing theoretical, methodological, and empirical insights, it motivates the development of a DSGE

model that explicitly links balance sheet normalization to financial conditions and macroeconomic dynamics. The following section explains the theoretical framework of the model, which describes how quantitative tightening creates economic effects.

3. DSGE Model Framework

This section outlines the theoretical structure of the medium-scale New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model developed for this study. The framework bases its structure on household and firm decision-making processes, while it includes a complete model of the Bank of Japan's (BOJ) financial operations and its impact on market conditions. The design includes essential elements that describe the Japanese economic structure through its extended period of low inflation and its regular battles with the effective lower bound (ELB) of nominal interest rates and its dependence on big asset purchases for monetary policy execution (Eggertsson et al., 2021; Kiley & Roberts, 2017).

The model uses established DSGE mechanisms to analyze Japan's institutional framework through a single general-equilibrium system, which includes interest-rate tools and balance-sheet instruments together with reduced-form financial market constraints (Curdia & Woodford, 2010; Sims & Wu, 2021). The framework enables researchers to study short-term stabilization mechanisms and long-term balance-sheet recovery processes, which help them understand how quantitative tightening (QT) affects real economic performance, asset valuations, and credit availability. The following section presents a conceptual explanation of the model, which includes the complete set of linearized equilibrium conditions and measurement equations reported in **Appendix A (Table A.1)**, together with the stochastic processes governing exogenous shocks.

3.1 Economic Environment

The economy is populated by a continuum of infinitely lived households, monopolistically competitive firms, financial intermediaries, a fiscal authority, and a monetary authority represented by the Bank of Japan. The model uses discrete time, which follows an index system based on $\boldsymbol{t}$. All private agents use rational expectations to make their intertemporal decisions while following budget constraints and technological restrictions. Real, nominal, and financial shocks create the aggregate uncertainty that affects the economy.

Households provide labor to the market while using a general consumption product, and they save their income by purchasing government bonds and financial instruments, which pass through the financial network. Under monopolistic competition, firms create unique products that they must price through a process that includes nominal rigidities. Financial intermediaries enable savings to move between depositors and borrowers, while their financial condition affects the natural evolution of credit spreads. The government uses nominal debt to fund its operations, and at the same time, it uses fiscal policy measures. The BOJ sets the short-term policy rate and manages the size and composition of its balance sheet through asset purchases and sales.

The total production output must follow the regular rules that limit the available resources:

$$Y_t = C_t + I_t + G_t + NX_t \tag{1}$$

The model includes $\boldsymbol{Y_t}$ as real output and $\boldsymbol{C_t}$ as private consumption and $\boldsymbol{I_t}$ as investment and $\boldsymbol{G_t}$ as government expenditure and $\boldsymbol{NX_t}$ as net exports. The model operates mainly within domestic boundaries, but external connections work through financial and portfolio-balance systems, which affect asset values and risk levels and actual economic performance because of Japan's monetary system established after the global financial crisis.

3.2 Households

The model lets households maximize their expected lifetime utility by choosing their consumption and leisure activities, but external habit persistence causes them to follow their natural consumption patterns. The representative household makes decisions about consumption, labor supply, and asset management to achieve the highest possible discounted value of expected utility while following an intertemporal budget constraint.

Preferences are given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right] \tag{2}$$

The model includes $\boldsymbol{\beta} \in (\mathbf{0}, \mathbf{1})$ as a subjective discount factor and $\boldsymbol{h} \in [\mathbf{0}, \mathbf{1})$ to represent external habit formation and $\boldsymbol{\sigma} > \mathbf{0}$ to represent the coefficient of relative risk aversion and $\boldsymbol{N_t}$ to represent labor supply and $\boldsymbol{\varphi} > \mathbf{0}$ to represent the inverse elasticity of labor supply.

The nominal intertemporal budget constraint is:

$$P_t C_t + B_t = (1 + i_{t-1}) B_{t-1} + W_t N_t + \Pi_t - T_t \tag{3}$$

where $\boldsymbol{P_t}$ is the aggregate price level, $\boldsymbol{B_t}$ denotes one-period nominal government bond holdings, $\boldsymbol{i_{t-1}}$ is the nominal interest rate, $\boldsymbol{W_t}$ is the nominal wage, $\boldsymbol{\Pi_t}$ represents firm profits, and $\boldsymbol{T_t}$ denotes lump-sum taxes. Households purchase government bonds either directly or indirectly through financial intermediaries, which connect public debt issuance with central bank asset purchase programs.

Optimality yields the standard consumption Euler equation:

$$(C_t - hC_{t-1})^{-\sigma} = \beta E_t \left[(C_{t+1} - hC_t)^{-\sigma} \frac{1 + i_t}{\pi_{t+1}} \right] \tag{4}$$

and the intertemporal labor supply condition:

$$\frac{W_t}{P_t} = (C_t - hC_{t-1})^{\sigma} N_t^{\varphi} \tag{5}$$

The market conditions determine how total market demand and labor market employment statistics will develop. Households adjust their behavior based on how monetary policy and balance-sheet actions modify their real interest rates, their income expectations, and their expenses for financial intermediation.

3.3 Firms and Price Setting

The production sector consists of a perfectly competitive final-good producer and a continuum of monopolistically competitive intermediate-goods producers. The final good is produced by aggregating differentiated intermediate goods using a Dixit–Stiglitz aggregator:

$$Y_t = \left(\int_0^1 Y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} \, di \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{6}$$

The model includes an elasticity of substitution parameter $\boldsymbol{\varepsilon}$which represents the degree of substitution between different product varieties.

Intermediate firms produce output using capital and labor according to:

$$Y_{i,t} = A_t K_{i,t}^{\alpha} N_{i,t}^{1-\alpha} \tag{7}$$

where $\boldsymbol{A_t}$ represents aggregate productivity and $\boldsymbol{\alpha} \in [\mathbf{0}, \mathbf{1}]$ is the capital share. Capital is treated as predetermined in the short run, and its accumulation dynamics are abstracted from the baseline model for tractability, allowing the analysis to focus on monetary and financial transmission mechanisms.

Prices are adjusted subject to Calvo-type nominal rigidities. In each period, a fraction $\mathbf{1} - \boldsymbol{\theta}$ of firms can reoptimize prices, while the remaining fraction $\boldsymbol{\theta}$ keeps prices unchanged. Optimal price-setting behavior yields the New Keynesian Phillips Curve:

$$\pi_t = \beta E_t[\pi_{t+1}] + \kappa mc_t + u_t \tag{8}$$

The model includes $\boldsymbol{\pi_t}$ as inflation while $\boldsymbol{\kappa}$represents a combined factor which shows both price rigidity and substitution flexibility and $\boldsymbol{mc_t}$ represents real marginal costs and $\boldsymbol{u_t}$ represents cost-push shocks. Real marginal cost is proportional to the real wage adjusted for productivity and factor shares and is derived from the firm's cost minimization problem. The existence of nominal rigidities enables monetary policy and central bank balance-sheet operations to produce actual economic impacts during the first few years following their implementation.

3.4 Monetary Policy Rule

Monetary policy is conducted by the Bank of Japan using the short-term policy interest rate as its primary conventional instrument. The policy rule contains a forward-looking Taylor-type specification which includes interest-rate smoothing:

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[i^* + \phi_\pi(\pi_t - \pi^*) + \phi_y \tilde{Y}_t\right] + \varepsilon_t^i \tag{9}$$

where $\boldsymbol{i^*}$ is the long-run nominal policy rate, $\boldsymbol{\tilde{Y}_t}$ denotes the output gap, and $\boldsymbol{\varepsilon_t^i}$ is a monetary policy shock.

Given Japan's prolonged experience at the ELB, the observed policy rate is constrained according to:

$$i_t = \max\left(i_t^{\text{shadow}}, ELB\right) \tag{10}$$

The shadow rate governs policy behavior when the ELB binds and is used for model solution and simulation purposes.

3.5 BOJ Balance Sheet and Asset Holdings Block

The model includes government bond holdings of the BOJ as state variables, which form its core component. BOJ holdings of long-term government bonds evolve according to:

$$B_t^{BOJ} = (1-\delta_b)B_{t-1}^{BOJ} + \Delta B_t^{BOJ} \tag{11}$$

The model represents the redemption rate through $\boldsymbol{\delta_b}$ while $\boldsymbol{\Delta B_t^{BOJ}}$ shows net asset purchases which turn negative during quantitative tightening operations. The monetary base is linked to asset holdings via:

$$M_t = \lambda B_t^{BOJ} + Z_t \tag{12}$$

The portfolio-balance channel determines term premia levels:

$$TP_t = \gamma(B_t^{Total} - B_t^{BOJ}) + \varepsilon_t^{TP} \tag{13}$$

where $\boldsymbol{B_t^{Total}}$ denotes the outstanding stock of government bonds, treated as exogenous.

3.6 Financial Conditions Block

Financial frictions are incorporated through an explicit financial intermediary sector that generates an endogenous corporate credit spread. The credit spread follows:

$$S_t = f(\text{Leverage}_t, \text{Risk}_t, \dots) \tag{14}$$

The lending rate is given by:

$$r_t^L = r_t^f + S_t \tag{15}$$

The model enables financial conditions to affect investment and output levels when the policy rate reaches its effective lower bound. The framework unites these structural components into a complete DSGE system, which enables researchers to assess different quantitative tightening approaches that Japan could implement.

4. Data and Model Measurement

The following section explains how researchers built their data and performed their initial statistical tests before they could estimate the DSGE model. The researchers describe their data selection process and variable selection, and

transformation methods, which they used to match their theoretical framework with the Japanese institutional environment. The document includes descriptive statistics and time-series data properties, which include unit root and cointegration tests to confirm the statistical quality of the dataset for DSGE framework development. **Appendix A (Fig. A.1)** presents the time series of the observed macroeconomic and financial variables used in the estimation.

4.1 Data and Variable Description

Sample, Coverage, and Policy Relevance: The research uses quarterly data, which includes 15 macroeconomic and financial indicators for Japan throughout 127 observations from 1994Q1 to 2025Q3. The research period includes Japan's extended period of low inflation and its multiple encounters with the effective lower bound and its ongoing use of unorthodox monetary tools (Aoki & Ueda, 2025; Kubota & Shintani, 2024). The research contains vital policy frameworks that allow DSGE models to study balance-sheet tools and their ability to restore typical economic operations (Aoki & Ueda, 2025). The framework allows researchers to create controlled quantitative tightening scenarios that need to span appropriate timeframes according to Hayashi and Koeda (2019) and Tanaka (2022).

Variable Blocks and Transformations for DSGE Estimation: The selected variable set, summarized in Table 1, is designed to capture the macro-financial dynamics most relevant for DSGE analysis of Japan and aligns closely with variable choices in existing DSGE studies of BOJ unconventional policies and bond-market transmission (Basu & Wada, 2023; Wang, 2021). The model applies logarithmic transformations to Real Gross Domestic Product, Private Final Consumption Expenditure, and Gross Fixed Capital Formation data to analyze growth patterns and meet the needs of DSGE measurement equations (Basu & Wada, 2023; Wang, 2021). The Consumer Price Index serves as a price level indicator that exists in logarithmic form to create endogenous inflation dynamics through the Phillips-curve system and policy responses that match Japan's economic conditions following the Quantitative and Qualitative Easing.

Table 1 Summary of Variables Used in the DSGE Model

Block	SN	Variable Name	Short Form	Transformed
Real Economic Activity	1	Real Gross Domestic Product (SA, BLN ¥)	RGDP	LOG(RGDP)
	2	Private Final Consumption Expenditure (SA, BLN ¥)	PFCE	LOG(PFCE)
	3	Gross Fixed Capital Formation (SA, BLN ¥)	GFCF	LOG(GFCF)
Price Dynamics	4	Consumer Price Index (Base 2020=100)	CPI	LOG(CPI)
Monetary Policy Stance	5	Short-Term Policy Interest Rate	STPR	STPR
Central Bank Balance Sheet	6	BoJ Holdings of Japanese Government Bonds (TLN ¥)	JGBH	LOG(JGBH)
	7	Monetary Base (SA, BLN ¥)	MBASE	LOG(MBASE)
	8	Bank of Japan Total Assets (BLN ¥)	BOJTA	LOG(BOJTA)
Financial Market Conditions	9	Japan 10-Year Government Bond Yield	JGB10YY	JGB10YY
	10	Corporate Credit Spread (AA Rated)	CCSAA	CCSAA
Credit Channel	11	Bank Loans to Non-Financial Firms	BLNFF	LOG(BLNFF)
Fiscal Stance	12	Debt-to-GDP Ratio	DGDPR	LOG(DGDPR)
External Sector Linkages	13	Real Effective Exchange Rate	REER	LOG(REER)
Capital Flows	14	Foreign Portfolio Investment Ratio	FPIR	FPIR
Labor Market Dynamics	15	Employment Ratio	EMPR	EMPR

The short-term policy interest rate functions as the conventional monetary policy instrument because it represents the standard policy tool that affects short-term liquidity levels in Japan’s economy, where rates have remained near the effective lower bound for many years (Kubota & Shintani, 2024). The stance of unconventional monetary policy is captured through BOJ holdings of Japanese government bonds, the monetary base, and total BOJ assets, all expressed in logarithmic form to reflect the scale and evolution of the central bank’s balance sheet and its implications for balance-sheet normalization (Basu & Wada, 2023; Wang, 2021).

The 10-year Japanese government bond yield serves as a financial condition indicator because it reflects how long-term interest rates and term premia affect QE and QT operations (Basu & Wada, 2023; Carriere-Swallow et al., 2025). The research uses corporate credit spreads as equilibrium objects that develop naturally from financial frictions while following the same patterns as DSGE frameworks that show risk premia respond to economic disturbances and government actions (Atenga et al., 2021; Salem et al., 2024). The credit channel receives its proxy from bank loans provided to non-financial business entities. The Phillips-curve block obtains its transmission channels through bank loans to non-financial firms and three additional variables, which include the debt-to-GDP ratio, the real effective exchange rate, the foreign portfolio investment ratio, and the employment ratio.

Descriptive Properties and Implications for Estimation: The descriptive statistics in Table 2 present essential measures of dispersion and distribution that affect the process of DSGE model estimation. Log-transformed real activity and balance-sheet variables exhibit stable central tendencies and moderate variability, reflecting gradual structural change and sustained policy interventions rather than abrupt regime shifts (Kubota & Shintani, 2024). The policy-constraint and financial-condition variables STPR, JGB10YY, CCSAA, and FPIR demonstrate positive skewness and excess kurtosis, which result in occasional large deviations from their typical values. The Jarque–Bera test reveals that most series fail to satisfy normality requirements, which macro-financial data typically exhibits when subject to lower-bound constraints and policy nonlinearities (Ikeda et al., 2023). The properties of these variables make it necessary to use a Bayesian DSGE framework, which needs multiple stability tests for different measurement approaches, shock distribution models, and financial-friction channel measurement precision (Atenga et al., 2021; Salem et al., 2024).

Table 2 Summary of descriptive statistics for the 15 variables

Variable	Mean	Median	Max.	Min.	SD	Skew.	Kurt.	JB	Prob.	Sum	S.SD	OBS
LOG(RGDP)	13.19	13.19	13.29	13.04	0.07	-0.22	1.91	7.33	0.03	1674.83	0.60	127
LOG(PFCE)	12.58	12.60	12.67	12.44	0.06	-0.69	2.30	12.63	0.00	1597.76	0.45	127
LOG(GFCF)	11.91	11.93	12.04	11.75	0.07	-0.94	3.66	20.83	0.00	1512.82	0.54	127
LOG(CPI)	4.58	4.57	4.72	4.54	0.04	1.85	6.36	132.36	0.00	582.27	0.17	127
STPR	0.00	0.00	0.02	0.00	0.00	3.34	14.45	929.58	0.00	0.27	0.00	127
LOG(JGBH)	6.01	6.02	7.81	4.04	1.16	-0.12	1.89	6.77	0.03	763.67	169.40	127
LOG(MBASE)	14.26	13.91	15.73	12.93	0.95	0.36	1.62	12.89	0.00	1811.52	113.85	127
LOG(BOJTA)	19.27	19.18	21.00	17.73	1.06	0.14	1.70	9.28	0.01	2447.34	142.09	127
JGB10YY	0.01	0.01	0.05	0.00	0.01	1.18	4.67	44.31	0.00	1.55	0.01	127
CCSAA	0.00	0.00	0.01	0.00	0.00	1.39	7.35	141.20	0.00	0.27	0.00	127
LOG(BLNFF)	13.29	13.23	13.52	13.11	0.14	0.37	1.63	12.84	0.00	1687.96	2.36	127
LOG(DGDPR)	5.19	5.29	5.55	4.44	0.32	-0.89	2.63	17.52	0.00	659.23	13.09	127
LOG(REER)	4.90	4.93	5.45	4.40	0.26	-0.03	2.11	4.21	0.12	622.80	8.77	127
FPIR	0.00	0.00	0.02	0.00	0.00	2.77	11.73	565.60	0.00	0.52	0.00	127
EMPR	0.59	0.59	0.62	0.56	0.02	0.12	1.54	11.61	0.00	75.17	0.04	127

4.2 Unit Root Testing

To avoid spurious regression and unreliable inference, the stationarity properties of all variables are examined prior to estimation. Three complementary unit root tests are employed, namely the Augmented Dickey–Fuller (ADF), Phillips–Perron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests. While the ADF and PP tests have the presence of a unit root as the null hypothesis, the KPSS test assumes stationarity under the null. Following standard empirical practice, the final integration order is determined based on the majority outcome across the three tests. The complete results are reported in Table 3.

The results indicate a mixture of stationary and non-stationary processes among the fifteen macroeconomic and financial variables. Three variables, real output (LOG(RGDP)), the short-term policy interest rate (STPR), and the

foreign portfolio investment ratio (FPIR), exhibit stationarity at levels, with the ADF and PP tests rejecting the unit-root null hypothesis. Although the KPSS test gives mixed evidence for STPR, the overall results support classifying these variables as integrated of order zero, I(0). The remaining twelve variables are non-stationary in levels but become stationary after first differencing, implying integration of order one. These include consumption, investment, prices, central bank balance-sheet variables, long-term yields, credit spreads, bank lending, public debt, the real effective exchange rate, and employment. For all of these series, both ADF and PP tests reject the unit-root hypothesis at first differences, while KPSS statistics generally support stationarity. For LOG(JGBH), despite borderline KPSS behavior at first differences, strong rejections from the ADF and PP tests confirm an I(1) classification, with no evidence of higher-order integration. Overall, the system consists of three I(0) variables and twelve I(1) variables, with no I(2) series present. This satisfies the standard preconditions for cointegration analysis and DSGE-based multivariate modeling.

Table 3 Summary of Unit Root Testing

Variable	ADF				PP				KPSS				Integration Order
	Level		1st Diff.		Level		1st Diff.		Level		1st Diff.		
	t-Stat.	CV	t-Stat.	CV	t-Stat.	CV	t-Stat.	CV	LM-Stat.	CV	LM-Stat.	CV	
LOG(RGDP)	-3.45 *	-3.45	-	-	-3.63 *	-3.45	-	-	0.08 *	0.15	-	-	I(0)
LOG(PFCE)	-2.22	-3.45	-15.10 *	-3.45	-2.52	-3.45	-16.08 *	-3.45	0.29	0.15	0.06 *	0.15	I(1)
LOG(GFCF)	-1.17	-3.45	-9.56 *	-3.45	-1.52	-3.45	-9.56 *	-3.45	0.25	0.15	0.08 *	0.15	I(1)
LOG(CPI)	-0.15	-3.45	-3.29 *	-3.45	1.23	-3.45	-11.60 *	-3.45	0.29	0.15	0.14 *	0.15	I(1)
STPR	-4.64 *	-2.89	-	-	-5.73 *	-2.89	-	-	0.60	0.46	0.12 *	0.15	I(0)
LOG(JGBH)	-2.93	-3.45	-3.13	-3.45	-1.62	-3.45	-5.00 *	-3.45	0.11 *	0.15	0.55	0.46	I(1)
LOG(MBASE)	-1.65	-3.45	-4.89 *	-3.45	-2.68	-3.45	-4.89 *	-3.45	0.18	0.15	0.12 *	0.15	I(1)
LOG(BOJTA)	-3.28	-3.45	-2.53 *	-3.45	-2.84	-3.45	-9.94 *	-3.45	0.20	0.15	0.07 *	0.15	I(1)
JGB10YY	-2.80	-2.89	-9.97 *	-2.89	-0.01	-2.89	-8.34 *	-2.89	1.01	0.74	0.45 *	0.46	I(1)
CCSAA	-2.71	-2.89	-11.28 *	-2.89	-0.55	-2.89	-10.25 *	-2.89	0.79	0.74	0.11 *	0.15	I(1)
LOG(BLNFF)	0.32	-3.45	-9.86 *	-3.45	-0.97	-3.45	-9.28 *	-3.45	0.32	0.15	0.04 *	0.15	I(1)
LOG(DGDPR)	-0.73	-3.45	-3.93 *	-3.45	-0.86	-3.45	-14.51 *	-3.45	0.32	0.15	0.04 *	0.15	I(1)
LOG(REER)	-0.74	-3.45	-10.06 *	-3.45	-0.87	-3.45	-10.05 *	-3.45	1.26	0.74	0.03 *	0.35	I(1)
FPIR	-5.56 *	-2.89	-	-	-4.26 *	-2.89	-	-	0.39	0.46	0.11 *	0.15	I(0)
EMPR	-0.72	-2.89	-8.46 *	-2.89	-0.72	-2.89	-9.28 *	-2.89	0.33	0.46	0.04 *	0.15	I(1)

ADF = Augmented Dickey–Fuller; PP = Phillips–Perron; KPSS = Kwiatkowski–Phillips–Schmidt–Shin. Reported values are test statistics and 5% critical values (CV). * Indicates rejection at 5% for ADF/PP: unit root rejected (t < CV); for KPSS: stationarity accepted (LM < CV). Integration order is assigned from the 5% decisions. LOG(JGBH) shows mixed unit-root test outcomes; majority rules are therefore not applied, and the PP test result motivates its classification as I(1).

4.3 Johansen Cointegration Analysis

Prior to estimating the DSGE-consistent multivariate system, long-run equilibrium relationships among the non-stationary variables were examined using Johansen's cointegration methodology. The unit root analysis indicates that the system contains a mixture of I(0) and I(1) variables, with no series exceeding first-order integration, thus satisfying the requirements for Johansen testing. The lag length of the underlying VAR in levels was selected as two based on standard information criteria, namely AIC, SIC, and HQ, together with the sequential likelihood ratio test. In Table 4, cointegration rank was assessed using both the trace and maximum eigenvalue statistics under a linear deterministic trend. While the trace test suggests multiple cointegrating relationships, the maximum eigenvalue test identifies four cointegrating vectors and is therefore adopted as the primary selection criterion. Accordingly, the cointegration rank is set at four, allowing the estimation of a DSGE-consistent error-correction representation that captures both short-run dynamics and long-run equilibrium relationships.

Table 4 Johansen Cointegration Test Results (Trace and Max-Eigen Statistics)

Hypothesized no. of CE(s)	Eigen value	Trace stat.	CV (5%)	Prob.	Max-eigen stat.	CV (5%)	Prob.
None *	0.5675	543.77	334.98	0.0000	103.93	76.58	0.0000
At most 1 *	0.5134	439.84	285.14	0.0000	89.32	70.54	0.0004
At most 2 *	0.4753	350.52	239.24	0.0000	79.98	64.50	0.0009
At most 3 *	0.4257	270.54	197.37	0.0000	68.77	58.43	0.0036
At most 4	0.3374	201.77	159.53	0.0000	51.04	52.36	0.0679
At most 5	0.2836	150.73	125.62	0.0006	41.36	46.23	0.1519
At most 6	0.2014	109.37	95.75	0.0042	27.88	40.08	0.5704

Note: No cointegration by both Trace and Max-eigen tests at Critical Value (5%). CE(s) = cointegrating equation(s). MacKinnon–Haug–Michelis (1999) p-values. Trend: linear deterministic; lag interval in first differences: 1–2.

5. Solution and Estimation

The following section explains how the DSGE model introduced in Section 3 is applied for empirical analysis. The objective is to discipline the theoretical framework with Japanese macroeconomic and financial data in order to analyze the transmission of unconventional monetary policy and quantitative tightening (QT). The model is estimated using Bayesian methods, which combine prior information on structural parameters with the likelihood implied by observed data (Herbst & Schorfheide, 2015). The method works best for Japan because the country faces three major economic challenges, including extended periods of low inflation, zero interest rates, and repeated episodes in which policy rates operate near the effective lower bound.

5.1 Steady State and Calibration Targets

Prior to estimation, the non-stochastic steady state of the model is derived. The steady state represents the long-term equilibrium that prevails when there are no external shocks, and it functions as the base for linear approximation. It is obtained by setting all stochastic innovations to zero and imposing time invariance on endogenous variables, yielding a system of non-linear equations that describe the deterministic equilibrium.

Given the explicit modeling of the Bank of Japan's balance sheet and financial conditions, the steady state is calibrated to reflect key features of the Japanese economy, including persistently low inflation, a near-zero policy rate, and a large central bank balance sheet. The model requires a limited number of deep structural parameters for calibration while allowing the remaining parameters to be estimated.

The discount factor (β) receives its value from the selection of annual real interest rates between 1.0 and 1.5 percent, which results in β values between 0.995 and 0.996 at quarterly frequency. The model applies $\sigma = 1.0$ or $\sigma = 2.0$ as relative risk aversion coefficients and $\varphi = 1.0$ as the inverse labor supply elasticity. The model generates steady-state markups between 10 and 20 percent through its use of external habit formation (h) values between 0.5 and 0.8 and elasticity of substitution (ε) values between 6 and 10. The capital share (α) is calibrated between 0.30 and 0.35.

The monetary policy-related parameters indicate that institutional barriers are present. The inflation target (π^*) lies between 0.5 percent and 1.0 percent (annualized), and the effective lower bound (i^ELB) is assigned a small negative value, while the BOJ bond redemption rate (δ) is calibrated using the typical JGB investment duration.

5.2 Linearization and Solution Method

The model contains a network of non-linear stochastic difference equations that arise from optimization processes, market equilibrium conditions, financial market restrictions, and government intervention mechanisms. To render the system tractable, all equilibrium conditions are linearized around the steady state using a first-order Taylor approximation. This yields a system of linear rational expectations equations that provides an accurate local approximation to the model's dynamics. The linearized model is solved using a first-order perturbation method, which

produces a single stable solution when determinacy conditions are met. The solution exists in state-space form and shows how endogenous variables relate to their past values, structural disturbances, and forward-looking expectations. The representation provides the best format for performing statistical estimation and inference procedures. All steps, including steady-state computation, linearization, and solution, are implemented in Dynare, which also facilitates the computation of impulse response functions (IRFs) that trace the effects of monetary, financial, and balance-sheet shocks on key variables.

5.3 Bayesian Estimation Setup

The remaining structural parameters are estimated through Bayesian model estimation. The selection of priors depends on theoretical frameworks, empirical data, and the specific characteristics of Japanese institutional structures. The Taylor-rule inertia follows a Beta distribution with a mean value of 0.7, while policy reaction coefficients draw from Gamma or Normal distributions. The Calvo parameter is assigned a Beta prior with mean 0.75. The model uses Normal and Gamma distributions to specify financial friction parameters, while Inverse Gamma and Beta distributions are used to model shock standard deviations and persistence parameters. The likelihood is evaluated using the Kalman filter applied to the linearized state-space system. The dataset consists of 15 quarterly Japanese macroeconomic and financial variables covering 1994Q1 to 2025Q3. The measurement equations use transformation methods that follow the unit-root analysis from Section 4.2 to connect observable data with latent variables. The Metropolis–Hastings algorithm performs posterior inference using multiple chains to assess convergence.

5.4 Model Diagnostics

The reliability of the model is assessed through convergence diagnostics, which include trace plots and Geweke and Raftery–Lewis statistics. Posterior moments and credible intervals are reported, and model-implied moments are compared with their empirical counterparts. The model employs two validation approaches, including posterior predictive checks and historical shock decompositions of essential variables. The research validates IRFs through analysis to confirm that the model produces realistic economic behavior consistent with the theoretical frameworks described in Section 3.

6. Empirical Results

The section presents the empirical results of the estimated DSGE model for Japan. The research follows a four-stage analysis process. The section reports posterior estimates that show how monetary policy operates through its structural components and how financial systems influence economic outcomes. Second, the impulse response functions demonstrate that quantitative tightening shocks generate immediate changes in financial market conditions and affect both real economic indicators and inflation dynamics. The third stage uses historical shock decomposition to show how structural disturbances drive movements in macroeconomic variables. The final part of the analysis applies counterfactual quantitative tightening scenarios to examine alternative exit strategies and their effects on the economy.

6.1 Estimated Parameters

Table 5 reports the prior and posterior distributions of the key structural parameters governing monetary policy behavior, balance-sheet dynamics, and financial transmission in the Japan DSGE model. The research team established priors through theoretical foundations and empirical data, and Japan's institutional framework, which they used in their Bayesian analysis as described in Section 5.3. The estimation produces stable posterior distributions for all parameters, which show good behavior while the parameters' uncertainty levels decrease substantially from their initial prior values. The research data from Japanese macroeconomic financial sources between 1994Q1 and 2025Q3 serves as evidence for model identification through empirical research. Fig. 1 visualizes the posterior distributions of the key structural parameters reported in Table 5, illustrating the degree of concentration and uncertainty reduction achieved through Bayesian estimation. **Appendix B (Fig. B.1–B.4)** reports Brooks–Gelman (1998) MCMC convergence diagnostics for all estimated structural parameters and shock standard deviations, confirming stable convergence and reliable posterior inference.

Balance-Sheet Dynamics: The persistence of the Bank of Japan's balance sheet is governed by ρ_β, which captures the autoregressive component of BOJ asset holdings. The posterior mean of 0.9751 indicates strong persistence because it falls within a 90 percent credible interval that is very narrow. The economic data show that BOJ asset holdings change at a slow pace because government bonds have long maturities, and the extended period of unconventional monetary policy has built up significant effects. The process of balance-sheet normalization requires multiple years to complete because it follows the policy approach that the abstract describes.

Table 5 Prior and Posterior Distributions of Key Structural Parameters

Parameter	Economic Interpretation	Prior Mean	Prior SD	Posterior Mean	Posterior SD	90% Credible Interval
ρβ	Persistence of BOJ balance-sheet dynamics	0.9000	0.1000	0.9751	0.0062	[0.9670, 0.9800]
ψ_QT	Effectiveness of QT shock on BOJ assets	0.2000	0.0500	0.1900	0.0374	[0.1153, 0.2399]
χ_TP	Balance-sheet impact on term premia	0.1000	0.0500	0.0193	0.0046	[0.0122, 0.0265]
χ_SP	Term-premium pass-through to spreads	0.5000	0.1500	0.3293	0.1148	[0.1464, 0.5122]
φ_π	Monetary policy response to inflation	1.5000	0.2500	1.1255	0.0962	[1.0101, 1.2637]
ρ_i	Interest rate smoothing	0.8000	0.1000	0.7951	0.0279	[0.7547, 0.8457]

Effectiveness of Quantitative Tightening: The direct impact of quantitative tightening shocks is summarized by ψ_{QT}, which is estimated at a posterior mean of 0.1900. The current value stays near its past average, while the estimation method produced accurate results, which prove that QT shocks create a statistically important but limited impact on BOJ asset management. The research data shows that QT functions as an effective yet restricted policy instrument that enables the execution of a gradual and managed phase-out process.

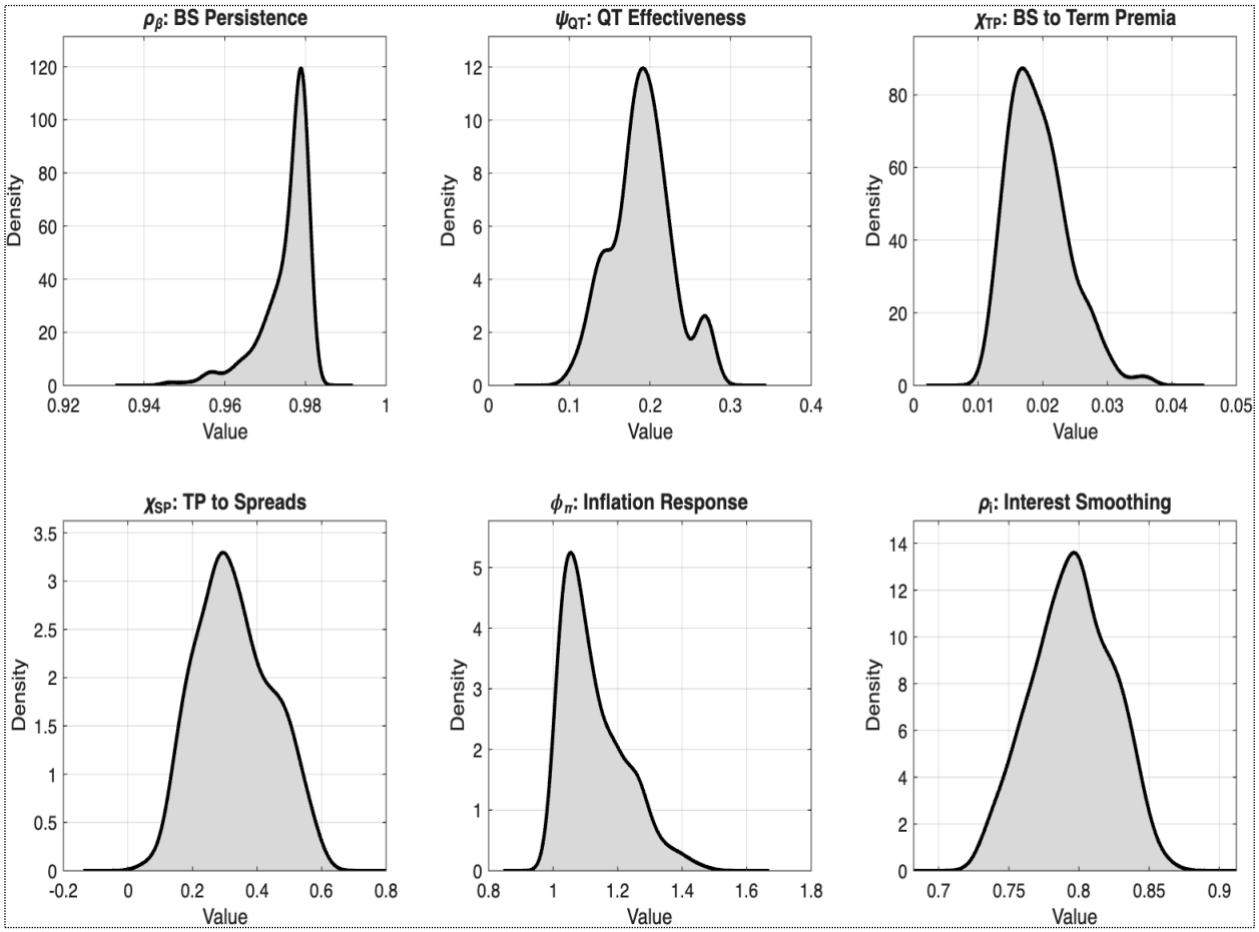


Fig. 1 Posterior Distributions of Key Structural Parameters.

Term Premia and Financial Transmission: The financial transmission mechanism stands as the primary research discovery. The balance-sheet effect on term premia, captured by χ_{TP}, is estimated to be small, with a posterior mean of 0.0193. The data indicate that BOJ asset management activities create only minimal effects on interest rates, which extend over long periods because Yield Curve Control has maintained stable long-term interest rates while reducing the impact of quantity changes. In contrast, the pass-through from term premia to corporate credit spreads, governed by χ_{SP}, remains economically meaningful. The posterior mean of 0.3293 indicates that term premia movements trigger significant credit spread changes because endogenous financial frictions serve as the main factor that enhances these changes. The research confirms that credit spread modeling needs to be included as an essential component for studying how quantitative tightening affects financial markets.

Monetary Policy Rule: The estimated monetary policy rule parameters provide insight into the BOJ's reaction function. The inflation response coefficient ϕ_π has an estimated value of 1.1255, which fulfills the Taylor principle, yet it falls short of typical advanced economy estimates that other countries have used. The data indicate that the central bank maintains a dovish monetary policy, which matches Japan's ongoing low inflation situation. Interest-rate smoothing, captured by $\rho_i = 0.7951$, shows a high level, which indicates that the system prefers to make its policy changes through slow and forecastable methods.

Overall, the monetary policy system maintains strong balance-sheet stability through its long-term existence and quantitative tightening methods, and credit spreads function as its main channel for financial transmission. The following sections will use these features to understand the results from impulse response and quantitative tightening scenario analyses.

6.2 Impulse Response Functions

The following section analyzes how quantitative tightening (QT) affects the economy through impulse response functions, which stem from the DSGE model estimation. The research aims to achieve two main goals, which involve studying how BOJ balance sheet contractions affect financial market conditions and then analyzing how these financial impacts interact with monetary policy adjustments that banks make naturally to produce actual economic results. The discussion emphasizes the timing and magnitude of dynamic responses across variables. Fig. 2 presents the impulse responses of key financial variables to a quantitative tightening shock.

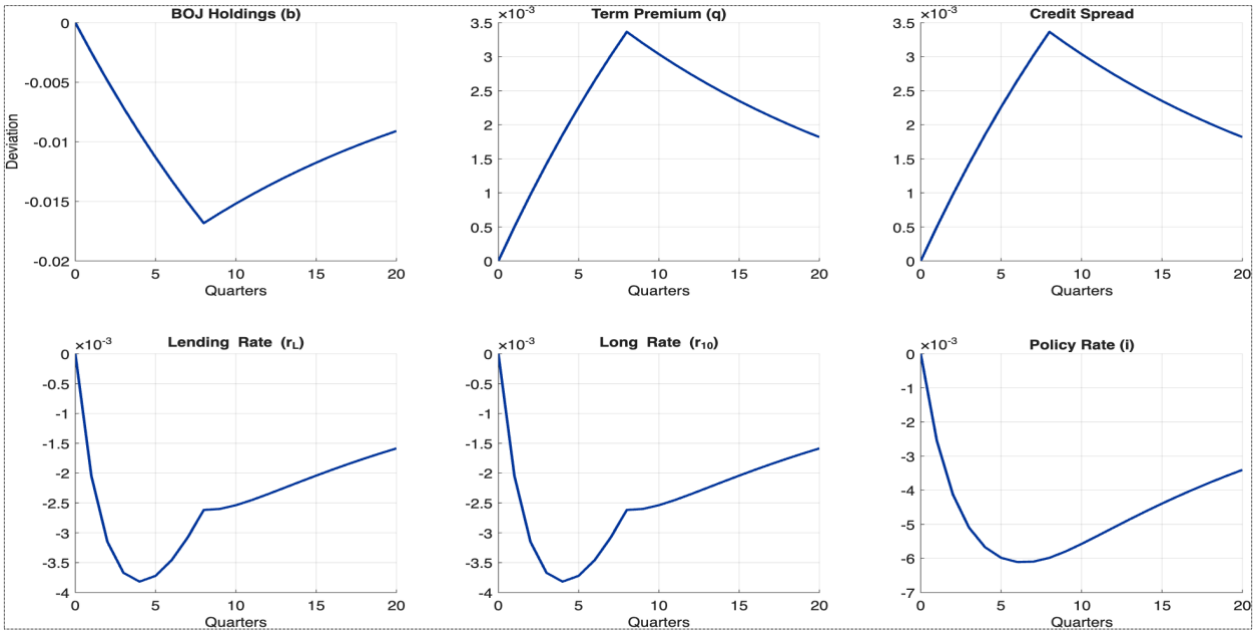


Fig. 2 Impulse Responses of Financial Variables to a Quantitative Tightening Shock

Financial Transmission of a QT Shock: The model represents a QT shock through an external decrease in BOJ asset ownership, which occurs under conditions of complete market prediction. The financial systems of these countries maintained stable operations because their central banks reduced their bond holdings at both short-term and long-term intervals. As shown in Table 6, BOJ asset holdings (b) reach a peak contraction of −0.0185, equivalent to a 1.85 percent deviation from the steady state, by Quarter 5. The market continues to show interest in these assets because Japanese institutions face strict rules that force them to delay their investment decisions.

The reduction in central bank absorption of government bonds through BOJ balance sheet contraction forces private investors to take on more long-term government securities, which leads to higher term premiums. The term premium (q) experienced a substantial increase from the start of the period until it reached its peak at 0.0037 percentage points during Quarter 5. The close alignment between the timing of balance-sheet contraction and the peak in q highlights the direct link between central bank bond holdings and long-term risk premia.

Higher term premia feed into corporate borrowing conditions through the financial-conditions block. The corporate credit spread (spread) widens almost one-for-one with the term premium and peaks at 0.0037 percentage points by Quarter 5. The pattern demonstrates that QT creates financial performance changes because it leads to higher funding expenses, which stem from risk assessments, while expectations of future short-term interest rates remain relatively stable.

The effective lending rate (rL) and long-term interest rate (r10) experience an upward movement during the initial period of time. The policy response included accommodation, but rL and r10 reached their highest point at −0.0025 percentage points during Quarter 8 before they started to return to zero at extended time periods. The decomposition reveals that QT transmission depends on increasing borrowing expenses, which result from risk-premium components, while monetary policy offsets but does not fully neutralize these effects.

The sequence of responses through time follows an economic pattern that makes sense. Financial variables demonstrate quick reactions to market changes, which produce their peak effects during the first five to eight quarters of the study duration. The research shows that market prices adjust through fast transmission channels that receive balance-sheet information. The process of balance-sheet normalization occurs through a slow and continuous method reflecting strong balance-sheet persistence.

Real and Policy Responses: Tighter financial conditions generate contractionary real effects. The model shows that both consumption (c) and output (y) experience a fast decline, which results in matching minimum points of −0.0164 during Quarter 2. This synchronized contraction reflects the sensitivity of aggregate demand to higher borrowing costs under financial frictions. The answers show how borrowing expenses impact total demand because financial institutions encounter balance-sheet and intermediation constraints.

The New Keynesian Phillips curve shows that inflation (π) will decrease when real economic activity decreases because lower market demand becomes visible in the system. The inflation rate bottomed at −0.0081 percentage points during Quarter 2 before it stayed at low levels throughout multiple following quarters, which is consistent with empirical evidence for Japan that financial tightening generates persistent disinflationary pressures. Fig. 3 presents the impulse responses of real variables and the policy interest rate following a quantitative tightening shock.

Monetary policy responds endogenously. The policy rule decreases the short-term nominal interest rate when output and inflation rates drop below their target levels. The policy rate (i) reached its most negative point at −0.0059 percentage points during Quarter 6. The response partially offsets the adverse effects of financial constraints, but it does not remove their entire influence. As a result, the lending rate and long-term interest rates remain elevated during the short to medium horizon despite policy accommodation.

The IRFs demonstrate how interest rates change through QT models by showing their individual effects on interest rates. Premium components show an upward trend after the balance sheet decreases in size, while the policy rate follows an opposite direction. In the short run, premium effects dominate, which results in elevated borrowing expenses that produce negative real economic performance.

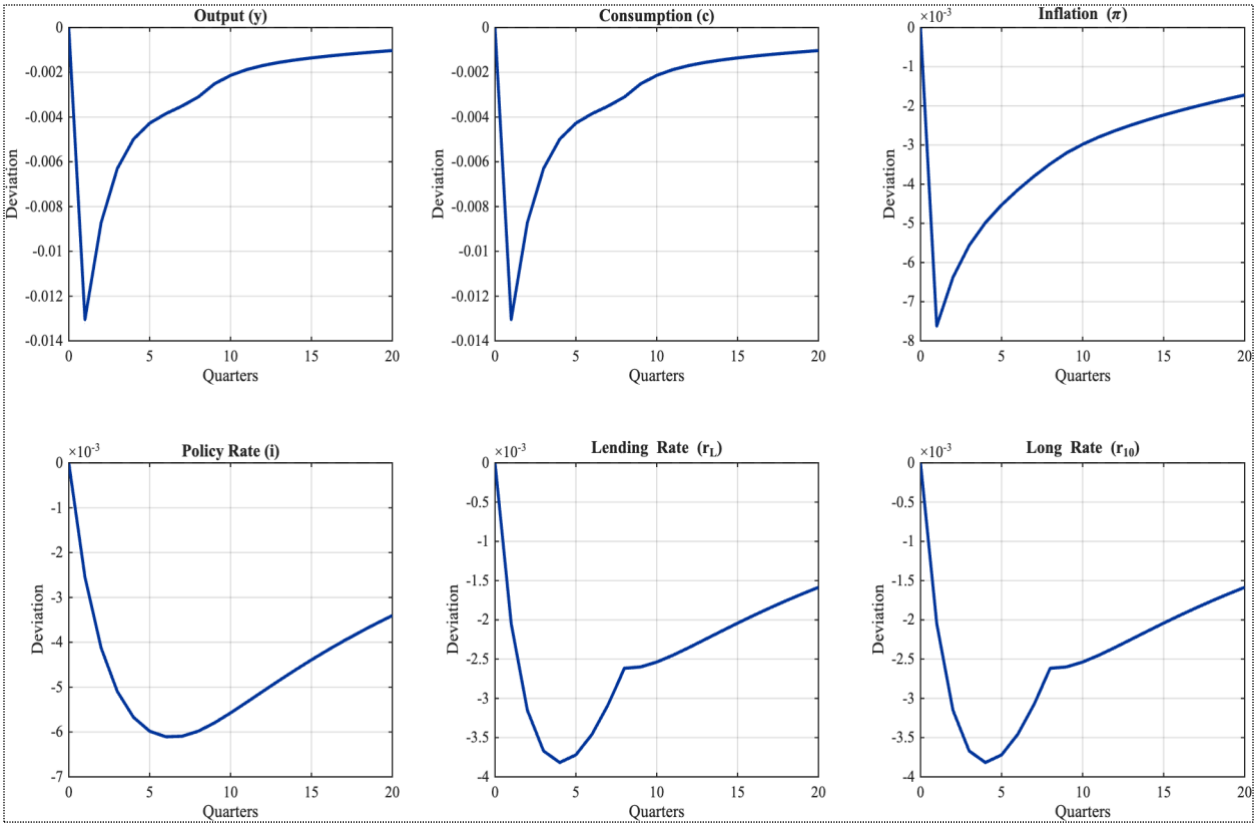


Fig. 3 Impulse Responses of Real and Policy Responses to a Quantitative Tightening Shock.

Identification and Timing: The IRFs confirm that the model correctly identifies its parameters through its identification strategy. The model shows a logical sequence of events that starts with balance-sheet reduction, followed by rising term premiums and credit spreads before output and inflation rates begin to decrease. Financial variables show the quickest and most significant responses to changes, yet real variables need a brief time to achieve their equilibrium positions. This timing structure mirrors established empirical findings for Japan and supports the model's causal transmission mechanism.

Peak and Trough Responses: Table 6 summarizes the peak and trough responses of key variables following the QT shock, together with the timing of these extrema. Financial variables peak early in the adjustment process, while real variables reach their troughs shortly thereafter. This pattern reinforces the interpretation that QT operates primarily through fast-moving financial channels, with real effects emerging as a secondary but persistent consequence.

Table 6 Peak and Trough Responses to a QT Shock

Variable	Description	Units	Min. (Peak Contraction)	Quarter	Max.	Quarter
b	Bank of Japan Asset Holdings	Percentage deviation from steady state	-0.0185	5	0.0000	1
q	Term Premium	Percentage points	0.0000	1	0.0037	5
r10	10-Year Interest Rate	Percentage points	-0.0025	8	0.0000*	201
spread	Corporate Credit Spread	Percentage points	0.0000	1	0.0037	5
rL	Lending Rate	Percentage points	-0.0025	8	0.0000*	201
c	Consumption	Percentage deviation from steady state	-0.0164	2	0.0000	1
y	Output	Percentage deviation from steady state	-0.0164	2	0.0000	1
π	Inflation	Percentage points	-0.0081	2	0.0000	1
i	Short-Term Policy Rate	Percentage points	-0.0059	6	0.0000	1

6.3 Historical Shock Decomposition

The following section assesses how structural shocks have affected macroeconomic performance through the analysis of DSGE framework-derived smoothed data. The research evaluates which transmission channels of the model produce output changes that align with actual economic responses from central bank unconventional monetary policies. The research focuses on output as its main variable because it directly affects economic performance and brings benefits to society. Accordingly, Fig. 4 presents the historical shock decomposition of output (y), while the corresponding decompositions for inflation (π) and the short-term policy rate (i) are reported in **Appendix C (Fig. C1-C2)** for completeness and transparency.

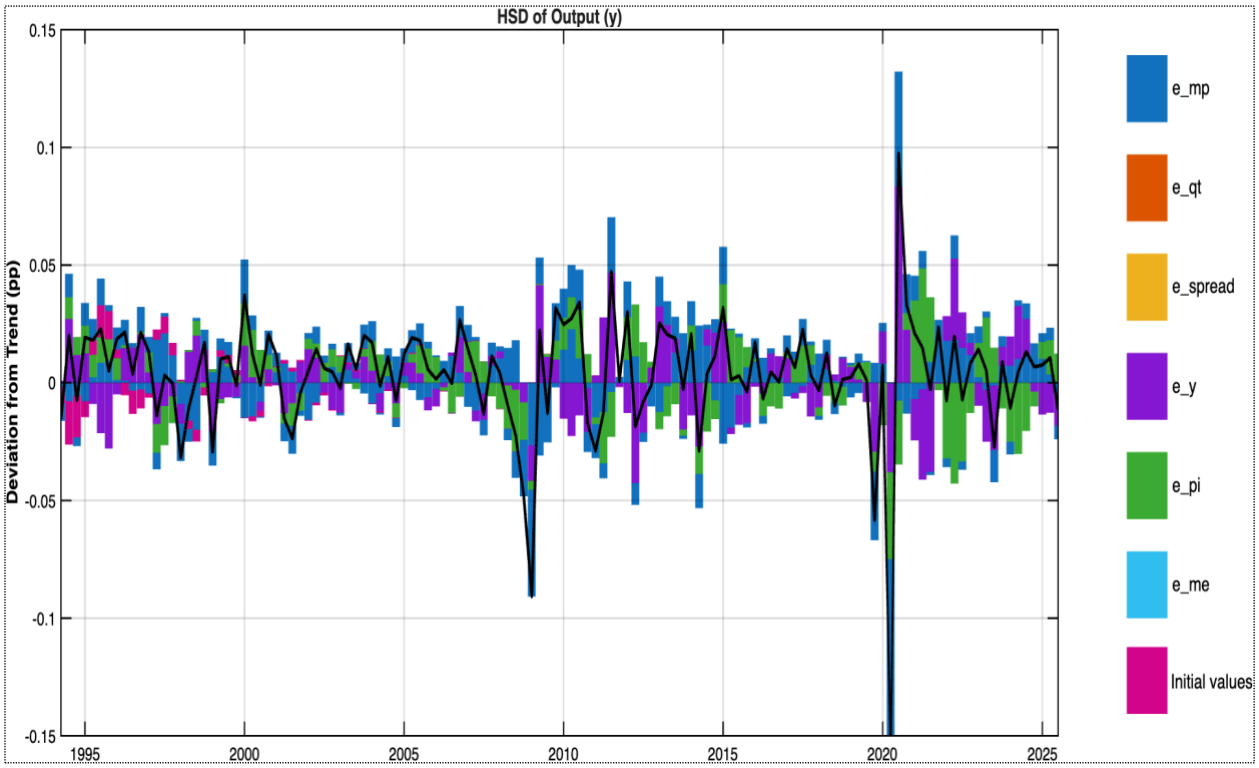


Fig. 4 Historical Shock Decomposition of Output (y) from the DSGE Model

The historical decomposition method shows that output changes result from multiple structural disturbances, which include real demand shocks, price-setting shocks, conventional monetary policy shocks, balance-sheet shocks from quantitative tightening, and residual measurement errors. The output fluctuations decomposition shows how different factors contributed to changes in output throughout the entire sample period. The majority of output episodes show that real demand, together with inflation-related shocks, function as the main factors that affect economic performance during the period of unconventional monetary policy in Japan. The real economic sector, together with price-level fluctuations, has been the main factors that influenced Japan's macroeconomic performance since the start of unconventional monetary policy.

Monetary policy shocks produce short-term output changes that become more apparent during times of high macroeconomic instability in the economy. Policy makers use economic shocks to address present-day macroeconomic issues instead of making choices that affect genuine economic performance, thus preventing these shocks from causing permanent output changes. The historical data show that output changes do not correlate with balance-sheet shocks, which result from quantitative tightening, because these shocks have no significant impact on economic activity. The data show that balance-sheet policies modify macro-financial conditions, but their past external factors failed to produce independent economic cycles that affect output levels. Their influence works through

financial conditions, which they shape to either boost or reduce the impact of real economic disturbances and monetary disturbances.

The historical shock decomposition shows that unconventional monetary policy exists to guide economic activities instead of producing independent macroeconomic issues. Quantitative tightening creates its primary output effects through changes in financial conditions, which affect how other economic disturbances spread throughout the system. The research provides essential empirical evidence that supports the analysis of quantitative tightening scenarios through balance-sheet normalization as a policy tool in the following section.

6.4 Counterfactual Quantitative Tightening Scenarios

The following section evaluates different quantitative tightening exit strategies through perfect-foresight simulations that are implemented within a DSGE model structure. The analysis examines three different counterfactual scenarios, which include Gradual QT (S1), Accelerated QT (S2), and Stress QT (S3). The research design enables researchers to identify how the Bank of Japan's balance-sheet reduction speed and its initial implementation timing affect Japanese financial market conditions, interest rate effects, and real economic performance. The research follows a three-stage analysis process. First, the research evaluates Stress QT through peak and trough evidence. Second, the analysis evaluates all scenarios to determine how their results differ in both magnitude and timing. Finally, the study presents its findings through a mechanism-based analysis that explains the QT transmission process.

6.4.1 Stress QT Dynamics: Peak–Trough Evidence

Table 7 reports peak and trough values for key variables that occurred during Stress QT, together with their associated time points.

Table 7 Peak and Trough Responses under Stress QT (S3)

Variable	Trough (Min)	Period (T)	Peak (Max)	Period (T)
BOJ Balance Sheet (b)	-0.0078	3	0.0000	1
Term Premium (q)	0.0000	1	0.0008	3
Long-Term Rate (r10)	0.0000	1	0.0003	3
Credit Spread (spread)	0.0000	1	0.0004	3
Effective Lending Rate (rL)	-0.0002	7	0.0000	201
Consumption (c)	-0.0012	2	0.0000	1
Output (y)	-0.0012	2	0.0000	1
Inflation (π)	-0.0005	2	0.0000	1
Policy Rate (i)	-0.0005	6	0.0000	1

Note: The Stress QT (S3) scenario from perfect-foresight simulations produced steady-state deviations that the values report as peak and trough values. For variables where the maximum equals zero, the reported value corresponds to the initial steady state prior to the QT shock. The model uses percentage deviations to represent real variables, but interest rates and spreads appear as percentage points. The long-run period denotes convergence back to steady the state at the end of the simulation horizon.

The BOJ balance sheet shrinks rapidly at the beginning of the simulation before it reaches its maximum deviation from steady state in Quarter 3. This quick adjustment occurs because of the exogenous runoff embedded in the stress design, which serves as the main driving force for subsequent system behavior.

Financial conditions display early and rapid responses relative to real economic activity. Market-based financing conditions tighten quickly as term premia and credit spreads reach their highest points by Quarter 3. The simulation shows the long-term rate peaking early, while the effective lending rate turns negative by Quarter 7, reflecting the interaction between rising risk premia and accommodative monetary policy through short-rate adjustments.

Real variables require only a short delay before responding and then continue to show effects over time. Output, consumption, and inflation reach their troughs by Quarter 2 following the initial financial tightening. This early response illustrates how quickly QT transmission operates, even though the overall magnitudes remain moderate.

Overall, Table 7 shows that Stress QT follows a clear time sequence, beginning with balance-sheet contraction, followed by financial tightening, and eventually leading to real economic contraction. Table 7 is placed immediately after this subsection to anchor the discussion.

6.4.2 Cross-Scenario Comparison and Effects

Table 8 compares the three QT scenarios by reporting peak and trough values together with their timing. Two findings stand out.

Table 8 Cross-Scenario Comparison of QT Outcomes (S1 vs S2 vs S3)

Variable	Metric	Gradual QT (S1)	Accelerated QT (S2)	Stress QT (S3)
BOJ Holdings (b)	Trough (Min)	-0.0067 (T=9)	-0.0074 (T=5)	-0.0078 (T=3)
Term Premium (q)	Peak (Max)	0.0007 (T=9)	0.0007 (T=5)	0.0008 (T=3)
Credit Spread	Peak (Max)	0.0003 (T=9)	0.0004 (T=5)	0.0004 (T=3)
Consumption (c)	Trough (Min)	-0.0008 (T=2)	-0.0010 (T=2)	-0.0012 (T=2)
Output (y)	Trough (Min)	-0.0008 (T=2)	-0.0010 (T=2)	-0.0012 (T=2)
Inflation (π)	Trough (Min)	-0.0005 (T=2)	-0.0005 (T=2)	-0.0005 (T=2)
Policy Rate (i)	Trough (Min)	-0.0005 (T=8)	-0.0005 (T=6)	-0.0005 (T=6)
10-Year Rate (r10)	Net response	-0.0002 (T=3)	0.0002 (T=5)	0.0003 (T=3)
Lending Rate (rL)	Trough (Min)	-0.0003 (T=5)	-0.0002 (T=3)	-0.0002 (T=7)

Notes: Values are deviations from steady state under perfect-foresight QT scenarios. Brackets report the quarter of the key event: **P** = peak, **T** = trough, **E** = net event quarter (peak or trough depending on the series). Percent variables are in **%**, rates/spreads in **percentage points (pp)**.

First, QT intensity plays a central role in determining timing. More front-loaded QT leads financial variables to reach their peaks and troughs earlier. For example, the BOJ holdings trough occurs in Quarter 3 under Stress QT, compared with Quarter 9 under Gradual QT. In contrast, real-side troughs consistently appear in Quarter 2 across all scenarios, indicating that QT pace primarily affects the magnitude rather than the timing of real responses.

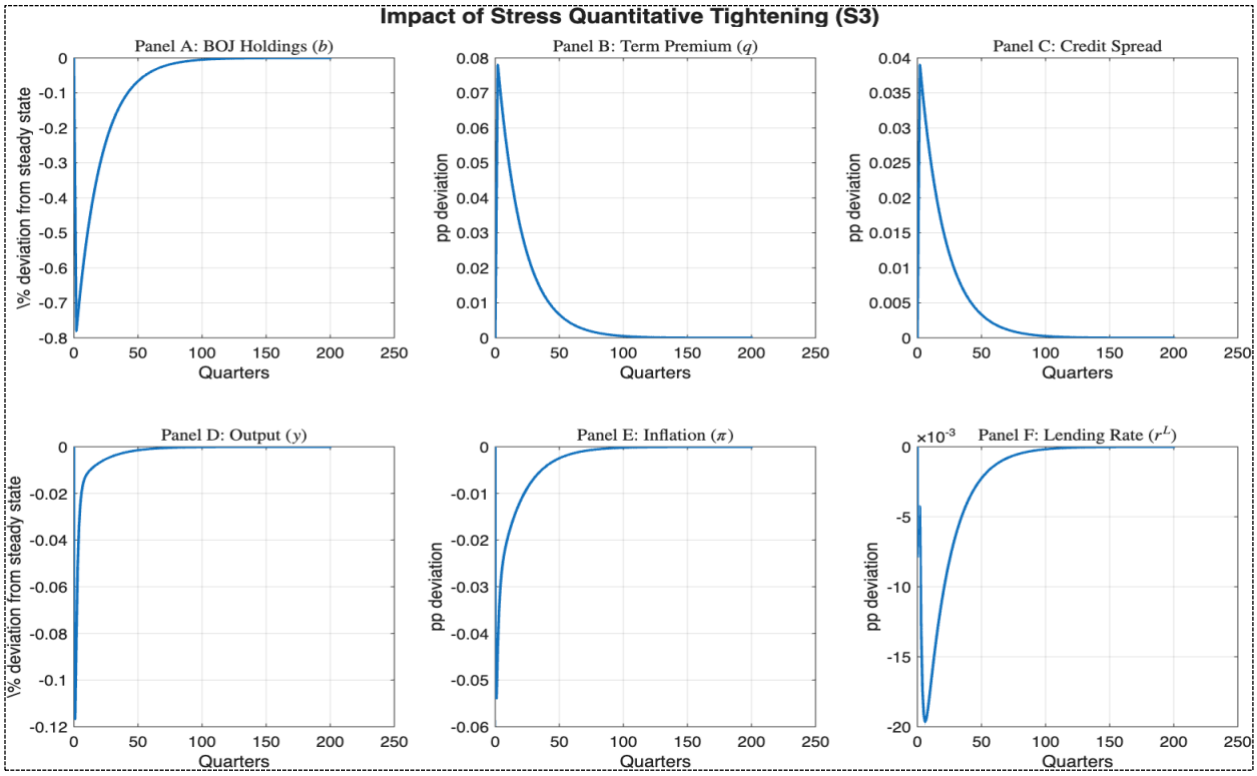


Fig. 5 Dynamic Effects of Stress Quantitative Tightening (S3)

Second, real-side contractions increase proportionally with QT intensity. Output and consumption experience their largest declines under Stress QT, indicating that more aggressive QT produces stronger real effects. Financial variables show similar scaling behavior, with increases occurring in a relatively linear manner.

Inflation and the policy rate reach identical trough magnitudes across all scenarios, suggesting that stronger QT deepens real contractions without generating disproportionate disinflation. The ten-year rate displays a negative net response under Gradual QT but turns positive under Accelerated and Stress QT, indicating that policy accommodation partially offsets term-premium effects when normalization proceeds more slowly.

6.4.3 Dynamic Adjustment under Stress QT

Fig. 5 presents the complete dynamic paths under Stress QT. Financial variables respond immediately to the shock and then gradually return toward the steady state. In contrast, real variables adjust more slowly and remain below their equilibrium levels for a prolonged period. This contrast highlights the difference between a fast-moving financial channel and a slower real economic adjustment process.

Interest-rate dynamics illustrate the interaction between market tightening and monetary policy accommodation. Initial increases in premia and spreads raise long-term and lending rates, while subsequent short-rate adjustments generate downward pressure on effective lending costs.

6.4.4 Transmission Mechanism of Quantitative Tightening

Fig. 6 provides a mechanism-based illustration of QT transmission. The sequence begins with balance-sheet reduction, which tightens financial conditions, increases market interest rates, and ultimately reduces real economic activity. The upper panel shows how balance-sheet runoff feeds into term premia and credit spreads. The middle panel links financial conditions to market interest rates. The lower panel shows how interest-rate movements translate into declines in output and inflation. The mechanism operates consistently across all scenarios, while the speed and intensity of transmission depend on the QT design.

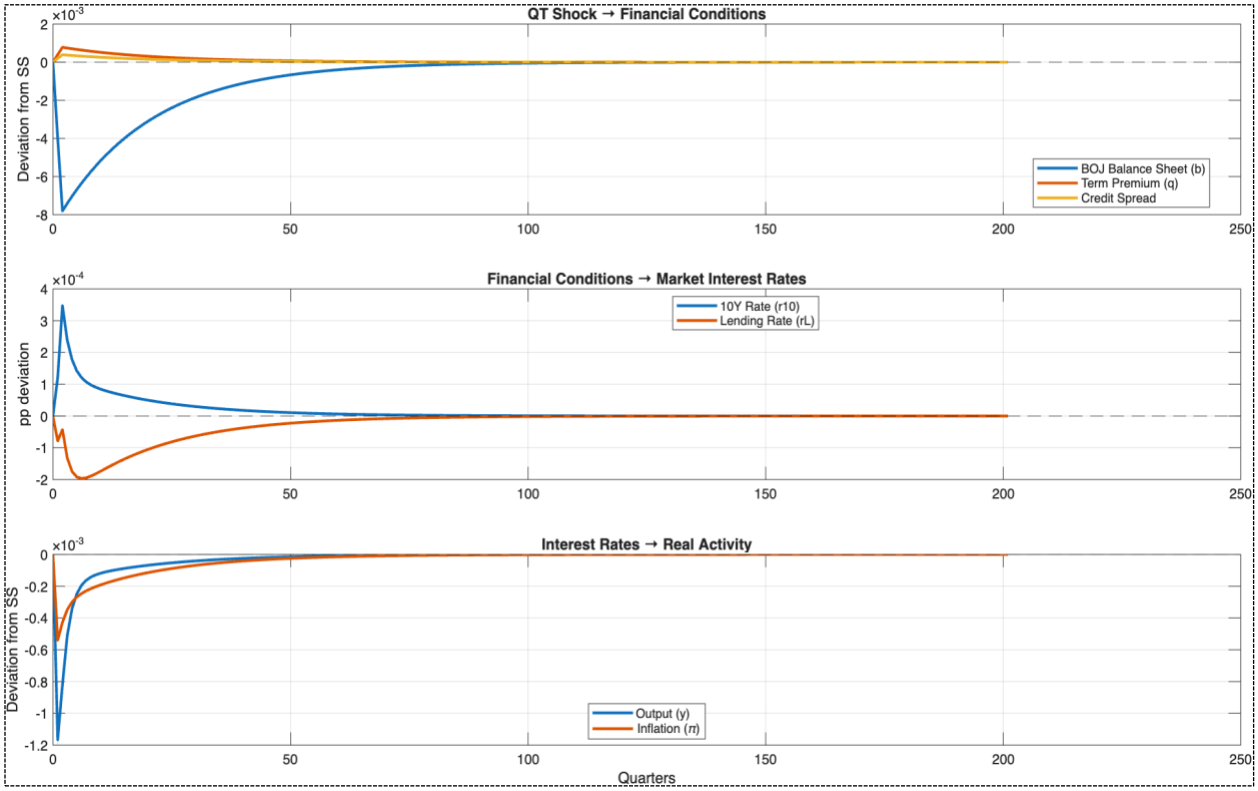


Fig. 6 Transmission Mechanism of Stress Quantitative Tightening (S3)

7. Robustness and Sensitivity Analysis

The following section evaluates whether assumptions regarding prior distributions, observable data, and shock identification methods materially affect the core results of the paper. The research aims to verify the stability of quantitative tightening (QT) scenarios and their transmission mechanisms rather than to replicate exact baseline magnitudes under alternative settings. Across all exercises, the analysis preserves its essential results.

Alternative Priors and Key Parameter Sensitivity: The research begins by assessing how alternative prior assumptions influence model results for key parameters that control QT transmission and real-side adjustment. These include nominal rigidity, monetary policy rule parameters, and the financial channel coefficients governing the mapping from BOJ balance-sheet movements to term premia and from term premia to corporate credit spreads. The research bases this analysis on Japan's extended near-ELB period, where data may only weakly identify certain structural parameters. The objective is therefore to test the sensitivity of policy conclusions, rather than to search for an optimal calibration. The re-estimation process with different prior distributions produces results that remain economically meaningful and consistent with the baseline findings. Most importantly, the ordering of QT scenarios is unchanged. Stress QT continues to generate the strongest tightening in financial conditions and the largest output and consumption costs, followed by Accelerated and Gradual QT. While magnitudes adjust in expected ways, there are no sign reversals or breakdowns in the balance-sheet to premia to real-activity transmission. These results confirm that the study's central conclusions are data-driven and not an artefact of restrictive prior assumptions.

Alternative Observable Sets and Measurement of Financial Conditions: We assess robustness to alternative measurements of financial conditions in the observable set. The baseline specification contains separate indicators capturing long-term interest rate conditions and corporate borrowing costs. The analysis considers alternative specifications that either minimize redundancy among correlated financial series or replace individual indicators with a composite borrowing-cost measure that better represents the model's effective lending rate. This exercise is necessary because QT transmission in the model operates primarily through financial market conditions. If the mechanism depended on a single market proxy, the policy relevance of the results would be weakened. Across alternative observable sets, the financial channel remains active and economically significant. The parameters linking BOJ balance-sheet movements to term premia and credit spreads preserve their sign and relative importance. Scenario simulations continue to show that more front-loaded QT leads to faster deterioration of financial conditions and larger real-side contractions. These findings indicate that the QT mechanism reflects structural financial amplification rather than data construction choices.

Alternative Shock Specifications and Persistence Assumptions: The research conducts two complementary exercises to distinguish QT-induced tightening from generic financial stress. This is achieved by comparing the propagation of QT shocks with that of exogenous financial disturbances, such as premium or spread shocks that do not affect BOJ holdings. In addition, we vary the persistence of the QT impulse by adjusting the reversion speed of the balance-sheet state variable while holding scenario design constant. The two disturbances operate through distinct transmission mechanisms. QT shocks follow a sequential process that begins with BOJ balance-sheet reduction and proceeds through endogenous premia adjustment, while generic financial shocks affect lending conditions without altering central bank asset holdings. The analysis shows that faster and more front-loaded QT remains more contractionary regardless of persistence assumptions, confirming that the scenario ranking does not depend on a specific timing calibration. These results support the interpretation that the paper captures exit-strategy dynamics rather than generic financial tightening effects.

Summary and Policy Robustness: The analysis satisfies a stringent policy-relevant robustness criterion. Across all configurations, faster and more front-loaded QT generates stronger tightening in terms of premia and credit spreads and larger output and inflation costs. The balance sheet to financial conditions to real-activity transmission mechanism remains stable throughout. Robustness is defined not by invariance of magnitudes, but by the preservation of scenario ranking and transmission logic. The results, therefore, support the conclusion that a gradual and well-communicated

QT strategy dominates front-loaded normalization in an environment characterized by strong financial sensitivity and uncertain inflation dynamics.

8. Conclusion and Policy Implications

The research assesses Japan's unorthodox monetary policy exit strategies through a model that includes both Bank of Japan (BOJ) balance-sheet operations and financial conditions transmission mechanisms within a New Keynesian DSGE framework. The research uses counterfactual quantitative tightening (QT) experiments with perfect foresight to examine how different speeds and timings of BOJ balance-sheet reduction impact term premia, corporate credit spreads, and effective borrowing costs, and how these financial changes affect output and inflation when the short rate adjusts endogenously through a shadow-rate framework. The research reveals that QT design operates primarily through premium value changes and spread movements because the BOJ uses short-rate adjustments to support real economic stability, yet these adjustments cannot fully neutralize the effects of initial financial tightening when amplification effects become strong.

8.1 Major Empirical Findings

The empirical analysis yields several robust findings:

- First, QT speed generates a clear and stable financial tightening pattern. Faster balance-sheet reduction leads to larger and earlier declines in BOJ asset holdings, which translate into higher term premia and wider corporate credit spreads. The ranking across scenarios remains consistent, with Stress or front-loaded QT producing the strongest and earliest premium tightening, followed by Accelerated QT, and then Gradual QT, which produces the smallest effects.
- Second, real-side costs increase monotonically with financial tightening. All three QT scenarios produce declines in output, inflation, and consumption, with larger contractions associated with faster balance-sheet runoff. This pattern indicates that the macroeconomic costs of QT in Japan arise primarily through the financial-conditions channel rather than through balance-sheet arithmetic alone.
- Third, endogenous policy-rate dynamics generate a mixed normalization pattern. The short rate moves in an easing direction in response to weaker activity and lower inflation, consistent with the shadow-rate interpretation in a low-interest-rate environment. As a result, long-term and lending rates decompose into rising premium components and falling short-rate components. This decomposition explains why borrowing-rate measures may appear muted at certain horizons, even as term premia and spreads continue to increase, and highlights the need to evaluate QT jointly with the short-rate reaction function.
- Fourth, timing is as important as magnitude. Front-loaded QT shifts the peak tightening of premia and spreads to earlier periods, increasing the likelihood that normalization coincides with fragile inflation dynamics or weak demand conditions. By contrast, gradual QT spreads adjustment over time and reduces the risk of abrupt repricing in credit conditions.
- Finally, robustness and sensitivity analysis indicate that while the qualitative ordering of scenarios remains stable, quantitative outcomes are most sensitive to parameters governing financial amplification from BOJ holdings to term premia and from premia to credit spreads. This result underscores the importance of continuous monitoring of market-based indicators of premia and spreads during normalization.

8.2 Operational implications for the BOJ

The results support a pragmatic exit strategy centered on sequencing, pace, communication, and risk management.

Sequencing: QT can tighten financial conditions even when short-term interest rates are declining. Balance-sheet runoff should therefore not be relied upon as the primary tightening instrument when inflation remains weak or insufficiently anchored. In such conditions, the BOJ should prioritize short-rate guidance and targeted liquidity

operations, while maintaining a slow and predictable runoff path. Faster balance-sheet normalization becomes more appropriate only once inflation approaches target levels and private demand demonstrates resilience to higher premia.

Pace: Across all scenarios, faster QT induces larger and earlier increases in term premia and credit spreads, alongside deeper contractions in output and inflation. A gradual, state-dependent runoff path therefore dominates front-loaded normalization in a low-inflation environment. Front-loaded QT compresses adjustment into a short time window, increases the risk of non-linear market reactions, and raises the likelihood that the BOJ must offset tightening through more aggressive short-rate easing, complicating communication and policy credibility. If accelerated normalization becomes necessary, it should proceed through small and reversible steps rather than discrete jumps.

Communication: Because anticipated QT affects pricing ahead of implementation, communication itself functions as a policy instrument. The BOJ should frame QT within a rule-like framework that specifies conditions under which runoff accelerates, pauses, or reverses, such as sustained inflation momentum, stable credit spreads, and orderly market functioning. Clear guidance that QT is not a substitute for interest-rate policy, and that runoff will be adjusted if premia widen materially or inflation expectations weaken, can reduce the risk of abrupt repricing.

Risk Management: The analysis shows that the primary channel of QT costs operates through premium and spread tightening. Term premia and credit spreads should therefore be treated as operational state variables during normalization. Risk-mitigation tools include standing liquidity facilities, collateral policy adjustments, temporary reinvestment flexibility, and close coordination with supervisory authorities to monitor leverage and liquidity mismatches. The objective is not to prevent all premium adjustments, but to avoid disorderly movements that disproportionately harm demand and inflation.

Policy choice under uncertainty: Given uncertainty surrounding the strength of financial amplification, a cautious ramp strategy is appropriate. The BOJ should begin with small runoff steps, evaluate responses in premia, spreads, and effective lending rates, and scale normalization only if financial conditions remain orderly and inflation proves resilient.

8.3 Limitations and Future Research

Several limitations warrant acknowledgment. First, the QT channel is implemented through reduced-form mappings from BOJ holdings to term premia and from premia to credit spreads. While parsimonious, this approach abstracts from heterogeneous investors, segmented markets, and intermediary balance-sheet constraints. Second, QT experiments are conducted under perfect foresight, omitting learning dynamics, credibility shocks, and state-dependent risk pricing that may generate non-linear responses. Third, the real-side block is intentionally compact, excluding richer investment dynamics, bank credit quantities, and fiscal interactions.

These limitations motivate future research directions, including the introduction of an explicit intermediary sector to endogenize spreads and capture non-linear amplification, the adoption of imperfect-credibility or anticipated-policy frameworks to study communication effects, and the expansion of the observable set to incorporate richer real and credit-side dynamics.

Overall, the evidence supports a clear policy conclusion: a gradual, state-contingent QT strategy, anchored by transparent communication and supported by market-functioning tools, offers the most effective approach for minimizing macroeconomic disruption while enabling balance-sheet normalization in Japan’s low-inflation environment.

Statements and Declarations

Funding

The author received no specific funding for this study.

Conflict of interest

The author declares that there is no conflict of interest.

Ethical approval

This study does not involve human participants or animals.

Data Availability Statement:

The research data originated from public sources, which provide free access to all information. Japanese monetary and financial variables, including policy interest rates, long-term government bond yields, and Bank of Japan balance-sheet series, were collected from the Bank of Japan Statistics portal (https://www.stat-search.boj.or.jp/) and the Statistics Bureau of Japan (https://www.stat.go.jp/), OECD Statistics (https://stats.oecd.org/), and Federal Reserve Economic Data (FRED) maintained by the Federal Reserve Bank of St. Louis (https://fred.stlouisfed.org/). Selected macroeconomic and financial series were cross-validated with the IMF International Financial Statistics (IFS) and the World Bank World Development Indicators (WDI). All raw data are publicly available from the respective sources. The processed dataset used for DSGE estimation and simulation is available from the corresponding author upon reasonable request.

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Appendix A: Model Structure, Data, and Estimation Details

Table A.1 Model Equations and Definitions

Block	Equations and Description	Eq. No.
Aggregate Resource Constraint	Aggregate output equals the sum of private consumption, investment, government expenditure, and net exports: (Government expenditure and net exports are treated as exogenous and absorbed into the steady state.) $$Y_t = C_t + I_t + G_t + NX_t$$	(A.1)
Households – Preferences	Households maximize expected lifetime utility with external habit formation: $$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right]$$	(A.2)
Households – Budget Constraint	Nominal intertemporal budget constraint: $$P_t C_t + B_t = (1 + i_{t-1}) B_{t-1} + W_t N_t + \Pi_t - T_t$$	(A.3)
Households – Euler Equation	Optimal consumption choice implies: $$\left(C_t - hC_{t-1} \right)^{-\sigma} = \beta E_t \left[(C_{t+1} - hC_t)^{-\sigma} \frac{1 + i_t}{\pi_{t+1}} \right]$$	(A.4)
Households – Labor Supply	Optimal labor supply condition: $$\frac{W_t}{P_t} = (C_t - hC_{t-1})^{\sigma} N_t^{\varphi}$$	(A.5)
Firms – Final Good Aggregation	Dixit–Stiglitz aggregator for final output: $$Y_t = \left(\int_0^1 Y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}$$	(A.6)
Firms – Intermediate Production	Intermediate firms produce using capital and labor: $$Y_{i,t} = A_t K_{i,t}^{\alpha} N_{i,t}^{1-\alpha}$$	(A.7)
Firms – Phillips Curve	Price rigidity generates the New Keynesian Phillips Curve: $$\pi_t = \beta E_t[\pi_{t+1}] + \kappa mc_t + u_t$$ where u_t denotes a cost-push (price-setting) shock.	(A.8)
Monetary Policy Rule	Taylor-type rule with interest-rate smoothing: $$i_t = \rho_i i_{t-1} + (1 - \rho_i)\left[i^* + \phi_\pi (\pi_t - \pi^*) + \phi_y \tilde{Y}_t \right] + \varepsilon_t^i$$ where $\tilde{Y}_t$ denotes the output gap.	(A.9)
Effective Lower Bound	Policy rate constrained by the ELB: $$i_t = \max\left(i_t^{shadow}, ELB \right)$$	(A.10)
BOJ Balance Sheet	Evolution of BOJ government bond holdings: $$B_t^{BOJ} = (1 - \delta_b) B_{t-1}^{BOJ} + \Delta B_t^{BOJ}$$	(A.11)
Monetary Base Link	Monetary base linked to BOJ assets: $$M_t = \lambda B_t^{BOJ} + Z_t$$	(A.12)
Term Premia (Portfolio Balance)	Term premia determined by BOJ bond holdings: $$TP_t = \gamma (B_t^{Total} - B_t^{BOJ}) + \varepsilon_t^{TP}$$ where B_t^{Total} denotes total outstanding government bonds.	(A.13)
Financial Conditions – Credit Spread	Endogenous corporate credit spread: $$S_t = f(\text{Leverage}_t, \text{Risk}_t, \dots)$$	(A.14)
Lending Rate	Lending rate includes the credit spread: $$r_t^L = r_t^f + S_t$$	(A.15)

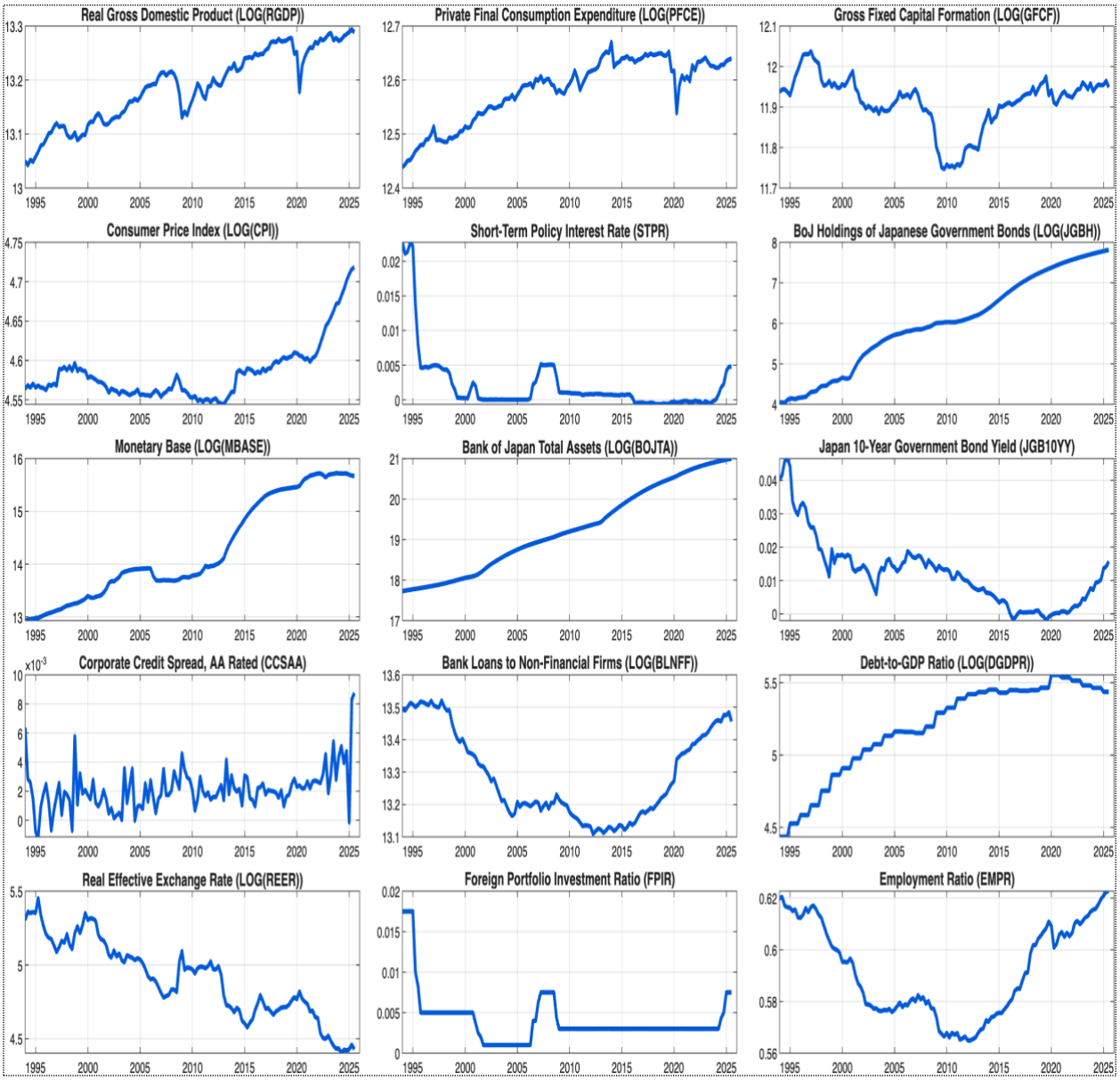


Fig. A.1 Time Series of Observed Macroeconomic and Financial Variables Used in Model Estimation

Table A.2 List of Abbreviations

The following abbreviations are used in this manuscript:

BOJ	Bank of Japan	IRF	Impulse Response Function
DSGE	Dynamic Stochastic General Equilibrium	MCMC	Markov Chain Monte Carlo
NK	New Keynesian	ELB	Effective Lower Bound
QE	Quantitative Easing	ZLB	Zero Lower Bound
QT	Quantitative Tightening	HPD	Highest Posterior Density
YCC	Yield Curve Control	AIC	Akaike Information Criterion
JGB	Japanese Government Bond	SIC	Schwarz Information Criterion
TP	Term Premium	MH	Metropolis–Hastings
UMP	Unconventional Monetary Policy	BOJTA	Bank of Japan Total Assets
CCS	Corporate Credit Spread	JGB10Y	10-Year Japanese Government Bond Yield

Appendix B: MCMC Convergence Diagnostics (Brooks and Gelman, 1998)

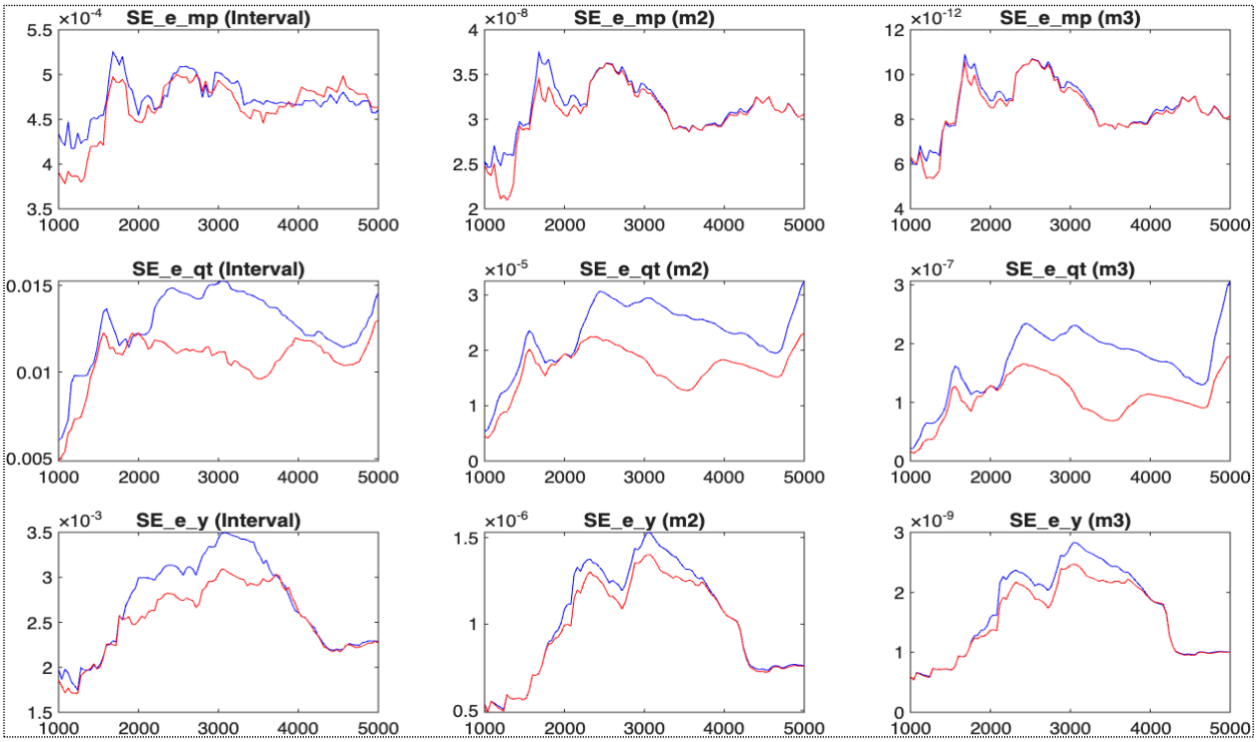


Fig. B.1 Brooks–Gelman (1998) MCMC Convergence Diagnostics for Structural Shock Standard Deviations (Set I)

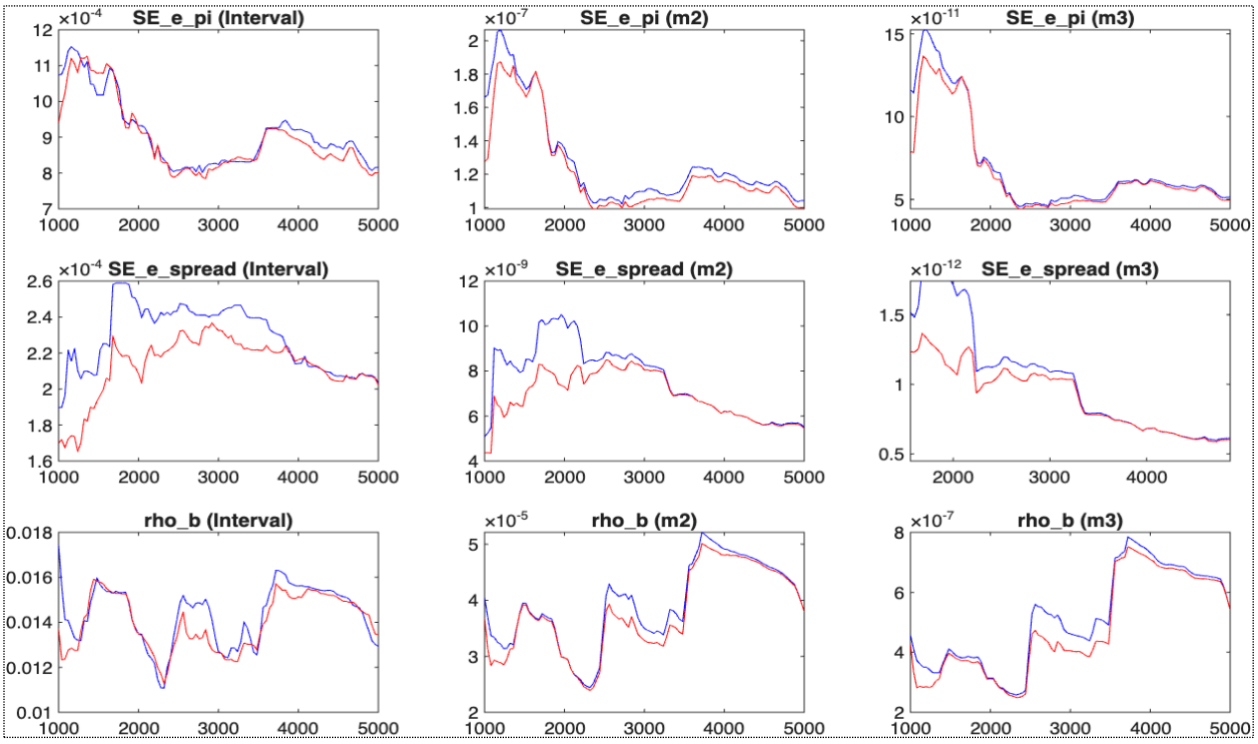


Fig. B.2 Brooks–Gelman (1998) MCMC Convergence Diagnostics for Structural Shock Standard Deviations (Set II)

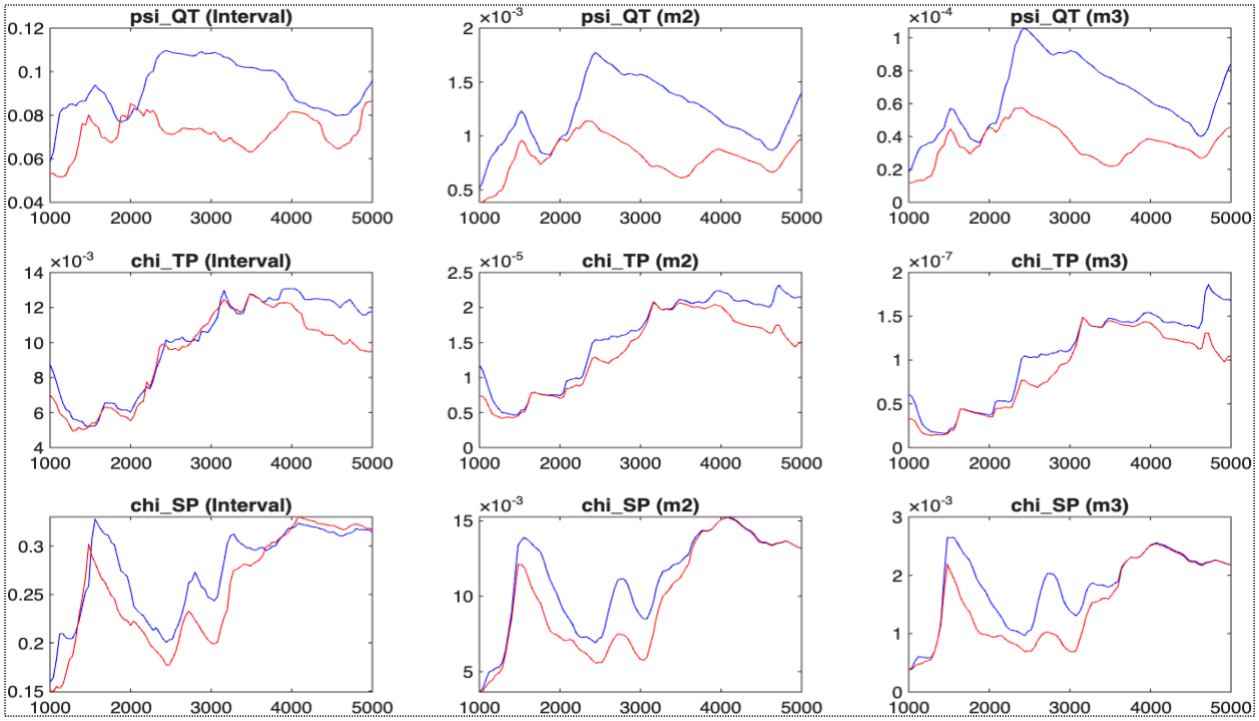


Fig. B.3 Brooks–Gelman (1998) MCMC Convergence Diagnostics for Structural Parameter Estimates (Set I)

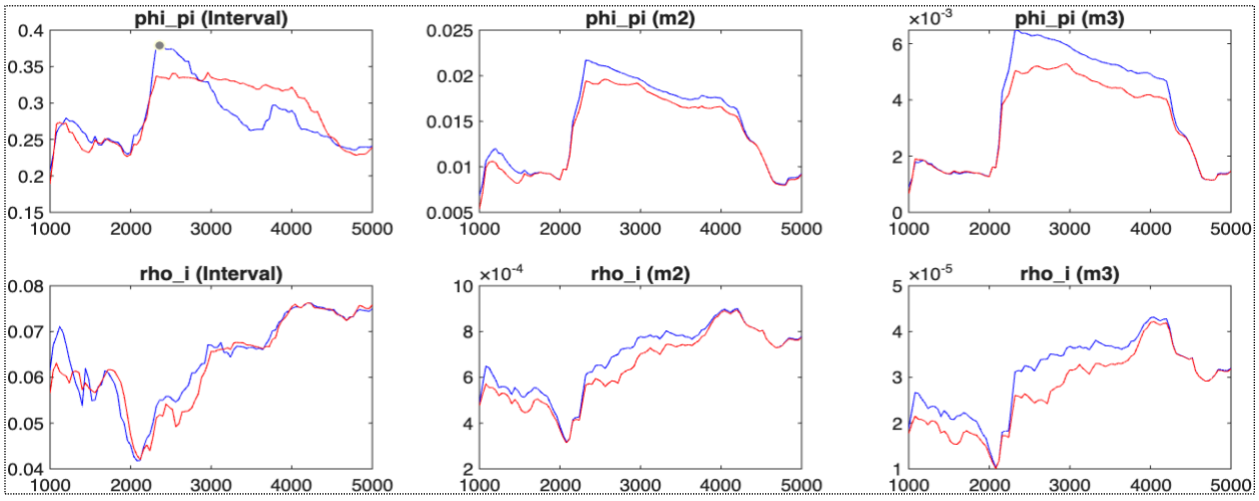


Fig. B.4 Brooks–Gelman (1998) MCMC Convergence Diagnostics for Structural Parameter Estimates (Set II)

Note: Fig. B.1–B.4 report Brooks–Gelman (1998) MCMC convergence diagnostics for all estimated structural parameters and shock standard deviations in the Japan DSGE model. The diagnostics rely on multiple independent Markov chains and assess convergence using interval- and moment-based measures. The results indicate stable convergence and proper chain mixing, supporting the reliability of Bayesian estimation and subsequent policy and counterfactual analysis.

Appendix C: Historical Shock Decomposition

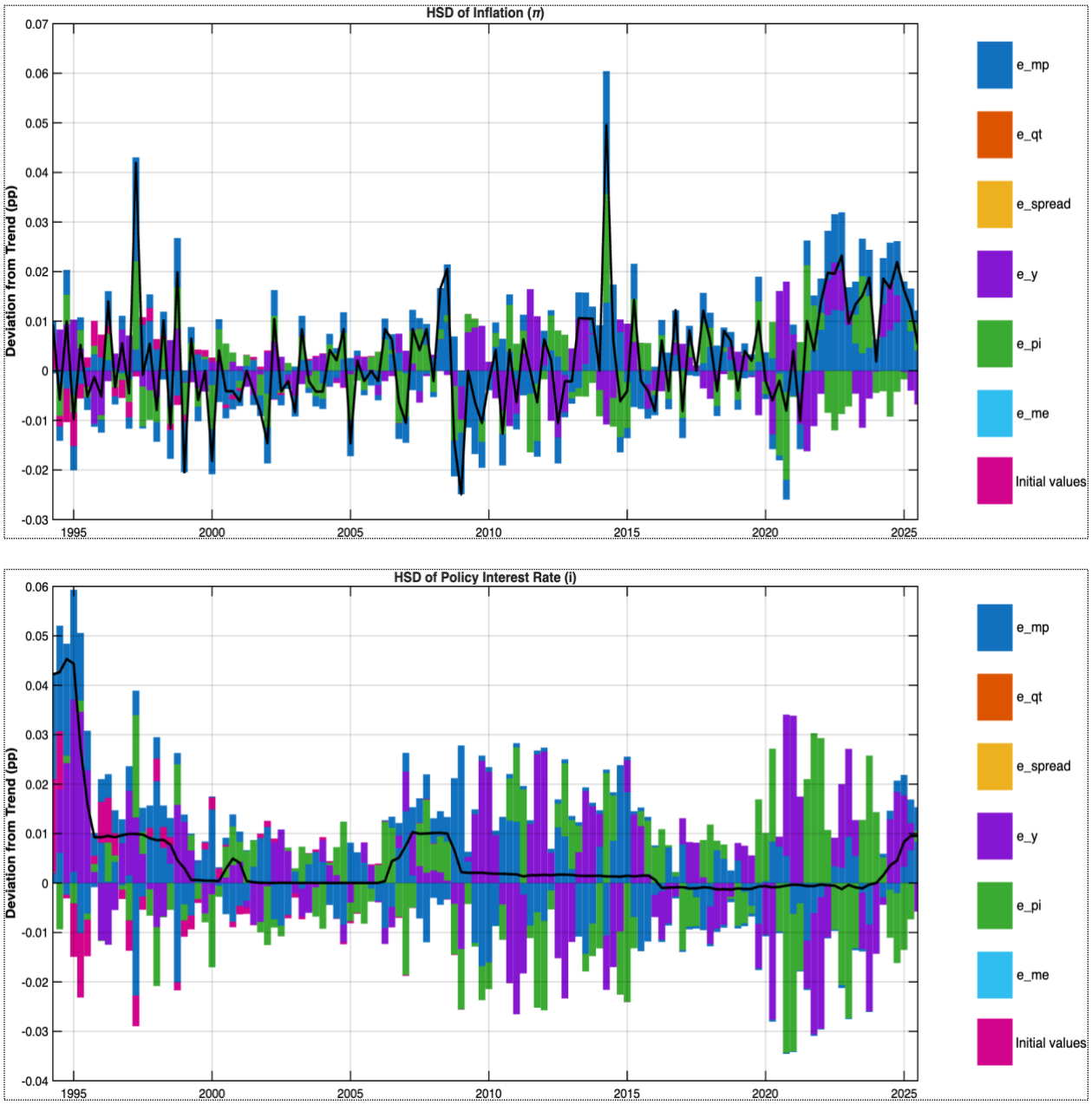


Fig. C.1 Historical Shock Decomposition of Inflation (π) and the Policy Interest Rate (i)

Note: These figures present the historical shock decomposition of inflation (π) and the short-term policy interest rate (i) obtained from the estimated DSGE model. The stacked bars show how different structural shocks contribute to deviations from steady state through monetary policy, demand, inflation, and balance-sheet and financial-conditions channels. Real and price-setting shocks dominate inflation movements, while financial and balance-sheet shocks primarily influence policy dynamics. The initial values normalize the system at its steady-state condition.