Yield-Curve Control Policy under Inelastic Financial Markets*

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Abstract

We develop a New Keynesian framework that incorporates the term structure of financial markets, emphasizing the role of government and central bank balance sheet composition in monetary policy transmission. Our model accounts for microfounded market segmentation across asset classes and maturities based on finite and estimable asset demand elasticities. We show that unconventional policy interventions, such as large-scale asset purchase programs and yield-curve control policies, effectively stabilize the economy during normal periods and at the zero lower bound, albeit by extending ZLB episodes and reducing the efficacy of future short-term rate adjustments.

Keywords: Term Structure, Yield-Curve Control, Market Segmentation
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Note: The ordering of the names of the authors is not indicative of relative contributions; it was chosen arbitrarily (or by mutual agreement) for practical reasons.

1 Introduction

Since the 2007–2008 Global Financial Crisis, unconventional monetary policies have become mainstream. Constrained by the zero lower bound (ZLB) on short-term rates, policymakers adopted strategies—such as expanding central bank balance sheets and increasing government debt issuance—to lower long-term rates, stimulate aggregate demand, and mitigate recessionary pressures. The COVID-19 pandemic further intensified this dynamic, prompting the Federal Reserve to implement another round of unconventional interventions as the policy rate once again reached the ZLB.[1]

This paper develops a tractable New Keynesian framework that incorporates an endogenous term structure of interest rates in bond markets, enabling an analysis of both conventional and unconventional monetary and fiscal policies. In contrast, standard log-linearized models typically include only a single policy rate, neglecting both the term structure of interest rates and heterogeneous asset returns. This limitation arises from the absence of frictions in asset substitution (e.g., asset demands are perfectly elastic), which leads to the equalization of expected returns across assets and maturities.[2] As a result, additional assets become redundant in monetary policy analysis.

To address these limitations, our framework builds on prior studies that emphasize market segmentation and the inelastic demand across bonds of different maturities as critical for understanding the effectiveness of quantitative easing programs. We integrate: (i) financial market segmentation, represented by demand curves with finite own and cross elasticities; (ii) households' endogenous portfolio rebalancing across asset classes and maturities; and (iii) the real effects of government and central bank balance sheet size and composition. These components are essential for understanding the transmission mechanism of unconventional monetary policies.

We examine the cyclical properties of various monetary interventions implemented as simple policy rules. Initially, we analyze a conventional policy rule for the short-term rate and its impact on the yield curve and the broader economy. We then introduce a yield-curve control (YCC) policy, in which the central bank directly manipulates the entire yield curve. Our framework reveals notable differences between these policies, particularly dur-

[1]In March 2020, the Federal Reserve lowered its policy rate to 0% - 0.25%. The Fed committed to keeping interest rates low until the economy achieved full employment and maintained 2% inflation consistently. Concurrently, the unprecedented CARES Act injected nearly \$500 billion in support of the Fed.

[2]This outcome also follows from the absence of a price of risk under log-linear approximation, resulting in the well-known *expectations hypothesis*, which posits that long-term bond returns equal the average of expected future short-term rates.

ing episodes when the policy rate is constrained by the ZLB. For instance, under conventional policy, a reduction in the supply of risk-free government bonds is recessionary at the ZLB, consistent with the safe-asset shortage literature (see, e.g., Caballero and Farhi (2017) and Caballero et al. (2021)). In contrast, under YCC, the central bank shifts the entire yield curve downward, reducing the effective household savings rate and stimulating aggregate demand, thus preventing a recession.[3] We find that YCC policies generally provide more effective economic stabilization and improve household welfare relative to conventional short-term rate policy.

However, YCC policy has side effects, such as prolonging ZLB episodes. By actively easing long-maturity yields, YCC generates additional downward pressure on short-term bond returns through household portfolio reallocation. Lower long-term rates prompt households to shift wealth from long-term bonds into: (i) short-maturity bonds, which further depress short-term yields; and (ii) private loan markets, which reduces firms' borrowing costs and consumption prices through lower production costs.[4] When the ZLB binds, YCC primarily operates by manipulating long-term bond yields, delaying the exit from the ZLB. Thus, household portfolio reallocation creates a feedback loop between ZLB duration and reliance on YCC: YCC extends ZLB duration while the economy becomes increasingly dependent on its stabilization. To the best of our knowledge, this outcome is novel.

Our asset demand systems incorporate finite demand elasticities and cross elasticities across asset classes and maturities, allowing households to rebalance their portfolios in response to relative changes in returns or other fundamentals, though not as perfectly as in log-linearized conventional models. A key advantage of this approach is that the demand elasticity for each asset class serves as a sufficient statistic for its degree of market segmentation, facilitating empirical testing and estimation of the segmented market hypothesis. We estimate the bond market's segmentation degree—or its demand elasticity—based on our model structure.

In Online Appendix D, we develop a microfoundation for inelastic asset demands based on imperfect information about asset returns. We assume that each household is subdivided into a continuum of families and family members, each with a distinct, imperfect informa-

[3]Even under conventional policy, a declining short-term rate lowers long-term bond yields through households' endogenous portfolio reallocation, reducing the effective savings rate. However, this channel is insufficient for boosting aggregate demand when the economy is constrained by the ZLB and conventional policy becomes ineffective.

[4]Decreases in the aggregate price index further intensify downward pressure on the short-term policy rate under an inflation-targeting rule, extending the duration of ZLB episodes.

tion set regarding future asset returns, while consumption is perfectly insured within the household. Lacking a common signal, the household allocates aggregate savings uniformly among its members, who then invest their share in the asset they deem most profitable. This behavior leads to the inelastic portfolio demand function, with cross-sectional dispersion in expected asset returns determining the degree of market segmentation for each asset class. To simplify aggregation of individual portfolio choices, we model differences in expected returns as Fréchet-distributed shocks around their rationally anticipated levels.[5] Borrowing this aggregation technique from the international trade literature (e.g., Eaton and Kortum (2002)), our framework seamlessly incorporates new asset types and varying degrees of segmentation across assets and maturities, yielding tractable formulas for household portfolio shares as functions of relative expected asset returns. Our formulation encompasses the classic *expectations hypothesis* as a special case while allowing for deviations due to imperfect information and behavioral factors.

Related Literature We contribute to several strands of the macroeconomics and finance literature. Early work emphasizes the role of macroeconomic factors in explaining the term structure of interest rates (Ang and Piazzesi, 2003; Rudebusch and Wu, 2008; Bekaert et al., 2010).[6] However, these models typically employ an ad hoc affine term structure (e.g., Duffie and Kan (1996)) without microfoundations. We extend this literature by modeling the term structure in a setting with multiple asset classes (e.g., government bonds and private loans) and nominal rigidities. By explicitly incorporating government and central bank balance sheets alongside households' endogenous portfolio choices across the yield curve, our framework links business cycle dynamics, financial markets, and monetary policy.

The preferred-habitat theory of the term structure has been developed in works such as Modigliani and Sutch (1966), Vayanos and Vila (2021), and Kekre et al. (2023).[7] Building on Vayanos and Vila (2021), Ray (2019) proposes a New Keynesian model that links monetary policy, business cycles, and the term structure; in his model, an arbitrageuer's capacity to absorb risks determines term premia along the yield curve, which in turn determines the effective savings rate that households face for their intertemporal substitution. In contrast, our framework abstracts from arbitrageurs and introduces an asset demand system

[5]For general properties of the Fréchet distribution, see, e.g., Gumbel (1958).

[6]By examining the joint dynamics of bond yields and macroeconomic variables in a VAR setting with a no-arbitrage restriction, Ang and Piazzesi (2003) show that models incorporating business cycle factors yield better forecasts than those relying solely on unobservable factors.

[7]In international macroeconomics, Gourinchas et al. (2022) and Greenwood et al. (2022) explore how the preferred-habitat setting jointly determines exchange rates and the term structure of interest rates.

with finite elasticities that leads to financial market segmentation, following the recent demand system literature (Koijen and Yogo, 2019) and the inelastic market literature (Gabaix and Koijen, 2022). Even in a log-linearized version of the model, our framework generates positive term premia both at the steady state and out of the steady state. Also, the endogenous portfolio rebalancing—also examined by Alpanda and Kabaca (2020) in the context of LSAP spillovers—yields distinctive dynamics (see Section 2.1).[8]

Another literature strand (Gertler and Karadi, 2011; Cúrdia and Woodford, 2011; Christensen and Krogstrup, 2018, 2019; Karadi and Nakov, 2021) explores the link between the central bank's balance sheet and monetary policy, providing insights into how large-scale asset purchases mitigate disruptions in financial markets.[9] Most studies focus on aggregate balance sheet expansion rather than multiple bond maturities. Our unified framework demonstrates how central banks can adjust bond portfolios along the yield curve for stabilization, and our finding that active long-term bond manipulation improves welfare aligns with Sims and Wu (2021).[10]

While our analysis of the ZLB recessions mirrors prior work (Swanson and Williams, 2014; Caballero and Farhi, 2017; Caballero et al., 2021), we further emphasize the benefits of managing both the size and composition of the central bank's balance sheet across maturities when the ZLB binds. To our knowledge, this is one of the first general equilibrium models to combine the term structure of interest rates, a binding ZLB, multiple financial assets, yield-curve control policies, the portfolio balance channel under demand functions with finite elasticities.

Layout Section 2 introduces the model and derives the main results. Section 3 examines the steady-state implications of various policies and calibration choices. Section 4 explores the short-run cyclical responses of the model to different shocks under alternative monetary policy regimes and economic conditions, including the ZLB. Section 5 concludes. The Appendix contains additional figures and tables. Online Appendix A provides detailed derivations and proofs; Online Appendix B outlines our calibration and estimation strate-

[8]For empirical assessments of the market-segmentation hypothesis as a determinant of the term structure, see, e.g., D'Amico and King (2013) and Droste et al. (2021).

[9]Gertler and Karadi (2011) note that compared with private market intermediaries, the central bank faces fewer balance sheet constraints, and as private intermediaries' constraints tighten during crises, central bank intermediation becomes more beneficial; Cúrdia and Woodford (2011) find targeted asset purchases effective under exogenous market disruptions.

[10]Sims and Wu (2021) assume that a wholesale firm and fiscal authorities issue perpetuities with decaying coupon payments. In contrast, we consider bonds with different maturities.

gies; and Online Appendix C derives the second-order approximation to welfare. Online Appendix D provides a microfoundation for our inelastic financial markets. Supplementary Material in Online Appendices E-H includes further figures and explanations.

2 Model

2.1 Representative Household

The representative household maximizes its expected discounted utility:

$$\max_{\{C_{t+j},N_{t+j}\}} \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left[\log(C_{t+j}) - \frac{\eta}{\eta+1} \left(\frac{N_{t+j}}{\bar{N}_{t+j}} \right)^{1+\frac{1}{\eta}} \right] , \tag{1}$$

where C_t denotes final good consumption and $N_t = \left(\int_0^1 N_t(\nu)^{\frac{\eta+1}{\eta}} \, \mathrm{d}\nu \right)^{\frac{\eta}{\eta+1}}$ is the aggregate labor index with $N_t(\nu)$ representing labor supplied in intermediate industry ν. The parameter η is the Frisch elasticity of labor supply, and $\bar{N}_t$ is the balanced-growth population, growing at a constant gross rate GN.

Each period, the household invests in f-period zero-coupon government bonds (with $f = 1, \ldots, F$) and provides loans to firms.[11] Its budget constraint is

$$C_t + \frac{L_t}{P_t} + \frac{\sum_{f=1}^{F} B_t^{H,f}}{P_t} = \frac{\sum_{f=0}^{F-1} R_t^f B_{t-1}^{H,f+1}}{P_t} + \frac{R_t^K L_{t-1}}{P_t} + \int_0^1 \frac{W_t(\nu) N_t(\nu)}{P_t} \, \mathrm{d}\nu + \frac{\Lambda_t}{P_t} , \tag{2}$$

where L_t denotes one-period loans to firms, yielding a return R_t^K; $W_t(\nu)$ is the wage in industry ν; and Λ_t aggregates transfers from lump-sum taxation and profits from the central bank and firms. $B_t^{H,f}$ represents nominal investment in f-maturity government bonds that pay one dollar at time $t + f$, with Q_t^f denoting the bond price (by definition, $Q_t^0 = 1$ at maturity). Households cannot issue risk-free bonds. The one-period return on an f-period bond is given by $R_t^f = \frac{Q_t^f}{Q_{t-1}^{f+1}}$, which captures the rate of bond price revaluation between adjacent periods. The gross yield of a zero-coupon bond with maturity f is defined as $YD_t^f := \left(Q_t^f \right)^{-1/f}$.[12]

[11] Alternatively, this may be interpreted as households purchasing one-period corporate bonds. Banks and financial intermediaries are abstracted from our framework; in the absence of intermediation frictions, both representations yield equivalent results.

[12] It follows that bond returns can alternatively be expressed as $R_t^f = \frac{\left(YD_t^f\right)^{-f}}{\left(YD_{t-1}^{f+1}\right)^{-(f+1)}}$.

2.1.1 Inelastic Portfolio Demands

The representative household determines optimal consumption, employment, and savings S_t, which are allocated between government bonds $B_t^H = \sum_{f=1}^F B_t^{H,f}$ and firm loans L_t, so that $S_t = B_t^H + L_t$.

Following the literature (Koijen and Yogo, 2019; Gabaix and Koijen, 2022), we assume that households' portfolio shares are determined by downward-sloping demand functions with finite own- and cross-price elasticities. This structural representation offers two advantages. First, the estimated demand elasticities (see Online Appendix B) summarize market segmentation across maturities. Second, it nests the benchmark New Keynesian model as a special case. Online Appendix D provides a microfoundation for these finite elasticity portfolio demand functions based on heterogeneous information about asset returns.

Let the household's portfolio share of the f-maturity bond in total government bond holdings be denoted by $\lambda_t^{HB,f}$, i.e., $\lambda_t^{HB,f} \equiv \frac{B_t^{H,f}}{B_t^H}$. We assume $\lambda_t^{HB,f}$ is given by:

$$\lambda_t^{HB,f} = \left(\frac{z_t^f \, \mathbb{E}_t[Q_{t,t+1} R_{t+1}^{f-1}]}{\Phi_t^B} \right)^{\kappa_B}, \tag{3}$$

where $\Phi_t^B \equiv \left[\sum_{j=1}^F \left(z_t^j \, \mathbb{E}_t[Q_{t,t+1} R_{t+1}^{j-1}] \right)^{\kappa_B} \right]^{\frac{1}{\kappa_B}}$. Here, κ_B represents the elasticity of the demand for the f-maturity bond with respect to its expected return R_{t+1}^{f-1}, discounted by the household's stochastic discount factor $Q_{t,t+1}$.[13] We assume $\kappa_B > 0$ throughout the paper.

Additionally, we introduce z_t^f as a shock to the portfolio preference for the f-maturity bond. For example, an increase in z_t^f will raise the household's f-maturity share of government bond holdings, given returns and other macroeconomic states. In equilibrium, this shock will raise the price of the f-maturity bond Q_t^f and induce households to reallocate their portfolios toward other maturities and private loans, thus pushing down their returns.[14] This shock, combined with the household's endogenous portfolio "rebalancing", is an important source of variation that generates an upward-sloping yield curve both at and away from the steady state. In the context of the preferred-habitat literature (Vayanos and Vila, 2021), this shock can be interpreted as a shock to the preferred-habitat demand for

[13] In our framework, $\mathbb{E}_t[Q_{t,t+1} R_{t+1}^{f-1}]$ does not equal 1 due to the inelasticity of demand in (3), consistent with the literature.

[14] Under our calibration and estimated κ_B, decreases in returns of other assets are smaller than the decrease in the original return R_{t+1}^f. This produces a phenomenon known as "localization" of demand shocks, as documented in Vayanos and Vila (2021) and Droste et al. (2021).

the f-maturity bond.

Given equation (3), the aggregate return on the household's bond portfolio is:

$$R_{t+1}^{HB} = \sum_{f=0}^{F-1} \lambda_t^{HB,f+1} R_{t+1}^{f}. \tag{4}$$

Using the effective bond return from (4), the household's portfolio share of total savings allocated to loans is given by:

$$\lambda_t^K = \left(\frac{z_t^K \, \mathbb{E}_t[Q_{t,t+1} R_{t+1}^K]}{\Phi_t^S} \right)^{\kappa_S}, \tag{5}$$

where $\Phi_t^S = \left[\left(\mathbb{E}_t[Q_{t,t+1} R_{t+1}^{HB}] \right)^{\kappa_S} + \left(z_t^K \mathbb{E}_t[Q_{t,t+1} R_{t+1}^K] \right)^{\kappa_S} \right]^{\frac{1}{\kappa_S}}$. Here, κ_S represents the elasticity of the demand for private loans with respect to their expected return R_{t+1}^K, discounted by the household's stochastic discount factor $Q_{t,t+1}$.[15] We assume $\kappa_S > 0$ throughout the paper. As the bond return R_{t+1}^{HB} depends on the bond portfolio $\{\lambda_t^f\}_{f=1}^F$, given by (3), our portfolio demand follows a nested constant elasticity of substitution (CES) structure.

Additionally, we introduce z_t^S as a shock to the portfolio preference for private loans. Similar to the case for $\{z_t^f\}$, this shock induces households to rebalance their portfolios, which affects the equilibrium returns of bonds with different maturities and private loans.[16]

Based on (3) and (5), the aggregate bond holdings by maturity f are:

$$B_t^{H,f} = \left(1 - \lambda_t^K\right) \lambda_t^{HB,f} S_t, \quad \forall f = 1, \ldots, F,$$

and the aggregate return on household savings is:

$$R_t^S = \left(1 - \lambda_{t-1}^K\right) R_t^{HB} + \lambda_{t-1}^K R_t^K. \tag{6}$$

Therefore, R_t^S is a weighted average of returns from bonds (across maturities) and loans,[17] representing the effective savings rate of households. The household's budget constraint

[15] Again, $\mathbb{E}_t[Q_{t,t+1} R_{t+1}^K]$ does not equal 1 in our framework, due to the assumed inelasticity of demand in (5), consistent with the literature.

[16] Equation (5) implies that the household's portfolio share in loans increases in response to higher loan returns R_{t+1}^K and decreases in response to the aggregate bond return R_{t+1}^{HB}.

[17] While our analysis assumes a one-period duration for private loans, extending the model to incorporate a term structure in the loan market is feasible. However, given our focus on unconventional monetary policy via central bank purchases of government bonds, we restrict our discussion to the term structure for bonds to maintain model tractability.

(2) can be rewritten as:

$$C_t + \frac{S_t}{P_t} = \frac{R_t^S S_{t-1}}{P_t} + \int_0^1 \frac{W_t(\nu)N_t(\nu)}{P_t}\,\mathrm{d}\nu + \frac{\Lambda_t}{P_t}. \tag{7}$$

Despite the richer asset structure and market segmentation, the representative household's problem ultimately resembles that of a conventional New Keynesian model.

Expectations Hypothesis Note that as $\kappa_B \to \infty$, $\kappa_S \to \infty$, and $z_t^f = z_t^S = 1$ for all f, t, our framework converges to a conventional New Keynesian model represented by:

$$\mathbb{E}_t[Q_{t,t+1}R_{t+1}^{f-1}] = \mathbb{E}_t[Q_{t,t+1}R_{t+1}^K] = 1, \quad \forall f. \tag{8}$$

In its log-linearized form, equation (8) becomes:

$$\mathbb{E}_t[\hat{R}_{t+1}^{f-1}] = \mathbb{E}_t[\hat{R}_{t+1}^K] = \hat{R}_{t+1}^0, \quad \forall f, \tag{9}$$

which makes all returns other than the policy rate $\hat{R}_{t+1}^0$ redundant. Equation (9) corresponds to the classic expectations hypothesis. Thus, our model specification with inelastic financial markets nests the conventional expectations hypothesis result as a special case.

2.1.2 Optimality Conditions

The solution to the household's problem in (1), subject to the budget constraint in (7), yields the following equilibrium conditions:

$$\left(\frac{N_t(\nu)}{\bar{N}_t}\right)^{\frac{1}{\eta}} = \left(\frac{C_t}{\bar{N}_t}\right)^{-1} \frac{W_t(\nu)}{P_t}, \tag{10}$$

$$1 = \beta\,\mathbb{E}_t\left[\frac{R_{t+1}^S C_t}{C_{t+1}\Pi_{t+1}}\right], \tag{11}$$

where $\Pi_{t+1} = P_{t+1}/P_t$ is the gross inflation rate. In equation (11), the effective savings rate R_{t+1}^S serves as the benchmark rate for intertemporal consumption decisions. This rate is a composite measure reflecting the returns on bonds of various maturities and loans, each weighted by its share in the aggregate portfolio. As a result, the endogenous portfolio rebalancing channel becomes central to the business cycle dynamics under forward-looking unconventional monetary policies (see Section 4).

Remarks Our results regarding imperfect substitution across assets are similar to those found in bond-in-the-utility models with finite substitution elasticities (e.g., Alpanda and Kabaca (2020)), but our formulation preserves the standard aggregate dynamics (i.e., equations (10) and (11)), which enhances tractability.[18]

Moreover, unlike the previous preferred-habitat literature, our framework does not rely on financial arbitrageurs to generate an upward-sloping yield curve; in our model, the bond market is segmented with the degree directly captured by the parameters κ_B and κ_S, and household portfolios are subject to each asset maturity and class-specific preference shocks $\{z_t^f\}_{f=1}^F, z_t^K$, which in equilibrium lead to different levels of term premium along the yield curve.

2.2 Capital Producer

A representative firm produces capital K_t and rents it to intermediate goods producers at price P_t^K. Capital is accumulated by investing final goods, depreciates at rate δ, and new investment I_t is implemented with a one-period lag. Hence, capital evolves according to

$$K_t = (1-\delta)K_{t-1} + I_{t-1}.$$

The firm's profits are given by

$$\Lambda_t^K = P_t^K K_t - P_t I_t,$$

with P_t denoting the final good price index. Maximizing profits with respect to I_t yields the first-order condition

$$1 = \mathbb{E}_t\Big[Q_{t,t+1}\,\Pi_{t+1}\left((1-\delta) + \frac{P_{t+1}^K}{P_{t+1}}\right)\Big],$$

where $\Pi_{t+1} = \frac{P_{t+1}}{P_t}$ is the gross inflation rate.

[18] Harrison (2024) similarly introduces a portfolio friction that creates a wedge between short- and long-run bond returns, allowing the central bank's quantitative easing policy to work.

2.3 Firms

There is a continuum $\nu \in [0,1]$ of intermediate goods, each produced by a monopolist using capital and labor according to

$$Y_t(\nu) = \left(\frac{K_t(\nu)}{\alpha}\right)^{\alpha} \left(\frac{A_t N_t(\nu)}{1-\alpha}\right)^{1-\alpha}, \tag{12}$$

where $A_t = \exp(u_t^A)$ denotes aggregate technology with $u_t^A = \mu + u_{t-1}^A + \varepsilon_t^A, \quad \varepsilon_t^A \sim N(0, \sigma_A^2)$, and the gross growth rate is $GA_t \equiv A_t/A_{t-1} = \exp(\mu + \varepsilon_t^A)$.

A representative competitive firm aggregates intermediate products into a final good using a Dixit–Stiglitz aggregator:

$$Y_t = \left[\int_0^1 Y_t(\nu)^{\frac{\epsilon-1}{\epsilon}} \, d\nu\right]^{\frac{\epsilon}{\epsilon-1}},$$

with $\epsilon > 1$ as the elasticity of substitution. The demand for intermediate good ν is

$$Y_t(\nu) = \left(\frac{P_t(\nu)}{P_t}\right)^{-\epsilon} Y_t \,, \tag{13}$$

and the aggregate price index is defined as

$$P_t = \left[\int_0^1 P_t(\nu)^{1-\epsilon} \, \mathrm{d}\nu\right]^{\frac{1}{1-\epsilon}} . \tag{14}$$

Intermediate producers face sticky prices à la Calvo (1983) and reset their prices each quarter with probability $1-\theta$. Firms that adjust set the optimal price P_t^*, and the equilibrium aggregate price index satisfies $P_t^{1-\epsilon} = (1-\theta)(P_t^*)^{1-\epsilon} + \theta \, P_{t-1}^{1-\epsilon}$.

Each intermediate firm rents capital at price P_t^K from the capital producer. To finance production, firm ν borrows a fraction γ of its potential revenue $(1+\zeta^F)P_t(\nu)Y_t(\nu)$, where ζ^F represents a production subsidy. Specifically, a firm ν that borrows $L_t(\nu)$ must repay $R_{t+1}^K \, L_t(\nu)$ in the next period, with the rate R_{t+1}^K contracted at time t. This borrowing constraint can be interpreted as a financial friction faced by intermediate firms, such as a working capital constraint.

Firm ν maximizes its discounted profit stream:

$$\max \sum_{j=0}^{\infty} \mathbb{E}_t \Bigg[Q_{t,t+j} \Big((1+\zeta^F) P_{t+j}(\nu) Y_{t+j}(\nu) - W_{t+j}(\nu) N_{t+j}(\nu) - P_{t+j}^K K_{t+j}(\nu) \\ - R_{t+j}^K L_{t+j-1}(\nu) + L_{t+j}(\nu) \Big) \Bigg], \tag{15}$$

where $Q_{t,t+j} = \beta^j \left(\frac{P_{t+j}}{P_t} \cdot \frac{C_{t+j}}{C_t} \right)^{-1}$ is the stochastic discount factor between periods t and $t+j$. At period $t+j$, firm ν repays $R_{t+j}^K L_{t+j-1}(\nu)$ on the loan taken in period $t+j-1$.

Minimizing production costs with respect to labor and capital yields the input demand functions:

$$N_t(\nu) = (1-\alpha) \frac{Y_t(\nu)}{A_t} \left(\frac{\frac{P_t^K}{P_t}}{\frac{W_t(\nu)}{P_t A_t}} \right)^{\alpha}, \quad \frac{K_t(\nu)}{A_t} = \alpha \frac{Y_t(\nu)}{A_t} \left(\frac{\frac{P_t^K}{P_t}}{\frac{W_t(\nu)}{P_t A_t}} \right)^{-(1-\alpha)}. \tag{16}$$

2.4 Bond Market

The bond market equilibrium is given by

$$B_t^{H,f} + B_t^{G,f} + B_t^{CB,f} = 0, \quad \forall f = 1, \dots, F, \tag{17}$$

where $B_t^{H,f}$ denotes households' holdings of f-maturity bonds, while $B_t^{G,f}$ and $B_t^{CB,f}$ represent bonds held by the government[19] and the central bank, respectively. We assume that only the government and the central bank can issue riskless claims—and therefore hold negative bond positions.[20]

Allowing the government to issue bonds (and hold negative positions) is essential; our specifications for technology growth GA_t and population growth GN ensure that, at the steady state, the government's debt remains nonzero but non-explosive, so it consistently supplies risk-free debt despite cyclical fluctuations.

Defining $\lambda_t^{G,f}$ and $\lambda_t^{CB,f}$ as the shares of f-maturity bonds held by the government and

[19] By assumption, the government issues bonds across maturities, so $B_t^{G,f} \leq 0$ for all f.

[20] In practice, a negative position of the central bank can be interpreted as holding interest-bearing excess reserves (see, e.g., Frost (1971), Güntner (2015), Mattingly and Abou-Zaid (2015), Primus (2017), and Ennis (2018)).

the central bank, respectively, we can rewrite (17) as

$$\lambda_t^{HB,f} B_t^H + \lambda_t^{G,f} B_t^G + \lambda_t^{CB,f} B_t^{CB} = 0, \quad \forall f = 1, \dots, F. \tag{18}$$

2.5 Government

The government's budget constraint is given by

$$G_t + \zeta^F Y_t + \frac{B_t^G}{P_t} = T_t + \frac{R_t^G B_{t-1}^G}{P_t}, \text{ with } B_t^G = \sum_{f=1}^{F} B_t^{G,f}, \;\; R_t^G = \sum_{f=0}^{F-1} \lambda_{t-1}^{G,f+1} R_t^f. \tag{19}$$

Here, B_t^G is the government's nominal bond position, G_t denotes real government spending, T_t represents taxes, and R_t^G is the aggregate bond return on its portfolio, where $\lambda_t^{G,f}$ is the fraction of government debt held as an f-maturity bond. By assumption, $B_t^{G,f} = \lambda_t^{G,f} B_t^G$ for all $f = 1, \dots, F$, and both $\lambda_t^{G,f}$ and B_t^G are exogenous.[21]

Rearranging (19), the constraint can be written as

$$\frac{B_t^G}{P_t} = \frac{R_t^G B_{t-1}^G}{P_t} - \left[\zeta_t^G + \zeta^F - \zeta_t^T\right] Y_t, \tag{20}$$

where $\zeta_t^G = \frac{G_t}{Y_t}$ and $\zeta_t^T = \frac{T_t}{Y_t}$ denote government spending and taxation as shares of GDP, respectively, and are exogenous in our framework.

2.6 Central Bank

The profits generated by the bonds held on the central bank's balance sheet are given by

$$\Lambda_t^{CB} = R_t^{CB} B_{t-1}^{CB} - B_t^{CB}, \text{ with } B_t^{CB} = \sum_{f=1}^{F} B_t^{CB,f}, \;\; R_t^{CB} = \sum_{f=0}^{F-1} \lambda_{t-1}^{CB,f+1} R_t^f, \tag{21}$$

where B_t^{CB} denotes the central bank's total nominal bond holdings, and R_t^{CB} is the aggregate bond return on its portfolio $\{B_{t-1}^{G,f}\}_{f=1}^F$. The fraction of bonds held with maturity f is given by $\lambda_t^{CB,f}$. Formally,

$$B_t^{CB,f} = \lambda_t^{CB,f} \cdot B_t^{CB}, \;\; \forall f = 1, \dots, F. \tag{22}$$

[21] We abstract from the government's optimal maturity structure problem and assume its gross bond positions and portfolios across maturities are exogenous, focusing on the central bank's monetary policy.

Both B_t^{CB} and $\lambda_t^{CB,f}$ depend on the monetary policy rules, which will be described shortly. The central bank's profits Λ_t^{CB} are transferred as a lump-sum payment to the household, forming part of the total transfer Λ_t in (2).

2.7 Monetary Policy

Equation (22) introduces F additional conditions, so the central bank's monetary policy now has F degrees of freedom that must be specified to achieve a determinate nominal equilibrium.[22] Monetary authorities may implement policy by:

1. Setting a rule for each f-maturity bond's holdings $B_t^{CB,f}$, allowing bond prices (and yields) to adjust accordingly.

2. Setting a rule for each f-maturity bond's yield YD_t^f (or equivalently, its price Q_t^f), and then adjusting the purchase amounts $B_t^{CB,f}$ to achieve the target yield.

3. Employing a combination of the two approaches across different maturities.

In Case 1, the central bank directly controls the expansion of its bond holdings, resembling traditional rules on money supply growth.[23] Case 2 exemplifies yield-curve control (YCC), as implemented by the Bank of Japan in 2016.[24] Case 3 combines elements of both and includes, for example, the traditional short-term rate target of conventional monetary policy.

While unconventional policies could be implemented according to any of the three cases above, we assume that their defining characteristic is an intent to influence asset returns along the entire yield curve (in contrast to conventional policies, which focus on short-term rates). Consequently, we adopt a YCC policy rule as the representative unconventional policy within our framework. In what follows, we formally characterize the equations describing both conventional and YCC policy rules.

[22] The central bank selects its bond portfolio across maturities and its total debt position. In conventional New Keynesian models, this portfolio problem is typically abstracted away since the explicit term structure is absent, as discussed in Section 2.1.1.

[23] This approach reflects the idea that bond purchases increase money supply. It also specifies the portfolio composition across maturities, even though we do not explicitly incorporate money as a separate variable.

[24] On September 21, 2016, the Bank of Japan set a short-term rate target of -0.1% and capped its 10-year government bond yield near zero. For the U.S. case, see Humpage (2016) regarding the Fed's yield-curve control during World War II.

Conventional Policy Conventional monetary policy targets the short-term interest rate (Case 3), whereby the central bank sets a rule for the one-period bond yield YD_t^1 while leaving longer-term bonds unchanged. We assume that the central bank maintains normalized positions for long-term bonds (i.e., adjusted for technology, population, and price growth) as follows:

$$R_{t+1}^0 \equiv YD_t^1 = \max\left\{YD_t^{1*},\, 1\right\}, \tag{23a}$$

$$\frac{YD_t^{1*}}{\overline{YD}^1} = \left(\frac{YD_{t-1}^{1*}}{\overline{YD}^1}\right)^{\rho_1}\left(\frac{YD_{t-2}^{1*}}{\overline{YD}^1}\right)^{\rho_2}\left[\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma_\pi}\left(\frac{Y_t}{\bar{Y}_t}\right)^{\gamma_y}\exp\left(\tilde{\epsilon}_t^{YD^1}\right)\right]^{1-(\rho_1+\rho_2)}, \tag{23b}$$

$$\frac{B_t^{CB,f}}{A_t\bar{N}_tP_t} = \overline{\frac{B^{CB,f}}{A\bar{N}P}}, \quad \forall\, f = 2,\ldots,F, \tag{23c}$$

where YD_t^{1*} follows a standard Taylor rule that targets deviations in inflation and output, with $\tilde{\epsilon}_t^{YD^1}$ representing a monetary policy shock. When YD_t^{1*} falls below 1, the ZLB binds, so that $R_{t+1}^0 \equiv YD_t^1 = 1$ as specified in (23a).[25]

Yield-Curve-Control policy Yield-curve control policy targets the entire yield curve by applying a Taylor rule to each bond maturity—including the short-term rate rule defined in (23)—as follows:

$$\frac{YD_t^{f*}}{\overline{YD}^f} = \left(\frac{YD_{t-1}^{f*}}{\overline{YD}^f}\right)^{\rho_1}\left(\frac{YD_{t-2}^{f*}}{\overline{YD}^f}\right)^{\rho_2}\left[\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma_\pi^f}\left(\frac{Y_t}{\bar{Y}_t}\right)^{\gamma_y^f}\exp\left(\tilde{\varepsilon}_t^{YD^f}\right)\right]^{1-(\rho_1+\rho_2)}, \tag{24a}$$

$$YD_t^{YCC,f} = \overline{YD}^f\left(\frac{YD_t^{CP,f}}{\overline{YD}^f}\right)^{\gamma_{CP}^f}\left[\frac{YD_t^{f*}}{\overline{YD}^f}\right]^{1-\gamma_{CP}^f}, \tag{24b}$$

where γ_π^f and γ_y^f capture the responsiveness to inflation and output deviations for maturities $f = 1,\ldots,F$, and $\tilde{\varepsilon}_t^{YD^f}$ is a monetary policy shock affecting the yield on an f-maturity bond. The term $YD_t^{CP,f}$ denotes the yield that would prevail under conventional monetary policy – see equation (23). $\gamma_{CP}^f \in [0,1]$ governs the influence of the conventional target within the yield-curve control framework. When $\gamma_{CP}^f = 1$, the rule reverts to conventional policy; when $\gamma_{CP}^f = 0$, the yield for the f-maturity bond is determined solely by the YCC

[25] For example, a sudden increase in the preference parameter z_t^1 may boost household demand for one-period bonds, pushing the yield toward zero and potentially inducing recessionary pressures as consumption falls under the ZLB constraint.

rule, that is:

$$YD_t^{YCC,f} = \overline{YD}^f \left(\frac{YD_{t-1}^{f*}}{\overline{YD}^f}\right)^{\rho_1} \left(\frac{YD_{t-2}^{f*}}{\overline{YD}^f}\right)^{\rho_2} \left[\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma_\pi^f} \left(\frac{Y_t}{\bar{Y}_t}\right)^{\gamma_y^f} \exp\left(\tilde{\varepsilon}_t^{YD^f}\right)\right]^{1-(\rho_1+\rho_2)} .$$

In this pure case, the central bank ignores balance sheet exposure concerns for bonds with maturity f – see equation (23c). Intermediate values $0 < \gamma_{CP}^f < 1$ allow the monetary authority to balance yield-curve intervention with considerations of balance sheet composition and size. For simplicity, in our subsequent analysis we set $\gamma_{CP}^f = 0$ for all f, representing a pure yield-curve control policy.

2.8 Market Clearing

Using the bond market equilibrium condition (17), the total transfers to households—comprising profits from firms, the central bank, and capital producers, net of government taxes—are given by

$$\Lambda_t = P_t Y_t - P_t G_t - P_t I_t - \int_0^1 W_t(\nu) N_t(\nu)\, d\nu - R_t^K L_{t-1} + L_t + B_t^H - R_t^H B_{t-1}^H. \quad (25)$$

Combining (25) with the household's budget constraint (2) yields the standard aggregate market-clearing condition:

$$C_t + G_t + I_t = Y_t \ . \quad (26)$$

2.9 Aggregation

Aggregating labor demand equation (16) across intermediate firms yields:

$$\frac{N_t}{\bar{N}_t} = (1-\alpha)^{\left(\frac{\eta}{\eta+\alpha}\right)} \left(\frac{C_t}{A_t \bar{N}_t}\right)^{-\alpha\left(\frac{\eta}{\eta+\alpha}\right)} \left(\frac{Y_t}{A_t \bar{N}_t}\right)^{\left(\frac{\eta}{\eta+\alpha}\right)} \left(\frac{P_t^K}{P_t}\right)^{\alpha\left(\frac{\eta}{\eta+\alpha}\right)} \Delta_t^{\frac{\eta}{\eta+1}}, \quad (27)$$

where Δ_t is a measure of price dispersion, recursively defined as:

$$\Delta_t = (1-\theta)\left(\frac{P_t^*}{P_t}\right)^{-\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)} + \theta \Pi_t^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)} \Delta_{t-1}. \quad (28)$$

Note from equation (27) that, for a given (normalized) level of consumption and output, the required labor N_t increases with price dispersion Δ_t—a proxy for the inefficiency induced by nominal rigidities. Moreover, a higher $\frac{P_t^K}{P_t}$ raises the rental cost of capital, prompting firms to substitute capital with labor, thereby increasing N_t. This substitution channel is also captured in the aggregate capital equilibrium condition:[26]

$$\frac{K_t}{A_{t-1}\bar{N}_{t-1}} = \alpha(1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}} \cdot GA_t \cdot GN \cdot \left(\frac{C_t}{A_t\bar{N}_t}\right)^{\frac{\eta(1-\alpha)}{\eta+\alpha}} \left(\frac{Y_t}{A_t\bar{N}_t}\right)^{\frac{\eta+1}{\eta+\alpha}} \left(\frac{P_t^K}{P_t}\right)^{-\left(\frac{\eta(1-\alpha)}{\eta+\alpha}\right)} \Delta_t. \tag{29}$$

Consequently, aggregate capital K_t rises when consumption, output, or price dispersion increases and/or when the rental price of capital falls. These two equations highlight the role of firms' substitution between capital and labor during production.

The representative household satisfies the Euler equation (11), with effective savings rate R_{t+1}^S determined by (6), λ_t^K given by (5), and $\lambda_t^{HB,f}$ specified in (3). The equilibrium condition for the household's allocation between loans and bonds is:

$$\frac{L_t}{B_t^H} = \frac{\gamma(1+\zeta^F)P_tY_t}{B_t^H} = \frac{\lambda_t^K}{1-\lambda_t^K}, \tag{30}$$

where B_t^H and L_t represent the aggregate household bond and loan holdings, respectively.

2.9.1 Conventional Policy

Under conventional monetary policy (i.e., (23)), the central bank does not adjust its normalized holdings of long-term bonds. Consequently, for $f > 1$ the ratio $\frac{B_t^{CB,f}}{A_t\bar{N}_tP_t}$ remains constant. In this setting, the household's bond portfolio share, $\lambda_t^{HB,f}$, must satisfy:

$$\lambda_t^{HB,f} = -\frac{\frac{B_t^{G,f}}{A_t\bar{N}_tP_t} + \overline{\frac{B^{CB,f}}{A\bar{N}P}}}{\frac{B_t^H}{A_t\bar{N}_tP_t}}, \quad \forall f > 1. \tag{31}$$

2.9.2 Yield-Curve Control Policy

In the yield-curve control case (i.e., (24)), monetary policy influences households' bond portfolio across maturities $\{\lambda_t^{HB,f}\}_{f=1}^F$ and the effective bond return R_t^{HB} through the fol-

[26]We normalize K_t by $A_{t-1}\bar{N}_{t-1}$, as K_t is determined in period $t-1$, while N_t, C_t, and Y_t are normalized by $A_t\bar{N}_t$, and P_t^K is normalized by P_t.

lowing relationships:

$$\lambda_t^{HB,f} = \left(\frac{z_t^f \mathbb{E}_t \left[Q_{t,t+1} R_{t+1}^{f-1} \right]}{\Phi_t^B} \right)^{\kappa_B}, \quad R_{t+1}^{f-1} = \frac{\left(YD_{t+1}^{f-1} \right)^{-(f-1)}}{\left(YD_t^f \right)^{-f}}. \tag{32}$$

Changes in the household's bond portfolio composition affect the effective bond rate R_t^{HB} (from (4)), the loan rate R_t^K (from (5)), and the effective savings rate R_t^S (from (6)). These adjustments, in turn, influence consumption via the Euler equation (11) and other aggregate outcomes as captured by equations (26), (27), (29), and (30).

Figure III.2 in Appendix III provides a graphical illustration of the model. Appendix I provides shock processes for portfolio preference shocks $\{z_t^f\}_{f=1}^F$ and z_t^K, government spending ratio ζ_t^G and the revenue ratio ζ_t^T, government bond shares $\{\lambda_t^{G,f}\}_{f=1}^F$, and monetary policy shocks $\{\tilde{\varepsilon}_t^{YD^f}\}_{f=1}^F$.

We present all other equilibrium conditions and derivations in Online Appendix A.

3 Steady-State (Long-Run) Analysis

3.1 Steady-State Relations

We assume that the central bank's total bond holdings, B^{CB}, equal a constant fraction ζ^{CB} of the total government bond issuance, B^G; that is, $B^{CB} = \zeta^{CB} B^G$.[27] Given the portfolio shares $\{\lambda^{CB,f}\}_{f=1}^F$, the steady-state relation in the Treasury market (i.e., (18)) becomes:

$$\lambda^{HB,f} = \frac{\lambda^{G,f} + \lambda^{CB,f} \zeta^{CB}}{1 + \zeta^{CB}}.$$

Thus, the household's steady-state bond portfolio shares $\{\lambda^{HB,f}\}_{f=1}^F$ are determined by the exogenous parameters $\{\lambda^{G,f}, \lambda^{CB,f}\}_{f=1}^F$ and ζ^{CB}.

In steady state, the government's budget constraint can be expressed as:

$$\frac{B^G}{A\bar{N}P} = -\left(1 - \frac{R^G}{\Pi \cdot GA \cdot GN} \right)^{-1} \left[\zeta^G + \zeta^F - \zeta^T \right] \frac{Y}{A\bar{N}}.$$

Given the normalized output level $\frac{Y}{A\bar{N}}$ and a positive primary deficit ratio $\zeta^G + \zeta^F - \zeta^T > 0$,

[27] Since $B^G < 0$ and $B^{CB} > 0$ in steady state, it follows that $\zeta^{CB} < 0$.

an increase in the interest rate on government debt, R^G, results in a larger volume of bond issuance $|B^G|$ (recall that $B^G < 0$) and a higher debt-to-output ratio, as the government must pay more in interest on its debt.[28]

The remaining steady-state relationships and the procedures for characterizing these conditions are detailed in Online Appendix A.1.3.

3.2 Results

3.2.1 Calibration

We use publicly available data on (i) Treasury yields, (ii) the Federal Reserve's holdings of Treasury bonds (December 2002–June 2007), and (iii) the U.S. Treasury's outstanding bonds (January 1990–January 2007) to calibrate the model's term structure parameters. We set $F = 120$ to represent maturities up to 30 years (i.e., 120 quarters).[29] Parameter values are summarized in Table II.2 in Appendix II, with standard macroeconomic parameters calibrated to widely accepted values in the literature.

Household demand for maturity-f bonds, $\lambda_t^{HB,f}$, is driven by the maturity-specific preference shock z_t^f and the demand elasticity κ_B; similarly, loan demand λ_t^K is driven by z_t^K and κ_S. We calibrate the yield curve's slope using $\{z^f\}_{f=1}^F$ and its level using z^K, with fixed values for the demand elasticities κ_B and κ_S. Specifically, we set $\kappa_B = 10$, estimated from macro data using our bond portfolio equation (3) in Online Appendix B, and $\kappa_S = 6$, based on Kekre and Lenel (2023). With these values, $\{z^f\}$ is selected to match the relative yields across maturities, while z^K is calibrated to reproduce the steady-state return on the household bond portfolio, R^{HB}. The detailed calibration procedure is provided in Online Appendix B.1. We also set $\gamma = 3$, which constitutes an upper bound for private debt-to-GDP ratios in advanced economies. Under our calibration, the untargeted steady-state value of R^K is 8.12%, close to the average Moody's Seasoned BAA Corporate Bond Yield of 7.88% during 1990–2007.

Figure 1 displays the bond shares across maturities for households, government, and the central bank, along with the resulting steady-state yield curve. The calibrated values of z^K and $\{z^f\}_{f=1}^F$ are reported in Table II.1 and Figure II.1. Notably, $z^1 = 1$ is relatively large

[28]To maintain a positive primary deficit through non-explosive bond issuance in steady state, we require $R^G < \Pi \cdot GA \cdot GN$, a condition that holds under our calibration. This condition is consistent with recent literature on debt sustainability, such as Blanchard (2019).

[29]When yield data are missing, we interpolate to generate a smooth yield curve. Data source: https://fiscaldata.treasury.gov/datasets/monthly-statement-public-debt

compared to z^f for $f \geq 2$, reflecting the fact that short-term yields have historically been lower than longer-term yields. This discrepancy likely captures the safety and/or liquidity premium of short-term bonds, a phenomenon extensively documented in the literature (e.g., Krishnamurthy and Vissing-Jorgensen (2012) and Caballero and Farhi (2017)).

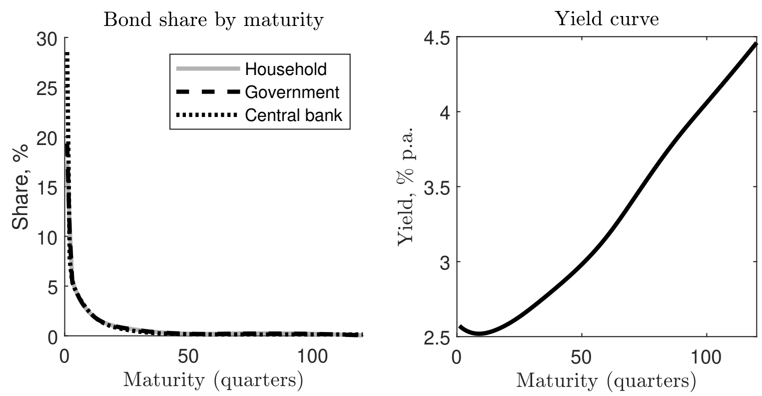


Figure 1: Steady-state bond shares of different entities, with the yield curve

Lastly, our calibration of Taylor coefficients, γ_π^1, $\gamma_\pi^{f\geq 2}$, γ_y, $\gamma_y^{f\geq 2}$, satisfies model determinacy both in conventional policy and yield-curve control policy regimes, where increasing monetary responsiveness to output and inflation generically guarantees that our model yields unique equilibrium. We characterize the determinacy conditions in Online Appendix H.

3.2.2 Government's Supply and Central Bank's Demand for Bonds

We now examine how changes in the government's debt structure—captured by its Treasury issuance shares $\{\lambda^{G,f}\}_{f=1}^F$—affect the steady-state yield curve. Figure 2 shows alternative debt issuance arrangements (left panel) and the corresponding yield curve shifts (right panel); dashed and dotted lines indicate higher long-term issuance compared to the benchmark (solid line).[30] The model generates a positive correlation between yields and the relative supply $\lambda^{G,f}$; higher issuance at a given maturity increases its yield. This effect not only targets that maturity but also influences equilibrium returns in both Treasury and private loan markets via household portfolio rebalancing, thereby affecting the government's overall bond issuance in general equilibrium.

[30]For illustration purposes, the shifts in portfolio shares are arbitrary.

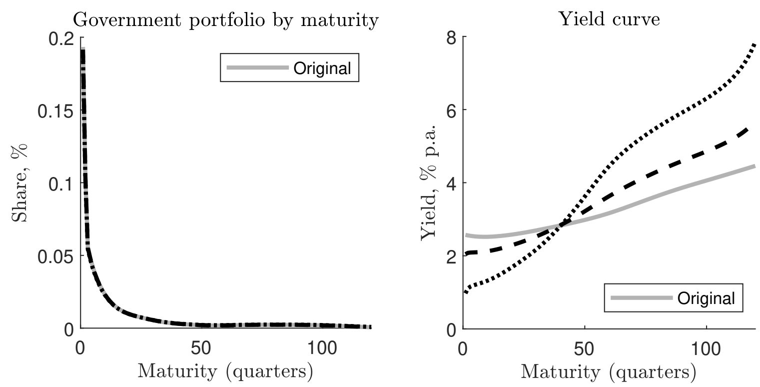


Figure 2: Government's bond issuance portfolio and yield curve

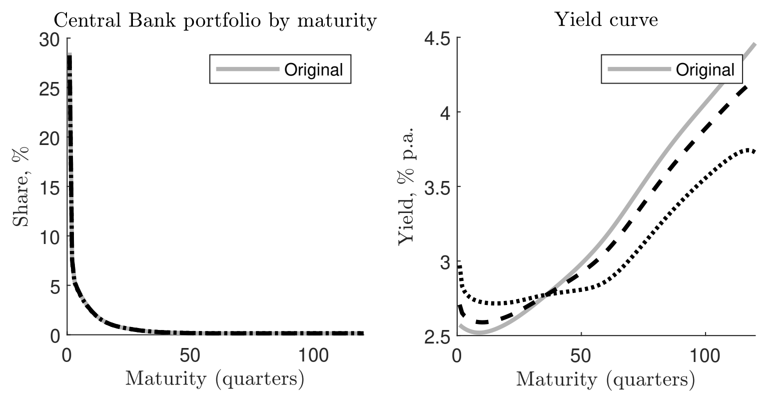


Figure 3: Variations in central bank's bond portfolio across maturities

Figure 3 illustrates an alternative scenario in which the central bank adjusts its bond portfolio composition. Here, the dashed and dotted lines represent higher long-term bond purchases relative to the benchmark (solid line). An increased relative purchase of a given maturity is associated with a lower yield, which is consistent with evidence that central bank bond purchases act as an additional demand shock in segmented markets under general equilibrium (e.g., Ray (2019) and Droste et al. (2021)).[31]

[31] Krishnamurthy and Vissing-Jorgensen (2011) document that QE2, which focused on Treasury bonds, had a disproportionate impact on Treasuries and Agencies relative to mortgage-backed and corporate bonds. D'Amico and King (2013) also identify stock and flow effects of QE on Treasury yields, supporting the view of imperfect substitution in the Treasury market.

3.2.3 Comparative Statics with Deficit Ratio

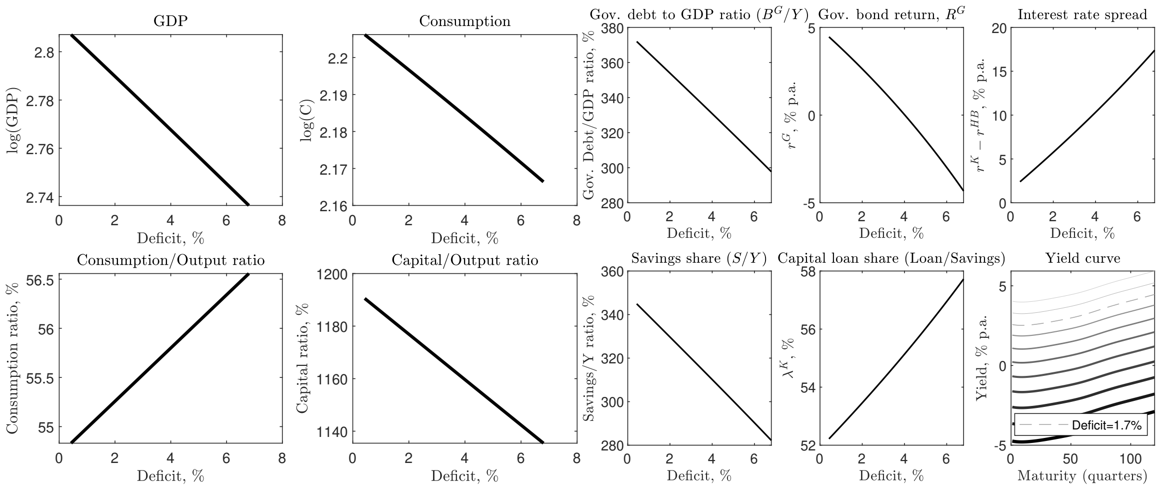


Figure 4: Variations in deficit ratio $\zeta^F + \zeta^G - \zeta^T$

Figure 4 shows comparative statics for variations in the deficit ratio $\zeta^F + \zeta^G - \zeta^T$. A higher deficit ratio can be sustained only if (i) the government issues more bonds, (ii) the effective bond rate R^G decreases, or (iii) output declines, thereby lowering nominal deficit expenditure.

Examining the first case, if the government increases debt issuance for a given output level, the supply effectdiscussed in Section 3.2.2 raises R^G, which in turn forces even more debt issuance to cover higher interest costs—a process that spirals indefinitely. In contrast, the second and third cases operate jointly: a higher deficit ratio reduces output, consumption, and capital, which lowers the nominal deficit and government bond issuance, thereby depressing R^G. Meanwhile, the loan rate R^K remains relatively stable, leading to an increased credit spread $r^K - r^{HB}$. Notably, our finding that the debt-to-GDP ratio $\frac{B^G}{Y}$ declines and the entire yield curve shifts downward in response to an increased deficit ratio aligns with previous literature.[32]

Additional comparative statics results are provided in Online Appendix F.

[32] Laubach (2009) estimates that a 1% point increase in the projected debt-to-GDP ratio raises long-term interest rates by approximately 3–4 basis points.

4 Short-Run Analysis

4.1 Log-linearization

We now present the log-linearized solution of the model. Lower-case letters denote normalized variables, e.g., $k_t \equiv \frac{K_t}{A_{t-1}N_{t-1}}$, $y_t \equiv \frac{Y_t}{A_t N_t}$, $c_t \equiv \frac{C_t}{A_t N_t}$, $n_t \equiv \frac{N_t}{N_t}$, $p_t^K \equiv \frac{P_t^K}{P_t}$, while hats denote log-deviations from the steady state. Given our system's complexity, we highlight a few key equilibrium equations here; complete derivations are provided in Online Appendix A.

Linearizing the Euler equation (11) yields the dynamic IS equation featuring the effective savings rate $\hat{r}_{t+1}^S$:

$$\hat{c}_t = \mathbb{E}_t \left[\hat{c}_{t+1} - \left(\hat{r}_{t+1}^S - \hat{\pi}_{t+1} \right) \right], \tag{33}$$

where $\hat{r}_t^S$ is derived from (6) as

$$\hat{r}_t^S = \frac{\lambda^K \left(R^K - R^{HB} \right)}{R^S} \hat{\lambda}_{t-1}^K + \frac{(1-\lambda^K) R^{HB}}{R^S} \hat{r}_t^{HB} + \frac{\lambda^K R^K}{R^S} \hat{r}_t^K. \tag{34}$$

Note that $\hat{r}_t^S$ depends on the effective bond rate $\hat{r}_t^{HB}$, the loan rate $\hat{r}_t^K$, and the loan share $\hat{\lambda}_{t-1}^K$, capturing the portfolio rebalancing between bonds and loans. The effective bond rate $\hat{r}_t^{HB}$ is obtained by linearizing (4):

$$\hat{r}_t^{HB} = \sum_{f=1}^{F} \frac{\lambda^{HB,f} \left(Y D^{f-1} \right)^{-(f-1)}}{R^{HB} \left(Y D^f \right)^{-f}} \left[\hat{\lambda}_{t-1}^{HB,f} - (f-1) \cdot \hat{yd}_t^{f-1} + f \cdot \hat{yd}_{t-1}^f \right]. \tag{35}$$

It depends on past yields $\{\hat{yd}_{t-1}^f\}_{f=1}^F$, current yields $\{\hat{yd}_t^{f-1}\}_{f=1}^F$, and household bond portfolio shares $\{\hat{\lambda}_{t-1}^{HB,f}\}_{f=1}^F$, capturing the impact of aggregate bond price revaluations and portfolio composition on overall bond returns.

To study portfolio reallocation, we linearize the household's optimal bond portfolio (see (3)) and express the bond shares as functions of past and current yields:

$$\hat{\lambda}_{t-1}^{HB,f} = \kappa^B \mathbb{E}_{t-1} \left[\hat{z}_{t-1}^f - \hat{\pi}_t + \hat{c}_{t-1} - \hat{c}_t - (f-1) \cdot \hat{yd}_t^{f-1} + f \cdot \hat{yd}_{t-1}^f - \hat{\phi}_{t-1}^B \right], \tag{36}$$

where $\hat{\phi}_t^B$ comprises $\{\hat{yd}_t^{f-1}, \hat{yd}_{t-1}^f\}_{f=1}^F$ and other aggregate variables. Substituting equation (36) into (35) represents the household's effective bond rate as a function of the entire yield curve.

Finally, linearizing the household's optimal portfolio choice between bonds and loans (i.e., (5)) yields:

$$\hat{\lambda}_t^K = \kappa^S \left(1 - \lambda^K\right) \left(\hat{z}_t^K + \mathbb{E}_t \left[\hat{r}_{t+1}^K - \hat{r}_{t+1}^{HB}\right]\right).$$

Here, increases in $\hat{z}_t^K$ and in the expected spread $\mathbb{E}_t[\hat{r}_{t+1}^K - \hat{r}_{t+1}^{HB}]$ raise the loan share $\hat{\lambda}_t^K$. Since $\hat{r}_{t+1}^K$ directly enters the effective savings rate $\hat{r}_{t+1}^S$ (see (33)), it influences consumption via the intertemporal substitution channel. Changes in $\hat{r}_{t+1}^K$ also affect λ_t^K, altering loan issuance L_t, output (see (30)), and, consequently, aggregate labor (see (27)) and capital (see (29)) accumulation.

4.2 Results

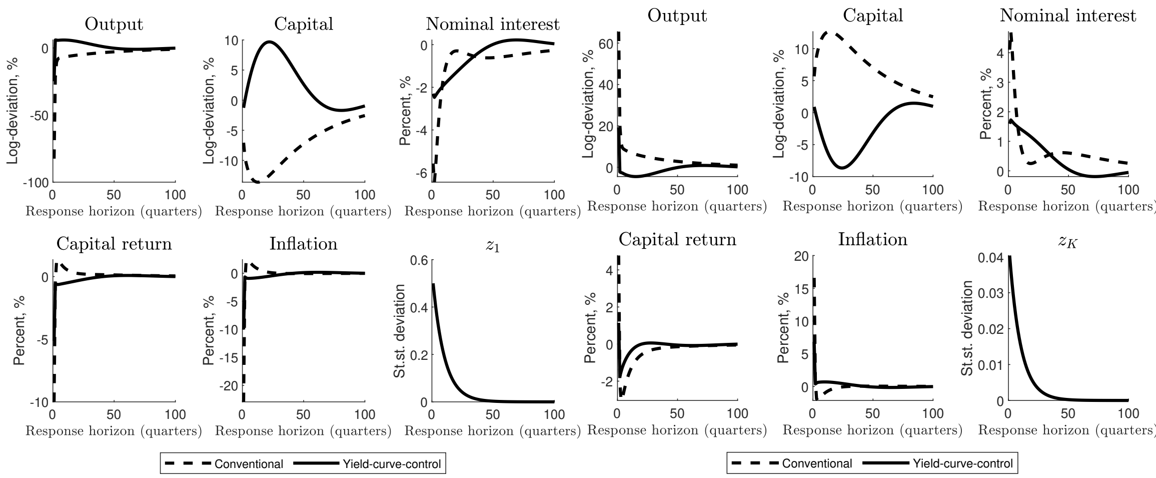
4.2.1 Impulse-Response without the ZLB

We first analyze impulse responses to various shocks in an economy that remains above the ZLB. The shocks considered are z_t^1 (household preference shock for short-term bonds), z_t^K (household preference shock for loans), and ε_t^T (tax shock). Graphs for additional shocks appear in Online Appendix G.

Short-term Bond Preference Shock, z_t^1: Figure 5a shows that a positive z_t^1 shock raises household demand for short-maturity bonds that feature the lowest returns along the yield curve at the steady state. Under conventional policy (dashed lines), this shock is recessionary since it induces households to save relatively more in overpriced short-term assets with lower returns, lowering aggregate consumption demand. Under our calibration, a one standard deviation z_t^1 shock reduces output by 3–4%. In contrast, under YCC policy (solid lines), the central bank can mitigate a recession by lowering the effective bond return. This additional monetary easing alleviates drops in aggregate consumption demand, stabilizing inflation and output.

More broadly, a positive z_t^1 shock can be interpreted as a negative financial shock, such as a disruption in the bond market—similar to a flight-to-safety or liquidity shock affecting demand for short-term bonds. Under conventional policy, this would typically induce a recession, whereas YCC achieves near-perfect stabilization.

Loan Preference Shock, z_t^K: Figure 5b illustrates that a positive z_t^K shock causes households to allocate more savings toward loans. This portfolio shift reduces loan returns and increases aggregate capital, which subsequently boosts output and inflation. In response, the central bank raises the policy rate. As in previous cases, YCC dampens these fluctuations more effectively than conventional policy.



(a) z_t^1 shock (b) z_t^K shock

Figure 5: Impulse response to z_t^1 and z_t^K without ZLB

Tax Shock, ε_t^T: Figure 6 depicts impulse responses to a positive tax shock, ε_t^T. Under conventional policy, higher tax revenues lead the government to issue fewer bonds. This reduction triggers a decline in bond and loan returns[33] and in factor prices (loan rates and wages) via household portfolio reallocation and firms' input substitution. Under our calibration, the conventional policy response is insufficient to counteract the negative output effects of reduced bond issuance. In contrast, the YCC policy achieves better stabilization because the entire yield curve shifts downward in response to the shock. This coordinated adjustment results in smaller changes in individual maturities and thus a modest reduction in the effective household savings rate r_{t+1}^S, which supports aggregate consumption and mitigates output losses.

These results highlight that while conventional policy may induce significant business cycle fluctuations following shocks, a yield-curve control regime can more effectively stabilize the economy by actively managing the entire term structure.

[33]This shock thus reduces aggregate consumption demand, as bonds become more expensive in equilibrium and the household's elasticity of substitution between bonds and private loans is finite.

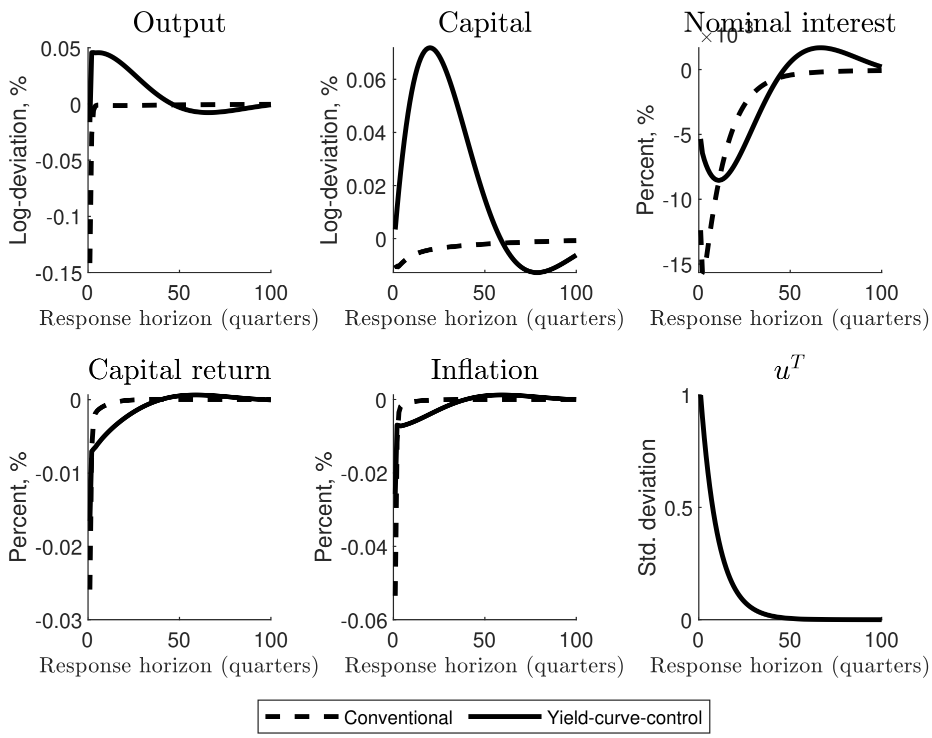


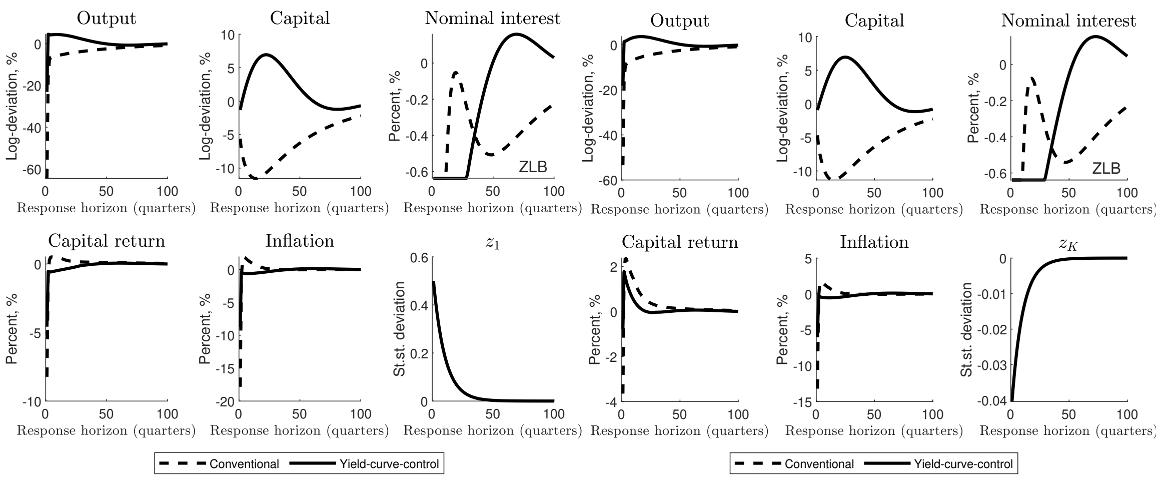
Figure 6: Impulse-response to ε_t^T shock without ZLB

4.2.2 Impulse-Response at the ZLB

In this section, we present impulse responses to various shocks under the ZLB. To illustrate independent ZLB episodes, we calibrate shocks to very large (albeit highly improbable) magnitudes.

Short-term Bond Preference Shock, z_t^1: Figure 7a shows that a positive z_t^1 shock —increasing household demand for short-term bonds—lowers the short-term rate under conventional policy (dashed lines) and causes a recession with deflation and output drop by 3–4% per standard deviation. In contrast, under a YCC regime (solid lines), the central bank increases long-term bond purchases, lowering long-term rates and the effective savings rate. This boosts aggregate demand and mitigates the recession.

However, this intervention also extends the ZLB episode, as the downward pressure on long-term yields feeds back into the household's portfolio decisions. Households shift their portfolios further toward short-term bonds, which further binds the short-term rate at zero.



(a) z_t^1 shock

(b) z_t^K shock

Figure 7: Impulse response to z_t^1 and z_t^K with ZLB

Loan Preference Shock, z_t^K: Figure 7b depicts that a sizable negative z_t^K shock induces households to reduce loan investments and reallocate toward bonds. Consequently, bond rates decline and the policy rate remains at the ZLB, while output, capital, inflation, and loan rates all fall. As with the z_t^1 shock, YCC achieves better stabilization but extends the ZLB duration.

Tax Shock, ε_t^T: Figure 8 shows that a positive tax shock leads to a reduction in bond issuance under conventional policy. The resulting lower bond and loan returns and lower aggregate consumption, combined with the endogenous portfolio reallocation by households and firms' input substitution, deepen the recession—causing declines in output, capital, inflation, and capital returns. Under YCC, the central bank lowers the entire yield curve, reducing the household's effective savings rate and stimulating aggregate demand, thereby mitigating the negative impact of reduced bond issuance. However, as with previous cases, this policy also extends the ZLB episode due to its effect on household portfolio decisions.

In summary, while yield-curve control policies effectively stabilize the economy by offsetting shocks across the term structure, they tend to extend the duration of ZLB episodes compared to conventional policy, highlighting a trade-off in the stabilization benefits of unconventional monetary measures.

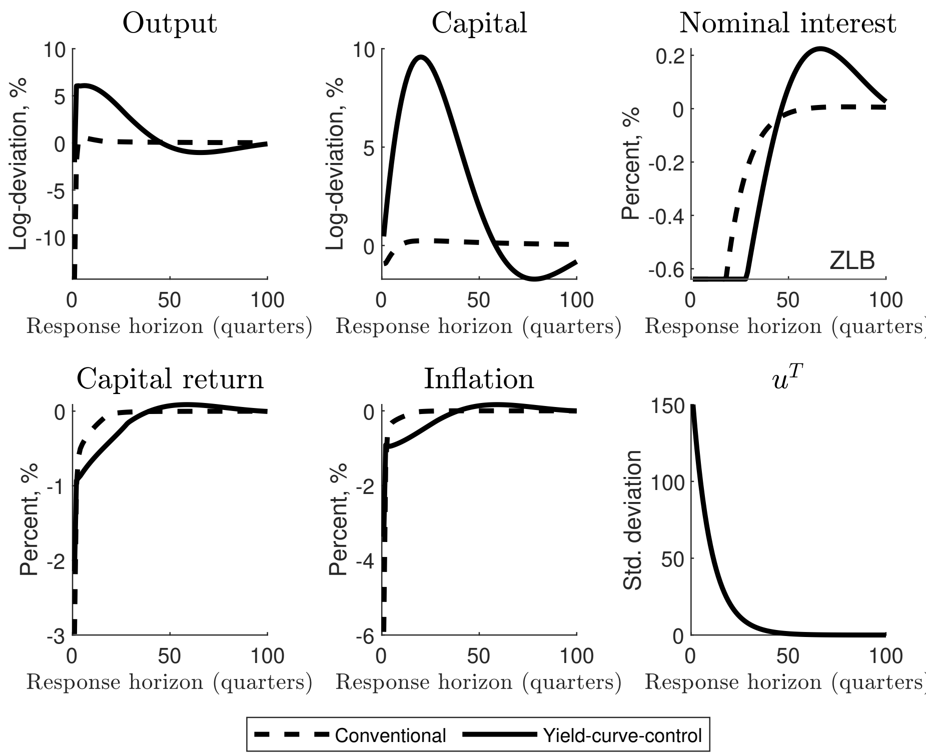


Figure 8: Impulse-response to ε_t^T shock with ZLB

4.2.3 Policy Comparison

We follow the literature (e.g., Woodford (2003) and Coibion et al. (2012)) by computing a second-order approximation of household utility.

Proposition 1 *A second-order approximation of the expected per-period household welfare is given by*

$$\mathbb{E}U_t - \bar{U}^F = \Omega_n \operatorname{Var}(\hat{n}_t) + \Omega_\pi \operatorname{Var}(\hat{\pi}_t) + \textit{t.i.p.} + \textit{h.o.t.},$$

where Ω_n and Ω_π are coefficients that capture the disutility arising from fluctuations in labor and inflation, respectively; $\bar{U}^F$ denotes the efficient (i.e., flexible-price) steady-state[34] *utility around which the approximation is centered; and the acronyms $t.i.p.$ and $h.o.t.$ refer to terms independent of policy and to higher-order terms, respectively.*

Proof. See Online Appendix C. ■

[34]Due to assumed trend inflation at the steady state ($\Pi > 1$), our steady state is not efficient; see Coibion et al. (2012).

Based on the welfare criterion provided in Proposition 1, we compare three monetary policy regimes: (i) conventional policy (i.e., (23)); (ii) yield-curve control (YCC) policy (i.e., (24)); and (iii) a "mixed" policy in which the central bank adopts YCC only when the policy rate hits the ZLB.[35] We evaluate these regimes using ex-ante per-period welfare, mean and median ZLB duration, and ZLB frequency.

	Conventional	**Yield-Curve-Control**	**Mixed Policy**
Mean ZLB duration	4.5533 quarters	6.2103 quarters	5.5974 quarters
Median ZLB duration	3 quarters	3 quarters	2 quarters
ZLB frequency	15.9596%	13.4242%	17.4141%
Welfare	-1.393%	-1.2424%	-1.3662%

Table 1: Policy Comparisons

Table 1 shows that, compared to conventional policy, both YCC and mixed policies improve welfare by 0.16 and 0.03 percentage points, respectively. However, YCC extends ZLB spells (6.2 vs. 4.6 quarters), while mixed policy outcomes lie between the two benchmarks.

Under mixed policy, stabilization during ZLB episodes is enhanced relative to conventional policy because YCC is activated during ZLB periods. However, due to the household portfolio rebalancing channel (see Section 4.2.2), mixed policy may also prolong the ZLB spell. In contrast, YCC allows the central bank to adjust the entire yield curve even outside ZLB periods. By lowering long-term rates in response to adverse shocks, YCC supports aggregate demand and reduces the likelihood of entering the ZLB. However, its strong downward pressure on short-term rates results in the longest average ZLB duration.[36]

5 Conclusion

This paper presents a New Keynesian model that integrates the term structure of financial markets and the size and maturity composition of government and central bank balance sheets as active drivers of the business cycle. Our model highlights that market segmentation across asset classes and maturities—stemming from inelastic financial market de-

[35]Upon exiting the ZLB, the central bank immediately resets its holdings of $f \geq 2$-maturity bonds to their steady-state levels. This approach differs from Karadi and Nakov (2021), who argue that a gradual exit from QE is optimal given that banks face reduced recapitalization incentives without additional QE.

[36]Note that the statistics in Table 1 are ex-ante, reflecting the potential impact of a wide range of shocks; specific shocks may produce different patterns across regimes.

mand—and households' endogenous portfolio reallocation are key for understanding unconventional monetary policy.

We show that government debt issuance and central bank purchases of bonds with different maturities are the primary determinants of the yield curve's level and slope. Furthermore, the issuance of risk-free government bonds can stimulate the economy when conventional monetary policy is constrained by the ZLB, aligning with the literature on safe-asset shortages. We compare three policy regimes: (i) conventional policy, (ii) yield-curve control (YCC), where the central bank actively manipulates the entire yield curve, and (iii) a mixed regime, where YCC is employed only when the ZLB binds. Our results suggest that YCC interventions offer greater stabilization than conventional policy, both during normal periods and at the ZLB, though they also tend to extend the duration of ZLB episodes. This occurs because easing long-term rates induces households to shift their portfolios toward shorter maturities, further depressing short-term rates. In this sense, unconventional policies become "addictive": central banks rely on them for economic stabilization, yet their use exacerbates conditions that make conventional policy ineffective.

Our model provides a framework for future research on quantitative tightening in high inflation environments and for examining the political economy and taxpayer risks associated with expanding central bank balance sheets. Additionally, we aim to extend this framework to international macroeconomics, revisiting issues such as global imbalances (e.g., Caballero et al. (2008, 2021)) and global monetary cycles (e.g., Miranda-Agrippino and Rey (2021)) with endogenous term structure fluctuations.

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I Shock Processes

We assume that the household portfolio preference shocks $\{z_t^f\}_{f=1}^F$ and z_t^K follow $AR(1)$ processes, given by $z_t^f = \rho_z \, z_{t-1}^f + \varepsilon_t^{z,f}$ with $\mathrm{Var}(\varepsilon_t^{z,f}) = \sigma_z^2$, and $z_t^K = \rho_z^K \, z_{t-1}^K + \varepsilon_t^{z,K}$ with $\mathrm{Var}(\varepsilon_t^{z,K}) = (\sigma_z^K)^2$.

For the government spending ratio ζ_t^G and the revenue ratio ζ_t^T, we assume the following shock processes:

$$\zeta_t^G = \frac{1}{1 + a^G \exp\left(-u_t^G\right)}, \quad \zeta_t^T = \frac{1}{1 + a^T \exp\left(-u_t^T\right)}, \tag{I.1}$$

where a^G and a^T are constants, and u_t^G and u_t^T follow $AR(1)$ processes $u_t^G = \rho_G \, u_{t-1}^G + \varepsilon_t^G$ and $u_t^T = \rho_T \, u_{t-1}^T + \varepsilon_t^T$, with ε_t^G and ε_t^T being i.i.d. shocks.

As the government's bond shares across maturities, $\{\lambda_t^{G,f}\}_{f=1}^F$, are exogenously given, we specify their processes as follows:

$$\lambda_t^{G,1} = \frac{1}{1 + \sum_{l=2}^{F} a^{B,l} \exp\left(\tilde{u}_t^{B,l}\right)}, \quad \lambda_t^{G,f} = \frac{a^{B,f} \exp\left(\tilde{u}_t^{B,f}\right)}{1 + \sum_{l=2}^{F} a^{B,l} \exp\left(\tilde{u}_t^{B,l}\right)}, \quad \forall f > 1, \tag{I.2}$$

where $a^{B,f}$ for all $f > 1$ are constants. When F is large, we reduce the number of independent shocks to $J \leq F$ by assuming

$$\tilde{u}_t^{B,f} = \sum_{j=2}^{J} \tau_{fj}^B u_t^{B,j}, \tag{I.3}$$

where $u_t^{B,j}$ follows an independent $AR(1)$ process, and τ_{fj}^B is a constant for all j, f.

Similarly, we reduce the state space of shocks in the yield-curve control regime by representing the monetary policy shocks $\{\tilde{\varepsilon}_t^{YD^f}\}_{f=1}^F$ for different maturities as linear combinations of several factors:

$$\tilde{\varepsilon}_t^{YD^f} = \sum_{l=1}^{L} \tau_{f,l}^{YD} \varepsilon_t^{YD^l}, \tag{I.4}$$

where $\tau_{f,l}^{YD}$ (for all l, f) are constants, $\varepsilon_t^{YD^l}$ are i.i.d. shocks, and $L \leq F$.

II Calibration

Steady-state values		
$\frac{C}{A\bar{N}}$	9.0112	Normalized consumption
$\frac{Y}{A\bar{N}}$	16.3315	Normalized output
$\frac{K}{A\bar{N}}$	192.6312	Normalized capital
$\frac{C}{Y}$	0.5518	Consumption per GDP
$\frac{K}{Y}$	11.7951	Capital per GDP
$\frac{P^K}{P}$	0.0335	Normalized rental price of capital
$\lambda^{HB,f}$	See Figure 1	Household's bond portfolio
λ^K	0.5322	Household's loan share out of total savings
R^K	1.0203	Household's loan rates (quarterly)
YD^f	See Figure 1	Equilibrium yield curve

Table II.1: Steady-state values derived from parameter calibration in Table II.2

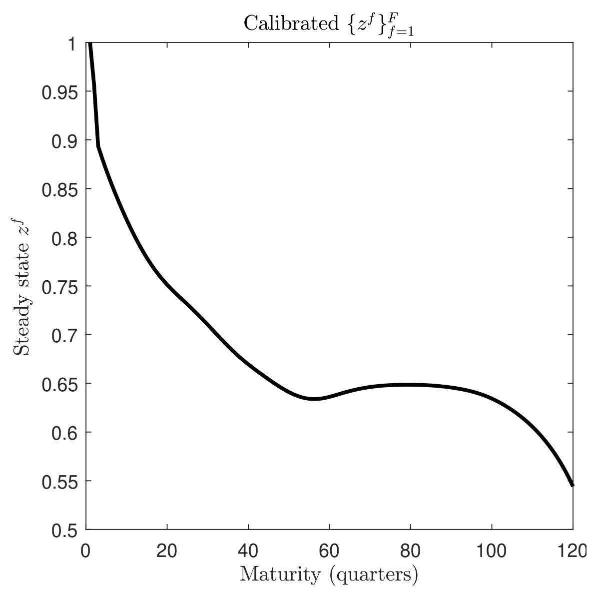


Figure II.1: Calibrated scale parameters of the Fréchet distribution, $\{z^f\}_{f=1}^F$

Households		
(β, η)	$(0.998, 1)$	Discount factor and Frisch labor elasticity
GN	1.00275	Population growth rate
Intermediate good firms		
μ	0.00375	Technology growth rate
γ	3	Loan-to-GDP ratio
α	0.4	Capital income share
ϵ	10	Elasticity of substitution between differentiated goods
θ	0.45	Calvo price stickiness parameter
σ_A	0.0036	Standard deviation of technology shock
δ	0.025	Capital depreciation rate
Term structure		
$\{z^f\}_{f=1}^F$	See Figure II.1	Bond maturity scale (mean) parameters (Appendix B.1)
z^K	1.0089	Capital scale (mean) parameter (Appendix B.1)
κ_B	10	Bond maturity shape (volatility) parameter (Appendix B.2)
κ_S	6	Capital shape parameter: Kekre and Lenel (2023)
(ρ_z, ρ_z^K)	$(0.9, 0.9)$	Autoregressive coefficient: z_t^f and z_t^K
(σ_z, σ_z^K)	4×10^{-9}	Standard deviation: z_t^f and z_t^K
Government		
ζ^F	0.1111	Government's optimal subsidy to firms
ζ^G	0.0789	Government expenditure per GDP (net subsidy ζ^F)
a^G	11.6761	Government expenditure coefficient
$\zeta^F + \zeta^G - \zeta^T$	0.017	Government deficit per GDP
ζ^T	0.1730	Government tax revenue per GDP
(ρ_G, ρ_T)	$(0.9, 0.9)$	Autoregressive coefficient: expenditure and tax shocks
(σ_G, σ_T)	0.00148	Standard deviation: expenditure and tax shocks
Central bank		
ζ^{CB}	-0.18	Central bank's balance sheet per issued government bond
$\bar{\pi}$	$\frac{0.023}{4} = 0.00575$	Trend inflation (steady-state inflation)
γ_π^1	2.5	Taylor coefficient of YD_t^1: responsiveness to inflation
$\gamma_\pi^{f\geq 2}$	1.5	Taylor coefficient of $YD_t^{f\geq 2}$: responsiveness to inflation
γ_y	0.15	Taylor coefficient: responsiveness to output
$\gamma_y^{f\geq 2}$	0.15	Taylor coefficient of $YD_t^{f\geq 2}$: responsiveness to output
(ρ_1, ρ_2)	$(1.05, -0.13)$	Autocorrelation in monetary policy: Coibion et al. (2012)
σ^{YD^1}	9.6×10^{-4}	Standard deviation: monetary policy shock (for YD_t^1)
$\sigma^{YD^{f\geq 2}}$	4×10^{-9}	Standard deviation: monetary policy shock (for $YD_t^{f\geq 2}$)
τ^{YD}	$I_{F\times F}$	State reduction matrix (for $YD_t^{f\geq 2}$)

Table II.2: Parameter values

III Additional Figures

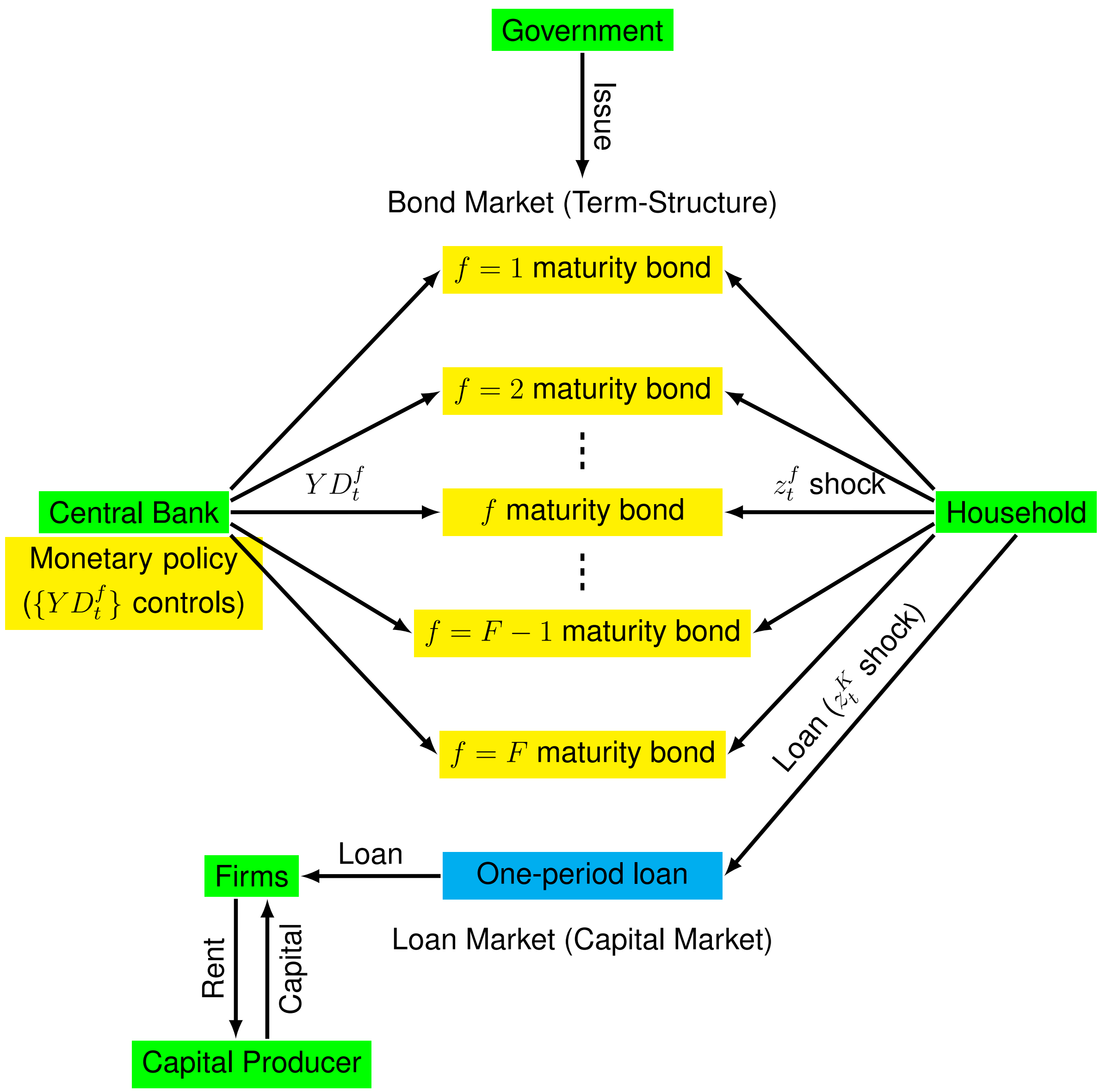


Figure III.2: Markets, Agents, and Mechanisms: households allocate wealth between bonds and extending loans to intermediate goods producers. The government issues bonds with $f = 1 \sim F$ maturities. Under a conventional monetary policy, the central bank manipulates the yield of $f = 1$ bond without adjusting the holdings for longer-term bonds. Under the yield-curve-control, the central bank manages yields of $f = 1 \sim F$.

A Derivation and Proofs

A.1 Detailed Derivations in Section 2

As in (15), an intermediate firm ν resetting its price at period t maximizes

$$\max \sum_{j=0}^{\infty} \mathbb{E}_t \Bigg[\theta^j Q_{t,t+j} \cdot \Bigg[\Big[1 - \gamma_L \cdot \Big(\widetilde{R}^K_{t+j+1} - 1 \Big) \Big] \cdot (1+\zeta^F) \cdot P_{t+j}(\nu) Y_{t+j}(\nu) \\ - W_{t+j}(\nu) N_{t+j}(\nu) - P^K_{t+j-1} K_{t+j-1}(\nu) \Bigg] \Bigg], \tag{A.1}$$

where $Q_{t,t+j}$ is the firm's stochastic discount factor between periods t and $t+j$ and ζ^F is a production subsidy. Also, we define $\widetilde{R}^K_{t+j+1} \equiv \mathbb{E}_{t+j}[Q_{t+j,t+j+1} R^K_{t+j+1}]$. Solving for the optimal resetting price at period t, P^*_t, we obtain

$$\frac{P^*_t}{P_t} = \frac{\mathbb{E}_t \left[\sum_{j=0}^{\infty} \theta^j Q_{t,t+j} \left(\frac{P_{t+j}}{P_t} \right)^{\epsilon+1} Y_{t+j} \left(\frac{(1+\zeta^F)^{-1}\epsilon}{\epsilon - 1} \right) \left(\frac{MC_{t+j|t}(\nu)}{P_{t+j}} \right) \right]}{\mathbb{E}_t \left[\sum_{j=0}^{\infty} \theta^j Q_{t,t+j} \left(\frac{P_{t+j}}{P_t} \right)^{\epsilon} Y_{t+j} \left[1 - \gamma_L \cdot \left(\widetilde{R}^K_{t+j+1} - 1 \right) \right] \right]}, \tag{A.2}$$

where subindex $t+j|t$ represents the value of the variable conditional on the firm having reset its price last time at period t, and $MC_{t+j|t}(\nu)/P_t$ is the real marginal cost of production, defined as

$$\frac{MC_{t+j|t}(\nu)}{P_{t+j}} = \left(\frac{P^K_{t+j}}{P_{t+j}} \right)^{\alpha} \left(\frac{W_{t+j|t}(\nu)}{P_{t+j} A_{t+j}} \right)^{1-\alpha}. \tag{A.3}$$

A.1.1 Detailed Derivation in Section 2.9

Using equations equation (10), equation (12), equation (13) and equation (A.3) we can express firm-specific marginal costs as a function of the aggregate variables as in

$$\frac{MC_{t+j|t}(\nu)}{P_{t+j}} = (1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}} \left(\frac{C_{t+j}}{A_{t+j}\bar{N}_{t+j}} \right)^{\frac{\eta(1-\alpha)}{\eta+\alpha}} \left(\frac{Y_{t+j}}{A_{t+j}\bar{N}_{t+j}} \right)^{\frac{1-\alpha}{\eta+\alpha}} \left(\frac{P^K_{t+j}}{P_{t+j}} \right)^{\alpha\left(\frac{\eta+1}{\eta+\alpha}\right)} \left(\frac{P^*_t}{P_{t+j}} \right)^{-\left(\frac{\epsilon(1-\alpha)}{\eta+\alpha}\right)}.$$

Similarly, we integrate loan and labor demand across the continuum of firms and obtain the following expressions for the loan and labor aggregation conditions.

$$\frac{K_t}{A_{t-1}\bar{N}_{t-1}} = \alpha(1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}} \cdot GA_t \cdot GN \cdot \left(\frac{C_t}{A_t\bar{N}_t}\right)^{\frac{\eta(1-\alpha)}{\eta+\alpha}} \left(\frac{Y_t}{A_t\bar{N}_t}\right)^{\frac{\eta+1}{\eta+\alpha}} \left(\frac{P_t^K}{P_t}\right)^{-\left(\frac{\eta(1-\alpha)}{\eta+\alpha}\right)} \Delta_t, \tag{A.4}$$

$$\frac{N_t}{\bar{N}_t} = (1-\alpha)^{\left(\frac{\eta}{\eta+\alpha}\right)} \left(\frac{C_t}{A_t\bar{N}_t}\right)^{-\alpha\left(\frac{\eta}{\eta+\alpha}\right)} \left(\frac{Y_t}{A_t\bar{N}_t}\right)^{\left(\frac{\eta}{\eta+\alpha}\right)} \left(\frac{P_t^K}{P_t}\right)^{\alpha\left(\frac{\eta}{\eta+\alpha}\right)} \Delta_t^{\frac{\eta}{\eta+1}}, \tag{A.5}$$

where Δ_t is a measure of price-dispersion that can be recursively defined as

$$\Delta_t = (1-\theta)\left(\frac{P_t^*}{P_t}\right)^{-\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)} + \theta\Pi_t^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}\Delta_{t-1}. \tag{A.6}$$

Plugging the real marginal cost and the expressions for Q_{t+j} into the optimal resetting price equation (i.e., equation (A.2)), we obtain

$$\left(\frac{P_t^*}{P_t}\right)^{1+\epsilon\left(\frac{1-\alpha}{\eta+\alpha}\right)} = \frac{\mathbb{E}_t\left[\sum_{j=0}^{\infty}(\theta\beta)^j(1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}}\frac{(1+\varsigma_F)^{-1}\epsilon}{\epsilon-1}\left(\frac{C_{t+j}}{A_{t+j}\bar{N}_{t+j}}\right)^{-\alpha\frac{\eta+1}{\eta+\alpha}}\left(\frac{Y_{t+j}}{A_{t+j}\bar{N}_{t+j}}\right)^{\frac{\eta+1}{\eta+\alpha}}\left(\frac{P_{t+j}}{P_t}\right)^{\epsilon\frac{\eta+1}{\eta+\alpha}}\left(\frac{P_{t+j}^K}{P_{t+j}}\right)^{\alpha\frac{\eta+1}{\eta+\alpha}}\right]}{\mathbb{E}_t\left[\sum_{j=0}^{\infty}(\theta\beta)^j\left(\frac{P_{t+j}}{P_t}\right)^{\epsilon-1}\left(\frac{C_{t+j}}{A_{t+j}\bar{N}_{t+j}}\right)^{-1}\left(\frac{Y_{t+j}}{A_{t+j}\bar{N}_{t+j}}\right)\left[1-\gamma_L\cdot\left(\widetilde{R}_{t+j+1}^K-1\right)\right]\right]}. \tag{A.7}$$

We can simplify this expression as

$$\frac{P_t^*}{P_t} = \left(\frac{F_t}{H_t}\right)^{\frac{1}{1+\epsilon\left(\frac{1-\alpha}{\eta+\alpha}\right)}}, \tag{A.8}$$

where F_t and H_t are recursively written as

$$\begin{aligned} F_t &= (1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}}\left(\frac{(1+\varsigma_F)^{-1}\epsilon}{\epsilon-1}\right)\left(\frac{C_t}{A_t\bar{N}_t}\right)^{-\alpha\left(\frac{\eta+1}{\eta+\alpha}\right)}\left(\frac{Y_t}{A_t\bar{N}_t}\right)^{\frac{\eta+1}{\eta+\alpha}}\left(\frac{P_t^K}{P_t}\right)^{\alpha\left(\frac{\eta+1}{\eta+\alpha}\right)} + \theta\beta\mathbb{E}_t\left[\Pi_{t+1}^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}F_{t+1}\right], \\ H_t &= \left(\frac{C_t}{A_t\bar{N}_t}\right)^{-1}\frac{Y_t}{A_t\bar{N}_t}\left[1-\gamma_L\cdot\left(\widetilde{R}_{t+1}^K-1\right)\right] + \theta\beta\mathbb{E}_t\left[\Pi_{t+1}^{\epsilon-1}H_{t+1}\right]. \end{aligned} \tag{A.9}$$

Using (A.9), we obtain the following equilibrium price-resetting condition:

$$\frac{F_t}{H_t} = \left(\frac{1-\theta}{1-\theta\Pi_t^{\epsilon-1}}\right)^{\left(\frac{1}{\epsilon-1}\right)\left[1+\epsilon\left(\frac{1-\alpha}{\eta+\alpha}\right)\right]}. \tag{A.10}$$

We now rewrite equation (11) as

$$1 = \beta \cdot \mathbb{E}_t \left[\frac{R^S_{t+1}}{\Pi_{t+1} G A_{t+1} G N} \cdot \frac{\left(\frac{C_t}{A_t \bar{N}_t} \right)}{\left(\frac{C_{t+1}}{A_{t+1} \bar{N}_{t+1}} \right)} \right].$$

Since R^S_{t+1} depends on bonds return R^{HB}_{t+1} and loans return R^K_{t+1} while shares of savings that flow into bonds $(1-\lambda^K_t)$ and loans (λ^K_t) are endogenous, we start from analyzing R^{HB}_{t+1}. We can rewrite the aggregate return indices as functions of the bond yields $\{YD^f_t\}^F_{f=1}$ as

$$R^j_t = \sum_{f=0}^{F-1} \lambda^{j,f+1}_{t-1} \frac{\left(YD^f_t\right)^{-f}}{\left(YD^{f+1}_{t-1}\right)^{-(f+1)}}, \;\; j \in \{H, G, CB\},$$

and also the household's bond portfolio share as

$$\lambda^{HB,f}_t = \left(\frac{\mathbb{E}_t \left[\frac{\beta \cdot z^f_t}{\Pi_{t+1} \cdot GA_{t+1} \cdot GN} \cdot \frac{\left(\frac{C_t}{A_t \bar{N}_t} \right)}{\left(\frac{C_{t+1}}{A_{t+1} \bar{N}_{t+1}} \right)} \cdot \frac{\left(YD^{f-1}_{t+1}\right)^{-(f-1)}}{\left(YD^f_t\right)^{-f}} \right]}{\Phi^B_t} \right)^{\kappa_B}, \;\; \forall f \; ,$$

$$\Phi^B_t = \left[\sum_{j=1}^{F} \mathbb{E}_t \left[\frac{\beta \cdot z^j_t}{\Pi_{t+1} \cdot GA_{t+1} \cdot GN} \cdot \frac{\left(\frac{C_t}{A_t \bar{N}_t} \right)}{\left(\frac{C_{t+1}}{A_{t+1} \bar{N}_{t+1}} \right)} \cdot \frac{\left(YD^{j-1}_{t+1}\right)^{-(j-1)}}{\left(YD^j_t\right)^{-j}} \right]^{\kappa_B} \right]^{\frac{1}{\kappa_B}}.$$

Now we find the equilibrium condition for the bond shares of the agents. Using the bond market equilibrium condition (i.e., (17)), we obtain

$$\lambda^{HB,f}_t = \frac{B^{G,f}_t + B^{CB,f}_t}{B^G_t + B^{CB}_t} = \frac{\lambda^{G,f}_t B^G_t + \lambda^{CB,f}_t B^{CB}_t}{B^G_t + B^{CB}_t}. \tag{A.11}$$

We can rearrange the previous expression as

$$\lambda_t^{CB,f} = \lambda_t^{HB,f} + \left(\lambda_t^{HB,f} - \lambda_t^{G,f}\right) \cdot \frac{B_t^G}{B_t^{CB}}. \tag{A.12}$$

Summing from $f = 2$ to F, and using $\sum_{f=2}^{F} \lambda_t^{j,f} = 1 - \lambda_t^{j,1},\ j \in \{H, G, CB\}$ we obtain

$$\sum_{f=2}^{F} \lambda_t^{CB,f} = 1 - \lambda_t^{HB,1} + \left(\lambda_t^{G,1} - \lambda_t^{HB,1}\right) \cdot \frac{B_t^G}{B_t^{CB}}. \tag{A.13}$$

Plugging (A.13) into (A.12) and after some rearrangements, we obtain

$$\lambda_t^{CB,f} = \frac{\lambda_t^{HB,f}\left(\lambda_t^{CB,1} - \lambda_t^{G,1}\right) - \lambda_t^{G,f}\left(\lambda_t^{CB,1} - \lambda_t^{HB,1}\right)}{\lambda_t^{HB,1} - \lambda_t^{G,1}}, \quad f > 1. \tag{A.14}$$

Now, we can obtain an expression for the central bank's bond holdings using (A.13) as

$$B_t^{CB} = \left(\frac{\lambda_t^{HB,1} - \lambda_t^{G,1}}{\lambda_t^{CB,1} - \lambda_t^{HB,1}}\right) \cdot B_t^G. \tag{A.15}$$

Combining (17) and (A.15), we obtain

$$\frac{B_t^H}{A_t \bar{N}_t} = -\left(\frac{\lambda_t^{CB,1} - \lambda_t^{G,1}}{\lambda_t^{CB,1} - \lambda_t^{HB,1}}\right) \cdot \frac{B_t^G}{A_t \bar{N}_t}. \tag{A.16}$$

Combining $L_t = \lambda_t^K S_t$ and $B_t^H = (1 - \lambda_t^K) S_t$ with $L_t = \gamma_L \cdot \left(1 + \zeta^F\right) \cdot P_t Y_t$, we obtain

$$\frac{B_t^H}{A_t \bar{N}_t P_t} = \gamma_L \cdot \left(1 + \zeta^F\right) \cdot \left(\frac{1 - \lambda_t^K}{\lambda_t^K}\right)\left(\frac{Y_t}{A_t \bar{N}_t}\right). \tag{A.17}$$

Combining equation (A.16) and equation (A.17), we get the following equation

$$-\left(\frac{\lambda_t^{CB,1} - \lambda_t^{G,1}}{\lambda_t^{CB,1} - \lambda_t^{HB,1}}\right) \cdot \frac{B_t^G}{A_t \bar{N}_t P_t} = \gamma_L \cdot \left(1 + \zeta^F\right) \cdot \left(\frac{1 - \lambda_t^K}{\lambda_t^K}\right)\left(\frac{Y_t}{A_t \bar{N}_t}\right). \tag{A.18}$$

A.1.2 Conventional Policy in Section 2.9.1

Using the bond market equilibrium (i.e., (17)) with $\sum_{f=2}^{F} \lambda_t^{HB,f} = 1 - \lambda_t^{HB,1}$, we get

$$B_t^H = -\frac{\sum_{i=2}^{F} \left(B_t^{G,i} + B_t^{CB,i} \right)}{1 - \lambda_t^{HB,1}}. \tag{A.19}$$

Combining (A.19) with (17) and (23c), we obtain the equilibrium set of equations,

$$\frac{\lambda_t^{HB,f}}{1 - \lambda_t^{HB,1}} = \frac{\dfrac{B_t^{G,f}}{A_t \bar{N}_t P_t} + \dfrac{\overline{B^{CB,f}}}{A \bar{N} P}}{\sum_{i=2}^{F} \left(\dfrac{B_t^{G,i}}{A_t \bar{N}_t P_t} + \dfrac{\overline{B^{CB,i}}}{A \bar{N} P} \right)}, \quad \forall f > 1. \tag{A.20}$$

Combining (A.17), (A.19), and (23c) yields the following equilibrium equation:

$$-\frac{\sum_{i=2}^{F} \left(\dfrac{B_t^{G,i}}{A_t \bar{N}_t P_t} + \dfrac{\overline{B^{CB,i}}}{A \bar{N} P} \right)}{1 - \lambda_t^{HB,1}} = \gamma_L \cdot \left(1 + \zeta^F\right) \cdot \left(\frac{1 - \lambda_t^K}{\lambda_t^K} \right) \left(\frac{Y_t}{A_t \bar{N}_t} \right), \tag{A.21}$$

where normalized bond positions of the central bank are exogenously given. Finally, combining (A.20) and (A.21), we finally obtain

$$-\left(\frac{B_t^{G,f}}{A_t \bar{N}_t P_t} + \frac{\overline{B^{CB,f}}}{A \bar{N} P} \right) \cdot \left(\lambda_t^{HB,f} \right)^{-1} = \gamma_L \cdot \left(1 + \zeta^F\right) \cdot \left(\frac{1 - \lambda_t^K}{\lambda_t^K} \right) \left(\frac{Y_t}{A_t \bar{N}_t} \right), \quad \forall f > 1. \tag{A.22}$$

A.1.3 Steady-State Derivations in Section 3.1

At the steady state, the central bank decides the level of bond holdings of maturities $B^{CB,f}$ that it wants to hold. It can be calibrated to match the data of the central bank's balance sheet. Given $\left\{ \lambda^{CB,f} \right\}$ and the size of its portfolio B^{CB}, which is ζ^{CB} fraction of total government bond issuance satisfying $B^{CB} = \zeta^{CB} \cdot B^G$, we obtain the steady state households' bond shares as

$$\lambda^{HB,f} = \frac{\lambda^{G,f} + \lambda^{CB,f} \cdot \zeta^{CB}}{1 + \zeta^{CB}}. \tag{A.23}$$

From the definition of R^{HB} we have

$$\sum_{f=1}^{F} \lambda^{HB,f} \cdot \left(\frac{R^f}{R^{HB}}\right) = 1,$$

which together with equation (3) can be rearranged as:

$$\lambda^{HB,f} = \left(\frac{z^f \cdot \dfrac{R^f}{R^{HB}}}{\tilde{\Phi}^B}\right)^{\kappa_B}, \ \forall f, \ \text{ with } \ \tilde{\Phi}^B = \left[\sum_{j=1}^{F}\left[z^j \cdot \frac{R^j}{R^{HB}}\right]^{\kappa_B}\right]^{\frac{1}{\kappa_B}}. \tag{A.24}$$

The above (A.23) and (A.24) jointly determine the steady state yields and household shares. Unfortunately, there is no analytical expression for them and we have to solve for the steady state values numerically. How we proceed, relying on simple iterations:

1. Assume some initial guess for $\left\{\frac{R^{f,guess}}{R^{HB}}\right\}_{f=1}^{F}$.
2. Construct $\tilde{\Phi}^{B,old}$ using previous guess with $\tilde{\Phi}^B$ in equation (A.24).
3. Update estimates on $\left\{\frac{R^f}{R^{HB}}\right\}_{f=1}^{F}$ with the following rules:

$$\frac{R^{1,new}}{R^{HB}} = \frac{1 - \sum_{f=2}^{F} \lambda^{HB,f}\left(\dfrac{R^f}{R^{HB}}\right)}{\lambda^{HB,1}}, \quad \frac{R^{f,new}}{R^{HB}} = \left(\lambda^{HB,f}\right)^{\frac{1}{\kappa_B}} \left(z^f\right)^{-1} \tilde{\Phi}^{B,old}, \quad f > 1.$$

4. Construct new shares of households $\lambda^{HB,f,new}$ by plugging $\left\{\frac{R^{f,new}}{R^{HB}}\right\}_{f=1}^{F}$ into (A.24). Compute the discrepancy between these shares and the true ones found in (A.23). If the error is big, set $\frac{R^{f,guess}}{R^{HB}} = \frac{R^{f,new}}{R^{HB}}$ and repeat from Step 2 until convergence.

Using (6) and (11), we obtain

$$R^{HB} = \frac{\beta^{-1}\Pi \cdot GA \cdot GN}{1-\lambda^K} - \frac{\lambda^K}{1-\lambda^K} R^K. \tag{A.25}$$

We can rewrite R^G as

$$R^G = \Xi \cdot R^{HB}, \ \ \Xi = \sum_{f=1}^{F} \lambda^{G,f} \cdot \left(\frac{R^f}{R^{HB}}\right), \tag{A.26}$$

and from (A.25), it becomes

$$R^G = \Xi \cdot \left[\frac{\beta^{-1}\Pi \cdot GA \cdot GN}{1-\lambda^K} - \frac{\lambda^K}{1-\lambda^K} R^K \right]. \tag{A.27}$$

Using (5), we obtain an expression for the steady-state share of loans as

$$\lambda^K = \frac{\left(z^K \cdot \frac{R^K}{R^{HB}} \right)^{\kappa_S}}{1 + \left(z^K \cdot \frac{R^K}{R^{HB}} \right)^{\kappa_S}}. \tag{A.28}$$

Further combining (A.25) and (A.28), we obtain

$$\frac{\lambda^K}{1-\lambda^K} \equiv \left(z^K \cdot \frac{R^K}{R^{HB}} \right)^{\kappa_S} = \frac{\beta^{-1} \cdot \Pi \cdot GA \cdot GN - R^{HB}}{R^K - \beta^{-1} \cdot \Pi \cdot GA \cdot GN} \tag{A.29}$$

The equilibrium government bonds are obtained from its budget constraint (i.e., (20)) and written as

$$\frac{B^G}{A\bar{N}P} = -\left(1 - \frac{R^G}{\Pi \cdot GA \cdot GN}\right)^{-1} \left[\zeta^G + \zeta^F - \zeta^T\right] \left(\frac{Y}{A\bar{N}}\right). \tag{A.30}$$

The model needs the government to be a borrower, so $B^G < 0$ at the steady-state. Also, we would like to match the data in which the government runs primary deficit $\zeta^G + \zeta^F - \zeta^T > 0$. The only way to achieve that is by having $R^G < \Pi \cdot GA \cdot GN$. Combining $B^{CB} = \zeta^{CB} \cdot B^G$, $B_t^H = -\left(B_t^G + B_t^{CB}\right)$, (A.17), (A.26), and (A.29) yields

$$\gamma_L = \left(\frac{1+\zeta^{CB}}{1+\zeta^F}\right) \cdot \left[\zeta^G + \zeta^F - \zeta^T\right] \cdot \left(1 - \frac{\Xi}{\Pi \cdot GA \cdot GN} \cdot R^{HB}\right)^{-1} \cdot \left[\frac{\beta^{-1} \cdot \Pi \cdot GA \cdot GN - R^{HB}}{R^K - \beta^{-1} \cdot \Pi \cdot GA \cdot GN}\right]. \tag{A.31}$$

(A.29) and (A.31) form a nonlinear system of equations on the unknown steady-states of R^K and R^{HB}. After then, we can then simply back out bond returns as

$$R^f = R^{HB} \cdot \left(\frac{R^f}{R^{HB}}\right).$$

Now that we have found the bond returns, we can recursively obtain the bond yields using

$$YD^f = \left[R^f \cdot \left(YD^{f-1}\right)^{f-1}\right]^{\frac{1}{f}},$$

where $YD^0 = 1$. The price dispersion is given by

$$\Delta = \left[\frac{1-\theta}{1-\theta\Pi^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}}\right]\left(\frac{1-\theta\Pi^{\epsilon-1}}{1-\theta}\right)^{\left(\frac{\epsilon}{\epsilon-1}\right)\left(\frac{\eta+1}{\eta+\alpha}\right)}. \tag{A.32}$$

From the capital producer's optimization, we obtain an expression for P^K

$$\frac{P^K}{P} = \beta^{-1}\cdot GA\cdot GN - (1-\delta). \tag{A.33}$$

The steady state representation of firms' pricing (i.e., (A.9) can be written as

$$F = \xi^F\cdot\left(\frac{C}{A\bar{N}}\right)^{-\alpha\left(\frac{\eta+1}{\eta+\alpha}\right)}\left(\frac{Y}{A\bar{N}}\right)^{\frac{\eta+1}{\eta+\alpha}}, \tag{A.34}$$

$$H = \xi^H\cdot\left(\frac{C}{A\bar{N}}\right)^{-1}\left(\frac{Y}{A\bar{N}}\right), \tag{A.35}$$

$$\text{with}\quad \xi^F = (1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}}\left[1-\theta\beta\Pi^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}\right]^{-1}\left(\frac{(1+\zeta^F)^{-1}\epsilon}{\epsilon-1}\right)\left(\frac{P^K}{P}\right)^{\alpha\left(\frac{\eta+1}{\eta+\alpha}\right)},$$

$$\xi^H = \left[1-\gamma_L\cdot\left(\frac{R^K}{R^S}-1\right)\right]\cdot\left[1-\theta\beta\cdot\Pi^{\epsilon-1}\right]^{-1}.$$

Using (A.34), (A.35) and (A.10), we obtain

$$\left(\frac{C}{A\bar{N}}\right)^{\left(\frac{(1-\alpha)\eta}{\eta+\alpha}\right)} = \xi^Y\cdot\left(\frac{Y}{A\bar{N}}\right)^{-\left(\frac{1-\alpha}{\eta+\alpha}\right)},\quad \text{with}\quad \xi^Y = \left(\frac{\xi^H}{\xi^F}\right)\left(\frac{1-\theta}{1-\theta\Pi^{\epsilon-1}}\right)^{\left(\frac{1}{\epsilon-1}\right)\left[1+\epsilon\left(\frac{1-\alpha}{\eta+\alpha}\right)\right]}. \tag{A.36}$$

Combining (A.36) and (A.4), we obtain

$$\frac{K}{A\bar{N}} = \xi^K\cdot\left(\frac{Y}{A\bar{N}}\right),\quad \text{with}\quad \xi^K = \alpha\cdot(1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}}\cdot GA\cdot GN\cdot\left(\frac{P^K}{P}\right)^{-\left(\frac{\eta(1-\alpha)}{\eta+\alpha}\right)}\Delta\cdot\xi^Y. \tag{A.37}$$

Plugging (A.37) into the aggregate resource constraint, we obtain

$$\frac{C}{A\bar{N}} = \xi^C\cdot\left(\frac{Y}{A\bar{N}}\right),\quad \text{with}\quad \xi^C = (1-\zeta^G) - \xi^K\cdot\left[1-\left(\frac{1-\delta}{GA\cdot GN}\right)\right]. \tag{A.38}$$

Combining (A.36) and (A.38), we obtain

$$\frac{Y}{A\bar{N}} = \left(\xi^{Y}\right)^{\left(\frac{1}{1-\alpha}\right)\left(\frac{\eta+\alpha}{\eta+1}\right)} \left(\xi^{C}\right)^{-\left(\frac{\eta}{\eta+1}\right)}. \tag{A.39}$$

A.1.4 Log-linearization

We start by log-linearizing the equations that are common to the conventional policy model and the yield-curve-control one, then derive the ones that are different. Log-linearize (I.1),

$$\hat{ga}_t = \hat{\varepsilon}_t^A, \;\; \hat{\zeta}_t^G = \frac{a^G}{1+a^G} \cdot \hat{u}_t^G, \;\; \hat{\zeta}_t^T = \frac{a^T}{1+a^T} \cdot \hat{u}_t^T. \tag{A.40}$$

Equations (34) and (11) with the help of (A.40) can be linearized as

$$\hat{c}_t = \left[\left(1-\zeta^G\right) \cdot \frac{Y}{C}\right] \left[\hat{y}_t - \frac{1}{1+a^G} \cdot \hat{u}_t^G\right] + \left[\frac{1-\delta}{GA \cdot GN} \frac{K}{C}\right] (\hat{k}_t - \hat{\varepsilon}_t^A) - \frac{K}{C}\hat{k}_{t+1}, \tag{A.41}$$

$$\hat{c}_t = \mathbb{E}_t \left[\hat{c}_{t+1} - \left(\hat{r}_{t+1}^S - \hat{\pi}_{t+1}\right)\right], \tag{A.42}$$

where we use (A.40) to solve for $\hat{\zeta}_t^G$ and $\hat{ga}_t$. Plugging (A.41) into (A.42), we obtain the following dynamic IS equation for output $\hat{y}_t$.

$$\hat{y}_t = \mathbb{E}_t \Bigg[\hat{y}_{t+1} - \left[\frac{(1-\zeta^G)^{-1}(1-\delta)}{GA \cdot GN} \cdot \frac{K}{Y}\right] (\hat{k}_t - \hat{\varepsilon}_t^A) + (1-\zeta^G)^{-1} \left[1 + \frac{1-\delta}{GA \cdot GN}\right] \frac{K}{Y}\hat{k}_{t+1}$$
$$- (1-\zeta^G)^{-1}\frac{K}{Y}\hat{k}_{t+2} - (1-\zeta^G)^{-1}\frac{C}{Y}\left(\hat{r}_{t+1}^S - \hat{\pi}_{t+1}\right) + \frac{1-\rho_G}{1+a^G} \cdot \hat{u}_t^G\Bigg]. \tag{A.43}$$

Linearizing the household's bond portfolio conditions (i.e., (3)) yields

$$\hat{\lambda}_t^{HB,f} = \kappa^B \mathbb{E}_t \left[\hat{z}_t^f - \hat{\pi}_{t+1} - \hat{ga}_{t+1} + \hat{c}_t - \hat{c}_{t+1} - (f-1)\hat{yd}_{t+1}^{f-1} + f\hat{yd}_t^f - \hat{\phi}_t^B\right], \tag{A.44}$$

where

$$\hat{\phi}_t^B = \mathbb{E}_t \left(-\hat{\pi}_{t+1} - \hat{ga}_{t+1} + \hat{c}_t - \hat{c}_{t+1}\right) + \sum_{j=1}^{F} \left[\frac{\beta z^j \left(YD^{j-1}\right)^{-(j-1)}}{\Pi \cdot GA \cdot GN \cdot \Phi^B \left(YD^j\right)^{-j}}\right]^{\kappa^B} \hat{z}_t^j$$
$$+ \sum_{j=1}^{F} j \left[\frac{\beta z^j \left(YD^{j-1}\right)^{-(j-1)}}{\Pi \cdot GA \cdot GN \cdot \Phi^B \left(YD^j\right)^{-j}}\right]^{\kappa^B} \hat{yd}_t^j - \sum_{j=0}^{F-1} j \left[\frac{\beta z^{j+1} \left(YD^j\right)^{-j}}{\Pi \cdot GA \cdot GN \cdot \Phi^B \left(YD^{j+1}\right)^{-(j+1)}}\right]^{\kappa^B} \mathbb{E}_t(\hat{yd}_{t+1}^j). \tag{A.45}$$

Combining (A.44) and (A.45), we obtain the following expression for $\hat{\lambda}_t^{HB,f}$:

$$\hat{\lambda}_t^{HB,f} = \sum_{j=1}^{F} \Psi_1^{fj} \hat{z}_t^j + \sum_{j=1}^{F} \Psi_2^{fj} \hat{yd}_t^j + \sum_{j=1}^{F} \Psi_3^{fj} \mathbb{E}_t \left[\hat{yd}_{t+1}^j \right], \tag{A.46}$$

where

$$\Psi_1^{fj} = \begin{cases} \left[1 - \left[\dfrac{\beta \cdot z^j \left(YD^{j-1} \right)^{-(j-1)}}{\Pi \cdot GA \cdot GN \cdot \Phi^B \left(YD^j \right)^{-j}} \right]^{\kappa^B} \right] \cdot \kappa^B & \text{, if } f = j, \\ - \left[\dfrac{\beta \cdot z^j \left(YD^{j-1} \right)^{-(j-1)}}{\Pi \cdot GA \cdot GN \cdot \Phi^B \left(YD^j \right)^{-j}} \right]^{\kappa^B} \cdot \kappa^B & \text{, if } f \neq j, \end{cases}$$

$$\Psi_2^{fj} = j \cdot \Psi_1^{fj},$$

$$\Psi_3^{fj} = \begin{cases} -j \cdot \left[1 - \left[\dfrac{\beta \cdot z^{j+1} \left(YD^j \right)^{-j}}{\Pi \cdot GA \cdot GN \cdot \Phi^B \left(YD^{j+1} \right)^{-(j+1)}} \right]^{\kappa^B} \right] \cdot \kappa^B & \text{, if } j = f - 1, \\ j \cdot \left[\dfrac{\beta \cdot z^{j+1} \left(YD^j \right)^{-j}}{\Pi \cdot GA \cdot GN \cdot \Phi^B \left(YD^{j+1} \right)^{-(j+1)}} \right]^{\kappa^B} \cdot \kappa^B & \text{, if } j \neq f - 1, \\ 0 & \text{, if } j = F. \end{cases}$$

We can put the system of F equation in matrix format as

$$\overrightarrow{\hat{\lambda}_t^{HB}} = \Psi_1 \cdot \overrightarrow{\hat{z}}_t + \Psi_2 \cdot \overrightarrow{\hat{yd}_t} + \Psi_3 \cdot \mathbb{E}_t \left[\overrightarrow{\hat{yd}_{t+1}} \right], \tag{A.47}$$

where $\{\Psi_1, \Psi_2, \Psi_3\}$ are matrices containing elements of $\left\{ \Psi_1^{fj}, \Psi_2^{fj}, \Psi_3^{fj} \right\}$, with f representing rows and j columns. Linearizing equations (I.2) and (I.3) yields

$$\overrightarrow{\hat{\lambda}_t^G} = \widetilde{\Xi} \cdot \overrightarrow{\hat{\tilde{u}}_t^B}, \ \ \overrightarrow{\hat{\tilde{u}}_t^B} = \mathcal{T}^B \cdot \overrightarrow{\hat{u}_t^B}.$$

where $\widetilde{\Xi}$ is a matrix whose elements $\widetilde{\Xi}_{fj}$ (f-rows, j-columns) are

$$\widetilde{\Xi}_{fj} = \begin{cases} 0 & \text{, if } f = 1 \ \& \ j = f, \\ 1 - \lambda^{G,f} & \text{, if } f \geq 2 \ \& \ j = f, \\ -\lambda^{G,j} & \text{, if } j \neq f, \end{cases}$$

and similarly $\mathcal{T}^B$ is a matrix containing elements τ^B_{fj} from (I.3). By defining $\Xi = \widetilde{\Xi} \cdot \mathcal{T}^B$, we can combine the previous two equations to obtain

$$\overrightarrow{\hat{\lambda}^G_t} = \Xi \cdot \overrightarrow{\hat{u}^B_t}. \tag{A.48}$$

Therefore, with the help of (A.48), we obtain

$$\overrightarrow{\hat{b}^G_t} = \Xi \cdot \overrightarrow{\hat{u}^B_t} + \overrightarrow{1}_{Fx1} \cdot \hat{b}^G_t, \tag{A.49}$$

where $\overrightarrow{1}_{Fx1}$ is a unit vector of size F. Log-linearizing the household's stochastic discount factor yields:

$$\hat{q}_{t,t+1} = \hat{c}_t - \hat{c}_{t+1} - \hat{\pi}_{t+1} - \hat{ga}_{t+1}. \tag{A.50}$$

Log-linearizing Φ^S_t in the household's portfolio between loans and bonds (i.e., (5)), we obtain

$$\hat{\phi}^S_t = \mathbb{E}_t\left[q_{t,t+1}\right] + \frac{\left(z^B R^{HB}\right)^{\kappa^S}}{\left(z^B R^{HB}\right)^{\kappa^S} + \left(z^K R^K\right)^{\kappa^S}} \mathbb{E}_t\left[\hat{r}^{HB}_{t+1}\right] + \frac{\left(z^K R^K\right)^{\kappa^S}}{\left(z^B R^{HB}\right)^{\kappa^S} + \left(z^K R^K\right)^{\kappa^S}} \left(\hat{z}^K_t + \mathbb{E}_t\left[\hat{r}^K_{t+1}\right]\right). \tag{A.51}$$

Log-linearizing the household's portfolio decision between loans and bonds (i.e., (5)) and making use of the previous expression (i.e., (A.51)), we obtain

$$\begin{aligned}\hat{\lambda}^K_t &= \kappa^S \cdot \left[\frac{\left(z^B R^{HB}\right)^{\kappa^S}}{\left(z^B R^{HB}\right)^{\kappa^S} + \left(z^K R^K\right)^{\kappa^S}}\right] \left(\hat{z}^K_t + \mathbb{E}_t\left[\hat{r}^K_{t+1} - \hat{r}^{HB}_{t+1}\right]\right) \\ &= \kappa^S \left(1 - \lambda^K\right) \left(\hat{z}^K_t + \mathbb{E}_t\left[\hat{r}^K_{t+1} - \hat{r}^{HB}_{t+1}\right]\right).\end{aligned} \tag{A.52}$$

By linearizing the formula for the effective savings rate of the household (i.e., (6)), we obtain

$$\hat{r}^S_t = \frac{\lambda^K \left(R^K - R^{HB}\right)}{R^S} \hat{\lambda}^K_{t-1} + \frac{(1-\lambda^K) R^{HB}}{R^S} \hat{r}^{HB}_t + \frac{\lambda^K R^K}{R^S} \hat{r}^K_t. \tag{A.53}$$

Log-linearizing the effective bond rates of households, government, and central bank,

$$\hat{r}^j_t = \sum_{f=1}^{F} \frac{\lambda^{j,f} \left(YD^{f-1}\right)^{-(f-1)}}{R^j \left(YD^f\right)^{-f}} \cdot \left[\hat{\lambda}^{j,f}_{t-1} - (f-1)\hat{yd}^{f-1}_t + f\hat{yd}^f_{t-1}\right], \;\; j \in \{HB, G, CB\},$$

with which we can express these equations on matrix format as

$$\hat{r}_t^j = \Psi^{j,4} \cdot \overrightarrow{\hat{\lambda}_{t-1}^j} - \Psi^{j,5} \cdot \overrightarrow{\hat{yd}_t} + \Psi^{j,6} \cdot \overrightarrow{\hat{yd}_{t-1}}\,, \qquad j \in \{HB, G, CB\}\,, \tag{A.54}$$

where $\{\Psi^{j,4}, \Psi^{j,5}, \Psi^{j,6}\}$ are $1xF$-sized matrices whose elements are defined as:

$$\Psi_{1f}^{j,4} = \frac{\lambda^{j,f}\left(YD^{f-1}\right)^{-(f-1)}}{R^j\left(YD^f\right)^{-f}}, \quad \Psi_{1f}^{j,6} = \frac{\lambda^{j,f}\left(YD^{f-1}\right)^{-(f-1)}}{R^j\left(YD^f\right)^{-f}}f.$$

$$\Psi_{1f}^{j,5} = \begin{cases} \dfrac{\lambda^{j,f+1}\left(YD^f\right)^{-f}}{R^j\left(YD^{f+1}\right)^{-(f+1)}}f & \text{, if } f < F, \quad j \in \{HB, G, CB\}\,, \\ 0 & \text{, if } f = F, \end{cases}$$

By plugging (A.48) into $\hat{r}^G$ in (A.54), we obtain

$$\hat{r}_t^G = \Psi^{G,4} \cdot \Xi \cdot \overrightarrow{\hat{u}_{t-1}^B} - \Psi^{G,5} \cdot \overrightarrow{\hat{yd}_t} + \Psi^{G,6} \cdot \overrightarrow{\hat{yd}_{t-1}}. \tag{A.55}$$

By plugging (A.47) into $\hat{r}^{HB}$ in (A.54), we obtain

$$\hat{r}_t^{HB} = \Psi^{HB,4}\Psi^1 \cdot \overrightarrow{\hat{z}_{t-1}} + \left[\Psi^{HB,4}\Psi^2 + \Psi^{HB,6}\right] \cdot \overrightarrow{\hat{yd}_{t-1}} + \Psi^{HB,4}\Psi^3 \cdot \mathbb{E}_{t-1}\left[\overrightarrow{\hat{yd}_t}\right] - \Psi^{HB,5} \cdot \overrightarrow{\hat{yd}_t}. \tag{A.56}$$

Taking the expectation operator $\mathbb{E}_t$ on the previous equation (A.56), we obtain

$$\mathbb{E}_t\left[\hat{r}_{t+1}^{HB}\right] = \Psi^{HB,4}\Psi^1 \cdot \overrightarrow{\hat{z}_t} + \left[\Psi^{HB,4}\Psi^2 + \Psi^{HB,6}\right] \cdot \overrightarrow{\hat{yd}_t} + \left[\Psi^{HB,4}\Psi^3 - \Psi^{HB,5}\right]\mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right]. \tag{A.57}$$

By plugging (A.52) and (A.57) into (A.53), we obtain the expected effective savings rate as follows.

$$\mathbb{E}_t\left[\hat{r}_{t+1}^S\right] = \Psi^7 \overrightarrow{\hat{z}}_t + \Psi^8 \overrightarrow{\hat{yd}_t} + \Psi^9 \mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right] + \Psi^{10}\hat{r}_{t+1}^K + \Psi^{11}\hat{z}_t^K, \tag{A.58}$$

where

$$\Psi^7 = \Psi^{HB,4}\Psi^1\left[\frac{(1+\kappa^S\lambda^K)(1-\lambda^K)R^{HB} - \kappa^S(1-\lambda^K)\lambda^K R^K}{R^S}\right],$$

$$\Psi^8 = \left[\Psi^{HB,4}\Psi^2 + \Psi^{HB,6}\right]\left[\frac{(1+\kappa^S\lambda^K)(1-\lambda^K)R^{HB} - \kappa^S(1-\lambda^K)\lambda^K R^K}{R^S}\right],$$

$$\Psi^9 = \left[\Psi^{HB,4}\Psi^3 - \Psi^{HB,5}\right]\left[\frac{(1+\kappa^S\lambda^K)(1-\lambda^K)R^{HB} - \kappa^S(1-\lambda^K)\lambda^K R^K}{R^S}\right],$$

$$\Psi^{10} = \frac{\left[1+\kappa^S(1-\lambda^K)\right]\lambda^K R^K - \kappa^S(1-\lambda^K)\lambda^K R^{HB}}{R^S}, \quad \Psi^{11} = \frac{\kappa^S\lambda^K(1-\lambda^K)\left(R^K - R^{HB}\right)}{R^S}$$

Plugging back the expression of the household's expected bonds rate (i.e., (A.57)) into her portfolio decision between loans and bonds (i.e., (A.52)), we obtain

$$\hat{\lambda}_t^K = \kappa^S \left(1-\lambda^K\right)\left(\hat{z}_t^K + \hat{r}_{t+1}^K\right) - \Psi^{12}\cdot \overrightarrow{\hat{z}_t} - \Psi^{13}\cdot \overrightarrow{\hat{yd}_t} - \Psi^{14}\cdot \mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right], \tag{A.59}$$

where $\Psi^{12} = \kappa^S(1-\lambda^K)\Psi^{HB,4}\Psi^1$, $\Psi^{13} = \kappa^S(1-\lambda^K)\left[\Psi^{HB,4}\Psi^2 + \Psi^{HB,6}\right]$, and $\Psi^{13} = \kappa^S(1-\lambda^K)\left[\Psi^{HB,4}\Psi^2 + \Psi^{HB,6}\right]$. If we linearize the loan aggregation (A.4) and use (A.40), we obtain

$$\hat{k}_t = \hat{\varepsilon}_t^A + \left(\frac{\eta+1}{\eta+\alpha}\right)\hat{y}_t - \left(\frac{\eta(1-\alpha)}{\eta+\alpha}\right)\cdot\left[\hat{p}_t^K - \hat{c}_t\right]. \tag{A.60}$$

Combining (A.41) and the above (A.60), we obtain

$$\begin{aligned} p_t^K =& \left[(1-\zeta^G)\frac{Y}{C} + \frac{\eta+1}{\eta(1-\alpha)}\right]\cdot\hat{y}_t - \left[(1-\zeta^G)\cdot\frac{Y}{C}\right]\left(\frac{1}{1+a^G}\right)\cdot u_t^G \\ &+ \left[\frac{1-\delta}{GA\cdot GN}\cdot\frac{K}{C} - \frac{\eta+\alpha}{\eta(1-\alpha)}\right]\cdot\left[\hat{k}_t - \hat{\varepsilon}_t^A\right] - \frac{K}{C}\cdot\hat{k}_{t+1}. \end{aligned} \tag{A.61}$$

If we linearize the supply block (i.e., (A.9), and (A.10)), we obtain

$$\begin{aligned} \hat{f}_t =& \left[1-\theta\beta\Pi^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}\right]\left(\frac{\eta+1}{\eta+\alpha}\right)\left[\hat{y}_t + \alpha\mathbb{E}_t\left[\hat{q}_{t,t+1} + \hat{p}_t^K - \hat{c}_t\right]\right] \\ &+ \theta\beta\Pi^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}\mathbb{E}_t\left[\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)\hat{\pi}_{t+1} + \hat{f}_{t+1}\right], \\ \hat{h}_t =& \left[1-\theta\beta\Pi^{\epsilon-1}\right]\left[\hat{y}_t - \hat{c}_t - \left(\frac{\gamma_L\cdot R^K}{R^S - \gamma_L\cdot(R^K - R^S)}\right)\cdot\left[\hat{r}_{t+1}^K + \mathbb{E}_t\left[\hat{q}_{t,t+1}\right]\right]\right] \\ &+ \theta\beta\Pi^{\epsilon-1}\mathbb{E}_t\left[(\epsilon-1)\hat{\pi}_{t+1} + \hat{h}_{t+1}\right], \end{aligned} \tag{A.62}$$

$$\hat{f}_t - \hat{h}_t = \left[1+\epsilon\left(\frac{1-\alpha}{\eta+\alpha}\right)\right]\left(\frac{\theta\Pi^{\epsilon-1}}{1-\theta\Pi^{\epsilon-1}}\right)\hat{\pi}_t. \tag{A.63}$$

Combining (A.42), (A.50), and (A.60) with (A.62), we obtain:

$$\begin{aligned} \hat{f}_t =& -\Psi^{16}\cdot\overrightarrow{\hat{z}_t} - \Psi^{17}\cdot\hat{z}_t^K - \Psi^{18}\cdot\left[\hat{k}_t - \hat{\varepsilon}_t^A\right] + \Psi^{19}\cdot\hat{y}_t - \Psi^{20}\cdot\overrightarrow{\hat{yd}_t} - \Psi^{21}\cdot\hat{r}_{t+1}^K \\ &- \Psi^{22}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right] + \Psi^{23}\cdot\mathbb{E}_t\left[\hat{\pi}_{t+1}\right] + \Psi^{24}\cdot\mathbb{E}_t\left[\hat{f}_{t+1}\right]. \end{aligned} \tag{A.64}$$

$$\begin{aligned} \hat{h}_t =& \Psi^{26}\cdot\overrightarrow{\hat{z}_t} + \Psi^{27}\cdot\hat{z}_t^K - \Psi^{28}\cdot\left[\hat{k}_t - \hat{\varepsilon}_t^A\right] + \Psi^{29}\cdot\hat{u}_t^G + \Psi^{30}\cdot\hat{y}_t + \Psi^{31}\cdot\overrightarrow{\hat{yd}_t} \\ &- \Psi^{32}\cdot\hat{r}_{t+1}^K + \Psi^{33}\cdot\hat{k}_{t+1} + \Psi^{34}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right] + \Psi^{35}\cdot\mathbb{E}_t\left[\hat{\pi}_{t+1}\right] + \Psi^{36}\cdot\mathbb{E}_t\left[\hat{h}_{t+1}\right]. \end{aligned} \tag{A.65}$$

where

$$\Psi^{15} = \left[1 - \theta\beta\Pi^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}\right]\left(\frac{\eta+1}{\eta+\alpha}\right) ,$$
$$\Psi^{16} = \alpha\Psi^{15}\Psi^{7} ,$$
$$\Psi^{17} = \alpha\Psi^{15}\Psi^{11} ,$$
$$\Psi^{18} = \Psi^{15}\left(\frac{\alpha}{1-\alpha}\right)\left(\frac{\eta+\alpha}{\eta}\right) ,$$
$$\Psi^{19} = \Psi^{15}\left[1 + \left(\frac{\alpha}{1-\alpha}\right)\left(\frac{\eta+1}{\eta}\right)\right] ,$$
$$\Psi^{20} = \alpha\Psi^{15}\Psi^{8} ,$$
$$\Psi^{21} = \alpha\Psi^{15}\Psi^{10} ,$$
$$\Psi^{22} = \alpha\Psi^{15}\Psi^{9} ,$$
$$\Psi^{23} = \theta\beta\Pi^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right) ,$$
$$\Psi^{24} = \theta\beta\Pi^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)} ,$$
$$\Psi^{25} = \left[1 - \theta\beta\Pi^{\epsilon-1}\right]\left(\frac{\gamma_L \cdot R^K}{R^S - \gamma_L \cdot (R^K - R^S)}\right) ,$$
$$\Psi^{26} = \Psi^{25}\Psi^{7} ,$$
$$\Psi^{27} = \Psi^{25}\Psi^{11} ,$$
$$\Psi^{28} = \left[1 - \theta\beta\Pi^{\epsilon-1}\right]\left[\frac{1-\delta}{GA \cdot GN} \cdot \frac{K}{C}\right] ,$$
$$\Psi^{29} = \left[1 - \theta\beta\Pi^{\epsilon-1}\right](1-\zeta^G)\frac{Y}{C}\left(\frac{1}{1+a^G}\right) ,$$
$$\Psi^{30} = \left[1 - \theta\beta\Pi^{\epsilon-1}\right]\left[1 - (1-\zeta^G)\frac{Y}{C}\right] ,$$
$$\Psi^{31} = \Psi^{25}\Psi^{8} ,$$
$$\Psi^{32} = \Psi^{25} \cdot \left(1 - \Psi^{10}\right) ,$$
$$\Psi^{33} = \left[1 - \theta\beta\Pi^{\epsilon-1}\right]\frac{K}{C} ,$$
$$\Psi^{34} = \Psi^{25}\Psi^{9} ,$$
$$\Psi^{35} = \theta\beta\Pi^{\epsilon-1}(\epsilon-1) ,$$
$$\Psi^{36} = \theta\beta\Pi^{\epsilon-1} .$$

Linearizing the government's budget constraint (i.e., (20)) yields

$$\begin{aligned}\hat{b}^G_t = &\frac{R^G}{\Pi \cdot GA \cdot GN}\left[\hat{r}^G_t - \hat{\pi}_t - \hat{ga}_t + \hat{b}^G_{t-1}\right] \\ &- \left[\zeta^G + \zeta^F - \zeta^T\right]\left(\frac{Y}{B/P}\right)\left[\hat{y}_t + \left(\frac{\zeta^G}{\zeta^G + \zeta^F - \zeta^T}\right)\left(\frac{a^G}{1+a^G}\right)\hat{u}^G_t - \left(\frac{\zeta^T}{\zeta^G + \zeta^F - \zeta^T}\right)\left(\frac{a^T}{1+a^T}\right)\hat{u}^T_t\right].\end{aligned} \tag{A.66}$$

Using the steady state equilibrium condition (i.e., (A.30)) with (A.40) and (A.55), we can express the previous (A.66) as

$$\begin{aligned}\hat{b}^G_t = &\frac{R^G}{\Pi \cdot GA \cdot GN}\left[\Psi^{G,4} \cdot \Xi \cdot \overrightarrow{\hat{u}^B_{t-1}} - \Psi^{G,5} \cdot \overrightarrow{\hat{yd}_t} + \Psi^{G,6} \cdot \overrightarrow{\hat{yd}_{t-1}} - \hat{\pi}_t - \hat{\varepsilon}^A_t + \hat{b}^G_{t-1}\right] \\ &+ \left(1 - \frac{R^G}{\Pi \cdot GA \cdot GN}\right)\left[\hat{y}_t + \left(\frac{\zeta^G}{\zeta^G + \zeta^F - \zeta^T}\right)\left(\frac{a^G}{1+a^G}\right)\hat{u}^G_t - \left(\frac{\zeta^T}{\zeta^G + \zeta^F - \zeta^T}\right)\left(\frac{a^T}{1+a^T}\right)\hat{u}^T_t\right].\end{aligned} \tag{A.67}$$

Linearizing the capital producer's optimization condition yields

$$0 = \mathbb{E}_t\left[\hat{q}_{t,t+1} + \hat{\pi}_{t+1} + \left(\frac{P^K/P}{1-\delta+P^K/P}\right)\hat{p}^K_{t+1}\right]. \tag{A.68}$$

By plugging (A.42) and (A.50) into the previous (A.68) and rearranging, we get

$$\mathbb{E}_t\left[\hat{r}^S_{t+1} - \hat{\pi}_{t+1}\right] = \left(\frac{P^K/P}{1-\delta+P^K/P}\right)\mathbb{E}_t\left[\hat{p}^K_{t+1}\right]. \tag{A.69}$$

Plugging expressions on the effective savings rate (i.e., (A.58)) and the rental price of capital (i.e., (A.61)) into (A.69) we obtain

$$\begin{aligned}\hat{r}^K_{t+1} = &- \Psi^{37} \cdot \overrightarrow{\hat{z}_t} - \Psi^{38} \cdot \hat{z}^K_t - \Psi^{39} \cdot \overrightarrow{\hat{yd}_t} - \Psi^{40} \cdot \mathbb{E}_t \left[\overrightarrow{\hat{yd}_{t+1}}\right] + \Psi^{41} \cdot \mathbb{E}_t \left[\hat{\pi}_{t+1}\right] \\ &+ \Psi^{42} \cdot \mathbb{E}_t \left[\hat{y}_{t+1}\right] + \Psi^{43} \cdot \hat{k}_{t+1} - \Psi^{44} \cdot \mathbb{E}_t \left[\hat{k}_{t+2}\right] - \Psi^{45} \cdot \hat{u}^G_t \,,\end{aligned} \tag{A.70}$$

where we defined

$$\begin{aligned}
\Psi^{37} &= \left(\Psi^{10}\right)^{-1} \Psi^{7}, & \Psi^{42} &= \left(\Psi^{10}\right)^{-1} \left(\frac{\frac{P^K}{P}}{1-\delta+\frac{P^K}{P}}\right) \left[(1-\zeta^G)\frac{Y}{C} + \left(\frac{\eta+1}{\eta(1-\alpha)}\right)\right], \\
\Psi^{38} &= \left(\Psi^{10}\right)^{-1} \Psi^{11}, & & \\
\Psi^{39} &= \left(\Psi^{10}\right)^{-1} \Psi^{8}, & \Psi^{43} &= \left(\Psi^{10}\right)^{-1} \left(\frac{\frac{P^K}{P}}{1-\delta+\frac{P^K}{P}}\right) \left[\frac{1-\delta}{GA\cdot GN}\frac{K}{C} - \left(\frac{\eta+\alpha}{\eta(1-\alpha)}\right)\right], \\
\Psi^{40} &= \left(\Psi^{10}\right)^{-1} \Psi^{9}, & & \\
\Psi^{41} &= \left(\Psi^{10}\right)^{-1}, & \Psi^{44} &= \left(\Psi^{10}\right)^{-1} \left(\frac{\frac{P^K}{P}}{1-\delta+\frac{P^K}{P}}\right) \frac{K}{C}, \\
& & \Psi^{45} &= \left(\Psi^{10}\right)^{-1} \left(\frac{\frac{P^K}{P}}{1-\delta+\frac{P^K}{P}}\right) (1-\zeta^G)\frac{Y}{C} \left(\frac{\rho^G}{1+a^G}\right) .
\end{aligned}$$

Finally, plugging the effective savings rate (i.e., (A.58)) into the Euler equation (i.e., (A.43)), we obtain

$$\begin{aligned}\hat{y}_t = \mathbb{E}_t \Big[&\hat{y}_{t+1} + \Psi^{46} \cdot \hat{\pi}_{t+1} - \Psi^{47} \cdot \overrightarrow{\hat{z}}_t - \Psi^{48} \cdot \hat{z}^K_t - \Psi^{49} \cdot \overrightarrow{\hat{yd}_t} - \Psi^{50} \cdot \mathbb{E}_t \left[\overrightarrow{\hat{yd}_{t+1}}\right] \\ &- \Psi^{51} \cdot \hat{r}^K_{t+1} - \Psi^{52} \cdot (\hat{k}_t - \hat{\varepsilon}^A_t) + \Psi^{53} \cdot \hat{k}_{t+1} - \Psi^{54} \cdot \hat{k}_{t+2} + \Psi^{55} \cdot \hat{u}^G_t \Big],\end{aligned} \tag{A.71}$$

where we defined

$$\begin{aligned}
\Psi^{46} &= (1-\zeta^G)^{-1}\frac{C}{Y}, & \Psi^{52} &= \frac{(1-\zeta^G)^{-1}(1-\delta)}{GA\cdot GN}\frac{K}{Y}, \\
\Psi^{47} &= \Psi^{27}\Psi^{7}, & \Psi^{53} &= (1-\zeta^G)^{-1}\left[1+\frac{1-\delta}{GA\cdot GN}\right]\frac{K}{Y}, \\
\Psi^{48} &= \Psi^{27}\Psi^{11}, & & \\
\Psi^{49} &= \Psi^{27}\Psi^{8}, & \Psi^{54} &= (1-\zeta^G)^{-1}\frac{K}{Y}, \\
\Psi^{50} &= \Psi^{27}\Psi^{9}, & \Psi^{55} &= \frac{1-\rho_G}{1+a^G}. \\
\Psi^{51} &= \Psi^{27}\Psi^{10}, & &
\end{aligned}$$

Linearizing the labor aggregation condition (i.e., (A.5)) yields

$$\hat{n}_t = -\alpha\left(\frac{\eta}{\eta+\alpha}\right)\hat{c}_t + \left(\frac{\eta}{\eta+\alpha}\right)\hat{y}_t + \alpha\left(\frac{\eta}{\eta+\alpha}\right)\cdot\hat{p}_t^K. \tag{A.72}$$

Plugging equation (A.41) and equation (A.61) into equation (A.72), we obtain

$$\hat{n}_t = \left(\frac{\eta}{\eta+\alpha}\right)\left[1+\left(\frac{\alpha}{1-\alpha}\right)\left(\frac{\eta+1}{\eta}\right)\right]\cdot\hat{y}_t - \left(\frac{\alpha}{1-\alpha}\right)\cdot\left[\hat{k}_t - \hat{\varepsilon}_t^A\right]. \tag{A.73}$$

Log-linearization: the conventional policy specific derivations Linearizing the bond market equilibrium condition (i.e., (A.22)), we obtain

$$\hat{\lambda}_t^{HB,f} = \left(\frac{B^{G,f}}{B^{G,f}+B^{CB,f}}\right)\hat{b}_t^{g,f} - \hat{y}_t + \frac{1}{1-\lambda^K}\cdot\hat{\lambda}_t^K,\quad f\geq 2. \tag{A.74}$$

From $\lambda_t^{HB,1} = 1-\sum_{f=2}^{F}\lambda_t^{HB,f}$ we obtain

$$\hat{\lambda}_t^{HB,1} = -\sum_{f=2}^{F}\frac{\lambda^{HB,f}}{\lambda^{HB,1}}\hat{\lambda}_t^{HB,f}. \tag{A.75}$$

We can rearrange the previous expressions (i.e., (A.74) and (A.75)) in the matrix form as

$$\Theta^1\cdot\overrightarrow{\hat{\lambda}_t^{HB}} = \Theta^2\cdot\overrightarrow{\hat{b}_t^g} - \Theta^3\cdot\hat{y}_t + \Theta^4\cdot\hat{\lambda}_t^K, \tag{A.76}$$

where $\{\Theta^1,\ \Theta^2\}$ are FxF-sized matrices with elements Θ^1_{jf} (row j, column f) and $\{\Theta^3,\ \Theta^4\}$ are $Fx1$ vectors with $j-$element Θ^3_{j1}. We define their elements as

$$\Theta^1_{jf} = \begin{cases} 1 & \text{, if } j=f, \\ \dfrac{\lambda^{HB,f}}{\lambda^{HB,1}} & \text{, if } j=1\,\&\,f>1, \end{cases} \qquad \Theta^3_{j1} = \begin{cases} 0 & \text{, if } j=1, \\ 1 & \text{, otherwise,} \end{cases},$$

$$\Theta^2_{jf} = \begin{cases} \dfrac{B^{G,f}}{B^{G,f}+B^{CB,f}} & \text{, if } j>1\,\&\,j=f, \\ 0 & \text{, otherwise,} \end{cases} \qquad \Theta^4 = \frac{1}{1-\lambda^K}\cdot\Theta^3 .$$

By inverting Θ^1 in (A.76), we can rewrite (A.76) as

$$\overrightarrow{\hat{\lambda}_t^{HB}} = \Theta^5\cdot\overrightarrow{\hat{b}_t^g} - \Theta^6\cdot\hat{y}_t + \Theta^7\cdot\hat{\lambda}_t^K, \tag{A.77}$$

where we define $\Theta^5 = (\Theta^1)^{-1}\Theta^2$, $\Theta^6 = (\Theta^1)^{-1}\Theta^3$, $\Theta^7 = (\Theta^1)^{-1}\Theta^4$. Plugging the government's bond portfolio (i.e., (A.49)), the household's loan share (i.e., (A.59)), and the rental price of capital (i.e., (A.61)) into (A.77), we obtain

$$\overrightarrow{\hat{\lambda}_t^{HB}} = \Theta^8 \cdot \hat{b}_t^G - \Theta^6 \cdot \hat{y}_t + \Theta^9 \cdot \left(\hat{z}_t^K + \hat{r}_{t+1}^K\right) - \Theta^{10} \cdot \overrightarrow{\hat{yd}_t} - \Theta^{11} \cdot \mathbb{E}_t \left[\overrightarrow{\hat{yd}_{t+1}}\right] - \Theta^{12} \cdot \overrightarrow{\hat{z}_t} + \Theta^{13} \cdot \overrightarrow{\hat{u}_t^B},$$

where we define

$$\begin{aligned} \Theta^8 &= \Theta^5 \cdot \overrightarrow{1_{Fx1}}, & \Theta^{10} &= \Theta^7 \cdot \Psi^{13}, & \Theta^{12} &= \Theta^7 \cdot \Psi^{12}, \\ \Theta^9 &= \Theta^7 \cdot \kappa^S \left(1 - \lambda^K\right), & \Theta^{11} &= \Theta^7 \cdot \Psi^{14}, & \Theta^{13} &= \Theta^5 \cdot \Xi. \end{aligned}$$

By plugging the household's optimal portfolio (i.e., (A.47)) into the above, we obtain

$$\overrightarrow{\hat{yd}_t} = \Theta^{14} \cdot \hat{b}_t^G - \Theta^{15} \cdot \hat{y}_t + \Theta^{16} \cdot \hat{r}_{t+1}^K - \Theta^{17} \cdot \mathbb{E}_t \left[\overrightarrow{\hat{yd}_{t+1}}\right] - \Theta^{18} \cdot \overrightarrow{\hat{z}_t} + \Theta^{19} \cdot \hat{z}_t^K + \Theta^{20} \cdot \overrightarrow{\hat{u}_t^B},$$

where $\Theta^{14} = \left[\Theta^{10} + \Psi^2\right]^{-1}\Theta^8, \Theta^{15} = \left[\Theta^{10} + \Psi^2\right]^{-1}\Theta^6, \Theta^{16} = \left[\Theta^{10} + \Psi^2\right]^{-1}\Theta^9, \Theta^{17} = \left[\Theta^{10} + \Psi^2\right]^{-1}\left[\Theta^{11} + \Psi^3\right], \Theta^{18} = \left[\Theta^{10} + \Psi^2\right]^{-1}\Theta^{12}, \Theta^{19} = \left[\Theta^{10} + \Psi^2\right]^{-1}\left[\Theta^9 - \Psi^1\right], \Theta^{20} = \left[\Theta^{10} + \Psi^2\right]^{-1}\Theta^{13}$.

Log-linearization: the Yield-Curve-Control (YCC) policy specific derivations Linearizing the Taylor rule for f-maturity bond (i.e., (24b)) yields[1]

$$\hat{yd}_t^{YCC,f} = \gamma_{CP}^f \hat{yd}_t^{CP,f} + \left(1 - \gamma_{CP}^f\right)\left[\gamma_\pi^f \hat{\pi}_t + \tilde{\varepsilon}_t^{YD^f}\right], \quad f \geq 2. \tag{A.78}$$

We define a $(F-1)\times(F-1)$ matrix Γ^{CP} with $\Gamma_{ff}^{CP} = \gamma_{CP}^{f+1}$ for $f = 1 \sim F-1$ and $\Gamma_{ij}^{CP} = 0$ for $i \neq j$. From (I.4), we define $\mathcal{T}_{(f\geq 2)}^{YD}$, a $(F-1)\times L$ matrix with $\mathcal{T}_{(f\geq 2),f,l}^{YD} = \tau_{f+1,l}^{YD}$ (row f, column l) and the vector of Taylor coefficients $\overrightarrow{\gamma_{\pi(f\geq 2)}} = \left[\gamma_\pi^2, \ldots, \gamma_\pi^F\right]'$. If we construct such vectors as

$$\overrightarrow{\hat{yd}_t^{YCC}}_{(f\geq 2)} = \left[\hat{yd}_t^{YCC,2}, \ldots, \hat{yd}_t^{YCC,F}\right]', \quad \overrightarrow{\hat{yd}_t^{CP}}_{(f\geq 2)} = \left[\hat{yd}_t^{CP,2}, \ldots, \hat{yd}_t^{CP,F}\right]', \tag{A.79}$$

then above equation (A.78) can be written in vector form as

$$\overrightarrow{\hat{yd}_t^{YCC}}_{(f\geq 2)} = \Gamma^{CP}\overrightarrow{\hat{yd}_t^{CP}}_{(f\geq 2)} + \left(I - \Gamma^{CP}\right)\cdot\left[\overrightarrow{\gamma_{\pi(f\geq 2)}} \cdot \hat{\pi}_t + \mathcal{T}_{(f\geq 2)}^{YD} \cdot \overrightarrow{\varepsilon_t^{YD}}\right], \tag{A.80}$$

[1] If $\rho_1 \neq 0$ or $\rho_2 \neq 0$ in (24b), then the policy rule in (A.78) should account for them and target output as well. We intentionally assume that the policy rule here targets inflation only for simplicity of expressions.

where I is the identity matrix of size $F-1$. Since $\overrightarrow{\hat{yd}_t^{CP}}$ is the yield vector that prevails in the counterfactual scenario where the current yield is determined by conventional monetary policy, its dynamics will follow

$$\overrightarrow{\hat{yd}_t^{CP}} = \Theta^{14} \cdot \hat{b}_t^G - \Theta^{15} \cdot \hat{y}_t + \Theta^{16} \cdot \hat{r}_{t+1}^K - \Theta^{17} \cdot \mathbb{E}_t \left[\overrightarrow{\hat{yd}_{t+1}^{CP}} \right] - \Theta^{18} \cdot \overrightarrow{\hat{z}_t} + \Theta^{19} \cdot \hat{z}_t^K + \Theta^{20} \cdot \overrightarrow{\hat{u}_t^B} \,,$$

where coefficients Θ^i for $i = 14 \sim 20$ are the same as in the conventional policy case, and $\overrightarrow{\hat{yd}_t^{CP}}$ and $\overrightarrow{\hat{yd}_t^{YCC}}$ are defined as $\overrightarrow{\hat{yd}_t^{YCC}} = [\hat{yd}_t^{YCC,1}, \overrightarrow{\hat{yd}_t^{YCC}}'_{(f\geq 2)}]'$, $\overrightarrow{\hat{yd}_t^{CP}} = [\hat{yd}_t^{YCC,1}, \overrightarrow{\hat{yd}_t^{CP}}'_{(f\geq 2)}]'$. where $\hat{yd}_t^{YCC,1}$ follows the Taylor rules in (23a) and (23b). Now that $\overrightarrow{\hat{yd}_t^{YCC}}$ governs households' intertemporal decisions, (A.71) becomes

$$\begin{aligned}\hat{y}_t = \mathbb{E}_t \Big[& \hat{y}_{t+1} + \Psi^{46} \cdot \hat{\pi}_{t+1} - \Psi^{47} \cdot \overrightarrow{\hat{z}}_t - \Psi^{48} \cdot \hat{z}_t^K - \Psi^{49} \cdot \overrightarrow{\hat{yd}_t^{YCC}} - \Psi^{50} \cdot \mathbb{E}_t \left[\overrightarrow{\hat{yd}_{t+1}^{YCC}} \right] \\ & - \Psi^{51} \cdot \hat{r}_{t+1}^K - \Psi^{52} \cdot (\hat{k}_t - \hat{\varepsilon}_t^A) + \Psi^{53} \cdot \hat{k}_{t+1} - \Psi^{54} \cdot \hat{k}_{t+2} + \Psi^{55} \cdot \hat{u}_t^G \Big] \,.\end{aligned}$$

B Calibration and Estimation Strategy

B.1 Calibrating $\{z^f\}_{f=1}^F$ and z^K at the Steady State

Calibration of $\left\{z^f\right\}_{f=1}^F$ We explain how to calibrate $\left\{z^f\right\}_{f=1}^F$ to match the yield curve. Based on data on yields of bonds with different maturities, we calculate each f-maturity bond's average holding returns $\left\{R^f\right\}$, which we would use as our calibration target.

1. Compute the return ratio $\left\{\frac{R^F}{R^{HB}}\right\}$.[2]

2. Back out steady state bond shares $\left\{\lambda^{HB,f}\right\}$ using equation (A.23).

3. Normalize $z^1 = 1$ and obtain initial guess for $\{z^{j,guess}\}$. Set $z^{j,old} = z^{j,guess}$ in the iteration below.

4. Construct $\tilde{\Phi}^{old}$ using the following formula, where the return ratios $\{\frac{R^f}{R^{HB}}\}$ across

[2] To determine the return on the household's bond portfolio R^{HB}, we combine the data on the average returns by maturity $\{R^f\}_{f=1}^F$ with the portfolio shares $\{\lambda^{HB,f}\}_{f=1}^F$.

maturities are obtained from the data:

$$\tilde{\Phi}^{old} = \left[1 + \sum_{f=2}^{F}\left[z^j\left(\frac{R^f}{R^{HB}}\right)\right]^{\kappa_B}\right]^{\frac{1}{\kappa_B}}.$$

5. Back out new $z^{f,new}$, $f = 2, \ldots, F$ estimates using:

$$z^{f,new} = \left(\lambda^{HB,f}\right)^{\frac{1}{\kappa_B}}\left(\frac{R^f}{R^{HB}}\right)^{-1}\tilde{\Phi}^{old}.$$

6. If difference with $\tilde{\Phi}^{old}$ is large, set $z^{f,old} = z^{f,new}$ and start again from the step 4.

Calibration of z^K We calibrate z^K such that the model's steady-state return on the household's bond portfolio, R^{HB}, matches with the observed data average. This alignment is achieved by finding the steady-state value of R^K from (A.31),[3] and subsequently replacing the values of R^{HB} and R^K into equation (A.29), which enables us to recover the z^K value consistent with the model's moment.

B.2 Elasticity Estimation, κ_B

Combining the log-linear approximation of equation (3), we obtain

$$\widehat{\log\left(\lambda_t^{H,f}\right)} = \kappa_B \cdot \left(1 - \lambda^{H,f}\right) \cdot E_t\left[\hat{r}_{t+1}^{f-1}\right] - \kappa_B \cdot \sum_{j \neq f} \lambda^{H,j} \cdot E_t\left[\hat{r}_{t+1}^{j-1}\right] + \varepsilon_t^f\ ,$$

where $\varepsilon_t^f \equiv \kappa_B \cdot \sum_{j \neq f} \lambda_t^{H,j} \cdot \left[\widehat{\log\left(z_t^f\right)} - \widehat{\log\left(z_t^j\right)}\right]$ is a residual term containing the effects on the households' bond portfolio of shocks to different maturity preferences along the yield curve. Differentiation across maturities yields the following expression

$$\log\left(\lambda_t^{H,f}\right) - \log\left(\lambda_t^{H,l}\right) = \alpha^{fl} + \kappa_B \cdot E_t\left[r_{t+1}^{f-1} - r_{t+1}^{l-1}\right] + \varepsilon_t^{fl}\ , \tag{B.1}$$

where α^{fl} denotes a constant, and $\varepsilon_t^{fl} = \varepsilon_t^f - \varepsilon_t^l$ represents a residual term embodying the discrepancy between the preference shocks for bond maturities f and l. The expected bond

[3] In the context of our present calibration, the derived R^K is situated within the range corresponding to the average corporate debt rate across varied ratings.

return spread, denoted as $E_t\left[r_{t+1}^{f-1} - r_{t+1}^{l-1}\right]$, poses challenges for empirical observation. Therefore, we turn to the following approximation centered on the bond yield spread:

$$
\begin{aligned}
E_t\left[r_{t+1}^{f-1} - r_{t+1}^{l-1}\right] =& yd_t^f - yd_t^l \\
& - (f-1)\cdot \underbrace{E_t\left[yd_{t+1}^f - yd_t^f\right]}_{\text{add as control}} + (l-1)\cdot \underbrace{E_t\left[yd_{t+1}^l - yd_t^l\right]}_{\text{add as control}} \\
& + (f-1)\cdot \underbrace{E_t\left[yd_{t+1}^f - yd_{t+1}^{f-1}\right]}_{\approx 0 \text{ (by assumption)}} - (l-1)\cdot \underbrace{E_t\left[yd_{t+1}^l - yd_{t+1}^{l-1}\right]}_{\approx 0 \text{ (by assumption)}},
\end{aligned}
$$

where the spread $yd_t^f - yd_t^l$ in the initial line is directly observable from the data, the expected yield change in the subsequent line can be approximated by employing the realized changes as control variables, and the terms in the final line may be assumed to be close to zero over short time intervals. The final equation used for the empirical estimation of the elasticity parameter κ_B becomes:

$$
\log\left(\lambda_{t+h}^{H,f}\right) - \log\left(\lambda_{t+h}^{H,l}\right) = \alpha_h^{fl} + \kappa_{B,h}\cdot\left[yd_t^f - yd_t^l\right] + \mathbf{x_t'}\beta_{\mathbf{h}}^{\mathbf{fl}} + \varepsilon_{t+h}^{fl},\ h \geq 0\ , \tag{B.2}
$$

where $\mathbf{x_t}$ denotes a vector of control variables accompanied by the corresponding coefficients $\beta_{\mathbf{h}}^{\mathbf{fl}}$, and the time subindex $h \geq 0$ accommodates a lagged effect from the yield spread to the bond portfolio composition which might occur in practice. Equation (B.2) is estimated across various horizons h utilizing Jordà local projection methods, thereby facilitating the determination of a plausible range for the elasticity parameter κ_B.

The unbiased estimation of κ_B in equation (B.2) requires the fluctuations in the bond yield spread $yd_t^f - yd_t^l$ to be uncorrelated with shocks in the relative preferences for each maturity, as captured by ε_{t+h}^{fl}. This implies that any other aggregate shocks, uncorrelated to the contemporaneous (and/or future) maturity preferences of households, could serve as potentially valid instruments for the yield spread. Following this rationale, we instrument the changes in the contemporaneous yield spread with its own lagged value, while at the same time, we incorporate the lags of the dependent variable as controls to eliminate any potential serial correlation of the preference shocks. The dependent variable is defined as the log-difference between the aggregate household portfolio shares in a group of long-maturity bonds and a group of short-maturity bonds, respectively. For the long-maturity group, we calculate the share of bonds with maturities ranging from 5 to 10 years within the households' portfolio, whereas for the short-maturity group, bonds with maturi-

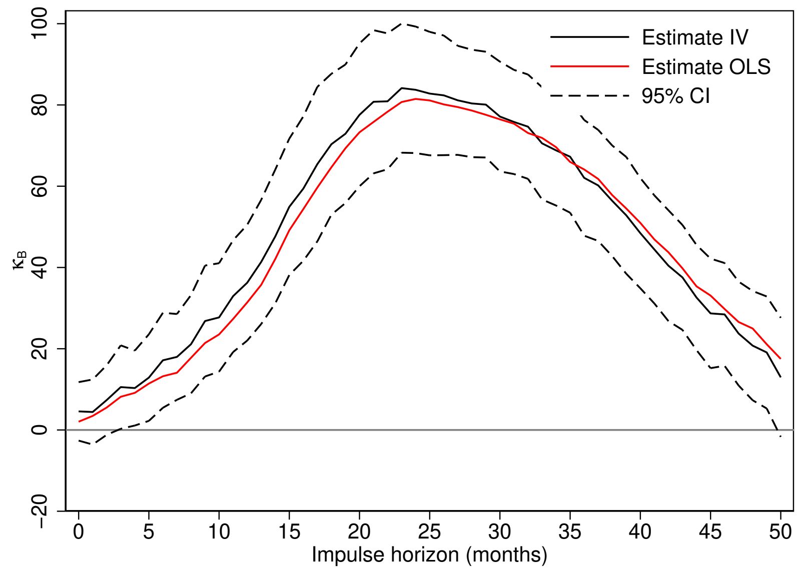


Figure B.1: Impulse-Response to a shock in the yield spread, $yd_t^f - yd_t^l$. The figure presents the coefficient estimates for the bond portfolio elasticity, κ_B, in equation (B.2), following the estimation methodology detailed in appendix B.2. The solid black line illustrates the estimate from the instrumental variables (IV) regression, with dashed lines indicating the 95% robust confidence intervals. The red line exhibits alternative OLS estimates. The sample period is from 2003m3 to 2019m3.

ties spanning from 15 to 90 days are considered. For both groups, the aggregate household portfolio holdings are computed on a monthly basis by deducting the U.S. Treasury securities held by the Federal Reserve from the Government's outstanding Treasury amounts within the selected maturity ranges.[4] The principal regressor employed is the spread between the market yields of the 7-year and the 1-month constant maturity U.S. Treasury securities, which lie within the maturity bands of the selected portfolio shares in the dependent variable. Additionally, we control for the one-month-ahead changes in the 7-year and the 1-month constant maturity yields, along with the first three lags of the dependent variable. The regressions are estimated across the sample period extending from 2003m3 to 2019m3.[5]

Figure B.1 delineates the IV and OLS estimates derived from Jordà local projections across a fifty-month horizon, accompanied by the 95% robust confidence bands pertinent

[4]The outstanding amounts of Government Treasuries are reported in the U.S. Treasury Monthly Statement of the Public Debt (MSPD).

[5]The lower bound of the sample period is dictated by the availability of maturity-disaggregated statistics concerning the Federal Reserve's Treasury bond portfolio, commencing from 2002m12.

to the primary IV regression. Both estimates largely align with the anticipated reaction of aggregate household portfolio shares, as posited by the model, in response to a shock to the yield spread. For calibration purposes, we select a value of $\kappa_B = 10$, which is consistent with the short-term portfolio response observed in the Figure B.1.

C Welfare

C.1 Deriving a second-order welfare approximation

In order to approximate welfare up to a second-order, we cannot discard $\hat{\Delta}_t$, which is the price dispersion's log-deviation from its steady-state value in the presence of trend inflation.

Step 1: For any variable X, we define $\bar{X}$ as its steady-state value (with the positive trend inflation $\bar{\Pi} > 1$) and $\bar{X}^F$ as its flexible price steady-state value. Also define (small) letter $\tilde{x}$ as log-deviation of X around $\bar{X}^F$, and $\hat{x}$ as log-deviation of X around $\bar{X}$.

Constrained efficient (i.e., flexible-price) steady state With the optimal production subsidy $\zeta^F = (\epsilon - 1)^{-1}$ that eliminates the monopolistic competition distortion, there is no distortion other than the firms' financing constraint in the flexible-price steady state economy anymore.[6] In particular, each firm's price resetting condition (i.e., (A.2)) becomes

$$1 = \frac{P_t^*}{P_t} = \underbrace{\frac{(1+\zeta^F)^{-1}\epsilon}{\epsilon - 1}}_{=1} \cdot \frac{MC_t}{P_t} = \frac{MC_t}{P_t}, \tag{C.1}$$

where we use the fact that all firms become identical, and thus $MC_t(\nu) = MC_t$ for all $\nu \in [0,1]$. Therefore, the real marginal cost becomes 1 for all firms. Plugging the unit real marginal cost (i.e., (A.3)) into the individual firm's labor demand (i.e., (16)) with $W_t(\nu) = W_t$ for $\forall \nu$, and defining $n_t = \frac{N_t}{\bar{N}_t}$ and $y_t = \frac{Y_t}{A_t \bar{N}_t}$, we obtain

$$n_t = (1-\alpha) y_t \left(\frac{P_t^K}{P_t}\right)^{\alpha} \left(\frac{W_t}{P_t A_t}\right)^{-\alpha} = (1-\alpha) y_t \left(\frac{W_t}{P_t A_t}\right)^{-1}, \tag{C.2}$$

which, with the household's intra-temporal consumption-labor decision (i.e., (10)), be-

[6] The capital producing firm is competitive and thus our economy features no friction other than the firms' financing constraint if it were not nominal rigidity nor trend inflation. Still, the constraint on loan issuance does not affect firms' marginal decisions on labor and capital.

comes:

$$\frac{n_t^{\frac{1}{\eta}}}{c_t^{-1}} = (1-\alpha)\frac{y_t}{n_t}, \tag{C.3}$$

which is the social efficiency condition that ensures that the household's marginal rate of substitution matches with the marginal rate of technical substitution. Therefore, at the flexible-price steady state, the new constant Φ, which will turn out to enter in the per-period welfare later, can be calculated as

$$\Phi \equiv (\bar{n}^F)^{1+\frac{1}{\eta}} = (1-\alpha)\frac{\bar{y}^F}{\bar{c}^F} = (1-\alpha)\frac{\bar{Y}^F}{\bar{C}^F}, \tag{C.4}$$

where $\bar{n}^F$, $\bar{y}^F$, and $\bar{c}^F$ are values of normalized labor, output, and consumption, respectively.

Step 2: With aggregation equations (A.5) and (A.4), we obtain

$$\left(\frac{N_t}{\bar{N}_t}\right)^{1-\alpha}\left(\frac{K_t}{A_{t-1}\bar{N}_{t-1}}\right)^{\alpha} = \alpha^{\alpha}(1-\alpha)^{1-\alpha}(GA_t \cdot GN)^{\alpha}\left(\frac{Y_t}{A_t\bar{N}_t}\right)\Delta_t^{(1-\alpha)\left[\frac{\eta}{\eta+1}+\frac{\alpha}{1-\alpha}\right]}, \tag{C.5}$$

which is the aggregate production function with the price dispersion Δ_t. Plugging steady-state (with trend-inflation) capital (i.e., A.37)) and output (i.e., (A.39)) into (C.5) yields

$$\frac{N}{\bar{N}} = \left[\alpha^{\alpha}(1-\alpha)^{1-\alpha}(GA \cdot GN)^{\alpha}\left(\xi^K\right)^{-\alpha}\right]^{\frac{1}{1-\alpha}}\Delta^{\frac{\eta+\alpha}{(\eta+1)(1-\alpha)}}\left(\xi^Y\right)^{\frac{1}{1-\alpha}\left(\frac{\eta+\alpha}{\eta+1}\right)}\left(\xi^C\right)^{-\frac{\eta}{\eta+1}} \tag{C.6}$$

where ξ^K in (A.37), ξ^Y in (A.39), and ξ^C in (A.38) all depend on θ and the trend inflation Π. Therefore, we see that $\bar{n} \neq \bar{n}^F$ and define $\log X_n \equiv \log \bar{n} - \log \bar{n}^F$, which will turn out to be useful later when we calculate the household's first-order labor cost.

Step 3: Price dispersion with positive trend inflation

Delta method Before we start, we would use this approximation throughout this section. For a random variable X with $E(X) = \mu_X$, we have

$$\text{Var}\left(f(X)\right) = f'(\mu_X)^2 \cdot \text{Var}(X) + \text{h.o.t.} \tag{C.7}$$

Price dispersion We use lower-case p_t and $p_t(\nu)$ as logarithms of P_t and $P_t(\nu)$. By applying the above delta method to $P_t^{1-\epsilon} = \mathbb{E}_\nu\left(P_t(\nu)^{1-\epsilon}\right)$, we obtain

$$p_t = \underbrace{\int_0^1 p_t(\nu)d\nu}_{\equiv \bar{p}_t} + \frac{1}{2}\left(\frac{1}{1-\epsilon}\right)\frac{\mathrm{Var}_\nu\left(P_t(\nu)^{1-\epsilon}\right)}{\mathbb{E}_\nu\left(P_t(\nu)^{1-\epsilon}\right)^2} + \text{h.o.t.} \tag{C.8}$$

where we define $\bar{p}_t \equiv \mathbb{E}_\nu(p_t(\nu))$. Applying the delta method to $\mathrm{Var}_\nu(P_t(\nu)^{1-\epsilon})$, we have

$$\mathrm{Var}_\nu\left(P_t(\nu)^{1-\epsilon}\right) = (1-\epsilon)^2 \cdot [\exp((1-\epsilon)\bar{p}_t)]^2 \cdot \mathrm{Var}_\nu(p_t(\nu)), \tag{C.9}$$

where we define $D_t \equiv \mathrm{Var}_\nu(p_t(\nu))$. Applying the delta method to $\mathbb{E}_\nu(P_t(\nu)^{1-\epsilon})$, we obtain

$$\mathbb{E}_\nu\left(P_t(\nu)^{1-\epsilon}\right) = \exp((1-\epsilon)\bar{p}_t)\left[1 + \frac{(1-\epsilon)^2}{2}D_t\right]. \tag{C.10}$$

Plugging (C.9) and (C.10) into (C.8), we obtain

$$p_t = \bar{p}_t + \frac{1-\epsilon}{2} \cdot \frac{D_t}{\left[1 + \frac{(1-\epsilon)^2}{2}D_t\right]^2}, \tag{C.11}$$

which we linear-approximate around $D_t = \bar{D}$ and obtain

$$p_t - \bar{p}_t = \underbrace{\frac{1-\epsilon}{2} \cdot \frac{\bar{D}}{\left[1 + \frac{(1-\epsilon)^2}{2}\bar{D}\right]^2}}_{\equiv \Theta_1^p} + \underbrace{\frac{1-\epsilon}{2} \cdot \frac{1 - \frac{(1-\epsilon)^2}{2}\bar{D}}{\left[1 + \frac{(1-\epsilon)^2}{2}\bar{D}\right]^3}}_{\equiv \Theta_2^p} \cdot (D_t - \bar{D}) = \Theta_1^p + \Theta_2^p(D_t - \bar{D}). \tag{C.12}$$

Now from our original definition of the price dispersion Δ_t (i.e., (28)), we take logarithm on both sides, linear-approximate around $\bar{D}$, and plug (C.12) into it to attain

$$\begin{aligned}
\ln \Delta_t &= \ln \int_0^1 \left(\frac{P_t(\nu)}{P_t}\right)^{\frac{-\epsilon(\eta+1)}{\eta+\alpha}} d\nu \\
&= \frac{\epsilon(\eta+1)}{\eta+\alpha}(p_t - \bar{p}_t) + \ln\left(1 + \frac{1}{2}\left(\frac{\epsilon(\eta+1)}{\eta+\alpha}\right)^2 \bar{D}\right) + \frac{\frac{1}{2}\left(\frac{\epsilon(\eta+1)}{\eta+\alpha}\right)^2}{1 + \frac{1}{2}\left(\frac{\epsilon(\eta+1)}{\eta+\alpha}\right)^2 \bar{D}}(D_t - \bar{D}) \\
&= \Theta_1^\Delta + \Theta_2^\Delta \cdot (D_t - \bar{D}) + \text{h.o.t,}
\end{aligned}$$

where

$$\Theta_1^{\Delta} \equiv \frac{\epsilon(\eta+1)}{\eta+\alpha} \cdot \frac{1-\epsilon}{2} \cdot \frac{\bar{D}}{\left[1+\frac{(1-\epsilon)^2}{2}\bar{D}\right]^2} + \ln\left(1+\frac{1}{2}\left(\frac{\epsilon(\eta+1)}{\eta+\alpha}\right)^2 \bar{D}\right), \tag{C.13}$$

$$\Theta_2^{\Delta} \equiv \frac{\epsilon(\eta+1)}{\eta+\alpha} \cdot \frac{1-\epsilon}{2} \cdot \frac{1-\frac{(1-\epsilon)^2}{2}\bar{D}}{\left[1+\frac{(1-\epsilon)^2}{2}\bar{D}\right]^3} + \frac{\frac{1}{2}\left(\frac{\epsilon(\eta+1)}{\eta+\alpha}\right)^2}{1+\frac{1}{2}\left(\frac{\epsilon(\eta+1)}{\eta+\alpha}\right)^2\bar{D}}. \tag{C.14}$$

If we define b_t as the logarithm of the newly price-resetting firm's relative price P_t^*/P_t and $\bar{b}$ as its steady state value, we have $\bar{b} \neq 0$ due to the trend inflation. Combining (A.8) and (A.10) and linearizing, we obtain

$$b_t \equiv p_t^* - p_t = \bar{b} + \underbrace{\frac{\theta\Pi^{\epsilon-1}}{1-\theta\Pi^{\epsilon-1}}}_{\equiv M}\hat{\pi}_t = \bar{b} + M \cdot \hat{\pi}_t, \text{ with } \bar{b} = \frac{1}{\epsilon-1}\ln\left(\frac{1-\theta}{1-\theta\Pi^{\epsilon-1}}\right). \tag{C.15}$$

With $D_t = \mathrm{Var}_\nu(p_t(\nu)) = \mathbb{E}_\nu((p_t(\nu) - p_t + p_t - \bar{p}_t)^2)$, we can write it as

$$D_t = \int_0^{1-\theta}(p_t^* - p_t)^2 d\nu + 2\left(\int_0^{1-\theta}(p_t^* - p_t)d\nu\right)(p_t - \bar{p}_t) \tag{C.16}$$
$$+ (1-\theta)(p_t - \bar{p}_t)^2 + \int_{1-\theta}^1 (p_{t-1}(\nu) - \bar{p}_t)^2 d\nu$$
$$= (1-\theta)(p_t^* - p_t)^2 + 2(1-\theta)(p_t^* - p_t)(p_t - \bar{p}_t) + (1-\theta)(p_t - \bar{p}_t)^2 + \theta D_{t-1} + \theta(\bar{p}_t - \bar{p}_{t-1})^2, \tag{C.17}$$

where we use

$$\int_{1-\theta}^1 (p_{t-1}(\nu) - \bar{p}_t)^2 d\nu = \theta D_{t-1} + \theta(\bar{p}_{t-1} - \bar{p}_t)^2. \tag{C.18}$$

Conjecture Following Coibion et al. (2012), we conjecture the dynamics of D_t up to a second-order as[7]

$$D_t - \bar{D} = \kappa_D\hat{\pi}_t + Z_D(\hat{\pi}_t)^2 + F_D(D_{t-1} - \bar{D}) + G_D(D_{t-1} - \bar{D})\hat{\pi}_t + H_D(D_{t-1} - \bar{D})^2. \tag{C.19}$$

[7] Following Coibion et al. (2012), we assume κ_D is of the same order as the shock processes, so that the first term becomes of a second-order. Then our log-linearized model derivation without price dispersion term is valid.

with

$$
\begin{aligned}
\bar{D} &= (\bar{b}+\Theta_1^p)^2 + \frac{\theta}{1-\theta}(\bar{\pi})^2 \quad \text{(i.e., steady state value of } D_t\text{)},\\
\kappa_D &= \left[1-2(1-\theta)\Theta_2^p(\bar{b}+\Theta_1^p)+2\theta\Theta_2^p\bar{\pi}\right]^{-1}\left[2(1-\theta)M(\bar{b}+\Theta_1^p)+2\theta\bar{\pi}\right],\\
Z_D &= \left[1-2(1-\theta)\Theta_2^p(\bar{b}+\Theta_1^p)+2\theta\Theta_2^p\bar{\pi}\right]^{-1}\left[(1-\theta)M^2+2(1-\theta)M\Theta_2^p\kappa_D+(\Theta_2^p)^2(\kappa_D)^2+\theta-2\theta\Theta_2^p\kappa_D\right],\\
F_D &= \left[1-2(1-\theta)\Theta_2^p(\bar{b}+\Theta_1^p)+2\theta\Theta_2^p\bar{\pi}\right]^{-1}\left[\theta+2\theta\Theta_2^p\bar{\pi}\right],\\
G_D &= \left[1-2(1-\theta)\Theta_2^p(\bar{b}+\Theta_1^p)+2\theta\Theta_2^p\bar{\pi}\right]^{-1}\left[2(1-\theta)M\Theta_2^pF_D+2(\Theta_2^p)^2\kappa_DF_D-2\theta\Theta_2^pF_D\right.\\
&\qquad\qquad\left.+2\theta\Theta_2^p-2\theta(\Theta_2^p)^2\kappa_D\right],\\
H_D &= \left[1-2(1-\theta)\Theta_2^p(\bar{b}+\Theta_1^p)+2\theta\Theta_2^p\bar{\pi}\right]^{-1}\left[(\Theta_2^p)^2(F_D)^2+\theta(\Theta_2^p)^2-2\theta(\Theta_2^p)^2F_D\right].
\end{aligned}
\tag{C.20}
$$

With no trend inflation, we would have $\pi = 0$ and $\bar{D} = 0$, thus D_t becomes the second-order variable around 0 and we would have $\kappa_D = 0$. However with steady-state inflation $\pi > 0$ and the price dispersion measure $\bar{D} > 0$, as we see in (C.19), D_t includes $\hat{\pi}_t$ term as one of its components, with κ_D being of the first-order. Our objective is to derive (C.19) from firms' optimal pricing behaviors and the price dispersion's effects on the aggregate price itself. Plugging (C.12) and (C.15) into (C.16) and replace $(D_t - \bar{D})$ with the conjectured form in (C.19) up to a second-order,[8] and comparing coefficients, we obtain the set of coefficients in (C.20).

Consumption utility We can second-order approximate the utility of consumption as

$$
u(c_t) = \log c_t = u(\bar{c}^F) + u'_{\bar{c}^F}\cdot\bar{c}^F\cdot\underbrace{\left(\frac{c_t-\bar{c}^F}{\bar{c}^F}\right)}_{=\tilde{c}_t+\cancel{\frac{1}{2}(\tilde{c}_t)^2}} + \frac{1}{2}u''_{\bar{c}^F}\cdot(\bar{c}^F)^2\cdot\underbrace{\left(\frac{c_t-\bar{c}^F}{\bar{c}^F}\right)^2}_{=\cancel{(\tilde{c}_t)^2}} + \text{h.o.t} = u(\bar{c}^F)+\tilde{c}_t+\text{h.o.t.}
\tag{C.21}
$$

<u>Step 4</u>: Labor aggregation and cost

By applying the delta method (i.e., (C.7)) to the labor aggregator, we can obtain[9]

$$
\tilde{n}_t - \mathbb{E}_\nu(\tilde{n}_t(\nu)) = \underbrace{\frac{\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)\overline{\nabla}}{1+\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)^2\overline{\nabla}}}_{\equiv\Theta_1^n} + \underbrace{\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)\frac{1-\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)^2\overline{\nabla}}{\left[1+\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)^2\overline{\nabla}\right]^3}}_{\equiv\Theta_2^n}\cdot(\nabla_t-\overline{\nabla})
\tag{C.22}
$$

[8] In the right-hand side of the expression, $(p_t - \bar{p}_t)^2$ appears and has a second-order term $(D_t - \bar{D})^2$ from (C.12), and we use (C.19) to replace this term with terms related to $(\hat{\pi}_t)^2$, $(D_{t-1} - \bar{D})^2$, and $\hat{\pi}_t(D_{t-1} - \bar{D})$.

[9] In the flexible-price steady-state, there is no heterogeneity among firms, i.e., $\bar{n}^F(\nu) = \bar{n}^F$ for $\forall\nu$.

where $\nabla_t \equiv \mathrm{Var}_\nu(\log n_t(\nu))$. The second-order approximation to the firm ν-specific labor cost around the flexible-price steady state yields

$$\frac{\eta}{\eta+1}\left(\frac{N_t(\nu)}{\bar{N}_t}\right)^{\frac{\eta+1}{\eta}} = \frac{\eta}{\eta+1}(\bar{n}^F)^{\frac{\eta+1}{\eta}} + \Phi\left[\tilde{n}_t(\nu) + \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)\tilde{n}_t(\nu)^2\right] + h.o.t \tag{C.23}$$

where the constant Φ is from (C.4). Aggregating (C.23) over firms $\nu \in [0,1]$ and plugging (C.22) results in

$$\begin{aligned}
\frac{\eta}{\eta+1}\int_0^1\left(\frac{N_t}{\bar{N}_t}\right)^{\frac{\eta+1}{\eta}} d\nu - \frac{\eta}{\eta+1}(\bar{n}^F)^{\frac{\eta+1}{\eta}} &= \Phi\left[\mathbb{E}_\nu(\tilde{n}_t(\nu)) + \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)\int_0^1 \tilde{n}_t(\nu)^2 d\nu\right] \\
&= -\Phi\left(\Theta_1^n - \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)(\Theta_1^n)^2\right) + \Phi\Bigg[\left(1-\left(\frac{\eta+1}{\eta}\right)\Theta_1^n\right)\tilde{n}_t + \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)\tilde{n}_t^2 \\
&\quad + \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)(\Theta_2^n)^2\left(\mathrm{Var}_\nu(\tilde{n}_t(\nu)) - \overline{\nabla}\right)^2 - \frac{\eta+1}{\eta}\Theta_2^n\tilde{n}_t\left(\mathrm{Var}_\nu(\tilde{n}_t(\nu)) - \overline{\nabla}\right) \\
&\quad + \left(\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)(1+2\Theta_1^n\Theta_2^n) - \Theta_2^n\right)\left(\mathrm{Var}_\nu(\tilde{n}_t(\nu)) - \overline{\nabla}\right) + \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)\overline{\nabla}\Bigg].
\end{aligned} \tag{C.24}$$

Labor dispersion From individual firm's labor and capital demand (i.e., (16)) and the household's intra-marginal condition (i.e., (10)), we obtain

$$\tilde{k}_t(\nu) = \left(1+\frac{1}{\eta}\right)\tilde{n}_t(\nu) + \text{aggregate}, \tag{C.25}$$

where 'aggregate' stands for aggregate variables. Therefore, we obtain

$$\tilde{y}_t(\nu) = \left(1+\frac{\alpha}{\eta}\right)\tilde{n}_t(\nu) + \text{aggregate}, \tag{C.26}$$

by plugging (C.25) into each firm's production function $\tilde{y}_t(\nu) = \alpha\tilde{k}_t(\nu) + (1-\alpha)\tilde{n}_t(\nu)$. From the Dixit-Stiglitz good demand (i.e., (13)) and with (C.26), we can get

$$\mathrm{Var}_\nu(\tilde{n}_t(\nu)) = \left(\frac{\epsilon}{1+\frac{\alpha}{\eta}}\right)^2 \mathrm{Var}_\nu(p_t(\nu)), \quad \text{with } \overline{\nabla} = \left(\frac{\epsilon}{1+\frac{\alpha}{\eta}}\right)^2 \bar{D}. \tag{C.27}$$

Step 5: Constructing a welfare function: Combining the consumption utility (i.e., (C.21)) and the labor disutility (i.e., (C.24)), we can construct welfare as

$$\mathbb{E}U_t - \bar{U}^F = \mathbb{E}\Bigg[\tilde{c}_t + \Phi\left(\Theta_1^n - \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)(\Theta_1^n)^2\right) - \Phi\Bigg\{\left(1 - \left(\frac{\eta+1}{\eta}\right)\Theta_1^n\right)\tilde{n}_t + \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)\tilde{n}_t^2 + \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)(\Theta_2^n)^2\left(\mathrm{Var}_\nu(\tilde{n}_t(\nu)) - \overline{\nabla}\right)^2 - \frac{\eta+1}{\eta}\Theta_2^n\tilde{n}_t\left(\mathrm{Var}_\nu(\tilde{n}_t(\nu)) - \overline{\nabla}\right) + \left(\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)(1 + 2\Theta_1^n\Theta_2^n) - \Theta_2^n\right)\left(\mathrm{Var}_\nu(\tilde{n}_t(\nu)) - \overline{\nabla}\right) + \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)\overline{\nabla}\Bigg\}\Bigg], \tag{C.28}$$

with from (A.38), (A.39), and (C.6) the flexible-price steady-state utility given as

$$\begin{aligned}\bar{U}^F &= \bar{c}^F - \frac{\eta}{\eta+1}\left(\frac{N^F}{\bar{N}}\right)^{\frac{\eta+1}{\eta}} \\ &= \frac{1}{\eta+1}\left[\log\left(\xi^{C,f}\right) + \frac{\eta+\alpha}{1-\alpha}\log\left(\xi^{Y,f}\right)\right] - \frac{\eta}{\eta+1}\left[\alpha^\alpha(1-\alpha)^{1-\alpha}(GA\cdot GN)^\alpha\left(\xi^{K,f}\right)^{-\alpha}\right]^{\frac{\eta+1}{(1-\alpha)\eta}}\left(\xi^{Y,f}\right)^{\frac{\eta+\alpha}{(1-\alpha)\eta}}\left(\xi^{C,f}\right)^{-1},\end{aligned}$$

where

$$\begin{aligned}&\xi^{F,f} = (1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}}\left[\beta^{-1}\cdot GA\cdot GN - (1-\delta)\right]^{\alpha\left(\frac{\eta+1}{\eta+\alpha}\right)}, \quad \xi^{H,f} = 1 - \gamma_L\left(\frac{R^K}{R^S} - 1\right), \quad \xi^{Y,f} = \frac{\xi^{H,f}}{\xi^{F,f}}, \\ &\xi^{K,f} = \alpha(1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}}\cdot GA\cdot GN\cdot\left[\beta^{-1}\cdot GA\cdot GN - (1-\delta)\right]^{-\frac{\eta(1-\alpha)}{\eta+\alpha}}\xi^{Y,f}, \\ &\xi^{C,f} = 1 - \zeta^G - \xi^{K,f}\left(1 - \frac{1-\delta}{GA\cdot GN}\right).\end{aligned}$$

$\xi^{C,f}$, $\xi^{Y,f}$, and $\xi^{K,f}$ are levels of ξ^C, ξ^Y, and ξ^K when $\theta = 0$ (i.e., flexible price steady state). With

$$\log\frac{\xi^Y}{\xi^{Y,f}} = \log\left(\frac{1 - \theta\beta\Pi^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}}{1 - \theta\beta\Pi^{\epsilon-1}}\right) + \frac{1}{\epsilon-1}\left[1 + \epsilon\left(\frac{1-\alpha}{\eta+\alpha}\right)\right]\log\left(\frac{1-\theta}{1-\theta\Pi^{\epsilon-1}}\right), \tag{C.29}$$

and

$$\log\frac{\xi^K}{\xi^{K,f}} = \log\left(\frac{\xi^Y}{\xi^{Y,f}}\right) + \log\Delta, \tag{C.30}$$

$$\log\frac{\xi^C}{\xi^{C,f}} = \log\frac{1 - \zeta^G - \xi^K\left(1 - \frac{1-\delta}{GA\cdot GN}\right)}{1 - \zeta^G - \xi^{K,f}\left(1 - \frac{1-\delta}{GA\cdot GN}\right)}, \tag{C.31}$$

where Δ at the steady state with trend inflation is defined in (A.32), which gives

$$\log\Delta = \log\left(\frac{1-\theta}{1-\theta\Pi^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}}\right) + \frac{\epsilon}{\epsilon-1}\left(\frac{\eta+1}{\eta+\alpha}\right)\log\left(\frac{1-\theta\Pi^{\epsilon-1}}{1-\theta}\right). \tag{C.32}$$

If we define $\log X_c = \tilde{c}_t - \hat{c}_t$ as the log-difference in consumption between our steady state (with trend-inflation) and the flexible price steady state, we obtain

$$\log X_c \equiv \bar{c} - \bar{c}^F = \frac{1}{\eta+1}\left[\log\left(\frac{\xi^C}{\xi^{C,f}}\right) + \frac{\eta+\alpha}{1-\alpha}\log\left(\frac{\xi^Y}{\xi^{Y,f}}\right)\right]. \tag{C.33}$$

For labor, we define $\log X_n$ as the log-difference in labor between our steady state with trend inflation and the flexible price steady state, which is, with the help of (C.6), given by

$$\log X_n \equiv \bar{n} - \bar{n}^F = -\frac{\alpha}{1-\alpha}\log\frac{\xi^K}{\xi^{K,f}} + \frac{1}{1-\alpha}\left(\frac{\eta+\alpha}{\eta+1}\right)\log\frac{\xi^Y}{\xi^{Y,f}} - \frac{\eta}{\eta+1}\log\frac{\xi^C}{\xi^{C,f}} + \frac{\eta+\alpha}{(\eta+1)(1-\alpha)}\log\Delta. \tag{C.34}$$

With $\tilde{c}_t = \hat{c}_t + \log X_c$, $\tilde{n}_t = \hat{n}_t + \log X_n$, and the stationarity assumption (following Coibion et al. (2012)), we can get

$$\mathbb{E}\left[\tilde{c}_t - \Phi\left(1-\left(\frac{\eta+1}{\eta}\right)\Theta_1^n\right)\tilde{n}_t\right] = \log X_c - \Phi\left(1-\left(\frac{\eta+1}{\eta}\right)\Theta_1^n\right)\log X_n. \tag{C.35}$$

Second order terms: With $\tilde{n}_t = \hat{n}_t + \log X_n$, second-order terms can be collected as

$$\begin{aligned}
-\Phi\Bigg[&\frac{\eta+1}{2\eta}\mathbb{E}\left(\hat{n}_t^2\right) + \frac{\eta+1}{2\eta}(\Theta_2^n)^2\mathbb{E}\left(\left(\mathrm{Var}_\nu(\tilde{n}_t(\nu)) - \overline{\nabla}\right)^2\right) - \frac{\eta+1}{\eta}\Theta_2^n\mathbb{E}\left(\hat{n}_t\left(\mathrm{Var}_\nu(\hat{n}_t(\nu)) - \overline{\nabla}\right)\right) \\
&+\left(\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)(1+2\Theta_1^n\Theta_2^n) - \Theta_2^n - \frac{\eta+1}{\eta}\Theta_2^n\log X_n\right)\mathbb{E}\left(\mathrm{Var}_\nu(\hat{n}_t(\nu)) - \overline{\nabla}\right)\Bigg]\Bigg],
\end{aligned} \tag{C.36}$$

which, after we can plug (C.27) into, becomes

$$\begin{aligned}
-\Phi\Bigg[&\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)\mathrm{Var}\left(\hat{n}_t\right) + \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)(\Theta_2^n)^2\left(\frac{\epsilon}{1+\frac{\alpha}{\eta}}\right)^4\mathbb{E}(D_t-\bar{D})^2 \\
&-\frac{\eta+1}{\eta}\Theta_2^n\left(\frac{\epsilon}{1+\frac{\alpha}{\eta}}\right)^2\mathrm{Cov}(\hat{n}_t, D_t) \\
&+\left(\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)(1+2\Theta_1^n\Theta_2^n) - \Theta_2^n\left(1+\frac{\eta+1}{\eta}\log X_n\right)\right)\left(\frac{\epsilon}{1+\frac{\alpha}{\eta}}\right)^2\mathbb{E}(D_t-\bar{D})\Bigg]\Bigg].
\end{aligned} \tag{C.37}$$

Finally, by plugging (C.19) into (C.37), we get the following proposition. Sine κ_D is of the same order as shock processes, up to a second-order, we can ignore covariance terms and the square term of D_t. Therefore, a 2^{nd}-order approximation to the expected per-period welfare would be given as

$$\mathbb{E}U_t - \bar{U}^F = \Omega_0 + \Omega_n \mathrm{Var}(\hat{n}_t) + \Omega_\pi \mathrm{Var}(\hat{\pi}_t) + h.o.t, \tag{C.38}$$

with

$$\begin{aligned}
\Omega_0 &= \log X_c - \Phi\left(1 - \left(\frac{\eta+1}{\eta}\right)\Theta_1^n\right)\log X_n + \Phi\left(\Theta_1^n - \frac{1}{2}\left(\frac{\eta+1}{\eta}\right)(\Theta_1^n)^2\right) - \Phi\frac{1}{2}\frac{\eta+1}{\eta}(\log X_n)^2 \\
&\quad - \Phi\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)\left(\frac{\epsilon}{1+\frac{\alpha}{\eta}}\right)^2 \bar{D}, \\
\Omega_n &= -\Phi\frac{1}{2}\left(\frac{\eta+1}{\eta}\right), \qquad \text{(C.39)} \\
\Omega_\pi &= -\Phi\left[\left(\frac{1}{2}\left(\frac{\eta+1}{\eta}\right)(1+2\Theta_1^n\Theta_2^n) - \Theta_2^n\left(1+\frac{\eta+1}{\eta}\log X_n\right)\right)\left(\frac{\epsilon}{1+\frac{\alpha}{\eta}}\right)^2 \frac{Z_D}{1-F_D}\right],
\end{aligned}$$

where $\log X_c$ and $\log X_n$ are defined in (C.33) and (C.34), respectively; the coefficients Θ_1^n and Θ_2^n are given in (C.22); and $\bar{D}$ is determined by jointly solving (C.12) (i.e., the definition of Θ_1^p) and (C.20). The parameters κ_D, Z_D, F_D, G_D, and H_D are specified in (C.20). Higher-order terms are denoted by $h.o.t$. Finally, the coefficient Ω_0 is part of the policy-independent terms ($t.i.p.$) that appear in Proposition 1.

D Microfoundation for Demand Systems

In this section, we provide a microfounded model for our demand systems represented by equations (3) and (5).

As explained in Section 2.1.1, the representative household chooses optimal consumption, employment, and savings S_t, which are allocated between government bonds $B_t^H = \sum_{f=1}^{F} B_t^{H,f}$ and firm loans L_t, so that $S_t = B_t^H + L_t$. To generate a downward-sloping demand curve for each asset—preventing the linearized model from equalizing expected returns across different maturities (see, e.g., Froot (1989))—we introduce a mechanism based on preference heterogeneity. Once the household determines its savings S_t, it is partitioned into a continuum of families (indexed by $m \in [0, 1]$), each favoring either loans or government bonds. This diversity arises from optimal portfolio allocation under imperfect and heterogeneous information about future asset returns.

For families that invest in bonds, we further subdivide each family into a continuum of members (indexed by $n \in [0,1]$), with each member preferring a specific bond maturity f (where $f = 1, \dots, F$). These variations in preference, reflecting differences in expectations regarding future bond returns and price revaluations, determine the demand across bond maturities. All families and their members share the same overall household savings S_t; moreover, perfect consumption insurance holds within each family, as in the literature (Del Negro et al., 2017), and no trading is allowed among members or between families. We address this allocation problem recursively in the subsequent sections.

Bond Family Suppose that family m selects bonds as its preferred savings vehicle. Each member n then maximizes the expected discounted return:

$$\max \sum_{f=1}^{F} \mathbb{E}_{m,n,t}\left[Q_{t,t+1} R_{t+1}^{f-1} B_{m,n,t}^{H,f}\right] \text{ s.t. } B_{m,n,t}^{H} \equiv \sum_{f=1}^{F} B_{m,n,t}^{H,f} = S_t, \;\; B_{m,n,t}^{H,f} \geq 0,$$

Here, $\mathbb{E}_{m,n,t}$ is the individual expectation operator and $Q_{t,t+1}$ the stochastic discount factor. Due to the linearity of the problem, the optimal allocation is a corner solution: member n invests her entire savings in the bond with the highest expected discounted return,

$$B_{m,n,t}^{H,i} = \begin{cases} S_t & \text{if } i = \arg\max_{1 \leq j \leq F}\{\mathbb{E}_{m,n,t}[Q_{t,t+1} R_{t+1}^{j-1}]\}, \\ 0 & \text{otherwise.} \end{cases}$$

Under benchmark rational expectations, all members of family m choose the same bond, thereby equalizing the expected discounted returns $\mathbb{E}_t[Q_{t,t+1} R_{t+1}^{f-1}]$ across maturities—consistent with the *expectation hypothesis* in log-linearized models.[10] In this case, long-term yields are solely determined by conventional monetary policy, leaving little room for alternative policies such as quantitative easing (QE), despite empirical evidence (e.g., Krishnamurthy and Vissing-Jorgensen (2011)).

To generate a downward-sloping demand curve for bonds, we depart from the expectations hypothesis by introducing heterogeneity in individual expectations. Specifically, we assume that each member n forms expectations as

$$\mathbb{E}_{m,n,t}\left[Q_{t,t+1} R_{t+1}^{f-1}\right] = z_{n,t}^{f} \cdot \mathbb{E}_t\left[Q_{t,t+1} R_{t+1}^{f-1}\right], \quad \forall f = 1, \dots, F,$$

[10] In the linearized setting, omitting the covariance between $Q_{t,t+1}$ and R_{t+1}^{f-1} equalizes expected returns across maturities.

where $z^f_{n,t}$ is a maturity-f shock reflecting imperfect and heterogeneous information (cf. Angeletos and La'O (2013)). We assume that family m cannot aggregate these individual signals and therefore divides its savings equally among its members, who then choose their preferred bond maturity independently.

For analytical tractability, we model $z^f_{n,t}$ as i.i.d. Fréchet-distributed with location zero, scale parameter z^f_t, and shape parameter κ_B (see, e.g., Eaton and Kortum (2002) and Dordal i Carreras et al. (2023)). The shape parameter governs the dispersion of expectation shocks, with $\kappa_B \to \infty$ implying convergence to rational expectations. Each member n then selects the maturity f that maximizes $z^f_{n,t}\,\mathbb{E}_t[Q_{t,t+1}R^{f-1}_{t+1}]$.

Let $\lambda^{HB,f}_t$ denote the probability that a member chooses the f-maturity bond. By the properties of the Fréchet distribution, this probability is given by

$$\lambda^{HB,f}_t = \left(\frac{z^f_t\,\mathbb{E}_t[Q_{t,t+1}R^{f-1}_{t+1}]}{\Phi^B_t}\right)^{\kappa_B}, \tag{D.1}$$

where $\Phi^B_t \equiv \left[\sum_{j=1}^F \left(z^j_t\,\mathbb{E}_t[Q_{t,t+1}R^{j-1}_{t+1}]\right)^{\kappa_B}\right]^{\frac{1}{\kappa_B}}$. An increase in the f-maturity return or in the scale parameter z^f_t thus raises the probability of choosing that maturity.

Aggregating over families and individuals, the household's total holdings of f-maturity bonds are

$$B^{H,f}_t = \lambda^{HB,f}_t \cdot B^H_t, \quad \forall f = 1,\ldots,F, \tag{D.2}$$

where B^H_t is the aggregate bond holding. Consequently, the aggregate return on the household's bond portfolio is

$$R^{HB}_{t+1} = \sum_{f=0}^{F-1} \lambda^{HB,f+1}_t\, R^f_{t+1}\,. \tag{D.3}$$

Bond vs. Loans Family After allocating savings across bond maturities, family m chooses between bonds and loans by maximizing its expected savings return:

$$\begin{gathered}\max\ \mathbb{E}_{m,t}\left[Q_{t,t+1}R^{HB}_{t+1}B^H_{m,t}\right] + \mathbb{E}_{m,t}\left[Q_{t,t+1}R^K_{t+1}L_{m,t}\right] \quad \text{s.t.}\\ B^H_{m,t} + L_{m,t} = S_t,\ \ B^H_{m,t} \geq 0,\ \text{ and }\ L_{m,t} \geq 0.\end{gathered}$$

If family m selects bonds, it follows the investment strategy in (D.1) and earns the aggregate bond return R^{HB}_{t+1} (see (D.3)). Under benchmark rational expectations, families would equalize $\mathbb{E}_t[Q_{t,t+1}R^{HB}_{t+1}]$ and $\mathbb{E}_t[Q_{t,t+1}R^K_{t+1}]$, rendering them indifferent. We depart from this by assuming family m's expectation for loans deviates from rational expectations:

$$\mathbb{E}_{m,t}\left[Q_{t,t+1}R^K_{t+1}\right] = z^K_{m,t}\,\mathbb{E}_t\left[Q_{t,t+1}R^K_{t+1}\right],$$

where $z^K_{m,t}$ is modeled as a Fréchet-distributed shock with zero location, scale parameter z^K_t, and shape parameter κ_S (with $\lim_{\kappa_S\to\infty}\mathrm{Var}(z^K_{m,t}) = 0$). Setting $z^K_t = \Gamma(1-1/\kappa_S)^{-1}$ ensures $\mathbb{E}(z^K_{m,t}) = 1$, so that as $\kappa_S \to \infty$ the model converges to rational expectations.

Aggregating across families, the share of aggregate savings allocated to loans is

$$\lambda^K_t = \left(\frac{z^K_t\,\mathbb{E}_t\left[Q_{t,t+1}R^K_{t+1}\right]}{\Phi^S_t}\right)^{\kappa_S}, \tag{D.4}$$

with $\Phi^S_t = \left[\left(\mathbb{E}_t\left[Q_{t,t+1}R^{HB}_{t+1}\right]\right)^{\kappa_S} + \left(z^K_t\,\mathbb{E}_t\left[Q_{t,t+1}R^K_{t+1}\right]\right)^{\kappa_S}\right]^{\frac{1}{\kappa_S}}$. [11] The scale parameter z^K_t governs the overall portfolio preference for loans.

Using (D.4), the aggregate bond holdings by maturity f become

$$B^{H,f}_t = \left(1-\lambda^K_t\right)\lambda^{HB,f}_t\,S_t, \quad \forall f = 1,\ldots,F,$$

and the aggregate return on household savings is

$$R^S_t = \left(1-\lambda^K_{t-1}\right)R^{HB}_t + \lambda^K_{t-1}R^K_t. \tag{D.5}$$

Thus, R^S_t is a weighted average of returns from bonds (across maturities) and loans. The household's budget constraint (2) can then be rewritten as

$$C_t + \frac{S_t}{P_t} = \frac{R^S_t\,S_{t-1}}{P_t} + \int_0^1 \frac{W_t(\nu)N_t(\nu)}{P_t}\,\mathrm{d}\nu + \frac{\Lambda_t}{P_t}. \tag{D.6}$$

Despite the richer asset structure and market segmentation, the representative household's problem ultimately resembles that of a conventional New-Keynesian model.

Remarks on Aggregation Modeling individual deviations from rational expectations as extreme Fréchet shocks generates market segmentation both between bond and loan markets and among bonds of different maturities. The shape parameters κ_B and κ_S control

[11] Equation (D.4) implies that a family's preference for loans increases when the return on loans R^K_{t+1} exceeds the aggregate bond return R^{HB}_{t+1}.

the degree of segmentation; as κ_B, $\kappa_S \to \infty$, our framework nests the conventional expectations hypothesis. Importantly, the nested CES structure facilitates extension to a wide range of assets and maturity structures. These parameters summarize the demand elasticity for financial products in response to movements in expected returns (see (D.1) and (D.4)), and can be empirically estimated—for instance, we estimate κ_B in Appendix B.[12]

Remarks on Assumptions and Differences with the Literature Household members act as agents with evolving preferred habitats (cf. Modigliani and Sutch (1966)), with their choice of bond maturity—or the decision between bonds and loans—responsive to anticipated one-period returns. In equilibrium, the heterogeneity in asset return information induces a margin of habitat-switchers, yielding a downward-sloping asset demand curve that reflects relative returns and aggregate information shocks $\{z_t^K, \{z_t^f\}_{f=1}^F\}$. This contrasts with frameworks such as Ray (2019) and Droste et al. (2021), who assume that the household's aggregate portfolio distribution along the yield curve is exogenously given and only arbitrageurs constant change their portfolios.

[12] Note that our specification assumes a constant elasticity across bond maturities; see Droste et al. (2021) for evidence that substitution elasticities may vary with maturity proximity. Our model can be extended to allow for heterogeneous κ_B without altering its qualitative features.

E Summary of Equilibrium Equations

E.1 Equilibrium Equations: Conventional Policy (CP)

$$(i).\ \frac{C_t}{A_t\bar{N}_t} = \left(1-\zeta_t^G\right)\left(\frac{Y_t}{A_t\bar{N}_t}\right) + \left(\frac{1-\delta}{GA_t \cdot GN}\right)\left(\frac{K_t}{A_{t-1}\bar{N}_{t-1}}\right) - \left(\frac{K_{t+1}}{A_t\bar{N}_t}\right) \tag{E.1}$$

$$(ii).\ 1 = \beta \cdot \mathbb{E}_t\left[\frac{R_{t+1}^S}{\Pi_{t+1}\cdot GA_{t+1}\cdot GN}\frac{\left(\frac{C_t}{A_t\bar{N}_t}\right)}{\left(\frac{C_{t+1}}{A_{t+1}\bar{N}_{t+1}}\right)}\right] \tag{E.2}$$

$$(iii).\ \lambda_t^{HB,1} = 1 - \sum_{f=2}^{F}\lambda_t^{HB,f} \tag{E.3}$$

$$(iv).\ -\left(\frac{B_t^{G,f}}{A_t\bar{N}_tP_t} + \frac{\overline{B^{CB,f}}}{A\bar{N}P}\right)\cdot\left(\lambda_t^{HB,f}\right)^{-1} = \gamma_L\cdot\left(1+\zeta^F\right)\cdot\left(\frac{1-\lambda_t^K}{\lambda_t^K}\right)\left(\frac{Y_t}{A_t\bar{N}_t}\right)\ ,\ \ \forall f>1 \tag{E.4}$$

$$(v).\ YD_t^1 = \max\left\{YD_t^{1*},1\right\} \tag{E.5}$$

$$(vi).\ YD_t^{1*} = \overline{YD}^1\cdot\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma_\pi}\left(\frac{Y_t}{\bar{Y}}\right)^{\gamma_y}\cdot\exp\left(\tilde{\varepsilon}_t^{YD^1}\right) \tag{E.6}$$

$$(vii).\ \lambda_t^{HB,f} = \left(\frac{\mathbb{E}_t\left[\frac{\beta z_t^f}{\Pi_{t+1}\cdot GA_{t+1}\cdot GN}\cdot\frac{\left(\frac{C_t}{A_t\bar{N}_t}\right)}{\left(\frac{C_{t+1}}{A_{t+1}\bar{N}_{t+1}}\right)}\frac{\left(YD_{t+1}^{f-1}\right)^{-(f-1)}}{\left(YD_t^f\right)^{-f}}\right]}{\Phi_t^B}\right)^{\kappa_B}\ ,\qquad \forall f \tag{E.7}$$

$$(viii).\ \Phi_t^B = \left[\sum_{j=1}^{F}\mathbb{E}_t\left[\frac{\beta z_t^j}{\Pi_{t+1}\cdot GA_{t+1}\cdot GN}\cdot\frac{\left(\frac{C_t}{A_t\bar{N}_t}\right)}{\left(\frac{C_{t+1}}{A_{t+1}\bar{N}_{t+1}}\right)}\frac{\left(YD_{t+1}^{j-1}\right)^{-(j-1)}}{\left(YD_t^j\right)^{-j}}\right]^{\kappa_B}\right]^{\frac{1}{\kappa_B}} \tag{E.8}$$

$$(ix).\ \lambda_t^K = \left(\frac{z_t^K\mathbb{E}_t\left[Q_{t,t+1}R_{t+1}^K\right]}{\Phi_t^S}\right)^{\kappa_S} \tag{E.9}$$

$$(x).\ \Phi_t^S = \left[\left(\mathbb{E}_t\left[Q_{t,t+1}R_{t+1}^{HB}\right]\right)^{\kappa_S} + \left(z_t^K\mathbb{E}_t\left[Q_{t,t+1}R_{t+1}^K\right]\right)^{\kappa_S}\right]^{\frac{1}{\kappa_S}} \tag{E.10}$$

$$(xi).\;\; R_t^j = \sum_{f=0}^{F-1} \lambda_{t-1}^{j,f+1} \frac{\left(YD_t^f\right)^{-f}}{\left(YD_{t-1}^{f+1}\right)^{-(f+1)}},\;\; j \in \{HB, G, CB\} \tag{E.11}$$

$$(xii).\;\; R_t^S = \left(1-\lambda_{t-1}^K\right) R_t^{HB} + \lambda_{t-1}^K R_t^K \tag{E.12}$$

$$(xiii).\;\; 1 = \mathbb{E}_t\left[Q_{t,t+1}\Pi_{t+1}\left[(1-\delta) + \frac{P_{t+1}^K}{P_{t+1}}\right]\right] \tag{E.13}$$

$$(xiv).\;\; F_t = (1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}} \left(\frac{(1+\varsigma_F)^{-1}\epsilon}{\epsilon-1}\right)\left(\frac{C_t}{A_t\bar{N}_t}\right)^{-\alpha\left(\frac{\eta+1}{\eta+\alpha}\right)}\left(\frac{Y_t}{A_t\bar{N}_t}\right)^{\frac{\eta+1}{\eta+\alpha}}\left(\frac{P_t^K}{P_t}\right)^{\alpha\left(\frac{\eta+1}{\eta+\alpha}\right)} + \theta\beta\mathbb{E}_t\left[\Pi_{t+1}^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}F_{t+1}\right] \tag{E.14}$$

$$(xv).\;\; H_t = \left(\frac{C_t}{A_t\bar{N}_t}\right)^{-1}\frac{Y_t}{A_t\bar{N}_t}\left[1-\gamma_L\cdot\left(\widetilde{R}_{t+1}^K - 1\right)\right] + \theta\beta\mathbb{E}_t\left[\Pi_{t+1}^{\epsilon-1}H_{t+1}\right] \tag{E.15}$$

$$(xvi).\;\; \frac{F_t}{H_t} = \left(\frac{1-\theta}{1-\theta\Pi_t^{\epsilon-1}}\right)^{\left(\frac{1}{\epsilon-1}\right)\left[1+\epsilon\left(\frac{1-\alpha}{\eta+\alpha}\right)\right]} \tag{E.16}$$

$$(xvii).\;\; \Delta_t = (1-\theta)\left(\frac{1-\theta\Pi_t^{\epsilon-1}}{1-\theta}\right)^{\left(\frac{\epsilon}{\epsilon-1}\right)\left(\frac{\eta+1}{\eta+\alpha}\right)} + \theta\Pi_t^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}\Delta_{t-1} \tag{E.17}$$

$$(xviii).\;\; \frac{N_t}{\bar{N}_t} = (1-\alpha)^{\left(\frac{\eta}{\eta+\alpha}\right)}\left(\frac{C_t}{A_t\bar{N}_t}\right)^{-\alpha\left(\frac{\eta}{\eta+\alpha}\right)}\left(\frac{Y_t}{A_t\bar{N}_t}\right)^{\left(\frac{\eta}{\eta+\alpha}\right)}\left(\frac{P_t^K}{P_t}\right)^{\alpha\left(\frac{\eta}{\eta+\alpha}\right)}\Delta_t^{\frac{\eta}{\eta+1}} \tag{E.18}$$

$$(xix).\;\; \frac{K_t}{A_{t-1}\bar{N}_{t-1}} = \alpha(1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}}\cdot GA_t\cdot GN\cdot\left(\frac{C_t}{A_t\bar{N}_t}\right)^{\frac{\eta(1-\alpha)}{\eta+\alpha}}\left(\frac{Y_t}{A_t\bar{N}_t}\right)^{\frac{\eta+1}{\eta+\alpha}}\left(\frac{P_t^K}{P_t}\right)^{-\left(\frac{\eta(1-\alpha)}{\eta+\alpha}\right)}\Delta_t \tag{E.19}$$

$$(xx).\;\; \frac{B_t^G}{P_tA_t\bar{N}_t} = \frac{R_t^G}{\Pi_t\cdot GA_t\cdot GN}\cdot\frac{B_{t-1}^G}{P_{t-1}A_{t-1}\bar{N}_{t-1}} - \left[\zeta_t^G + \zeta^F - \zeta_t^T\right]\left(\frac{Y_t}{A_t\bar{N}_t}\right) \tag{E.20}$$

$$(xxi).\;\; \lambda_t^{G,1} = \frac{1}{1+\sum_{l=2}^{F} a^{B,l}\exp\left(\tilde{u}_t^{B,l}\right)},\;\; \lambda_t^{G,f} = \frac{a^{B,f}\exp\left(\tilde{u}_t^{B,f}\right)}{1+\sum_{l=2}^{F} a^{B,l}\exp\left(\tilde{u}_t^{B,l}\right)},\;\; \forall f>1 \tag{E.21}$$

$$(xxiii).\;\; \tilde{u}_t^{B,f} = \sum_{j=1}^{J}\tau_{fj}^B u_t^{B,j} \tag{E.22}$$

$$(xxiv).\;\; u_t^{B,j} = \rho_B u_{t-1}^{B,j} + \varepsilon_t^{B,j} \tag{E.23}$$

$$(xxv).\;\; B_t^{G,f} = \lambda_t^{G,f}B_t^G, \qquad \forall f = 1,\ldots,F \tag{E.24}$$

$$(xxvi).\;\; GA_t = \exp(\mu + \varepsilon_t^A) \tag{E.25}$$

$$(xxvii).\;\; \zeta_t^G = \frac{1}{1+a^G\exp\left(-u_t^G\right)} \tag{E.26}$$

$$(xxviii).\;\; \zeta_t^T = \frac{1}{1+a^T\exp\left(-u_t^T\right)} \tag{E.27}$$

$$(xxix).\;\; u_t^G = \rho_G\cdot u_{t-1}^G + \varepsilon_t^G \tag{E.28}$$

$$(xxx).\;\; u_t^T = \rho_T\cdot u_{t-1}^T + \varepsilon_t^T \tag{E.29}$$

E.2 Equilibrium Equations: Yield-Curve-Control Policy (YCC)

Summary of relevant equilibrium conditions:

$$(i).\ \frac{C_t}{A_t\bar{N}_t} = \left(1-\zeta_t^G\right)\left(\frac{Y_t}{A_t\bar{N}_t}\right) + \left(\frac{1-\delta}{GA_t\cdot GN}\right)\left(\frac{K_t}{A_{t-1}\bar{N}_{t-1}}\right) - \left(\frac{K_{t+1}}{A_t\bar{N}_t}\right) \tag{E.30}$$

$$(ii).\ 1 = \beta\mathbb{E}_t\left[\frac{R^S_{t+1}}{\Pi_{t+1}\cdot GA_{t+1}\cdot GN}\frac{\left(\frac{C_t}{A_t\bar{N}_t}\right)}{\left(\frac{C_{t+1}}{A_{t+1}\bar{N}_{t+1}}\right)}\right] \tag{E.31}$$

$$(iii).\ -\left(\frac{\lambda_t^{CB,1}-\lambda_t^{G,1}}{\lambda_t^{CB,1}-\lambda_t^{HB,1}}\right)\cdot\frac{B_t^G}{A_t\bar{N}_tP_t} = \gamma_L\cdot\left(1+\zeta^F\right)\cdot\left(\frac{1-\lambda_t^K}{\lambda_t^K}\right)\left(\frac{Y_t}{A_t\bar{N}_t}\right) \tag{E.32}$$

$$(iv).\ \lambda_t^{CB,f} = \frac{\lambda_t^{HB,f}\cdot\left(1-\sum_{i\neq\{f,1\}}\lambda_t^{CB,i}-\lambda_t^{G,1}\right)-\lambda_t^{G,f}\cdot\left(1-\sum_{i\neq\{f,1\}}\lambda_t^{CB,i}-\lambda_t^{HB,1}\right)}{\left(\lambda_t^{HB,1}+\lambda_t^{HB,f}\right)-\left(\lambda_t^{G,1}+\lambda_t^{G,f}\right)}, \qquad f=2,\dots,F \tag{E.33}$$

$$(v).\ YD_t^1 = \max\left\{YD_t^{1*},1\right\} \tag{E.34}$$

$$(vi).\ YD_t^{1*} = \overline{YD}^1\cdot\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma_\pi^1}\left(\frac{Y_t}{\bar{Y}}\right)^{\gamma_y^1}\cdot\exp\left(\tilde{\varepsilon}_t^{YD^1}\right) \tag{E.35}$$

$$(vii).\ YD_t^{YCC,f} = \overline{YD}^{YCC,f}\cdot\left(\frac{YD_t^{CP,f}}{\overline{YD}^{CP,f}}\right)^{\gamma_{CP}^f}\left[\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma_\pi^f}\left(\frac{Y_t}{\bar{Y}}\right)^{\gamma_y^f}\cdot\exp\left(\tilde{\varepsilon}_t^{YD^f}\right)\right]^{1-\gamma_{CP}^f}, \quad f\geq 2 \tag{E.36}$$

$$(viii).\ \lambda_t^{HB,f} = \left(\frac{\mathbb{E}_t\left[\frac{\beta z_t^f}{\Pi_{t+1}\cdot GA_{t+1}\cdot GN}\frac{\left(\frac{C_t}{A_t\bar{N}_t}\right)}{\left(\frac{C_{t+1}}{A_{t+1}\bar{N}_{t+1}}\right)}\frac{\left(YD_{t+1}^{f-1}\right)^{-(f-1)}}{\left(YD_t^f\right)^{-f}}\right]}{\Phi_t^B}\right)^{\kappa_B}, \quad \forall f \tag{E.37}$$

$$(ix).\ \Phi_t^B = \left[\sum_{j=1}^F\mathbb{E}_t\left[\frac{\beta z_t^j}{\Pi_{t+1}\cdot GA_{t+1}\cdot GN}\frac{\left(\frac{C_t}{A_t\bar{N}_t}\right)}{\left(\frac{C_{t+1}}{A_{t+1}\bar{N}_{t+1}}\right)}\frac{\left(YD_{t+1}^{j-1}\right)^{-(j-1)}}{\left(YD_t^j\right)^{-j}}\right]^{\kappa_B}\right]^{\frac{1}{\kappa_B}} \tag{E.38}$$

$$(x).\ \lambda_t^K = \left(\frac{z_t^K\cdot\mathbb{E}_t\left[Q_{t,t+1}R_{t+1}^K\right]}{\Phi_t^S}\right)^{\kappa_S} \tag{E.39}$$

$$(xi).\ \ \Phi_t^S = \left[\left(\mathbb{E}_t\left[Q_{t,t+1}R_{t+1}^{HB}\right]\right)^{\kappa_S} + \left(z_t^K \mathbb{E}_t\left[Q_{t,t+1}R_{t+1}^{K}\right]\right)^{\kappa_S}\right]^{\frac{1}{\kappa_S}} \tag{E.40}$$

$$(xii).\ \ R_t^j = \sum_{f=0}^{F-1} \lambda_{t-1}^{j,f+1} \frac{\left(YD_t^f\right)^{-f}}{\left(YD_{t-1}^{f+1}\right)^{-(f+1)}} \qquad j \in \{HB, G, CB\} \tag{E.41}$$

$$(xiii).\ \ R_t^S = \left(1-\lambda_{t-1}^K\right) R_t^{HB} + \lambda_{t-1}^K R_t^K \tag{E.42}$$

$$(xiv).\ \ 1 = \mathbb{E}_t\left[Q_{t,t+1}\Pi_{t+1}\left[(1-\delta) + \frac{P_{t+1}^K}{P_{t+1}}\right]\right] \tag{E.43}$$

$$(xv).\ \ F_t = (1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}} \left(\frac{(1+\varsigma_F)^{-1}\epsilon}{\epsilon-1}\right) \left(\frac{C_t}{A_t\bar{N}_t}\right)^{-\alpha\left(\frac{\eta+1}{\eta+\alpha}\right)} \left(\frac{Y_t}{A_t\bar{N}_t}\right)^{\frac{\eta+1}{\eta+\alpha}} \left(\frac{P_t^K}{P_t}\right)^{\alpha\left(\frac{\eta+1}{\eta+\alpha}\right)} + \theta\beta\mathbb{E}_t\left[\Pi_{t+1}^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)} F_{t+1}\right] \tag{E.44}$$

$$(xvi).\ \ H_t = \left(\frac{C_t}{A_t\bar{N}_t}\right)^{-1} \frac{Y_t}{A_t\bar{N}_t}\left[1-\gamma_L\cdot\left(\widetilde{R}_{t+1}^K - 1\right)\right] + \theta\beta\mathbb{E}_t\left[\Pi_{t+1}^{\epsilon-1}H_{t+1}\right] \tag{E.45}$$

$$(xvii).\ \ \frac{F_t}{H_t} = \left(\frac{1-\theta}{1-\theta\Pi_t^{\epsilon-1}}\right)^{\left(\frac{1}{\epsilon-1}\right)\left[1+\epsilon\left(\frac{1-\alpha}{\eta+\alpha}\right)\right]} \tag{E.46}$$

$$(xviii).\ \ \Delta_t = (1-\theta)\left(\frac{1-\theta\Pi_t^{\epsilon-1}}{1-\theta}\right)^{\left(\frac{\epsilon}{\epsilon-1}\right)\left(\frac{\eta+1}{\eta+\alpha}\right)} + \theta\Pi_t^{\epsilon\left(\frac{\eta+1}{\eta+\alpha}\right)}\Delta_{t-1} \tag{E.47}$$

$$(xix).\ \ \frac{N_t}{\bar{N}_t} = (1-\alpha)^{\left(\frac{\eta}{\eta+\alpha}\right)} \left(\frac{C_t}{A_t\bar{N}_t}\right)^{-\alpha\left(\frac{\eta}{\eta+\alpha}\right)} \left(\frac{Y_t}{A_t\bar{N}_t}\right)^{\left(\frac{\eta}{\eta+\alpha}\right)} \left(\frac{P_t^K}{P_t}\right)^{\alpha\left(\frac{\eta}{\eta+\alpha}\right)} \Delta_t^{\frac{\eta}{\eta+1}} \tag{E.48}$$

$$(xx).\ \ \frac{K_t}{A_{t-1}\bar{N}_{t-1}} = \alpha(1-\alpha)^{\frac{1-\alpha}{\eta+\alpha}}\cdot GA_t\cdot GN\cdot\left(\frac{C_t}{A_t\bar{N}_t}\right)^{\frac{\eta(1-\alpha)}{\eta+\alpha}} \left(\frac{Y_t}{A_t\bar{N}_t}\right)^{\frac{\eta+1}{\eta+\alpha}} \left(\frac{P_t^K}{P_t}\right)^{-\left(\frac{\eta(1-\alpha)}{\eta+\alpha}\right)} \Delta_t \tag{E.49}$$

$$(xxi).\ \ \frac{B_t^G}{P_tA_t\bar{N}_t} = \frac{R_t^G}{\Pi_t\cdot GA_t\cdot GN}\frac{B_{t-1}^G}{P_{t-1}A_{t-1}\bar{N}_{t-1}} - \left[\zeta_t^G + \zeta^F - \zeta_t^T\right]\left(\frac{Y_t}{A_t\bar{N}_t}\right) \tag{E.50}$$

$$(xxii).\ \ \tilde{\varepsilon}_t^{YD,f} = \sum_{l=1}^{L}\tau_{fl}^{YD}\varepsilon_t^{YD,l} \tag{E.51}$$

E.3 Summary of Conventional Policy Linearized Equations

Those are the essential equations to solve the model, other variables can be found on the equations above.

$$(i).\ \ \hat{y}_t = \mathbb{E}_t\Big[\hat{y}_{t+1} + \Psi^{46}\cdot\hat{\pi}_{t+1} - \Psi^{47}\cdot\overrightarrow{\hat{z}}_t - \Psi^{48}\cdot\hat{z}^K_t - \Psi^{49}\cdot\overrightarrow{\hat{yd}_t} - \Psi^{50}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right]$$
$$- \Psi^{51}\cdot\hat{r}^K_{t+1} - \Psi^{52}\cdot(\hat{k}_t - \hat{\varepsilon}^A_t) + \Psi^{53}\cdot\hat{k}_{t+1} - \Psi^{54}\cdot\hat{k}_{t+2} + \Psi^{55}\cdot\hat{u}^G_t\Big]$$

$$(ii).\ \ \overrightarrow{\hat{yd}_t} = \Theta^{14}\cdot\hat{b}^G_t - \Theta^{15}\cdot\hat{y}_t + \Theta^{16}\cdot\hat{r}^K_{t+1} - \Theta^{17}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right] - \Theta^{18}\cdot\overrightarrow{\hat{z}_t} + \Theta^{19}\cdot\hat{z}^K_t + \Theta^{20}\cdot\overrightarrow{\hat{u}^B_t}$$

$$(iii).\ \ \hat{yd}^1_t = \max\left\{\hat{yd}^{1*}_t, 0\right\}$$

$$(iv).\ \ \hat{yd}^{1*}_t = \gamma_\pi\hat{\pi}_t + \gamma_y\hat{y}_t + \tilde{\varepsilon}^{YD^1}_t,\ \ \tilde{\varepsilon}^{YD^f}_t = \sum_{l=1}^{L}\tau^{YD}_{f,l}\varepsilon^{YD^l}_t$$

$$(v).\ \ \hat{r}^K_{t+1} = -\Psi^{37}\cdot\overrightarrow{\hat{z}_t} - \Psi^{38}\cdot\hat{z}^K_t - \Psi^{39}\cdot\overrightarrow{\hat{yd}_t} - \Psi^{40}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right] + \Psi^{41}\cdot\mathbb{E}_t\left[\hat{\pi}_{t+1}\right] + \Psi^{42}\cdot\mathbb{E}_t\left[\hat{y}_{t+1}\right]$$
$$+ \Psi^{43}\cdot\hat{k}_{t+1} - \Psi^{44}\cdot\mathbb{E}_t\left[\hat{k}_{t+2}\right] - \Psi^{45}\cdot\hat{u}^G_t$$

$$(vi).\ \ \hat{b}^G_t = \frac{R^G}{\Pi\cdot GA\cdot GN}\cdot\left[\Psi^{G,4}\Xi\overrightarrow{\hat{u}^B_{t-1}} - \Psi^{G,5}\overrightarrow{\hat{yd}_t} + \Psi^{G,6}\overrightarrow{\hat{yd}_{t-1}} - \hat{\pi}_t - \hat{\varepsilon}^A_t + \hat{b}^G_{t-1}\right]$$
$$+\left(1 - \frac{R^G}{\Pi\cdot GA\cdot GN}\right)\left[\hat{y}_t + \left(\frac{\zeta^G}{\zeta^G + \zeta^F - \zeta^T}\right)\frac{a^G}{1+a^G}\hat{u}^G_t - \left(\frac{\zeta^T}{\zeta^G + \zeta^F - \zeta^T}\right)\frac{a^T}{1+a^T}\hat{u}^T_t\right]$$

$$(vii).\ \ \hat{f}_t = -\Psi^{16}\cdot\overrightarrow{\hat{z}_t} - \Psi^{17}\cdot\hat{z}^K_t - \Psi^{18}\cdot\left[\hat{k}_t - \hat{\varepsilon}^A_t\right] + \Psi^{19}\cdot\hat{y}_t - \Psi^{20}\cdot\overrightarrow{\hat{yd}_t} - \Psi^{21}\cdot\hat{r}^K_{t+1} - \Psi^{22}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right]$$
$$+ \Psi^{23}\cdot\mathbb{E}_t\left[\hat{\pi}_{t+1}\right] + \Psi^{24}\cdot\mathbb{E}_t\left[\hat{f}_{t+1}\right]$$

$$(viii).\ \ \hat{h}_t = \Psi^{26}\cdot\overrightarrow{\hat{z}_t} + \Psi^{27}\cdot\hat{z}^K_t - \Psi^{28}\cdot\left[\hat{k}_t - \hat{\varepsilon}^A_t\right] + \Psi^{29}\cdot\hat{u}^G_t + \Psi^{30}\cdot\hat{y}_t + \Psi^{31}\cdot\overrightarrow{\hat{yd}_t} - \Psi^{32}\cdot\hat{r}^K_{t+1}$$
$$+ \Psi^{33}\cdot\hat{k}_{t+1} + \Psi^{34}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right] + \Psi^{35}\cdot\mathbb{E}_t\left[\hat{\pi}_{t+1}\right] + \Psi^{36}\cdot\mathbb{E}_t\left[\hat{h}_{t+1}\right]$$

$$(ix).\ \ \hat{f}_t - \hat{h}_t = \left[1 + \epsilon\left(\frac{1-\alpha}{\eta+\alpha}\right)\right]\left(\frac{\theta\Pi^{\epsilon-1}}{1-\theta\Pi^{\epsilon-1}}\right)\hat{\pi}_t$$

$$(x).\ \ u^{B,j}_t = \rho_B\cdot u^{B,j}_{t-1} + \varepsilon^{B,j}_t,\qquad \forall\ j = 1,\ldots,J$$

$$(xi).\ \ u^G_t = \rho_G\cdot u^G_{t-1} + \varepsilon^G_t$$

$$(xii).\ \ u^T_t = \rho_T\cdot u^G_{t-1} + \varepsilon^T_t$$

E.4 Summary of Yield-Curve Control Policy Linearized Equations

Those are the essential equation to solve the model, other variables can be found on equations above.

$$
\begin{aligned}
(i).\ \ \hat{y}_t = \mathbb{E}_t\Big[&\hat{y}_{t+1} + \Psi^{46}\cdot\hat{\pi}_{t+1} - \Psi^{47}\cdot\overrightarrow{\hat{z}}_t - \Psi^{48}\cdot\hat{z}^K_t - \Psi^{49}\cdot\overrightarrow{\hat{yd}^{YCC}_t} - \Psi^{50}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}^{YCC}_{t+1}}\right]\\
&- \Psi^{51}\cdot\hat{r}^K_{t+1} - \Psi^{52}\cdot(\hat{k}_t - \hat{\varepsilon}^A_t) + \Psi^{53}\cdot\hat{k}_{t+1} - \Psi^{54}\cdot\hat{k}_{t+2} + \Psi^{55}\cdot\hat{u}^G_t\Big]
\end{aligned}
$$

$$
(ii).\ \ \overrightarrow{\hat{yd}^{CP}_t} = \Theta^{14}\cdot\hat{b}^G_t - \Theta^{15}\cdot\hat{y}_t + \Theta^{16}\cdot\hat{r}^K_{t+1} - \Theta^{17}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}^{YCC}_{t+1}}\right] - \Theta^{18}\cdot\overrightarrow{\hat{z}_t} + \Theta^{19}\cdot\hat{z}^K_t + \Theta^{20}\cdot\overrightarrow{\hat{u}^B_t}
$$

$$
(iii).\ \ \hat{yd}^{YCC,1}_t = \max\left\{\hat{yd}^{1*}_t, 0\right\} = \hat{yd}^{CP,1}_t
$$

$$
(iv).\ \ \hat{yd}^{1*}_t = \gamma_\pi\hat{\pi}_t + \gamma_y\hat{y}_t + \tilde{\varepsilon}^{YD^1}_t,\ \ \tilde{\varepsilon}^{YD^1}_t = \sum_{l=1}^{L}\tau^{YD}_{1,l}\varepsilon^{YD^l}_t,
$$

$$
(v).\ \ \hat{yd}^{YCC,f}_t = \gamma^f_{CP}\hat{yd}^{CP,f}_t + \left(1-\gamma^f_{CP}\right)\left[\gamma^f_\pi\hat{\pi}_t + \gamma^f_y\hat{y}_t + \tilde{\varepsilon}^{YD^f}_t\right],\ \ \tilde{\varepsilon}^{YD^f}_t = \sum_{l=1}^{L}\tau^{YD}_{f,l}\varepsilon^{YD^l}_t, \quad f\geq 2
$$

$$
\begin{aligned}
(vi).\ \ \hat{r}^K_{t+1} =& - \Psi^{37}\cdot\overrightarrow{\hat{z}_t} - \Psi^{38}\cdot\hat{z}^K_t - \Psi^{39}\cdot\overrightarrow{\hat{yd}_t} - \Psi^{40}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right] + \Psi^{41}\cdot\mathbb{E}_t\left[\hat{\pi}_{t+1}\right] + \Psi^{42}\cdot\mathbb{E}_t\left[\hat{y}_{t+1}\right]\\
&+ \Psi^{43}\cdot\hat{k}_{t+1} - \Psi^{44}\cdot\mathbb{E}_t\left[\hat{k}_{t+2}\right] - \Psi^{45}\cdot\hat{u}^G_t
\end{aligned}
$$

$$
\begin{aligned}
(vii).\ \ \hat{b}^G_t =& \frac{R^G}{\Pi\cdot GA\cdot GN}\cdot\left[\Psi^{G,4}\Xi\overrightarrow{\hat{u}^B_{t-1}} - \Psi^{G,5}\overrightarrow{\hat{yd}^{YCC}_t} + \Psi^{G,6}\overrightarrow{\hat{yd}^{YCC}_{t-1}} - \hat{\pi}_t - \hat{\varepsilon}^A_t + \hat{b}^G_{t-1}\right]\\
&+ \left(1-\frac{R^G}{\Pi\cdot GA\cdot GN}\right)\left[\hat{y}_t + \left(\frac{\zeta^G}{\zeta^G+\zeta^F-\zeta^T}\right)\frac{a^G}{1+a^G}\hat{u}^G_t - \left(\frac{\zeta^T}{\zeta^G+\zeta^F-\zeta^T}\right)\frac{a^T}{1+a^T}\hat{u}^T_t\right]
\end{aligned}
$$

$$
\begin{aligned}
(viii).\ \ \hat{f}_t =& - \Psi^{16}\cdot\overrightarrow{\hat{z}_t} - \Psi^{17}\cdot\hat{z}^K_t - \Psi^{18}\cdot\left[\hat{k}_t - \hat{\varepsilon}^A_t\right] + \Psi^{19}\cdot\hat{y}_t - \Psi^{20}\cdot\overrightarrow{\hat{yd}_t} - \Psi^{21}\cdot\hat{r}^K_{t+1} - \Psi^{22}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right]\\
&+ \Psi^{23}\cdot\mathbb{E}_t\left[\hat{\pi}_{t+1}\right] + \Psi^{24}\cdot\mathbb{E}_t\left[\hat{f}_{t+1}\right]
\end{aligned}
$$

$$
\begin{aligned}
(ix).\ \ \hat{h}_t =& \Psi^{26}\cdot\overrightarrow{\hat{z}_t} + \Psi^{27}\cdot\hat{z}^K_t - \Psi^{28}\cdot\left[\hat{k}_t - \hat{\varepsilon}^A_t\right] + \Psi^{29}\cdot\hat{u}^G_t + \Psi^{30}\cdot\hat{y}_t + \Psi^{31}\cdot\overrightarrow{\hat{yd}_t} - \Psi^{32}\cdot\hat{r}^K_{t+1} + \Psi^{33}\cdot\hat{k}_{t+1}\\
&+ \Psi^{34}\cdot\mathbb{E}_t\left[\overrightarrow{\hat{yd}_{t+1}}\right] + \Psi^{35}\cdot\mathbb{E}_t\left[\hat{\pi}_{t+1}\right] + \Psi^{36}\cdot\mathbb{E}_t\left[\hat{h}_{t+1}\right]
\end{aligned}
$$

$$
(x).\ \ \hat{f}_t - \hat{h}_t = \left[1+\epsilon\left(\frac{1-\alpha}{\eta+\alpha}\right)\right]\left(\frac{\theta\Pi^{\epsilon-1}}{1-\theta\Pi^{\epsilon-1}}\right)\hat{\pi}_t
$$

$$
(xi).\ \ u^{B,j}_t = \rho_B\cdot u^{B,j}_{t-1} + \varepsilon^{B,j}_t, \qquad \forall\, j = 1,\dots,J
$$

$$
(xii).\ \ u^G_t = \rho_G\cdot u^G_{t-1} + \varepsilon^G_t
$$

$$
(xiii).\ \ u^T_t = \rho_T\cdot u^G_{t-1} + \varepsilon^T_t
$$

F Additional Results: Steady-State Comparative Statics

Comparative statics with κ_B Figure F.2 demonstrates the behavior of the steady-state yield curve as κ_B increases, as explained in Section 2.1.1. With $R^K > R^{HB}$ at the steady state and low levels of z^f for high f in Figure II.1, an increase in κ_B lowers the household's demand for long-term bonds (as markets are more competitive with higher κ_B), pushing up long-term yields. When $\kappa_B \to \infty$, we revert to the expectations hypothesis case, resulting in a flat yield curve in the steady-state.

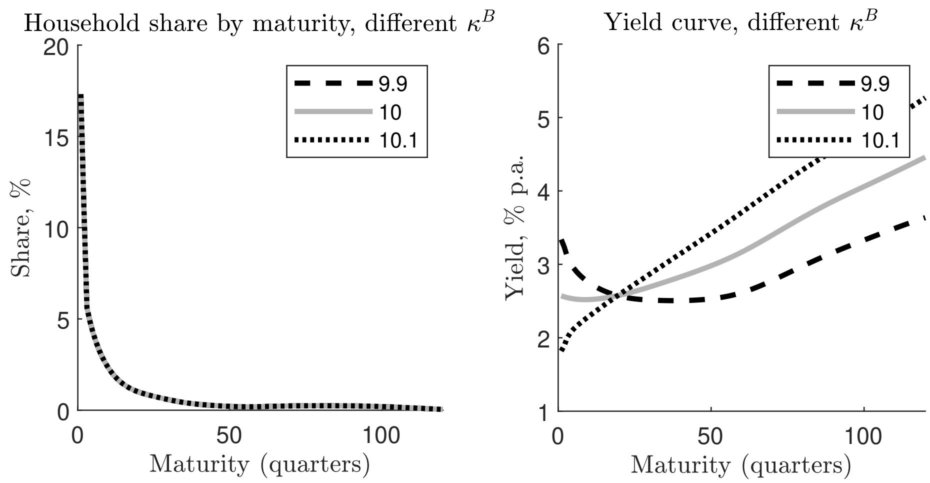


Figure F.2: Variations in κ_B (i.e., scale parameter): as $\kappa_B \to \infty$, the model converges to the expectation hypothesis, wherein all discounted expected returns become equalized. With current $R^K > R^{HB}$ at the steady state and low levels of z^f for high f in Figure II.1, higher κ_B lowers the household's demand for long-term bonds, pushing up their yields.

Comparative statics with z^K Figure F.3 illustrate comparative statics with respect to the scale parameter z^K, which is incorporated into the savings allocation between the Treasury and loan markets (i.e., (5)). Given the calibrated $\{z^f\}_{f=1}^F$ and for $z^K \in [0.8, 1.3]$, a higher z^K suggests that the household is more inclined to provide loans to firms rather than invest in the bond market, raising λ^K. This leads to higher capital, output, and consumption in the steady-state allocation. As households increase their loan investment, the average marginal propensity to consume and the equilibrium loan rate R^K decline, causing the entire yield curve to shift downward due to the household's endogenous portfolio reallocation —paradoxically raising credit spreads. Falling R^G lowers the government bond share with respect to GDP.

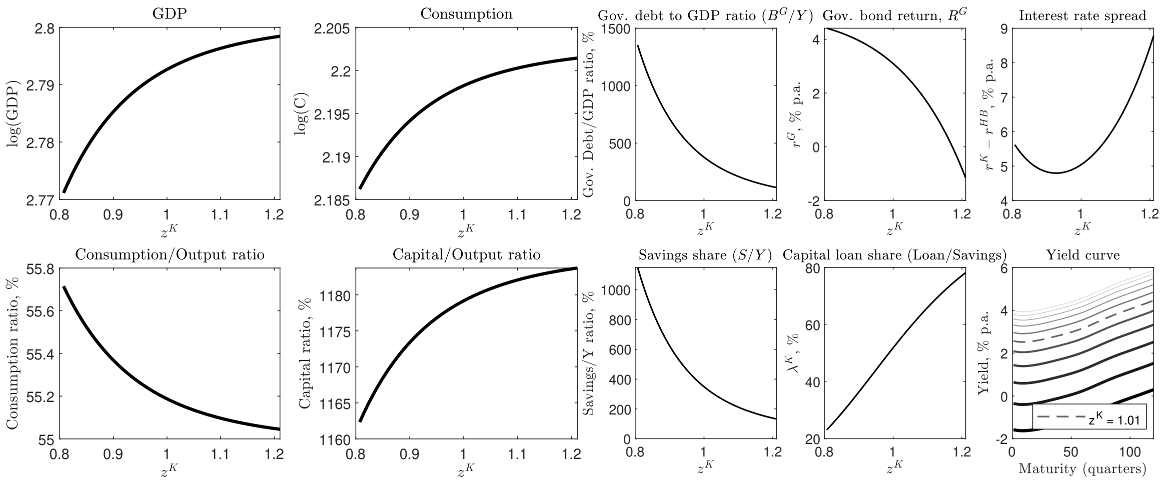


Figure F.3: Variations in z^K

Comparative statics with κ_S Figure F.4 depicts comparative statics of the shape parameter κ_S, which appears in the same savings allocation condition between bond and loan markets (i.e., equation (5)). Given the calibrated $\{z^f\}_{f=1}^F$ and z^K values, and for $\kappa_S \in [0, 25]$, a higher κ_S raises λ^K, as $R^K > R^{HB}$ at the steady state and higher κ_S implies that the market is more competitive. This results in a lower loan rate R^K, higher capital demand (as firms face lower interest costs), increased output and consumption while reducing the average marginal propensity to consume. Credit spreads widen, with a lower R^K depressing the government's effective bond return R^G and the entire yield curve even more. Consequently, the government's debt-to-GDP ratio falls.

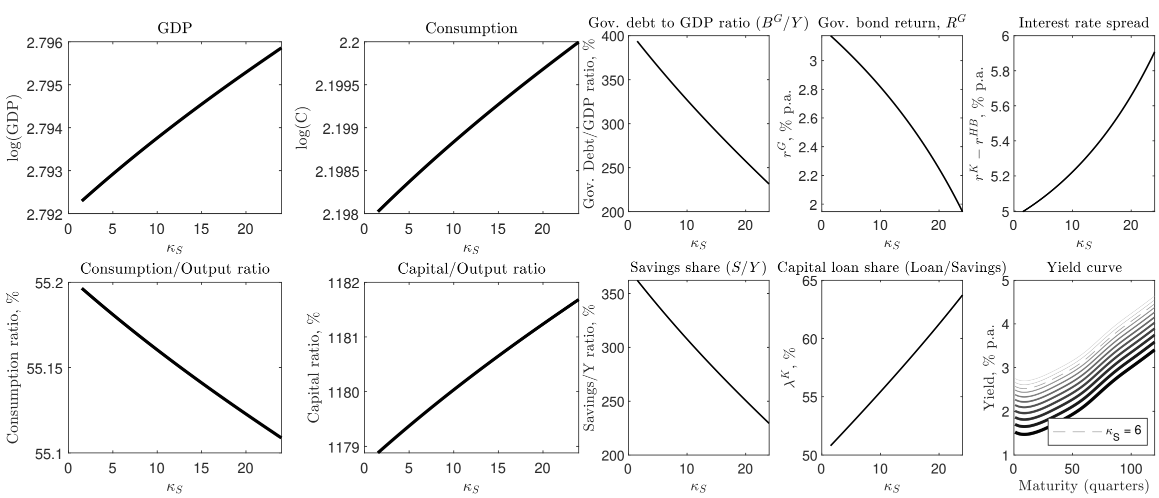


Figure F.4: Variations in κ^S

G Additional Results: Impulse-Responses

G.1 Without ZLB

Technology shock, ε_t^A: Figure G.5 displays the impulse-responses to a ε_t^A shock. A positive shock in technology growth GA_t yields similar effects as documented in prior literature under conventional policy,[13] with output increasing[14] as inflation decreases. Under the yield-curve-control regime, the normalized output decreases less: since inflation falls, bond yields shift downwards, boosting consumption and reducing both the return on capital and the wage.

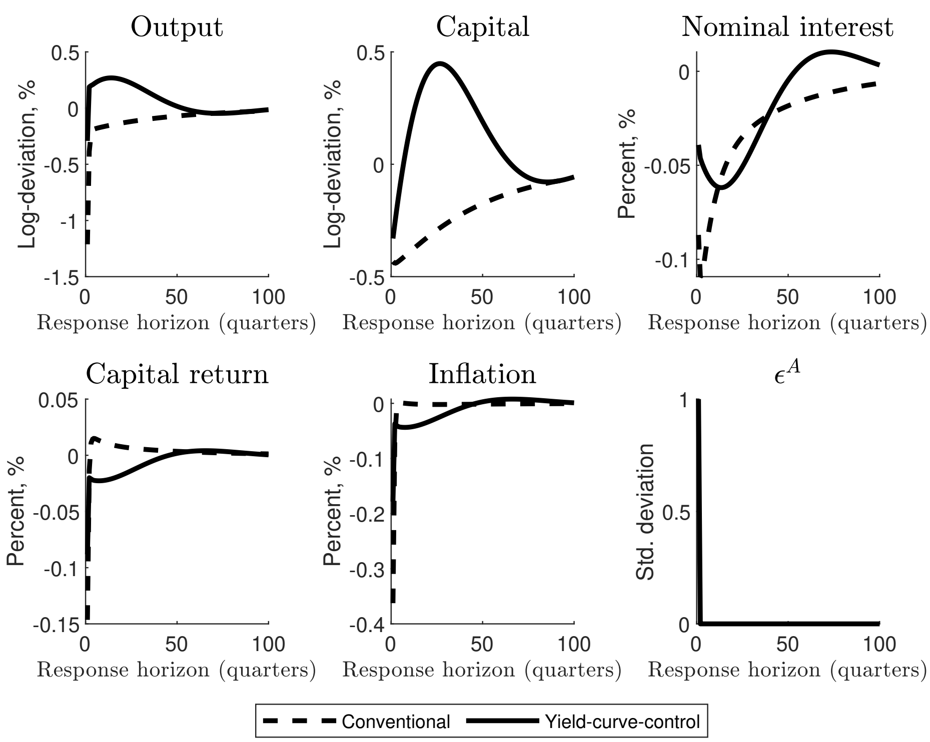


Figure G.5: Impulse response to a ε_t^A shock: A positive technology growth shock generates effects in line with the existing literature, resulting in an increase in output and a decline in inflation. As inflation decreases, all yields undergo a downward shift, which in turn lowers both the capital return and wage relative to the conventional scenario.

[13] For effects of technology shocks in a canonical New-Keynesian model, see Ireland (2004).

[14] Even if the 'normalized' output drops under our calibration, the output level rises.

Monetary policy shock, $\varepsilon_t^{YD^1}$: Figure G.6 presents the impulse-response to a $\varepsilon_t^{YD^1}$ shock. Under the conventional policy, a contractionary monetary policy shock paradoxically results in an increase in output, inflation, and capital. One potential channel is from increases in the household's interest incomes from higher rates on both bonds and loans. The yield-curve-control policy insulates the economy as before: in response to the shock, the central bank pushes down the entire yield curve, preventing input prices (i.e., loan rates and wages) from rising too high, and thereby mitigating changes in output and inflation.

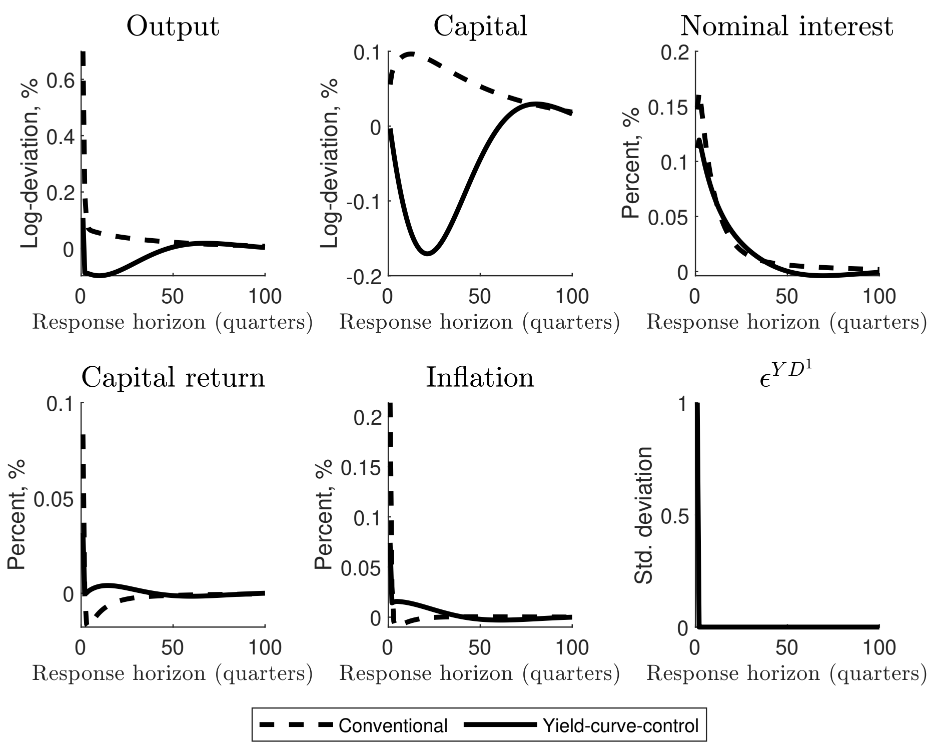


Figure G.6: Impulse response to a $\varepsilon_t^{YD^1}$ shock: A conventional contractionary monetary policy shock paradoxically leads to increases in output, inflation, and capital due to higher amounts of interest incomes that households earn from bonds and loans. The yield-curve-control policy insulates the economy against the shock through the central bank's purchases of long-term bonds.

G.2 With ZLB

With mixed policy, z_t^K: In Figure G.7, the mixed policy actually features the longest ZLB spell.

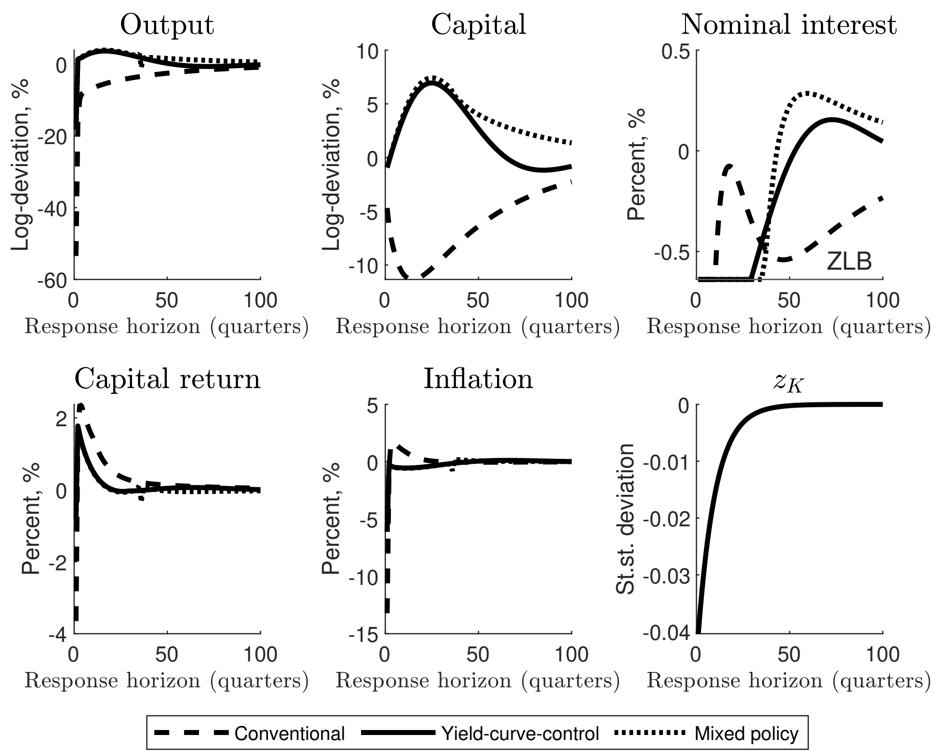
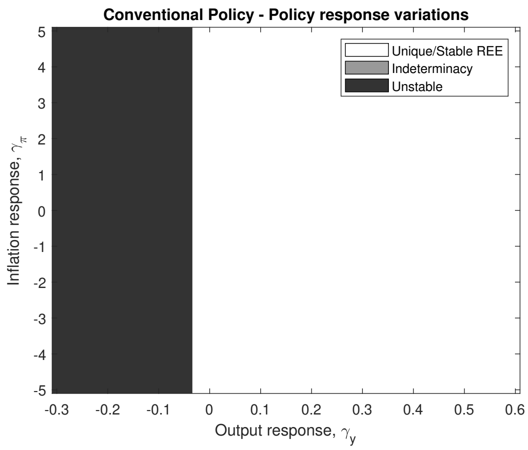


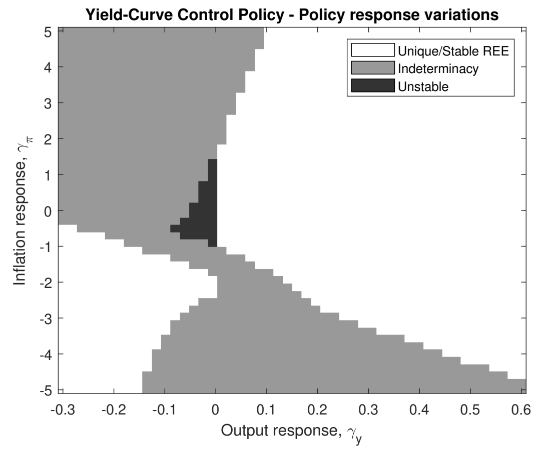
Figure G.7: Impulse-response to z^K shock with ZLB and mixed policy

H Additional Results: Model Determinacy

Under the conventional policy (23) and the yield-curve control policy (24), we derive conditions for model determinacy in terms of the Taylor coefficients—(γ_π, γ_y) for the conventional policy and $(\{\gamma_\pi^f\}_{f=1}^F, \{\gamma_y^f\}_{f=1}^F)$ for the yield-curve control policy. For illustration, we assume that $\gamma_\pi^f = \gamma_\pi$ and $\gamma_y^f = \gamma_y$ for all $f = 1, \ldots, F$.



(a) Conventional Policy



(b) Yield-Curve Control

Figure H.8: Determinacy Regions

Figures H.8a and H.8b show the determinacy regions in the (γ_π, γ_y) plane for the conventional and yield-curve control policies, respectively. Under the conventional policy, determinacy requires that the output responsiveness coefficient γ_y exceeds a specific negative threshold, largely independent of the inflation responsiveness γ_π. In contrast, the yield-curve control policy's determinacy depends on both coefficients. Notably, even when both coefficients are negative, the model can yield a unique, stable equilibrium under certain calibrations. These findings differ from those of the traditional New Keynesian model, which typically requires an aggressive inflation-targeting response (or a combination of responses to inflation and output) to ensure a unique and stable equilibrium. This difference arises from the portfolio rebalancing channel on the households' side and the input substitution channel on the firms' side: with a negative γ_π, a negative inflation shock leads the central bank to raise the entire yield curve, prompting households to reallocate funds toward bonds and increasing the loan rate R^K, which in turn incentivizes firms to raise prices and stabilize inflation.

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