Targeting Long Rates in a Model with Financial Frictions and Regime Switching*

Very Preliminary Draft

November 27, 2017

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Abstract

Increases in long term rates caused by raises of term premiums could be financially contractive and might require monetary policy stimulus. This paper uses measures of the term-premium calculated by Adrian et al. (2013) to perform Bayesian maximum likelihood estimation of a Markov-switching version of the macroeconomic model with financial frictions in long-term debt instruments developed by Carlstrom et al. (2017) to: (i) study how financial conditions have evolved in the U.S. since 1962, (ii) measure how the Federal Reserve Bank has responded to the evolution of term premiums and (iii) to perform counterfactual analysis of the potential evolution of macroeconomic and financial variables under alternative financial conditions and monetary policy responses. To be completed...

JEL: E12, E43, E44, E52, E58, C11

Keywords: Monetary policy, Term-structure, Market segmentation, Markov-switching DSGE, Bayesian Maximum Likelihood methods.

*The authors thank Junior Maih for making his RISE toolbox for the solution and estimation of Markov Switching Rational Expectations models available (https://github.com/jmaih/RISE_toolbox) and for patiently answering all of our questions. The views expressed in this presentation are those of the author, and not necessarily those of CEMLA or EGADE Business School of Tecnológico de Monterrey.

1 Introduction

"*To the extent that the decline in forward rates can be traced to a decline in the term premium, ..., the effect is financially stimulative and argues for greater monetary policy restraint, all else being equal. Specifically, if spending depends on long-term interest rates, special factors that lower the spread between short-term and long-term rates will stimulate aggregate demand. Thus, when the term premium declines, a higher short-term rate is required to obtain the long-term rate and the overall mix of financial conditions consistent with maximum sustainable employment and stable prices.*"

- FRB Chairman Ben S. Bernanke, March 20, 2006, "Reflections on the Yield Curve and Monetary Policy."

The above quote states that yields on long-term debt and specially the term premium, which is the extra compensation required by investors for bearing interest rate risk associated with short-term yields not evolving as expected, are an important determinant of aggregate demand.[1] It also underlies that the monetary authority should respond to term premium movements to stabilize the effects that the financial sector could have in the macroeconomy. However, this task is complicated by the fact that the term premium is not observed and because the mechanisms through which developments in long-term debt instruments affect the macroeconomy are not completely understood.

This paper uses measures of the term-premium calculated by Adrian et al. (2013) into the macroeconomic model with financial frictions in long-term debt instruments developed in Carlstrom et al. (2017) to: (i) study how financial conditions have evolved in the U.S. since 1962, (ii) measure how the Federal Reserve Bank has responded to the evolution of term premiums and (iii) to perform counterfactual analysis of the potential evolution of macroeconomic and financial variables under alternative financial conditions and monetary policy responses.

The Bayesian Maximum Likelihood estimation of the Markov Switching version of Carlstrom et al. (2017) shows that financial frictions, measured by the financial intermediaries portfolio adjustment costs to their net worth, had high probability of being high in the following four intervals: 1975q1 – 1976q4, 1980q3 – 1986q4, 2000q1 – 2003q1 and 2008q4 – 2010q2. Meanwhile, the estimation identifies the following as periods of high probability of high interest rate response to the term premium: 1980q4 – 1986q1, 1987q3 – 1989q2, 1990q3 – 1991q1, 1992q1 – 1993q2, 2001q3 – 2003q4, 2008q1 – 2011q4, 2013q1 – 2013q3. The counterfactual exercises allows to separately analyze the effects of financial conditions and monetary policy responses in the evolution of macroeconomic and financial variables.

The rest of the paper is organized as follows. Section 2 presents a model of segmented financial markets where financial institutions net worth limits the degree of arbitrage across the term structure (a financial friction), a "loan-in-advance" constraint increases the private cost of purchasing investment goods (creating real effects of the financial frictions), and an augmented monetary policy with response to the term premium. Section 3 discusses the solution and estimation techniques. Section 4 presents the results showing first the parameter estimates, then the regime probabilities together with a selected historical account of the developments in the US financial system and its monetary policy in the 1962 – 2017 period, the impulse response functions under different assumptions of financial frictions and monetary policy, and finally counterfactual exercises to analyze the role of financial frictions and monetary policy. Section 5 presents our conclusions.

[1] Rudebusch et al. (2006) show that a decline in the term premium has typically been associated with higher future GDP growth.

2 The Model

As the main objective is to explore the evolution of credit market imperfections and policy responses within the Carlstrom et al. (2017) model, this section follows exactly the description in that model. The economy consists of households, financial intermediaries (FIs), and firms. Many of the ingredients are standard with the chief novelty coming from their assumptions on household-FI interactions. We modify their model by allowing by a Markov-switching DSGE and allow for changes in financial frictions, monetary policy response to the term premium and stochastic volatility. Potential regime changes in financial frictions are captured by changes in the parameter associated to FIs' portfolio adjustment costs,ψ_n, where we use a state variable $\xi_t^{\psi_n}$ to distinguish the level of financial friction regime at time t. Meanwhile regime changes in the monetary policy's response to the term premium, where we use a state variable $\xi_t^{tp}$to differentiate among elasticities of short term interest rates to the term premium tp regime at time t. Concurrently, to allow for regime changes in the stochastic volatilities we model a third independent Markov-Switching process and use a state variable ξ_t^{vo} to distinguish the volatility vo regime at time t.

2.1 Households

Each household maximizes the utility function

$$E_0 \sum_{s=0}^{\infty} \beta^s e^{rn_{t+s}} \left\{ ln(C_{t+s} - hC_{t+s-1}) - B\frac{H_{t+s}^{1+\eta}(j)}{1+\eta} \right\} \tag{2.1}$$

where C_t is consumption, h is the degree of habit formation, $H_t(j)$ is the labor input of household j, and e^{rn} is shock to the discount factor. This intertemporal preferences shock follows the stochastic process

$$rn_t = \rho_{rn} rn_{t-1} + \sigma_{rn,\xi_t^{vo}} \varepsilon_{rn,t} \tag{2.2}$$

where $\sigma_{rn,\xi_t^{vo}}$ is the standard deviation of the stochastic volatility of the intertemporal preferences $\varepsilon_{rn,t}$ ~ i.i.d. N(0, σ_{rn}^2), whose ξ_t^{vo} subscript denotes that it is allowed to change across regimes at time-t. We follow the same convention in the notation for each shock. Each household is a monopolistic supplier of specialized labor, $H_t(j)$, as in Erceg et al. (2000). A large number of competitive employment agencies combine this specialized labor into a homogeneous labor input sold to intermediate firms, according to

$$H_t = \left[\int_0^1 H_t(j)^{1/(1+\lambda_{w,t})} dj \right]^{1+\lambda w,t} \tag{2.3}$$

The desired markup of wages over the household's marginal rate of substitution, $\lambda_{w,t}$, follows the exogenous stochastic process of the desired markup of wages over the household's marginal rate of substitution

$$log\lambda_{w,t} = (1-\rho_w) log\lambda_w + \rho_w log\lambda_{w,t-1} + \sigma_{w,\xi_t^{vo}} \varepsilon_{w,t} - \theta_w \sigma_{w,\xi_t^{vo}} \varepsilon_{w,t-1} \tag{2.4}$$

with $\varepsilon_{w,t}$ *i.i.d.* N(0,σ_w^2). This is the wage markup shock. Profit maximization by the perfectly competitive employment agencies implies that the real wage (W_t) paid by intermediate firms for their homogeneous labor input is

$$W_t = \left[\int_0^1 W_t(j)^{-1/\lambda_{w,t}} dj \right]^{-\lambda_{w,t}} \tag{2.5}$$

Every period a fraction θ_w^s of households cannot freely alter their nominal wage, so their wage follow the indexation rule.

$$W_t(j) = \frac{\Pi_{t-1}^{\iota_w}}{\Pi_t} W_{t-1}(j) \tag{2.6}$$

The remaining fraction of households chooses instead an optimal real wage $W_t(j)$ by maximizing

$$E_t \left\{ \sum_{s=0}^{\infty} \theta_w^s \beta^s \left[-e^{rn_{t+s}} B \left[\frac{H_{t+s}(j)^{1+\psi}}{1+\psi} \right] + \Lambda_{t+s} W_t(j) H_{t+s}(j) \right] \right\} \tag{2.7}$$

subject to the labor demand function coming from the employment agencies, and where Λ_{t+s} is the household's marginal utility of consumption. The existence of state-contingent securities ensures that household consumption (and thus Λ_{t+s}) is the same across all households. The household also earns income by renting capital to the intermediate goods firm.

The household has two means of intertemporal smoothing: short-term deposits (D_t) in the FI and accumulation of physical capital (K_t). Households also have access to the market in short-term government bonds ("T- bills"). But since T-bills are perfect substitutes with deposits, and the supply of T- bills moves endogenously to hit the central bank's short- term interest rate target, we treat D_t as the household's net resource flow into the FIs. To introduce a need for intermediation, we assume that all investment purchases must be financed by issuing new "investment bonds" that are ultimately purchased by the FI. We find it convenient to use the perpetual bonds suggested by Woodford (2001). In particular, these bonds are perpetuities with cash flows of 1, κ, κ^2, etc. Let Q_t denote the time-t price of a new issue. Given the time pattern of the perpetuity payment, the new issue price Q_t summarizes the prices at all maturities, e.g., κQ_t is the time-t price of the perpetuity issued in period $t-1$. The duration and (gross) yield to maturity on these bonds are defined as: duration $=(1-\kappa)^{-1}$, gross yield to maturity $= Q_t^{-1} + \kappa$. Let CI_t denote the number of new perpetuities issued in time-t to finance investment. In time-t, the household's nominal liability on past issues is given by

$$F_{t-1} = CI_{t-1} + \kappa CI_{t-2} + \kappa^2 CI_{t-3} + \cdots . \tag{2.8}$$

We can use this recursion to write the new issue as

$$CI_t = (F_t - \kappa F_{t-1}) \tag{2.9}$$

The representative's households constraints are thus given by

$$C_t + \frac{D_t}{P_t} + P_t^k I_t + \frac{F_{t-1}}{P_t} \leq W_t H_t + R_t^k K_t - T_t + \frac{D_{t-1}}{P_t} R_{t-1} + \frac{Q_t(F_t - \kappa F_{t-1})}{P_t} + div_t; \tag{2.10}$$

$$K_{t+1} \leq (1-\delta) K_t + I_t; \tag{2.11}$$

$$P_t^k I_t \leq \frac{Q_t(F_t - \kappa F_{t-1})}{P_t} = \frac{Q_t C I_t}{P_t}, \tag{2.12}$$

where P_t is the price level; P_t^k is the real price of capital; R_{t-1} is the gross nominal interest rate on deposits; R_t^k is the real rental rate; T_t are lump-sum taxes; and div_t denotes the dividend flow from the FIs. The household also receives a profit flow from the intermediate goods producers and the new capital producers, but this is entirely standard so we dispense from this added notation for simplicity. The "loan-in-advance" constraint (2.12) will increase the private cost of purchasing investment goods. Although for simplicity we place capital accumulation within the household problem, this model formulation is isomorphic to an environment in which household-owned firms accumulate capital subject to the loan constraint. The first order conditions to the household problem include:

$$\Lambda_t = E_t \beta \Lambda_{t+1} \frac{R_t}{\Pi_{t+1}}; \tag{2.13}$$

$$\Lambda_t P_t^k M_t = E_t \beta \Lambda_{t+1} \left[R_t^k + (1-\delta) P_{t+1}^k M_{t+1} \right]; \tag{2.14}$$

$$\Lambda_t Q_t M_t = E_t \beta \Lambda_{t+1} \frac{[1 + \kappa Q_{t+1} M_{t+1}]}{\Pi_{t+1}} \tag{2.15}$$

where $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ is gross inflation. Expression (2.13) is the familiar Fisher equation. The capital accumulation expression (2.14) is distorted relative to the familiar by the time- varying distortion M_t, where$M_t \equiv 1 + \frac{\vartheta_t}{\Lambda_t}$,and ϑ_t is the multiplier on the loan-in-advance constraint (2.12). The endogenous behavior of this distortion is fundamental to the real effects arising from market segmentation.

2.2 Financial Intermediaries

The FIs in the model are a stand- in for the entire financial nexus that uses accumulated net worth (N_t) and short-term liabilities (D_t) to finance investment bonds (F_t) and the long- term government bonds (B_t). The FIs are the sole buyers of the investment bonds and long-term government bonds. We again assume that government debt takes the form of Woodford-type perpetuities that provide payments of 1,κ,κ^2 etc. Let Q_t denote the price of a new- debt issue at time-t. The time-t asset value of the current and past issues of investment bonds is

$$Q_t C I_t + \kappa Q_t [C I_{t-1} + \kappa C I_{t-2} + \kappa^2 C I_{t-3} + \cdots] = Q_t F_t \tag{2.16}$$

The FI's balance sheet is thus given by

$$\frac{B_t}{P_t} Q_t + \frac{F_t}{P_t} Q_t = \frac{D_t}{P_t} + N_t = L_t N_t \tag{2.17}$$

where L_t denotes leverage. Note that on the asset side, investment lending and long-term bond purchases are perfect substitutes to the FI. Let $R_{t+1}^L \equiv \left(\frac{1+\kappa Q_{t+1}}{Q_t} \right)$. The FI's time-t profits are then given by

$$prof_t \equiv \frac{P_{t-1}}{P_t} \left[(R_t^L - R_{t-1}^d) L_{t-1} + R_{t-1} \right] N_{t-1} \tag{2.18}$$

The FI will pay out some of these profits as dividends div_t to the household, and retain the rest as net worth for subsequent activity. In making this choice the FI discounts dividends flows using the household's pricing kernel augmented with additional impatience. The FI accumulates net worth because it is subject to a financial constraint: the FI's ability to attract deposits will be limited by its net worth. We will use a simple hold- up problem to generate this leverage constraint, but a wide variety of informational restrictions will generate the same constraint. We assume that leverage is taken as given by the FI. We will return to this below. The FI's chooses dividends and net worth to solve.

$$V_t \equiv \max_{N_t, div_t} E_t \sum_{j=0}^{\infty} (\beta\zeta)^j \Lambda_{t+j} div_{t+j} \tag{2.19}$$

subject to financing constraint developed below and the following budget constraint:

$$div_t + N_t \left[1 + f(N_t)\right] \leq \frac{P_{t-1}}{P_t} \left[(R_t^L - R_{t-1}^d)L_{t-1} + R_{t-1}^d\right] N_{t-1} \tag{2.20}$$

The function $f(N_t) \equiv \frac{\psi_{n,\xi_t^{\psi_n}}}{2}(\frac{N_t - N_{ss}}{N_{ss}})$ denotes an adjustment cost function that dampens the ability of the FI to adjust the size of its portfolio in response to shocks. The $\xi_t^{\psi_n}$ indicates that this financial market segmentation parameter is allow to change across regime at time t. If we assumed no adjustment costs ($\psi_n = 0$) and that the net worth solution is interior, the FI's value function is linear and given by,

$$V_t = \frac{P_{t-1}}{P_t} \Lambda_t \left[(R_t^L - R_{t-1}^d)L_{t-1} + R_{t-1}^d\right] N_{t-1} \equiv X_t N_{t-1} \tag{2.21}$$

But with convex adjustment cost in net worth accumulation, the FI's value function will include a time varying additive term

$$V_t = X_t N_{t-1} + g_t$$

where $g_{ss} = 0$. The term g_t is a function of aggregate variables that are exogenous to the FI

The hold-up problem work as follows. At the beginning of period $t + 1$, but before aggregate shocks are realized, the FI can choose to default on its planned repayment to depositors. In this event, depositors can seize at most fraction $(1 - \Psi_t)$ of the FI's assets, where Ψ_t is a function of net worth and the other state variables. If the FI defaults, the FI is left with $\Psi_t R_{t+1}^L L_t N_t$, which it pays out to households and exits the world. To ensure that the FI will always repay the depositor, the time-t incentive compatibility constraint is thus given by

$$E_t V_{t+1} \geq \Psi_t L_t N_t E_t \Lambda_{t+1} \frac{P_t}{P_{t+1}} R_{t+1}^L \tag{2.22}$$

We will calibrate the model so that this constraint is binding in the steady state (and thus binding for small shocks around the steady state). For a fixed Ψ_t , the presence of g_t in the value function implies that leverage will typically vary with net worth, e.g., leverage will be decreasing in net worth if $E_t g_{t+1} > 0$. For simplicity, we avoid this complication by assuming that Ψ_t is a function of net worth in a manner symmetric with the convexity in the adjustment cost function. Although theoretically convenient, this assumption is quantitatively unimportant (as g_{ss}). In particular, we assume that the fraction of assets that the FI can keep in case of default is defined by

$$\Psi_t \equiv \Phi_t \left[1 + \frac{1}{N_t}\left(\frac{E_t g_{t+1}}{E_t X_{t+1}}\right)\right] \tag{2.23}$$

where Φ_t is an exogenous stochastic process that represents exogenous changes in the financial friction. For example, if $E_t g_{t+1} > 0$, assumption (2.23) implies that higher net worth makes the hold-up problem less severe. This decreased severity is chosen to counter the earlier implication that leverage would be decreasing in net worth. Assumption (2.23) implies that the binding incentive constraint (2.22) is given by

$$E_t \frac{P_t}{P_{t+1}} \Lambda_{t+1} \left[\left(\frac{R^L_{t+1}}{R^d_t} - 1\right) L_t + 1\right] = \Phi_t L_t E_t \Lambda_{t+1} \frac{P_t}{P_{t+1}} \frac{R^L_{t+1}}{R^d_t} \tag{2.24}$$

As anticipated, leverage is a function of aggregate variables but is independent of each FI's net worth. This implies that only aggregate net worth is needed to describe the model as all FIs are scaled versions of one another. Log-linearizing expression (2.24) we have,

$$\left(E_t r^L_{t+1} - r_t\right) = v l_t + \left[\frac{1 + L_{ss}(s-1)}{L_{ss} - 1}\right] \phi_t \tag{2.25}$$

where $v \equiv (L_{ss} - 1)^{-1}$ is the elasticity of the interest rate spread to leverage; s denotes the gross steady-state term premium, and the financial shock $\phi_t \equiv ln(\Phi_t)$ follows an AR(1) process:

$$\phi_t = (1 - \rho_\phi)\phi_{ss} + \rho_\phi \phi_{t-1} + \sigma_{\phi,\xi^{vo}_t} \varepsilon_{\phi,t} \tag{2.26}$$

Increases in ϕ_t will exacerbate the hold up problem, and thus "credit shocks", which will increase the spread and lower real activity. Qualitatively the log-linearized expression (2.25) for leverage is identical to the corresponding relationship in the more complex costly state verification (CSV) environment of, for example, Bernanke et al. (1999). In a CSV model, the primitives include: (i) idiosyncratic risk, (ii) death rate, and (iii) monitoring cost. One typically chooses these to match values for: (i) leverage, (ii) interest rate spread, and (iii) default rate. The hold- up model has only two primitives: (i) the impatience rate ζ , and (ii) the fraction of assets that can be seized Φ. In comparison to the hold-up model, the extra primitive in the CSV framework thus allows it to match one more moment of the financial data (default rates). One important quantitative difference is that interest rate spreads are more responsive to leverage in our framework than in the CSV model calibrated to the same steady-state leverage. For example, suppose we calibrated a CSV model to a leverage of 6.0, a risk premium of 100 basis points (bp), and a quarterly default rate of 0.205 percent (the default rate in the hold- up model is 0 percent). This would imply $v =$ 0.097. In the hold- up model analyzed here, a leverage of 6.0 implies $v=$ 0.20, about twice as large as the CSV counterpart.

Since the incentive constraint (2.24) is now independent of net worth, the FI takes leverage as given. The FI's optimal accumulation decision is given by

$$\Lambda_t \left[1 + N_t f'(N_t) + f(N_t)\right] = E_t \beta \zeta \Lambda_{t+1} \frac{P_t}{P_{t+1}} \left[\left(R^L_{t+1} - R^d_t\right) L_t + R^d_t\right] \tag{2.27}$$

Equations (2.24) and (2.27) are fundamental to the model as they summarize the limits to arbitrage between the return on long-term bonds and the rate paid on short-term deposits. The leverage constraint (2.24) limits the FI's ability to attract deposits and thus can eliminate the arbitrage opportunity between the deposit and lending rate. Increases in net worth allow for greater arbitrage and thus can eliminate this market segmentation. Equation (2.27) limits this arbitrage in the steady-state by additional impatience ($\zeta < 1$) and dynamically by portfolio adjustment costs $\left(\psi_{n,\xi_t^{seg}} > 0\right)$. Since the FI is the sole means of investment finance, this market segmentation means that central bank purchases that alter the supply of long-term debt will have repercussions for investment loans because net worth and deposits cannot quickly sterilize the purchases.

2.3 Final Good Producers

Perfectly competitive firms produce the final consumption good Y_t combining a continuum of intermediate goods according to the CES technology:

$$Y_t = \left[\int_1^0 Y_t(i)^{1/(1+\epsilon_p)} di\right]^{1+\epsilon_p} \tag{2.28}$$

Profit maximization and the zero profit condition imply that the price of the final good, P_t , is the familiar CES aggregate of the prices of the intermediate goods.

2.4 Intermediate Goods Producers

A monopolist produces the intermediate good i according to the production function

$$Y_t(i) = A_t K_t(i)^{\alpha} H_t(i)^{1-\alpha}, \tag{2.29}$$

where $K_t(i)$ and $H_t(i)$ denote the amounts of capital and labor employed by firm i. The variable lnA_t is the exogenous level of TFP and evolves according to

$$lnA_t = \rho_A lnA_{t-1} + \sigma_{a,\xi_t^{vo}} \varepsilon_{a,t} \tag{2.30}$$

Every period a fraction θ_p of intermediate firms cannot choose its price optimally, but instead resets it according to the indexation rule

$$P_t(i) = P_{t-1}(i) \Pi_{t-1}^{\iota_p}, \tag{2.31}$$

where $\Pi_t = \frac{P_t}{P_{t-1}}$ is gross inflation. The remaining fraction of firms chooses its price $P_t(i)$ optimally, by maximizing the present discounted value of future profits

$$E_t \left\{ \sum_{s=0}^{\infty} \theta_p^s \frac{\beta^s \Lambda_{t+s}/P_{t+s}}{\Lambda_t/P_t} \left[P_t(i) \left(\prod_{k=1}^{s} \Pi_{t+k-1}^{\iota_p} \right) Y_{t+s}(i) - W_{t+s} H_{t+s}(i) - P_{t+s} R_{t+s}^k K_{t+s}(i) \right] \right\} \tag{2.32}$$

where the demand function $Y_{t+s}(i)$ comes from the final goods producers.

2.5 New Capital Producers

New capital is produced according to the production technology that takes I_t investment goods and transforms them into $\mu_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t$ new capital goods. The time-t profit flow is thus given by

$$P_t^k \mu_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t - I_t, \tag{2.33}$$

where the function S captures the presence of adjustment costs in investment, as in Christiano et al. (2005), is given by $S\left(\frac{I_t}{I_{t-1}}\right) \equiv \frac{\psi_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$. These firms are owned by households and discount future cash flows with Λ_t. The investment shock follows the stochastic process

$$log\mu_t = \rho_\mu log\mu_{t-1} + \sigma_{\mu,\xi_t^{vo}} \varepsilon_{\mu,t} \tag{2.34}$$

where $\varepsilon_{\mu,t}$ is i.i.d $N(0, \sigma_\mu^2)$.

2.6 Central Bank Policy

We assume that the central bank follows a familiar Taylor rule over the short rate (T- bills and deposits):

$$ln(R_t) = (1-\rho)ln(R_{ss}) + \rho ln(R_{t-1}) + (1-\rho)(\tau_\pi \pi_t + \tau_y y_t^{gap} + \tau_{tp,\xi_t^{tp}} tp_t) + \sigma_{r,\xi_t^{vo}} \epsilon_t^r \tag{2.35}$$

where $y_t^{gap} \equiv (Y_t - Y_t^f)/Y_t^f$ denotes the deviation of output from its flexible price counterpart and ϵ_t^r is an exogenous and auto-correlated policy shock with AR(1) coefficient ρ_r. The ξ_t^{tp} indicates that these elasticities of short term interest rates to the term premium parameter is allow to change across regime at time t. We will think of this as the Federal Funds Rate (FFR). We will also investigate if the central bank responds to the term premium (tp_t) into the Taylor rule. The supply of short-term bonds (T- bills) is endogenous, varying as needed to support the FFR target.

Term premium can be defined as the difference between the observed yield on a ten-year bond and the corresponding yield implied by applying the expectation hypothesis (EH) of the term structure to the series of short rates. The price of the hypothetical EH bond satisfies

$$r_t = E_t \frac{\kappa q_{t+1}^{EH}}{R_{ss}} - q_t^{EH} \tag{2.36}$$

while it yield is given by

$$r_t^{EH,10} = \left(\frac{R_{ss} - \kappa}{R_{ss}}\right) q_t^{EH} \tag{2.37}$$

Using this definitions, the term premium can be expressed as

$$tp_t \equiv (r_t^{10} - r_t^{EH,10}) = -\left(\frac{R_{ss}^L - \kappa}{R_{ss}^L}\right) q_t + \left(\frac{R_{ss} - \kappa}{R_{ss}}\right) q_t^{EH} \tag{2.38}$$

Fiscal policy is entirely passive. Government expenditures are set to zero. Lump sum taxes move endogenously to support the interest payments on the short and long debt.

2.7 Debt Market Policy

We need one more restriction to pin down the behavior in the long-term debt. For this study, we consider one a policy regime of exogenous debt. The variable b_t denotes the real value of the long-term government debt on the balance sheet of the FIs, where $b_t \equiv ln\left(\frac{\overline{B}_t}{\overline{B}_{ss}}\right)$. This variable could fluctuate for two reasons. First, the central bank could engage in long bond purchases ("quantitative easing", or QE). Second, the fiscal authority could alter the mix of short debt to long debt in its maturity. Both of these scenarios will be modeled as exogenous movements in long debt. Under either scenario, the long yield R_t^{10} will be endogenous. To model a persistent and hump-shaped QE policy shock we will use an AR(2):

$$b_t = \rho_1^b b_{t-1} + \rho_2^b b_{t-2} + \epsilon_t^b \tag{2.39}$$

2.8 The Effect of Financial Frictions

As previously explained ψ_n is the adjustment cost parameter hindering the ability of FI to adjust the size of its portfolio in response to shocks and it is associated to financial frictions. To gain intuition about the importance of this financial parameter for the macroeconomy we can combine the log-linear versions of the FI incentive compatibility constraint (2.24) and the FI optimal net worth accumulation decision (2.27) given by:

$$E_t(r_{t+1}^L - r_t) = \left(\frac{1}{L_{ss}-1}\right) l_t + \left[\frac{1+(s-1)L_{ss}}{L_{ss}-1}\right]\phi_t \tag{2.40}$$

and

$$\psi_{n,\xi_t^{seg}} n_t = \left[\frac{sL_{ss}}{1+L_{ss}(s-1)}\right] E_t(r_{t+1}^L - r_t) + \left[\frac{(s-1)L_{ss}}{1+L_{ss}(s-1)}\right] l_t \tag{2.41}$$

to get

$$E_t(r_{t+1}^L - r_t) = \frac{1}{L_{ss}}\psi_n n_t + (s-1)\phi_t \tag{2.42}$$

This expression shows the importance of ψ_n for the supply of credit. If $\psi_n = 0$ the supply of credit is perfectly elastic, independent of the financial intermediaries net worth. As ψ_n becomes larger, the financial friction becomes more intense and the supply of credit depends positively on the financial intermediaries net worth.

3 Solution and Estimation

Given that the traditional stability concepts for constant DSGE models does not hold for the Markov switching case, to solve the linear version of the model we use the solution method proposed by Maih (2015),[2] which uses the minimum state variable (MSV)[3] concept to present the solution of the system in the following form:

$$X_t\left(s_t, s_{t-1}\right) = T\left(\xi_t^{sp}, \theta^{sp}\right) X_{t-1}\left(s_{t-1}, s_{t-2}\right) + R\left(\xi_t^{vo}, \theta^{sp}\right)\varepsilon_t \tag{3.1}$$

[2]Based in perturbation methods as the approach pesented by Barthélemy and Marx (2011) and Foerster et al. (2014).
[3]See McCallum (1983).

where T and R matrices contains the model's parameters. X_t stands for the $(n \times 1)$ vector of endogenous variables,ε_t is the $(k \times 1)$ vector of exogenous processes.

As mentioned in the previous section, we introduce the possibility of regime change for two structural parameters (sp) and to shock volatilities (vo) through three independent Markov chains: $\xi_t^{\psi_n}$, ξ_t^{tp} and ξ_t^{vo}, respectively. The three chains denote the unobserved regimes associated with the market segmentation, $\psi_{n,\xi_T^{\psi_n}}$, monetary policy response to the term premium, $\tau_{tp,\xi_t^{tp}}$, and volatilities. These processes are subject to regime shifts and takes on discrete values $i \in \{1,2\}$, where regime 1 implies high absolute values for parameters of market segmentation, monetary policy response to the term premium and volatilities, and the opposite is true for low parameters.[4]

The three Markov chains are assumed to follow a first-order process with the following transition matrices, respectively:

$$H^i = \begin{pmatrix} H_{12} & H_{12} \\ H_{21} & H_{22} \end{pmatrix} \; for\; i = \psi_n,\; tp,\; vol \tag{3.2}$$

where $H_{ij} = p\left(sp_t = j \mid sp_{t-1} = i\right)$, for $i, j = 1, 2$. Then, H_{ij} stands for the probability of being in regime j at t given that one was in regime i.

Various authors have focused in the concept of Mean Square Stability solutions (MSS)[5] for (3.1). As is emphasized by Maih (2015) and Foerster (2016), this condition implies finite first and second moments in expectations for the system:

$$\lim_{j\to\infty} \mathbb{E}_t\left[X_{t+j}\right] = \bar{x} \tag{3.3}$$

$$\lim_{j\to\infty} \mathbb{E}_t\left[X_{t+j}X_{t+j}^{'}\right] = \sum \tag{3.4}$$

Additionally, as pointed by Costa et al. (2006), and Foerster (2016), the solution of the system (3.1) given that the matrix $T\left(\xi^{sp}, \theta^{sp}, H\right)$ does not satisfies the standard stability condition, a necessary and sufficient condition of MSS stability implies that all the eigenvalues of the matrix Ψ are in the unit circle (Alstadheim et al., 2013):

$$\Psi = \left(\mathbb{H} \otimes I_{n^2}\right) \begin{bmatrix} T_1T_1 & & \\ & \ddots & \\ & & T_hT_h \end{bmatrix} \tag{3.5}$$

Finally, to complete the state form of the model combine (3.1) with the measurement equations (3.6):

$$Y_t^{obs} = MX_t \tag{3.6}$$

where:

[4]The identification for each regime will be described in detail in subsection 3.2.
[5]See Costa et al. (2006); Cho (2014); Foerster et al. (2014); Maih (2015).

$$Y_t^{obs} = \begin{bmatrix} \Delta\, GDP_t \\ \Delta\, Investment_t \\ \Delta\, Real\ wages_t \\ Inflation_t \\ Labor_t \\ Federal\ fund\ rate_t \\ Term\ premium_t \end{bmatrix} \tag{3.7}$$

The presence of unobserved DSGE states X_t and unobserved parameters (controlled by the Markov chains), implies that the standard Kalman filter cannot be used to compute the likelihood. Additionally, the filtering procedure requires to be updated conditioning on the information of the current and past value of the states present in the respective Markov chains. Kim and Nelson (1999) proposed an operational filter that introduces all the possible path of the system and limits the number of states that introduces each iteration of the Kalman filter. The proposed filter utilizes the "collapse" function to reduce the number of possible paths taking a weighted average that account the respective probability of each one.

This paper uses the Bayesian approach to estimate the model.:

1. Using Maih (2015) algorithm we introduce non-linearities a unobserved chains employing the Kim and Nelson (1999) filter to compute the likelihood combined with the prior density of the parameters to form the posterior kernel, which is maximized.

2. Construct the mode of the posterior kernel, resulting from the Bee_gate[6] optimizer routine.

3. We use the mode of the posterior distribution as the initial value for a Metropolis Hasting algorithm,[7] with 50.000 iterations, to construct the full posterior distribution.

4. Utilizing mean and variance of the last 40.000 iterations we compute moments.

3.1 Database

We use US data from 1962Q1 to 2017Q3 for the estimation of the model. The database take the original series reported in Carlstrom et al. (2017) but extend the sample from 2008Q4 to 2017Q3.

Quarterly series for the annualised growth rates of real GDP, real gross private domestic investment, real wages, inflation rate - PCE index - and real wages.[8] The labor input series was constructed substituting the trend component from the non-farm business sector (hours of all persons) series. The series for the FFR is obtained averaging monthly figures downloaded from the St. Louis Fed web-site.[9] Additionally, for the term premium, we take the Treasury Term Premia series from the New York Fed web-site, estimated by Adrian et al. (2013). All data are demeaned.

[6]RISE toolbox optimization routine.

[7]With an acceptance ratio of $\alpha = 0.28$.

[8]Defined as nominal compensation in the non-farm business sector divided by the consumption deflator.

[9]A new exercise is currently being estimated with the Shadow rate series for the Fed interest rate, estimated by Wu and Xia (2016) for the modelling the monetary policy actions between the ZLB period.

Table 1: Calibrated parameters

Parameter	value
β	0.99
α	0.33
δ	0.025
$\rho_{r_t^{10}}$	0.85
$\epsilon_p = \epsilon_w$	5
L_{ss}	6
R^L_{ss}	$1/\beta$
$(1-\kappa)^{-1}$	40

3.2 Prior Specification

As in Adrian et al. (2013); Carlstrom et al. (2017), we calibrate several parameters to match the long run features of the US data which are reported in Table 1. The choice of prior distribution for the estimated non-switching parameters are presented in Table 2. These are based on the *posterior* distribution reported in line with the same authors.

Table 2: Prior distribution of non-swtiching parameters

Parameter	**Description**	**Density**	**Prior**		
			Mean	5%	95%
	Non-switching parameters				
η	Inverse substitution elasticity	*Gamma*	2.0259	1.2673	2.7526
h	Degree of habit formation	*Beta*	0.6225	0.5760	0.6687
φ	Inverse of supply curve for investment elasticity	*Gamma*	3.2821	2.1857	4.3639
τ_π	Monetary Policy reaction to annual inflation	*Normal*	1.4202	1.2828	1.5493
τ_y	Monetary Policy reaction to output gap	*Normal*	0.4906	0.3566	0.6292
ρ_i	Interest rate smoothing parameter	*Beta*	0.7712	0.7309	0.8109
ι_p	Price level indexation	*Beta*	0.4172	0.2752	0.5610
ι_w	Wage level indexation	*Beta*	0.5110	0.4085	0.6205
κ_{pc}	Price sensibility of Phillips curve	*Beta*	0.0860	0.0104	0.1544
κ_w	Labor distortion sensibility of Phillips curve	*Beta*	0.0002	0.0001	0.0004
ρ_a	Productivity shock persistence	*Beta*	0.9921	0.9841	0.9997
ρ_μ	Investment shock persistence	*Beta*	0.8695	0.8281	0.9122
ρ_φ	Credit shock persistence	*Beta*	0.9821	0.9682	0.9963
ρ_{mk}	Price Markup shock persistence	*Beta*	0.6650	0.4945	0.8405
ρ_{mkw}	Wage Markup shock persistence	*Beta*	0.2059	0.1036	0.3027
ρ_m	Monetary Policy shock persistence	*Beta*	0.1564	0.0646	0.2515
ρ_{rn}	Intertemporal preferences shock persistence	*Beta*	0.9483	0.9212	0.9751

For the Markov-chain switching parameters, the priors are reported in Table 3. For identification purposes, we characterized the high financial market segmentation regime, $\left(\psi_{n,\xi_t^{\psi_n=1}}\right)$, to be a regime where credit market present high portfolio adjustment cost (i.e. $\psi_{n,\xi_t^{\psi_n=1}} > \psi_{n,\xi_t^{\psi_n=2}}$). Meanwhile, for regime changes in the monetary policy's response to the term premium, we define $\left(\tau_{tp,\xi_t^{tp=1}}\right)$to be the regime where the central bank responds strongly to these variations (i.e. $\left|\tau_{tp,\xi_t^{tp=1}}\right| > \left|\tau_{tp,\xi_t^{tp=2}}\right|$). The model also allows for regime switching in the shocks, thus we let the volatility shocks to follow another independent two-state Markov-process. Then, we indicate the high volatility regime $\left(\sigma_{i,\xi_t^{vo=1}}\right)$ to be the regime where the volatility of the investment shock is highest, i.e. $\left(\sigma_{i,\xi_t^{vo=1}} > \sigma_{i,\xi_t^{vo=2}}\right)$.

The transition probabilities for the 3 independent two-state Markov-processes are presented in Table 4.

Table 3: Prior distribution Markov-chain switching parameter

Parameter	Description	Density	Prior			
			Mean	**St.Dev.**	**LB**	**UB**
	Markov switching parameters					
$\psi_{n,1}$	Credit response to High Mkt. segmentation	*Uniform*	6	2.89	0.0001	10
$\psi_{n,2}$	Credit response to Low Mkt. segmentation	*Uniform*	5	0.30	0.0001	10
$\tau_{tp,1}$	High MP response to the term premium	*Normal*	-1.00	0.50	0.0001	10
$\tau_{tp,2}$	Low MP response to the term premium	*Normal*	-.03	0.50	0.0001	10
$\sigma_{a,1}$	Productivity shock response to high volatility	*Inv.Gamma*	0.5	1	0.0001	10
$\sigma_{a,2}$	Productivity shock response to low volatility	*Inv.Gamma*	0.5	1	0.0001	10
$\sigma_{i,1}$	Investment shock response to high volatility	*Inv.Gamma*	5.5	2	0.0001	10
$\sigma_{i,2}$	Investment shock response to low volatility	*Inv.Gamma*	0.5	1	0.0001	10
$\sigma_{mp,1}$	Monetary p. shock response to high volatility	*Inv.Gamma*	0.2	1	0.0001	10
$\sigma_{mp,2}$	Monetary p. shock response to low volatility	*Inv.Gamma*	0.2	1	0.0001	10
$\sigma_{mk,1}$	Price markup shock response to high volatility	*Inv.Gamma*	0.2	1	0.0001	10
$\sigma_{mk,2}$	Price markup shock response to low volatility	*Inv.Gamma*	0.2	1	0.0001	10
$\sigma_{mkw,1}$	Wage markup shock response to high volatility	*Inv.Gamma*	0.2	1	0.0001	10
$\sigma_{mkw,2}$	Wage markup shock response to low volatility	*Inv.Gamma*	0.2	1	0.0001	10
$\sigma_{rn,1}$	Intertemp. pref. shock response to high volatility	*Inv.Gamma*	0.2	1	0.0001	10
$\sigma_{rn,2}$	Intertemp. pref. shock response to low volatility	*Inv.Gamma*	0.2	1	0.0001	10
$\sigma_{\psi,1}$	Credit shock response to high volatility	*Inv.Gamma*	0.5	1	0.0001	10
$\sigma_{\psi,2}$	Credit shock response to low volatility	*Inv.Gamma*	0.5	1	0.0001	10

Table 4: Prior distribution of Transition Probabilities

Parameter	Description	Density	Prior			
			Mean	**St.Dev.**	**LB**	**UB**
$H_{1,2}^{\psi_n}$	Transition probabilities: $H_{1,2}^{\psi_n} = p(S_{t+1} = 2 \| S_t = 1)$	*Beta*	0.15	0.01	0	1
$H_{2,1}^{\psi_n}$	Transition probabilities: $H_{2,1}^{\psi_n} = p(S_{t+1} = 1 \| S_t = 2)$	*Beta*	0.15	0.01	0	1
$H_{1,2}^{tp}$	Transition probabilities: $H_{1,2}^{tp} = p(S_{t+1} = 2 \| S_t = 1)$	*Beta*	0.15	0.01	0	1
$H_{2,1}^{tp}$	Transition probabilities: $H_{2,1}^{tp} = p(S_{t+1} = 1 \| S_t = 2)$	*Beta*	0.15	0.01	0	1
$H_{1,2}^{vo}$	Transition probabilities: $H_{1,2}^{vo} = p(S_{t+1} = 2 \| S_t = 1)$	*Beta*	0.2	0.01	0	1
$H_{2,1}^{vo}$	Transition probabilities: $H_{1,2}^{vo} = p(S_{t+1} = 1 \| S_t = 2)$	*Beta*	0.2	0.01	0	1

4 Results

4.1 Parameter Estimation

In this section, we report the posterior parameter estimates. The Bayesian uses the posterior mode as initial value. Tables 5 and 6 report the estimates of the non-switching and switching parameters, respectively. Additionally, table 7 reports the estimated transition probabilities associated to the three Markov chains.

Table 5: Posterior distribution (non-swtiching parameters)

Parameter	Density	Posterior				
		Mean	Mode	St.dev	10%	90%
Panel A: Non-switching parameters						
η	*Gamma*	1.5772	1.5632	0.1394	1.2528	1.7655
h	*Beta*	0.762	0.7788	0.0557	0.6005	0.7861
φ	*Gamma*	3.4219	3.3911	0.2104	3.1716	3.9569
τ_π	*Normal*	1.5567	1.6318	0.1024	1.3561	1.7042
τ_y	*Normal*	0.1043	0.0249	0.155	0.0219	0.4686
ρ_i	*Beta*	0.7356	0.8109	0.055	0.6562	0.8202
ι_p	*Beta*	0.3855	0.5053	0.1243	0.1485	0.5258
ι_w	*Beta*	0.2409	0.23	0.0749	0.157	0.4038
κ_{pc}	*Beta*	0.3329	0.3706	0.0746	0.1492	0.3935
κ_w	*Beta*	0.0002	0.0001	0.0002	0.0001	0.0006
ρ_a	*Beta*	0.9909	0.9973	0.011	0.9692	0.9999
ρ_μ	*Beta*	0.9603	0.9733	0.0212	0.9398	0.9761
ρ_φ	*Beta*	0.9863	0.9965	0.0161	0.941	0.9978
ρ_{mk}	*Beta*	0.5625	0.5156	0.0553	0.4924	0.6755
ρ_{mkw}	*Beta*	0.1706	0.0976	0.1015	0.0561	0.3395
ρ_m	*Beta*	0.277	0.3248	0.0953	0.0715	0.3808
ρ_{rn}	*Beta*	0.7848	0.7816	0.0098	0.7778	0.8054

Table 6: Posterior distribution (swtiching parameters)

Parameter	Density	Posterior				
		Mean	Mode	St.dev	10%	90%
Panel B: Markov switching parameters						
$\psi_{n,1}$	*Uniform*	0.6220	0.6387	0.0402	0.5549	0.6810
$\psi_{n,2}$	*Uniform*	2.0105	1.9769	0.0529	1.9263	2.0821
$\tau_{tp,1}$	*Normal*	-1.8393	-1.8217	0.1376	-2.1747	-1.6532
$\tau_{tp,2}$	*Normal*	-1.1795	-1.2124	0.0660	-1.2523	-1.0706
$\sigma_{a,1}$	*Inv.Gamma*	3.7755	3.7477	0.3078	3.0869	4.2683
$\sigma_{a,2}$	*Inv.Gamma*	6.8327	6.8596	0.0606	6.7182	6.9079
$\sigma_{i,1}$	*Inv.Gamma*	4.3727	4.4895	0.1420	4.0848	4.5090
$\sigma_{i,2}$	*Inv.Gamma*	4.0014	4.0162	0.0430	3.8985	4.0540
$\sigma_{mp,1}$	*Inv.Gamma*	7.0718	7.0848	0.3020	6.6402	7.8091
$\sigma_{mp,2}$	*Inv.Gamma*	2.1348	2.1254	0.2676	1.5009	2.5399
$\sigma_{mk,1}$	*Inv.Gamma*	5.3022	5.3147	0.0646	5.1641	5.3791
$\sigma_{mk,2}$	*Inv.Gamma*	6.6414	6.7206	0.2392	6.2655	7.1166
$\sigma_{mkw,1}$	*Inv.Gamma*	3.4280	3.4642	0.1181	3.1356	3.5680
$\sigma_{mkw,2}$	*Inv.Gamma*	3.4802	3.4385	0.0721	3.3890	3.5967
$\sigma_{rn,1}$	*Inv.Gamma*	7.9631	7.8955	0.2858	7.6079	8.6913
$\sigma_{rn,2}$	*Inv.Gamma*	4.9926	5.0456	0.0603	4.8934	5.0935
$\sigma_{\psi,1}$	*Inv.Gamma*	4.3681	4.2690	0.1362	4.2500	4.6625
$\sigma_{\psi,2}$	*Inv.Gamma*	2.9481	2.9707	0.2558	2.3182	3.3109

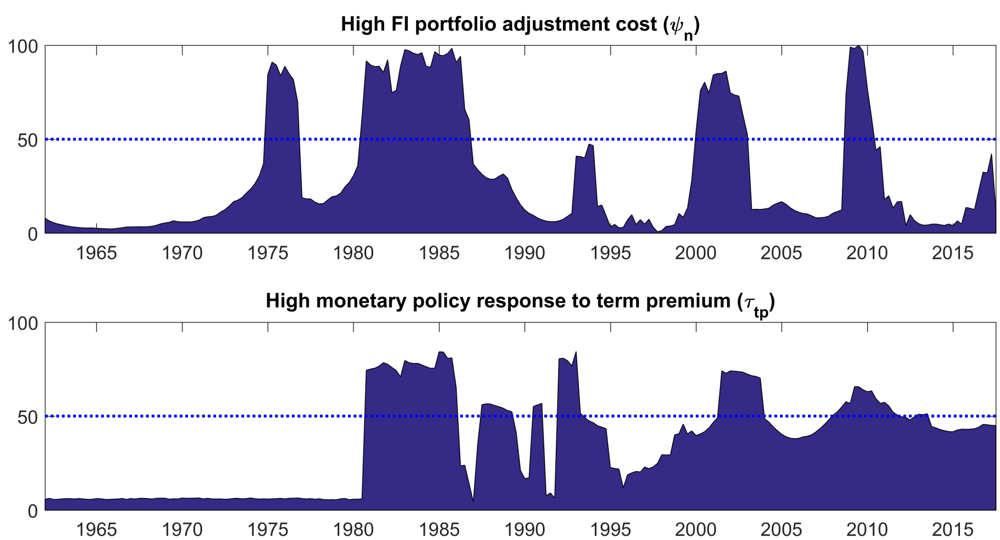
Table 7: Posterior distribution of Transition Probabilities

Parameter	Description	Density	Posterior				
			Mean	**Mode.**	**St.dev.**	**10%**	**90%**
$H^{\psi_n}_{1,2}$	Transition probabilities: $H^{\psi_n}_{1,2} = p(S_{t+1} = 2 \vert S_t = 1)$	*Beta*	0.15	0.2988	0.2467	0.0574	0.2332
$H^{\psi_n}_{2,1}$	Transition probabilities: $H^{\psi_n}_{2,1} = p(S_{t+1} = 1 \vert S_t = 2)$	*Beta*	0.15	0.7848	0.8649	0.1354	0.4922
$H^{tp}_{1,2}$	Transition probabilities: $H^{tp}_{1,2} = p(S_{t+1} = 2 \vert S_t = 1)$	*Beta*	0.15	0.6323	0.7119	0.0712	0.5362
$H^{tp}_{2,1}$	Transition probabilities: $H^{tp}_{2,1} = p(S_{t+1} = 1 \vert S_t = 2)$	*Beta*	0.15	0.1699	0.1320	0.0704	0.0615
$H^{vo}_{1,2}$	Transition probabilities: $H^{vo}_{1,2} = p(S_{t+1} = 2 \vert S_t = 1)$	*Beta*	0.2	0.0503	0.0276	0.0503	0.0060
$H^{vo}_{2,1}$	Transition probabilities: $H^{vo}_{1,2} = p(S_{t+1} = 1 \vert S_t = 2)$	*Beta*	0.2	0.4832	0.5067	0.0425	0.4217

4.2 Regime Probabilities and Historical Accounts

The estimation provides us the probabilities of the high and low portfolio adjustment cost and monetary policy response to the term premium regimes. Figure 1, below, shows the smoothed probabilities of each regime.

Figure 1: Smoothed probabilities



According to these preliminary probability estimates, we identify that financial frictions, measured by the financial intermediaries portfolio adjustment costs to their net worth, had high probability of being high in the following four intervals: 1975q1 – 1976q4, 1980q3 – 1986q4, 2000q1 – 2003q1 and 2008q4 – 2010q2. Meanwhile, the estimation identifies the following as periods of high probability of high interest rate response to the term premium: 1980q4 – 1986q1, 1987q3 – 1989q2, 1990q3 – 1991q1, 1992q1 – 1993q2, 2001q3 – 2003q4, 2008q1 – 2011q4, 2013q1 – 2013q3. In the next sub-sections we provide a period by period historical analysis for these periods in order to identify some historical episodes that make sense with the smoothed probabilities reported in the model estimation.

4.2.1 1975Q1 to 1976Q3: Stagflation and Post-Vietnam War Era

At the beginning/mid of the 1970s, the computer revolution drove down the cost of information storage and retrieval, allowing prospective lenders anywhere in the U.S. to assess a borrower's creditworthiness without having to rely in information that could only be obtained locally. By that time only four states have legal codes that permit the intrastate bank branching. the spike in oil prices around the world caused stagflation in the U.S. economy. putting pressure into the banking system. In addition, the accelerating price inflation was also generated because the government began to run deficits in order to pay the war in Vietnam and President Lyndon Johnson's Great Society programs. Ceilings on passive nominal interest rates tied with high inflation gave negative real yields to depositors prompting them to move their funds out of the banks. The core bank deposit as percentage of total personal financial wealth had drop from a 35% to a 29% approximately (Calomiris and Haber, 2014).

After the World War II, the drive to maintain global military superiority has pushed the United States toward permanent "war economy". Some authors such as Borch and Wallace (2010), argument that this emergence of new military economy actually not improve effectively the welfare of the U.S. economy. Many of the risks inherent of these policies, including persistently high inflation if the central bank fully adhered to the program, were subestimated (English et al., 2017).

Monetary policy was focused on production and employment without fully taking into account the consequences in the price level. Despite the financial stress, interest rates had a mild response to the term premium.

4.2.2 1979Q3 to 1986Q4: The Savings and Loans Crisis

From the time of the Revolutionary War through the second mid-twentieth century, the US banking system was dominated by a coalition composed between small unit-bankers (operating with no branches) and agrarian populists.

At the late 1970s, the Fed introduce a contractionary monetary policy with inflation targeting (rising the FFR from 9 to 12 along the 3 last quarters of the 1979). A spike in interest rates caused banks and Savings and Loans (S&L or thrifts, which are specialized banks in taking deposits from small associations) with large exposures to real estate lending (with fixed interest rates) to suffer major losses. Banks had contributed to increase their losses due the aggressive risk taking behavior and abuse of government protection such as the deposit insurance and the access of the Fed's discount window. Thus by the 1980s, the conditions that had permitted a stable unit-bank had crumble. The 1980s' banking system was affected by a series unexpected and unusual confluence of shocks: agricultural , oil and gas price collapses, decrease in the values of real estate and volatility shocks; that wiped out many small rural banks and financial institutions based in Texas and Oklahoma.

The US legislation, finance regulatory and unit-banking system not allow FIs to diversify risk by pooling the risk of different regions or respond to liquidity shortage by shifting resources across branches of an interconnected network. As a result S&L companies, whose business model was dependent of two key economic conditions: low inflation and depositor discipline, were demised. These thrifts borrowed short-term from depositors and then lent long-term on fixed-rate mortgages. Since the passive rate was a market rate and the active rate was imposed by the law, again the high levels of inflation of 1979 lead this companies to have negative real yields. The stress in the financial industry is captured in figure 1, which shows that between 1979Q3 to 1986Q4 FIs' portfolio adjustment cost was high with a high probability.

For the first time since the beginning of our sample, monetary policy turned aggressive responding to the term premium. Figure 1 shows that the monetary policy response to the term premium was high between 1980Q4-1986Q1. This period stars with the 1980 monetary control low and the conquest of American inflation. This reduction of inflation partly due to monetary policy and the Oil price reduction. At the 1985Q3, the U.S., Germany, Japan, France and Great Britain signed the Plaza Accord to depreciate the Dollar.

The increase in government bailout of banks began to shift public sentiment, encouraging depositors to rely in other financial instruments as commercial paper issued by non-financial companies. The S&L crisis cost the taxpayers around $124 billion estimated by the Federal Deposit Insurance Corporation (Calomiris and Haber, 2014). The experience with the S&L bankruptcy trigger the rescue of Continental Illinois in 1984. The moral hazard problems associated to the "too bog to fail" condition were only limited by the FDIC improvement act in 1991.

The financial crisis of 1980s exposed the instability of the weak financial institutions and their lack of ability to diversify their risk. The result was the end of the unit banker-agrarian populist coalition era. In figure 1 we can see that from 1987Q1 to early the 1990s the high portfolio adjustment cost have low probability . This could be a result of the several reforms that produced produced changes at state and federal level. A process that begins in 1982 with the Great Moderation and which many states began to relax their branching restrictions. By 1986, merges between small local banks and acquisitions of unit-banks in bankruptcy by larger banks were crucial source of funding. We also can see a little period of high financial frictions in the early 1990s. The 1977 Community Reinvestment Act (CRA), which gave incentives to lenders to search for high-quality borrowers in low-income segments, take participation in the 1980s to reduce the high market segmentation originated for the high portfolio adjustment costs of the FIs. Due to these incentives were too weak, the CRA became more valuable in the 1990s. In 1994, the Congress passed the Riegle-Neal Act, that stipulates the banks now could branch at intra- and interstate levels. With this movement the last financial entities that remain in the old unit bank system were blown.

4.2.3 2000Q1 to 2003Q3: The Rise of Megabanks and GSEs

Since the Great Depression, the U.S. hadn't experienced other financial crisis that severe until the Subprime mortgage crisis. But why this recession was so harsh if with the regulatory changes of the 1980s-90s the U.S. branch banking system was so efficient? To have a better comprehension of the section below, we need to see how was the financial system and the mortgages market in the United States in the years before the subprime crisis.

In the mid 1990s, the incentives to become a megabank were multiple. The past financial crises had made clear the efficiency of the branch banking system. Several criteria could be used to block approval of a bank merger; for example, the good citizenship. As mention in the section above, the CRA took great importance in the intern culture of the banks. By 1999Q4, president Bill Clinton enforces several redistributive policies in the U.S., granting more privileges to those institutions that will grant more lending to low-income segments. We can see in the figure 1 that from 2000Q1 to 2003Q3 that financial frictions were high with high probability. There are several phenomena before and during this period of time. Along the 1999, the Long-Term Capital management collapsed and the Glass-Setagal Act was repealed, allowing banks to issue stocks. The early 2000, was characterized by reduction of the interest rates before the recession and a fall in the investment; multiple corporate scandals such as the Enron case. Also was the start and end of the dotcom bubble market crash, and geopolitical tension generated by events like the 09/11 attacks to the World Trade Center towers.

During this period of financial distress, monetary policy responded aggressively to the term premium between 2001Q3-2003Q4.

4.2.4 2008Q3 to 2010Q4: The Subprime Crisis

The economic and political conditions previous mentioned led to the erosion of the mortgage standards. According to Calomiris and Haber (2014), there is no consensus among scholars, practitioners and politicians about the key causes of the subprime crisis: Creation of new and riskier financial securities like the Mortgage Back Securities (MBS) and other financial derivatives, the FFR near to zero bound leading to a quantitative easing policy of the Fed, excessive risk taking by GSEs such as Fannie Mae and Freddie Mac, the Bush-era free market ideology. Pushing Fannie and Freddie to purchase highly leveraged, risky mortgages to increase the liquidity and the capability of the lenders to extend more credits targeted to particular borrowers had huge effects on the mortgage markets.

Figure 1 shows that between 2008Q3 and 2010Q4 the cost of portfolio adjustment cost of the FIs was high with a high probability. This figure also shows that between 2008Q1-2011Q4, the Fed responded aggressively to the term premium.

The mortgage securities market were highly unregulated. One of the prudential regulations more neglected was that one related to bank capital cushions. With the development of the MBS (backed up by Fannie and Freddie). Holding MBSs required less capital cushion than holding the mortgage itself ($1.60/100 and $4.00/100, respectively). Thus by 2006, new high-risk mortgages equaled $1 trillion and accounted for 36% of all new mortgages lending. In 2008, the market was filled up with subprime mortgages (around half of all the mortgages were high risk) and Bear Stearns hedge funds enter in bankruptcy. Financial indicator such as the LIBOR/OIS spread gave signs of stress and uncertainty in the U.S. economy.

Rating agencies play a big role in this event. Credit ratings assigned by rating agencies can affect the allocation of risk capital in the economy. Higher credit ratings allow firms to borrow at better terms and thus positively affect a firm's value (Bae et al., 2015).

After the market crash, the Federal government of the U.S. and the Fed took unprecedented actions. Fannie Mae and Freddie Mac became government owned bank after their bailout. Liquidity-support programs were designed to support the different markets in distress(Calomiris and Haber, 2014). As measure of prevention and supervision, the president Obama pass the Dodd-Frank Act to reform and regulate the banking system thought the creation of a series of governmental agencies.

4.3 Impulse Responses (To be completed)

Figures 2 to 6 shows the impulse response functions (IRF) of investment, TFP, natural rate and monetary policy shocks, respectively. Each graph compares the responses of each variable under the four policy regimes controlling the effect of switching volatilities.[10]

[10] In order to analyze the differences between monetary and fiscal policy interactions we isolate the effects of high or low volatility taking the medium value for the volatilities of each shock.

Figure 2: Investment Shock

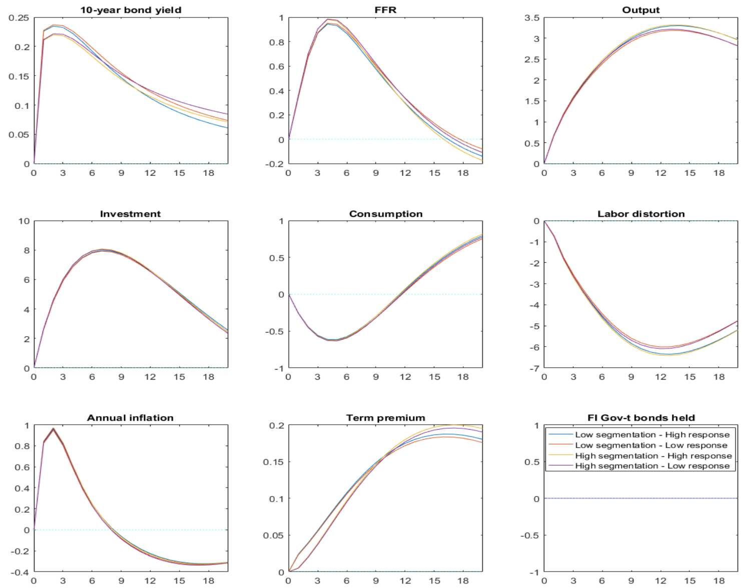


Figure 3: TFP Shock

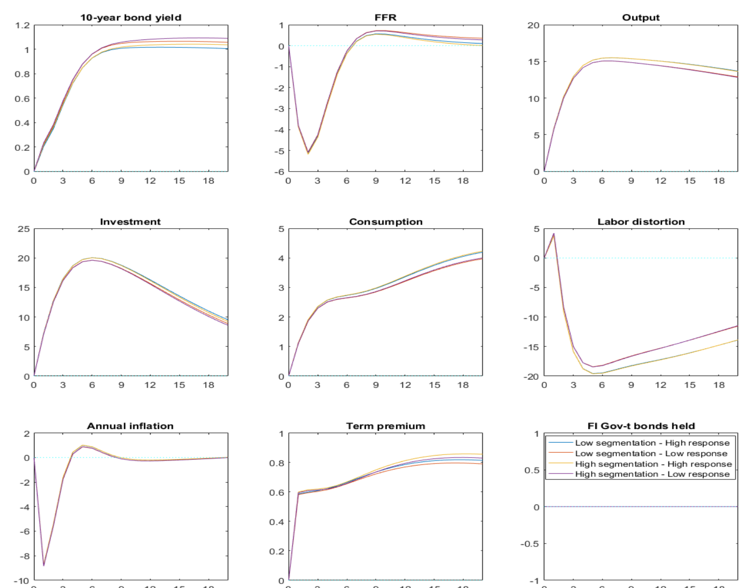


Figure 4: Natural rate shock

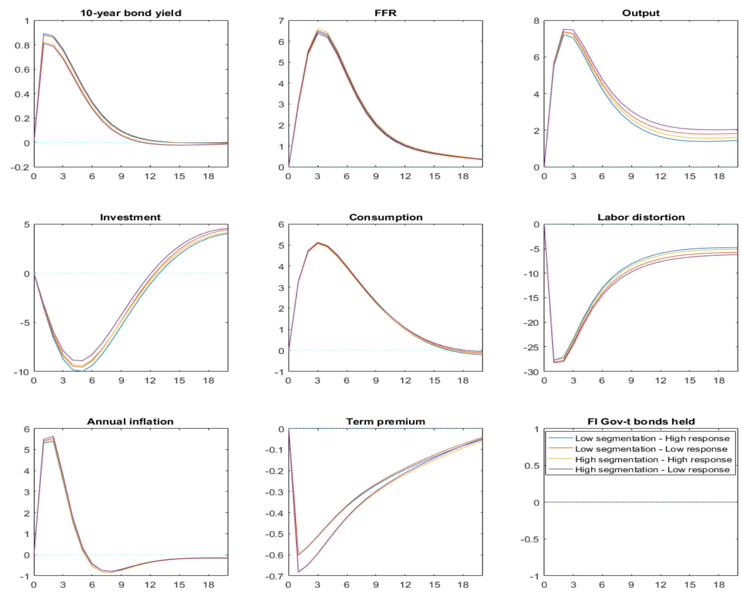


Figure 5: Credit Shock

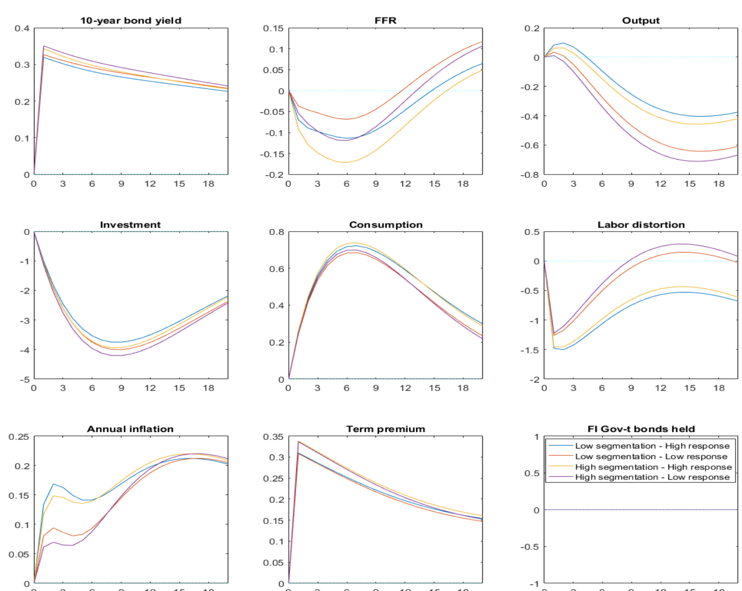
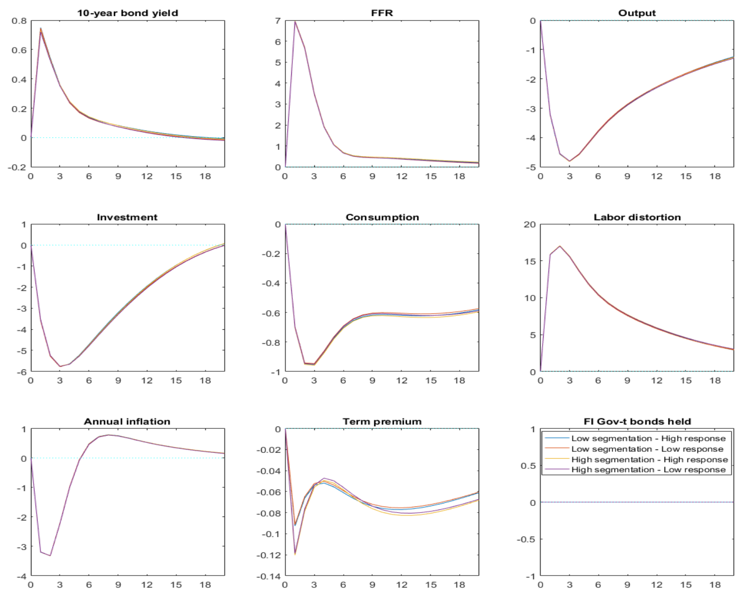


Figure 6: Credit Shock



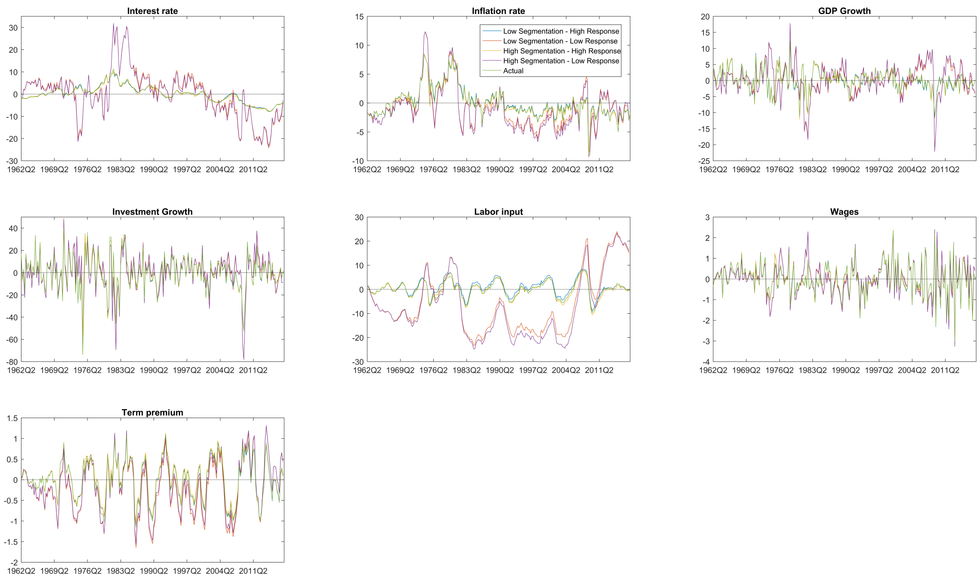
4.4 Counterfactual Analysis (To be completed)

To explore the characteristics of the MS-DSGE model with multiple regimes, in this exercise we generate counterfactual series based on conditional forecast simulations. Particularly, this analysis will permit us to have an idea of what would have happened if the financial frictions and/or monetary policy regimes have remained in a single regime for the full sample. Also, we can design experiments around each regime switch considering the situation were the change was fully credible, non credible, or the status quo had remained.

Once the model is estimated, we generate forecast from the MS-DSGE model conditional on the realized path of all the shocks (weighted series). The first quarter in every sample are used as initial conditions. The parameters utilized are the estimated posterior distribution of the coefficients for each regime. The results of the counterfactual exercises for the demeaned series are shown in figure 7:[11]

[11] Using the Shadow Rate estimated by Wu and Xia (2016).

Figure 7: Counterfactual series



5 Conclusions

To be completed.

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Appendix

A Linearized Model

Let $b_t \equiv ln\left(\frac{\overline{B}_t}{\overline{B}_{ss}}\right)$ and $f_t \equiv ln\left(\frac{\overline{F}_t}{\overline{F}_{ss}}\right)$, where $\overline{B}_t \equiv Q_t \frac{B_t}{P_t}$ and $\overline{F}_t \equiv Q_t \frac{F_t}{P_t}$denote the real market value of the bonds available to FIs. We will focus on bonds of ten- year maturities, so R_t^{10} will denote their gross yield. The variable L_{ss} denotes steady-state leverage. Using lower case letters to denote log deviations, the log-linearized model is given by the following:

Marginal utility of consumption

$$\lambda_t = \frac{1}{(1-\beta h)(1-h)} E_t\left[\beta h c_{t+1} - \left(1+\beta h^2\right) c_t + h c_{t-1}\right] + \frac{1}{1-\beta h}\left(rn_t - \beta h E_t rn_{t+1}\right) \tag{A.1}$$

Labor supply

$$rn_t + \eta h_t - \lambda_t = mrs_t \tag{A.2}$$

Labor Phillips curve

$$\pi_t^w - \iota_w \pi_{t-1} = \kappa_w\left(mrs_t - w_t\right) + \beta\left(\pi_{t+1}^w - \iota_w \pi_t\right) + \epsilon_t^w \tag{A.3}$$

Nominal wages

$$w_t = w_{t-1} + \pi_t^w - \pi_t \tag{A.4}$$

First order conditions

Fisher equation

$$\lambda_t = E_t \lambda_{t+1} + r_t - E_t \pi_{t+1} \tag{A.5}$$

Euler equation

$$\lambda_t + p_t^k + m_t = E_t\left\{\lambda_{t+1} + \left[1-\beta\left(1-\delta\right)\right] r_{t+1}^k + \beta(1-\delta)(p_{t+1}^k + m_{t+1})\right\} \tag{A.6}$$

Bond issuance equation

$$\lambda_t + q_t + m_t = E_t \lambda_{t-1} - E_t \pi_{t+1} + \beta \kappa E_t(q_{t+1} + m_{t+1}) \tag{A.7}$$

Link between investment bond (f) and investment

$$(1-\kappa)(p_t^k + i_t) = f_t - \kappa(f_{t-1} + q_t - q_{t-1} - \pi_t) \tag{A.8}$$

Return on the FI's real asset portfolio/price of EH bond

$$r_{t+1}^L = \frac{\kappa q_{t+1}}{R_{ss}^L} - q_t \tag{A.9}$$

Return on a 10-year bond available to the FIs/yield of EH bond

$$r_t^{10} = -\left(\frac{R_{ss}^L - \kappa}{R_{ss}^L}\right) q_t \tag{A.10}$$

FI's profits

$$E_t(r_{t+1}^L - r_t) = \left(\frac{1}{L_{ss} - 1}\right) l_t + \left[\frac{1 + (s-1)L_{ss}}{L_{ss} - 1}\right] \phi_t \tag{A.11}$$

Net worth adjustment cost

$$\psi_{n,\xi_t^{seg}} n_t = \left[\frac{sL_{ss}}{1 + L_{ss}(s-1)}\right] E_t(r_{t+1}^L - r_t) + \left[\frac{(s-1)L_{ss}}{1 + L_{ss}(s-1)}\right] l_t \tag{A.12}$$

Hold-up constraint

$$\frac{\overline{B}_{ss}}{L_{ss}N_{ss}} b_t + \left(1 - \frac{\overline{B}_{ss}}{L_{ss}N_{ss}}\right) f_t = n_t + l_t \tag{A.13}$$

Real wages

$$w_t = mc_t + mpl_t \tag{A.14}$$

Real rental rate

$$r_t^k = mc_t + mpk_t \tag{A.15}$$

Phillips curve

$$\pi_t = \frac{\kappa_\pi}{1 + \beta \iota_p} mc_t + \frac{\beta}{1 + \beta \iota_p} E_t \pi_{t+1} + \frac{\iota}{1 + \beta \iota_p} \pi_{t-1} + \epsilon_t^p \tag{A.16}$$

Investment supply decision

$$p_t^k = \psi_i \left[(i_t - i_{t-1}) - \beta E_t (i_{t+1} - i_t)\right] - \mu_t \tag{A.17}$$

Accounting identity

$$\left(1 - \frac{I_{ss}}{Y_{ss}}\right) c_t + \frac{I_{ss}}{Y_{ss}} i_t = a_t + \alpha k_t + (1 - \alpha) h_t \tag{A.18}$$

Capital acummulation

$$k_{t+1} = (1 - \delta) k_t + \delta(\mu_t + i_t) \tag{A.19}$$

Taylor rule

$$r_t = \rho r_{t-1} + (1 - \rho)\left(\tau_\pi \pi_t + \tau_y y_t^{gap} + \tau_{tp,\xi_t^{tp}} tp_t\right) + \sigma_{r,\xi_t^{vo}} \epsilon_t^r \tag{A.20}$$

QE policy shock

$$b_t = \rho_1^b b_{t-1} + \rho_2^b b_{t-2} + \epsilon_t^b \tag{A.21}$$

A.1 Exogenous stochastic processes

Table 8: Log-linearized stochastic exogenous processes

Description	**Shock**	**Process**
Intertemporal preferences shock	ε_{rn}	$rn = \rho_{rn} rn_{t-1} + \sigma_{rn,\xi_t^{vo}} \varepsilon_{rn,t}$
Desired markup of wages shock	ε_{mkw}	$\lambda_{w,t} = \rho_w \lambda_{w,t-1} + \sigma_{mkw,\xi_t^{vo}} \varepsilon_{mkw,t}$
Credit shock	ε_{ψ_n}	$\psi_t = \rho_\phi \psi_{t-1} + \sigma_{\psi,\xi_t^{vo}} \varepsilon_{\psi,t}$
Technology process	ε_a	$a_t = \rho_a a_{t-1} + \sigma_{a,\xi_t^{vo}} \varepsilon_{a,t}$
Investment shock	ε_i	$\mu_t = \rho_\mu \mu_{t-1} + \sigma_{\mu,\xi_t^{vo}} \varepsilon_{\mu,t}$
Monetary Policy Response	ε_{mp}	$mp_t = \rho_m mp_{t-1} + \sigma_{mp,\xi_t^{vo}} \varepsilon_{mp,t}$
Desired markup prices process	ε_{mk}	$mk_t = \rho_{mk} mk_{t-1} + \sigma_{mk,\xi_t^{vo}} \varepsilon_{mk,t}$

A.2 Variables description

Table 9: List of variables in log-linearized model

Variable	Description
p_t^k	Real price of capital
c_t	Level of consumption
i_t	Level of investment
mrs_t	Marginal Rate of Substitution
π_t	Gross inflation
π_t^w	Inflation on wages
w_t	Real wage
r_t	Interest rate
r_t^{10}	Return on a 10-year Bond
m_t	Segmentation distortion/mark-up on the price on new capital goods
r_t^k	Real rental rate
r_t^L	Active interest rate
s	Presence of adjustment cost in investment
q_t	Time-t price of a new issue
f_t	Finance investment bonds
R_{ss}^L	Steady sate lending rate
L_{ss}	Steady state leverage level
$\overline{B}_{ss}$	Steady state long-term government bonds
$\overline{N}_{ss}$	Steady state FI's net worth
n_t	FI's Net worth
l_t	Leverage level
mc_t	Firms' Marginal Cost
mpl_t	Marginal price of labor
mpk_t	Marginal price of capital
I_{ss}	Steady state investment level
Y_{ss}	Steady state output level
k_t	FI's accumulation of physical capital