Limited Borrowing Capacity of Financial Intermediaries and the Equity Premium*

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Abstract

This paper investigates the relationship between financial intermediaries' limited borrowing capacity and the equity premium in a production economy. We consider a medium-scale New Keynesian model, featuring an agency problem between financial intermediaries and their private creditors, and generalized recursive preferences. The model considers not only the linkages between banking frictions with the macroeconomy, but also with financial markets. The findings show that banking frictions associated with the agency problem generate a plausible and novel enhancing mechanism for the equity premium. In the benchmark setting, banking frictions increase the level of the equity premium substantially and the model produces a fourfold greater response to shocks compared to the case of no banking frictions. The paper also finds that the interaction between monetary policy and banking frictions plays a crucial role in determining the dynamics of the equity premium.

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1 Introduction

Macroeconomic models with financial frictions have received substantial attention after the recent financial crisis. Financial frictions introduce a wedge between lenders and borrowers that amplifies business cycle fluctuations in macroeconomic models. With negative shocks, the amplification mechanism is driven by the disruption of asset value that reduces the borrowing capacity of financial intermediaries. As the producers' financing reduces, economic production further declines, creating a vicious cycle that intensify the recession. While the macroeconomic literature has examined how limited borrowing capacity of financial intermediaries affects business cycle fluctuations (e.g., Gertler and Karadi, 2011; and Gertler and Kiyotaki, 2015), few studies addressed its implications on the asset pricing.

This paper investigates the links between limited borrowing capacity of financial intermediaries due to an agency problem and the equity premium in a production economy. To this end, we consider a medium-scale New Keynesian dynamic stochastic general equilibrium (DSGE) model incorporating banking frictions in the spirit of Gertler and Karadi (2011). The model we present here, however, includes generalized recursive preferences, which enables distinction of high risk aversion from the intertemporal elasticity of substitution and, thus, resolving the risk-free rate puzzle of Weil (1989). As far as we know, this is the first paper to study the relationship between banking frictions and asset pricing.

The main findings are as follows. First, banking frictions make a significant contribution to the size of the equity premium. The equity premium rises by 45 basis points with banking frictions, which accounts for a sizable fraction of the observed data. Second, the model produces a fourfold greater response of the equity premium to a negative technology shock compared to the case of no banking frictions. Third, the dynamics of the equity premium are affected by the interaction between monetary policy and banking frictions.

The intuition for the amplification mechanism of limited borrowing capacity of financial intermediaries is straightforward. In response to a negative technology shock, the marginal productivity of capital decreases and this leads to a lower capital return. The net worth of financial intermediaries then declines because the return to capital is the only source of profits for the bank in the model. A decline in net worth weakens the borrowing capacity of financial intermediaries, reducing the supply of loan and the demand for capital. In turn, it leads to a decline in the price of capital, which further reduces capital returns and lowers the net worth of financial intermediaries. This amplification mechanism increases the volatility of consumption and the stochastic discount factor, leading to a rise in the equity premium.

Banking frictions not only generate a deeper recession but also attenuate the rise of inflation in response to a negative technology shock. The deeper recession puts a downward pressure on the nominal interest rate. Accordingly, the nominal interest rate rises less than expected inflation, leading to a decline in the real risk-free interest rate. In contrast, the negative technology shock can even cause the real risk-free rate to rise when banking frictions are absent and monetary policy is conducted by a Taylor rule without interest rate smoothing. Since the real risk-free rate is a key determinant of business cycle fluctuations and the stochastic discount factor, the interaction between monetary policy and banking frictions plays an important role in accounting for the dynamics of the equity premium.[1]

Our findings have important implications for both macroeconomics and finance. Traditionally, to capture sufficiently large risk premia, previous studies increase the quantity of risk in the model: for example, through model uncertainty (e.g., Weitzman, 2007; and Barillas, Hansen, and Sargent, 2009), long-run risk (e.g., Bansal and Yaron, 2004; and Croce, 2014), rare disasters (e.g., Rietz, 1988; Barro, 2006; and Gourio, 2012), or heterogeneous agents (e.g., Constantinides and Duffie, 1996; and Schmidt, 2015).[2] This paper differs from these previous studies in that we attempt to expand the understanding of the interaction between the macroeconomy and financial markets by analyzing the effect of banking frictions on the equity premium.[3]

[1]The equity premium is defined as the difference between the real equity return and the real risk-free rate.

[2]More recently, there have been attempts to solve the equity premium puzzle through various methods such as wage rigidities, price rigidities, and deep habits (e.g., Favilukis and Lin, 2016; Weber, 2015; and van Binsbergen, 2016).

[3]It is natural to relate rare disasters to banking crises as experienced in the Great Recession and the Great Depression. Bank runs are not modeled in this paper due to multiple equilibria issues, which cannot be solved using perturbation methods. In spite of the fact, our findings show that time-varying limited borrowing capacity of financial intermediaries due to the agency problem can contribute to the equity premium both quantitatively and qualitatively. It is worth mentioning that while the banking friction model here endogenously amplifies the effect of technology shocks, the approach modeling exogenous rare disasters explores a negatively skewed distribution for technology shocks.

This paper is closely related to two strands of the literature. One strand studies the impact of financial frictions on business cycle fluctuations. Kiyotaki and Moore (1997) and Bernanke, Gertler, and Gilchrist (1999, henceforth BGG) focusing on firms' limited borrowing capacity are the most fundamental studies of this field. More recently, Gertler and Karadi (2011) and Gertler and Kiyotaki (2015) investigate the role of financial intermediaries' borrowing constraints in accounting for the recent financial crisis. The other strand of the literature initiated by the seminal paper of Tallarini (2000) considers generalized recursive preferences in a standard macroeconomic model for asset pricing. In recent papers, Campanale, Castro, and Clementi (2010) and Swanson (2016) study whether macroeconomic models with generalized recursive preferences are able to generate substantial risk premia without distorting their ability to match macroeconomic facts. This paper takes the key ingredients from these two strands of literature for asset pricing. The model we consider includes banking frictions and generalized recursive preferences. With this framework, we investigate not only the effect of banking frictions on the macroeconomy, but also on the equity premium dynamics.

A number of recent studies examine implications of firms' limited borrowing capacity for asset pricing. Gomes, Yaron, and Zhang (2003) explore a model based on Carlstrom and Fuerst (1997) to study implications of firms' borrowing constraints on asset pricing, while Nezafat and Slavík (2015) and Bigio and Schneider (2017) study how firms' liquidity constraints affect asset pricing using the model of Kiyotaki and Moore (2012). These papers find that models with financial frictions produce a higher equity premium, but counterfactual movements in the equity price or the equity premium.[4] Our paper differs from the previous studies in that we examine the impact of banking frictions, instead of firms' borrowing constraints on the equity premium and show that a shock driving an economic downturn generates a procyclical response of the equity price and a countercyclical response of the equity premium as observed in the data.

Our paper focuses on the study of how financial intermediaries' borrowing constraints affect the

[4]See Shi (2015) for the detailed discussion of the counterfactual response. Livdan, Sapriza, and Zhang (2009, henceforth LSZ) also report that more financially constrained firms have higher average equity returns. Their approach considers a partial equilibrium model with collateral constraints following Kiyotaki and Moore (1997). This paper differs from LSZ in that we analyze the impact of banking frictions both on the equity premium dynamics and on the economy using a general equilibrium model.

equity premium. In this regard, He and Krishnamurthy (2013) is close in spirit to our paper. They consider an overlapping generation model incorporating financial intermediaries, which are subject to equity financing constraints. Using the model, they investigate how financial intermediaries' constraints on equity financing affect risk premia on mortgage-backed securities in an endowment economy. Unlike He and Krishnamurthy (2013), we focus on intermediaries' debt financing constraints rather than equity financing constraints and on pricing equity securities rather mortgage-backed securities. This paper also differs from He and Krishnamurthy (2013) in that our model considers a production economy, instead of an endowment economy, with real and nominal frictions, which is useful to investigate the dynamic relationship between household's stochastic discount factor and asset pricing.

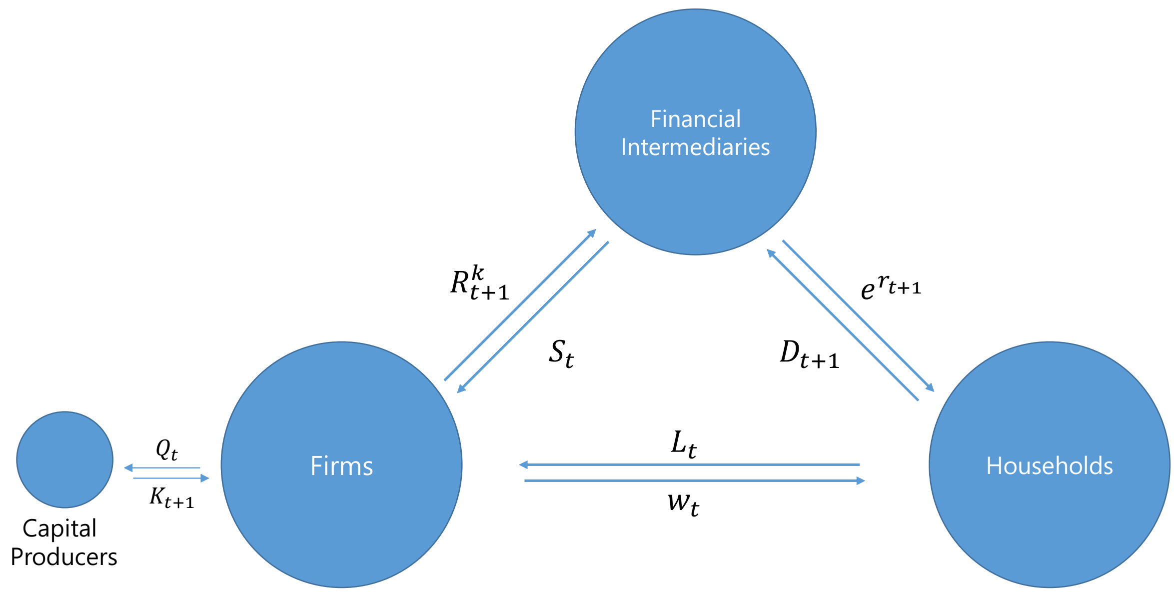
The organization of the paper is as follows. Section 2 describes the baseline model with limited borrowing capacity of financial intermediaries and generalized recursive preferences. Section 3 lays out the calibration results. Sections 4 presents additional discussion and extensions. Section 5 concludes.

2 The Baseline Model

In this section, we begin by outlining a medium-scale New Keynesian DSGE model and use it to price equity. The model has two important ingredients: limited borrowing capacity of financial intermediaries (e.g., Gertler and Karadi, 2011) and generalized recursive preferences (e.g., Tallarini, 2000; and Swanson, 2016). Agency problems in financial intermediaries constrain the ability of financial intermediaries to obtain funds and allow the model to have the feedback between the financial market and the economy. Generalized recursive preferences allow the model to match the size of the equity premium in the data.

Figure 1 displays the building blocks of the model. There are four types of agents in the model: households, financial intermediaries, non-financial firms, and capital producers. In order to produce output, non-financial firms purchase capital from capital producers and hire labor from households.

Figure 1: STRUCTURE OF THE MODEL



Firms issue security claims, S_t, to buy capital, K_{t+1}, and pay the gross rate of return, R^k_{t+1}, to financial intermediaries. Households deposit funds, D_t, in financial intermediaries and receive the risk-free return on deposits, $e^{r_{t+1}}$. Finally, the price of capital, Q_t, is endogenously determined by capital demand from non-financial firms and supply from capital producers.

2.1 Households

There is a unit continuum of identical households. Each household is endowed with generalized recursive preferences as in Epstein and Zin (1989) and Weil (1989). For simplicity, we employ the additive separability assumption for period utility.[5]

[5] Van Binsbergen et al. (2012) use Cobb-Douglas preferences since they consider consumption and leisure as a composite good.

$$u(c_t, l_t) = \left(c_t^{\nu}(1-l_t)^{1-\nu}\right)^{\frac{1-\gamma}{\theta}}$$

In this case, the stochastic discount factor is a bit more complicated. On the other hand, the additive separability assumption facilitates a simpler stochastic discount factor which is affected by the growth of consumption rather than the composite good.

$$u\left(c_t,\, l_t\right) \equiv \log c_t - \chi_0 \frac{l_t^{1+\chi}}{1+\chi}, \tag{1}$$

where c_t is household consumption, l_t is labor in period t, and $\chi_0 > 0$ is the relative weight on labor in the utility function, and $\chi > 0$ is the inverse Frisch elasticity of labor supply. The assumption of the logarithmic period utility for consumption allows a balanced growth path and a unit intertemporal elasticity of substitution as in King and Rebelo (1999).[6] Households deposit in financial intermediaries to earn the continuously-compounded risk-free interest rate, and provide labor to non-financial firms for wages.[7] The household's budget constraint is given by:

$$c_t + \frac{d_{t+1}}{P_t} = w_t l_t + e^{i_t} \frac{d_t}{P_t} + \Pi_t, \tag{2}$$

where d_t is deposits, P_t is the aggregate price level, w_t is the real wage, e^{i_t} is the nominal gross risk-free return from deposits, and Π_t is the household's share of profits in the economy.

Following Hansen and Sargent (2001) and Swanson (2016), we assume that the household has multiplier preferences.[8] In every period, the household faces the budget constraint (2) and maximizes lifetime utility with the no-Ponzi game constraint. The household's value function $V^h\left(d_t; \Theta_t\right)$ satisfies the Bellman equation:

[6] This paper does not consider habit in consumption. As Lettau and Uhlig (2000) and Rudebusch and Swanson (2008) point out, habit-based DSGE models cannot fit the term premium in a production economy because habit preferences generate "super" consumption smoothing.

[7] Using continuous compounding is convenient for equity pricing and comparison with the finance literature.

[8] Rudebusch and Swanson (2012) use a generalized Epstein-Zin-Weil specification with nonnegative period utility:

$$V_t = u(c_t,\, l_t) + \beta \left(E_t V_{t+1}^{1-\alpha}\right)^{\frac{1}{1-\alpha}}$$

which is similar to expected utility preferences except "twisted" and "untwisted" by the factor $1-\alpha$. Note that the expected utility preferences are the special cases of generalized recursive preferences when $\alpha = 0$. The household's intertemporal elasticity of substitution is the same as that of the expected utility preferences, but risk aversion can be amplified or attenuated by the additional curvature parameter α when $\alpha \neq 0$. Although this form is convenient to interpret, an Epstein-Zin-Weil specification depends on the sign of period utility $u\left(\cdot\right)$. Therefore, Hansen and Sargent (2001) and Swanson (2016) consider multiplier preferences as they are free from the sign of period utility. When $\rho \to 0$, multiplier preferences can be obtained from the specification in Epstein and Zin (1989):

$$U_t = \left[\tilde{u}(c_t,\, l_t)^{\rho} + \beta \left(E_t U_{t+1}^{\tilde{\alpha}}\right)^{\frac{\rho}{\tilde{\alpha}}}\right]^{\frac{1}{\rho}}.$$

$$V^h(d_t;\Theta_t) = \max_{c_t,\, l_t \in \Gamma} (1-\beta)\, u(c_t,\, l_t) - \beta\alpha^{-1} \log\left[E_t \exp\left(-\alpha V^h(d_{t+1};\Theta_{t+1})\right)\right], \tag{3}$$

where Γ is the choice set for c_t and l_t, Θ_t is the state of the economy, β is the household's time discount factor, and α is a parameter. Risk aversion is closely related to the Epstein-Zin parameter α which amplifies risk aversion by including the additional risk for the lifetime utility of households.[9] The household's stochastic discount factor is given by[10]

$$m_{t+1} = \beta \frac{c_t}{c_{t+1}} \frac{\exp\left(-\alpha V^h(d_{t+1};\Theta_{t+1})\right)}{E_t \exp\left(-\alpha V^h(d_{t+1};\Theta_{t+1})\right)}. \tag{4}$$

The first order necessary conditions for deposit and labor are given by:

$$d_{t+1}: \;\; 1 = E_t\left(m_{t+1} e^{i_{t+1}} \frac{1}{\pi_{t+1}}\right), \tag{5}$$

$$l_t: \;\; \chi_0 l_t^{\chi} \left(\frac{1}{c_t}\right)^{-1} = w_t, \tag{6}$$

where $\pi_{t+1} \equiv P_{t+1}/P_t$ is the inflation rate.

Then, the one-period continuously-compounded risk-free real interest rate, r_{t+1}, is given by

$$e^{-r_{t+1}} = E_t m_{t+1}, \tag{7}$$

where $e^{r_{t+1}} \equiv e^{i_{t+1}} \frac{1}{\pi_{t+1}}$.

2.2 Financial Intermediaries

There is a unit continuum of risk neutral bankers, and each banker runs a financial intermediary.

[9] Precisely, we hold $R^c = \alpha + \left(1 + \frac{\chi_0}{\chi}\right)^{-1}$ for the case with period utility as (1). This closed-form expression considers both consumption and labor which provides additional cushion to the household against the negative shock.

[10] The household's optimization problem with generalized recursive preferences can be solved using the standard Lagrangian method. See Rudebusch and Swanson (2012) for more detail.

Following Gertler and Karadi (2011), the financial intermediaries lend funds to non-financial firms by using their own net worth and deposits from households, and the presence of agency problems between bankers and depositors constrains the ability of financial intermediaries to obtain deposits from households. It is assumed that only a fraction σ of bankers remain in the financial industry until the next period, while the remaining fraction $(1-\sigma)$ retire and consume their net worth when they leave. This assumption prevents financial intermediaries from accumulating sufficient net worth, forcing them to borrow from households in equilibrium.

The financial intermediary's asset, $Q_t s_t$, thus, is financed by equity capital (net worth) and deposits. The financial intermediary's balance sheet constraint is given by

$$Q_t s_t = n_t + d_{t+1}, \tag{8}$$

where Q_t is the relative price of financial claims on firms, s_t is the quantity of claims, d_t is the deposits of households and n_t is the intermediary's net worth.

To introduce the intermediary's limited borrowing capacity, as in Gertler and Karadi (2011), we assume that there are moral hazard problems between the banker and depositors: the banker diverts a fraction ϑ of assets for personal use after deposits are collected. Accordingly, the following incentive constraint must hold for households not to withdraw their deposits from the financial intermediary:

$$V_t^b \geq \vartheta Q_t s_t, \tag{9}$$

where V_t^b is the franchise value of the financial intermediary, which is the present discounted value of future gains from operating honestly. As long as the franchise value V_t^b exceeds the gain from diverting a fraction of assets, households decide to keep their deposits in the financial intermediary.

The risk neutral banker's objective is to maximize its net worth at the exit period:

$$\max V_t^b = E_t \left[\sum_{j=1}^{\infty} \beta^j (1-\sigma) \sigma^{j-1} n_{t+j} \right]. \tag{10}$$

The financial intermediary's terminal wealth, n_{t+j}, is consumed by the banker in the exit period.[11] That is, the banker's consumption, c^b_{t+j}, is equal to n_{t+j} when he exits the financial sector. (10) can be written in the first-order recursive form:

$$V_t^b = \beta E_t \left[(1-\sigma) n_{t+1} + \sigma V_{t+1}^b \right]. \tag{11}$$

The franchise value, V_t^b, is the discounted weighted average of the expected value of net worth and the expected future franchise value V_{t+1}^b. The franchise value at $t+1$ is n_{t+1} when exiting, while it is $V_{t+1}^b = \beta E_{t+1} \left[(1-\sigma) n_{t+2} + \sigma V_{t+2}^b \right]$ when continuing.

The net worth of a surviving banker in the next period is defined as the earnings from bank assets net of the cost of debts:

$$\begin{aligned} n_{t+1} &= R_{t+1}^k Q_t s_t - e^{r_{t+1}} d_{t+1} \\ &= \left(R_{t+1}^k - e^{r_{t+1}} \right) Q_t s_t + e^{r_{t+1}} n_t, \end{aligned} \tag{12}$$

where R_{t+1}^k is the ex-post gross return of capital. The net worth evolves according to (12). Then, the growth rate of net worth can be written as:

$$\frac{n_{t+1}}{n_t} = \left(R_{t+1}^k - e^{r_{t+1}} \right) \phi_t + e^{r_{t+1}}, \tag{13}$$

where $\phi_t \equiv \frac{Q_t s_t}{n_t}$ is the "leverage multiple." As long as the spread, $R_{t+1}^k - e^{r_{t+1}}$, is positive, the banker is willing to borrow from depositors to maximize the franchise value of the financial intermediary. However, the agency problem constraints the intermediary's ability to raise funds from households, preventing the spread from converging to zero.

[11] For tractability, the financial intermediary is assumed to be risk neutral as in BGG and Gertler and Kiyotaki (2015). So, the bankers discount net worth with β rather than the household's stochastic discount factor m_{t+j}.

The financial intermediary's problem can be summarized as:

$$\begin{aligned}\frac{V_t^b}{n_t} &= \max_{\phi_t} E_t\left[\beta\left((1-\sigma)+\sigma\frac{V_{t+1}^b}{n_{t+1}}\right)\left(\left(R_{t+1}^k - e^{r_{t+1}}\right)\phi_t + e^{r_{t+1}}\right)\right] \\ &= \max_{\phi_t} \mu_t\phi_t + \nu_t\end{aligned} \tag{14}$$

where $\mu_t \equiv \beta E_t \Omega_{t+1}\left(R_{t+1}^k - e^{r_{t+1}}\right)$ is the expected discounted excess return of assets over deposits, $\nu_t \equiv \beta E_t \Omega_{t+1} e^{r_{t+1}}$ is the expected discounted marginal cost of deposits, and $\Omega_{t+1} \equiv (1-\sigma)+\sigma\frac{V_{t+1}^b}{n_{t+1}}$ is the weighted average of the franchise values of exiting and remaining bankers per unit of net worth. The $\frac{V_t^b}{n_t}$ can be interpreted as Tobin's q ratio (e.g., Gertler and Kiyotaki 2015). The banker is willing to increase the leverage multiple ϕ_t to maximize its franchise value per unit of net worth subject to the incentive constraint

$$\frac{V_t^b}{n_t} \geq \vartheta\phi_t. \tag{15}$$

Accordingly, the financial intermediary's franchise value is maximized when the incentive constraint (15) binds. This maximization problem yields the leverage multiple:

$$\phi_t = \frac{\nu_t}{\vartheta - \mu_t}, \tag{16}$$

when the expected discounted marginal gain from honestly managing assets, μ_t, is less than the fraction ϑ of assets diverted by the banker. Since the determinants of the leverage multiple ϕ_t are the same across financial intermediaries, the relationship between total financial assets and total net worth in the financial industry is given by

$$Q_t S_t = \phi_t N_t, \tag{17}$$

where S_t is the aggregate quantity of claims and N_t is the aggregate net worth.

The aggregate net worth consists of two components. The first is the net worth of surviving financial intermediaries, $\sigma\left(R_t^k Q_{t-1}S_{t-1} - e^{r_t}D_t\right)$. The second corresponds to seed money, $\omega Q_t S_{t-1}$, that an entering banker receives from their respective households. This seed money is a small fraction, ω, of the assets of exiting financial intermediaries. Accordingly, the aggregate net worth of the entire financial sector is

$$N_t = \sigma \left(R_t^k Q_{t-1} S_{t-1} - e^{r_t} D_t \right) + \omega Q_t S_{t-1}, \tag{18}$$

where D_t is the aggregate deposit.

Lastly, the aggregate consumption level of exiting bankers, C_t^b, is equal to the fraction $(1-\sigma)$ of net earnings on assets:

$$C_t^b = (1-\sigma) \left[R_t^k Q_{t-1} S_{t-1} - e^{r_t} D_t \right]. \tag{19}$$

2.3 Firms

2.3.1 Non-Financial Firms

Final good Y_t is produced by combining a continuum of intermediate goods indexed by $f \in [0,1]$ using the following production function:

$$Y_t = \left(\int_0^1 y_t(f)^{\frac{1}{1+\theta}} df \right)^{1+\theta}, \tag{20}$$

where $y_t(f)$ is an intermediate good, and $\theta > 0$ is a parameter that captures the nonstochastic steady state markup. The final goods firms are perfectly competitive. The zero profit condition yields a downward sloping demand curve for each intermediate good:

$$y_t(f) = \left(\frac{p_t(f)}{P_t} \right)^{-\frac{1+\theta}{\theta}} Y_t, \tag{21}$$

where P_t is the CES aggregate price of the final good:

$$P_t = \left(\int_0^1 p_t(f)^{-\frac{1}{\theta}} df \right)^{-\theta}, \tag{22}$$

which can be derived from the zero-profit condition and the demand curve.

The economy contains a continuum of intermediate goods producing firms. The production function for intermediate goods is given by:

$$y_t(f) = A_t k_t(f)^{1-\eta} l_t(f)^{\eta}, \tag{23}$$

where $k_t(f)$ and $l_t(f)$ are firm f's capital and labor inputs, respectively. $\eta \in (0,1)$ denotes the elasticity of output with respect to labor. A_t is total factor productivity which follows an exogenous AR(1) process:

$$\log A_t = \rho_A \log A_{t-1} + \epsilon_t^A, \tag{24}$$

where $\rho_A \in (-1, 1]$, and ϵ_t^A follows an $i.i.d.$ white noise process with mean zero and variance σ_A^2. We set $\rho_A = 1$ for comparability to the asset pricing literature (e.g., Tallarini, 2000; and Swanson, 2016). The intermediate goods firm issues claims, s_t, to financial intermediaries to purchase capital from capital producers and pays the gross return of capital, R_{t+1}^k, to financial intermediaries. For simplicity, we assume that the firm resells the remaining capital to the capital producer at the end of each period.[12] Given the demand function and the production function, the intermediate goods firm chooses labor, $l_t(f)$, and capital, $k_t(f)$ to minimize the cost of production. The first order necessary conditions are:

$$l_t(f): \;\; w_t P_t = \varphi_t(f) \eta A_t \left(\frac{k_t(f)}{l_t(f)} \right)^{1-\eta}, \tag{25}$$

$$k_t(f): \;\; R_t^k P_t Q_{t-1} - Q_t P_t (1-\delta) = \varphi_t(f)(1-\eta) A_t \left(\frac{k_t(f)}{l_t(f)} \right)^{-\eta}, \tag{26}$$

where $\varphi_t(f)$ is the Lagrange multiplier of the cost minimization problem, and δ denotes the depreciation rate of capital. The term $Q_t P_t (1-\delta)$ in (26) is the value of the remaining capital stock from the previous period. Combining the first order conditions yields the capital-labor ratio:

[12] This assumption prevents the firm from accumulating capital so that it results in the conventional equation for R_{t+1}^k as given by (30).

$$\frac{k_t(f)}{l_t(f)} = \frac{1-\eta}{\eta}\frac{w_t}{R_t^k Q_{t-1} - Q_t(1-\delta)}. \tag{27}$$

Since the capital-labor ratio is the same for all firms as shown in (27), we hold:

$$\frac{k_t(f)}{l_t(f)} = \frac{K_t}{L_t}, \tag{28}$$

where K_t is the aggregate capital stock and L_t is the aggregate quantity of labor. Marginal cost is the same across firms since every firm chooses capital and labor in the same way. Let $mc_t(f) \equiv \frac{\varphi_t(f)}{P_t}$ be the real marginal cost. Then, $mc_t(f) = MC_t$ for all f. The real marginal cost is given by:

$$MC_t = \frac{1}{A_t} w_t^\eta \left(R_t^k Q_{t-1} - (1-\delta)Q_t\right)^{1-\eta} \left(\frac{1}{\eta}\right)^\eta \left(\frac{1}{1-\eta}\right)^{1-\eta}. \tag{29}$$

Therefore, the demand functions for capital and labor are as follows:

$$R_{t+1}^k = \frac{MC_{t+1}\left(1-\eta\right)A_{t+1}\left(\frac{K_{t+1}}{L_{t+1}}\right)^{-\eta} + \left(1-\delta\right)Q_{t+1}}{Q_t}, \tag{30}$$

$$w_t = MC_t \eta A_t \left(\frac{K_t}{L_t}\right)^{1-\eta}. \tag{31}$$

Each intermediate goods firm sets the new contract price $P_t(f)$ to maximize the firm's lifetime profit in a staggered fashion: only a fraction, $1-\xi$, of firms are able to adjust its price optimally each period, while the remaining firms index their prices to the steady state inflation rate. Hence, the real value of the firm is given by:

$$\max_{P_t(f)} E_t \sum_{j=0}^{\infty} m_{t,t+j}\xi^j \left[\left(P_t(f)e^{j\bar{\pi}}y_{t+j}(f) - mc_{t+j}^n(f)y_{t+j}(f)\right)/P_{t+j}\right], \tag{32}$$

where $m_{t,t+j} \equiv \Pi_{i=1}^j m_{t+i}$ is the stochastic discount factor of the household from period t to $t+j$, $\bar{\pi}$ is the steady-state inflation rate, and $mc_t^n(f)$ is firm-specific nominal marginal cost.

The first order necessary condition of (32) with respect to $P_t(f)$ yields the optimal price given by:

$$p_t^*(f) = \frac{(1+\theta)E_t \sum_{j=0}^{\infty} m_{t,t+j}\xi^j MC_{t+j} P_{t+j}^{\frac{1+\theta}{\theta}} Y_{t+j}}{E_t \sum_{j=0}^{\infty} m_{t,t+j}\xi^j P_{t+j}^{\frac{1}{\theta}} Y_{t+j} e^{j\bar{\pi}}} \tag{33}$$

where $p_t^*(f) \equiv P_t^*(f)/P_t$. Note that the optimal price $p_t^*(f)$ is a markup over a weighted average of current and expected future marginal costs.

2.3.2 Capital Producers

Lastly, there is a continuum of representative capital producers. They produce new capital using the final output at price unity subject to convex adjustment costs and sell it to intermediate goods firms at price Q_t. The capital producer chooses new capital, I_t, to maximize the sum of expected discounted profits over her lifetime:

$$\max_{I_t} E_t \sum_{j=0}^{\infty} m_{t,t+j} \left\{ \left(Q_{t+j} - 1\right) I_{t+j} - \frac{\kappa}{2}\left(\frac{I_{t+j}}{I_{t+j-1}} - 1\right)^2 I_{t+j} \right\}, \tag{34}$$

where the parameter κ determines the size of the adjustment.[13] Given zero investment adjustment costs, $\kappa = 0$, the capital producer would produce infinite capital if $Q_t > 1$. The presence of the adjustment cost yields the gradual movement of capital.

The first order necessary condition with respect to I_t yields:

$$Q_t = 1 + \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 + \kappa\left(\frac{I_t}{I_{t-1}} - 1\right)\left(\frac{I_t}{I_{t-1}}\right) - E_t m_{t,t+1}\kappa\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2, \tag{35}$$

which is the supply of new capital.

[13] At the end of each period, the capital producer purchases the remained captial at price Q_t and sells old captial along with new capital at the same price. This assumption yields the conventional objective function of the captial producer (Gertler, Kiyotaki, and Queralto, 2012) and the captial demand equation, (30)

2.4 Aggregate Resource Constraints and Monetary Policy

We keep the model as simple as possible by considering technology shocks only. According to Rudebusch and Swanson (2012), the response of the term premium to a technology shock shows a greater response by a factor of 250 and 625 than to a monetary policy shock or a government spending shock, respectively. For the same reason, Tallarini (2000), Gomes, Yaron, and Zhang (2003), and Swanson (2016) also did not consider any exogenous shock other than a technology shock.

Combining the downward sloping demand curve and the production function yields the aggregate output:

$$Y_t = \triangle_t^{-1} A_t K_t^{1-\eta} L_t^{\eta}, \tag{36}$$

where $\triangle_t \equiv \int_0^1 \left(\frac{p_t(f)}{P_t}\right)^{-\frac{1+\theta}{\theta}} df$ denotes the cross-sectional price dispersion.

Monetary policy is conducted by à la Taylor rule with interest-rate smoothing:

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[r + \log \pi_t + \phi_\pi (\log \pi_t - \log \bar{\pi}) + \frac{\phi_y}{4}(y_t - \bar{y}_t)\right], \tag{37}$$

where $\rho_i \in (0,1)$ is the smoothing parameter, $r = \log(1/\beta)$ is the continuously compounded real interest rate in steady state, π_t is the inflation rate, $\bar{\pi}$ is the target inflation of the monetary authority, y_t is the log of output Y_t, and $\bar{y}_t$ is a trailing moving average of y_t:

$$\bar{y}_t = \rho_{\bar{y}} \bar{y}_{t-1} + (1-\rho_{\bar{y}})\, y_t, \tag{38}$$

where ϕ_π, $\phi_y \in \mathbb{R}$ and $\rho_{\bar{y}} \in [0,1)$ are parameters. As suggested by Swanson (2016), the term $(y_t - \bar{y}_t)$ in (37) is an empirically motivated measure of the output gap. In practice, the central bank adjusts the short term nominal interest rate when the output deviates from its recent history.

Finally, the economy-wide resource constraint is given by:

$$Y_t = C_t + C_t^b + \left\{ 1 + \frac{\kappa}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right\} I_t, \tag{39}$$

where $C_t = c_t$ denotes the aggregate consumption of households.

2.5 The Equity Premium

We follow the conventional asset pricing theory using the stochastic discount factor obtained from the model (e.g., Mehra and Prescott, 1985; and Cochrane, 2009). In addition, we model stocks as levered claims on the aggregate consumption following Abel (1999), Gourio (2012), Campbell et al. (2014), and Swanson (2016). In every period, the equity pays a dividend, which is equal to C_t^{υ}. As pointed out by Swanson (2016), the parameter υ can be interpreted as capturing broad leverage in the economy, including operational and financial leverage.[14] Operational leverage arises from fixed production costs of firms (Gourio, 2012; and Campbell et al., 2014).[15]

The price of an equity security in equilibrium is given by:

$$p_t^e = E_t \left(m_{t+1} \left(C_{t+1}^{\upsilon} + p_{t+1}^e \right) \right), \tag{40}$$

where p_t^e denotes the ex-dividend price of an equity at time t. Let R_{t+1}^e be the ex-post gross return on equity, $R_{t+1}^e \equiv \frac{C_{t+1}^{\upsilon} + p_{t+1}^e}{p_t^e}$. Then, (40) is equivalent to

$$1 = E_t \left(m_{t+1} R_{t+1}^e \right), \tag{41}$$

which is the same form as the intertemporal Euler equation.

We define the equity premium as the difference between the expected real return to equity and the

[14] The dividend is defined as a levered consumption claim. This definition of dividend captures the fact that firms finance their investment by issuing both equity and debt in the economy. Our results do not change when dividend is modeled on the basis of the profit of the monopolistic intermediate goods producer. It is because dividend is highly correlated with consumption in the model.

[15] The degree of leverage is positively associated with fixed production costs.

risk-free rate, $\psi_t^e \equiv E_t R_{t+1}^e - e^{r_{t+1}}$. By the definition of covariance, (41) is equivalent to

$$E_t\left(m_{t+1} R_{t+1}^e\right) = \text{Cov}_t\left(m_{t+1}, R_{t+1}^e\right) + E_t m_{t+1} E_t R_{t+1}^e \tag{42}$$

where Cov_t denotes the conditional covariance. Using (7) and (42), and dividing both sides by $E_t m_{t+1}$ yields,

$$\psi_t^e = -\text{Cov}_t\left(\frac{m_{t+1}}{E_t m_{t+1}}, R_{t+1}^e\right) \tag{43}$$

The equity premium is thus sensitive to any changes in the consumption, even at a distant period. Recall that the household's stochastic discount factor is comprised of the consumption and the value function, V_t^h, that is the infinite sum of discounted future period utilities.

2.6 Solution Method

We solve the medium-scale dynamic stochastic general equilibrium model using a third-order perturbation method based on the algorithm of Swanson, Anderson, and Levin (2006). We use this solution method for three reasons. First, the model with banking frictions has many state variables including A_{t-1}, $\triangle_{t-1}$, D_{t-1}, I_{t-1}, i_{t-1}, K_{t-1}, r_{t-1}, and $\bar{y}_{t-1}$. Due to high dimensionality, projection methods are not computationally tractable. Second, a third-order perturbation shows almost the same performance as projection methods for models with generalized recursive preferences, but with much faster computing time (Caldara, Fernández-Villaverde, Rubio-Ramírez, and Yao, 2012). Lastly, a third-order perturbation is necessary to capture the dynamics of the risk premia, such as the impulse-response analysis of the equity premium.

Table 1: BASELINE CALIBRATION

Parameters	Value	Descriptions	Source
β	0.9925	Discount rate	
χ_0	0.79	Relative utility weight of labor	To normalize $L = 1$
χ	3	Inverse Frisch elasticity of labor supply	Del Negro et al. (2015)
R^c	60	Relative risk aversion	Swanson (2016)
η	0.6	Labor share	
δ	0.025	Depreciation rate	
θ	0.1	Monopolistic markup	Smets and Wouters (2007)
ξ	0.8	Calvo contract parameter	Altig et al. (2011)
ρ_A	1	Persistence of technology	Tallarini (2000)
σ_A	0.007	Standard deviation of technology shocks	King and Rebelo (1999)
κ	3	Elasticity of investment adjustment cost	Del Negro et al. (2015)
ϑ	0.19	Seizure rate	Gertler and Kiyotaki (2015)
ω	0.002	Proportional transfer to new bank	Gertler and Karadi (2011)
σ	0.95	Survival probability of bank	Gertler and Kiyotaki (2015)
ρ_i	0.73	Smoothing parameter of monetary policy	Rudebusch (2002)
ϕ_π	0.53	Response of monetary policy to inflation	Rudebusch (2002)
ϕ_y	0.93	Response of monetary policy to output	Rudebusch (2002)
$\bar{\pi}$	0.008	The monetary authority's inflation target	Swanson (2016)
$\rho_{\bar{y}}$	0.9	Coefficient of trailing moving average	Swanson (2016)
υ	3	Degree of leverage	Abel (1999)

3 Model Analysis

3.1 Calibration

Table 1 presents the choice of parameter values for the baseline model with banking frictions. There are twenty parameters in the baseline model. As can be seen in Table 1, the parameter values are fairly standard in the literature.

For the household's discount factor, β, the depreciation rate, δ, and the elasticity of output with respect to labor, η, we use conventional values. We set the relative utility weight of labor, $\chi_0 = 0.79$, to normalize the steady state labor, L, to unity. We choose a relatively high risk aversion of $R^c = 60$ because the quantity of risk is very small in the model. Tallarini (2000), Rudebusch and Swanson (2012) and Swanson (2016) consider 100, 75, and 60 for their baseline calibration of risk aversion, respectively.[16] As discussed in Bloom (2009), agents face many uncertainties in the real economy, while agents in the model perfectly know all parameter values and how the economy works. Therefore, a high risk aversion is necessary for the model to match the observed equity premium. Barillas, Hansen, and Sargent (2009) show that generalized recursive preferences with high risk aversion are observationally equivalent to the expected utility preferences with low risk aversion when models have more uncertainty.

For the rest of the macroeconomic parameters, we adopt estimates from previous studies. The inverse Frisch elasticity of labor supply, χ, is set to 3 as in Del Negro, Giannoni, and Schorfheide (2015). The calibrated value of the Calvo parameter, $\xi = 0.8$, implies that the average duration of price contracts is five quarters as in Altig, Christiano, Eichenbaum, and Lindé (2011) and Del Negro, Giannoni, and Schorfheide (2015). The elasticity of investment adjustment costs is set to $\kappa = 3$, which is consistent with the estimate in Del Negro, Giannoni, and Schorfheide (2015) and Gelain and Ilbas (2017). We set the steady state markup, θ, to 10 percent as in Smets and Wouters (2007). The persistence of technology, ρ_A, is set to 1 following Tallarini (2000). The standard deviation of technology shocks, σ_A, is set to 0.007, consistent with the estimates in King and Rebelo (1999).

Turning to the parameters for the financial sector, we set the fraction of capital diverted by the banker, ϑ, to 0.19, as in Gertler and Kiyotaki (2015). This value is half of the parameter value adopted by Gertler and Karadi (2011). Proportional transfer to a new financial intermediary, ω, is set to 0.002 as in Gertler and Karadi (2011). Following Gertler and Kiyotaki (2015), we set the survival rate of the bankers, σ, to 0.95, which implies the expected lifetime for the bankers is twenty quarters.

We set the parameters associated with monetary policy at $\rho_i = 0.73$, $\phi_y = 0.93$, and $\phi_\pi = 0.53$, as in Rudebusch (2002). The monetary authority's inflation target, $\bar{\pi}$, is set to 0.008, which implies

[16]Piazzesi and Schneider (2006) estimate risk aversion to be 57, and Van Binsbergen, Fernández-Villaverde, Koijen, and Rubio-Ramírez (2012) estimate it to be about 65.

the steady state inflation rate is 3.2 percent per year. As in Swanson (2016), the parameter for the moving average of output is set to $\rho_{\bar{y}} = 0.9$.[17] Finally, we set the degree of leverage at $\upsilon = 3$ to match the empirical estimates of dividend growth's volatility following Abel (1999) and Bansal and Yaron (2004).

3.2 Macroeconomic Implications

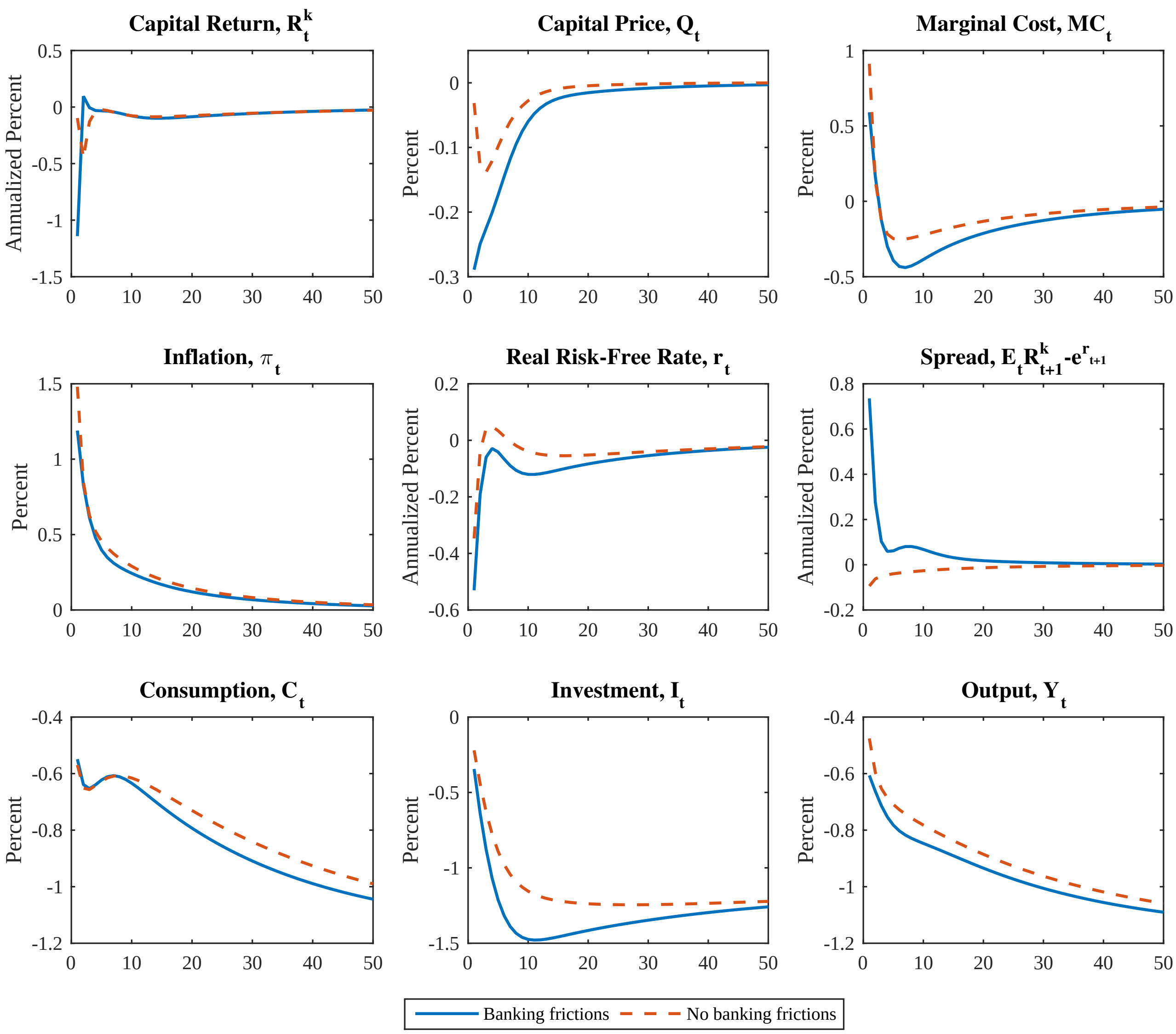
Figure 2 depicts the impulse response functions to a one-standard-deviation (0.7 percent) negative technology shock for the third-order solutions of the baseline model. To better highlight the role of banking frictions, we compare the impulse responses of the baseline model to those obtained when banking frictions are eliminated from the baseline model. In this article, the model that does not incorporate banking frictions is referred to as the frictionless model although it still includes nominal and real frictions. The arbitrage condition between the return of capital and the real gross risk-free return holds in the absence of banking frictions. The impulse responses are computed by the period-by-period difference between two scenarios: (i) given nonstochastic steady state values of state variables, we simulate out the variables in the absence of a shock and (ii) we repeat the same process in the presence of the shock in the first period.[18] The horizontal axes are periods (quarters) and the vertical axes are percentage deviations from the nonstochastic steady state values.

Figure 2 shows the impulse responses of the key aggregate variables to the negative technology shock. The solid blue lines in each panel plot the impulse response functions of the baseline model, and the dashed orange lines plot the impulse response functions when banking frictions are abstracted from the baseline model. The baseline model generates the stronger responses of the aggregate variables compared to the frictionless model. The negative technology shock lowers the marginal productivity of capital and therefore the return on capital, leading to a decline in the price of capital. The reduction in the capital price deteriorates the balance sheets of financial intermediaries, yielding

[17] Note that the average historical lag is about 10 quarters.

[18] There are many other alternatives. For example, we draw random numbers for the technology shock ϵ_t^A from its distribution using a random number generator and use these values for the simulation. There is, however, no large difference in the results between these two methods because agents in the model economy do not have perfect foresight.

Figure 2: IMPACT OF LIMITED BORROWING CAPACITY ON MACRO VARIABLES



Note: The figure plots the third-order impulse response functions of the key aggregate variables to a negative one-standard-deviation (0.7 percent) technology shock. The solid blue lines in each panel plot the impulse response functions from the baseline model incorporating banking frictions, and the dashed orange lines plot the impulse response functions when banking frictions are abstracted from the baseline model. See text for details.

a contraction in their borrowing and lending capacity. Thus, the decline of output is greater in the baseline model compared to that of the frictionless model.

The response of marginal cost is attenuated in the baseline model with banking frictions. Since the return on capital declines further with banking frictions, the production cost of intermediate goods

Table 2: THE MODEL-IMPLIED EQUITY PREMIUM

Model without banking frictions				Model with banking frictions			
ψ_t^e	$\sigma_t(r_{t+1}^e)$	$\sigma_t(r_{t+1})$	$\frac{\psi_t^e}{\sigma_t(r_{t+1}^e)}$	ψ_t^e	$\sigma_t(r_{t+1}^e)$	$\sigma_t(r_{t+1})$	$\frac{\psi_t^e}{\sigma_t(r_{t+1}^e)}$
6.14	7.59	0.35	0.81	6.59	8.91	0.57	0.74

Note: This table reports the model-implied equity premium, ψ_t^e, the conditional standard deviation of the net equity return, $\sigma_t(r_{t+1}^e)$, the conditional standard deviation of the net risk-free return, $\sigma_t(r_{t+1})$, and the Sharpe ratio, $\frac{\psi_t^e}{\sigma_t(r_{t+1}^e)}$, in annualized percentage points. See the text for more details.

firms rises less. The declining return on capital moderately offsets the rise in marginal cost driven by the negative technology shock. As a result, inflation rises less when banking frictions are embedded into the model. The real risk-free rate declines further in the presence of banking frictions as can be seen in the middle center panel. This is because a stronger contraction in economic activity causes the central bank to lower the nominal interest rate. The spread between $E_t R_{t+1}^k$ and $e^{r_{t+1}}$ rises in the baseline model. This is due to the drop in the intermediary capital. In contrast, the spread slightly declines in the frictionless model. The impulse response of the spread is not zero when banking frictions are absent since the figure is obtained from the third-order approximation of the model. In the first-order approximation, the spread always shows a zero response as in Gertler and Karadi (2011). Finally, the bottom panels show a more pronounced fall in consumption and investment in the baseline model.

3.3 Equity Premium Results

Table 2 reports the model-implied equity premium, ψ_t^e, the conditional standard deviation of the net equity return, $\sigma_t(r_{t+1}^e)$, and the conditional standard deviation of the net risk-free return, $\sigma_t(r_{t+1})$, from the baseline model and the frictionless model. The fifth column reports the equity premium, ψ_t^e, predicted by the baseline model with banking frictions. The model-implied equity premium, $\psi_t^e = 6.59$, matches its empirical estimate (typically about 4 to 8.4 percent at an annual rate).[19] The sixth and seventh columns show that the standard deviation for the net equity return is 8.91 percent

[19]See, Table 1 in Mehra and Prescott (2003).

and the standard deviation of the risk-free return is 0.57 percent when banking frictions are present. The volatilities predicted by the baseline model are short of fully accounting for their counterparts observed in the data (typically about 15 to 20 percent for the equity return and 1 to 2 percent for the risk-free rate).[20] The baseline model predicts the annualized Sharpe ratio, $\psi_t^e/\sigma_t(r_{t+1}^e)$, to be 0.74, which is in line with the empirical estimates of Campbell and Cochrane (1999) and Lettau and Ludvigson (2010) at 0.43 and 0.78, respectively.[21] The model-implied Sharpe ratio is higher than the estimate of Campbell and Cochrane (1999), but slightly lower than that of Lettau and Ludvigson (2010).[22]

The first column presents the equity premium when banking frictions are abstracted from the baseline model. The frictionless model predicts an equity premium of 6.14 percent.[23] The absence of banking frictions reduces the equity premium by about 45 basis points. This difference originated from imperfect financial markets accounts for 7.3 percent of the equity premium.[24] As shown in the second, third, and fourth columns, the conditional standard deviation of the net equity return is 7.59 percent, the standard deviation of the risk-free return is 0.35, and the annualized Sharpe ratio is 0.81 in the absence of banking frictions. This result shows that the frictionless model overpredicts the Sharpe ratio compared to the observed data.

We investigate the underlying mechanism by which banking frictions increase the equity premium. As shown in Figure 2, the presence of banking frictions amplifies the response of consumption, leading to a rise in the volatility of the stochastic discount factor. The standard deviation of the stochastic discount factor is 65 percentage points in the baseline model, while it is 62 percent-

[20]See, Table 2 in Rudebusch and Swanson (2012) and Table 3 in Croce (2014). Li and Palomino (2014) point out that incorporating less persistent shocks such as a monetary policy shock or a government spending shock into the model helps mitigate this problem.

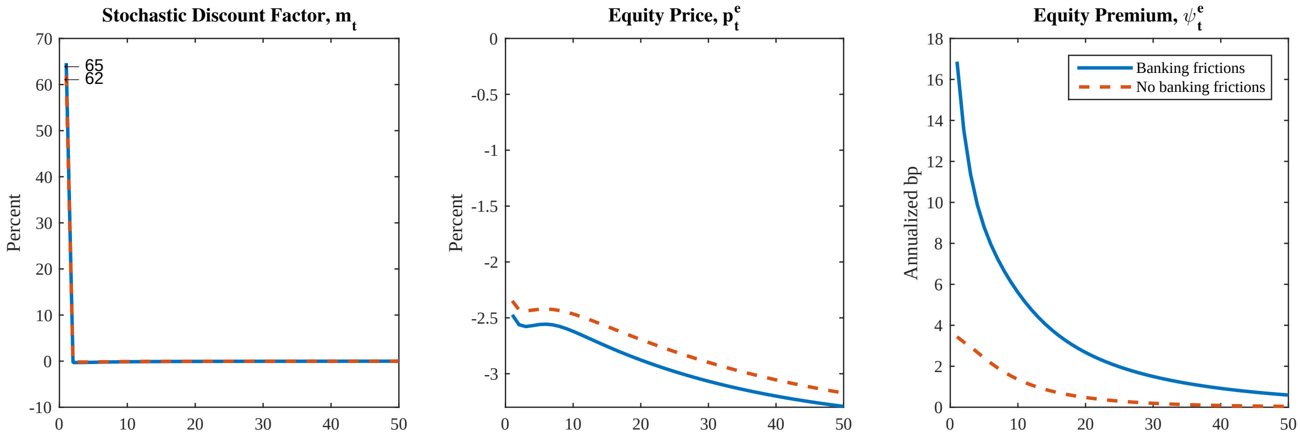
[21]The average quarterly Sharpe ratio is $1.65/4.46 = 0.37$ with banking frictions.

[22]In the existing literature, the model-implied Sharpe ratio is often overpredicted when the model economy has only one technology shock (Swanson, 2016).

[23]As shown in Swanson (2016), generalized recursive preferences with a high risk aversion parameter play a crucial role in accounting for the size of the equity premium.

[24]Gomes, Yaron, and Zhang (2003) investigate the implications of costly external finance of firms on asset price fluctuations using a real business cycle framework. They find that the equity premium is significantly higher with financial frictions compared to frictionless models. Nevertheless, the model-implied equity premium is very small (0.022 percent with financial frictions) and procyclical. The model with banking frictions by contrast, predicts a countercyclical equity premium and accounts for a sizable fraction of the equity premium.

Figure 3: IMPACT OF LIMITED BORROWING CAPACITY ON FINANCIAL VARIABLES



Note: The figure plots the third-order impulse response functions for the stochastic discount factor, m_t, the equity price, p^e_t, and the equity premium, ψ^e_t, to a negative one-standard-deviation (0.7 percent) technology shock. The solid blue lines in each panel plot the impulse response functions from the baseline model incorporating banking frictions, and the dashed orange lines plot the impulse response functions in the absence of banking frictions. See the text for more details.

age points in the frictionless model. A negative technology shock leads to a decline in the return of capital, R^k_t. The reduction lowers the aggregate net worth, N_t, as the decline in the return of capital reduces the value of assets for financial intermediaries. The decline in financial intermediaries' net worth weakens their borrowing and lending capacity, driving down the quantity of claims, S_t, and capital, K_{t+1}. In turn, the price of capital, Q_t, falls as the demand for capital declines. The lower capital price further pushes down the net worth of financial intermediaries, deteriorating their borrowing and lending capacity. As a consequence, the aggregate production and consumption decline further with banking frictions, leading to an increase in the volatility of the stochastic discount factor. The increased volatility of the stochastic discount factor or consumption drives up the equity premium. Notice that the equity premium, ψ^e_t, can be written as $\psi^e_t = -\rho_{m,e}\frac{\sigma_t(m_{t+1})}{E_t m_{t+1}}\sigma_t\left(R^e_{t+1}\right)$ where $\rho_{m,e}$ is the correlation coefficient between m_{t+1} and R^e_{t+1}. The equation shows that the equity premium is linked to the volatility of the stochastic discount factor and the gross return on equity. The volatility of the gross return on equity depends on the volatility of consumption since we hold $R^e_{t+1} = \frac{C^v_{t+1}+p^e_{t+1}}{p^e_t}$.

Figure 3 plots the impulse response functions to a one-standard-deviation (0.7 percent) negative technology shock. The solid blue lines and the dashed orange lines in each panel depict the impulse response functions for the baseline model and the frictionless model, respectively. The left panel reports the impulse response function for the stochastic discount factor, m_t, to the shock. The stochastic discount factor jumps about 65 percent in response to the negative technology shock in the presence of banking frictions, while it jumps about 62 percent in the absence of banking frictions.

The middle panel presents the impulse response function for the equity price, p_t^e. The baseline model predicts that the equity price plummets about 2.5 percent in response to the shock and gradually converges to its new nonstochastic steady state. In the absence of banking frictions, the equity price drops less and remain higher for a considerable time period than what the baseline model predicts. Thus, the middle panel shows that banking frictions impose more risk on equity holding.

The right panel presents the response of the equity premium. The initial response of the equity premium in the baseline model is four times larger than that of the frictionless model. This evidence shows that financial intermediaries' borrowing constraints have a substantial contribution to the equity premium. The equity premium is countercyclical, indicating that the conditional covariance between the stochastic discount factor and the return of the equity is negative.

4 Additional Discussion and Extensions

In this section, we discuss whether alternative calibrations of the model parameters can alter the impact of banking frictions on the macroeconomy and the equity premium.

4.1 Monetary Policy and Equity Premium

This subsection analyzes the role of monetary policy and banking frictions in determining the equity premium.[25] In particular, we are interested in whether the interaction between banking frictions and interest rate smoothing policy has a considerable impact to the equity premium.

Table 3 reports the model-implied equity premiums calculated with alternative values of the in-

[25]Our focus is on interest rate smoothing policy. Even though we do not report here, our findings indicate that the monetary authority's attitude toward inflation and the output gap has a relatively smaller impact on the equity premium than that of interest rate smoothing policy.

Table 3: COMPARISON OF EQUITY PREMIUM WITH DIFFERENT SMOOTHING PARAMETERS

	Model without banking frictions		Model with banking frictions	
	$\rho_i = 0.65$	$\rho_i = 0.85$	$\rho_i = 0.65$	$\rho_i = 0.85$
ψ_t^e	6.26	5.88	6.56	6.68
$\frac{\psi_t^e}{\sigma_t(r_{t+1}^e)}$	0.83	0.74	0.75	0.73

Note: This table reports the annualized equity premium and the Sharpe ratio implied by the model with different values of smoothing parameter of monetary policy, ρ_i. See the text for more details.

terest rate smoothing parameter, while fixing other parameters at their benchmark calibration. The second and third columns report the equity premiums when banking frictions are eliminated from the baseline model. The last two columns present the equity premiums predicted by the frictionless model. Embedding banking frictions into the frictionless model increases the equity premium by 30 basis points when $\rho_i = 0.65$, while it increases the equity premium by 80 basis points when $\rho_i = 0.85$. Notice that the interest rate smoothing parameter, ρ_i, is often estimated to be around 0.85 in the literature. For example, the estimate of ρ_i is 0.84 in Justiniano and Primiceri (2008), and 0.85 in Christiano, Motto, and Rostagno (2014).

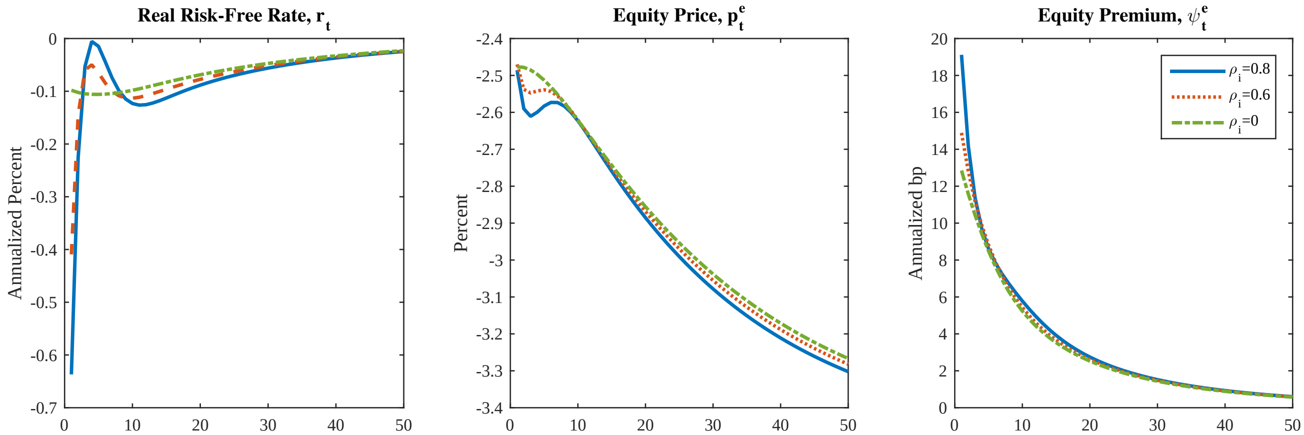
When the parameter ρ_i increases from 0.65 from 0.85, the equity premium rises by 12 basis points in the baseline model. On the other hand, the equity premium declines by 38 basis points in the frictionless model. This issue is investigated in Figure 4.

Figure 4 plots the impulse response functions for the risk-free return, the equity price, and the equity premium to a negative one-standard-deviation technology shock. Figure 4.a and 4.b are for the baseline model and the frictionless model, respectively. The solid blue, dashed orange, and dash-dot green lines in each panel plot impulse response functions for $\rho_i = 0.85$, $\rho_i = 0.65$, and $\rho_i = 0.0$, respectively.

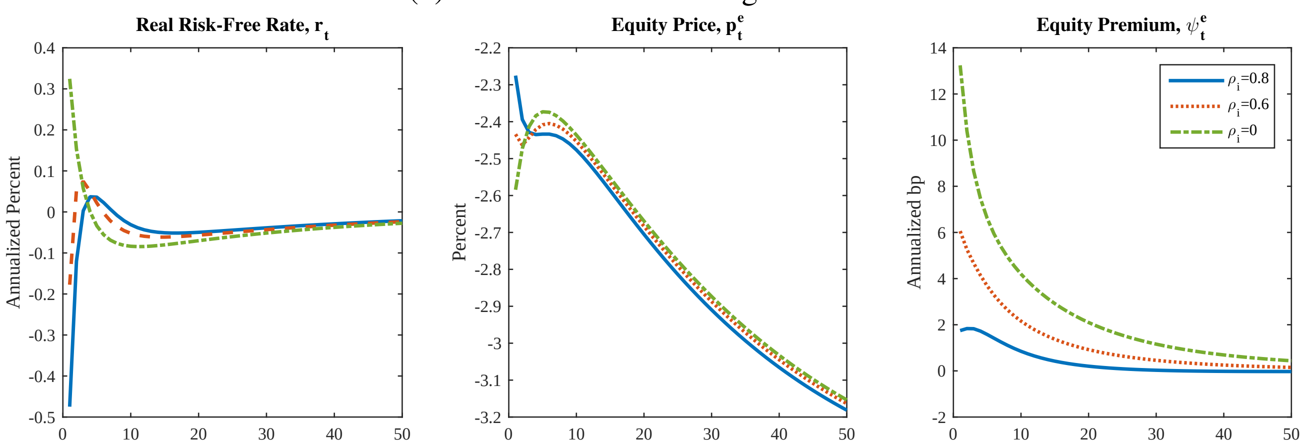
The baseline model implies that the real risk-free rate declines more as the degree of interest rate smoothing increases. In response to the negative technology shock, inflation rises sharply while the nominal interest rate rises slowly and gradually under interest rate smoothing policy. Setting $\rho_i = 0$, the response of the real risk-free rate is smaller than the case of $\rho_i > 0$. This is because no smoothing

Figure 4: IMPULSE RESPONSE FUNCTIONS WITH DIFFERENT SMOOTHING PARAMETERS

(a) Model with Banking Frictions



(b) Model without Banking Frictions



Note: The figure plots the third-order impulse response functions of the net risk-free return, r_t, the equity price, p_t^e, and the equity premium, ψ_t^e, to a negative one-standard-deviation (0.7 percent) technology shock. The blue solid, the dashed orange, and dash-dot green lines report the impulse response functions from the models when $\rho_i = 0.85,\ 0.65,$ and 0, respectively. See text for details.

policy leads to an immediate, but rather moderate increase in the nominal interest rate in response to a sharp rise in inflation.[26]

Our results show that interest rate smoothing policy leads to a considerable decline in the real risk-free rate, leading to an upward pressure on the equity premium. Notice that the equity premium is defined as the difference between the expected real equity return and the real risk-free rate. The

[26]The nominal interest rate rises moderately as banking frictions place a downward pressure on economic activity.

Table 4: COMPARISON OF EQUITY PREMIUM WITH DIFFERENT MORAL HAZARD PARAMETERS

	$\vartheta = 0.38$	$\vartheta = 0.68$
ψ_t^e	6.67	6.71
$\sigma(m_t)$	65	67

Note: This table reports the model-based equity premium, ψ_t^e, and the standard deviation of the stochastic discount factor, $\sigma(m_t)$ with alternative values of the seizure rate, ϑ. All numbers are in percentage points. See text for details.

decline in the real risk-free rate helps stabilize business cycle and consumption fluctuations and therefore may lower the equity premium. However, this effect appears to be relatively small in that, as the figure shows, the equity premium rises in response to the shock.

Figure 4.b shows that the direction of the risk-free rate depends on the degree of interest rate smoothing in the frictionless model. The figure shows that the real risk-free rate rises in the face of the negative technology shock when the parameter ρ_i is set to zero. Under no smoothing policy, the rise of the nominal interest rate is relatively larger than expected inflation in the frictionless model. The absence of banking frictions allows the nominal interest rate to rise more. Thus, no interest rate smoothing policy leads to a rise in the real risk-free rate, which in turn lowers economic activity and the equity price, making business cycle fluctuations more volatile. It has a positive contribution to the equity premium.

4.2 Moral Hazard and Equity Premium

This subsection analyzes how the fraction ϑ of assets the banker diverts from the financial intermediary affects the macroeconomy and the equity premium. This parameter capturing the banker's moral hazard problem determines borrowing capacity of the financial intermediary. As shown in (16), the leverage multiple, ϕ_t, is negatively related to the moral hazard parameter ϑ. To analyze the role of the moral hazard parameter in accounting for business cycle fluctuations and the equity premium, we set it to 0.38 and 0.68 following Gertler and Karadi (2011) and Gelain and Ilbas (2017), holding the other parameters of the baseline model fixed at their benchmark calibration.

Table 5: COMPARISON OF EQUITY PREMIUM WITH DIFFERENT RELATIVE RISK AVERSION

	Model without banking frictions			Model with banking frictions		
	$R^c = 10$	$R^c = 30$	$R^c = 90$	$R^c = 10$	$R^c = 30$	$R^c = 90$
ψ_t^e	0.99	3.05	9.23	1.07	3.28	9.90
$\sigma(m_t)$	10	31	95	10	32	99

Note: This table reports the model-based equity premium, ψ_t^e, and the standard deviation of the stochastic discount factor, $\sigma(m_t)$ with alternative values of the risk aversion coefficient, R^c. All numbers are in percentage points. See text for details.

Table 4 presents the equity premiums predicted by the model with the alternative values of ϑ. The model-implied equity premiums are higher than that of the baseline model with the parameter ϑ fixed at 0.19. The equity premium rises by 8 basis points when the parameter ϑ increases from 0.19 to 0.38. The rise in the parameter ϑ from 0.38 to 0.68 increases the equity premium by 4 basis points. The reason for these results is associated with the fact that the volatility of the stochastic discount factor increases with the parameter ϑ.

4.3 Relative Risk Aversion and Equity Premium

This subsection studies whether the contribution of banking frictions to the equity premium varies with the coefficient of relative risk aversion, which measures the household's attitude toward risk. Table 5 presents the equity premium with various values of the relative risk aversion coefficient, R^c, holding the other model parameters fixed at their benchmark calibration. The panel shows that the equity premium increases with risk aversion since the latter makes the stochastic discount factor more volatile. In addition, the panel also shows that the equity premium driven by banking frictions rises as the risk aversion coefficient increases. Although the contribution of banking frictions to the equity premium is positively associated with the relative risk aversion, the percentage contribution of banking frictions to the equity premium does not change much with the relative risk aversion. For example, in the case of $R^c = 10$, the equity premium increases from 0.99 to 1.07 due to banking frictions. The increased equity premium due to banking frictions is 8 percent. In the case of $R^c = 90$,

Table 6: EQUITY PREMIUM AND INVESTMENT ADJUSTMENT COSTS

	Model without banking frictions			Model with banking frictions		
	$\kappa = 10$	$\kappa = 20$	$\kappa = 30$	$\kappa = 10$	$\kappa = 20$	$\kappa = 30$
ψ_t^e	6.24	6.29	6.33	6.55	6.51	6.48
$\sigma(m_t)$	62.59	62.61	62.61	64.65	64.40	64.22

Note: This table reports the model-based the equity premium, ψ_t^e, and the standard deviation of the stochastic discount factor, $\sigma(m_t)$ with alternative values of investment adjustment costs. All numbers are in percentage points. See text for details.

banking frictions drive up the equity premium by 7.3 percent from 9.23 to 9.90.

4.4 Investment Adjustment Costs and Equity Premium

This subsection studies whether the equity premium is affected by investment adjustment costs. Table 6 shows the model-implied equity premium for various investment adjustment costs with and without banking frictions. The table shows that the equity premium is not very sensitive to the investment adjustment cost parameter κ, regardless of the presence of banking frictions. In the absence of banking frictions, the equity premium increases only 19 basis points when the investment adjustment cost increases unrealistically from 3 to 30.[27] In contrast, the increased investment adjustment cost slightly decreases the equity premium in the baseline model. The equity premium declines only about 11 basis points even though the investment adjustment cost parameter, κ, rises sharply from 3 to 30. A rise in the parameter κ reduces the variability of capital, lowering the volatility of the bank's net worth. In turn, this leads to a decline in the volatility of consumption and the equity premium. Overall, we find that the equity premium does not change much in response to a change in the investment adjustment cost parameter.

[27] Jermann (1998) and Gomes, Yaron, and Zhang (2003) point out that increasing the adjustment costs of capital improves the asset pricing performance by raising both the volatility of consumption and stock returns. Our model differs from theirs in that households do not own the capital stock. Accordingly, the inelastic supply of capital has little effect on the volatility of consumption and does not substantially raise the volatility of the stochastic discount factor.

5 Conclusion

This paper examines the effect of banking frictions on the equity premium. In the model of financial intermediation, borrowing capacity of financial intermediaries is tightly linked to the moral hazard of bankers. Our findings show that the presence of banking frictions increases the volatility of the stochastic discount factor and therefore the equity premium.

We adopt the financial intermediation model of Gertler and Karadi (2011) to investigate the importance of banking frictions in accounting for the equity premium. The Gertler-Karadi model does not consider a bank run equilibrium although it captures the fact that the financial intermediary's borrowing and lending capacity shrinks with net worth during recessions. With this in mind, Gertler and Kiyotaki (2015) extend the model to consider a situation where a bank run equilibrium does exist and show that economic activity shrinks more severely during banking crises than normal recessions. Although we do not analyze the case of a bank run equilibrium due to technical issues, allowing bank runs in the model economy is likely to increase the equity premium more since banking crises is expected to increase the volatility of the stochastic discount factor further. It might be worth investigating this issue in future research since our model is likely to underpredict the contribution of banking frictions to the equity premium due to the absence of bank runs.

A Appendix: Model Equations

We summarize the equations describing how the economy works within a medium-scale New Keynesian DSGE model with banking frictions and generalized recursive preferences.

Householder

$$V_t = (1-\beta)\left(\log C_t - \chi_0 \frac{L_t^{1+\chi}}{1+\chi}\right) - \beta\alpha^{-1}\log \text{Vexp}_t \tag{A.1}$$

$$\text{Vexp}_t = E_t \exp\left(-\alpha V_{t+1}\right) \tag{A.2}$$

$$1 = E_t\left(\beta \frac{C_t}{C_{t+1}} \frac{\exp\left(-\alpha V_{t+1}\right)}{\text{Vexp}_t} e^{r_{t+1}}\right) \tag{A.3}$$

$$\chi_0 L_t^{\chi}\left(\frac{1}{C_t}\right)^{-1} = \frac{w_t}{P_t} \tag{A.4}$$

Banking sector

$$Q_t K_{t+1} = \phi_t N_t \tag{A.5}$$

$$Q_t K_{t+1} = N_t + D_{t+1} \tag{A.6}$$

$$\phi_t = \frac{\beta E_t\left((1-\sigma) + \sigma\vartheta\phi_{t+1}\right)e^{r_{t+1}}}{\vartheta - \mu_t} \tag{A.7}$$

$$\mu_t = \beta E_t\left((1-\sigma) + \sigma\vartheta\phi_{t+1}\right)\left(R_{t+1}^k - e^{r_{t+1}}\right) \tag{A.8}$$

$$N_t = \sigma\left[R_t^k Q_{t-1} K_t - e^{r_t} D_t\right] + \omega Q_t K_t \tag{A.9}$$

$$C_t^b = (1-\sigma)\left[R_t^k Q_{t-1} K_t - e^{r_t} D_t\right] \tag{A.10}$$

Capital Producer

$$Q_t = 1+\frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2+\kappa\left(\frac{I_t}{I_{t-1}}-1\right)\left(\frac{I_t}{I_{t-1}}\right)-E_t\beta\frac{C_t}{C_{t+1}}\frac{\exp\left(-\alpha V_{t+1}\right)}{\text{Vexp}_t}\kappa\left(\frac{I_{t+1}}{I_t}-1\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \tag{A.11}$$

$$K_{t+1} = (1-\delta)K_t + I_t \tag{A.12}$$

Intermediate goods sector

$$R^k_{t+1} = \frac{MC_{t+1}\left(1-\eta\right)A_{t+1}\left(\frac{K_{t+1}}{L_{t+1}}\right)^{-\eta}+\left(1-\delta\right)Q_{t+1}}{Q_t} \tag{A.13}$$

$$spread_t = E_t R^k_{t+1} - e^{r_{t+1}} \tag{A.14}$$

$$\frac{w_t}{P_t} = MC_t\eta A_t\left(\frac{K_t}{L_t}\right)^{1-\eta} \tag{A.15}$$

$$zn_t = \left(1+\theta\right)MC_tY_t + \xi E_t\beta\frac{C_t}{C_{t+1}}\frac{\exp\left(-\alpha V_{t+1}\right)}{\text{Vexp}_t}\left(e^{\pi_{t+1}-\bar{\pi}}\right)^{\frac{1+\theta}{\theta}}zn_{t+1} \tag{A.16}$$

$$zd_t = Y_t + \beta E_t\beta\frac{C_t}{C_{t+1}}\frac{\exp\left(-\alpha V_{t+1}\right)}{\text{Vexp}_t}\left(e^{\pi_{t+1}-\bar{\pi}}\right)^{\frac{1}{\theta}}zd_{t+1} \tag{A.17}$$

$$p^*_t = \frac{zn_t}{zd_t} \tag{A.18}$$

$$\left(e^{\pi_{t+1}-\bar{\pi}}\right)^{-\frac{1}{\theta}} = \left(1-\xi\right)\left(p^*_t\right)^{-\frac{1}{\theta}}\left(e^{\pi_t-\bar{\pi}}\right)^{-\frac{1}{\theta}} + \xi \tag{A.19}$$

Final goods sector

$$Y_t = \triangle_t^{-1}A_tK_t^{1-\eta}L_t^{\eta} \tag{A.20}$$

$$\log A_t = \rho_A \log A_{t-1} + \epsilon_t^A \tag{A.21}$$

$$\triangle_t = (1-\xi)\left(p_t^*\right)^{-\frac{1+\theta}{\theta}} + \xi \triangle_{t-1} \tag{A.22}$$

Policy rule

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[\log \frac{1}{\beta} + \pi_t + \phi_\pi \left(\log \pi_t - \log \bar{\pi}\right) + \frac{\phi_y}{4} \log\left(\frac{Y_t}{\bar{Y}_t}\right)\right] \tag{A.23}$$

Aggregate

$$Y_t = C_t + C_t^b + \left\{1 + \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right\} I_t \tag{A.24}$$

In the absence of banking frictions, the arbitrage condition $E_t(m_{t+1}e^{r_{t+1}}) = E_t(m_{t+1}R_{t+1}^k)$ holds.

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