# Limited Borrowing Capacity of Financial Intermediaries and the Equity Premium

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**Abstract**

This paper investigates the relationship between the mechanism of limited borrowing capacity of financial intermediaries and the equity premium in a production economy. A medium-scale New Keynesian model is proposed, 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 are that banking frictions associated with the agency problem generate a plausible and novel enhancing mechanism for risk premia. 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 recent financial crises. 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. Although it is widely agreed that limited borrowing capacity of financial intermediaries could have a significant impact on business cycle fluctuations, there are very few studies toward understanding the influence on asset prices and risk premia.

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. A medium-scale New Keynesian model is proposed with the agency problem in financial intermediaries for asset pricing. The model includes generalized recursive preferences, which enables distinction between high risk aversion from the intertemporal elasticity of substitution and, thus, resolving the risk-free rate puzzle of Weil (1989).[1] As far as I know, this is the first paper to study the dynamics of 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 46 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. Finally, the equity premium rises with interest rate smoothing in the model with banking frictions.

The intuition for the amplification mechanism of limited borrowing capacity of financial intermediaries is straightforward. During recessions, 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 decreases the borrowing capacity of financial intermediaries, reducing security offering and 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. Even a small shock in

[1] In this paper, generalized recursive preferences are explored rather than expected utility preferences or habit preferences. 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.

this cycle can have a large impact on the economy, increasing the volatility of consumption and the stochastic discount factor.

Banking frictions not only generate a deeper recession, they also attenuate the rise of inflation in response to a negative technology shock. The deeper recession causes the nominal interest rate to rise less than expected inflation increases, leading to a decline in the real risk-free interest rate. In contrast, the real risk-free rate can 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 matters in accounting for the dynamics of the equity premium.[2]

My findings have important implications for the macro-finance literature. Traditionally, to capture sufficiently large risk premia, previous studies increase 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).[3] This paper, therefore, attempts to expand the understanding of the interaction between the macroeconomy and financial markets by analyzing the effect of banking frictions on the equity premium.[4]

This paper is closely related to two strands of the literature. One strand considers financial frictions in macroeconomic models. Kiyotaki and Moore (1997) and Bernanke, Gertler, and Gilchrist (1999, henceforth BGG) focusing on firms' limited borrowing capacity are the most representatives of this field. More recently, Gertler and Karadi (2011) and Gertler and Kiyotaki (2015) construct quantitative DSGE models incorporating financial intermediaries with limited borrowing capacity that is endogenously determined by balance sheet constraints. The other strand of the literature incorporates generalized recursive preferences into asset pricing models, introduced in the seminal paper of Tallarini (2000). In recent papers, Campanale, Castro, and Clementi (2010) and Swanson (2016) show that generalized recursive preferences allow models to generate substantial risk premia without distorting their ability to match macroeconomic facts. This paper considers these two

[2] The equity premium is defined as the difference between the real equity return and the real risk-free rate. Accordingly, monetary policy plays an important role in determining the equity premium.

[3] 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).

[4] 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, my findings show that time-varying limited borrowing capacity of financial intermediaries due to the agency problem can contribute to the equity premium. 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.

strands of literature combining banking frictions as in Gertler and Karadi (2011) with generalized recursive preferences. However, in contrast to these papers, the model proposed here considers not only the effect of banking frictions on the macroeconomy, but also on financial markets. Financial market disruptions cause a sharp contraction of the real economy due to limited borrowing capacity of financial intermediaries, which impacts the equity premium.

A number of recent studies examine implications of firms' limited borrowing capacity for asset pricing (e.g., Gomes, Yaron, and Zhang, 2003; Nezafat and Slavík, 2015; and Bigio and Schneider, 2017). Gomes, Yaron, and Zhang (2003) build on Carlstrom and Fuerst (1997) to incorporate financial market imperfections into a macroeconomic model, while Nezafat and Slavík (2015) and Bigio and Schneider (2017) investigate the importance of a financial shock following the approach in Kiyotaki and Moore (2012). These papers find that models with financial frictions produce a higher equity premium than frictionless models. Nevertheless, they generate counterfactual movements in the equity price or the equity premium because recessions (times of low liquidity) are associated with a low equity premium.[5] To overcome this difficulty, the propsed model here adopts the conventional asset pricing model as in Mehra and Prescott (1985) and Cochrane (2009) and solve the model nonlinearly to reflect the risk of the model. Therefore, in the model, a shock that drives an economic downturn generates a procyclical response of the equity price and a countercyclical response of the equity premium as observed in the data.

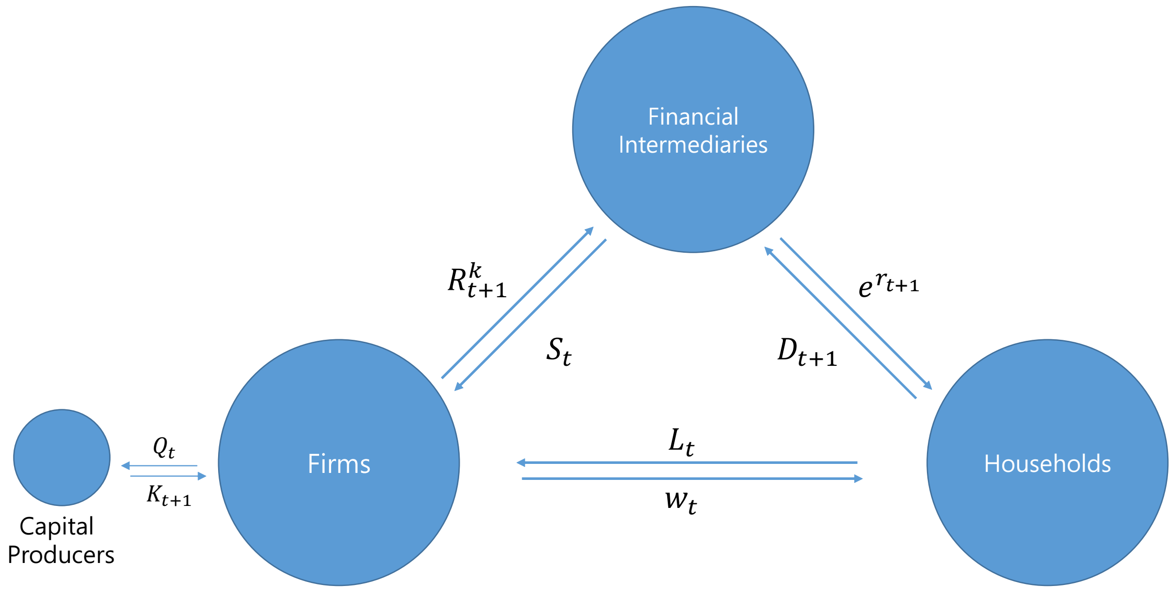
Livdan, Sapriza, and Zhang (2009, henceforth LSZ) report that more financially constrained firms have higher average equity returns. Their approach considers a partial equilibrium model with collateral constraints following Kiyotaki and Moore (1997). The proposed model in this paper complements LSZ in the sense that it analyzes the impact of banking frictions on the equity premium dynamics and on the economy. In particular, the present paper compares the effects of monetary policy on the equity premium, with and without limited borrowing capacity of financial intermediaries.

Lastly, He and Krishnamurthy (2013) build a model that considers financial intermediaries as marginal investors in asset pricing, and a more complex asset pricing structure to calibrate risk-premia. However, He and Krishnamurthy (2013) use a simple overlapping generation model in an endowment economy for tractability. The model proposed here is, instead, a standard New Keynesian model in a production economy that can be used to investigate the dynamics of 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

[5] See Shi (2015) for the detailed reason of the counterfactural response.

Figure 1: STRUCTURE OF THE MODEL




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 and discusses the direction of the future research. An appendix to the paper provides additional details of how the model is solved.

## 2 The Baseline Model

In this section, I 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 (as in Gertler and Karadi, 2011) and generalized recursive preferences (as in Tallarini, 2000; and Swanson, 2016). Limited borrowing capacity of financial intermediaries introduces frictions between financial intermediaries and households and allows 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

There are four types of agents in the model: households, financial intermediaries, non-financial firms, and capital producers. The latter are required to make the endogenous capital price tractable as suggested by BGG. Figure 1 displays the building blocks of the model. In order to produce output, non-financial firms purchase capital and hire labor from capital producers and households, respectively. Firms issue security claims, $S_t$, to buy capital, $K_{t+1}$, and pay gross return of capital, $R^k_{t+1}$, to financial intermediaries. Households give funds to financial intermediaries as deposits, $D_t$, and receive a risk-free return, $e^{r_{t+1}}$. Finally, the price of capital, $Q_t$, is endogeneously 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, the model in the present paper employs the additive separability assumption for period utility following Woodford (2003).[6]

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

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. Moreoever, assuming logarithmic period utility for consumption allows a balanced growth path and unit intertemporal elasticity of substitution as in King and Rebelo (1999). Households deposit to financial intermediaries to earn the continuously-compounded default free interest rate, and provide labor to non-financial firms to receive their wages. Using continuous compounding is convenient for equity pricing and comparison with the finance literature. Hence, 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 (to be defined later), $w_t$ is the real wage, $e^{i_t}$ is the nominal gross risk-free return from deposits, and $\Pi_t$ is the household's share of profits in the economy.

Following Hansen and Sargent (2001) and Swanson (2016), I assume that households have multiplier preferences.[7] In every period, the household faces the budget constraint (2) and maximizes lifetime uitility with the

[6] van Binsbergen et al. (2012) uses Cobb-Douglas preferences since they consider consumption and leisure as composit good.

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

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

[7] Rudebusch and Swanson (2012) use a generalized form of 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 no-Ponzi game constraint. The household's value function $V^h(d_t;\Theta_t)$ satisfies the Bellman equation:

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

where $\Gamma$ is the choice set for $c_t$ and $l_t$, $\Theta_t$ is the state of the economy, $\beta$ is the household's time discount factor, and $\alpha$ is a parameter. Risk aversion is closely related to the Epstein-Zin parameter $\alpha$ which amplifies risk aversion by including the additional risk for the lifetime utility of households.[8] The household's stochastic discount factor is given by[9]

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

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 continuosly-compounded risk-free real interest rate, $r_{t+1}$, is

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

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

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

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

[8] Precisely, $R^c = \alpha + \left(1 + \frac{\chi_0}{\chi}\right)^{-1}$ 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.

[9] 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.

## 2.2 Financial Intermediaries

There is a unit continuum of bankers, and each risk neutral banker runs a financial intermediary.[10] The financial intermediaries lend funds to non-financial firms by using their own net worth or issuing deposits to households. As suggested by Gertler and Karadi (2011), I introduce two key assumptions to ensure that there is always friction between financial intermediaries and households. First, financial intermediaries have to borrow from households each period in the form of deposits, implying that $d_{t+1} > 0$ in each period. This assumption prevents the financial intermediary from lending funds to non-financial firms with their own capital alone. Formally, the financial intermediary's balance sheet constraint is given by:

$$\text{Balance Sheet Constraint (BC)}: \; Q_t s_t = n_t + d_{t+1}, \tag{8}$$

where $Q_t$ is the relative price of financial claims on firms that the bank holds, $s_t$ is the quantity of claims, and $n_t$ is the banker's net worth. The asset of the financial intermediary, $Q_t s_t$, is composed of equity capital (or net worth), $n_t$, and positive debt, $d_{t+1}$. To keep the number of bankers stable and to prevent the accumulation of net worth, there is an $i.i.d.$ survival probability $\sigma$ for the fraction who can remain in the financial industry in the next period. So, $(1-\sigma)$ fraction of bankers retire and consume their net worth when they leave. Second, households are willing to deposit in financial intermediaries. There is a moral hazard problem between depositors and financial intermediaries: a financial intermediary may divert a portion of its assets after deposits are collected. Consequently, the incentive constraint must hold in order to avoid households punishing diverting bankers by ceasing to supply deposits:

$$\text{Incentive Constraint (IC)}: \; V_t^b \geq \vartheta Q_t s_t, \tag{9}$$

where $\vartheta$ is a fraction when the banker diverts the assets of the financial intermediary, and $V_t^b$ is the bank's franchise value (defined below). As long as the banker is constrained due to the agency frictions, the risk neutral banker's objective is to maximize its consumption at the exit period:

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

Observe that the financial intermediary's terminal wealth, $n_{t+j}$, is the banker's consumption, $c_{t+j}^b$, in the exit

[10] With a slight abuse of notation, I use the terms "financial intermediaries" and "banks" interchangeably in this paper.

period.[11] (10) can be written in the first-order recursive form:

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

The net worth of a surviving financial intermediary in the next period, $n_{t+1}$, is simply the gross return of the asset 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 gross return of capital. Then, the growth rate of net worth is

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

where $\phi_t \equiv \frac{Q_t s_t}{n_t}$ is the "leverage multiple." Note that the growth rate of net worth is increasing in the leverage multiple when the spread, $R_{t+1}^k - e^{r_{t+1}}$, is positive.

Since (8) and (11) are constant returns to scale, (11) is equivalent to the following:[12]

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

where $\mu_t \equiv \beta E_t \Omega_{t+1} \left( R_{t+1}^k - e^{r_{t+1}} \right)$ is the excess marginal value of assets over deposits, $\nu_t \equiv \beta E_t \Omega_{t+1} e^{r_{t+1}}$ is the 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 marginal values of net worth to exiting and to continuing bankers at $t+1$.

Combining (9) and (14) yields the leverage multiple:

$$\phi_t = \frac{\nu_t}{\vartheta - \mu_t}, \tag{15}$$

if and only if $\mu_t \in (0, \vartheta)$ so that the incentive constraint (9) binds. Since all financial intermediaries face the

[11] For tractability, I assume the financial intermediary is risk neutral following BGG and Gertler and Kiyotaki (2015). So, the bankers discount net worth with $\beta$ rather than the household's stochastic discount factor $m_{t+j}$.

[12] Gertler and Kiyotaki (2015) calls the franchise value per unit of net worth, $\frac{V_t^b}{n_t}$, as Tobin's Q.

same the leverage multiple as in (15), the aggregate leverage constraint is

$$Q_t S_t = \phi_t N_t, \tag{16}$$

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. With the survival probability, $\sigma$, the banker remains in the banking sector, in which case the banker earns the net revenue, $R_t^k Q_{t-1} S_{t-1} - e^{r_t} D_t$. The second corresponds to seed money, $\omega Q_t S_{t-1}$, that a new banker receives in every period from their respective household. This seed money is a small fraction, $\omega$, of the value of the exiting financial intermediary's assets. Accordingly, the aggregate net worth of the entire banking sector is

$$N_t = \sigma \left( R_t^k Q_{t-1} S_{t-1} - e^{r_t} D_t \right) + \omega Q_t S_{t-1}, \tag{17}$$

where $D_t$ is the aggregate amount of deposits.

Lastly, aggregate consumption of exiting bankers is the fraction $(1 - \sigma)$ of net earnings of assets:

$$C_t^b = (1 - \sigma) \left[ R_t^k Q_{t-1} S_{t-1} - e^{r_t} D_t \right], \tag{18}$$

where $C_t^b = c_t^b$ denotes aggregate consumption demanded by bankers.

## 2.3 Firms

### 2.3.1 Non-Financial Firms

There is a single final good which is produced using a continuum of intermediate goods indexed by $f \in [0, 1]$ with the following production function:

$$Y_t = \left( \int_0^1 y_t(f)^{\frac{1}{1+\theta}} df \right)^{1+\theta}, \tag{19}$$

where $y_t(f)$ is an intermediate good, and $\theta > 0$ is a parameter captures the equilibrium markup. The final goods firms are perfectly competitive and maximize profits subject to the production function. This implies a downward sloping demand curve for each intermediate good:

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

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

$$P_t = \left(\int_0^1 p_t(f)^{-\frac{1}{\theta}} df\right)^{-\theta}, \tag{21}$$

which can be derived from the zero profit condition.

The economy contains a continuum of monopolistically competitive intermediate goods firms indexed by $f \in [0,1]$. Firms purchase capital goods from capital producers and hire labor from households. They also issue claims, $s_t$, to financial intermediaries in order to obtain financing. Firms have identical Cobb-Douglas production functions:

$$y_t(f) = A_t k_t(f)^{1-\eta} l_t(f)^{\eta}, \tag{22}$$

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

$$\log A_t = \rho_A \log A_{t-1} + \epsilon_t^A, \tag{23}$$

where $\rho_A \in (-1,1]$, and $\epsilon_t^A$ follows an $i.i.d.$ white noise process with mean zero and variance $\sigma_A^2$. I set $\rho_A = 1$ for comparability to the asset pricing literature (e.g., Tallarini, 2000; and Swanson, 2016). Subject to the demand function and the production function, the intermediate goods firm chooses labor, $l_t(f)$, and capital, $k_t(f)$. The first order necessary conditions are:

$$l_t(f): \;\; w_t P_t = \varphi_t(f) \eta A_t \left(\frac{k_t(f)}{l_t(f)}\right)^{1-\eta}, \tag{24}$$

$$k_t(f): \;\; R_t^k P_t Q_{t-1} - Q_t P_t (1-\delta) = \varphi_t(f)(1-\eta) A_t \left(\frac{k_t(f)}{l_t(f)}\right)^{-\eta}, \tag{25}$$

where $\varphi_t(f)$ is the Lagrange multiplier of the cost minimization problem, and $\delta$ denotes the depreciation rate of capital. Note that $Q_t P_t (1-\delta)$ in (25) is the value of the remained capital stock from the previous period. Combining these conditions yields the capital-labor ratio:

$$\frac{k_t(f)}{l_t(f)} = \frac{1-\eta}{\eta} \frac{w_t}{R_t^k Q_{t-1} - Q_t(1-\delta)}. \tag{26}$$

Since the capital-labor ratio is the same for all firms as in (26), it is the same to the aggregate ratio:

$$\frac{k_t(f)}{l_t(f)} = \frac{K_t}{L_t}, \tag{27}$$

where $K_t$ is aggregate capital and $L_t$ is the aggregate quantity of labor. Moreoever, every firm hires capital and labor in the same way, so marginal cost is also the same across firms. Let $mc_t(f) \equiv \frac{\varphi_t(f)}{P_t}$ be the real marginal cost. Then, $mc_t(f) = MC_t$ for all $f$ since $\varphi_t(f)$ is not an individual firm-specific factor either:

$$MC_t = \frac{1}{A_t} w_t^\eta \left(R_t^k Q_{t-1} - (1-\delta)Q_t\right)^{1-\eta} \left(\frac{1}{\eta}\right)^\eta \left(\frac{1}{1-\eta}\right)^{1-\eta}. \tag{28}$$

Therefore, the demand functions for capital and labor are:

$$R_{t+1}^k = \frac{MC_{t+1}\left(1-\eta\right) A_{t+1} \left(\frac{K_{t+1}}{L_{t+1}}\right)^{-\eta} + \left(1-\delta\right) Q_{t+1}}{Q_t}, \tag{29}$$

$$w_t = MC_t \eta A_t \left(\frac{K_t}{L_t}\right)^{1-\eta}. \tag{30}$$

Each intermediate goods firm sets the new contract price $p_t(f)$ to maximize the firm's lifetime profit according to Calvo contracts: only a fraction, $1-\xi$, can adjust its price each period. Hence, the value of the firm is given by:

$$\max_{p_t(f)} E_t \sum_{j=0}^{\infty} m_{t,t+j}(P_t/P_{t+j})\xi^j \left[p_t(f)e^{j\bar{\pi}} y_{t+j}(f) - mc_{t+j}^n(f) y_{t+j}(f)\right], \tag{31}$$

where $m_{t,t+j} \equiv \Pi_{i=1}^{j} m_{t+i}$ is the stochastic discount factor of 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 (31) with respect to $p_t(f)$ yields the standard New Keynesian price optimality condition:

$$p_t^*(f) = \frac{(1+\theta) E_t \sum_{j=0}^{\infty} m_{t,t+j} \xi^j MC_{t+j} P_{t+j}^{\frac{1+\theta}{\theta}} Y_{t+j}}{E_t \sum_{j=0}^{\infty} m_{t,t+j} \xi^j P_{t+j}^{\frac{1}{\theta}} Y_{t+j} e^{j\bar{\pi}}}. \tag{32}$$

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 sell new capital to intermediate goods firms at price $Q_t$, and produce it using the input from the final output at price unity subject to convex (quadratic) investment adjustment cost.[13] The capital producer chooses new capital, $I_t$, in order to maximize expected discounted profits over her lifetime:

$$\max_{I_t} E_t \sum_{j=0}^{\infty} m_{t,t+j} \left\{ \left(Q_{t+j} - 1\right) I_{t+j} - \frac{\kappa}{2} \left( \frac{I_{t+j}}{I_{t+j-1}} - 1 \right)^2 I_{t+j} \right\}, \tag{33}$$

where $\kappa$ denotes the elasticity of the investment adjusment costs. Observe that with zero investment adjustment costs, $\kappa = 0$, the firms would produce infinite capital if $Q_t > 1$. A large elasticity of the investment adjusment costs $\kappa$ implies that the capital producer cannot change her supply easily.

The first order necessary condition with respect to $I_t$ yields:

$$Q_t = 1 + \frac{\kappa}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2 + \kappa \left( \frac{I_t}{I_{t-1}} - 1 \right) \left( \frac{I_t}{I_{t-1}} \right) - E_t m_{t,t+1} \kappa \left( \frac{I_{t+1}}{I_t} - 1 \right) \left( \frac{I_{t+1}}{I_t} \right)^2, \tag{34}$$

which is the supply of new capital.

## 2.4 Aggregate Resource Constraints and Monetary Policy

As the goal of this paper is illustrating the underlying mechanisms of how limited borrowing capacity of financial intermediaries affects the risk premium, I want to keep the model as simple as possible by considering technology shocks only. This is not an unreasonable assumption: 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 government spending shock, respectively. Thus, Tallarini (2000), Gomes, Yaron, and Zhang (2003), and Swanson (2016) also did not consider any exogenous shock other than a technology shock.

[13] While there are multiple ways to introduce the investment adjustment cost, this paper follows along the lines of Gertler, Kiyotaki, and Queralto (2012).

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

$$Y_t = \triangle_t^{-1} A_t K_t^{1-\eta} L_t^{\eta}, \tag{35}$$

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.

A monetary authority in the model determines the one-period nominal interest rate, $i_t$, by a simple Taylor-type rule with interest-rate smoothing:

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[r + \log \pi_t + \phi_\pi (\log \pi_t - \log \bar{\pi}) + \frac{\phi_y}{4}(y_t - \bar{y}_t)\right], \tag{36}$$

where $\rho_i \in (0,1)$ is the smoothing parameter, $r = \log(1/\beta)$ is the continuously compounded real interest rate in steady state, $\pi_t$ is the inflation rate, $\bar{\pi}$ is the target inflation of the monetary authority, $y_t$ is the log of output $Y_t$,

$$\bar{y}_t = \rho_{\bar{y}} \bar{y}_{t-1} + (1-\rho_{\bar{y}})\, y_t, \tag{37}$$

is a trailing moving average of $y_t$, and $\phi_\pi$, $\phi_y \in \mathbb{R}$ and $\rho_{\bar{y}} \in [0,1)$ are parameters. As suggested by Swanson (2016), the term $(y_t - \bar{y}_t)$ in (36) 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. Since monetary policy also affects the real risk-free return according to the Fisher equation, setting the output gap with (37) helps to generate the risk premium consistent with the actual data.

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

$$Y_t = C_t + C_t^b + \left\{1 + \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right\} I_t, \tag{38}$$

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

## 2.5 The Equity Premium

I 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, I model stocks as a levered claim on the aggregate consumption for simplicity.[14] In every period, the levered equity pays the consumption stream $C_t^v$. Note that

[14] This interpretation of dividends is simpler and more realistic asset pricing method rather than using a claim on the firm's profit. This is because firms issue both equity and debt in the real world (e.g., Abel, 1999; Gourio, 2012; Campbell, Pflueger, and Viceira,

$\upsilon$ is the degree of leverage which captures broad leverage in the economy, including operational and financial leverage. Therefore, the price of an equity security in equilibrium is given by:

$$p_t^e = E_t\left(m_{t+1}\left(C_{t+1}^{\upsilon} + p_{t+1}^e\right)\right), \tag{39}$$

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, (39) is equivalent to

$$1 = E_t\left(m_{t+1}R_{t+1}^e\right), \tag{40}$$

which is the same form as the intertemporal Euler equation.

Defining the equity premium as the difference between the expected return to equity and the risk-free rate, $\psi_t^e \equiv E_t R_{t+1}^e - e^{r_{t+1}}$. By the definition of covariance, (40) is equivalent to

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

where $\mathrm{Cov}_t$ denotes the conditional covariance. Using (5) and (41), and dividing both sides by $E_t m_{t+1}$ yields,

$$\begin{aligned} \psi_t^e &= \frac{1}{E_t m_{t+1}} - \frac{\mathrm{Cov}_t\left(m_{t+1}, R_{t+1}^e\right)}{E_t m_{t+1}} - e^{r_{t+1}} \\ &= -\frac{\mathrm{Cov}_t\left(m_{t+1}, R_{t+1}^e\right)}{E_t m_{t+1}} \\ &= -\mathrm{Cov}_t\left(\frac{m_{t+1}}{E_t m_{t+1}}, R_{t+1}^e\right). \end{aligned} \tag{42}$$

Intuitively, (42) shows why the equity is a very long-lived asset. 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. The equity premium is thus sensitive to any changes in the consumption, even at a distant period.

### 2.6 Solution Method

I solve the model above using a third-order perturbation method based on the algorithm of Swanson, Anderson, and Levin (2006). I use this solution method for three reasons. First, I have eight state variables: $A_{t-1}$,

2014; and Swanson, 2016).

$\triangle_{t-1}$, $D_{t-1}$, $I_{t-1}$, $i_{t-1}$, $K_{t-1}$, $r_{t-1}$, $\bar{y}_{t-1}$ and one shock $\epsilon_t^A$. Due to high dimensionality, projection methods are computationally not feasible. 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). The model incorporates limited borrowing capacity of financial intermediaries which has the amplification structure containing many state variables. Thus, computation time is also important because a third-order accurate solution may take considerable time to compute. Lastly, a third-order perturbation is necessary to capture the dynamic of the risk premia, such as the impulse-response analysis of the equity premium.

# 3 Model Results

I calibrate the model rather than estimate the parameters since the main objective of this study is to illuminate the role of limited borrowing capacity of financial intermediaries on asset pricing. As can be seen in Table 1, the baseline calibration is fairly standard for both macroeconomics and finance variables.

For the household's discount factor, $\beta$, the depreciation rate, $\delta$, and the elasticity of output with respect to labor, $\eta$, I use conventional values. I also set the relative utility weight of labor, $\chi_0 = 0.79$, to normalize the steady state labor, $L = 1$. I use relatively high risk aversion $R^c = 60$ for simplicity and comparability to the asset pricing literature. Moreover, this relatively high value is common in the macro-finance literature, and is due to the small amount of uncertainty in the simple model.[15] As Bloom (2009) shows, the real economy has many uncertainties. In contrast, agents in the model perfectly know all parameter values and equations, so the quantity of risk is very small. Barillas, Hansen, and Sargent (2009) document that increasing the uncertainty of the model could lower risk aversion. Another method is to increase the quantity of risk by introducing additional shocks such as long-run risk, heterogeneous agents, or rare disaster.

For the rest of the macroeconomic parameters, I use estimates from previous studies. The inverse Frisch elasticity of labor supply, $\chi$, is set to 3 as in Del Negro, Giannoni, and Schorfheide (2015). The calibrated value of the Calvo contract parameter, $\xi = 0.8$, implies that the lifetime of the contract is five quarters as in Altig, Christiano, Eichenbaum, and Lindé (2011) and Del Negro, Giannoni, and Schorfheide (2015). I also set the elasticity of investment adjustment costs $\kappa = 3$ as the estimate in Del Negro, Giannoni, and Schorfheide (2015)

[15] Empirical papers using generalized recursive preferences estimate a relatively high risk aversion. For instance, Piazzesi and Schneider (2006) estimate risk aversion to 57, and van Binsbergen et al. (2012) estimate a value of about 65. In addition, Tallarini (2000), Rudebusch and Swanson (2012) and Swanson (2016) use baseline calibration of risk aversion as 100, 75, and 60, respectively.

Table 1: BASELINE CALIBRATION

| Parameters | Value | Descriptions | Source |
|---|---|---|---|
| $\beta$ | 0.992 | Discount rate | |
| $\chi_0$ | 0.79 | Relative utility weight of labor | To normailize $L = 1$ |
| $\chi$ | 3 | Inverse Frisch elasticity of labor supply | Del Negro et al. (2015) |
| $R^c$ | 60 | Relative risk aversion | |
| $\eta$ | 0.6 | Labor share | |
| $\delta$ | 0.025 | Depreciation rate | |
| $\theta$ | 0.1 | Monopolistic markup | Smets and Wouters (2007) |
| $\xi$ | 0.8 | Calvo contract parameter | Altig et al. (2011) |
| $\rho_A$ | 1 | Persistence of technology | Tallarini (2000) |
| $\sigma_A$ | 0.007 | Standard deviation of technology shocks | King and Rebelo (1999) |
| $\kappa$ | 3 | Elasticity of investment adjusment cost | Del Negro et al. (2015) |
| $\vartheta$ | 0.19 | Seizure rate | Gertler and Kiyotaki (2015) |
| $\omega$ | 0.002 | Proportional transfer to new bank | Gertler and Karadi (2011) |
| $\sigma$ | 0.95 | Survival probability of bank | Gertler and Kiyotaki (2015) |
| $\rho_i$ | 0.73 | Smoothing parameter of monetary policy | Rudebusch (2002) |
| $\phi_\pi$ | 0.53 | Response of monetary policy to inflation | Rudebusch (2002) |
| $\phi_y$ | 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) |
| $\upsilon$ | 3 | Degree of leverage | Abel (1999) |

and Gelain and Ilbas (2017). I set firm's steady state markup, $\theta$, as 10 percent, consistent with the estimates in Smets and Wouters (2007). The persistence of technology, $\rho_A$, is set to 1 as in Tallarini (2000), and the standard deviation of technology shocks, $\sigma_A$, is set to 0.007, consistent with the estimates in King and Rebelo (1999). These calibrated values generate high enough risk in the model so that the equity premium in the model is sufficiently large.

Turning to the financial sector parameters, I set the fraction of capital that can be diverted to $\vartheta = 0.19$, as in Gertler and Kiyotaki (2015). Proportional transfer to a new financial intermediary, $\omega$, is set to 0.002 as in Gertler and Karadi (2011). Lastly, I set survival probability in banking industry, $\sigma = 0.95$, implying twenty quarters of the expected lifetime for financial intermediary as in Gertler and Kiyotaki (2015).

I set the smoothing parameter of monetary policy, $\rho_i = 0.73$, the response of monetary policy to output, $\phi_y = 0.93$, and the response of monetary policy to inflation, $\phi_\pi = 0.53$, as in Rudebusch (2002). The monetary authority's inflation target, $\bar{\pi}$, is set to 0.008 which implies 3.2 percent per year in the nonstochastic steady state as in Swanson (2016). I set the coefficient of trailing moving average of output to $\rho_{\bar{y}} = 0.9$, which implies that the central bank considers the whole history of past output levels, because $\bar{y}_t$ is an infinite moving average of past $y_t$.[16] Finally, I calibrate the degree of leverage as $\upsilon = 3$ to match the empirical estimates of dividend growth's volatility following Abel (1999) and Bansal and Yaron (2004).

### 3.1 Macroeconomic Implications

Figure 2 depicts the impulse response functions to a one-standard-deviation (0.7 percent) negative technology shock for the third-order solution of the models. These are computed by the period-by-period difference between two scenarios: (i) given nonstochastic steady state values of state variables, I simulate out the variables in the absence of a shock and (ii) I repeat the same process in the presence of one standard deviation to the shock in the first period.[17] The horizontal axes are periods (quarters) and the vertical axes are percentage deviations from the nonstochastic steady state.

To better highlight the role of limited borrowing capacity of financial intermediaries, I compare the model responses to those of a model without limited borrowing capacity of financial intermediaries. This alternative model is a medium-scale New Keynesian DSGE model with gerenralized recursive preferences, and the calibration is the same as the baseline model. Moreover, in the alternative model, the arbitrage condition between the return of capital and the real gross risk-free return holds due to the absence of banking frictions. The solid blue lines in each panel plot impulse response functions to the baseline model, and the dashed orange lines plot the impulse response functions for the alternative model.

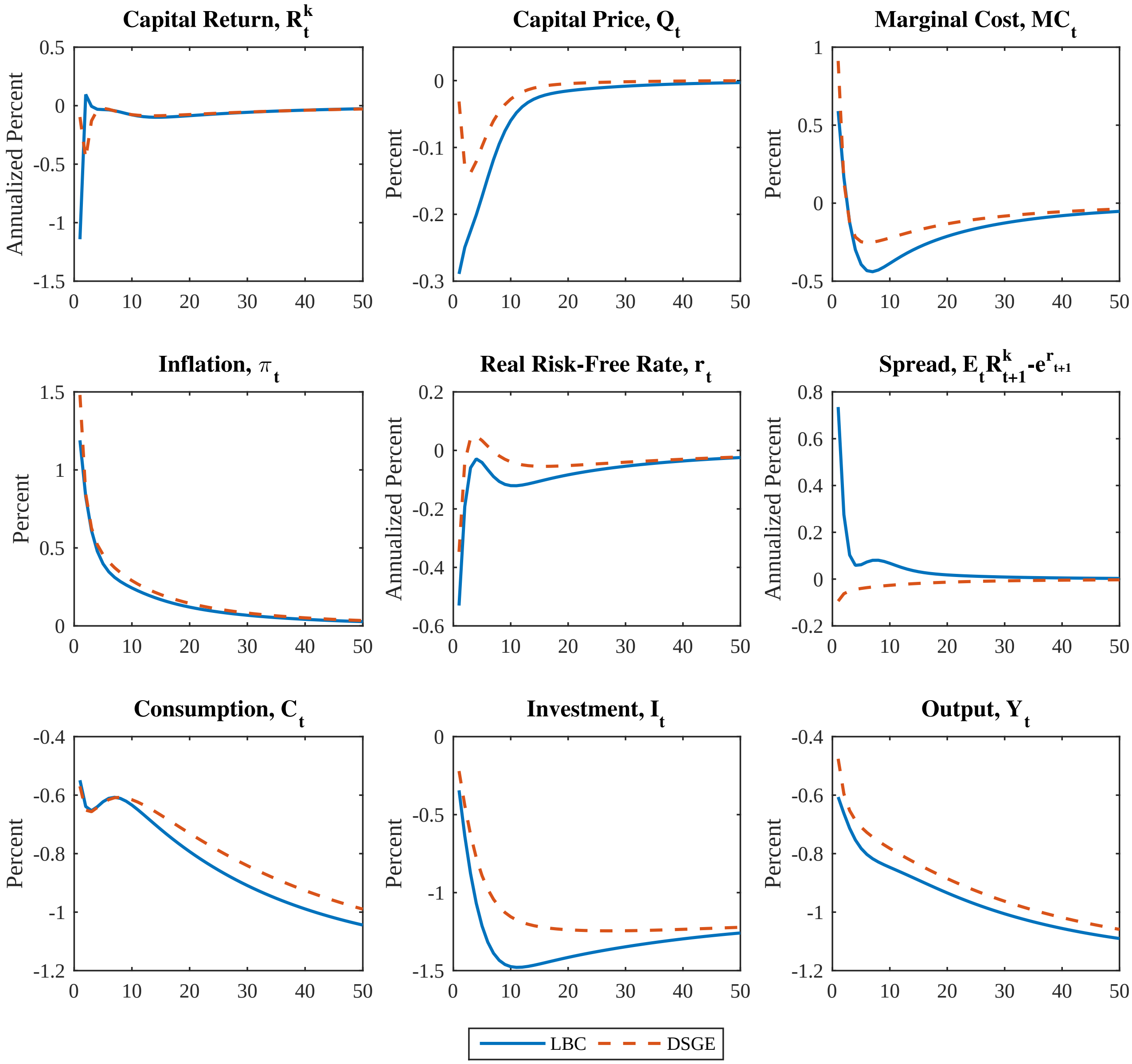
Figure 2 shows the impulse responses of the key macroeconomic variables to the negative technology shock. The baseline model generates the stronger responses of the aggregate variables compared to the alternative model. The negative shock reduces the marginal productivity of capital and therefore the return on capital. As a consequence, the capital price declines. A reduction in the capital price deteriorates the balance sheets of financial intermediaries, leading to a decline in their borrowing and lending capacity. Thus, the baseline model produces a stronger contraction in economic activity.

As the top right panel illustrates, the response of marginal cost is attenuated in the baseline model with

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

[17] There are many other alternatives. For example, I draw random numbers for the technology shock $\epsilon_t^A$ 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 third-order impulse response functions of the return of capital, $R_t^k$, price of capital, $Q_t$, marginal cost, $MC_t$, inflation rate, $\pi_t$, the net risk-free return, $r_{t+1}$, the spread, $E_tR_{t+1}^k - e^{r_{t+1}}$, consumption, $C_t$, investment, $I_t$, and output, $Y_t$, to a one-standard-deviation (0.7 percent) negative technology shock. The solid blue lines in each panel plot impulse response functions with limited borrowing capacity of financial intermediaries (the baseline model), and the dashed orange lines plot impulse response functions without banking frictions. See text for details.

limited borrowing capacity of financial intermediaries. Since the return on capital further declines with banking frictions, the production cost of intermediate goods firms falls. The negative technology shock drives up marginal cost, while the reduction in the return on capital moderately offsets the rise in marginal cost. As a

Table 2: THE MODEL-IMPLIED EQUITY PREMIUM

| Alternative (without LBC) | | | Baseline (with LBC) | | |
|---|---|---|---|---|---|
| $\psi_t^e$ | $\sigma_t(r_{t+1}^e)$ | $\sigma_t(r_{t+1})$ | $\psi_t^e$ | $\sigma_t(r_{t+1}^e)$ | $\sigma_t(r_{t+1})$ |
| 6.06 | 6.19 | 0.35 | 6.52 | 7.40 | 0.57 |

*Note:* This table reports the model-implied equity premium, $\psi_t^e$, 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, $\sigma_t(r_{t+1})$, in annualized percentage points. The baseline model is a New Keynesian DSGE model with generalized recursive preferences and limited borrowing capacity of financial intermediaries, while the alternative model has no banking frictions. See the text for more details.

result, inflation rises less in the baseline model with banking frictions.[18] The real risk-free rate, in turn, 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 allows 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, while it declines in the alternative model without banking frictions.[19] The bottom panels shows a more pronounced fall in consumption, investment, and output in the baseline model. Lastly, the similarity in impulse response functions for key macroeconomic variables in this model and these in the literature allow us to focus on implications for the equity premium.

### 3.2 Equity Premium Results

Table 2 reports the model-implied equity premium, $\psi_t^e$, 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 alrternative model. The forth column reports the equity premium, $\psi_t^e$, implied by the model with banking frictions, solved to third order, holding other parameters of the model set at their benchmark values. The model-implied equity premium, $\psi_t^e = 6.52$, matches its empirical estimate (typically about 4 to 8.4 percent for quarterly excess returns at an annual rate).[20] The fifth and sixth columns show that the standard devation for the net equity return is 7.4 percent and the standard devation of the risk-free return is 0.57 percent.

[18] Although the mechanisms are different, the behavior of inflation is similar to that of Gilchrist, Schoenle, Sim, and Zakrajšek (2017). The authors find through micro-level data that only intermediary goods firms that are bound by financial constraints raise their prices in recession and explain why inflation has remained low since the Great Recession.

[19] In models without banking frictions, the impulse response of the spread is not completely zero, because the figure is the third-order impulse response. On the other hand, in the first-order impulse response, the spread always shows a zero response as in Gertler and Karadi (2011).

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

The volatilities predicted by the baseline model are short of fully accounting for its counterpart observed in the data (typically about 1 to 2 percent for the risk-free rate and 15 to 20 percent for the equity return).[21] Accordingly, the Sharpe ratio, $\psi_t^e/\sqrt{\mathrm{Var}_t(r_{t+1}^e)}$, is 0.88, which is larger than the empirical estimates by Lettau and Ludvigson (2010) at about 0.2 to 0.4. However, this is not surprising. Since the baseline model has one exogenous shock the model-implied standard deviation is relatively small. This problem can be mitigated by adding other shocks to the model. Shocks that are less persistent than a technology shock such as a monetary policy shock or a government spending shock increase the volatility of the equity return without much changing the equity premium (Li and Palomino, 2014).

The first column presents the equity premium from the alternative model without banking frictions, which predicts a high equity premium of 6.03 percent.[22] The absence of banking frictions reduces the equity premium by about 46 basis points. This difference originated from imperfect borrowing markets accounts for 7.6 percent of the equity premium.[23] As shown in the second and third colums, the conditional standard deviation of the net equity return is 6.19 percent and the Sharpe ratio is 0.98 in the absence of banking frictions.

One might be interested in the underlying mechanism by which banking frictions increase the equity premium. The presence of banking frictions amplifies business cycle fluctuations, leading to a rise in the volatility of the stochastic discount factor. The standard deviation of the stochastic discount factor is 64.72 percentage points in the presence of financial frictions, while it is 62.22 percentage points in the frictionless model. In response to a negative technology shock, the technology declines, yielding a decline in the return of capital, $R_t^k$. The reduction in the return of capital lowers the aggregate net worth of the financial intermediaries, $N_t$, as the decline in the return of capital reduces the value of assets for financial intermediaries. The reduction in financial intermediaries' net worth weakens their lending capacity, reducing 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 return of capital, the net worth of financial intermediaries, and the price of capital, respectively. As a consequence, the amplification mechanism of limited borrowing capacity of financial intermediaries increases the volatility of the stochastic discount factor.

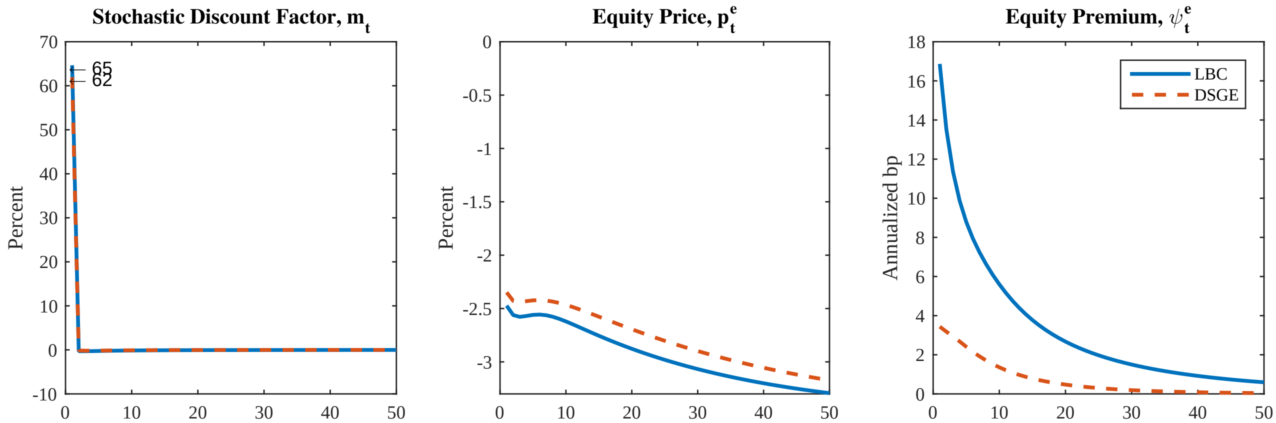
Figure 3 plots the impulse response functions to a one-standard-deviation (0.7 percent) negative technology

[21] See, Table 2 in Rudebusch and Swanson (2012) and Table 3 in Croce (2014).

[22] This result implies that generalized recursive preferences play an important role in accounting for the size of the equity premium.

[23] Gomes, Yaron, and Zhang (2003) investigate the implications of costly external finance of firms on asset price fluctuations within a real business cycle framework. They find that the equity premium in thier model is very small (0.012 to 0.022 percent) and is procyclical. As they point out, this property of the equity premium is at odds with the data. In contrast to their model, the baseline model predicts a countercyclcial equity preium.

Figure 3: IMPACT OF LIMITED BORROWING CAPACITY ON FINANCIAL VARIABLES




*Note:* Third-order impulse response functions for the stochastic discount factor, $m_t$, the equity price, $p_t^e$, and the equity premium, $\psi_t^e$, to a one-standard-deviation (0.7 percent) negative technology shock. The solid blue lines in each panel plot impulse response functions with limited borrowing capacity of financial intermediaries (the baseline model), and the dashed orange lines plot impulse response functions without banking frictions. See the text for more details.

shock. The solid blue lines and the orange dashed lines in each panel depict the impulse response functions for the baseline model and the alternative model without banking frictions, respectively. The left-hand 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 for the baseline model, while it jumps about 62 percent for the alternative model without banking frictions.

The right panel shows that the equity premium rises more with banking frictions. The initial response of the equity premium is 4 times larger in the baseline model compared to that of the alternative model. This evidence indicates that financial intermediaries' borrowing constraints generate a substantial contribution to the equity premium. The sign of the equity premium is positive, indicating that the conditional covariance between the stochastic discount factor and the return of the equity is negative. The middle panel shows the impulse response function for the equity price, $p_t^e$. The baseline model predicts that the equity price plumments 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.

# 4 Additional Discussion and Extensions

In this section, I discuss whether a particular parameter can increase the impact of banking frictions on the macroeconomy and the equity premium.

## 4.1 Smoothing Parameter of Monetary Policy

This subsection analyzes the impacts of monetary policy on the equity premium by controlling the smoothing parameter, $\rho_i$, rather than only the inflation coefficient or the output gap coefficient separately. Limited borrowing capacity of financial intermediaries affects to setting of the monetary authority's policy instrument, since it reduces output more and increases inflation less when there is a negative technology shock. With a high degree of policy inertia, the central bank adjusts the nominal risk-free rate gradually in response to changes in economic conditions. This implies that the equity premium can be influenced by the smoothing parameter of monetary policy, which interacts with banking frictions.

Panel A in Table 3 reports the model-implied equity premiums calculated with different smoothing parameters, while fixing other parameters at their benchmark calibration as in Table 1. In the model with limited borrowing capacity of financial intermediaries, the equity premium increases along with the smoothing parameter of monetary policy. By contrast, the model without banking frictions decreases the equity premium with more persistence in interest rate. The smoothing parameter increases the equity premium by 8 basis points in the baseline model when $\rho_i$ is changed to 0.8 from 0.6, while it decreases the equity premium by 31 basis points in the alternative model without banking frictions.

The model-implied equity premium is more sensitive to the interest rate smoothing in the frictionless model. The risk-free rate increases as the interest rate inertia decreases, since inflation is relatively higher in the model without banking frictions. This reduces the inflation gap but destabilizes output, which induces more compensation for holding equity. As a result, a smaller smoothing parameter increases the equity premium in the frictionless model. Conversely, banking frictions produce a deeper recession and partially offset increase in inflation when there is a negative technology shock. In turn, the real risk-free interest rate decreases in response to the economic downturn, leading to a faster recovery in consumption and reducing the volatility of the stochastic discount factor.

The smoothing parameter also affects the dynamics of the equity premium with banking frictions. Figure

Table 3: COMPARISON OF EQUITY PREMIUM

| Smoothing parameter $\rho_i$ | Seizure rate $\vartheta$ | Risk aversion $R^c$ | Equity premium without LBC | Equity premium with LBC |
|---|---|---|---|---|
| Panel A | | | | |
| 0.6 | 0.19 | 60 | 6.24 | 6.48 |
| 0.8 | 0.19 | 60 | 5.93 | 6.56 |
| Panel B | | | | |
| 0.73 | 0.38 | 60 | 6.06 | 6.60 |
| 0.73 | 0.68 | 60 | 6.06 | 6.67 |
| Panel C | | | | |
| 0.73 | 0.19 | 10 | 0.98 | 1.06 |
| 0.73 | 0.19 | 30 | 3.01 | 3.24 |
| 0.73 | 0.19 | 90 | 9.12 | 9.80 |

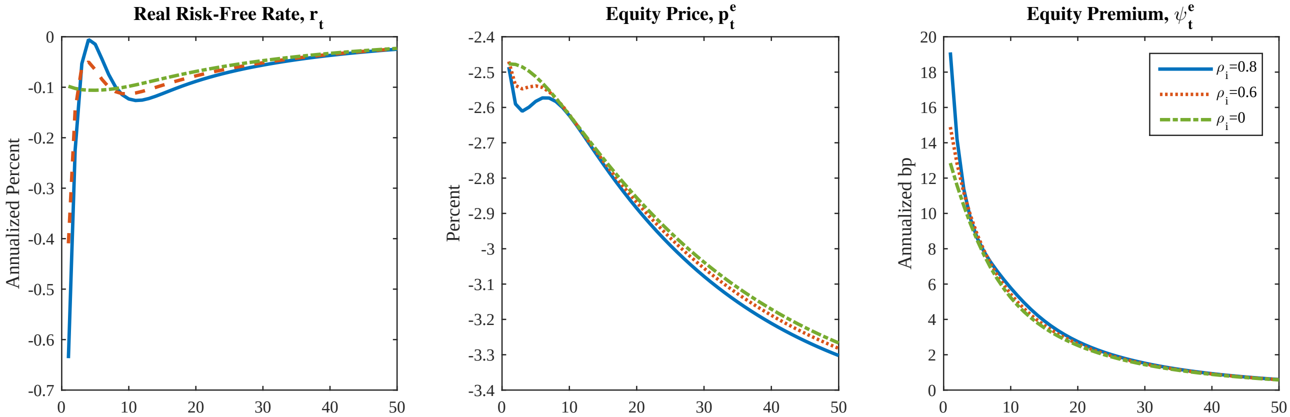
*Note:* This table reports the equity premium implied by the model in annualized percentage points with different values of smoothing parameter of monetary policy, $\rho_i$, seizure rate, $\vartheta$, and risk aversion, $R^c$. Model with LBC is a New Keynesian DSGE model with generalized recursive preferences and limited borrowing capacity of financial intermediaries, while Model without is a standard New Keynesian DSGE model without banking frictions. See the text for more details.

4 plots the impulse response functions for the risk-free return, the equity price, and the equity premium to 0.7 percent negative technology shock with different interest rate inertia values. The solid blue lines in each panel plot impulse response functions for a stronger smoothing parameter ($\rho_i = 0.8$), the dashed orange lines plot the impulse response functions for weaker inertia ($\rho_i = 0.6$), and the dash-dot green lines plot the impulse response functions for no interest rate smoothing. Generally, the central bank concerns the increased inflation gap more because the coefficient of the inflation gap, $\phi_\pi$, is 0.53 and the coefficient of the output gap, $\phi_y$, is about 0.23 per quarter.

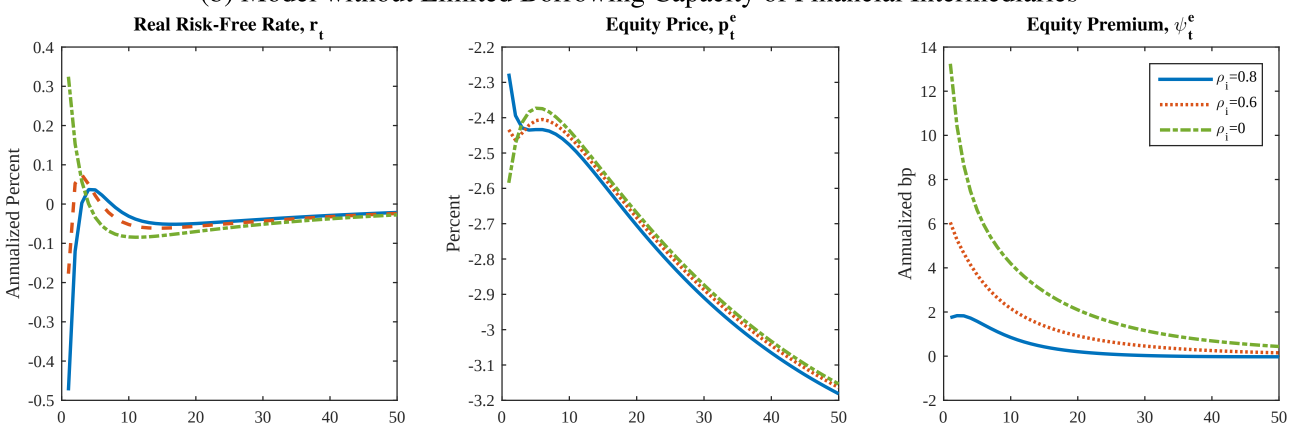
In the presence of banking frictions, the risk-free return always responds negatively even if there is no inertia

Figure 4: IMPULSE RESPONSE FUNCTIONS WITH DIFFERENT SMOOTHING PARAMETERS

(a) Model with Limited Borrowing Capacity of Financial Intermediaries




(b) Model without Limited Borrowing Capacity of Financial Intermediaries




*Note:* The figure plots third-order impulse response functions of the net risk-free return, $r_t$, the equity price, $p_t^e$, and the equity premium, $\psi_t^e$, to a one-standard-deviation (0.7 percent) negative technology shock. The blue solid, the dashed orange, and dash-dot green lines report the impuls response functions from the models when $\rho_i$ =0.8, 0.6, and 0, respectively. See text for details.

due to a deeper recession and mild inflation. The responses of consumption and equity price are therefore not as volatile as in the frictionless model, and higher interest rate smoothing parameter increases the response of the equity premium as in the right panel at (a). On the other hand, the case is different in the frictionless model. Since inflation is relatively higher and output is less decreased, the central bank sets the risk-free interest rate positively when there is no interest rate inertia as in the left panel at (b). In turn, the responses of consumption and the equity price are further reduced and more volatile due to output destabilization. As a consequence, the equity premium responds more positively with smaller interest rate inertia.

### 4.2 Seizure Rate

This subsection analyzes how the seizure rate, $\vartheta$, affects the macroeconomy and the equity premium through limited borrowing capacity of financial intermediaries. The seizure rate is the fraction of capital assets that can be diverted by the financial intermediary. This is one of the most important parameters for banking frictions because the incentive constraint (9) binds when the excess marginal value of assets over deposits, $\mu_t$, lies between zero and the seizure rate. Accordingly, the multiple leverage, $\phi_t$, depends on the seizure rate while the amplification effect of banking frictions varies by changing the seizure rate. To analyze the role of the seizure rate, I set it to 0.38 and 0.68 following Gertler and Karadi (2011) and Gelain and Ilbas (2017), holding other parameters of the model set at their benchmark calibration.

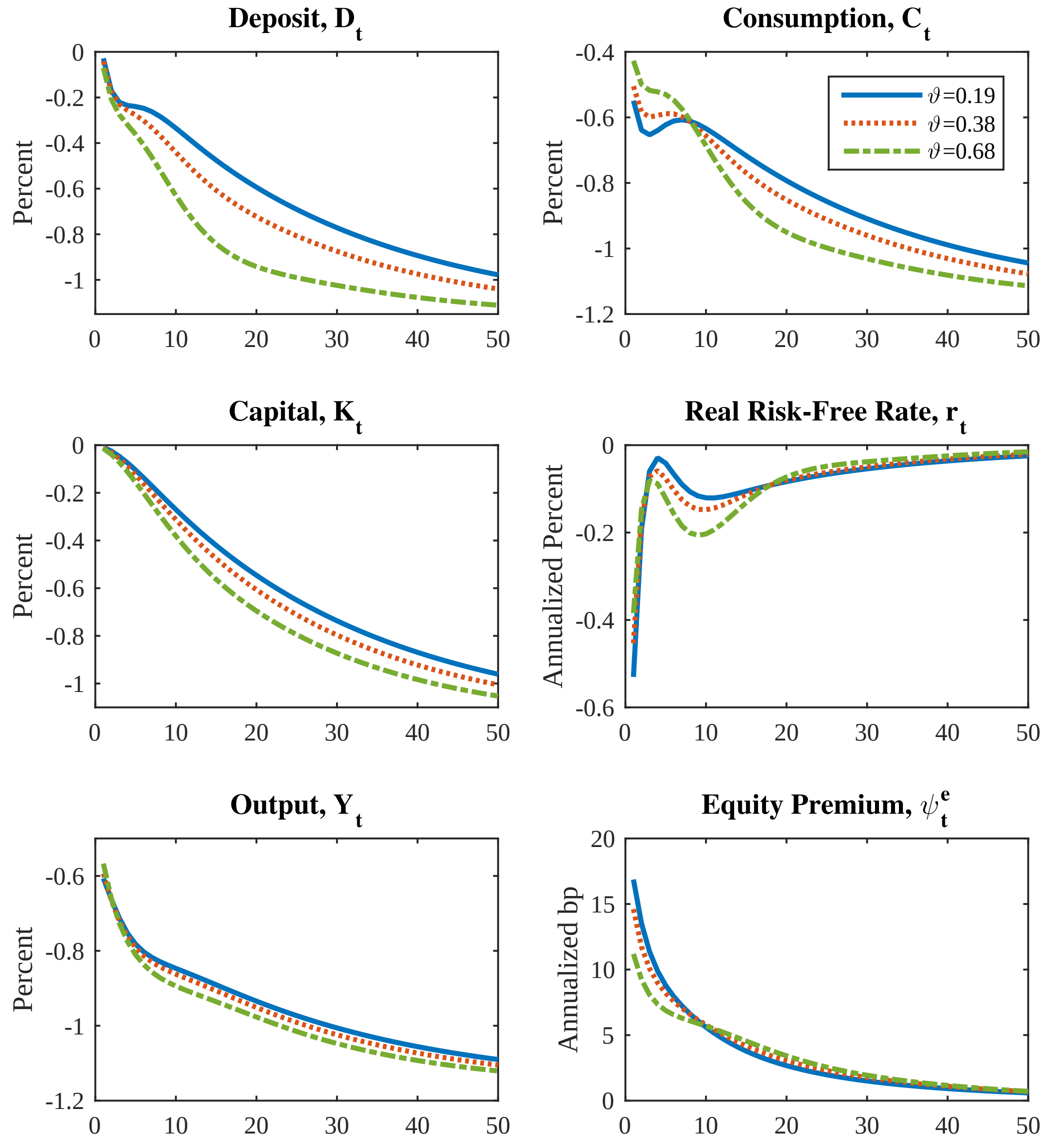
Panel B in Table 3 presents the equity premium with higher seizure rates. This table suggests that increasing $\vartheta$ increases the equity premium. For example, when the seizure rate increases to 0.68, the equity premium is 6.67 percent. In this case, the difference with the equity premium from the model without banking frictions is 61 basis points. The reason for this result is that the volatility of the stochastic discount factor increases. The standard deviation of the stochastic discount factor is 66.86 percentage points when the seizure rate is 0.68.

Figure 5 plots the impulse response functions to a one-standard-deviation negative technology shock with different seizure rates. The blue solid, the dashed orange, and dash-dot green lines report the impulse response functions when $\vartheta = 0.19$, 0.38, and 0.68, respectively. As can be seen on the top left panel, households reduce deposits due to higher seizure rate after the technology shock. This is because higher rate of seizure means that households are reluctant to deposit at financial intermediaries since they face higher costs for the moral hazard problem. As deposits decrease, net worth of financial intermediaries decreases, thus reducing capital stock as shown in the middle left panel. Therefore, output declines more due to the higher seizure rate, meaning that the effect of banking frictions increases.

The top right panel shows that consumption responds less to the technology shock when seizure rates are high at first because households do not want to deposit with the higher seizure rate. Then, consumption declines more rapidly as the recession gets worse over time when the seizure rate is high. Since consumption becomes more volatile, the stochastic discount factor is also volatile and the equity premium increases.

The bottom right panel plots that the response of the equity premium decreases when the seizure rate increases, although the mean of the equity premium increases with the seizure rate. This is because the central bank reduces the interest rate relatively less at first as can be seen in the middle right panel. Output is relatively

Figure 5: Impulse Response Functions with Different Seizure Rates




*Note:* The figure plots third-order impulse response functions of deposits, $D_t$, consumption, $C_t$, Capital, $K_t$, the net risk-free return, $r_{t+1}$, output, $Y_t$, and the equity premium, $\psi_t^e$, to a one-standard-deviation (0.7 percent) negative technology shock. The blue solid, the dashed orange, and dash-dot green lines report the impuls response functions from the baseline model when $\vartheta$ =0.19, 0.38, and 0.68, respectively. See text for details.

less declined as consumption responds less. However, the equity premium responds more with higher seizure rate over time since the central bank lowers the interest rate more to stimulate economic activity.

## 4.3 Relative Risk Aversion

This subsection analyzes the effect of the coefficient of relative risk aversion on the equity premium along with limited borrowing capacity of financial intermediaries. The coefficient of relative risk aversion, which measures the household's attitudes toward risk, directly related to the equity premium. Swanson (2012) analytically shows that any risk premium positively depends on risk aversion in a second order approximation. Thus, the risk aversion is one of the most important parameters for the mean of the equity premium because the positive relationship does not change even in a higher order approximation.

Panel C in Table 3 presents the equity premium with various values of relative risk aversion, $R^c$, holding other parameters of the model set at their benchmark calibration. The equity premium increases with risk aversion since it raises the volatility of the stochastic discount factor. At first glance, the difference in the equity premium due to limited borrowing capacity of financial intermediaries seems to be increasing as the risk aversion increases. However, the ratio of increase is quite stable at around 8 percent even if the difference is increasing. This ratio of increase is very stable and barely depend on risk aversion. For example, in the case of $R^c = 90$, the equity premium increases 68 basis points; this difference accounts for 7.5 percent of the equity premium from the model without limited borrowing capacity of financial intermediaries.

## 4.4 Investment Adjustment Costs

Jermann (1998) and Gomes, Yaron, and Zhang (2003) astutely note that increasing the adjustment costs of capital improves the asset pricing performance by raising both the volatility of consumption and stock returns. Table 4 shows the model-implied equity premium for various investment adjustment costs. The equity premium is not very sensitive to $\kappa$, with or without limited borrowing capacity of financial intermediaries. For example, in the frictionless model, the equity premium increases only 18 basis points, even if the investment adjustment cost is raised unrealistically to 30 from 3.[24] Therefore, the equity premium is not sensitive to the presence of investment adjustment costs.

The main reason for this is that, as in BGG, my model introduces separate capital producers to easily determine the capital price endogenously. Since households do not own the capital stock, the inelastic supply of capital has little effect on the volatility of consumption of households and does not raise the volatility of the

[24] This is a big difference from Gomes, Yaron, and Zhang (2003) where the equity premium increases by a factor of four in respect to a similar change.

Table 4: INVESTMENT ADJUSTMENT COSTS

| | Model without LBC | | | | Model with LBC | | | |
|---|---|---|---|---|---|---|---|---|
| | $\kappa = 3$ | $\kappa = 10$ | $\kappa = 20$ | $\kappa = 30$ | $\kappa = 3$ | $\kappa = 10$ | $\kappa = 20$ | $\kappa = 30$ |
| $\sigma(m_t)$ | 62.22 | 62.29 | 62.31 | 62.30 | 64.72 | 64.42 | 64.15 | 63.96 |
| $\sigma(m_t^C)$ | 0.55 | 0.60 | 0.63 | 0.64 | 0.58 | 0.58 | 0.58 | 0.57 |
| $\sigma(m_t^V)$ | 61.68 | 61.70 | 61.69 | 61.67 | 64.16 | 63.86 | 63.60 | 63.41 |
| $\psi_t^e$ | 6.06 | 6.16 | 6.21 | 6.24 | 6.52 | 6.48 | 6.44 | 6.40 |

*Note:* This table reports the model-based unconditional moment of the stochastic discount factor, $\sigma(m_t)$, and the equity premium, $\psi_t^e$. $\sigma(m_t^C)$ denotes the standard deviation of the stochastic discount factor due to consumption growth, and $\sigma(m_t^V)$ denotes the additional standard deviation of the stochastic discount factor due to generalized recursive preferences. Model with LBC is a New Keynesian DSGE model with generalized recursive preferences and limited borrowing capacity of financial intermediaries, while Model without LBC is a standard New Keynesian DSGE model without banking frictions. All numbers are in percentage points. See text for details.

stochastic discount factor substantially. In contrast, consumption smoothing requires more cost for households with the high elasticity of investment adjustment costs in the standard DSGE model. Accordingly, the stochastic discount factor fluctuates more and this increases the equity premium in Jermann (1998).

Moreover, households do not have habit preferences in the model. If the household owns the capital stock, consumption smoothing can be affected greatly by habit, as in Jermann (1998). At the same time, the equity premium decreases as the investment adjustment costs get larger in the model with limited borrowing capacity of financial intermediaries. For instance, the equity premium is reduced about 12 basis points by increasing the elasticity of investment adjustment costs to 30 from 3. As $\kappa$ increases, the variability of capital decreases, which reduces the volatility of the bank's net worth. Accordingly, it is less costly to smooth consumption for the households although the impact is very small.

Finally, for a more detailed examination, I decompose the standard deviation of the stochastic discount factor into two parts. The first is a marginal rate of substitution of consumption, so it is the same as the stochastic discount factor from the expected utility preferences. The second is the additional volatility of the stochastic discount factor due to generalized recursive preferences. The result tells us that the volatility of the stochastic discount factor varies due to the additional part, rather than from changes of consumption growth in two models. In the model with limited borrowing capacity of financial intermediaries, the adjustment costs of investment have a small impact on the household's consumption smoothing; therefore, it does not change the equity premium substantially.

## 5 Conclusion

This paper examines the effect of limited borrowing capacity of financial intermediaries on the equity premium with two modifications to a medium-scale New Keynesian DSGE model: first, the model includes banking frictions, which allows the model to have interactions between the financial market and the macroeconomy, and second, generalized recursive preferences, which generate a substantial risk premium without compromising stylized macroeconomic facts. A quantitative analysis of the model shows that limited borrowing capacity of financial intermediaries is a very plausible and new amplification mechanism for asset pricing in the model because it increases the volatility of the stochastic discount factor and lowers the risk-free rate. Limited borrowing capacity of financial intermediaries increases the price of the risk in the model since it makes consumption more volatile. Moreover, limited borrowing capacity of financial intermediaries generates more severe recessions but lower inflation in response to a negative technology shock. Due to the lower inflation, the central bank has more incentive to lower the risk-free interest rate in a recession and this increases the equity premium–the difference between the expected return to equity and the risk-free rate.

In a nutshell, the model makes progress on the task of consolidating the analysis of asset prices and macroeconomics with financial frictions. However, there is still substantial potential for improvement because the model has been simplified to understand the underlying mechanism of limited borrowing capacity of financial intermediaries and its impact on the equity premium. In future research, it may be useful to extend the role of lenders to taking into account the collateral of the borrower, because housing finance was a particularly big issue in the Great Recession and household consumption was dampened due to the subprime mortgage crisis. Extending the model to incorporate housing prices such as Iacoviello (2005) and Liu, Wang, and Zha (2013) would be an interesting idea since the financial intermediary could have a greater influence on household consumption and the stochastic discount factor.

# A Appendix: Model Equations

The following equations show how I incorporate generalized recursive preferences and limited borrowing capacity of financial intermediaries into a medium-scale New Keynesian DSGE model.

**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**

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

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

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

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

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

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

**Capital Producer**

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

$$K_{t+1} = (1-\delta)K_t + \left\{1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right\} I_t \tag{A.12}$$

**Intermediate goods sector**

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

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

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

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

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

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

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

**Final goods sector**

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

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

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

**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**

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

For the alternative model, there is no banking sector and 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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