Stock Returns under Intermediary Investment

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Abstract

The recent financial crisis highlights the effects of shocks amplified by financial intermediaries under monetary policy such as low interest rates. This paper examines these effects on firms' stock returns through a large size macro-finance model. Stock risk premia were captured by a global solution of a state-of-the-art simulation-projection algorithm. Based on heterogeneous capital quality shocks, a cross-sectional analysis reveals the novel stock return predictability of intermediaries' capital investment (*ICI*) and firms' effective capital for marginal production (*KMP*). The underlying force is that capital shocks and financial frictions reduce credit supply and asset valuations via intermediaries' amplification mechanism.

Keywords: Asset Pricing; Financial Intermediation; Financial Frictions; Capital Quality Shock; Monetary Policy

JEL Classification: G12; G21; G32; E22

1 Introduction

The Great Recession and subsequent slow recovery raise the question on how adverse economic shocks that are amplified by financial intermediaries affect the excess returns of firms' stocks funded by intermediaries. The previous work on this issue is less and not conclusive, which focuses on different intermediary stochastic discount factors (Adrian, Etula, and Muir, 2014; He, Kelly, and Manela, 2017) or intermediaries' liquid assets (Drechsler, Savov, and

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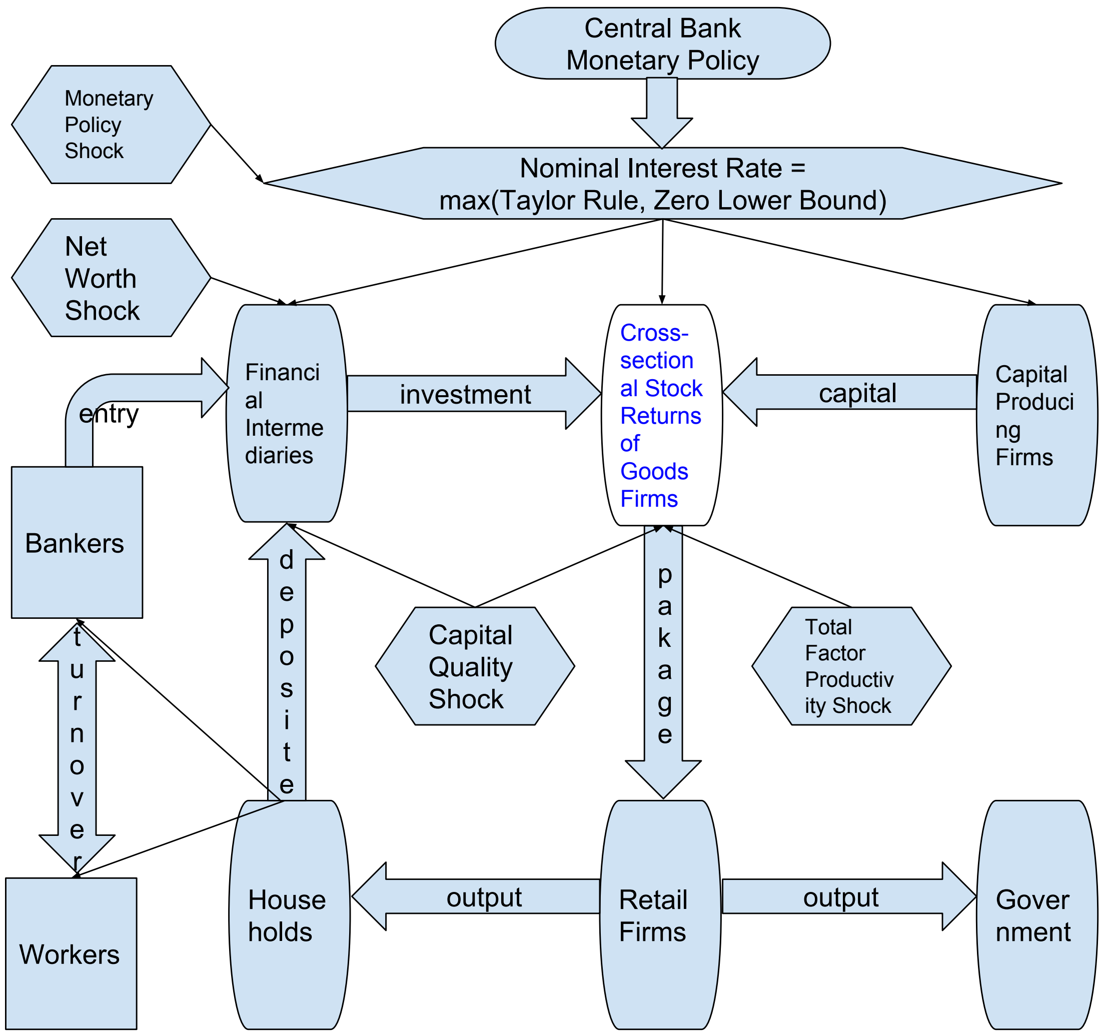

Figure 1. Structure of the macro-finance model for intermediation-based asset pricing. The chart only portrays main links for clarity, though exogenous shocks affect all of the agents who interact with each other through the model.

Schnabl, 2017). The literature lacks an answer to the question about the interacting effects of firms characteristics, financial intermediaries, economic shocks, and monetary policy such as the prolonged low interest rate on stock returns.

This paper reveals the underlying mechanism of intermediary asset pricing and related pricing factors through a large size New-Keynesian macro-finance model with about forty variables. To capture time-varying risk premia and high non-linearity, a global solution is obtained by implementing a state-of-the-art projection algorithm based on iterated simulation grids proposed by Maliar and Maliar (2015). The model is an extension to Gertler and Karadi (2011) featuring intermediary borrowing constraints and capital quality shocks etc., see Figure 1 for an illustration of the model structure.

The model offers novel explanations to the variation of risk premia in the cross section based on a financial intermediary amplification mechanism of economic shocks. After introducing heterogeneous capital quality shocks, we rationalize the stock return predictability of intermediaries' capital investment (ICI) and firms' effective capital for marginal production (KMP) through a cross-sectional analysis. The underlying economic force is that financial constraints and adverse shocks under constrained monetary policy reduce credit supply, real investment, production, profits, and asset valuations substantially via the intermediary amplification mechanism. This paper is the first to study the amplification effects of financial intermediaries on firms' stock returns.

Specifically, the results show that financial intermediary investment has implications for firms' stock returns. When the fund that intermediaries can borrow from depositors is limited, the market value of a firm reflects the value of its capital invested by intermediaries, since the firm can utilize the limited capital to expand real investment and production. The capital also makes the firm's decisions forward looking and therefore potentially provides information about the firm's future value. Inspired by the two views, we use firm-level regressions on the model-generated data to show that a 1 percent point increase in the the logarithm of ICI ratio (the ratio of an *individual* firm's capital invested by intermediaries to the aggregate intermediary net worth) is associated with an increase of 9 percent points in the firm's annual future stock return. Furthermore, the annual excess returns of ten portfolios sorted on the logarithm of ICI vary from -2.6 percent to 13.1 percent. Such difference is referred to as 'the intermediary investment spread', which reflects the relatively lower risk of the firms with low intermediary investment under the financial friction of intermediaries.

This paper relates to a few strands of literature. Academics and practitioners renewed research interest on stock return predictability after the seminal work of Welch and Goyal (2008), who report that macroeconomic and financial predictors cannot forecast out-of-sample US stock returns. Nevertheless, Campbell and Thompson (2008) find that weak restrictions on regressions provide meaningful forecasts. Fama and French (2008) summarize much evidence of stock return predictability for firms with particular characteristics. Belo, Lin, and Bazdresch (2014) show that firms' hiring rates and labor market frictions explain asset prices. Kung and Schmid (2015) demonstrate that research and development predict both equity premium and value premium. van Binsbergen (2016) discovers that low returns and volatilities are associated with firms producing goods with high habit level. Overall, recent developments in empirical studies confirm significant return predictability using macroeconomic or microeconomic variables, which motivates the study here.

This paper is connected to previous studies on the predictive power of aggregate intermediary balance sheets and credit for risk premia. Adrian, Moench, and Shin (2010) show that the former predicts excess returns of portfolios of equity and bonds. Longstaff and Wang (2012) rationalize that the latter predicts expected stock returns through influencing risk sharing. Brunnermeier and Sannikov (2016) reveal that financial frictions limit credit flow and thus financial intermediaries allocate more funds to more productive agents. They point out that a negative aggregate productivity shock reduces intermediaries' wealth shares and pushes up risk premia. This mechanism is similar to the effect of the negative capital quality shock that we examine.

The negative capital quality shock is inspired by real business cycle studies. It is introduced to a New Keynesian setting by Christiano, Eichenbaum, and Evans (2005) and an asset pricing setting by Gourio (2012). It is also named as 'valuation shock' or 'depreciation shock'. In Brunnermeier and Sannikov (2014), it captures the 'effectiveness' of capital stock and changes in the expectation about its future productivity. Gertler and Karadi (2011) use this shock to contract real economy like the recent financial crisis. Large reallocation due to financial crisis destructs capital or makes some capital goods worthless. This shock and other exogenous shocks are further amplified and propagated by financial intermediaries ('financial accelerator' effects). These shocks motivate this study to examine risk prices of shocks, *ICI*, and *KMP* in the content of cross-sectional asset prices.

This paper also investigates the effects of low interest rates on stock returns. Since late 2008, many central banks targeted a historically low policy rate near zero (the Zero Lower Bound, ZLB) and they could not reduce their policy rates further to offset negative shocks. The adverse effects of exogenous shocks were amplified in the economy constrained at the

ZLB (Christiano, Eichenbaum, and Rebelo, 2011). The long duration of the ZLB further contributed to endogenous uncertainty and non-linearity (Basu and Bundick, 2015). In return, the uncertainty caused by the ZLB makes forward-looking households and firms reduce consumption and output (Nakata, 2013). The ZLB added more challenges on examining the risk premia of firms' equity financing under financial intermediaries, frictions, and shocks.

The literature typically uses local linear perturbation methods to economics models or solves low-dimensional problems by applying expensive global solution methods. However, the recent literature emphasizes that perturbation methods make unrealistic assumptions and produce large misleading results to the models with occasional binding constraints, e.g. the ZLB. Richter and Throckmorton (2015) point out that the frequency and duration of the ZLB require a nonlinear solution that accurately acknowledges the expectation effects of the endogenously binding ZLB. Fernández-Villaverde, Gordon, Guerrón-Quintana, and Rubio-Ramirez (2015) address that linearizing equilibrium equations poorly describes a recessional economy. Hence, this paper extends a numerical algorithm in Maliar and Maliar (2015) to solve the large size high-dimensional model with the non-linear ZLB constraint.

The paper proceeds as follows. Section 2 presents the intermediation-based asset pricing model with financial frictions and the ZLB. Section 3 summarizes parameter calibration and investigates the accuracy and robustness of the global solution. Section 4 provides a detailed analysis of stock return predictability and the economic mechanisms. Section 5 concludes.

2 A intermediation-based asset pricing model

The model carries key features prevalent in canonical NK-DSGE models (e.g. Christiano et al., 2005; Smets and Wouters, 2007) to maintain reasonable quantitative performance and the specific model allow for financial intermediation as Gertler and Karadi (2011). We consider firms' equity financing in the NK-DSGE model with unconventional monetary policy and examine the associated asset pricing implications.

To begin with, nominal price rigidity and capital adjustment costs in the NK-DSGE model induce countercyclical markups that amplify the reaction of aggregate activity to credit market disruptions (e.g. **?**). In addition, financial intermediaries in Gertler and Karadi

(2011) incur frictions from an agency problem that constrains their abilities to obtain funds from households. The financial sector suffers a significant capital loss in the case of a shock to the quality of capital since the frictions prevent the economy from replenishing effective capital stocks. Such loss tightens credit, which results in a significant downturn in output. Furthermore, the effect of the financial market disruptions is further amplified when the zero lower bound on the nominal interest is endogenously binding since the central bank cannot offset the crisis by adopting the monetary policy of reducing the nominal rate.

2.1 Households

Consider a continuum of identical households of unit mass. Within each household, the members can be either workers or bankers. We follow Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) to keep the tractability of the representative agent approach. They assume that the two groups of agents have identical preferences and the idiosyncratic consumption risks within each household can be completely insured by using the available full set of Arrow-Debreu securities.

Bankers take a fraction f of the members of a representative household at any period. Bankers can only live for a finite horizon with probability 1 hence they cannot overcome financial constraints to fund all investments through accumulate their own capital. A banker exits and turnovers to a worker with i.i.d. probability $1-\theta$ next period, which indicates an average survival time $1/(1-\theta)$. When exiting, the banker returns their net worth to their household. Meanwhile, an equal $(1-\theta)f$ number of workers become bankers within each household to keep the proportion of workers and bankers constant. Each new banker obtains a start-up fund from their household, which equals a small constant fraction of the exiting banker's final total assets described later.

The preference of the representative household is

$$\mathbb{E}_t\left[\sum_{\tau=0}^{\infty}\beta^{\tau}\left(\frac{(C_{t+\tau}-hC_{t+\tau-1})^{1-\gamma}}{1-\gamma}-\frac{\chi}{1+\varphi}{L_{t+\tau}}^{1+\varphi}\right)\right], \tag{1}$$

where C_t and L_t are the consumption and the labor supply (working hours) at time t respectively. The inverse Frisch elasticity of labor supply $\varphi>0$. The subject discount rate β and the habit parameter h fall in the domain (0,1). The relative utility weight of labor $\chi>0$.

Assume that the bankers and workers can obtain a nominally risk-free rate by holding nominally risk-free government debt or intermediary deposits that are perfect substitutes. The corresponding real gross interest rate R_t from $t-1$ to t is random since the inflation is random up to the information set at time $t-1$. Denote the total quantity of debt acquired by the household at the end of period t by B_{t+1}. The household has a budget constraint

$$C_t = W_t L_t + \Sigma_t + T_t + R_t B_t - B_{t+1}, \tag{2}$$

where W_t is the real wage, Σ_t denotes the profits from the both non-financial and financial firms (described later) that are owned by the household, and T_t denotes the real lump-sum taxes.

Denote the marginal utility of consumption by ϱ_t. The household's first-order conditions for the corresponding utility maximization problem lead to the intra-temporal Euler equation for labor supply

$$\varrho_t W_t = \chi L_t^{\varphi}, \tag{3}$$

and the inter-temporal Euler equation for consumption

$$\varrho_t = (C_t - hC_{t-1})^{-1} - \beta h \mathbb{E}_t[(C_{t+1} - hC_t)^{-1}], \tag{4}$$

and the inter-temporal Euler equation for risk-free bond holding

$$\mathbb{E}_t \left[\beta \Lambda_{t,t+1} R_t\right] = 1, \tag{5}$$

where

$$\Lambda_{t,t+1} = \frac{\varrho_{t+1}}{\varrho_t}. \tag{6}$$

Hence, $\beta^{\tau} \Lambda_{t,t+\tau}$ is the stochastic discount factor (SDF) of the representative agent applying to earning at $t+\tau$, which also coincides with the banker's SDF used later.

2.2 Financial intermediaries

Financial intermediaries are characterized below following Gertler and Karadi (2011). They receive deposits from households by paying the real gross interest rate R_t. They pool deposits with their own net worth and then they lend funds to (non-financial) intermediate goods firms (described later). Therefore, the balance sheet of a intermediary/banker j at the end of period t is

$$Q_t S_{j,t} = N_{j,t} + B_{j,t+1}, \tag{7}$$

where Q_t is the price of financial claims on the intermediate goods firms that the intermediary purchases, $S_{j,t}$ is the quantity of these claims (*assets*), $N_{j,t}$ is net worth or *equity* capital, and $B_{j,t+1}$ is the deposits obtained from households or the intermediary's debt (*liability*). The financial claims $S_{j,t}$ provide a gross return $R_{k,t+1}$ to the intermediary at time $t+1$. Thus, the intermediary's net worth evolves as

$$N_{j,t+1} = (R_{k,t+1} - R_{t+1})Q_t S_{j,t} + R_{t+1}N_{j,t}, \tag{8}$$

where the **risk premium** $R_{k,t+1} - R_{t+1}$ earned by the intermediary is highly countercyclical and surges during the 2007–2009 recession (Justiniano, Primiceri, and Tambalotti, 2010).

The intermediary only lends funds to non-financial firms if the expected discounted risk premium is non-negative, which induces the value-maximizing financial intermediary to lever up its assets infinitely by borrowing funds from households. To guarantees an equilibrium, the model assume that the intermediary incurs a borrowing constraint restricting the intermediary's ability to obtain funds from households' deposits.

Specifically, a simple moral hazard/costly enforcement problem is introduced to motivate the borrowing constraint below. The banker can divert the fraction λ of available funds from the intermediary's assets to his household, e.g. large bonuses and dividends. The cost to the banker is that the depositors can recover the remaining fraction $1 - \lambda$ of assets by forcing the intermediary into bankruptcy. Thus, households are willing to deposit funds only if the incentive constraint holds

$$V_{j,t} \geq \lambda Q_t S_{j,t}, \tag{9}$$

where $V_{j,t}$ is the value function of the value-maximizing financial intermediary.

The value of the intermediary can expressed as a linear combination of its assets and net worth:

$$V_{j,t} = \nu_t Q_t S_{j,t} + \eta_t N_{j,t}, \tag{10}$$

with

$$\nu_t = \mathbb{E}_t[(1-\theta)\beta\Lambda_{t,t+1}(R_{k,t+1} - R_{t+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1}\nu_{t+1}], \tag{11}$$

$$\eta_t = \mathbb{E}_t[(1-\theta) + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t+1}], \tag{12}$$

where $x_{t,t+1} \equiv Q_{t+1}S_{j,t+1}/Q_tS_{j,t}$ and $z_{t,t+1} \equiv N_{j,t+1}/N_{j,t}$ are the gross growth rates of assets and net worth respectively.

To apply the local linear perturbation solution, Gertler and Karadi (2011) assume that the equilibrium can be constructed by using reasonable parameter values such that the incentive constraint (9) always binds in the local region of the steady state. Our global projection solution can loose this assumption by directly incorporating the *occasional binding constraint* (9). Using (9) and (10) gives the positive relation between the assets acquired by the intermediary and its equity capital:

$$Q_tS_{j,t} \leq \frac{\eta_t}{\lambda - \nu_t}N_{j,t} = \phi_t N_{j,t} \tag{13}$$

where $\phi_t = \eta_t/(\lambda - \nu_t)$. The constraint (13) implies an endogenous constraint on the assets acquired by the intermediary in the agency problem. Positive net worth indicates that the incentive constraint binds only if $0 < \nu_t < \lambda$.

Summing across all individual intermediary demands leads to the total intermediary demand for assets

$$Q_tS_t = \phi_t N_t \tag{14}$$

where S_t and N_t are the aggregate quantity of intermediaries' assets and net worth.

The aggregate net worth N_t consists of the net worth of existing intermediaries $N_{e,t}$ and the new bankers $N_{n,t}$. The fraction θ of bankers survive until t from $t-1$ results in

$$N_{e,t+1} = \theta[(R_{k,t} - R_t)\phi_{t-1} + R_t]N_{t-1}\iota_t, \tag{15}$$

where ι_t is the intermediary net worth shock. Each new intermediary receives a fraction $\omega/(1-\theta)$ of the final period assets of the exiting intermediaries $(1-\theta)Q_tS_{t-1}$ under the **Capital Quality Shock (CQS)** ξ_t, which gives

$$N_{n,t} = \omega Q_t S_{t-1}\xi_t. \tag{16}$$

2.3 Intermediate goods firms

Financial intermediaries invest in the financial claims of competitive intermediate goods firms that produce intermediate goods used by the retail firms (described later). We extend the model in Gertler and Karadi (2011) to a specification incorporating cross-sectional stock returns and firm characteristics.

Consider one representative intermediate goods firm without wealth. This firm sells its financial claims to some financial intermediaries in exchange for a lump sum of proceeds $L_{m,t}$, which is the total investment of intermediaries in this firm. Then the firm uses the proceeds to purchase capital K_{t+1} from the capital producing firm (described later) for production in the next period. Given the unit capital price Q_t, the proceeds from intermediaries are equal to the outflows for purchasing capital:

$$L_{m,t} = Q_t K_{t+1}. \tag{17}$$

We define the *individual* **Firm's Intermediary Leverage (FIL)** $\phi_{m,t}$ for this firm by

$$\phi_{m,t} = \frac{L_{m,t}}{N_t} = \frac{Q_t K_{t+1}}{N_t}. \tag{18}$$

A high individual FIL $\phi_{m,t}$ indicates that the firm receives a large proportion of capital investment from the aggregate intermediary net worth. This firm characteristic has a considerable effect on stock risk premia in the cross section, see Section 4.

Following the literature on stock returns (e.g. Belo et al., 2014), all intermediate goods firms in the economy are assumed to be all-equity financed.[1] Denote the stock price by $P_{s,t}$ and the number of shares by $N_{s,t}$. Using the all-equity assumption, We obtain

$$P_{s,t} N_{s,t} = Q_t K_{t+1}. \tag{19}$$

Denote the (gross) stock return by $R_{s,t}$ and the dividend by $D_{s,t}$. The dividend is given by

$$D_{s,t+1} = R_{s,t+1} P_{s,t} - P_{s,t+1}. \tag{20}$$

[1]To make the results generated in the model with all-equity financed firms consistent with the practice with both debt and equity, all model-implied returns are leveraged up by an average debt-to-equity ratio, which is 0.67 obtained by Belo et al. (2014).

To focus on stock returns, the shares are normalized to one unit. Then no arbitrage arguments show that the stock return $R_{s,t}$ should be equal to the risky return $R_{k,t+1}$ received by the financial intermediaries due to the capital investment $L_{m,t}$.

Denote the Total Factor Productivity (TFP) shock by a_t and the utilization rate of capital by U_t. The firm produces the intermediate goods output $Y_{m,t}$ using the production function

$$Y_{m,t} = a_t (U_t \xi_t K_t)^{\alpha} L_t^{1-\alpha}, \tag{21}$$

where α is the capital share. One one hand, we examine the aggregate stock risk premium by running time series analysis within the general equilibrium with an aggregate capital quality shock (CQS) ξ_t. On the other hand, to simulate a set of cross-sectional stock returns and firm characteristics, we extend the model to a partial equilibrium by randomly drawing different realizations of the CQS ξ_t for individual firms. In this case of model simulation, ξ_t is firm-specific productivity and the source of cross-sectional heterogeneity.

The following derivation of equilibrium equations is standard and follows Gertler and Karadi (2011). Let capital depreciation rate δ depends on the utilization rate U_t as

$$\delta(U_t) \equiv \delta_c + b \frac{U^{1+\zeta}}{1+\zeta}, \tag{22}$$

where δ_c and b are parameters, and ζ is the elasticity of marginal depreciation with respect to the utilization rate. Let $P_{m,t}$ denote the price of the output $Y_{m,t}$ of the intermediate good firm. The first-order conditions with respect to capital utilization rate U_t and labor L_t lead to the utilization rate and labor demand chosen by the firm as

$$P_{m,t} \alpha \frac{Y_{m,t}}{U_t} = \delta'(U_t) \xi_t K_t, \tag{23}$$

$$P_{m,t}(1-\alpha) \frac{Y_{m,t}}{L_t} = W_t. \tag{24}$$

The intermediate firm pays out the ex post return to capital to the financial intermediaries due to its zero wealth and zero economic profits, which implies

$$R_{k,t+1} = \frac{\left[P_{m,t+1} \alpha \frac{Y_{m,t+1}}{\xi_{t+1} K_{t+1}} + Q_{t+1} - \delta(U_{t+1})\right] \xi_{t+1}}{Q_t}. \tag{25}$$

We define the **Effective Capital for Marginal Production (KMP)** as

$$\text{KMVP} := \frac{\xi_t K_t}{P_{m,t} \alpha Y_{m,t}}. \tag{26}$$

KMP measures the capital utilized by the firm for one unit of production under the capital quality shock ξ_t and the monetary policy. This is another firm characteristic substantially affects cross-sectional stock risk premia in Section 4.

2.4 Capital producing firms

The representative competitive capital producing firm refurbishes worn out capital at unit cost and creates new capital $I_{n,t} = I_t - \delta \xi_t K_t$, where I_t is the gross investment/capital produced. It then sells both re-furbished and new capital at the price Q_t. Capital evolves as

$$K_{t+1} = \xi_t K_t + I_{n,t} = [1 - \delta(U_t)] \xi_t K_t + I_t. \tag{27}$$

Producing new capital $I_{n,t}$ involves flow adjustment costs as Christiano et al. (2005) but the costs depend on net investment as Gertler and Karadi (2011). Hence, there is no adjustment cost of replacing depreciated equipment and the capital decision is independent of the market price of capital. The adjustment costs are

$$f\left(\frac{I_{n,t} + I_{ss}}{I_{n,t-1} + I_{ss}}\right)(I_{n,t} + I_{ss}), \tag{28}$$

where I_{ss} is the steady state of I_t and the function f satisfies $f(1) = f^{'}(1) = 0$ and $f^{''}(1) > 0$, which is assumed to be the quadratic function

$$f(x) \equiv \frac{\eta_i}{2}(x-1)^2, \tag{29}$$

where η_i is the inverse elasticity of net investment to the price of capital. The first-order condition for the capital producer's discounted profits maximization problem results in the Q-relationship

$$Q_t = 1 + f(\cdot) + \frac{I_{n,t} + I_{ss}}{I_{n,t-1} + I_{ss}} f^{'}(\cdot) - \mathbb{E}_t \left[\beta \Lambda_{t,t+1} \left(\frac{I_{n,t} + I_{ss}}{I_{n,t-1} + I_{ss}}\right)^2 f^{'}(\cdot)\right]. \tag{30}$$

2.5 Retail firms

There is a continuum of mass unity of differentiated retail firms. Each retail firm f produces one unit of the differentiated good by re-packaging one unit of the intermediate good with the intermediate good price $P_{m,t}$ as the marginal cost. Denote the output of a retail firm f by $Y_{f,t}$, whose price is $P_{f,t}$. The final output Y_t is a constant elasticity of substitution (CES) composite

$$Y_t = \left[\int_0^1 Y_{f,t}^{\frac{\epsilon-1}{\epsilon}} df \right]^{\frac{\epsilon}{\epsilon-1}}, \tag{31}$$

where ϵ is the elasticity of substitution between goods.

The monopolistically competitive retail firms face a downward sloping demand for their goods. Following nominal rigidities in Christiano et al. (2005), a retail firm is able to choose its price P_t^* freely with probability $1 - \varsigma$ each period in order to maximize its discounted future profits. Between these periods the firm indexes its price to the lagged rate of inflation π_t with the price indexation parameter γ_P. The first order condition for the retailer's optimal pricing problem gives

$$\mathbb{E}_t \left\{ \sum_{\tau=0}^{\infty} \beta^\tau \varsigma^\tau \Lambda_{t,t+\tau} \left[\frac{P_t^*}{P_{t+\tau}} \prod_{k=1}^{\tau} (1 + \pi_{t+k-1})^{\gamma_P} - \frac{\epsilon - 1}{\epsilon} P_{m,t+\tau} \right] Y_{f,t+\tau} \right\} = 0. \tag{32}$$

Denote the inflation by Π_t. The law of large numbers results in the evolution of the price level

$$P_t^{1-\epsilon} = \varsigma(\Pi_{t-1}^{\gamma_P} P_{t-1})^{1-\epsilon} + (1 - \varsigma)(P_t^*)^{1-\epsilon}. \tag{33}$$

2.6 Monetary policy with the ZLB interest rate

Denote the net nominal interest rate at time t by i_t and its steady state by i_{ss}. Let Y^* the natural level of output in a flexible price equilibrium. The central bank uses a Taylor rule with interest rate smoothing to set the interest rate subject to the zero lower bound (**ZLB**) as

$$i_t = \max\{0, (1 - \rho_i)[i + \kappa_\pi \pi_t + \kappa_y (\log Y_t - \log Y_t^*)] + \rho_i i_{t-1} + m_t\}, \tag{34}$$

where ρ_i is the smoothing parameter within zero and unity, κ_π and κ_y are the inflation coefficient and output gap coefficient respectively, and m_t is an exogenous shock to monetary policy. In addition, the Fisher relation between the nominal and real interest rates is

$$1 + i_t = R_{t+1} \frac{\mathbb{E}_t P_{t+1}}{P_t}. \tag{35}$$

2.7 Resource constraint

The government consumes a fraction of output Y_t at period t, which is financed by lump sum taxes. The government expenditures G_t is disturbed by the government expenditure shock g_t:

$$G_t = G_{ss} g_t, \tag{36}$$

and the steady state proportion of government expenditures, G_{ss}/Y_{ss}, is assumed to be a constant, where G_{ss} and Y_{ss} are the steady states of G_t and Y_t. The economy-wide resource constraint for the final good output is

$$Y_t = C_t + I_t + f\left(\frac{I_{n,t} + I_{ss}}{I_{n,t-1} + I_{ss}}\right)(I_{n,t} + I_{ss}) + G_t. \tag{37}$$

The definition of equilibrium in this economy is standard and it is omitted.

2.8 Exogenous shocks

The capital quality shock ξ_t, intermediary net worth shock ι_t, monetary policy shock m_t, government expenditure shock g_t, and total factor production shock a_t evolve exogenously as the processes:

$$\log y_t = (1 - \rho_y) \log y_{ss} + \rho_y \log y_{t-1} + \sigma_y \epsilon_{y,t}, \quad y = \xi,\ \iota,\ m,\ g,\ \text{and } a. \tag{38}$$

where $y_{ss} = 1$ is the corresponding steady state of one of shock variables, $\epsilon_{y,t}$ is an i.i.d. standard normal disturbances with mean 0 and shock size σ_y.

3 Calibration and projection solutions

Table 1 lists the parameter values from the calibration in the literature. The financial sector parameters are taken from Gertler and Karadi (2011): the fraction of diverted capital λ, the proportional transfer to entering bankers ω, and the survival probability θ. In addition, the steady state utilization rate U is normalized at unity and minus the price markup is used as a proxy of the output gap.

Conventional values are chosen for the following conventional parameters: the discount rate β, the capital share α, the depreciation rate δ, the elasticity ϵ of substitution between goods, the government expenditure share G/Y, the feedback coefficient κ_π on inflation, the output gap coefficient κ_y, and the smoothing parameter ρ_i of the Taylor rule.

The estimates from Primiceri, Schaumburg, and Tambalotti (2006) are assigned to other conventional parameters: the habit parameter h, the elasticity ζ of marginal depreciation with respect to the utilization rate, the inverse elasticity η_i of net investment to the price of capital, the relative utility weight on labor χ, the inverse Frisch elasticity of labor supply φ, the price rigidity parameter ς, and the price indexing parameter γ_P.

The literature on the computational economy emphasizes that the widely used local linear perturbation solutions to NK-DSGE models produce large errors and particularly fails in accurately capturing the non-linearity caused by the ZLB and time-varying risk premia (Richter and Throckmorton, 2015; Fernández-Villaverde et al., 2015). The projection method can achieve accurate results but it usually becomes infeasible for high-dimensional problems.

To solve the high-dimensional NK-DSGE model with the ZLB constraint here, this paper extends an EDS projection algorithm of Maliar and Maliar (2015) to the medium-size problem with more than forty variables and equations. The key is to replace enormous simulated points with a small set of representative points by an EDS algorithm and then it solve the complex NK-DSGE model globally and accurately using projection techniques.

Specifically, the EDS projection algorithm reconstructs a subsequent grid iteratively until the grid convergence, i.e. the distance between each point of the new grid to a point of the old grid is smaller than 2ϵ, where ϵ and the number of points in each grid are endogenously determined given a target number of points. On a grid, the nonlinear equilibrium equations of the model is solved by a fixed-point iteration (FPI) method until a weighted sum ε of unit-free percentage residuals of the equations smaller than 10^{-7}. Each row of Table 2 lists the results for each grid. Columns 4-7 show the sum ε when the number of iteration is 2, 50, 100, 150, respectively. The last column gives the total number of iteration for convergence.

Table 1. Calibration Values of Model Parameters from Gertler and Karadi (2011)

Symbol	Value	Description
		Households
β	0.990	Discount rate
γ	1.000	Inverse intertemporal elasticity of substitution
h	0.815	Habit parameter
χ	3.409	Relative utility weight of labor
φ	0.276	Inverse Frisch elasticity of labor supply
		Financial Intermediaries
λ	0.381	Fraction of diverted capital
ω	0.002	Proportional transfer to the entering bankers
θ	0.972	Survival rate of the bankers
		Intermediate Good Firms
α	0.330	Capital share
$\delta(U)$	0.025	Steady state depreciation rate
ζ	7.200	Elasticity of marginal depreciation with respect to utilization rate
		Capital Producing Firms and Retail Firms
η_i	1.728	Inverse elasticity of net investment to the price of capital
ϵ	4.167	Elasticity of substitution between goods
ς	0.779	Probability of keeping the price constant
γ_P	0.241	Price indexation parameter
		Government
$\frac{G}{Y}$	0.200	Steady state proportion of government expenditures
ρ_i	0.800	Smoothing parameter of the Taylor rule
κ_π	1.500	inflation coefficient of the Taylor rule
κ_y	0.125	Output gap coefficient of the Taylor rule
		Shocks
$\rho_\xi = 0.66,\ \sigma_\xi = 0.02;\ \rho_a = \rho_g = 0.95,\ \sigma_a = \sigma_g = 0.01;\ \rho_\iota = \rho_m = 0.0,\ \sigma_\iota = \sigma_m = 0.01$		

Table 2. Grid Iteration and Fixed-Point Iteration (FPI) of EDS Projection Algorithm

	No. of Points	Dist. of Points ϵ	Weighted Sum ε of Residuals for No. of FPI 2	50	100	150	No. of FPI for $\varepsilon < 10^{-7}$
Grid 1	999	3.1728	0.3958066	0.0193931	0.0011896	0.0001596	580
Grid 2	994	3.1681	0.4495689	0.0014153	0.0000657	0.0000033	250
Grid 3	985	3.1789	0.5252199	0.0015016	0.0003673	0.0000638	340
Grid 4	1016	3.1644	0.3819274	0.0010072	0.0000754	0.0000048	270
Grid 5	1007	3.1618	0.7515274	0.0001112	0.0000051	0.0000003	180

Notes. This table reports the results obtained by solving the NK-DSGE model with both grid reconstruction and fixed-point iteration (FPI) of the EDS projection algorithm. It reconstructs a subsequent grid iteratively using the simulated time series from the previous grid until the grid convergence, i.e. the distance between each point of the new grid to a point of the old grid is smaller than 2ϵ. The ϵ and the number of points in each grid are determined by a bisection method given the target number of points at 1,000. The nonlinear equilibrium equations of the model is solved by a fixed-point iteration method, where the convergence criteria is a weighted sum ε of unit-free percentage equation residuals smaller than 10^{-7}. Each row lists the results for each grid. Columns 4-7 show the sum ε when the number of iteration is 2, 50, 100, 150, respectively. The last column gives the total number of iteration for convergence.

The table exhibits that the solutions on all grids converge and these grids converge at the fifth grid. Indeed, Figure 2 illustrates that Grid 5 converges fastest. These results on grid iteration also show strong robustness of the solution here.

Moreover, the accuracy test in Table 3 displays that the EDS projection solution is much more accurate than the 1st- and 2nd-order linear perturbation solutions. The accuracy test computes the unit-free percentage residuals across the equilibrium equations of the NK-DSGE model on a stochastic simulation of 10,000 simulated periods. The table reports the average absolute values of percentage residuals in $\log_{10}$ units. For instance, a percentage residual $res = -2$ means the residual as large as $10^{res} = 10^{-2} = 1\%$. The projection solution achieves relatively small residuals for the Euler equations that have the expectation $\mathbb{E}_{t+1}$ and in fact solves non-Euler equations analytically.

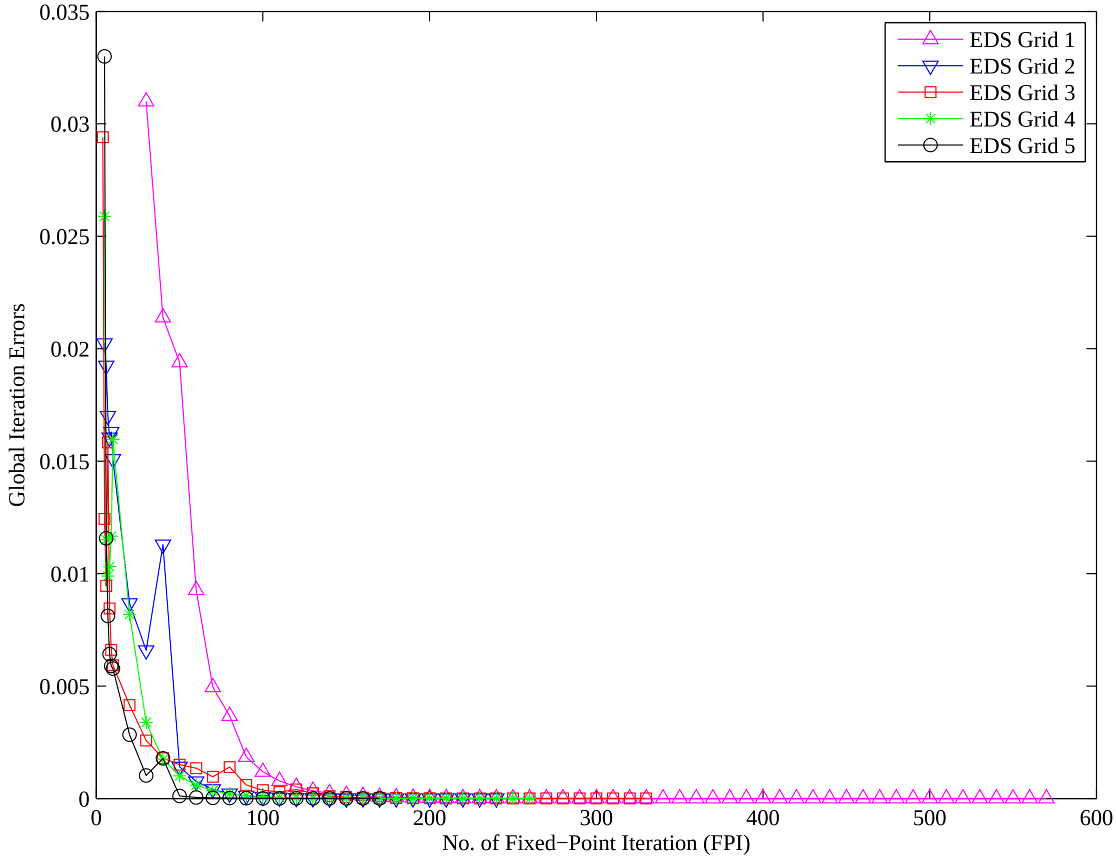

Figure 2. Global Iteration Errors of Five EDS Grids.
The figure plots the weighted sum ε of unit-free percentage residuals for the equilibrium equations of the NK-DSGE model versus the number of fixed-point iteration for five EDS Grids. The EDS projection algorithm reconstructs a subsequent grid iteratively using the simulated time series from the previous grid until the grid convergence, i.e. the distance between each point of the new grid to a point of old grid is smaller than 2ϵ. The ϵ and the number of points in each grid are determined by a bisection method given the target number of points at 1,000.

4 Intermediary cross-sectional asset pricing

In this section, we illustrate the links between the individual firm's intermediary leverage (FIL, or **'intermediary leverage'** for short), the effective capital for marginal production (KMP, or **'effective capital'** for short), and stock returns in the cross section. The results show the implications of the NK-DSGE based asset pricing model with financial accelerators, the zero lower bound (ZLB) of interest rate, and capital quality shocks (CQS).

Table 3. Residuals from Accuracy Test

	No ZLB		ZLB		
	PER 1st	PER 2nd	PER 1st	PER 2nd	EDS Grid
C	-2.8764	1.0194	-2.8030	0.3893	-3.1355
F	-1.8044	-0.9337	-1.8409	-0.9656	-2.2063
Z	-1.9139	-1.1296	-1.9866	-1.1593	-2.4697
R (Fisher)	-1.9931	-1.1519	-1.8840	-1.1508	-2.2540
Welfare	-5.8807	-2.6426	-5.5506	-2.6545	-5.8178
Q	-2.0145	-0.5891	-1.8718	-0.5972	-2.1981
R (Euler)	-1.8756	-1.1732	-1.8194	-1.1605	-2.1790
$R_k - R$	-1.8735	-1.1220	-1.9114	-1.1184	-2.2234
ν	-2.0145	-0.5891	-1.8718	-0.5972	-2.1981
η	-1.5529	-0.4715	-1.3583	-0.4547	-1.6952
Most non Euler	-3.1389	-3.1389	-3.1502	-3.1502	$-\infty$
Residuals Mean	-1.8173	-0.4355	-1.6597	-0.8863	-2.7306

Notes. The table reports the average absolute values of percentage residuals in $\log_{10}$ units, which is defined as: $res = \log_{10} \left|1 - \frac{\text{RHS}}{\text{LHS}}\right| \times 100\%$, where RHS (LHS) represents the right (left) hand side of an equation. For instance, $res = -2$ means the residual $\left|1 - \frac{\text{RHS}}{\text{LHS}}\right|$ is as large as $10^{res} = 10^{-2} = 1\%$. The residuals are computed across the equilibrium equations of the NK-DSGE model on a stochastic simulation of 10,000 simulated periods. The Columns 'PER 1st' and 'PER 2nd' are the 1st- and 2nd-order perturbation solutions, respectively; Column 'EDS Grid' is the 2nd-degree EDS projection solution using a EDS grid with the target number of grid points at 1,000. The first 10 rows are the residuals for the Euler equations with the expectation $\mathbb{E}_{t+1}$. 'Most non Euler' gives an example of residuals for a non-Euler equation; 'Residuals Mean' gives the mean of the residuals on equilibrium equations including Euler equations and non-Euler equations.

4.1 Firms' intermediary leverage ratios and stock returns

4.1.1 Excess returns of intermediary-leverage portfolios

To investigate the relationship between firms' intermediary leverage ratios and future stock returns in the cross section, we construct 10 portfolios sorted on the current (log) ratio of a firm's capital, which is invested by intermediaries, to intermediaries' net worth (equity), i.e. the (log) individual firm's intermediary leverage (FIL) for this firm, see Equation (18). This variable indicates the firm's characteristic of securing intermediary investment. We investigate the portfolio's post-formation average value-weighted stock returns across all firms, which provides a comprehensive picture of the links between individually intermediated funds, firm characteristics, and stock returns in the overall economy under the ZLB and financial shocks.

We construct the intermediary-leverage portfolios following the widely used factor method of Fama and French (1993) and the recent application of Belo et al. (2014) to labor's effects on asset prices. We sort the universe of firms' stocks at the end of June of year t into 10 portfolios based on the firm's log(FIL) at the end of year $t-1$. We compute the deciles of the log(FIL) cross-sectional distribution of all firms as the log(FIL) breakpoints for allocating firms into portfolios. After forming the portfolios, We track their returns from July of year t to June of year $t+1$ and then We repeat the above procedure at the end of June of year $t+1$.

Panel A of Table 4 lists the average stock excess returns, r^e, in excess of the time-varying real interest rate disturbed by the ZLB and shocks in the economy, and the Sharpe ratios (SR) of the 10 intermediary-leverage portfolios. (Another two panels about asset pricing tests will be discussed in the next subsection.) First, the intermediary investment in a firm forecasts stock returns across the set of data. The firms currently receiving larger investments from intermediaries on average earn subsequently higher returns than the firms with smaller intermediary investments do. The difference in returns is economically large and statistically significant. The average value-weighted return spread (L-H, the intermediary-leverage return spread) is -15.7 percent per year, which is more than 28 standard errors from zero.

Second, the Sharpe ratio of the intermediary-leverage portfolio increases with the intermediary investment as well. Across the set of stock returns, the Sharpe ratio of the portfolio with high intermediary investments is six times (in absolute values) larger than that of the portfolio consisting of the firms that obtain low investments from intermediaries.

Table 4. Risk Premia of 10 Portfolios Sorted on (log) Firm's Intermediary Leverage

	Low	2	5	9	High	L-H
			Panel A: Value-Weighted Stock Excess Returns: r^e			
r^e	-2.61	-2.04	0.42	6.16	13.10	-15.70
$[t]$	-1.42	-1.15	0.24	3.53	7.54	-28.16
SR	-0.18	-0.15	0.03	0.46	0.96	-3.43
			Panel B: CAPM: α^C, m.a.e. $= 3.34$			
α^C	-4.23	-3.62	-1.14	4.61	11.53	-15.77
$[t]$	-12.06	-20.78	-9.09	25.75	42.31	-28.40
b^C	1.03	1.01	0.99	0.99	1.00	0.04
$[t]$	135.62	250.67	318.80	206.76	101.40	1.95
R^2	0.93	0.99	0.99	0.99	0.96	0.01
			Panel C: Fama-French: α^F, m.a.e. $= 2.08$			
α^F	-1.05	-1.94	-1.06	2.11	8.33	-9.37
$[t]$	-2.51	-6.09	-4.29	7.56	13.32	-8.07
b^F	1.02	1.01	0.99	0.99	1.00	0.02
s	-0.46	-0.24	-0.01	0.33	0.49	-0.95
h	0.17	0.05	-0.02	0.13	-0.55	0.72
R^2	0.96	0.99	0.99	0.99	0.97	0.36

Notes. This table reports the quantitative analysis using simulated data from the model, obtained as averages from 500 samples of simulated data, each with 3,600 firms and 600 monthly observations. The table reports the average value-weighted excess returns and abnormal returns of 10 portfolios one-way sorted on (log) Firm's Intermediary Leverage (FIL) (only portfolios 1 [low], 2, 5, 9, and 10 [high] are reported). r^e is the average annualized ($1 \times 1{,}200$) portfolio excess stock return; $[t]$s are heteroscedasticity and autocorrelation consistent t-statistics (Newey-West); SR is the portfolio Sharpe ratio; α^C and α^F are portfolio average abnormal returns, obtained as the intercept from monthly CAPM or Fama-French (1993) regressions, respectively, reported in annual percentage ($1 \times 1{,}200$); m.a.e. is the mean absolute pricing errors (average of α^C or α^F); b^C are the portfolio market betas obtained as the slope coefficients associated with the market factor in the CAPM regression; b^F, s, and h are the portfolio market, SMB, and HML betas, respectively, obtained as the slope coefficients in the Fama-French regressions.

4.1.2 Asset pricing tests of intermediary-leverage portfolios

We run the unconditional capital asset pricing model (CAPM) and the Fama and French (1993) three-factor model to investigate whether exposure to standard risk factors can explain the variation in the average excess returns of the intermediary-leverage portfolios. The asset pricing test shows the class of models that can potentially explain the data.

To begin with, We perform time-series regressions of the monthly excess returns of each portfolio on a constant and the excess returns of the value-weighted market portfolio ('market') for testing the CAPM. Then, we add the size factor (small minus big, SMB) and the value factor (high minus low, HML) to the CAPM regressions for testing the Fama-French three-factor model. The pricing errors (abnormal returns) are given by the intercepts from these regressions. We calculate these factors by using the same data set for calculating the excess returns of the 10 portfolios.

Panels B and C of Table 4 show the pricing errors α^C and α^F from running the CAPM and the Fama-French three-factor model regressions on the 10 intermediary-leverage portfolios respectively. First, the CAPM cannot explain the cross-sectional variation in the average returns of the portfolios well. The CAPM-implied mean absolute pricing error (m.a.e.) is 3.3 percent per year using value-weighted returns across the set of stock returns. In addition, the pricing error α^C of the intermediary-leverage spread portfolio (L-H) is almost the same to the return spread itself at around -15.7 percent per year, which represents that the hurdle incurred by the CAPM model in the data set is the same to the return spread itself.

The underlying reason for the failure of the CAPM is that across the intermediary-leverage portfolios, the market betas (b) of the portfolios move in a direction that is opposite to the pattern of average returns. The portfolio of firms with currently high intermediary investments has a lower market beta than the portfolio of firms with currently low intermediary investments. Such pattern is inconsistent with the higher average returns and risk of the high intermediary-leverage portfolio since the CAPM uses the market beta to measure the quantity of risk of each portfolio.

Second, the Fama-French three-factor model here captures the pattern of average returns of the intermediary-leverage portfolios more successfully than the CAPM. The mean absolute pricing error of the Fama-French model (2.1 percent per year) is less than two-thirds of the mean absolute pricing errors of the CAPM (3.3 percent per year). Moreover, the Fama-French model also captures the returns of the intermediary-leverage spread portfolio better than the CAPM. The abnormal return α^F of the spread portfolio (L-H) is -9.4 percent per year, which is again less than two-thirds of the -15.8 percent abnormal return α^C of the spread portfolio in the CAPM.

Therefore, the Fama-French three-factor model explains a larger fraction of the cross-sectional variation in the average returns of the intermediary-leverage portfolios, which highlights the importance of using more than one aggregate risk factor to explain the return spreads. More importantly, the analysis implies that the connection between intermediary leverage ratios and stock returns can be interpreted by the class of risk-based asset pricing models in principle.

4.1.3 Firm characteristics of intermediary-leverage portfolios

To interpret the stock-return predictability of the intermediary-leverage portfolios, Table 5 reports their time-series averages of median portfolio-level characteristics at the time of portfolio formation and 1 year after portfolio formation. The intermediary investment in a firm is naturally relative to the firm's other characteristics.

The firm's size of market equity across portfolios is negatively correlated with the portfolio-level intermediary investment in the firm, which is measured by log(FIL). This fact is consistent with the empirical finding that small firms heavily rely on external capital investments mainly coming from financial intermediaries. Since high intermediary investments forecast high excess returns (as shown in Table 4), small equity sizes correspondingly forecast high excess returns as well. Intuitively, small firms' stocks are usually risky with high returns. This again implies that risk-based asset pricing models can interpret the aforementioned connection between stock returns and FIL. Moreover, by linking the intermediary leverage ratios to equity sizes, our analysis is thus also related to the well-known size effect of stock returns, but our sorting relies on a macroeconomic-based variable relating to financial intermediaries and monetary policy instead of a market-based variable. As we show above, the intermediary-leverage return spread is economically and statistically significant in our study.

Table 5. Characteristics of 10 Portfolios Sorted on (log) Firm's Intermediary Leverage

	Low	2	5	9	High
			Individual firm's intermediary leverage (FIL)		
$\log(\text{FIL}_t)$	1.08	1.19	1.37	1.69	1.92
$\log(\text{FIL}_{t+1})$	1.14	1.24	1.38	1.61	1.78
			Effective capital for marginal production (KMP)		
$\log(\text{KMP}_t)$	3.60	3.46	3.31	3.14	3.06
$\log(\text{KMP}_{t+1})$	3.60	3.48	3.31	3.13	3.05
			Capital quality shock		
$\log(\text{CQS}_t)$ (%)	1.34	0.92	0.14	-0.99	-1.48
$\log(\text{CQS}_{t+1})$ (%)	0.52	0.33	0.03	-0.36	-0.52
			Profitability		
ROA_t	0.11	0.13	0.15	0.18	0.19
ROA_{t+1}	0.11	0.13	0.15	0.18	0.19
			Valuation		
Size_t	7.30	6.51	5.46	4.34	3.89
Size_{t+1}	7.09	6.44	5.48	4.39	3.99

Notes. This table reports the time-series averages of the following portfolio-level characteristics of 10 portfolios one-way sorted on (log) firm's intermediary leverage (FIL). We report portfolios 1 (low), 2, 5, 9, and 10 (high). log(FIL) is the log individual intermediary leverage ratio; log(KMP) is the log effective capital for marginal production (KMP); ROA is return on assets (in the model, ROA is measured as profits scaled by the stock of physical capital); size is the market capitalization; The subscripts t and $t+1$ stand for portfolio-level characteristics measured at the time of portfolio formation (t) or 1 year after portfolio formation ($t+1$). The portfolio-level characteristics are computed as the median value of each characteristic across all firms in the portfolio in July of any given year. The statistics uses data simulated from the model, obtained as averages from 500 samples of simulated data, each with 3,600 firms and 600 monthly observations.

In addition, the average characteristic of return on assets (ROA) shows that the firms with high intermediary leverage ratios tend to be more profitable. Furthermore, the firms with large intermediary investments experience adverse capital quality shocks (CQS) that reduce their effective capital for marginal production (KMP). The adverse shocks increase these firms' risk and stock returns as well.

4.2 Intermediary leverage, effective capital, and stock returns

The previous section reveals that the firms receiving large investments from intermediaries, i.e. high individual firm's intermediary leverage (FIL), require low effective capital for marginal production (KMP) and provide high average excess returns. Such negative relationship between KMP and future stock returns is consistent with previous studies on neoclassical investment-based asset pricing models that reveal a negative correlation between the firm's capital investment rate and future stock returns in the cross section. Since FIL is negatively correlated with KMP, the negative correlation between KMP and future stock returns contributes to the positive link between the intermediary leverage ratios and future stock returns.

In this subsection, we extend the previous studies by examining the joint link between intermediary leverage ratios, effective capital for marginal production, and future stock returns in portfolios two-way sorted on the intermediary leverage and KMP. The variable KMP indicates the firm's characteristic of effectively utilizing capital for one unit of production under financial shocks and the ZLB monetary policy. We also analyze firm-level multivariate regressions including both the intermediary investment in the firm and the firm's KMP as return predictors.

4.2.1 Intermediary-leverage and effective-capital portfolios

We construct nine portfolios two-way sorted on (log) firm's intermediary leverage (FIL) and (log) effective capital for marginal production (KMP) following the well-known factor method of Fama and French (1993) and the application of Belo et al. (2014). We first sort the universe of stocks into three portfolios based on the firm's log(KMP) at the end of June of year t. Then, we sort the firms in each one of the three KMP portfolios into three portfolios according to their log(FIL). Such sequential sorting generates a balanced number of firms in each portfolio; otherwise an independent sorting results in unbalanced portfolios since KMP and FIL are negatively correlated. The breakpoints in year t are the 30th and 70th percentiles of the cross-sectional distributions of the sorting variables at the end of year $t-1$. After forming the portfolios, we track their returns from July of year t to June of year $t+1$ and repeat the procedure at the end of June of year $t+1$. The procedure is consistent with the construction of the portfolios one-way sorted on log(FIL) before.

Panel A of Table 6 report that the two-way sorting procedure generates reasonable spreads in average excess returns r^e across both dimensions of the (log) intermediary leverage ratios (row L-H) and the (log) effective capital for marginal production (col. L-H). Within columns of KMP, firms with high intermediary leverage ratios earn higher returns than firms with low intermediary leverage ratios. Within rows of FIL, firms requiring low effective capital for marginal production earn higher returns than firms demanding high KMP on average, which is referred to as the KMP return spread. Hence, the intermediary leverage ratio implies information about future stock returns that is not contained in the KMP and vice versa for the intermediary leverage ratio.

The magnitude of the intermediary-leverage return spread is comparable with the magnitude of the KMP return spread. Within each column of KMP, firms with high intermediated funds outperform firms with low intermediated funds by a value within the range of 2.6 percent and 10.3 percent per year. On average, the intermediary-leverage return spread across the three KMP columns is 5.7 percent per year. Similarly, within each row of FIL, firms with low KMP outperform firms with high KMP by a value varying from 5.0 percent to 12.6 percent per year. The average KMP return spread across the three FIL rows is 8.3 percent per year. Overall, the results demonstrate the coexistence of a intermediary-leverage and KMP return spread in the stock returns, and this coexistence is economically large and statistically significant.

In addition, Panels B to F of Table 6 report the results of asset pricing tests for the nine portfolios two-way sorted on FIL and KMP. The analysis of the results is qualitatively similar to the analysis of the 10 FIL portfolios in Section 4.1.2, which is omitted here.

4.2.2 Firm-level return predictability regressions

We run stock return predictability regressions at the firm level to investigate the predictability of intermediary leverage and effective capital on stock returns. A portfolio ap-

Table 6. Risk Premia of 9 Portfolios Two-Way Sorted on log(FIL) and log(KMP)

	KMP						*KMP*				
FIL	L	M	H	L-H	[t]	*FIL*	L	M	H	L-H	[t]
	A: Excess Returns r^e						D: Fama-French b^F				
L	2.30	-0.95	-2.66	4.96	-39.05	L	1.00	1.00	1.02	-0.02	-2.60
M	5.45	0.72	-1.87	7.32	-20.17	M	0.99	0.99	1.00	-0.01	-1.48
H	12.55	3.39	-0.07	12.63	-6.73	H	1.00	0.99	0.99	0.01	1.26
L-H	-10.25	-4.34	-2.58			L-H	-0.00	0.01	0.03		
[t]	11.78	27.73	42.41			[t]	-0.57	3.11	3.48		
	B: CAPM α^C, m.a.e. = 3.34						E: Fama-French s				
L	0.74	-2.54	-4.27	5.01	11.72	L	0.09	-0.15	-0.44	0.53	4.86
M	3.89	-0.83	-3.45	7.34	27.73	M	0.28	0.02	-0.21	0.49	12.08
H	10.99	1.84	-1.63	12.62	42.36	H	0.47	0.22	-0.03	0.50	7.51
L-H	-10.25	-4.37	-2.64			L-H	-0.38	-0.37	-0.41		
[t]	-39.13	-20.36	-6.76			[t]	-5.80	-10.32	-3.55		
	C: Fama-French α^F, m.a.e. = 2.08						F: Fama-French h				
L	0.09	-1.42	-1.25	1.35	2.41	L	-0.02	-0.04	0.19	-0.21	-1.37
M	1.76	-0.96	-1.97	3.73	9.32	M	0.13	-0.04	0.07	0.06	1.51
H	7.83	0.31	-1.47	9.30	15.02	H	-0.43	-0.06	0.06	-0.49	-5.43
L-H	-7.74	-1.73	0.22			L-H	0.41	0.02	0.13		
[t]	-13.29	-5.29	-0.69			[t]	4.87	0.78	1.03		

Notes. This table reports the averages of nine portfolios two-way sorted on log(FIL) and log(KMP) using 500 samples of simulated data, each with 3,600 firms and 600 monthly observations. The sorting on log(FIL) is reported across rows L (low), M (mid), and H (high), and the sorting on log(KMP) is reported across columns L, M, and H. L-H stands for the low-minus-high log(FIL) portfolio (across rows) or the low-minus-high log(KMP) portfolio (across columns). r^e is the annualized value-weighted excess returns; [t]s are heteroscedasticity and autocorrelation consistent t-statistics (Newey-West); α^C and α^F are annualized average abnormal returns from monthly CAPM or Fama-French (1993) regressions, respectively; m.a.e. is the mean absolute pricing errors; b^F, s, and h are the portfolio market, SMB, and HML betas, respectively.

proach cannot show which sorting variable has unique information about future returns since one has to specify the breakpoints, the number of portfolios, and the multivariate sorting order for the portfolio procedure. As all of these choices may influence the overall analysis, the firm-level regressions provides a cross validation.

We perform cross-sectional regressions at the firm level following the standard method of Fama and MacBeth (1973). We further check the results by applying one of panel data methods: the pooled time-series ordinary least squares (OLS) regression including year and firm fixed effects with robust standard errors clustered by firms. The two different econometric procedures use a constant and the lagged values of firms' (log) intermediary leverage ratios and effective capital (for marginal production) as predictors to predict stock returns.

In addition, we control for the possible effects of micro cap firms and the zero lower bound of nominal interest rates on the regression results. To this end, we also consider two specifications carrying two different dummy variables, 'Micro' and 'ZLB' respectively, which interact with the predictors. The dummy variable 'Micro' equals one if the firm is a micro cap firm in year $t-1$, which is defined as a firm with a market capitalization lower than the bottom 20th percentile of the cross-sectional distribution of firms' market capitalizations. Similarly, the dummy variable 'ZLB' for a firm equals one if the interest rate is expected to be at the zero lower bound in year $t-1$ according to the capital quality shock that the firm experiences.

Columns 1–4 of Tables 7 and 8 display the results of cross-sectional predictability regressions at a monthly frequency, which are consistent with the portfolio-level results. The intermediary leverage and effective capital jointly forecast stock returns r^s with statistically significant positive and negative slope coefficients respectively. More importantly, the model controlling for the effect of ZLB captures the predictability more accurate than another two models.

First, the estimated slope coefficient for the intermediary leverage, log(FIL), is economically large at around 0.9 on average in all three specifications. It ranges from 0.77 to 1.01 within the 95 percent confidence interval and all of these values are more than three standard errors from zero. Second, the corresponding standard deviation is only 0.05 in specification (3) controlling for the effect of the ZLB and effective capital, which is half of that in specifi-

Table 7. Firm-Level Stock Return Predictability Regressions

	Cross-Sectional Regressions $N = 3{,}600$				Pooled OLS Regressions $N = 176{,}400$			
	Mean	Std	2.5%	97.5%	Mean	Std	2.5%	97.5%
Specification (1): $r^s_{i,t} = a + b \times \log(\text{FIL}_{i,t-1}) + c \times \log(\text{KMP}_{i,t-1}) + e_{i,t}$								
log(FIL)	0.91	0.10	0.83	0.97	9.42	0.81	8.79	10.05
[t]	23.12	4.82	5.74	27.50	48.45	13.31	9.50	61.81
log(KMP)	-0.55	0.39	-0.85	-0.42	-7.34	4.25	-9.36	-5.84
[t]	-12.43	3.77	-17.18	-1.77	-23.87	8.42	-33.37	-2.26
Specification (2): $r^s_{i,t} = a + b \times \log(\text{FIL}_{i,t-1}) + c \times \log(\text{KMP}_{i,t-1}) + d \times \text{Micro}$ $+e \times \text{Micro} \times \log(\text{FIL}_{i,t-1}) + c \times \text{Micro} \times \log(\text{KMP}_{i,t-1}) + e_{i,t}$								
log(FIL)	0.90	0.14	0.77	1.01	11.01	1.73	10.10	11.82
[t]	20.95	5.12	3.36	25.96	47.79	15.35	6.69	64.92
log(KMP)	-0.29	0.49	-0.63	-0.14	-1.16	5.58	-3.25	0.65
[t]	-5.92	2.07	-8.90	-1.12	-4.71	1.90	-7.68	0.26
Micro×log(FIL)	-0.15	0.15	-0.28	0.03	-6.70	1.77	-7.82	-5.61
[t]	-2.61	1.14	-4.87	0.24	-16.79	4.55	-21.75	-3.93
Micro×log(KMP)	-2.20	0.63	-2.61	-1.61	-26.82	7.98	-32.17	-21.36
[t]	-13.31	3.61	-17.42	-2.56	-19.46	6.34	-26.26	-2.68

Notes. This table reports the results from two stock return predictability regressions. $r^s_{i,t}$ is the firm i stock return, $\text{FIL}_{i,t-1}$ and $\text{KMP}_{i,t-1}$ are the lagged values of firm i's intermediary leverage (FIL) and capital for marginal production (KMP), and Micro is a dummy variable that is equal to one if firm i is a micro cap firm at time $t-1$. Columns 1-4 report the slopes from Fama-MacBeth (1973) regressions at the monthly frequency; [t]s are Newey-West t-statistics. Columns 5-8 report the slopes obtained by pooled OLS regressions where $r^s_{i,t}$ is firm i's compounded annual stock return from July of year t to June of year $t+1$. The regression includes both year and firm fixed effects; [t]s are t-statistics computed from standard errors clustered by firm; and N is the number of firm-year observations included in the estimation. The regressions use 500 samples of simulated data, each with 3,600 firms and 600 monthly observations.

Table 8. Firm-Level Stock Return Predictability Regressions with the ZLB dummy

	Cross-Sectional Regressions $N = 3{,}600$				Pooled OLS Regressions $N = 176{,}400$			
	Mean	Std	2.5%	97.5%	Mean	Std	2.5%	97.5%
Specification (3): $r^s_{i,t} = a + b \times \log(\text{FIL}_{i,t-1}) + c \times \log(\text{KMP}_{i,t-1}) + d \times \text{ZLB}$ $+ e \times \text{ZLB} \times \log(\text{FIL}_{i,t-1}) + c \times \text{ZLB} \times \log(\text{KMP}_{i,t-1}) + e_{i,t}$								
log(FIL)	0.87	0.05	0.82	0.91	8.14	0.78	7.69	8.48
[t]	22.41	2.91	15.10	25.34	46.13	8.62	16.88	53.35
log(KMP)	-0.88	0.06	-0.98	-0.80	-11.93	0.67	-12.64	-11.21
[t]	-12.62	1.88	-15.33	-7.89	-40.18	7.53	-45.81	-14.90
ZLB×log(FIL)	-0.88	64.40	-1.84	0.89	9.08	7.57	5.24	13.73
[t]	-0.72	0.97	-2.53	1.10	11.10	5.13	1.24	19.56
ZLB×log(KMP)	0.87	28.32	-1.19	1.38	17.70	17.11	11.06	22.61
[t]	3.20	1.93	-0.67	6.55	15.96	7.67	1.34	30.32

Notes. This table reports the results from the stock return predictability regressions with the ZLB dummy. $r^s_{i,t}$ is the firm i stock return, $\text{FIL}_{i,t-1}$ and $\text{KMP}_{i,t-1}$ are the lagged values of firm i's intermediary leverage (FIL) and capital for marginal production (KMP), and ZLB is a dummy variable that is equal to one if the interest rate is expected to be at the zero lower bound in year $t-1$ according to the capital quality shock that the firm i experiences. Columns 1-4 report the slopes from Fama-MacBeth (1973) regressions at the monthly frequency; [t]s are Newey-West t-statistics. Columns 5-8 report the slopes obtained by pooled OLS regressions where $r^s_{i,t}$ is firm i's compounded annual stock return from July of year t to June of year $t+1$. The regression includes both year and firm fixed effects; [t]s are t-statistics computed from standard errors clustered by firm; and N is the number of firm-year observations included in the estimation. The regressions use 500 samples of simulated data, each with 3,600 firms and 600 monthly observations.

cation (1) and almost one-third of that in specification (2) controlling for the effect of micro cap firms and effective capital.

Third, the estimated slope coefficient for the effective capital, log(KMP), in specification (3) is close to the coefficient for log(FIL) with a similar standard deviation. The slope is about one and a half larger than that in specification (1) and about three times larger than that in specification (2). The standard deviations in (1) and (2) are almost ten times larger than the standard deviation in (3). In short, these comparisons highlight that the model controlling for the effect of the ZLB improves the estimation precision and the slopes for both predictors are significant.

Columns 5–8 of Tables 7 and 8 list the results produced by pooled OLS predictability regressions using an annual frequency. The time-series regressions provide an intuitive economic interpretation of the regression slopes and they are consistent with the analysis on the cross-sectional regressions above. The slope coefficients for the intermediary leverage (resp. effective capital) are positive (resp. negative) with large magnitudes of predictability. On average, a 1 percentage point increase in the intermediary investment obtained by firms brings a 9 percent increase, or a 11 percent increase for nonmicro cap firms, or a 8 percent increase for non ZLB bounding, in annual future stock returns, controlling for the effect of the effective capital. On the contrary, a 1 percentage point increase in the firm's effective capital on average leads to a 7 percent decrease, or a 1 percent decrease for nonmicro cap firms, or a 12 percent decrease for non ZLB bounding, in annual future stock returns, controlling for the effect of the intermediary leverage.

The results from the time-series regressions show the implications of the ZLB for the cross-sectional variation of stock prices. The ZLB makes firms' capital invested by intermediaries more valuable. Therefore, the firms with larger capital from intermediaries (hence higher FIL) are able to make more outputs and higher stock returns. Similarly, the more productive firms (hence lower KMP) bring higher stock returns.

4.3 The financial accelerator mechanism for asset pricing

This subsection examines the underlying economic mechanism for explaining cross-sectional stock returns in the framework with financial intermediaries. The discussion focuses on the ten portfolios one-way sorted on the (log) individual firm's intermediary leverage (FIL) for a clear exposition.

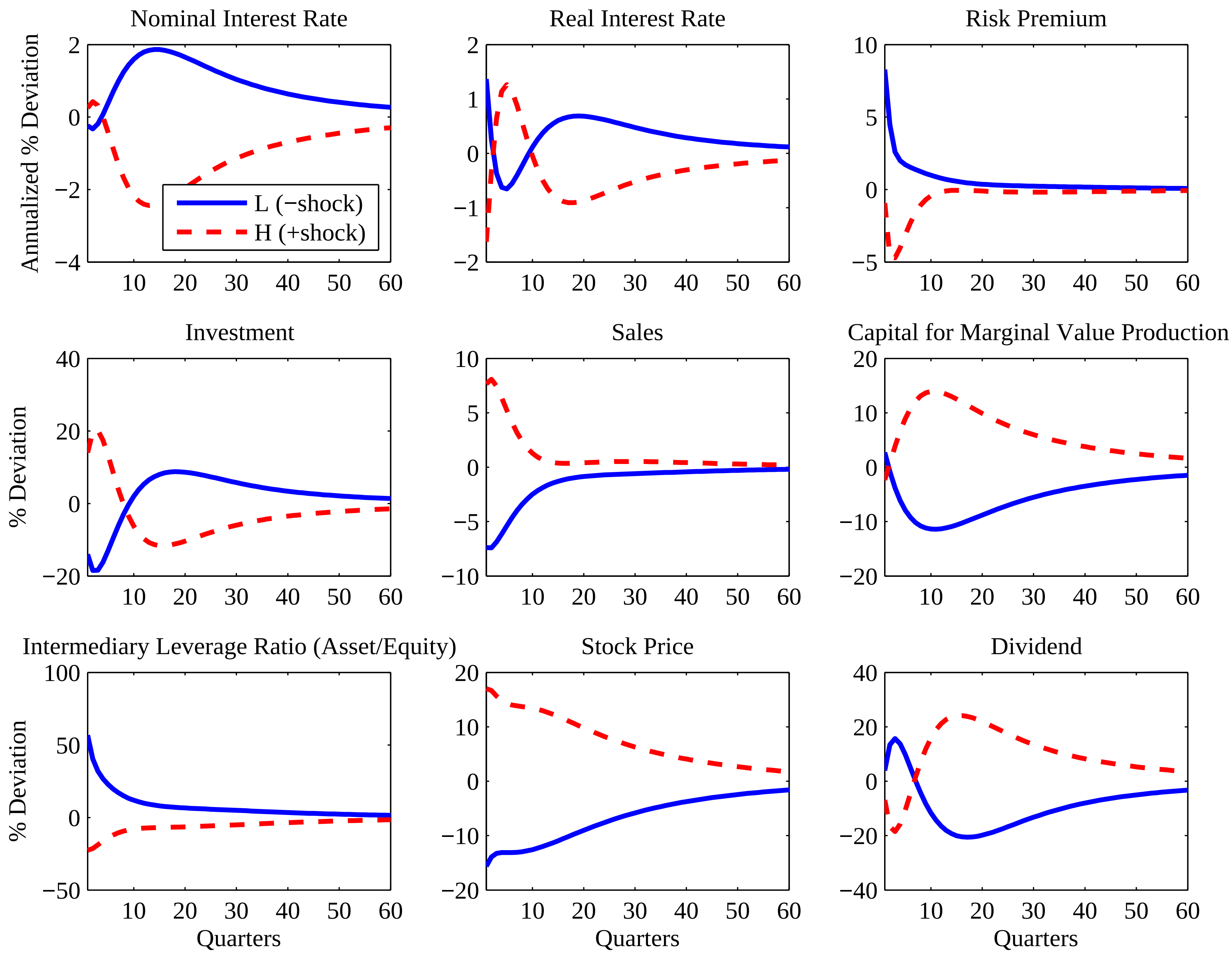

Figure 3. Impulse Responses to (±) log(Capital Quality Shock), $\log(\xi_t)$**.**

Impulse responses of selected endogenous variables to a 5% positive (H) or negative (L) log(capital quality shock), $\log(\xi_t)$. The responses are measured in percentage point deviations relative to the long-run average values.

4.3.1 Impulse responses to capital quality shock

To illustrate the underlying intermediary financial accelerator mechanism for cross-sectional asset pricing, Figure 3 displays the impulse responses of selected endogenous variables to a 5% positive (H) or negative (L) log(capital quality shock), $\log(\xi_t)$. Since all firms in the economy are ex ante identical, the cross-sectional heterogeneity is generated by examining two firms that experience a positive or negative capital quality shock respectively. The two firms correspond roughly to the low- and high-FIL firms in the model, though the difference in capital quality is not the only difference across these firms.

The negative shock is the same to Gertler and Karadi (2011) considering an AR(1) process of capital quality shock and fix a five percent decline in it with a quarterly autoregressive factor of 0.66, which produces an output downturn with a magnitude similar to the one in the recent financial crises. First, the negative disturbance in capital quality decreases the effective capital of intermediate goods firms, which equivalently weakens the intermediary assets and net worth like the general dynamics of the recent sub-prime crises. The unanticipated increase in the interest rate adds intermediaries' debt (households' deposits) as well. The disturbance thus tightens the leverage ratio constraints on private intermediaries because of their high degree of leverage. The tightening constraints induce a fall in real investment, asset demand, and the price Q_t per effective unit of capital, which further shrinks intermediary balance sheets.

Second, in the presence of financial frictions, intermediaries require risk premium from the capital that they invest in non-financial firms. A disturbance, e.g. a negative capital quality shock, raises the intermediaries' premium of capital, which substantially enhances a decline in the firms' real investment. In response to the unanticipated declines in firms' real investment, output and sales, the capital price also falls and intermediary balance sheets deteriorate, which further pushes up risk premium and the cost of capital. Hence, the enhanced decline in real investment produces an amplification of the decline in output relative to the framework without financial intermediaries.

Third, a negative capital quality shock decreases the effective capital for marginal production while increases the individual intermediary-leverage ratio since the shock reduces the intermediary net worth. The market value of the firm's stock jumps downward corresponding to a decline of firm value because of a combination of lower sales and investment, which leads to a sharp decrease in the firm's dividend distributions as well.

4.3.2 Risk prices of shocks on monetary policy and intermediary wealth

There is an aggregate shock m_t on the nominal interest rate i_t set by the monetary policy with the ZLB constraint. The total intermediary net worth N_t experiences an aggregate shock ι_t that impacts on the net worth of the existing intermediaries $N_{e,t}$. The two shocks disturb intermediaries' borrowing and lending abilities that further affect their leverage ratios and firms' future stock returns. Though the intermediary-leverage portfolio returns endogenously depend on the two aggregate risk factors in the equilibrium model, the corresponding prices of risk are specified exogenously. In this section, we use the model structure to estimate the two factor risk prices, and thus provide insights into the microeconomic effects of macroeconomic conditions on firms' stocks risk premia.

We use the ten one-way-sorted intermediary-leverage portfolios as the test assets. First, performing the time-series regression below provides the estimates of the sensitivity of the portfolios' excess returns to the two factors (shocks):

$$r_{i,t}^e = a_i + \beta_i^m \times m_t + \beta_i^N \times \iota_t + e_{i,t}. \tag{39}$$

The regression coefficients indicate the degree of co-movement between the excess returns of the intermediary-leverage portfolios and the two shocks affecting intermediaries' leverage ratios. Second, the two factor risk prices are estimated by the following cross-sectional regression:

$$\mathbb{E}_T[r_{i,t}^e] = \lambda_m \times \beta_i^m + \lambda_N \times \beta_i^N + \epsilon_{i,t}, \tag{40}$$

where $\mathbb{E}_T[r_{i,t}^e]$ is the in-sample mean of portfolio i's excess returns. The generalized method of moments (GMM) is applied to estimate the model parameters.

Panel A of Table 9 displays the positive and monotonically increasing sensitivity β^N of the excess returns of the intermediary-leverage portfolios to the intermediary net worth shock ι_t. This reveals that the intermediary-leverage return spread is largely driven by differential exposures of the portfolios to the shock ι_t. Intuitively, a realized positive intermediary net

Table 9. Risk prices of Shocks on ZLB Monetary Policy and Intermediary Wealth

Panel A: Time-Series Regressions $r^e_{i,t} = a_i + \beta^m_i \times m_t + \beta^N_i \times \iota_t + e_{i,t}$					
	Low	2	5	9	High
a	-1.33	-0.40	3.70	13.30	24.89
$[t]$	-0.72	-0.16	2.72	10.30	19.81
β^m	-3.61	-3.59	-3.57	-3.57	-3.58
$[t]$	-48.21	-57.47	-63.33	-62.28	-54.59
β^N	0.11	0.12	0.15	0.18	0.19
$[t]$	1.58	2.01	2.91	3.58	3.23
R^2	0.80	0.87	0.89	0.90	0.86

Panel B: GMM Cross-Sectional Regressions $\mathbb{E}_T[r^e_{i,t}] = \lambda_m \times \beta^m_i + \lambda_N \times \beta^N_i + \epsilon_{i,t}$					
Price of Risk	Mean	Median	Std	2.5% prc	97.5% prc
λ_m (%)	0.39	0.40	0.16	0.05	0.70
$[t]$	3.92	3.77	1.94	0.75	8.07
λ_N (%)	10.37	10.93	3.32	2.70	16.15
$[t]$	4.08	3.74	2.21	1.03	8.86

Notes. Panel A report the results from the following monthly time-series regression: $r^e_{i,t} = a_i + \beta^m_i \times m_t + \beta^N_i \times \iota_t + e_{i,t}$, where $r^e_{i,t}$ is the excess return of portfolio i, m_t is the aggregate shock on the nominal interest rate, and ι_t is the aggregate shock on the net worth of the existing intermediaries $N_{e,t}$. The test assets are the 10 log(FIL) portfolios using data simulated from the model. Panel A reports the estimation results for log(FIL) portfolio 1 (Low), 2, 5, 9, and 10 (High). The regression intercept a is expressed in annual percentage ($\times$ 1200); m.a.e. is the mean absolute pricing error across the 10 portfolios; $[t]$s are heteroscedasticity and autocorrelation consistent t-statistics (Newey-West); R^2 is the regression adjusted R-squared. Panel B estimates the factor risk prices from the cross-sectional regression $\mathbb{E}_T[r^e_{i,t}] = \lambda_m \times \beta^m_i + \lambda_N \times \beta^N_i + \epsilon_{i,t}$ using the generalized method of moments. $\mathbb{E}_T[r^e_{i,t}]$ is the in-sample time-series average excess return of portfolio i. The reported statistics for the model are obtained as averages from 200 samples of simulated data, each with 3,600 firms and 600 monthly observations.

worth shock is beneficial to firms because it strengthens intermediary balance sheets by raising intermediaries' net worth and assets. Since intermediary assets are the capital that they invested in firms in exchange for firms' stocks, the market values of stocks rise and meanwhile firms can enhance productivity and profits by using the capital from intermediaries to increase investments.

In contrast, the sensitivities β^m of the excess returns of the portfolios to the monetary policy shock m_t are negative and almost flat. This feature is intuitive. A positive monetary policy shock m_t leads to an unanticipated increase in the short term interest rate and intermediaries' debt (households' deposits). The effect persists because of the interest rate smoothing Taylor rule. The adverse shock triggers the financial accelerator mechanism through financial frictions and procyclical variation in intermediary balance sheets. A decline of intermediary net worth leads to a rise in the intermediaries' premium of capital, which amplifies the decrease in firms' real investment and output (Gertler and Karadi, 2011).

In short, the differential exposure of the portfolios to the two shocks ι_t and m_t indicates the fundamental distinction in the quantity of risk of the intermediary-leverage portfolios, which explains the cross-sectional variation of the portfolios' excess returns.

Panel B of Table 9 reports that the prices of risk of both intermediary net worth shock ι_t and monetary policy shock m_t are estimated to be positive ($\lambda_N = 10.37\%$ and $\lambda_m = 0.39\%$ per month). The risk price of shock ι_t is particularly high since the shock largely impacts on the capital that intermediaries can invest in firms and the shock further affects cross-sectional stock returns. The result thus confirms that the intermediary-leverage return spread is largely driven by firms' exposure to the intermediary net worth shock ι_t.

The risk price of shock ι_t further explains why the firms with higher individual firm's intermediary leverage (FIL) have higher expected returns (the negative intermediary-leverage return spread). When intermediaries experience a positive net worth shock ι_t, the high-FIL firms will benefit the most from the higher intermediary net worth because they receive larger capital investments from intermediaries, which allows them to expand faster and earn more profits. Given the positive price of risk of the shock ι_t and the positive sensitivity β^N to the shock, the returns of the high-FIL firms are thus relatively more risky and offer higher expected returns in equilibrium. Firms with low FILs also benefit from a positive net worth shock ι_t but these firms benefit much less from it because their low individual intermediary-leverage ratios determine that they receive relatively smaller capital investments from intermediaries.

5 Conclusion

In conclusion, when the economy is hit by adverse shocks, financial intermediaries' borrowing constraints and the ZLB monetary policy amplify the decline in credit supply, real investment, production, profits, and asset prices. To examine the implications of the economic situation for stock returns of cross-sectional non-financial firms, this paper solves a medium-size NK-DSGE by using a projection algorithm on iterated simulation grids to capture time-varying risk premia and non-linearity of the ZLB. The intermediary investment in a firm and the firm' effective capital for marginal value of production forecast stock returns and explain their cross-sectional variation.

A future research direction is to study the implication of financial intermediaries for stock risk premia in the economy that infrequently occurs rare disasters as Barro (2009) and Gourio (2012). Bai, Hou, Kung, and Zhang (2015) use an investment model with disasters to illustrate that value firms with high book-to-market equity earn higher average stock returns than growth firms because value stocks have higher exposures to disaster risk. Considering financial intermediaries in a framework with disasters may reveal more insights into cross-sectional stock prices.

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