ABSTRACT

NELSON, DANIEL OWEN. A Proposed Financial Regulatory Regime to Regulate Investment Banks Equity Capital Reserves. (Under the direction of Nora Traum.)

This paper proposes an unconventional monetary policy tool to be used by financial regulators to regulate investment banks holdings of equity capital reserves. The policy is motivated by the recent financial crisis, and the associated capital losses experienced by the financial industry. The solvency issues experienced by most major investment banks in 2007 and 2008 has refocused the debate surrounding financial regulation, and efforts like Basel III and the Dodd-Frank act have sought to both raise capital requirements, and distinguish between different types of capital reserves. The proposed monetary tool would offer interest to investment banks (IBs) on their equity capital reserves, allowing financial regulators to increase (by partially subsidizing) IBs holdings of equity capital, without explicitly changing reserve ratios. To examine the effects of this policy, a regulatory response function is constructed in the context of a monetary DSGE model with a robust financial sector.
A Proposed Financial Regulatory Regime to Regulate Investment Banks Equity Capital Reserves

by
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DEDICATION

To my Father, John, and his unwavering support for my education
BIOGRAPHY

The author has always had an interest in science and psychology, and discovered economics as an outlet for both early on in college. His interests range from political economics, macroeconomics, and monetary economics to statistical modeling and big data in economics.
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This paper examines some of the macroeconomic implications of imposing a simple regulatory regime on the financial subsidiaries of large banks; the monetary authority offers investment banks interest on their equity capital reserves in periods of loose credit conditions and in the face of large, negative financial shocks. The purpose of this paper is to allow the monetary authority to offer interest payments to investment banks on equity capital reserves in order to fix a desired equity capital ratio, and exercise a degree of control over the financing decisions of investment banks. The fraction of equity capital reserves deemed “adequate” protection against systemic risk may not be constant in all states of nature and all time periods \( t \), and mandating higher reserve ratios is costly, disruptive, and requires long lead times. Offering interest payments on equity reserves decreases the cost of equity financing and acts as a subsidy for investment banks, encouraging them to finance more of their market operations and investments with equity instead of issuing debt. The effects of this policy are examined by using a model that can account for interactions between the real economy and financial market activity, and then constructing the financial regulators response function for the target interest rate (that is the interest offered on equity capital reserves). Much of the model is based on work by Christiano, Motto, and Rostagno (2010) in explaining financial frictions role in economic fluctuations, and Bernanke, Gertler and Gilchrist (1999) model of the financial sector, including the standard debt contract (hereafter CMR and BGG, respectively).
CHAPTER 1. INTRODUCTION

The modeling innovations to CMR necessary to examine the effects of the proposed policy were limited to the financial side of the model. The investment banks first order profit condition changes to include revenue from interest on equity capital reserves. In the beginning of time $t$, investment banks observe a shock to the cost of raising equity, then decide how much to raise. At the end of the period, they pay back equity holders with proceeds from their lending activities and interest accrued. Impulse response functions to the financial shocks and the shock to the marginal efficiency of investment are included in the appendix.

To see the effects of offering investment banks interest on their equity reserves, four different regulatory rules are considered, where each rule sets the target interest rate based on investment banks equity capital reserves, an index used to gauge financial health, or both. This allows the response function to fluctuate with Investment Bank reserves as well as multiple indicators of financial health. When investment banks capital reserves fall or enough financial indicators move in the wrong direction, the Monetary Authority raises the interest rate offered on reserves.

The paper concludes with a counter factual exercise designed to test the efficacy of the proposed regulatory rule in adverse financial market conditions. The shock structure for five financial shocks were estimated using data from the financial crisis (2007-2009), and the same set of observables used to calibrate the baseline model. Then a forecast using the estimated shock structure was performed, in the baseline model and the model with the regulatory rule. Forecasts for financial variables and some important macro variables in the model with and without the rule are reported in the appendix. The forecasts imply that while offering interest on equity reserves have a marginal impact on IB’s financing decisions, it is not enough to make a significant impact in their decision to hold more capital.
2.1 Final and Intermediate Goods Production

Final goods firms bundle intermediate goods to produce final goods. They are competitive and employ homogeneous labor and capital. Intermediate goods firms are monopolistic. In each period a fraction of the intermediate firms can re-optimize their price, and do so to maximize profits, assuming they will not be able to re-optimize their price again. Both final and intermediate goods producing firms are competitive in factor markets. To finance production ahead of the opening of the goods market, they take out a working capital loan from the bank. Final goods producing firms produce both consumption and investment goods, which command separate prices that grow at different rates.

Final goods producing firms are modeled by a representative, perfectly competitive goods producing firm with Dixit Stiglitz production function

\[
Y_t = \left\{ \int_0^1 \frac{1}{Y_{f,t}^{\lambda_f,t}} \right\}^{\frac{\lambda_f,t}{\lambda_f,t}} , \lambda_{f,t} \in [0, \infty]. \tag{2.1}
\]
2.1. FINAL AND INTERMEDIATE GOODS PRODUCTION

The final goods producing firm bundles intermediate goods \( Y_{j,t} \) to produce consumption and investment goods, \( Y_t \), and choose both to maximize profits, given prices. It is assumed that there are persistent advances in technology related to the production of investment specific goods, at the rate of \( \Upsilon t \mu_{t,t} \). \( \Upsilon > 1 \) is the constant rate of technological change in the production of investment goods, and \( \mu_{t,t} \), a stationary stochastic process, is referred to by CMR as the relative price of investment shock. Final goods producing firms are perfectly competitive so their price and marginal cost are equal. It follows that the time \( t \) price of consumption and investment goods are \( P_t \) and \( \frac{P_t}{\Upsilon t \mu_{t,t}} \), respectively. \( \lambda_{f,t} \) is a shock to the demand for intermediate good \( Y_{j,t} \), and follows a first order autoregressive process.

Intermediate goods firms are monopolistic and produce \( Y_{j,t} \) using the production function

\[
Y_{j,t} = \begin{cases} 
\epsilon_t K_{j,t}^\alpha (z_t l_t)^{1-\alpha} - \Theta z_t^*, & \text{if } \epsilon_t K_{j,t}^\alpha (z_t l_t)^{1-\alpha} > \Theta z_t^* \\
0, & \text{if otherwise}
\end{cases}
\]  

(2.2)

where \( \alpha \in [0, 1] \), \( K_{j,t} \) and \( l_t \) are capital and homogenous labor, and \( \Phi \) is a non-negative constant that scales fixed costs. Intermediate firms experience two shocks to their production technology, a stationary shock, \( \epsilon_t \), and a persistent shock represented by the time series

\[
z_t = \mu_{z,t} z_{t-1},
\]

(2.3)

where \( \mu_{z,t} \) is also a stationary shock. Both shocks are normally distributed. The growth rate of output is driven by technological progress in the production of capital, and is determined by

\[
z_t^* = z_t \Upsilon t \mu_{t,t}^\alpha
\]

(2.4)

remembering that \( \Upsilon > 1 \). The firm's fixed costs, \( \Phi z_t^* \) were chosen to make the non-stochastic steady state exhibit a balanced growth path. Allowing fixed costs to grow on the same path as prices, \( z_t^* \), ensures they remain non trivial relative to firms revenues and variable costs after multiple periods of simulation.

Both final and intermediate goods producing firms are competitive in factor markets. They rent capital at nominal rental rate \( P_t \tilde{r}_t^k \), and hire labor at the nominal wage rate, \( W_t \). Each firm can only
pay a portion of their wage bills, $W_t l_{j,t}$ and rental costs, $P_t \hat{r}_t^k K_t$, before production, and must finance the difference with working capital loans. Let $\psi_k$ and $\psi_l$ represent the constant fraction needed to finance their capital and labor decisions, respectively, and $R_t$ be the gross interest rate on working capital loans. The marginal cost of producing one unit of output is then

\[ s_t = \left( \frac{1}{1 - \alpha} \right) \left( \frac{1}{\alpha} \right) \frac{\alpha (\hat{r}_t^k [1 + \psi_k R_t])^\alpha (\frac{W_t}{P_t} [1 + \psi_l R_t])^{1 - \alpha}}{e_t^{1 - \alpha}}, \] (2.5)

using the fact that in a perfectly competitive market for capital, the marginal cost is equal to the rental price of capital divided by its marginal productivity, the rental rate $\hat{r}_t^k$ can be expressed as

\[ \hat{r}_t^k = \frac{\alpha}{1 - \alpha} \left( \frac{K_t}{l_{j,t}} \right) \frac{\frac{W_t}{P_t} [1 + \psi_l R_t]}{1 + \psi_k R_t}. \] (2.6)

The single, representative firm's demand for homogeneous labor and the household supply of differentiated labor can be related by

\[ l_{j,t} = \left[ \int_0^1 (h_{j,t})^{\frac{1}{\lambda_w}} \right]^{\lambda_w}, 1 \leq \lambda_w. \] (2.7)

The function $h_{j,t}$ is determined in the households utility maximization problem, discussed below. A variation of Calvo sticky prices is used. Every period, $1 - \xi_p$ intermediate firms are allowed to adjust their prices. The $\xi_p$ portion of firms that are not allowed to re-optimize follow the updating rule,

\[ P_{i,t} = \tilde{\pi}_t P_{i,t-1}, \]

where

\[ \tilde{\pi}_t = (\pi_t^{target}) \left( \pi_{t-1} \right)^{1 - t}. \] (2.8)

$\pi_{t-1} = \frac{P_{t-1}}{P_{t-2}}$, and $\pi_t^{target}$ is the monetary authorities inflation target. The firms that can re-optimize set their time $t$ price to $P_{i,t} = \hat{P}_t$ to maximize future discounted profits, under the assumption that they will not be able to re-optimize prices again.
2.2 Capital Producers

Capital producers buy undepreciated used and new capital to convert into installed investment goods, which they sell to investors in the financial market. They face increasing costs of investment, and experience a shock to their marginal efficiency of investment. The capital producers maximize their profits subject to a zero profit condition.

In the model, capital is produced by a single, representative firm. At the end of period $t$, the capital producer invests in new equipment at price $P_t \{T_t \mu_t\}^{-1}$, and purchases the undepreciated used capital stock. Old and new capital are combined to produce new, installed capital using the production technology

$$x' = x + F(I_t, I_{t-1}, \zeta_{i,t}) = x + (1 - S(\zeta_{i,t} \frac{I_t}{I_{t-1}}))I_t$$

(2.9)

$F(\bullet)$ is the technology for converting the firms newly purchased investment goods into equipment ready for production. $F(\bullet)$ includes the cost of investment, $S$, which increases with the proportional change in the level of investment, and with an exogenous stochastic shock to the marginal efficiency of investment, $\zeta_t$.

Because the marginal rate of transformation of new and the deregulatory used capital are the same, they have the same price, $Q_{\bar{K},t}$. The firms time $t$ profits are

$$\Pi^k_t = Q_{\bar{K},t} \left[ x + (1 - S(\zeta_{i,t} \frac{I_t}{I_{t-1}}))I_t \right] - Q_{\bar{K},t} x - \frac{P_t}{T_t \mu_t} I_t,$$

(2.10)

and capital producers solve

$$\max_{x_{t+j},x_{t+j}} E_t \left[ \sum_{j=0}^{\infty} \beta^j \lambda_{t+j} \Pi^k_{t+j} \right].$$

(2.11)

The expectation in (11) is conditional on the producers time $t$ information set, including information about all contemporaneous shocks. $\lambda_t$ is the Lagrangian multiplier for the households budget constraint. $\bar{K}_{t+j}$ is the stock of capital in the economy in the beginning of period $t + j$, and $\delta$ is a constant depreciation rate of capital. Examining (10), it appears that any value of $x$ is consistent with profit maximizing behavior, so we set $x = (1 - \delta) \bar{K}_{t+j}$, equal to the entire stock of undepreciated capital at time $t + j$. 
2.3. HOUSEHOLDS

CHAPTER 2. THE MODEL

Substituting $x = (1 - \delta) \tilde{K}_{t+1}$ into (10) and solving (11) yields a relationship between $Q_{\tilde{K}, t}$, the price of installed capital, and $\frac{P_t}{\mu_{\bar{Y}, t}}$, the cost of investment goods,

$$E_t \left[ \lambda_t Q_{\tilde{K}, t} F_{1,t} - \frac{P_t}{\mu_{\bar{Y}, t}} + \beta \lambda_{t+1} Q_{\tilde{K}, t+1} F_{2,t+1} \right] = 0 \quad (2.12)$$

$F_{1,t}$ is the derivative of the transformation technology $F(I_t, I_{t-1}, \zeta_{i,t})$ with respect to its argument $i$. The law of motion for the aggregate stock of capital is

$$\tilde{K}_{t+1} = (1 - \delta) \tilde{K}_t + F(I_t, I_{t-1}, \zeta_{i,t}) = (1 - \delta) \tilde{K}_t + \left\{ 1 - S(\zeta_{i,t}, I_{t-1}) \right\} I_t. \quad (2.13)$$

2.3 Households

Households supply differentiated labor, consume, and make portfolio decisions. They hold currency, purchase short term securities, purchase equity in the investment bank, hold demand deposits at the commercial bank, and purchase government bonds. Households hold currency for the liquidity services it generates, invest in securities, and purchase equity in financial institutions to maximize the expected return on their portfolio. They are subjected to a tax on their income, and a lump sum tax. In each period, a fraction of households are allowed to re-optimize their wage.

We assume there is a unit mass of households indexed by $k \in (0, 1)$. Households supply differentiated labor, $h_{k,t}$, consume, save, hold currency, and supply short term and equity financing to the bank.

2.3.1 Household Utility

$$E_t^k \sum_{l=0}^{\infty} \beta^l \zeta_{c,t+l} \left[ u(C_{t+l} - b C_{t+l-1}) - \psi_l \right] h_{j,t+l+1}^{1+\sigma_L} \left( \frac{(1+\tau_c)C_{t+l}}{M_{t+l}} \right)^{1-\chi_{t+l}} \left( \frac{(1+\tau_c)P_{t+l}C_{t+l}}{D_{t+l}^m} \right)^{(1-\theta)} \left( \frac{(1+\tau_c)P_{t+l}C_{t+l}}{D_{t+l}^h} \right)^{\chi_{t+l}} \left[ 1-\sigma_q \right]$$

$$E_t^k$$ is the expectation conditional on all information up to and including time $t$. $C_t$ represents time $t$ consumption, $h_{k,t}$ time $t$ worked, $\tau_c$ a tax on consumption, and $\zeta_{c,t}$ is an exogenous shock to the households time $t$ consumption preferences. The fourth term is an expression capturing the utility households get from liquidity services generated from holding currency, $M_t$, purchasing short-term marketable securities, $D_t^m$, and making bank deposits, $D_t^h$. Liquidity services are an
increasing function of nominal consumption, \((1 + \tau^c)P_tC_t\), and are calibrated using the constant parameters \(\theta\) and \(v\). Liquidity preferences are subject to a shock to the demand for short-term marketable securities, \(\chi_t\), relative to other forms of liquidity. In order for the steady state to experience balanced growth, \(u\) is defined to be the natural logarithm. Allowing \(b > 0\) implies habit formation in consumption.

2.3.2 Source of Funds

Households have several sources of funds that arrive at both the beginning and the end of period \(t\). They start period \(t\) with \(M^b_t\) units of high powered money balances. They divide \(M_t\) into currency and demand deposits at the bank, subject to the constraint

\[
M^b_t - (M_t + A_t).
\]

Households then deposit \(A_t\) with the bank, and receives claim \(D^h_t\) against its deposit. Demand deposits generate interest payments \((1 + R^a_t)D^b_t\), received at the beginning of the period. Other contemporaneous sources of funds include after tax wage payments, \((1 - \tau^l)W_t, h_{k,t}\), and the return from short term securities \((1 + R^m_t)D^m_t\), and equity investments \((1 + R^T_t)T_{t-1}\), both of which were acquired at the end of the preceding period \(t-1\) and mature at the end of the current period. They receive two lump sum transfers, \(Lump_t\) and \((1 - \Theta)(1 - \gamma_t)V_t\), where \(V_t = \frac{N_{t+1} - W^e}{\gamma_t}\) is the net worth of each entrepreneur who exits the economy in time \(t\). It is assumed that households are the owners of capital producing firms, and during the current period all profits, \(\pi_t\), are remitted to them. They purchase insurance, \(A_{j,t}\), to hedge against variation in their income from not being able to re-optimize their wage rate.

Households receive a period \(t\) money injection from the monetary authority, so that they are now holding \(M_t + X_t\) units of currency. However, this injection arrives after the goods and financial markets are closed, so that \(X_t\) can not be used for current period purchases.

Households use their funds to purchase consumption goods, finance banking activity by purchasing short term securities \(D^m_{t+1}\), provide equity capital \(T_t\), to investment banks, and to acquire high powered money \(M^b_t\). Households pay a lump sum tax, \(W^e\), to finance the \(\gamma_t\) surviving financial market participants and the \((1 - \gamma_t)\) new market participants entering in period \(t\).

The households sources and use of funds can be summarized by

\[
(1 + R^a_t)(M^b_t - M_t) + X_t - T_t - D^m_{t+1}
\]

(2.16)
2.3. HOUSEHOLDS

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\[-(1 + \tau^c)p_t C_t + (1 - \Theta)(1 - \gamma_t)V_t - W^e + Lump p_t\]
\[-B^L_{t+40} + \eta^L_t (1 + R^L_t)B^L_t + (1 + R^T_T)T_{t-1} + (1 + R^m)D^m_t\]
\[+(1 - \tau^l)W_{j,t} h_{j,t} + M_t + \Pi_t + A_{j,t} \geq M^L_{t+1} > 0.\]

Households are allowed to purchase ten year government bonds, $B^L_{t+40}$ that yield $R^L$ at maturity, and is assumed to be zero in net supply. As in CMR, $B^L_t$ is included to help diagnose model fit. They concluded that if the mean value of $\eta^L_t$ is set at unity, and if the estimation procedure finds that the variance of $\eta^L_t$ is zero, then we can infer that the model is able to account for the term spread $B^L_t - R^e_t$. Households are aware of $R^L_t$ when they purchase the bond, and discover $\eta^L_t$ when the bond matures.

2.3.3 Wage and Labor Decisions

Household $k$ faces demand for labor

\[h_{k,t} = \left(\frac{W_{k,t}}{W_t}\right)^{\lambda w} l_t, \lambda w \geq 1.\]

$l_t$ is the demand for homogeneous labor by intermediate goods producers and banks, $W_{k,t}$ is the $k$th households wage rate, and $W_t$ is the prevailing wage rate. Households are monopolistic suppliers of differentiated labor, $h_{k,t}$, and can re-optimize their wage rate $W_{k,t}$ in period $t$ with probability $1 - \zeta_t$. The updating procedure for the $\zeta_t$ households that cannot optimize is

\[W_{k,t} = \tilde{\pi}_{w,t} (\mu_{z*,t})^{-\theta}(\mu_{z*,t}^*)^\theta W_{k,t-1},\]

where

\[\tilde{\pi}_{w,t} \equiv (\pi^\text{target}_t)^{t_w} (\pi_{t-1})^{1-t_w},\]

and

\[0 \leq \theta \leq 1,\]
\[0 \leq t_w \leq 1,\]

and $\pi^\text{target}_t$ is the target inflation rate set by the monetary authority.

The household maximizes utility (14) subject to non-negativity constraints, the demand for labor by intermediate firms and banks (7), the asset accumulation equation (16), in addition to Calvo wage setting frictions.
2.4 Financial Market Participants

The inclusion of a financial market whose participants interact with capital producers, firms, and banks establishes a link between the financial and real parts of the model economy. Market participants consider their time $t$ information set, and determine the utilization rate of capital. They use this information to enter into a transaction with the investment bank, where they choose a loan amount and interest rate to maximize their end of period net worth, in exchange for a one-time claim against period $t$ profits. After experiencing an idiosyncratic productivity shock, they use their existing net worth plus the loan from the investment bank to purchase newly installed capital from the capital producer, which it rents out to intermediate goods firms. At the end of the period, market participants sell the undepreciated capital back to the capital producer and settles their counter-party obligations with the investment bank. In each period, a portion of market participants will not have made a sufficient return on their investment to honor their contract with the investment bank. Their assets are seized by the bank and the participants are bankrupt until the beginning of the next period, when all market participants receive a lump sum transfer from households.

There are a large number of financial market participants who at the end of period $t$ have accumulated level of net worth $N_{t+1}$. They purchase new installed capital $\bar{K}_{t+1}$, from capital producers and rent them out to intermediate goods producing firms and banks, which allows the model to capture some of the dynamics between the financial side and the productive side of the economy.

After market participants invest in newly installed capital equipment, they experience an idiosyncratic shock to their investment, $\omega$, and their newly acquired capital $\bar{K}_{t+1}$ becomes $\bar{K}_{t+1}\omega$. $\omega$ is log normally distributed with mean $\mu_\omega$ and standard deviation $\sigma_t$. Market participants have cumulative density function $F_t(\omega)$.

Financial market participants observe period $t+1$ shocks, and then determine the utilization rate of capital and the rental rate $\bar{r}_{t+1}^k$ they can command in a competitive market for capital services. In determining utilization rates, market participants consider the user cost of capital:

$$P_{t+1}Y^{-1+t}\tau^{oil}_{t+1}a(u_{t+1})\omega\bar{K}_{t+1}.$$ (2.17)

In this specification, energy usage is an increasing function of capital utilization. $\tau^{oil}$ is treated as an exogenous shock, and $a(u_{t+1})$ is the cost as a function of the utilization rate. $a(u_{t+1})$ is set so that $u = 1, a(1) = 0, a'(u) = r^k$, and $a''(u) = \sigma_a r^k$, so that $\frac{a''(u)}{a'(u)} = \sigma_a$, where $\sigma_a$ is a parameter which...
controls for the convexity of costs. After renting out capital and earning rent net of utilization costs, market participants sell the undepreciated portion of capital, \(1 - \delta\), at capital price \(Q_{K,t+1}\) to capital producers. The total payoff in \(t+1\) for a financial market participant is then

\[
\left([u_{t+1}\bar{r}_{t+1} + \tau^{oi}_{t+1}a(u_{t+1})]P_{t+1} + (1 - \delta)Q_{K,t+1}\right)\omega\bar{K}_{t+1},
\]

which can be expressed as

\[
(1 + R^{k}_{t+1})Q_{K,t} \omega\bar{K}_{t+1}.
\]

\((1 + R^{k}_{t+1})\) is the average gross nominal rate of return for capital across all market participants in time \(t+1\),

\[
(1 + R^{k}_{t+1}) \equiv \frac{\left([u_{t+1}\bar{r}_{t+1} + \tau^{oi}_{t+1}a(u_{t+1})]P_{t+1} + (1 - \delta)Q_{K,t+1}\right) + \tau^{k}\delta}{Q_{K,t}}.
\]  

(2.18)

where \(\tau^{k}\) is a constant tax rate on capital. Following CMR and BGG, market participants self-finance only a portion of investments, and make up the difference by entering into a financial contract with the investment arm of the bank.

### 2.5 The Standard Debt Contract

The standard debt contract, as in BGG, is designed to maximize entrepreneurial wealth, and is exposed to an idiosyncratic “risk shock” \(\bar{\sigma}_{t}\), and various other shocks generating uncertainty about return to investment. Investments with \(\omega\) above an endogenously determined cutoff, \(\bar{\omega}_{t+1}\), pay back the principle with gross interest \(Z_{t+1}\). The cutoff for investments generating a positive return is

\[
\bar{\omega}_{t+1}(1 + R^{k}_{t+1})Q_{K',t}\bar{K}_{t+1} = Z_{t+1}B_{t+1},
\]  

(2.19)

where \(B_{t+1} = Q_{K',t}\bar{K}_{t+1} - N_{t+1}\) is the nominal value of the financial transaction entered into with the bank. Market participants with \(\omega < \bar{\omega}_{t+1}\) cannot fully repay their loans and go bankrupt. Market participants who are not able to service their loans must turn over their assets to the bank, which pays a monitoring cost, \(\mu(1 + R^{k}_{t+1})\omega Q_{K',t}\bar{K}_{t+1}\). The bank retains the liquidation value of the assets, \((1 - \mu)(1 + R^{k}_{t+1})\omega Q_{K',t}\bar{K}_{t+1}\). Both the loan amount \(B_{t+1}\), and the return to the bank, \(Z_{t+1}\) are determined as in the standard debt contract.

At the end of period \(t+1\), financial market participants settle their contracts with the bank, and sell undepreciated used capital to capital producers. Market participants exit the economy with
2.6. BANKS

There is a single, representative bank with a commercial and financial arm. The commercial section of the bank takes in household deposits, and provides working capital loans to intermediate firms and other banks. The financial arm of the bank is separate from the deposit taking arm of the bank, and intermediates the transfer of credit from households to entrepreneurs. The loan amount and the return on investment are contingent on shocks to the level of wealth and the riskiness of financial market transactions. The Dodd Frank act reinstated provisions of the Glass-Steagle act of 1933 which separated the deposit taking arm of the bank from the investment arm, and we consider the two separately in the model.

Banks are split up into two sections, a commercial bank, and an investment bank that is a subsidiary of the commercial bank (this paper uses the terms investment bank and financial
subsidiary interchangeably). The commercial bank takes deposits and pays interest to households, and issues working capital loans to intermediate goods producing firms and other banks. The financial subsidiary enters into risky financial transactions with market participants in exchange for a claim on future revenue streams. They finance these transactions in two ways. Investment banks can create short term marketable securities that it can sell to households, or they can raise equity financing from households. They experience a shock to the cost of equity financing which affects the composition of their trading book. In the end of period $t$, the investment bank remits a portion of their profits to equity stake holders, and settles its securities contracts with the household.

### 2.6.1 Commercial Banking

In the beginning of period $t$, prior to production, households deposit $A_t$ units of high powered currency with the bank in exchange for deposit liability, $D^h_t$,

$$D^h_t = A_t.$$  

Banks then extend working capital loans, $S^w_t$, in the form of demand deposits $D^f_t$, to intermediate goods producers and other banks. The interest charged on working capital loans is $R_t + R^a_t$. Since firms receive interest $R^a_t$ on deposits, the net interest rate on working capital loans is

$$1 + R_t)S^w_t = (1 + R_t)(\psi_1 W_t + L_t + \psi_2 P_t \tilde{r}_K K_t).$$  (2.22)

As in CMR, banks keep a portion of their demand deposits, $\tau$, as reserves, and allow demand deposits to generate liquidity services and pay interest, $R^a_t$. Following Chari, Christiano, and Eichenbaum (1995), the production technology banks employ to produce liquidity services is modeled as a function of homogeneous labor, capital services, and excess reserves,

$$\frac{D^h_t + D^f_t + \zeta D^m_t}{P_t} = x^{(a)} \left( (K^B_t)^{alpha} (z_t l^B_t)^{1-alpha} \right)^{1+ \xi_t} \left( \frac{E_t}{P_t} \right)^{1- \xi_t}. $$  (2.23)

$D^m_t$ is the households’ holdings of short term marketable securities and is discussed more thoroughly below, $\zeta$ is a positive scalar constant and $\alpha \in [0, 1]$. The production technology is exposed to two stochastic processes: the banks demand for excess reserves, $\xi_t$, and funding technology shock, $\alpha_t$. Excess reserves are included in the banks production technology for liquidity services as a reduced form way of capturing the banks precautionary motives for protection against unanticipated withdrawals. Excess reserves are defined as
2.6. BANKS

CHAPTER 2. THE MODEL

\[ E_t^r = A^r - \tau(D^h_t + D^f_t) \]  

(2.24)

2.6.2 Investment Banking

The investment arm of the bank enters into a standard debt contract with financial market participants, valued at \( B_{t+1} \), in exchange for a one time net payout, \( R_{t+1}^e \). The contract is entered into at the end of the current period and expires at the end of the subsequent period \( t+1 \). The transaction exposes the bank to market and credit risk, reflected in the external finance premium. These transactions are funded by the portion of equity investment not used as capital reserves, \( \tau^f T_t \), which entitles the holders of that equity to a portion of period \( t+1 \) profits, and short term security purchases by households, \( D_{t+1}^m \). Funding decisions are made after production in period \( t \).

\[ B_{t+1} = D_{t+1}^m + (1 - \tau^f T_t) \]  

(2.25)

The maturity of the short term securities issued coincide with the maturity of the underlying debt contract, and yield net return \( R_{t+1}^m \), where \( R_{t+1}^m < R_{t+1}^e \) in all dates and states. The bank issues a dividend to equity holders \( (1 + R_{t+1}^e) T_t \). Because equity holdings represent a partial ownership in the investment bank, holders of equity receive the same return on investment as the investment bank, \( R_t = R_t^e \). Banks do not provide liquidity services for equity holdings, but experience an exogenous shock to the cost of equity financing, \( \sigma_t^f \).

As mentioned in the previous section, the standard debt contract is designed to maximize financial market participants net worth. Because both the commercial and investment arms of the representative bank are assumed to be competitive, the contract is now constrained by the banks zero profit condition,

\[ [1 - F_t(\tilde{\omega}_{t+1})] Z_{t+1} B_{t+1} + (1 - \mu) \int_{0}^{\tilde{\omega}_{t+1}} \omega dF_t(\omega)(1 + R_{t+1}^k) Q_{t+1} \tilde{K}_{t+1} = (1 + R_{t+1}^e) B_{t+1} \]  

(2.26)

The object on the right of the equal sign is the return the financial arm of the bank must make to its parent institution (and thus equity holders) at the end of period \( t+1 \), which is known at the end of period \( t \). The first term on the left is the number of market participants that were able to meet their financial obligation to the bank times the principle and interest payments owed by each participant. The second term is the liquidation value of the assets of market participants who were not able to fully honor their contract with the bank and are thought of as “bankrupt”. Multiplying (26) by \( \frac{1 + R_{t+1}^e}{N_{t+1}} \), and using the definition of \( \tilde{\omega}_{t+1} \),
where
\[ \Gamma_t(\bar{\omega}_{t+1}) \equiv \bar{\omega}_{t+1} \left[ 1 - F_t(\bar{\omega}_{t+1}) + G_t(\bar{\omega}_{t+1}) \right], \]

\[ G_t(\bar{\omega}_{t+1}) \equiv \int_{0}^{\bar{\omega}_{t+1}} \omega d F_t(\omega). \]

\( \Gamma_t(\bar{\omega}_{t+1}) \) is the share of market participants return on investment received by the banks financial subsidiary before monitoring costs. \( \Gamma_t(\bar{\omega}_{t+1}) - \mu G_t(\bar{\omega}_{t+1}) \) is the share net of monitoring costs, or the share of earnings net the costs of liquidating the confiscated assets of bankrupt market participants. \( 1 - \Gamma_t(\bar{\omega}_{t+1}) \) is the share of return on investment retained by market participants. The optimization problem for financial transactions modeled by the standard debt contract is to maximize the net worth of market participants with respect to the loan amount and interest rate, and subject to the banks financial subsidiaries zero profit condition. \( \eta_{t+1} \) is the Lagrangian multiplier, and is contingent on the \( t + 1 \) state of nature.

\[
\max_{B_t, \omega_t} \quad E_t \left[ \left( 1 - \Gamma_t(\bar{\omega}_{t+1}) \right) \frac{1 + R_t^k}{1 + R_t^e} (B_t + N_{t+1}) - B_{t+1} \right] \quad \text{(2.27)}
\]

We assume the monetary authority regulates the proportion of equity capital reserves, \( \tau_{t+1}^f \), through adjustments to the interest rate for capital reserves, \( R_{t+1}^r \). For simplicity we do not require the investment bank to hold a minimum amount of equity capital. The end of period \( t \) return from equity capital reserves is

\[
(1 + R_{t+1}^r) \tau_{t+1}^f T_t. \quad \text{(2.29)}
\]

The total credit outstanding- the sum of working capital loans and financial market transactions - is summarized by

\[
B_{t+1}^T = \psi_{l} W_t l_t + \psi_{k} P_t^{\rho_k} K_t + B_{t+1} \quad \text{(2.30)}
\]

The banks period \( t \) net source of funds from its commercial banking activities and its financial subsidiary can be summarized by
The bank is competitive in financial and factor markets and takes rates of return and prices as given. \( B_{t+1} \) is chosen to maximize financial market participants end of period net worth as part of the standard debt contract, and is taken by the bank as given. In the beginning of period \( t \), the bank takes the equity raised, \( T_{t-1} \), and short term securities issued, \( D_m \), in the previous period, and chooses \( T_{t-1} \), \( D_m \), \( D_f \), \( A_t \), \( K_t^b \), \( I_t^b \), \( E_t^f \).

### 2.7 Resource Constraint

The aggregate resource constraint for the economy is

\[
\Pi_t^b = (1 + R_t + R_t^a)S_t^w + (1 + R_t^e)B_t + A_t + (1 - \tau_f^f)T_t + (1 + R_{t-1}^f)T_{t-1} + D_{t-1}^m - B_{t+1} - (1 + R_t^a)\left( D_t^b + D_t^f \right) - (1 + R_t^m)D_t^m - (1 + R_t^T)T_{t-1} - [(1 + \psi_k R_t)P_t \tilde{r}_k^b] - [(1 + \psi_l R_t)W_t l_t^b].
\]

The first term is the amount of final output used by the banks financial subsidiary in monitoring transactions with their counter-parties. The next term is the cost of capital utilization and is a function of the price of oil, the level of capital and the rate of technological change. \( \Theta(1 - \gamma_t) V_t \) is the amount transferred from financial market participants exiting the market to households in period \( t \). \( G_t \) is government spending, which grows with the rate of output, \( z^* \),

\[
G_t = z^* g_t,
\]

and \( g_t \) follows a stationary stochastic process. The last term on the left is the amount of final goods used in the production of investment goods. The stationary shock, \( \mu_{t,t} \), is specific to the production of investment goods and establishes a link between the price of final goods used in the production of investment goods and the price of investment goods themselves, \( \frac{1}{\Gamma^t \mu_{t,t}} \). Real gross domestic product (GDP) is measured as

\[
GDP_t = G_t + C_t + \frac{I_t}{\Gamma^t \mu_{t,t}}.
\]
2.8 Monetary Policy

A generalized Taylor rule to model monetary policy is implemented by the monetary authority. The target interest rate is \( R_{e,t+1} \), and the monetary authority’s response function is given by

\[
\hat{R}_{e,t+1} = \rho_i \hat{R}_e + (1 - \rho_i)\alpha_\pi \frac{\pi}{R_e} (E_t(\hat{\pi}_t + 1) - \hat{\pi}^{target}_t) + (1 - \rho_i)\alpha_{\Delta y} \frac{\alpha}{4R_e} \log \left( \frac{GDP_t}{Z_t GDP_{t-1}} \right) + (1 - \rho_i)\alpha_{\Delta c} \frac{\alpha}{400R_e} \xi_t + \frac{1}{400R_e} \epsilon_t
\]

where variables with a hat are percent deviations from their steady state. The central banks inflation objective is \( \hat{\pi}^{target}_t \), which has the time series representation

\[
\hat{\pi}^{target}_t = \rho_\pi \hat{\pi}^{target}_{t-1} + \epsilon^{target}_t, \quad E(\epsilon^{target}_t)^2 = \sigma_\pi^2,
\]

and \( \epsilon_t \) is the deviation of observed monetary policy from the rule.

2.9 Shocks

All shocks in the model (besides the monetary shock, \( \epsilon_t \)) follow a univariate first order autoregressive process.

Because a new shock variable, \( \tau^{f}_t \) is introduced to the model, the shocks calibrated in CMR were re-calibrated to include the shock to the cost of equity, \( \tau^{f}_t \). These include

\[
\left( x_t^b, \xi_t, \epsilon_t, \mu_{Y,t}, \gamma_t, \eta_t, \gamma_t, \sigma_t, \sigma_{\epsilon,t}, \sigma_{\gamma,t}, \tau^{oil}_t, \lambda_{f,t}, \tau^{f}_t \right).
\]

To re-estimate these shocks to include the cost of financing shock, the same U.S. data and observable processes from CMR were used. The priors from CMR were used for all priors in the re-estimation exercise, except the new parameters in the autoregressive process associated with the cost of equity financing shock, \( \rho^f \) and \( \sigma^f_t \).

Financial sector shocks include

\[
\left( \gamma_t, \sigma_t, \sigma^f_t, x_t^b, \xi_t \right),
\]

where \( \gamma_t \) is a financial wealth shock, \( \sigma_t \) is the idiosyncratic risk shock to financial market participants, \( \sigma^f_t \) is the shock to the cost of financing financial transactions by raising equity, \( x^b_t \) is a
shock to the banks funding technology, and $\zeta_{i,t}$.

### 2.10 Shock to the Cost of Equity Financing

The cost of equity financing shock was introduced in part to capture the difficulty investment banks experienced raising capital in the period following the financial crash in 2008, as well as to introduce another process by which the model could account for the term spread, $R^e - R$. The posterior means of the autoregressive parameter, $\rho_f$, and the standard deviation of $\sigma_f^t$ are .3505 and .1280, respectively. The shock to equity financing is modeled as an exogenous process to capture that portion of investors valuation of investment bank’s portfolios, and the market as a whole, which differ from their fundamental market prices. In the counter factual exercise which follows, this allows for movements in the cost of equity, and therefore banks financing decisions, which would not otherwise occur during the course of the business cycle. A positive shock corresponds to negative investor sentiments regarding individual portfolios, or the market as a whole, based on information other than that represented by the other financial shocks, $(\gamma_t, \zeta_{i,t}, \sigma_t, \sigma^F_t, x^B_t)$. This could include information or beliefs about future prices and perceived bubbles, such as the amount of systemic risk present in a financial system, the amount of leverage taken on by investment banks, or the riskiness of the credit instruments themselves.

### 2.11 Model Solution

The model evolves on a stochastic growth path driven by innovations in technology $z^*_t$, and increasing efficiency in the production of investment goods, $z^*_t \Gamma^i$, remembering that $\Gamma^i > 1$. Consumption, real wages, output growth, real net worth, and real credit and monetary aggregates all grow at rate $z^*_t$. Variables associated with investment specific production $z^*_t \Gamma^i$. Short and long term nominal interest rates, inflation, households supply of labor and the external finance premium are all stationary variables.

All parameter values, including the steady state values of the endogenous variables, were taken directly from CMR, with the following exception. The steady state value of the equity capital reserve ratio, $\tau^f_t$, is set to zero, to capture the notion that investment banks choose to keep the minimum amount of equity in reserve as possible, preferring that all their capital is productive and not sitting idle, and to simplify the calculation of the model’s steady state values.
3.1 NFCI

The NFCI is a weighted index, produced bi-weekly at the Chicago Federal Reserve, that is subdivided into three measures of financial market health: risk, credit, and leverage. From Brave and Butters (2011), “risk indicators capture volatility and funding risk in the financial sector, while credit indicators are composed of measures of credit conditions, and leverage indicators consist of debt and equity.” Brave and Butters (2011) also show that the NFCI is “highly predictive and robust at leading horizons up to one year...” and that measures of leverage especially, have an important role in the predictive capabilities of the index. A sub-index to the NFCI is constructed by taking measures in the NFCI which are also present in the model, and use generalized least squares to fit the model variables to the index. The Ordinary Least Squares (OLS) model is

\[ Y_t = \beta X_i + \epsilon_i, \]

where \( Y_t \) is the observed value of the NFCI, and the matrix \( X \) consists of model variables which are also included in the NFCI. All data used in the model was found in the FRED database, and aside from the VIX and the delinquency rate for corporate loans, all series are from 1984Q:1 to 2013Q:2.
The above model incorporates 2 measures of risk also included in the NFCI: $\sigma_t$ and the interest rate spread $R_t^e - R_t$, to model the VIX index and the Financial-Corporate bond spread, respectively. For the Financial-Corporate bond spread, we use the rate of return on equity, $R_t^e$, instead of $R_t^m$, to capture the notion that risk, as well as returns, drives the spread in rates. The interest rate $R_t$ is the gross no default interest rate that firms face for working capital loans, and can be thought of as the Aaa corporate bond yield. Data for $R_t^e$ was taken from the Fred series Average Return on Equity (USROE), and data from $R_t$ can be found in the series Moody’s Seasonal Aaa Corporate Bond Yield. We used an averaging aggregation technique to convert the bond yield series into quarterly data. Both measures are highly statistically significant; the financial-corporate yield spread has a coefficient of -.1175 and a standard error of .0176, and the VIX index has positive coefficient .0636 with standard error .0049.

The two measures of leverage in the sub-index are the level of corporate debt issuance, $S_t^w$, and the ratio of financial market transactions to the net worth collateralizing those transactions, $n_t/n_t - k_t$. We found that corporate debt issuance was even less of an explanatory variable in the subindex than the full index, and was dropped because of statistical insignificance. The percentage ratio of financial market debt/net worth is one of the driving factors in movements of the subindex, with a coefficient of -.1280 and standard error .0301. This result is consistent with the weight assigned to the ratio in the full NFCI index. To construct the ratio of financial market debt to net worth, we took the FRED series Financial Business; net worth(IMA) and divided it by the series Credit Market Instruments; Liability.

Because of the lack of household lending and the absence of risk in working capital loans extended to firms and banks, there is only one measure of credit that appears in the model. $\frac{F(\omega)}{1-F(\omega)}$ is the ratio of market participants who go bankrupt and cannot honor their counterparty obligation to those who do not go bankrupt and can fully repay their loan. In the context of the sub-index, we take this to be the ratio of performing loans to non-performing loans. Because this is not an endogenous process in the above model, this measure will not affect baseline results. It will, however, be pertinent to the results from the counterfactual exercise performed. As explained in detail later in the paper, a shock estimation was performed to estimate the series and sequence of shocks that drove fluctuations in financial variables in 2007 and 2008. That estimation suggested that shocks to credit risk were substantial, so the sub measure was left in the analysis. Because of the lack of data on the delinquency rate of counterparties in financial transactions to one another, we used the delinquency rate on business loans. This ratio is a main determinant of movements of key variable movements in the baseline model, and is also a big contributer to movements in the subindex. The coefficient is -.2155 with a standard error of .0481.

The full model for the sub-index to the NFCI is
\[ NFCI_t = \beta_0 + \beta_1 \left( \frac{n_t}{n_t - k_t} \right) + \beta_2 \frac{F(\omega_t)}{1 - F(\omega_t)} + \beta_3 \sigma_t + \beta_4 (R_t^e - R_t) + \epsilon_t. \]  

The expression multiplying \( \beta_1 \) is an expression for the ratio of net worth to debt in the financial market. Raising this ratio lowers the subindex, indicating tighter financial conditions. The term after is the ratio of performing loans to non performing loans. The next term is the idiosyncratic risk shock facing market participants, and the fourth term on the right side of the equality is the spread between the yields for financial and corporate bonds. The last term is the error term.

The explanatory variables do a good job explaining the variance in the NFCI; with just four variables out of 105, the regression yields an adjusted R squared of .938 and a Root Mean Squared Error of .1898.

### 3.2 Proposed Regulatory Rule

The model presented above contains financial market participants and institutions, who make financing decisions, engage in financial contracts, and experience financial shocks. The connection between the financial sector and the real economy is captured in two distinct ways. The first involves the investment banks financing decisions. Households are the suppliers of equity to investment banks, and financial market participants, as well as other investment banks, are the suppliers of credit. The second avenue through which financial decisions can have real economic effects in the model are through the more traditional effects of financing of intermediate goods producers - the availability of credit to finance working capital loans have a direct effect on the return intermediate goods producers can expect in the next period, and therefore how much they decide to produce this period. The next part of this paper is to introduce a regulatory regime to regulate the total amount of leverage in financial markets, with the auxiliary goal of decreasing volatility in financial markets as measured by a chief indicator of volatility.

In addition to the baseline model presented above, we introduce three different regulatory regimes which monitor investment bank's equity capital ratios. Financial subsidiaries are offered an interest rate, \( R^e_t \), on equity capital reserves, much like depository institutions are offered interest on their capital reserves. Financial regulators can then set equity capital ratios to a desired level by raising or lowering the offered interest rate. The three rules proposed are analyzed in the context of the above model, first with initial values corresponding to the model's steady state, then with a counterfactual exercise, where the initial values correspond to 2007 type shocks to the financial system.

For each rule, both in the baseline simulation and the counterfactual exercise, the optimal simple
rule for the coefficient of the response function, $\rho_f$, was estimated, according to

$$\min\{\rho_1 \text{var}(Util) + \rho_2 \text{var}(\tau_f) + \rho_3 \text{var}(NFCI) + \rho_4 \text{var}(Y)\}$$

subject to the models equilibrium conditions, and $\rho_f$, the coefficient on the proposed regulatory response function. The objective function is a weighted sum of the variances of average period utility ($Util$), the investment banks equity to capital ratio ($\tau_f$), output ($Y$), and the NFCI, which is discussed below. The variables were chosen so that the response function minimized the amount of variance in two key measures of financial health, $\tau_f$ and the NFCI, while also considering utility and total economic activity. The weights were set equally, $\rho_1 = \ldots = \rho_4$, to capture the notion that financial regulators should take into account the amount of total economic activity, not just that occurring in the financial market, as well as consumer utility. Different values of the $\rho$'s could be set according to the financial regulators goal (to minimize fluctuations in financial markets, household utility, total economic activity, etc). The first rule presented is based off of the National Financial Conditions Index, developed by the economists at the Chicago Federal Reserve.

Response Function based on the NCFI

The first regulatory response function considered has the form,

$$\log(\hat{R}) = (1 - \rho_1^f) + \log(\hat{NFCI}_{t-1}). \quad (3.2)$$

Variables with hats are percentage deviations from their steady states. The target rate, $R_t^f$, is raised to respond to increases in the riskiness of financial market transactions and the availability of credit, and decreases in the level of liquidity. The parameter $\rho_1^f$ is set by the optimal simple rule to minimize the variance in four key financial and economic variables, as discussed above. The target rate is implicitly moved by deviations of observable credit and liquidity conditions from their steady state, and can be seen by examining (33). The target rate, $R_t^f$, is conditional on the deviation of this subindex from its stationary state, and not on the individual components to capture the idea that equity reserves should respond to changes in the health of financial markets as a whole, not on one or two narrowly defined measures which are included in the sub-index. Another reason the response function is based on the sub-index and not on the equity reserve ratio directly is to capture the notion that it is more desirable to increase equity reserve ratios in periods of financial turmoil than in a financial market that is already near its steady state.
3.2. PROPOSED REGULATORY RULE

3.2.1 Response Function to Capital Ratios

The second response function proposed reacts only to deviations of investment banks equity capital ratios from their steady states. This regulatory response only explicitly considers capital ratios when setting the target rate, $R_t^*$, but implicitly, overall output, average per period utility, and the condition of the financial market as a whole also contribute to the response function, in the form of the parameter $\rho_f^2$. As discussed before, $\rho_f^2$ was chosen to minimize the variance of the four endogenous variables $Y$, $Util$, $NCFI$, and $\tau_f$. To test the sensitivity of $\rho_f$ to its initial guess, $\rho_{f,0}$, was set to .1, .8, 1.6, and 2.4. The result of the Optimal Simple Rule is used for the parameter $\rho_f^2$ in the second response function,

$$\log(\hat{R}) = (1 - \rho_f) \log(\tau_{f,t-1}),$$

(3.3)

where, as before, hats indicate deviation from steady state. The investment banks equity capital ratio, $\tau_f$, is an important variable in the investment banks funding decision (equation 17), and direct integration of $\tau_f$ in the response function guarantees a quicker response to the target rate to movements in $\tau_f$, but at the expense of considering the health of the financial system as a whole.

3.2.2 Response Function as a Linear Combination of Capital Ratios and the NCFI

The final response function considered reacts to deviations of both the NCFI and the equity capital ratio from their steady states. Because the NCFI includes capital ratios, in a sense, they are being accounted for doubly by this response function. However, this rule is still guaranteed to react less to movements in capital ratios. Remembering that the NCFI is defined as

$$NCFI_t = \beta_0 + \beta_1 \left( \frac{n_t}{n_t - k_t} \right) + \beta_2 \frac{F(\omega_t)}{1 - F(\omega_t)} + \beta_3 \sigma_t + \beta_4 (R_t^e - R_t) + \epsilon_t,$$

and considering the third regulatory response function,

$$\log(\hat{R}) = \rho_f NCFI_{t-1} + (1 - \rho_f) \log(\tau_{f,t-1}),$$

(3.4)

where variables with a hat over them indicate the deviation from steady state, we can say that

$$\rho_f^3 \beta_1 \tau_f + (1 - \rho_f^3) \tau_f < \rho_f^2 \tau_f$$

for all non negative values of $\tau_f$, given $\beta_1 \neq 0$. The response to the increase in the NCFI as a whole will also be less than the first model, due to the change in the functional form. However, when a simulation was ran incorporating the NCFI and $\tau_f$ multiplied by $\rho_{NCFI}$ and $\rho_{\tau_f}$, respectively, it
3.3. A COUNTERFACTUAL EXERCISE

was found that if
\[ \log(\hat{R}) = \rho_{NCFI} \log(\hat{NCFI}_{t-1}) + \rho_{\tau_f} \log(\hat{\tau}_{f,t-1}), \]
then
\[ \rho_{NCFI} < \rho_{\tau_f}. \]

In calibrating \( \rho_{\tau_f} \), the Optimal Simple Rule, which minimizes the variance of \( Y, Util, NCFI, \) and \( \tau_f \), subject to the equilibrium equations of the model and \( \rho_{\tau_f} \), several initial guesses were used to test the sensitivity of \( \rho_{\tau_f} \). Because \( \rho_{\tau_f} \) must necessarily take a value between zero and one, the starting values of .1, .3, .5, .7, and .9 were used, and all yielded final values centered around .42, to several decimal places.

3.3 A CounterFactual Exercise

To see what the effects of the proposed policies might be during periods of turbulence in financial markets, and whether they might have any mitigating effects on key financial variables such as capital reserves or financial stress indicators (NFCI), the above model is calibrated to mimic an economy experiencing a financial crisis. To do this, the size of the shock for the four financial shocks in the model, and the shock to the marginal efficiency of investment, were estimated using the US data and observables used to calibrate the CMR model, but only with data from July 1, 2007 through October 1, 2009. The beginning date of July 1, 2007, corresponds to the first quarter of negative growth in the recent crisis, the end coincides with the first two quarters of consecutive positive growth in GDP after the crisis.

After the parameters for the financial shock processes’ are calibrated using crisis economy data, simulations with and without the rule can be performed. Forecasts are extended out ten periods, and bounded by a 90 percent confidence interval.

3.3.1 Estimating Financial Shocks

We suppose that the economic events starting in 2007 were the result of large, unanticipated financial shocks. To replicate the economic environment of 2007-2009, the serial correlation parameter, \( \rho \), and the standard deviation \( \sigma \) for the four financial shocks, the shock to the marginal efficiency of investment \( \zeta_{i,t} \), and the shock to money supply \( x_t^p \) were estimated, while other shock processes were set at their normal steady state values. Estimating all of the shocks in the model would have yielded a better estimate for the shock paths in the model, but at the expense of obfuscating the mechanisms of the proposed rule. Estimating only the financial shocks, as well as
the shock to the efficiency of investment and the shock to money supply, captures the notion that financial regulators would use the proposed rule only in the face of financial shocks or stress, and not to respond to shocks to the real economy.

The prior modes and standard deviations for the parameters of the four financial shock processes, the shock to the marginal efficiency of investment and the shock to the money supply, were set according to the following procedure. A beta prior distribution was used to estimate the serial coefficient, $\rho$, of the cost to financing shock and the risk shock. Because of the lack of prior information for $\rho$, the prior mode and standard deviations were set at .5 and .2, respectively, to allow for a wide distribution of posterior results. Including the serial coefficients $\rho$ for the other three financial shocks caused the estimation procedure to be under-identified, and so were excluded from the analysis.

The standard deviation of the shocks were estimated using stricter guidelines for the prior distribution. The desire to match the magnitude of the movements in financial variables led to a prior mode that is three times the “normal” mode of the standard deviation of the shocks. The selection of the prior standard deviation was chosen to be relatively diffuse to allow for a wider range of posterior results.

To test the sensitivity of the posterior to the priors for $\rho$, a range of priors extending from the CMR priors for the shock to a prior centered around .9 was tested, and yielded similar results, with a small bias towards whatever side the prior erred on. To test for the sensitivity of the magnitude of the shocks to the prior, a range prior parameters was used, with a mean and standard deviation equal to the baseline at the low end of the range, and 3 times the mean with twice the standard deviation. The posterior wasn’t dramatically changed at either end of the spectrum. The conclusion is that these instruments have good explanatory power in the context of the model presented and the data, and are not overly sensitive to the choice of the priors. The prior and posterior results of the estimation are included in the Appendix.

The estimation suggests the following story. The first period of the crisis was defined by large, unanticipated financial shocks, including a shock to the perceived risk in financial markets, $\sigma_t$, the cost of equity financing, $\tau_f t$, the shock to banking technology, $x_b t$, and the marginal efficiency of investment $\zeta_i t$. The shock to the marginal efficiency of investment, $\zeta_i t$, returns to its steady state values at the same rate as the non-crisis economy. The availability of equity financing $\tau_f t$, and the perceived amount of risk in financial markets $\sigma$, take longer to trend back towards steady state in the crisis economy than in the non-crisis economy (the serial correlation for these two processes is higher in the crisis economy than in the non-crisis economy).

A Metropolis-Hastings in Gibbs algorithm is used for the estimation. 5,000 draws (precision to 10 decimal places) are taken, with 500 discarded for the burn in period. The acceptance rate is .34,
within the the .15-.4 range set by Gelman, Roberts and Gilks (1993).
The estimated paths of the shocks are then inputted in the model, first without the regulatory policy
as a baseline, then with the four response functions discussed above. None of the financial shocks
do an adequate job explaining some of the real variables in the data, which can be explained in one
of two ways. The first is that the economy also experienced real shocks in post crisis 2007 that drove
down productivity, hours worked, and consumption. The second is that while links between the
financial sector and production and household sectors of this model have been established, the
movement of financial variables in the model have a small multiplier effect on real economic
variables, and vice versa. Because of this, the measures with which the different policies are
compared are strictly financial, such as the equity capital ratio, and financial market health.

3.3.2 Simulation and Forecasting

To see how well the model does replicating a 2007 type financial shock, given the previous shock
estimation, several real and financial variables are considered. In the baseline model with the
estimated shocks imposed (Appendix), total output falls by about 6 percent over 10 periods, twice
as much as in the observed data. Net wealth falls precipitously in the data and the model, and after
10 periods is still well below it’s steady state value (1.68).
Short term marketable securities, \( d^m_t \), which investment banks use to finance working capital loans
and loans to entrepreneurs, fall after the initial financial shocks, and don’t recover to its steady state
value (9.0048) for over 4 periods. In the model, short term marketable securities can be thought of
as any security that matures by the end of the period. This could be from the repo market,
commercial paper, short term working loans from other financial institutions, or any security that
matures within period. This closely tracks the 2007-'08 experience, when commercial paper
outstanding declined 250 percent, the repo market shut down, and banks were wary of their
counterparites. This lack of short term financing manifested as a solvency issue for many major
investment banks, which shows up in the counterfactual exercise as a large decrease in short term
financing, as well as total loans issued (\( b^{tot}_t \)).
The NCFI increases dramatically during the financial crisis, and only starts to return to its steady
state several years after the crisis. The NCFI is particularly sensitive to measures of liquidity (Brave
and Butters, 2011); the increase in the index can be attributed largely to the adverse shock
investment banks experienced to their trading books following the crisis. In the model, a main
component of the index is the ratio of counterparties who default to those who honor their
contract, \( \left( \frac{n^d_t}{n^h_t} \right) \). Two other main components of the index to experience a large shock are the term
spread \( R^e_{t+1} - R_t \), and the amount of leverage carried by financial institutions.
Projected Path Under Proposed Rules

One of the notable characteristics of the proposed rules is that their effects are confined, for the most part, to the financial sector. Implementing one of the rules changes the projected path of the NCFI, and the amount of short term securities issued to investment banks. Real macro variables are unchanged, a result which will be discussed below. The proposed rules were less successful in moving the forecasted path of equity capital reserves ($\tau^t_f$) held by investment banks. Under the baseline counter factual exercise, the equity capital ratio decreased below steady state in period one under the imposed shocks. Within five periods, equity capital is back to it's steady state ratio, without any regulatory intervention. The effects of all three of the proposed rules on equity capital are negligible, which in the model, is dependent on $R^e_t$, $R^m_t$, and the cost of equity financing shock, $\sigma^f_t$. The large estimated magnitude of this shock, and the path of $R^e$, largely determine the path of the equity capital ratio, $\tau^f_t$.

The first proposed rule is a reaction function of only the NCFI. The forecast reaction to the target rate, $R^r_t$, can be found in the appendix (Appendix). In response to the increase in the NCFI, the target rate is raised to 2.3 percent and slowly allowed to fall. The forecast for the NCFI after the estimated shocks are imposed is significantly better under the rule than the baseline. In the baseline, the NCFI spikes after the shocks and plateaus above its steady state for over ten periods. The first rule sharply drops the NCFI, mainly through the decrease in short term securities that comes from a higher interest rate on equity capital, $R^r_t$. The forecast for short term securities, $d^m_t$, implies a slightly slower return to its steady state under the first rule than under the baseline.

The second rule, which is a function of only the equity capital ratio, $\tau^f_t$, doesn't have much of an effect on $\tau^f_t$ directly. The target rate is raised to about 2 percent in reaction to the decrease in equity capital, and allowed to fall to zero fairly quickly. Its effects on short term securities are less pronounced than for rule one, but still enough to move the NCFI index back down towards its steady state value.

The third rule and fourth rules are linear combinations of the above two rules, with one and two parameters, respectively. The target rate for the third rule rises to about 35 basis points, and falls sharply down to zero in response to a quick decline in the NCFI. The target interest rate, $R^r_t$, acts as a subsidy to the investment banks for attracting equity, and the forecast for short term securities shows the decline in issuance in response to the higher rate. The fourth rule achieves similar results, but with a much higher rate, almost hitting 60 basis points in the second period.
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Conclusion

In a 2008 congressional hearing, Alan Greenspan testified before the House Committee on Oversight and Government Reform, “[The] modern risk-management paradigm held sway for decades...The whole intellectual edifice, however, collapsed in the summer of last year[2007]...This crisis,” he told lawmakers, “has turned out to be much broader than anything I could have imagined. It has morphed from one gripped by liquidity restraints to one in which fears of insolvency are now paramount.” The crisis in 2007-â˘A´Z08 was unique from other recent crises in both scale and scope; for the first time since the Great Depression, large negative shocks to financial markets propagated into the real economy. The perturbations in financial markets led to, by many measures, the worst labor market conditions since the postwar era, a destruction of wealth not seen since the Great Depression, a “flight to quality” which drove down key interest rates, to the point of mitigating conventional monetary policy, and a peak to trough decline in real GDP of 5.1 percent (Q1:2008-Q2009). The crisis also had the effect, as Mr. Greenspan testified, of putting the efficacy of the “modern risk-management paradigm” into question. Much work has since been done, to theoretically model the dynamics between the financial sector and the real economy, and to set a regulatory framework into place that can manage systemic risk.

A host of regulatory regimes have been considered in order to mitigate the effects of future financial crises. The Dodd-Frank Wall Street Reform and Consumer Protection Act was signed into law by Barack Obama in July 2010, and was amended July 2012 to include the so called “Volcker ruleâ˘A˙I banning proprietary trading. And in June 2013, the Federal Reserve voted to approve a rule applying Basel III capital requirements to US banks. These efforts reversed the deregulatory trend that had persisted in the US since the start of the postwar era. Arguably the most important of these financial regulations was the decision to enforce Basel III capital requirements, which does away with the practice of risk weighting and specifies required leverage ratios.

The contribution of this paper is to propose a simple regulatory regime: the Federal Reserve offers an interest rate to investment banks on their equity capital reserves. In addition to decreasing the incentive of investment banks to shift assets from their trading book to their banking book (to avoid the stricter reserve requirements on market risk), it also gives the Federal Reserve an interest rate for excess capital reserves -\( R^*_t \)- that they can fix in order to set the desired required reserve ratio. A variable reserve rate is less costly and disruptive to banking activities than changing reserve requirements explicitly.

Once unanticipated shocks hit the economy, the proposed regulatory rule also acts as a way for the Monetary Authority to help recapitalize banks in tight credit markets. Instead of taking outright equity stakes in insolvent investment banks, an interest rate on equity reserves allows Monetary
Authorities to re-capitalise at arms length, making equity positions in investment banks more attractive by giving investors access to a higher risk free yield. The offered interest rate, $R^r_t$, primarily acts as a subsidy for investment banks acquisition of equity capital. The rate lowers the spread between the return investment banks expect from their investments, $R^e_{t+1}$, and the interest they are charged when they finance with short term securities. This can induce them to raise more capital through equity financing, despite the higher costs. Of the three variations of the regulatory rule, the third, a linear combination of the equity capital ratio and the NCFI with one parameter performed the best in the counterfactual exercise. Short term securities declined significantly relative to the baseline counterfactual, as did the measure of financial stress, the NCFI. Although the rate offered is not enough to significantly change investment banks reserves of equity capital, it can change their financing decisions away from financing with short term securities.


APPENDIX

A

BASELINE MODEL

A.1 Equilibrium Equations

Measure of Marginal Cost

\[ s_t = \left( \frac{1}{1 - \alpha} \right)^{1 - \alpha} \left( \frac{1}{\alpha} \right) \frac{r^k_t [1 + \psi_t r_t]^{\alpha}(\bar{w}_t [1 + \psi_t r_t])^{1 - \alpha}}{\epsilon} \]

Another Measure of Marginal Cost

\[ s_t = \frac{r^k_t [1 + \psi_t r_t]}{\alpha \epsilon_t \left( \frac{\mu^*_{f,t} \ell_t}{\bar{w}_t k_t} \right)^{1 - \alpha}} \]

Calvo Sticky Prices

\[ p^*_t = \left( 1 - \xi_p \right) \left( \frac{1 - \xi_p \left( \frac{\bar{p}_t}{\bar{\pi}_t} \right)^{\lambda_{f,t}}}{1 - \xi_p} \right)^{\lambda_{f,t}} \left( \frac{\bar{p}_t}{\bar{\pi}_t} p^*_t \right)^{\lambda_{f,t}} = 0 \]
APPENDIX A. BASELINE MODEL

\[ E_t \left\{ \lambda_{z,t} Y_{z,t} + \left( \frac{\bar{\pi}_{t+1}}{\pi_{t+1}} \right)^{-\lambda_{f,t}} \beta \xi_p F_{p,t+1} - F_{p,t} \right\} = 0 \]

\[ E_t \left\{ \lambda_{f,t} \lambda_{z,t} Y_{z,t} s_t + \beta \xi_p \left( \frac{\bar{\pi}_{t+1}}{\pi_{t+1}} \right)^{-\lambda_{f,t}/s_{t+1}} K_{p,t+1} - K_{p,t} \right\} = 0 \]

\[ K_{p,t} \text{ is a function of } F_{p,t}, \]

\[ K_{p,t} = F_{p,t} \left[ \frac{1 - \xi_p \left( \frac{\bar{\pi}_t}{\pi_t} \right)^{1/s_{t+1}}}{(1 - \xi_p)} \right]^{1-\lambda_{f,t}} \]

\[ \bar{\pi}_t = (\pi_{t,\text{target}}^{t-1})^{1-t} \]

\[ Y_{z,t} = (p^*_t)^{\lambda_{f,t}} \left\{ \epsilon_t v_t^l \left( u_t - k^*_t \right)^{\alpha} \left( w^*_t \right)^{1-\alpha} \right\} \]

\[ p^*_t \text{ is defined as} \]

\[ p^*_t = \frac{\int_0^{\lambda_{f,t}/s_{t+1}} p^{\lambda_{f,t}/s_{t+1}} d j}{p_t} \]

Aggregate homogeneous labor

\[ l_t \equiv \int_0^1 l_{j,t} d j = (w^*_t)^{1-\alpha} H_t, H_t \equiv \int_0^1 h_{j,t} d j \]

Supply of capital for capital producers

\[ E_t \left\{ \lambda_{z,t} q_t F_{1,t} - \lambda_{z,t} \frac{1}{\mu_{Y,t}} + \beta \frac{\lambda_{z,t+1}}{\mu_{z,t+1}} q_{t+1} F_{2,t+1} \right\} = 0 \]

where,

\[ F_{1,t} = -S' \left( \frac{\zeta_{i,t} i_t \mu_{z,t}^* Y_t}{i_{t-1}} \right) \frac{\zeta_{i,t} i_t \mu_{z,t}^* Y_t}{i_{t-1}} + 1 - S \left( \frac{\zeta_{i,t} i_t \mu_{z,t}^* Y_t}{i_{t-1}} \right) \]

and,

\[ F_{2,t+1} = S' \left( \frac{\zeta_{i,t+1} i_{t+1} \mu_{z,t+1}^* Y_{t+1}}{i_t} \right) \left( \frac{\zeta_{i,t+1} i_{t+1} \mu_{z,t+1}^* Y_{t+1}}{i_t} \right)^2 \]
A.1. EQUILIBRIUM EQUATIONS

APPENDIX A. BASELINE MODEL

Law of motion for capital accumulation
\[ \dot{k}_{t+1} = (1 - \delta) \frac{1}{\mu_{z,t}^{*}} \dot{k}_{t} + \left[ 1 - S \left( \frac{\zeta_{t,t} i_{t}^{*} \mu_{z,t}^{*} Y}{i_{t-1}} \right) \right] i_{t} \]

Capital utilization
\[ r_{t}^{k} = \tau^{oil} a'(u_{t}) \]

Rate of Return on capital
\[ R_{t}^{k} = \frac{u_{t} r_{t}^{k} - \tau^{oil} a(u_{t})}{\Upsilon q_{t-1}} + (1 - \delta) q_{t} + \tau^{k} \delta - 1 \]

Standard debt contract offered to financial market participants (BGG)
\[ E_{t} \left\{ [1 - \Gamma_{t}(\tilde{\omega}_{t+1})] \frac{1 + R_{t+1}^{k}}{1 + R_{t+1}^{e}} + \frac{\Gamma'_{t}(\tilde{\omega}_{t+1})}{\Gamma_{t}(\tilde{\omega}_{t+1}) - \mu G_{t}(\tilde{\omega}_{t+1})} \right\} \times \left[ \frac{1 + R_{t+1}^{k}}{1 + R_{t+1}^{e}} (\Gamma_{t}(\tilde{\omega}_{t+1}) - \mu G_{t}(\tilde{\omega}_{t+1}) - 1) \right] = 0 \]

Zero profit condition for investment banks loans to financial market participants
\[ (1 + R_{t+1}^{k}) [\Gamma_{t}(\tilde{\omega}_{t+1}) - \mu G_{t}(\tilde{\omega}_{t+1})] = 1 + R_{t+1}^{e} (q_{t} \bar{k}_{t+1} - n_{t+1}) \]

Law of motion for net worth
\[ n_{t+1} = \frac{\Upsilon_{t}}{\pi_{t} \mu_{z,t}^{*}} \left\{ (1 + R_{t}^{k}) \dot{k}_{t} q_{t-1} - \left[ 1 + R_{t}^{e} + \frac{\mu}{\bar{k}_{t} q_{t-1} - n_{t}} \int_{0}^{\tilde{\omega}_{t+1}} \omega F_{t}(\omega_{t}) (1 + R_{t}^{k}) \bar{k}_{t} q_{t-1} \right] \right\} \]

\[ \left( \bar{k}_{t} q_{t-1} - n_{t} \right) + w_{e} \]

Banking production function
\[ x_{t}^{b}(e_{v,t}) \tilde{z}_{t}^{e} e_{t}^{r} = \frac{m_{t}^{b} (1 - m_{t} + \zeta) d_{m,t}}{\frac{\pi_{t} \mu_{z,t}^{*}}{\mu_{z,t}^{*}}} + \psi_{t} w_{t,1_{t}} + \psi_{k} \frac{r_{t}^{k} \bar{k}_{t}}{\mu_{z,t}^{*} Y} \]

where
\[ e_{t}^{r} = \frac{m_{t}^{b}}{\pi_{t} \mu_{z,t}^{*}} (1 - \tau)(1 - m_{t}) - \tau \left( \psi_{t} w_{t,1_{t}} + \psi_{k} \frac{r_{t}^{k} \bar{k}_{t}}{\mu_{z,t}^{*} Y} \right) \]
A.1. EQUILIBRIUM EQUATIONS

APPENDIX A. BASELINE MODEL

Ratio of commercial banks excess reserves to value added

\[ e_{v,t} = \frac{(1 - \tau) \left( m^b_k - m_t \right) - \tau(\psi^k w_t l_t + \psi^k r^k_k k_t)}{(1 - \nu^k_k) \left( (1 - \nu^k_k) l_t \right)^{1 - \alpha}} \]

Banking efficiency condition

\[ R_{it} = \frac{(1 - \tau) h_{er,t} - 1}{\tau h_{er,t} + 1} R_t \]

\[ h_{er,t} = (1 - \xi_t) x_t^b (e_{v,t})^{-\xi_t} \]

Another banking efficiency condition

\[ E_t \left\{ \frac{\lambda_{z,t+1}}{\mu_{z,t+1}^* \pi_{t+1}} \left( 1 - \sigma_f \right) \left[ (1 - \tau_f^m) R_t^m + \tau_f^m R_t^f \right] - \frac{\xi R_{t+1}}{h_{er,t+1}^{t+1} (\tau + 1)} \right\} = 0 \]

Banks choice of labor

\[ w_t = \frac{R_t}{(1 + \psi^f_t R_t)} \left( 1 - \alpha \right) \xi_t x_t^b (e_{v,t})^{1 - \xi_t} \left( \frac{\mu^*_{z,t} \gamma (1 - \nu^k_k) l_t}{(1 - \nu^k_k) k_t} \right)^{-\alpha} \]

Households marginal utility of consumption

\[ E_t \left\{ u_{c,t}^z - \frac{\mu_{z,t}^* c_{t+1}}{c_t \mu_{z,t}^* - b c_{t-1}} + b \beta \frac{\zeta_{c,t+1}}{c_{t+1} \mu_{z,t+1}^* - b c_t} \right\} = 0 \]

Households consumption decision

\[ 0 = E_t \left\{ u_{c,t}^z - (1 + \tau) \lambda_{z,t} - \zeta_{c,t} v c_{t-1}^{-\sigma q} \left( \frac{\pi_t^* m^b_t}{m_t^b} \right)^{1 - \sigma q} \times \left[ \left( \frac{m_t}{m_t^*} \right)^{(1 - \chi_t)} \left( \frac{1}{1 - m_t} \right)^{(1 - \chi_t)} \left( \frac{1}{m_t^*} \right)^{(1 - \chi_t)(1 - \theta)} \left( \frac{1}{1 - m_t^*} \right)^{(1 - \chi_t)} \right] \right\} \]

Equations for Calvo sticky wages

\[ w_t^* = [(1 - \xi_w) \left( 1 - \xi_w \left( \frac{\pi_{w,t}^* (\mu_{z,t}^*)^{1 - \theta} (\mu_{z,t}^*)^\theta}{\xi_w} \right)^{\frac{1}{1 - \xi_w}} \right) \]

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A.1. EQUILIBRIUM EQUATIONS

\[ \xi_w \left( \frac{\hat{\pi}_{w,t} \mu_{z,t}}{\pi_{w,t}} \right) ^{(1-\theta) \mu_{z,t}^\theta} \frac{\lambda_{w}}{1-\lambda_{w}} \]

\[ E_t \left\{ \left( w_{t}^* \right)^{\lambda_{w} / \mu_{w}^*} \right\} + \beta \xi_w (\mu_{z,t})^{1-\theta} \xi_{w}^* = 0 \]

\[ (\mu_{z,t+1} - \mu_{z,t}) \frac{\lambda_{w}}{1-\lambda_{w}} F_{w,t+1} - F_{w,t} = 0 \]

\[ K_{w,t} = \text{a function of } F_{w,t}, \]

\[ \frac{1}{\psi_t} \left[ 1 - \xi_w \left( \frac{\hat{\pi}_{w,t} \mu_{z,t}}{\pi_{w,t}} \right) ^{(1-\theta) \mu_{z,t}^\theta} \frac{1}{1-\lambda_{w}} \right] ^{1-\lambda_{w}(1+\sigma_L)} \]

\[ \tilde{w}_t F_{w,t} - K_{w,t} = 0 \]

Recalling that \( w_{t}^* = W_t^* / W_t \) and:

\[ W_t^* = \left[ \int_0^1 W_t(j) \left( \frac{\lambda_{w}}{1-\lambda_{w}} \right) d j \right] \]

Households choice for equity holdings

\[ E_t \left\{ -\lambda_{z,t} + \frac{\beta}{\mu_{z,t+1} \pi_{t+1}} \lambda_{z,t+1} (1+R_{t+1}^T) \right\} = 0 \]

Choice \( M_t \)

\[ E_t \left\{ \xi_{c,t} \left[ 1 + \tau_c \right] c_t \left( \frac{1}{m_t} \right) ^{1-\xi_{c,t} \theta} \left( \frac{1}{1-m_t} \right) ^{(1-\xi_{c,t})} \right\} ^{1-\sigma_q} \]

\[ \times \left( \frac{\pi_{t} \mu_{z,t}^*}{m_t^b} \right) ^{2-\sigma_q} \left[ \frac{(1-\xi_{c,t}) \theta}{m_t} - (1-\xi_{c,t})(1-\theta) \right] \xi_{c,t} \xi_{t} H' \left( \frac{m_t m_t^b \pi_{t+1} \mu_{z,t+1}^*}{m_{t-1} m_t^b} \right) \]

\[ + \beta \xi_{c,t+1} H' \left( \frac{m_t m_t^b \pi_{t} \mu_{z,t}^*}{m_{t-1} m_t^b} \right) \left( \frac{m_t m_t^b}{m_{t-1} m_t^b} \right)^2 \]

\[ \left\{ -\lambda_{z,t} R_{t+1}^* \right\} = 0 \]
Choice for $D^m_{t+1}$

$$E_t \{ \beta \zeta_{c,t+1} v_t \chi_{t+1} [(1 + \tau^C) c_t + (1 - \tau^C)] \} (1 - \theta_t) \times \left( \frac{1}{m_{t+1}} \right) \left( \frac{1}{m_{t+1}} \right)^{(1 - \theta_t)} \times \left( \frac{1}{m_{t+1}} \right)^{(1 - \theta_t)}$$

$$\left( \frac{1}{d^m_{t+1}} \right)^{(1 - \sigma_q)} \frac{1}{d^m_{t+1}} \left( \frac{1}{m_{t+1}} \right)^{(1 - \sigma_q)} \lambda_{z,t} (1 + R^n_{t+1} - \lambda_{z,t}) = 0$$

Choice for $M^b_{t+1}$

$$E_t \{ \beta \zeta_{c,t+1} v_t (1 - \theta_t) (1 - \chi_{t+1}) [(1 + \tau^C) c_t + (1 - \tau^C)] \} (1 - \theta_t) \times \left( \frac{1}{m_{t+1}} \right) \left( \frac{1}{m_{t+1}} \right)^{(1 - \theta_t)} \times \left( \frac{1}{d^m_{t+1}} \right)^{(1 - \sigma_q)}$$

$$\left( \frac{1}{m_{t+1}} \right)^{(1 - \sigma_q)} \left( \frac{1}{m_{t+1}} \right)^{(1 - \sigma_q)} \lambda_{z,t} (1 + R^n_{t+1} - \lambda_{z,t}) = 0$$

Monetary policy:

$$\hat{R}^e_{t+1} = \rho_i \hat{R}^e_t + (1 - \rho_i) \alpha \frac{\pi}{4 R} (\hat{\pi} - \hat{\pi}^\text{target}) + (1 - \rho_i) \frac{\alpha \Delta \pi}{4 R} \log \left( \frac{GDP_t}{\mu z_t} \right)$$

$$+ (1 - \rho_i) \left[ \alpha \Delta \frac{\pi}{4 R} (\hat{\pi} - \hat{\pi}^\text{target}) + \frac{\alpha \Delta \pi}{4 R} \log \left( \frac{B_{t+1}^{\text{Total}}}{\mu z_t B_{t-1}^{\text{Total}}} \right) + \frac{\alpha \Delta \pi}{4 R} \frac{\hat{\pi}^4}{400 R} \right] + \frac{1}{400 R} \hat{\pi}^4$$

Law of motion for monetary base

$$m^b_{t+1} = \frac{1}{\pi_t \mu z_{t+1}} m^b_t (1 + x_t)$$

Resource constraint:

$$\mu G_t (\omega_t) (1 + R_t^k) q_{t-1} - \tilde{k}_t \frac{1}{\mu z_{t+1}} + \tau_{yi,t} a_i (u_t) \tilde{k}_t = \frac{1}{\pi_t} + c_t + \frac{i_t}{\pi_t} + \Theta \frac{1 - \gamma_t}{\Gamma_t} \left[ n_{t+1} - w^e \right] =$$

$$\left( p_t^e \right)^{\gamma_{y,t}} e_t \left( u_t \frac{\tilde{k}_t}{\mu z_{t+1}} \right)^{\phi} \left[ \left( w_t^e \right)^{\gamma_{y,t}} H_t \right]^{1-a} - \phi$$

Law of motion for broad money

$$m^b_{t+1} = m^b_t + d^m_{t+1} + \psi^i w_t l_t + \psi^r \frac{r_t^k}{\mu z_{t+1}} \tilde{k}_t$$
A.1. EQUILIBRIUM EQUATIONS

**APENDIX A. BASELINE MODEL**

Total bank loans

\[ b^T_t = \psi^l_t w_t l_t + \psi^k_t k_t + \frac{r^k_t u_t k_t}{\mu^{z,t}_t \bar{Y}} + (q_t \bar{k}_{t+1} - n_{t+1}) \]

External finance premium

\[ p^e_t = \mu \int_0^{\bar{\omega}} \omega d F_t(\omega)(1 + R_t^k) \bar{k}_{t-1} \]

Definition of narrow money

\[ m^Narrow_t = m^b_{t+1} + \psi^l_t w_t l_t + \psi^k_t k_t + \frac{r^k_t u_t k_t}{\mu^{z,t}_t} \]

Commercial bank reserves

\[ res_t = \frac{m^b_t}{\pi_t} (1 - m_t + x_t) \]

Investment bank equity reserves

\[ \tau^f_t = \frac{b^T_t - d_{t+1}^m}{b^T_t} \]
A.2 IRF’s to Financial Shocks in the Baseline Model

Figure A.1 No Rule, IRF to IRF to Risk Shock $\sigma_t$
**Figure A.2** No Rule, IRF to IRF to Risk Shock $\sigma_t$
Figure A.3 No Rule, IRF to IRF to Financial Wealth Shock $\gamma_t$
Figure A.4 No Rule, IRF to Financial Wealth Shock $\gamma_t$
Figure A.5 No Rule, IRF to Marg. Eff. of Invest., $\zeta_{i,t}$
Figure A.6 No Rule, IRF to Marg. Eff. of Invest., $\zeta_{i,t}$
Figure A.7 No Rule, IRF to Banking Tech. Shock, $x_t^b$
A.2. IRF’S TO FINANCIAL SHOCKS IN THE BASELINE MODEL APPENDIX A. BASELINE MODEL

Figure A.8 No Rule, IRF to Banking Tech. Shock, $x_t^b$
Figure A.9 No Rule, IRF to Cost of Financing Shock, $\sigma_f^t$
Figure A.10 No Rule, IRF to Cost of Financing Shock, $\sigma_t^f$
Figure A.11 Rule 1, IRF to Risk Shock $\sigma$
Figure A.12 Rule 1, IRF to Risk Shock $\sigma$
Figure A.13 Rule 1, IRF to Financial Wealth Shock $\gamma_t$
Figure A.14 Rule 1, IRF to Financial Wealth Shock $\gamma_t$
Figure A.15 Rule 1, IRF to Marg. Eff. of Invest., $\zeta_{l,t}$
Figure A.16 Rule 1, IRF to Marg. Eff. of Invest., $\xi_{i,t}$
Figure A.17 Rule 1, IRF to Cost of Financing Shock, $\sigma_f$
Figure A.18 Rule 1, IRF to Cost of Financing Shock, $\sigma_f$
Figure A.19 Rule 1, IRF to Banking Tech. Shock, $x_t^b$
Figure A.20 Rule 1, IRF to Banking Tech. Shock, $x_t^b$
Figure A.21 Rule 2, IRF to Risk Shock $\sigma_t$
A.2. IRF'S TO FINANCIAL SHOCKS IN THE BASELINE MODEL APPENDIX A. BASELINE MODEL

Figure A.22 Rule 2, IRF to Risk Shock $\sigma_t$
Figure A.23 Rule 2, IRF to Financial Wealth Shock $\gamma_t$
Figure A.24 Rule 2, IRF to Financial Wealth Shock $\gamma_t$
Figure A.25 Rule 2, IRF to Marg. Eff. of Invest., $\zeta_{i,t}$
Figure A.26 Rule 2, IRF to Marg. Eff. of Invest., $\zeta_{i,t}$
Figure A.27 Rule 2, IRF to Cost of Financing Shock, $\sigma_f^i$
A.2. IRF'S TO FINANCIAL SHOCKS IN THE BASELINE MODEL APPENDIX A. BASELINE MODEL

Figure A.28 Rule 2, IRF to Cost of Financing Shock, $\sigma_f^t$
A.2. IRF'S TO FINANCIAL SHOCKS IN THE BASELINE MODEL APPENDIX A. BASELINE MODEL

Figure A.29 Rule 2, IRF to Banking Tech. Shock, $x_t^b$
Figure A.30 Rule 2, IRF to Banking Tech. Shock, $x_t^b$
Figure A.31 Rule 3, IRF to Risk Shock $\sigma_t$
Figure A.32 Rule 3, IRF to Risk Shock $\sigma_t$.
Figure A.33 Rule 3, IRF to Financial Wealth Shock $\gamma_t$
Figure A.34 Rule 3, IRF to Financial Wealth Shock $\gamma_t$
Figure A.35 Rule 3, IRF to Marg. Eff. of Invest., $\zeta_{i,t}$
Figure A.36 Rule 3, IRF to Marg. Eff. of Invest., $\zeta_{t,t}$
Figure A.37 Rule 3, IRF to Cost of Financing Shock, $\tau_f^i$
Figure A.38 Rule 3, IRF to Cost of Financing Shock, $\tau_f^f$
Figure A.39 Rule 3, IRF to Banking Tech. Shock, $x_t^b$
Figure A.40 Rule 3, IRF to Banking Tech. Shock, $x_t^b$
APPENDIX

B

COUNTER FACTUAL EXERCISE

B.1 Estimation

Table B.1 Regression Results for NFCI Sub-Index

<table>
<thead>
<tr>
<th>Var</th>
<th>Name</th>
<th>Coefficient</th>
<th>White SE</th>
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<tr>
<td><strong>Measures of Risk</strong></td>
<td></td>
<td></td>
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<tr>
<td>$\sigma_t$</td>
<td>VIX</td>
<td>.0636</td>
<td>.0049</td>
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<tr>
<td>$R_t^e - R_t^e$</td>
<td>Aaa Corporate Bond Spread</td>
<td>-.1175</td>
<td>.0176</td>
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<td><strong>Measures of Leverage</strong></td>
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<tr>
<td>$\eta^w_t$</td>
<td>Corporate Debt Issuance</td>
<td>.00043</td>
<td>.00076</td>
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<tr>
<td>$\frac{n_t}{n_t-k_t}$</td>
<td>Ratio of Market Transaction to Net Worth</td>
<td>-.1280</td>
<td>.0301</td>
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<tr>
<td><strong>Measure of Credit</strong></td>
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<tr>
<td>$f^{(\omega_t)}_{\eta_t}$</td>
<td>Delinquency Rate</td>
<td>-.2155</td>
<td>.0481</td>
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</table>
B.2 Estimation

Figure B.1 90 Percent Confidence Intervals for 4 Financial Shocks plus the Shock to Bank Excess Demands, Money Demand, and Money Supply

Smoothed Observations for Financial Wealth \( (n_t) \), Short Term Interest Rate \( (R^e_t) \), Broad Money \( (m_t) \), Short Term Marketable Securities \( (d^m_{t+1}) \), Percentage Change GDP \( (\hat{Y}_t) \), Investments \( (i_t) \), and Credit \( (L = s^L_t + b_{t+1}) \)
Figure B.2 Smoothed Observables for 7 Key Variables
### Table B.2 Priors and Post's for Financial Shocks

<table>
<thead>
<tr>
<th>Var</th>
<th>Name</th>
<th>Prior Dist</th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>Post Mode</th>
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<tr>
<td>$\rho$</td>
<td>Serial Corr. Risk Shock</td>
<td>Beta</td>
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<td>.2</td>
<td>.464</td>
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<tr>
<td>$\rho$</td>
<td>Serial Corr. Financing Shock</td>
<td>Beta</td>
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<td>.2</td>
<td>.912</td>
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<td>$\sigma$</td>
<td>Risk Shock</td>
<td>Inv. Gamma</td>
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<td>inf</td>
<td>.012</td>
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<tr>
<td>$\sigma$</td>
<td>Cost of Finance Shock</td>
<td>Inv. Gamma</td>
<td>.015</td>
<td>inf</td>
<td>.186</td>
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<tr>
<td>$\sigma$</td>
<td>Wealth Shock</td>
<td>Inv. Gamma</td>
<td>.015</td>
<td>inf</td>
<td>.011</td>
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<tr>
<td>$\sigma$</td>
<td>Marg. Eff. of Invtm. Shock</td>
<td>Inv. Gamma</td>
<td>.018</td>
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<td>.0978</td>
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<td>Money Supply Shock</td>
<td>Inv. Gamma</td>
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<tr>
<td>$\sigma$</td>
<td>Banking Tech Shock</td>
<td>Inv. Gamma</td>
<td>.015</td>
<td>inf</td>
<td>.120</td>
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</table>
Figure B.3 Prior and Post’s for Financial Shocks
B.3 Forecasting

Figure B.4 Forecast for CounterFactual, Baseline
Figure B.5 Forecast for CounterFactual, Rule 1
Figure B.6 Forecast for CounterFactual, Rule 2
Figure B.7 Forecast for CounterFactual, Rule 3