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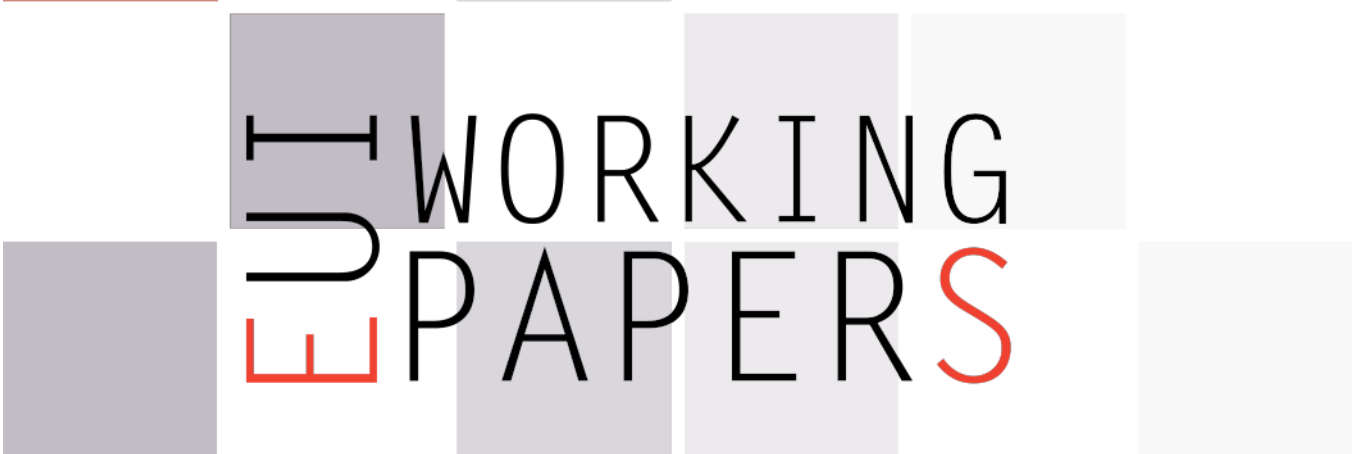
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IMPLICATIONS FOR BANKING STABILITY AND WELFARE UNDER CAPITAL SHOCKS AND COUNTERCYCLICAL REQUIREMENTS

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ABSTRACT

This paper incorporates anticipated and unexpected shocks to bank capital into a DSGE model with a banking sector. We apply this model to study Basel III countercyclical capital requirements and their implications for banking stability and household welfare. We introduce three different countercyclical capital rules. The first countercyclical capital rule responds to credit to output ratio. The second countercyclical rule reacts to deviations of credit to its steady state, and the third rule reacts to credit growth. The second rule proves to be the most effective tool in dampening credit supply, housing demand, household debt and output fluctuations as well as in enhancing the banking stability by ensuring that banks have higher bank capital and capital to asset ratio. After conducting a welfare analysis we find that the second rule outranks the other ones followed by the first rule, the baseline and the third rule respectively in terms of welfare accumulation.

JEL classification: E32; E44; E52
Keywords: Banking Stability; Basel III; Capital Requirements; News Shocks; Welfare Analysis

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1. INTRODUCTION

During the recent global financial crisis, the Basel II fixed capital requirement principles were not sufficient to maintain the banking stability as many banks had insufficient capital and low capital to asset ratio to withstand the financial crisis. Since the financial crisis, there has been great attention and discussion about reviewing and updating the Basel capital rule framework which aims at the enhancement of banking stability. The Basel III committee proposes a time-varying capital requirement or a countercyclical capital ratio requirement. The main idea of the latter is that the capital requirement increases during a boom phase and decreases during a bust phase. In this paper, we study different countercyclical capital rules in the event of anticipated and unanticipated shocks to bank capital and their implications for the banking stability and household welfare.

We introduce three Basel III countercyclical capital rules; the first rule is a countercyclical capital requirement principle responding to credit to GDP ratio, which is primarily recommended by the Basel committee. The second rule is a countercyclical requirement reacting to credit vis-à-vis its steady state ratio. The third one is a countercyclical capital requirement rule reacting to credit growth. The baseline rule is represented by the Basel II fixed capital ratio principle. The main purpose of this paper is to seek which of these three rules provides the best outcome in terms of banking stability and welfare. We use a DSGE model with a banking sector based on Gerali *et al.* (2010). We extend the model by incorporating countercyclical capital rules and news shocks and unanticipated shocks to bank capital.

Firstly, we examine the effects of anticipated and unexpected shocks to bank capital on the banking stability under the Basel II fixed capital rule. In our work, we utilize the term *instability* of the banking sector when capital to asset ratio is below its steady state. The main finding that under the Basel II fixed capital rule, a positive news' shock to bank capital induces banks to be less prudent hence they reduce the holding of capital to asset ratio. However, when the positive news about bank capital do not materialize, banks suddenly find themselves with a capital to asset ratio below its steady state, an effect that captures the instability of the banking sector.

Secondly, we analyze the effects of bank capital shocks on banking stability under three Basel III countercyclical capital rules. The first and the second countercyclical rules contribute to the banking stability because they induce banks to hold more bank capital than the one by the Basel II principle. Under these countercyclical capital buffer rules, banks have capital to asset ratios above their steady state even though banks anticipate that there will be a positive shock to their capital. Furthermore, the first and the second capital rules are more effective in dampening credit booms, housing demand, household debt and output fluctuations compared to the fixed capital

rule. The third countercyclical rule does not contribute to the banking stability because it does not induce banks to hold more capital. As a result the bank capital to asset ratio is below its steady state, exactly as in the Basel II case. Furthermore, we find that the second countercyclical capital rule is the most effective tool to enhance banking stability.

Thirdly, we study the implications of Basel III rules for household welfare. The implementation of the first and the second countercyclical capital rule improves household welfare relative to the fixed capital requirement. In particular, the second rule presents the highest household welfare. We find that the third rule is not welfare improving. We conduct a sensitivity analyses and the results indicate that the second countercyclical rule still provides the highest welfare compared to the other ones.

This paper is related to mainly two areas of DSGE studies: the news' shock literature and the literature on macroprudential policy. DSGE papers with news shocks such as by Beaudry and Portier (2004, 2006), Jaimovich and Rebelo (2009), Christiano *et al.* (2010) and Karnizova (2010) focus on technology news shocks while Lambertini *et al.* (2013) on multiple news shocks. However, those papers do not introduce news' shocks that are originated within the banking sector while we attempt to explore this event. Next, studies on capital requirements and implications for macroeconomic dynamics in a DSGE framework are also explored; for example, in Christensen *et al.* (2011), Angeloni and Faia (2013), Angelini *et al.* (2014), Rubio and Carrasco-Gallego (2014 and 2015). Our study is more tangible to Angelini *et al.* (2014) and Rubio and Carrasco-Gallego (2014 and 2015), nevertheless the main difference is two-fold: our paper has incorporated also anticipated shocks to bank capital, whilst we also study three countercyclical capital rules and their implications for banking stability and household welfare.

This paper is organized as follows. Section 2 describes the DSGE model. Section 3 presents the stochastic processes of anticipated and unanticipated shocks. Section 4 presents benchmark calibration and model parameters. Section 5 introduces the three countercyclical capital rules, while section 6 shows impulse responses for the investigated economy. Section 7 presents an exhaustive welfare analysis under the benchmark calibration as well as under different horizons of news' shocks, while it also investigates the welfare effect of financial distress under three countercyclical capital rules. Finally, section 8 concludes.

2. MODEL

2.1 Patient Household

The objective function of a representative patient household is

$$E_0 \sum_{t=0}^{\infty} \beta_U^t \left(lnC_{P,t} + \omega lnH_{P,t} - \frac{(N_{P,t})^{\eta+1}}{\eta+1} \right) \qquad (1)$$

where the index P refers to a patient household, β_P is the discount factor, $C_{P,t}$ is consumption, $H_{P,t}$ denotes the holding of housing stock, $N_{P,t}$ labor hours, ω is a weight on housing and η is the Frisch labor supply elasticity.

The patient household consumes and makes deposits $D_{P,t}$ at a bank. The nominal net deposit rate is denoted by $R_{D,t}$ and π_t is inflation rate, so $(1 + R_{D,t-1})/\pi_t$ is the real gross interest rate on deposits. The household purchases houses and real house prices are denoted by q_t. The patient household supplies labor hours for an entrepreneur and earns $(W_{P,t}/P_t)N_{U,t}$, where $W_{P,t}$ is the nominal wage and P_t is the price of consumption goods. It also receives a lump-sum transfer denoted by $\Pi_{P,t}$, which includes dividends from a retail firm and a bank. Our particular household faces the following budget constraint

$$C_{P,t} + D_{P,t} + q_t\left(H_{P,t} - H_{P,t-1}\right) = \frac{(1+R_{D,t-1})}{\pi_t} D_{P,t-1} + \frac{W_{P,t}}{P_t} N_{P,t} + \Pi_{P,t} \qquad (2)$$

It chooses $C_{P,t}$, $D_{P,t}$, and $H_{P,t}$ to maximize (1) subject to (2), and the first-order conditions are written as

$$\frac{1}{C_{P,t}} = \beta_P E_t\left[\frac{1}{C_{P,t+1}} \frac{(1+R_{D,t})}{\pi_{t+1}}\right] \qquad (3)$$

$$\frac{q_t}{C_{P,t}} = \frac{\omega}{H_{P,t}} + \beta_P E_t\left(\frac{q_{t+1}}{C_{P,t+1}}\right) \qquad (4)$$

and

$$\frac{W_{U,t}}{C_{U,t}} = N_{U,t}^\eta \qquad (5)$$

The trade-off between current and future consumption taking account the real interest rate is shown by equation (3). The marginal cost and the marginal benefit of housing define the optimal demand for housing in equation (4). The patient household takes into account the current cost of an extra house, a direct utility gain from having a house and the expected resale of the house when purchasing a house. Finally, equation (5) is the optimal labor supply for the patient household.

2.2 Impatient Household

In this case, the objective function of the representative impatient household is

$$E_0 \sum_{t=0}^{\infty} \beta_P^t \left(lnC_{M,t} + \omega lnH_{M,t} - \frac{(N_{M,t})^{\eta+1}}{\eta+1}\right) \qquad (6)$$

where the index M refers to the impatient household, β_M is the discount factor, $C_{M,t}$ is consumption, $H_{M,t}$ denotes the housing holding, $N_{M,t}$ denotes labor hours, ω is a weight on housing and η is again the Frisch labor supply elasticity. The impatient household obtains loans $L_{M,t}$ from a bank in order to buy houses. Moreover, the impatient household pays back the loans

to the bank $(1 + R_{M,t-1})L_{I,t-1}/\pi_t$, where $R_{M,t-1}$ is the net nominal interest rate on household loans. The household works for an entrepreneur and receives labor income $(W_{M,t}/P_t)N_{M,t}$, where $W_{M,t}/P_t$ is the real wage and the nominal wage $W_{M,t}$. Also it belongs to a labor union by paying a membership fee $\Pi_{M,t}$. The budget constraint in real terms is written as

$$C_{M,t} + q_t(H_{M,t} - H_{M,t-1}) + \frac{(1+R_{M,t-1})}{\pi_t}L_{M,t-1} = L_{M,t} + \frac{W_{M,t}}{P_t}N_{M,t} + \Pi_{M,t} \qquad (7)$$

The impatient household faces the following collateral constraint

$$E_t\left[\frac{(1+R_{M,t})}{\pi_{t+1}}\right]L_{M,t+1} \leq m_M E_t(q_{t+1}H_{M,t}) \qquad (8)$$

Additionally, it can borrow up to a fraction m_M of the expected value of house $E_t(q_{t+1}H_{M,t})$. The household maximizes the expected utility (6) subject to the budget constraint (7) and the collateral constraint (8)

$$\frac{1}{C_{M,t}} = \beta_M E_t\left[\frac{(1+R_{M,t})}{C_{M,t}\pi_{t+1}}\right] + \lambda_{M,t}E_t\left[\frac{(1+R_{M,t})}{\pi_{t+1}}\right] \qquad (9)$$

$$\frac{q_t}{C_{M,t}} = \frac{\omega}{H_{M,t}} + \beta_M E_t\left[\frac{q_{t+1}}{C_{M,t+1}}\right] + m_M \lambda_{M,t}E_t[q_{t+1}] \qquad (10)$$

and

$$\frac{W_{M,t}}{C_{M,t}} = N_{M,t}^{\eta} \qquad (11)$$

Equation (9) captures the optimal consumption for this impatient household. Aside from the real interest rate, the trade-off between current and future consumption is also affected by the housing collateral value. Equation (10) represents the optimal demand for housing. In our specific set-up the impatient household takes into account the current cost of an extra house, a direct utility gain from having a house, the expected resale value of house and the collateral value. Lastly, equation (11) is the optimal labor supply for our impatient household.

2.3 Entrepreneur

Next, the objective function for a representative entrepreneur is

$$E_0 \sum_{t=0}^{\infty} \beta_E^t (\ln C_{E,t}) \qquad (12)$$

where β_E is the entrepreneur's discount factor and $C_{E,t}$ is the entrepreneur's consumption. The entrepreneur produces intermediate goods $Y_{E,t}$ and sells the intermediate goods to retailers at a price P_t^W. The markup of the final goods over the intermediate goods is defined as $X_t = P_t/P_t^W$.[4] The entrepreneur faces the following production function

$$Y_{E,t} = (u_t K_{t-1})^{\alpha} N_t^{(1-\alpha)} \qquad (13)$$

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[4] Section 2.5 provides more details on retailers.

where N_t is aggregate labor, which comprises patient and impatient households' labors $N_t = (N_{P,t})^{\mu}(N_{M,t})^{1-\mu}$, where μ is the labor income share of a patient household. The capital share in the production function is denoted by α. K_t is capital stock and u_t is the capacity utilization rate. The entrepreneur faces the following budget constraint

$$C_{E,t} + \frac{W_{U,t}}{P_t}N_{P,t} + \frac{W_{F,t}}{P_t}N_{M,t} + \frac{(1+R_{E,t-1})}{\pi_t}L_{E,t-1} + q_{k,t}K_t + \psi(u_t)K_{t-1} = \frac{Y_{E,t}}{X_t} + L_{E,t}$$
$$+q_{k,t}(1-\delta)K_{t-1} \qquad (14)$$

where $L_{E,t}$ represent new loans to the entrepreneur, $R_{E,t}$ is the net nominal interest rate on loans to the entrepreneur, $q_{k,t}$ is the real capital price, and $\psi(u_t)$ is the adjustment cost of capital utilization. The entrepreneur faces the following collateral constraint

$$E_t\left[\frac{(1+R_{E,t})}{\pi_{t+1}}\right]L_{E,t+1} \le m_E E_t\big(q_{k,t+1}(1-\delta)K_t\big) \qquad (15)$$

Furthermore, the entrepreneur can borrow up to a fraction m_E of the expected value of capital $E_t\big(q_{k,t+1}(1-\delta)K_t\big)$ given the depreciation rate of capital. The entrepreneur maximizes (12) subject to (13), (14) and (15).

$$\frac{1}{C_{E,t}} = \beta_E E_t\left[\frac{(1+R_{E,t})}{C_{E,t+1}\pi_{t+1}}\right] + \lambda_{E,t}E_t\left[\frac{(1+R_{E,t})}{\pi_{t+1}}\right] \qquad (16)$$

$$r_{k,t} = \frac{\alpha}{X_t}\left[(u_t K_{t-1})^{(\alpha-1)}(N_t)^{(1-\alpha)}\right] \qquad (17)$$

$$r_{k,t} = \xi_1 + \xi_2(u_t - 1) \qquad (18)$$

$$\frac{q_{k,t}}{C_{E,t}} + \beta_E E_t\left[\xi_1(u_{t+1}-1) + \frac{\xi_2}{2}(u_{t+1}-1)^2\right] =$$
$$\beta_E E_t\left[\frac{r_{k,t+1}}{C_{E,t+1}}\right] + \beta_E E_t\left[\frac{q_{k,t+1}(1-\delta)}{C_{E,t+1}}\right] + \lambda_{E,t}E_t\big[q_{k,t+1}(1-\delta)\big] \qquad (19)$$

$$\mu(1-\alpha)\frac{Y_{E,t}}{X_t} = \frac{W_{U,t}}{P_t}N_{U,t} \qquad (20)$$

and

$$(1-\mu)\alpha\frac{Y_{E,t}}{X_t} = \frac{W_{F,t}}{P_t}N_{F,t} \qquad (21)$$

Equation (16) captures the optimal consumption condition for the entrepreneur. It can be seen that this condition is quite similar to that applied for an impatient household. Equation (17) captures $r_{k,t}$ as the return to capital and equation (18) represents the optimal level of capacity. The optimal demand for capital with collateral constraint is determined by equation (19). Equations (20) and (21) show the optimal demand for labor for the patient and impatient household respectively.

2.4 Capital Good Producer

We start off with the objective function of the capital producer which is

$$E_0 \sum_{t=0}^{\infty} \beta_E^t \, \Lambda_{E,t} \big[q_{k,t}(K_t - (1-\delta)K_{t-1}) - I_t \big] \qquad (22)$$

where $\beta_E \Lambda_{E,t}$ is the entrepreneur's stochastic discount factor, and I_t is investment goods. The capital producer chooses K_t and I_t to maximize (22) subject to the capital-accumulation equation

$$K_t = (1-\delta)K_{t-1} + \left[1 - \frac{\kappa_i}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] I_t$$

The first order condition for capital is given as

$$1 = q_{k,t} \left[1 - \frac{\kappa_i}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \frac{\kappa_i}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right] + \beta_E E_t \left[\Lambda_{E,t+1} q_{k,t+1} \kappa_i \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right] \qquad (23)$$

Equation (23) determines the optimal capital supply. The optimal demand for capital is given by previous equation (19).

2.5 Retailer

The retail sector is the source of sticky prices. Retailers buy intermediate goods from entrepreneurs at a competitive price, and transform them into the final goods which are sold at the retail price P_t. The retailers operate under monopolistic competition and face a price adjustment cost. The Phillips curve shows the relationship between inflation and output which is expressed as

$$1 - \varepsilon_y + \frac{\varepsilon_y}{X_t} - \frac{\kappa_p}{2} \left(\pi_t - \pi_{t-1}^{l_p} \pi^{l_p} \right) \pi_t + \beta_U E_t \left[\Lambda_{U,t+1} \kappa_p \left(\pi_{t+1} - \pi_t^{l_p} \pi^{l_p} \right) \pi_{t+1} \frac{Y_{t+1}}{Y_t} \right] = 0 \qquad (24)$$

where κ_p is a price adjustment cost, $X_t = P_t / P_t^W$ is the aggregate markup of the retail good prices over the intermediate good prices, and $\pi_t = P_t / P_{t-1}$ is the inflation.

2.6 Banking Sector

Our specification for the banking sector is originating from the work of Gerali *et al.* (2010). In particular, the banking sector consists of a continuum of monopolistically competitive banks. Each bank $i \in [0,1]$ has two retail units and a wholesale unit. The first retail unit of bank i offers slightly differentiated loan products to impatient households and entrepreneurs and the retailer sets the loan rates. The second retail unit collects deposits from patient households and sets the deposit rate. The wholesale unit provides wholesale loans - which is in fact another name for interbank loans to the retail loan unit. The wholesale unit collects deposits from the retail unit and uses the deposits and its own bank capital to finance its interbank lending. Moreover, the wholesale unit has to maintain its bank capital to asset ratio to meet a target capital requirement that is exogenously imposed by a macroprudential authority.

The next section presents the retail deposit unit and the retail loan unit. The retail deposit unit operates under monopolistic competition, thus it issues slightly differentiated deposit products $D_{P,t}$ to patient households. The retail deposit unit collects deposits from patient households and then sells them to the wholesale unit. The deposit unit faces adjustment costs when altering its deposit rate captured by a parameter κ_D as the degree of adjustment cost, which creates the lag effects of monetary policy on the deposit rate. The deposit rate setting condition is expressed as

$$\varepsilon_D - 1 - \varepsilon_D \frac{R_t}{R_{D,t}} - \kappa_D \left(\frac{R_{D,t}}{R_{D,t-1}} - 1\right)\frac{R_{D,t}}{R_{D,t-1}} + \beta_U E_t\left[\Lambda_{U,t+1}\kappa_D\left(\frac{R_{D,t+1}}{R_{D,t}} - 1\right)\left(\frac{R_{D,t+1}}{R_{D,t}}\right)^2\frac{D_{t+1}}{D_t}\right] = 0 \quad (25)$$

where $\varepsilon_D < -1$ is the elasticity of substitution of deposit.

The deposit rate setting condition shows that the current deposit rate $R_{D,t}$ depends on the expected deposit rate $E_t(R_{D,t+1})$, the last period deposit rate $R_{D,t-1}$ and the policy rate R_t. Furthermore, the current retail deposit rate adjusts slowly to changes in the policy rate because it is costly for the bank to adjust its deposit rate as $\kappa_D > 0$ that is why this represents sticky interest rates.

The retail loan unit obtains wholesale loans from the wholesale unit. The retail unit can transform wholesale loans to slightly differentiated loan products because the retail operates under monopolistic competition. We assume that the retail loan unit faces adjustment costs under varying loan rates which is captured by the parameter $\kappa_S > 0$. The adjustment costs introduce sticky loan interest rates, so the current retail loan rate slowly reacts to changes in the policy rate

$$1 - \varepsilon_S + \varepsilon_S \frac{R_{B,t}}{R_{S,t}} - \kappa_S\left(\frac{R_{S,t}}{R_{S,t-1}} - 1\right)\frac{R_{S,t}}{R_{S,t-1}} + \beta_U E_t\left[\Lambda_{U,t+1}\left(\frac{R_{S,t+1}}{R_{S,t}} - 1\right)\left(\frac{R_{S,t+1}}{R_{S,t}}\right)^2\frac{L_{S,t+1}}{L_{S,t}}\right] = 0 \quad (26)$$

where $\varepsilon_S > 1$ is the elasticity of substitution of loans. The loan rate setting condition shows that the current loan interest rate $R_{S,t}$ (indexed by $S = P, M$) depends on the expected loan interest rate $E_t(R_{S,t+1})$, the previous period loan interest rate $R_{S,t-1}$ and the wholesale loan rate $R_{B,t}$ which is influenced by the policy rate. Hence, the current retail loan rate does not immediately react to variations in the policy rate.

2.7 Wholesale Unit

The wholesale unit provides wholesale loans (interbank loans) B_t to the retail loan unit with the net wholesale loan rate being $R_{IB,t}$. The wholesale unit collects deposits D_t from the retail deposit unit on which the wholesale unit pays interest rate of $R_{W,t}$ (the net wholesale deposit rate). The wholesale unit manages its capital $K_{B,t}$ which is accumulated out of reinvested profits and the it uses $K_{B,t}$ and D_t to finance interbank loans. The wholesale unit also has to meet a target capital to asset ratio level ν_B which is imposed by a macroprudential authority. When the capital to asset

ratio $K_{B,t}/B_t$ deviates from the target level, the bank incurs the following cost $\frac{\kappa_B}{2}\left(\frac{K_{B,t}}{B_t} - v_B\right)^2 K_{B,t}$, where $\kappa_B > 0$ measures the intensity of cost of deviating its capital ratio from the target capital ratio, namely the *intensity of financial distress*. A higher κ_B means that financial markets become distressed, thus a small deviation of capital ratio from the target capital ratio makes it harder for banks to obtain funds form the interbank market. In section 9, we conduct a sensitivity analysis on the parameter κ_B and its implication for countercyclical capital rules and welfare accumulation.

The wholesale unit maximizes the following objective function

$$E_0 \sum_{t=0}^{\infty} \beta_U^t \Lambda_{U,t}\left[R_{IB,t}B_t - R_{W,t}D_t - \frac{\kappa_B}{2}\left(\frac{K_{B,t}}{B_t} - v_B\right)^2 K_{B,t}\right] \qquad (27)$$

subject to

The balance sheet constraint is

$$B_t = D_t + K_{B,t} \qquad (28)$$

and the bank capital accumulation equation

$$K_{B,t} = (1 - \delta_B)K_{B,t-1} + \Omega_{t-1}^B \qquad (29)$$

where $K_{B,t}$ is the real bank capital, δ_B measures resources used in managing bank capital and Ω_t^B is the bank real profit. We introduce anticipated and unexpected shocks to the bank capital in section 3. The optimal condition for credit supply is given as

$$R_{IB,t} = R_{W,t} - \kappa_B\left(\frac{K_{B,t}}{B_t} - v_B\right)\left(\frac{K_{B,t}}{B_t}\right)^2 \qquad (30)$$

We assume that each bank has access to unlimited finance from the central bank remunerated at the policy rate R_t, and through arbitrage the net wholesale deposit rate equals the policy rate that is $R_t = R_{W,t}$.

$$R_{IB,t} = R_t - \kappa_B\left(\frac{K_{B,t}}{B_t} - v_B\right)\left(\frac{K_{B,t}}{B_t}\right)^2 \qquad (31)$$

The left-hand side of equation (30) represents a loan supply. When loans increase, the capital–asset ratio falls below v_B and this induces the bank to raise the lending rate. The interbank loan spread is defined as the difference between the wholesale loan rate and the policy rate $R_{IB,t} - R_t$.

2.8 Central Bank

We present a Taylor rule in which monetary policy responds to inflation and output growth

$$(1 + R_t) = (1 + R_{t-1})^\rho (1 + R)^{(1-\rho)}\left(\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_Y}\right)^{(1-\rho)} \qquad (32)$$

where R is the policy rate at the steady state, $0 \leq \rho \leq 1$ measures interest-rate inertia, and $\phi_{\pi} \geq 0$ and $\phi_Y \geq 0$ capture the response of the policy rate to current inflation and output growth respectively.

3. STOCHASTIC BANK CAPITAL SHOCKS

This section introduces stochastic processes i.e., bank capital shocks which attempt to capture bank complacency before the U.S. financial crisis, hence their unpreparedness under the Basel II fixed capital requirement framework. The motivation for introducing bank capital shocks is the following: prior to the recent financial crisis banks were optimistic about the "health" and stability of the banking system. Banks anticipated a positive shock to their capital as they expected the banking system will continue to flourish, and this induced them to hold less current capital relative to assets. As a consequence, their assets rapidly grew more than the current capital, thus their current capital to asset ratio became very low. However, during the financial crisis, banking institutions suddenly found themselves unprepared for the crisis as they had low capital to asset ratios.

We attempt to capture the above story by incorporating a shock to bank capital ε_t^B. The bank capital evolves according to

$$K_{B,t} = (1 - \delta_B)K_{B,t-1}\varepsilon_t^B + \Omega_{t-1}^B \qquad (33)$$

where $K_{B,t}$ is the real bank capital, δ_B measures resources used in managing bank capital and Ω_t^B is the bank real profit. The exogenous shock to bank capital evolves as

$$\varepsilon_t^B = \rho_B \varepsilon_{t-1}^B + e_{B,t} + \xi_{B,t-p} \qquad (34)$$

where $0 < \rho_B < 1$. The error terms consist of an unexpected shock $e_{B,t}$ and an anticipated shock $\xi_{B,t-p}$ that is observed p quarters in advance. The unanticipated and anticipated shocks have a white noise property. For an illustrative purpose, we set p to be 8. In period 1, banks anticipate a positive shock to their capital which will occur in period 9. Thus, a positive anticipated shock induces banks to increase their credit supply while they reduce their capital, thus capital to asset ratio. However, in period 9 the positive shock to bank capital does not materialize, and this comes as a surprise to banks. Then banks realize that there is no a positive shock to their capital hence they find themselves to be inadequate to withstand the burden of such crisis because their capital to asset ratios are too low. Now the low capital to asset ratio threatens banking stability. These anticipated and unexpected shocks to bank capital aim to capture the complacency of banks before the financial crisis and their unpreparedness under Basel II fixed capital requirements. In section 5, we introduce three different countercyclical capital ratio rules and then we study their implications for banking stability and welfare.

4. PARAMETERIZATION AND CALIBRATION

We thereafter present a benchmark calibration; model value parameters originate from the study of Gerali *et al.* (2010). We solve the model by log-linearizing the non-linear system around the unique steady state utilizing Bayesian techniques according to Schmitt-Grohe and Uribe (2004) and Fernandez-Villaverde and Rubio-Ramirez (2004).

Table 1 reports the benchmark calibration. In particular, the patient household's discount factor β_P is set at 0.9443 to match the average monthly rate on M2 deposits. The impatient household and entrepreneur's discount factors β_I and β_E are 0.975, following Iacoviello (2005). We set the discount factor of the impatient household and entrepreneur to be smaller than that of the patient one because we want to ensure that the collateral constraints will be binding around the steady state (Iacoviello, 2005). The entrepreneur's LTV ratio m_E is set at 0.35, and the household's LTV ratio m_F is set at 0.7. For the banking parameters, the benchmark bank capital ratio v_B is set to 0.9, which reflects the Basel II capital ratio requirements. The cost for deviating from the bank capital requirement κ_B is estimated to be 11.07, albeit for which we will conduct a sensitivity analysis on this parameter at a later stage.

The steady-state spread between the interest rate on household loans and the wholesale loan rate is about 2.16 percentage points in annual terms. Therefore, the markup over the wholesale loan rate $\frac{\varepsilon_F}{\varepsilon_F - 1}$ is 1.56, so we set the elasticity of substitution of household loans ε_F to 2.79. The steady-state spread between the interest rate on business loans and the wholesale loan rate is approximately 1.82 percentage points in annual terms. Thus, this spread implies that the markup over the wholesale loan rate $\frac{\varepsilon_E}{\varepsilon_E - 1}$ is 1.47, and the elasticity of substitution of loans to entrepreneurs ε_E is 3.12. The steady-state spread between the policy rate and the deposit rate is approximately 1.57 percentage points in annual terms, so we set the elasticity of substitution of deposits ε_D to -1.46, which implies that the markdown over the policy rate $\frac{\varepsilon_D}{\varepsilon_D - 1}$ is 0.60. The persistence of the bank capital shock is set at 0.810, and the standard deviation of anticipated and unanticipated shocks is set at 0.031.

5. RULES FOR COUNTERCYCLICAL CAPITAL RATIO REQUIREMENTS

We propose three different types of Basel III countercyclical capital ratio rules. The first countercyclical rule employs a macroprudential authority in adjusting the capital to asset ratio requirement in response to movements in credit to output ratio, as suggested by the Basel III framework. A higher credit to output ratio leads to a higher capital requirement. The first countercyclical capital ratio rule is specified as

$$v_{B,t} = v_B \left(\frac{B_t}{Y_t}\right)^\tau \qquad (35)$$

where $v_{B,t}$ is the time varying capital to asset ratio requirement, v_B is the steady state of the capital to asset ratio, B_t is the total loan or total credit in the economy and τ is the degree of the countercyclical capital requirement. An increase in τ will make the capital to asset ratio requirement reacts more strongly to changes in credit to output ratio.

The second countercyclical capital ratio rule concerns the case whereby the capital to asset ratio requirement reacts to a deviation of credit from its steady state as

$$v_{B,t} = v_B \left(\frac{B_t}{B}\right)^\tau \qquad (36)$$

where B is the steady state of credit supply.

The third countercyclical capital ratio rule is applied when the capital to asset ratio requirement reacts to credit growth

$$v_{B,t} = v_B \left(\frac{B_t}{B_{t-1}}\right)^\tau \qquad (37)$$

The baseline rule is captured by the Basel II fixed capital requirements; it employs the steady-state of the capital to asset ratio requirement, i.e., $v_{B,t} = v_B$.

6. MODEL SIMULATIONS

To recall we have introduced three Basel III countercyclical capital ratio rules. The first one responds to credit vs. output ratio, the second rule reacts to a deviation of credit from its steady state and the third rule is implemented when capital requirement ratio reacts to credit growth. The baseline is represented by the Basel II fixed capital requirements. The purpose of this section is to analyze the effects of bank capital shocks upon banking stability and macro-dynamics. We define *instability* of the banking sector the case when capital to asset ratio is below its steady state.

Figure 1A to 1G show the impulse responses for anticipated and unanticipated shocks to bank capital for the various capital requirement cases. For an illustrative purpose, under the first, second and third countercyclical capital rules, we assign the coefficient τ to be greater than zero, namely at 1. The black line with crosses represents the first rule (credit to output ratio), the thick black line displays the impact of the second rule (credit to its steady state), the black dashed line illustrates the third rule (credit growth) and the baseline rule is represented by the green line. Under the baseline rule (Basel II), a positive news' shock about future bank capital induces banks to be less prudent and reduces the current bank capital, increasing their lending. The positive news shock captures the concept of banking institutions being complacent over a potential financial crisis also to an unexpected negative shock to the system. Specifically, as credit supply increases, the capital to asset ratio declines. Banks increase the amount of credit available to

impatient households and this effect encourages the households to borrow more and take on more debt. Low capital to asset ratio and high household debt make the banking sector become vulnerable to a sudden shock i.e., an unexpected negative shock to bank capital.

During this credit boom, inflation rate tends to be low.[5] The central bank responds to low inflation by cutting the policy rate to raise the inflation rate. However, a more expansionary monetary policy amplifies an expansion of mortgage credit and reduces the cost of deviating the capital to asset ratio from the capital target requirement. Hence, these impacts make banking sector even more vulnerable to a financial crisis.

In the long-run period 9, the positive news shock about future bank capital does not materialize as a consequence of the fact that the banks find themselves their capital and capital to asset ratios having reached a level below the steady state. The economy is now facing imminent banking instability, which employs capital to asset ratios below their steady state, thus making the banking sector extremely vulnerable to a financial crisis. The banks respond to this unfulfilled news by abruptly increasing the holding of capital and capital to asset ratio and cutting the credit supply, which in turns has a negative impact on the real economy. After an economic expansion, output suddenly drops and then it declines toward its steady state.

We conduct model simulations for the three different Basel III countercyclical capital rules. We see that under the first and second rule - following a positive news shock to bank capital - banks are required to hold more capital and capital to asset ratio compared to the third rule and the Basel II fixed capital requirement benchmark. Under the first or the second rule, a higher capital requirement forces banks to hold capital that is slightly below its steady state; as a result the capital to asset ratio stays above the steady state whereas the capital to asset ratio under the Basel II is below its steady state and the bank capital is considerably below its steady state. Moreover, in case of the first and second rules, the wholesale loan rate and the interest rate spreads are higher than that of Basel II and of the third Basel III rule. Hence, by introducing the first or the second capital buffer regulation, it contributes to banking stability as capital turns slightly below its steady state and the capital to asset ratio is above its steady state. The third capital rule yields very similar results to those of the Basel II fixed one.

Interestingly, in period 9 the positive shock to bank capital does not materialize and this comes as a surprise to banks; however, under the first and second Basel III regulation banks are more prepared against "surprise" as they have been building up their capital before the news shocks to bank capital are realized. As a result, the capital to asset ratio is higher under the first

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[5] A possible reason is that an increase in credit supply eases entrepreneurs' collateral constraints. As a result, the entrepreneurs employ more capital and the marginal product of labor rises while the marginal cost decreases. This effect creates downward pressure on inflation.

and the second rule. Consequently, the banking stability under the first or the second rule is stronger than of the third and the Basel II fixed capital rule. The first or second countercyclical capital rule induces banks to be caution about external shocks to the banking sector, and this contributes significantly toward banking stability.

Under the second countercyclical capital requirement regime, banks hold even more capital than under the first countercyclical capital requirement, so the level of capital to asset ratio under the second rule is higher than under the first rule. Moreover, the second rule is more effective in stabilizing housing demand, household debt and output than the first rule. Possible reasons include the following; changes in credit and changes in output tend to co-move thus variations in credit to output ratio tends be smaller than movements in credit relative to its steady state. As a result, the second rule tends to be more responsive than the first one.

We conclude that the second rule is the most effective one for maintaining banking stability, as banks are more equipped to withstand potential shocks to the system hence they are more resilient to an imminent or underlying financial crisis.

7. WELFARE ANALYSIS

7.1 Patient and impatient households

In this section, we compute welfare for both types of households under the three different Basel III countercyclical capital ratio rules. We follow Schmitt-Grohe and Uribe (2004) and solve the model by using a second-order approximation to the structural equations for given countercyclical capital rules and then we evaluate the welfare. Patient and impatient household welfare are defined as follows

$$Welf_{P,t} \equiv E_t \sum_{m=0}^{\infty} \beta_P^m \left(lnC_{P,t+m} + v_h lnH_{P,t+m} - \frac{(N_{P,t+m})^{\eta+1}}{\eta+1} \right) \quad (38)$$

and

$$Welf_{M,t} \equiv E_t \sum_{m=0}^{\infty} \beta_M^m \left(lnC_{I,t+m} + v_h lnH_{M,t+m} - \frac{(N_{M,t+m})^{\eta+1}}{\eta+1} \right) \quad (39)$$

Total household welfare is expressed as a weighted sum of the individual welfare as in Rubio and Carrasco-Gallego (2014, 2015) and Nilavongse (2016):

$$Welf_{H,t} = (1 - \beta_U)Welf_{P,t} + (1 - \beta_F)Welf_{M,t} \quad (40)$$

where $(1 - \beta_P)$ and $(1 - \beta_M)$ are the weights on patient and impatient households respectively.

We simulate the model for 50000 periods by feeding multiple anticipated and unanticipated bank capital shocks into the system of equations, and then we can calculate the mean of welfare. We define III as a Basel III countercyclical capital rule and II as the fixed capital requirement, which represents the Basel II regime. We follow Rubio and Carrasco-Gallego (2014 and 2015)

and present welfare results in terms of consumption equivalent units (CE). The definition of CE is the fraction of consumption that households should give away to obtain the benefits of the implementation of a Basel III countercyclical capital rule. In particular:

The CE for the patient household welfare is written as

$$CE_P = exp\big[(1 - \beta_P)(Welf_{P,t}^{III} - Welf_{P,t}^{II})\big] - 1 \quad (41)$$

The CE for the impatient household welfare is written as

$$CE_M = exp\big[(1 - \beta_I)(Welf_{M,t}^{III} - Welf_{M,t}^{II})\big] - 1. \quad (42)$$

The total CE can be written as

$$CE_H = exp\big[(1 - \beta_F)(Welf_{H,t}^{III} - Welf_{H,t}^{II})\big] - 1 \quad (43)$$

Next, we present the household welfare for the three countercyclical capital rules relative to the Basel II benchmark. Figures 2 and 3 show that the welfare of the patient and impatient household respectively. The results reveal that the implementation of the first or the second rule is welfare-improving for both types of households, whereas the third rule is welfare-deteriorating for both types of households. Moreover, Figure 4 shows that the introduction of the first or the second rule increases the total household welfare, while the application of the third rule has a negative effect on total welfare. This aftereffect could be of the following cause: the first and second countercyclical capital buffer regulation makes banks cautious hence this induces them to hold capital to asset ratios above steady state, which in turn dampens credit supply, household debt and assists both types of households towards smoothing their consumption and demand for housing. The third rule makes banks less cautious thus they hold a capital to asset ratio below its steady state. As a result this reaction amplifies the response of supply of loans and household debt and amplifies the response of household consumption and housing demand.

The second rule increases both types of household welfare and the total welfare more than the first one. A possible reason might be that the second rule dampens the supply of loans, household debt more than the first rule, as the second rule requires banks to be more cautious thereby hold more capital than under the second rule. The second regulation leads households to smoothing their consumption and demand for housing more effectively than the first one. The welfare under the second capital rule is higher than under the first ratio rule. The conclusion is that the second countercyclical capital rule is superior to and outranks the first, the third and the baseline rule in terms of welfare.

7.2 Welfare Analysis and horizon of News' Shocks

We now set anticipated shocks to be observed 4 quarters ahead, whereas in the previous section the anticipated shocks to bank capital were observed 8 quarters ahead. Firstly, we compare the

welfare effect of the anticipated changes 4 quarters to anticipated 8 quarters in advance, as in Schmitt-Grohe and Uribe (2012) and Lambertini *et al.* (2013). Secondly, we examine whether the welfare ranking of capital rules is still preserved when anticipated shocks are observed at a different period. In additional to anticipated shocks, the economic system is also affected by unanticipated shocks to bank capital as in the previous section.

Figures 5, 6 and 7 show that by allowing anticipated shocks to be observed 4 quarters ahead, this amplifies the welfare under different capital countercyclical rules. As we can see, when the anticipated shocks are observed 4 quarters ahead, the welfare gains from following the first and second Basel III capital rules are higher relative to the anticipated shocks observed 8 quarters ahead, whereas households become worse off under the third Basel III capital rule. Figure 8 indicates that the second countercyclical capital ratio rule still yields the highest welfare even though the anticipated shocks are observed 4 quarters in advance. The efficiency rank ordering in terms of welfare comprises the second rule, the first, the baseline and the third rule sequentially.

7.3 Financial Distress and Welfare

This section investigates *financial distress* and implications for welfare. Specifically, we conduct a sensitivity analysis directly on the parameter κ_B which captures the intensity of financial distress (please see wholesale unit, under section 2.6). We compare the total welfare under the benchmark calibration distress case against the welfare under a significantly higher financial distress case. Under the benchmark calibration, the intensity of financial distress is set to 8.49 whereas a high financial distress calibration rises to 18.

Firstly, we compare the effect of an increase in financial distress on welfare given our different capital countercyclical rules and next we examine whether the welfare ranking of capital rules is still preserved as financial distress intensifies. Figures 9, 10 and 11 show the effect of a rise in financial distress on welfare under the various rules relative to the baseline. It appears that as financial distress intensifies, the welfare gains from following the first and second Basel III capital rules are higher, whilst households become worse off under the third Basel III rule. Particularly, Figure 12 indicates that the second countercyclical buffer rule yields the highest welfare even though the degree of financial distress keeps increasing.

8. CONCLUSIONS

A countercyclical capital ratio requirement is designed to counteract financial imbalances and bolster banks' resilience against external shocks, thus strengthening banking stability. In this paper, we introduce three Basel III countercyclical capital ratio rules. The first countercyclical capital rule refers to the case whereby capital ratio requirements respond to the credit to output

ratio as recommended by the Basel committee. The second rule incorporates the scenario of the capital ratio requirement reacting to credit to its steady rate ratio, while the third rule is encountered when the capital ratio requirement respond to credit growth. The baseline rule is the Basel II fixed capital ratio requirement.

The results from model simulations show that under the Basel II regime, a positive news' shock about future capital induces banks to reduce holdings of bank capital, capital to asset ratios and expand their credit supply, which in turn cause their capital to asset ratios drop below their steady state and lead to a rise in household debt. When the positive shock to bank capital is not realized, this creates banking instability as banks have been complacent about building up their capital, and consequently the bank capital ratio is below the steady state level under the Basel II regime.

When the first or the second countercyclical capital rule is imposed, banks are required to hold more capital than under the Basel II and the third countercyclical rule even though banks anticipate a positive shock to their bank capital to occur. The first or the second rule induces banks to be more prudent hence these rules enhance banking stability as well as damp business cycle fluctuations. We also find that the third rule does not contribute toward banking stability whatsoever.

Lastly, we conduct a welfare analysis for these three capital ratio rules, while keeping the Basel II rule as the baseline. We find that the first or the second rule leads to welfare improving relative to the baseline rule, while the introduction of the third rule worsens household welfare relative to the baseline. The efficiency rank ordering in terms of welfare comprises the second rule, the first, the baseline and the third rule respectively. Furthermore, after conducting sensitivity analyses the rank ordering in term of welfare is still preserved as such. We conclude that a countercyclical capital rule that reacts to deviations of credit to its steady state, will promote further banking stability and improve significantly household welfare.

We contribute to the relevant literature in various ways. Specifically, Angelini *et al.* (2014) find that a time-varying capital ratio requirement can reduce macroeconomic volatility, regardless whether there is coordination between monetary and capital requirement policy or not. Rubio and Carrasco-Gallego (2014) find that a countercyclical capital requirement that reacts to credit growth, house prices and output, yields higher welfare than a fixed capital requirement. They also show that a capital requirement rule that reacts to deviations of credit from its steady state leads to a welfare improvement. The differences between our work and those studies are distinct; Angelini *et al.* (2014) and Rubio and Carrasco-Gallego (2014, 2015) do not consider different types of capital ratio rules, whereas in our paper we compare different countercyclical capital

rules. Moreover, Carrasco-Gallego (2014, 2015) do not incorporate shocks to the banking sector nor news' shocks either. Angelini *et al.* (2014) may show an unanticipated shock, however we consider both anticipated and unanticipated shocks to bank capital. Finally, they do not present an extensive welfare analysis as we pursued in our work.

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TABLE 1. BENCHMARK CALIBRATION

Parameter	Description	Value
β_I	Impatient household's discount factor	0.975
β_P	Patient household's discount factor	0.9943
β_E	Entrepreneur's discount factor	0.975
m_F	Impatient household's LTV	0.75
m_E	Entrepreneur's LTV	0.35
ω	Weight of housing in household's utility function	0.2
ν_B	Capital to loans ratio requirement	0.09
κ_B	Bank Leverage deviation cost	8.49
δ_B	Cost for managing the bank's capital position	0.1049
κ_D	Deposit rate adjustment cost	3.63
κ_F	Household rate adjustment cost	10.22
κ_E	Firm rate adjustment cost	9.51
ε_D	$\frac{\varepsilon_D}{\varepsilon_D-1}$ is the markdown on deposit rate	-1.46
ε_F	$\frac{\varepsilon_F}{\varepsilon_F-1}$ is the markdown on household loans	2.79
ε_E	$\frac{\varepsilon_E}{\varepsilon_E-1}$ is the markdown on business loans	3.12
α	Capital share in the production function	0.25
δ	Depreciation rate of capital	0.025
μ	Share of patient household's labor income	0.8
η	Inverse of the Frisch elasticity	1
l_p	Price indexation	0.17
ξ_1	Parameter of adjustment cost for capital utilization	0.0478
ξ_2	Parameter of adjustment cost for capital utilization	0.00478
ε_y	$\frac{\varepsilon_y}{\varepsilon_y-1}$ is the markup in the good market	6

|		
κ_p	*Parameter of adjustment cost for prices*	30.57
κ_i	*Parameter of adjustment cost for investment*	10.26
ϕ_π	*Taylor coefficient on inflation*	0.35
ϕ_Y	*Taylor coefficient on output growth*	2.01
ρ	*Taylor coefficient on interest rate inertia*	0.77
σ_B	*Standard deviation of bank capital shock*	0.031
ρ_B	*Persistence of bank capital shock*	0.810

FIGURE 1A
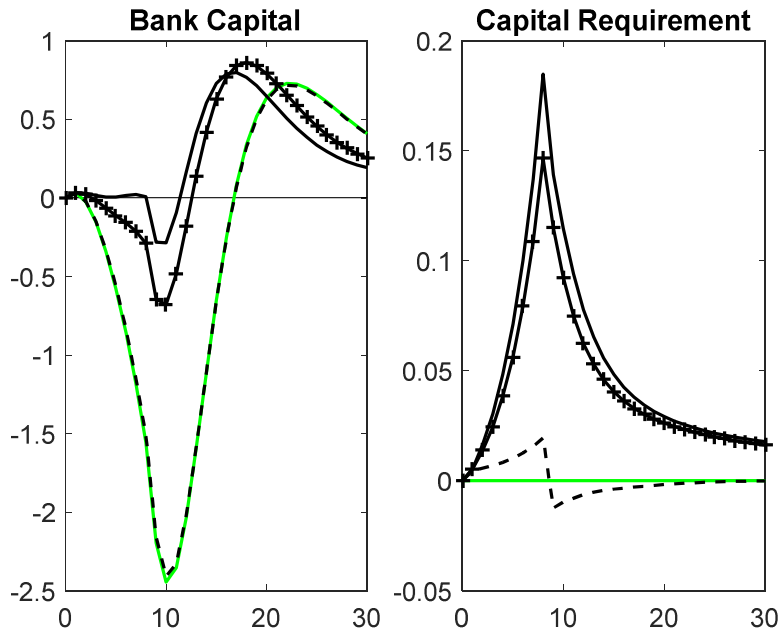
Notes: The black line with crosses represents the first rule (credit to output ratio), the thick black line represents the second rule (credit to its steady state), the black dashed line represents the third rule (credit growth) and the baseline rule is represented by the green line.
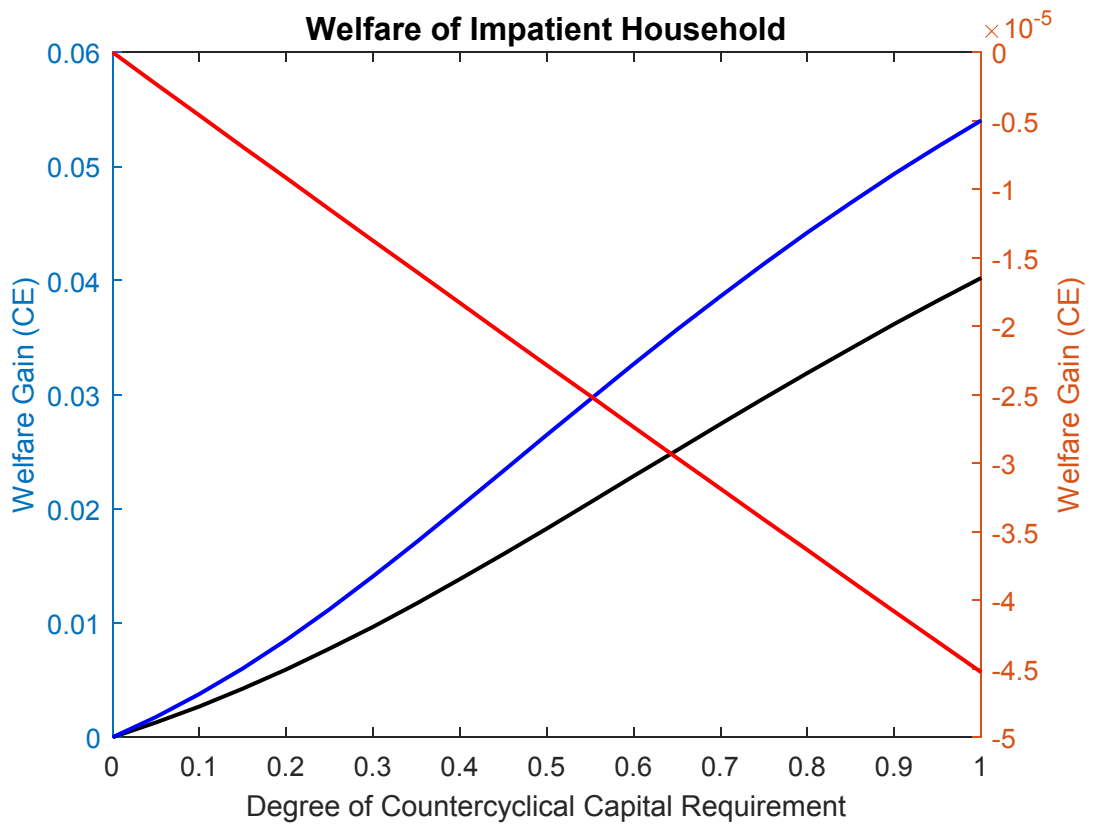
FIGURE 1B
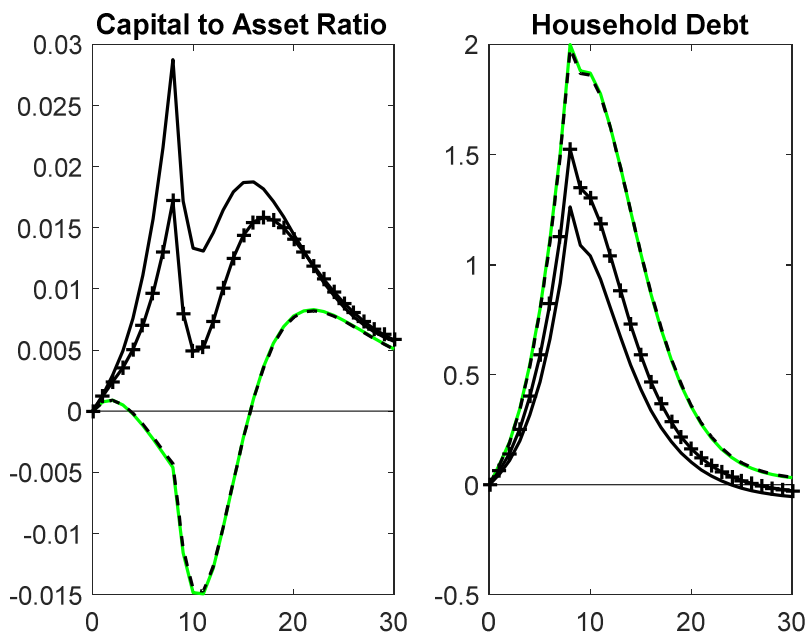
Notes: The black line with crosses represents the first rule (credit to output ratio), the thick black line represents the second rule (credit to its steady state), the black dashed line represents the third rule (credit growth) and the base rule is represented by the green line.

23
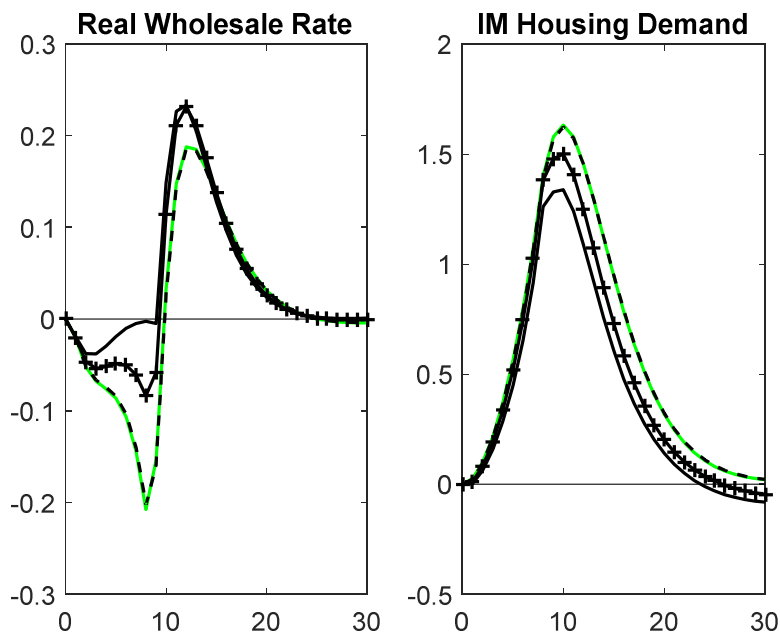
Notes: The black line with crosses represents the first rule (credit to output ratio), the thick black line represents the second rule (credit to its steady state), the black dashed line represents the third rule (credit growth) and the base rule is represented by the green line. IM stands for impatient household.
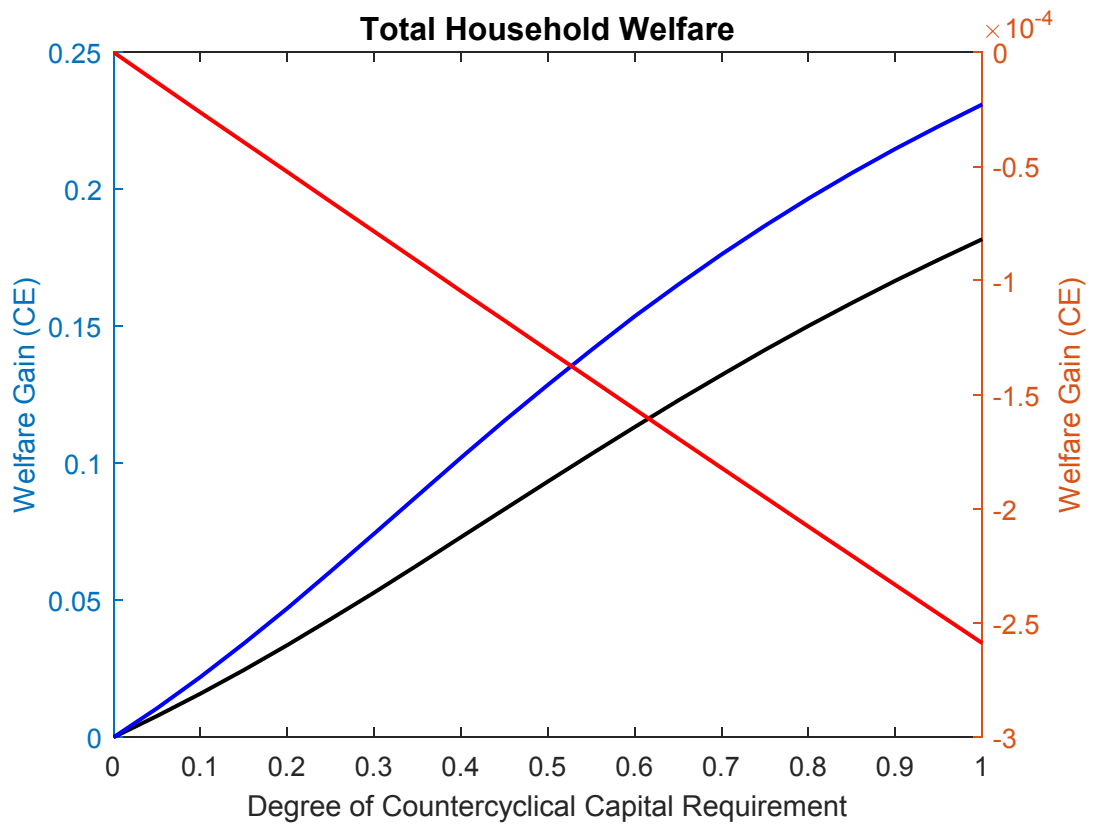
FIGURE 1D
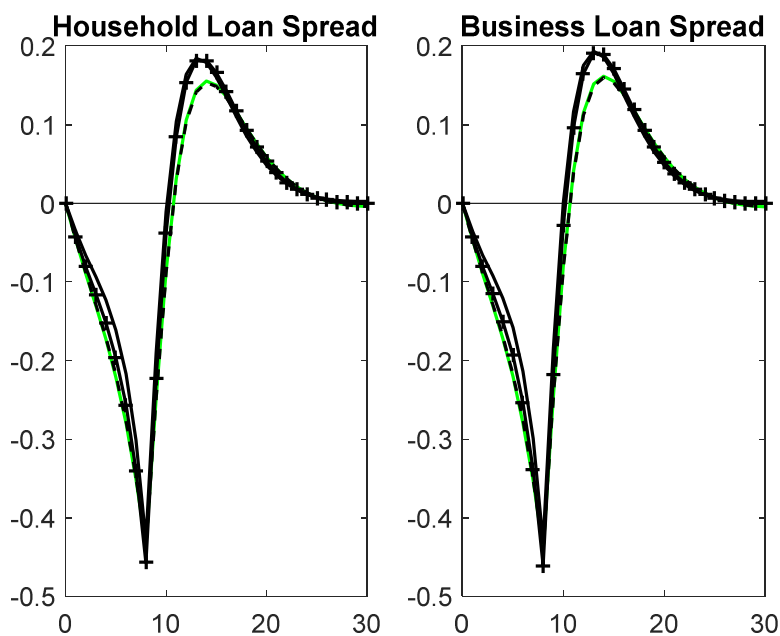
Notes: The black line with crosses represents the first rule (credit to output ratio), the thick black line represents the second rule (credit to its steady state), the black dashed line represents the third rule (credit growth) and the base rule is represented by the green line.
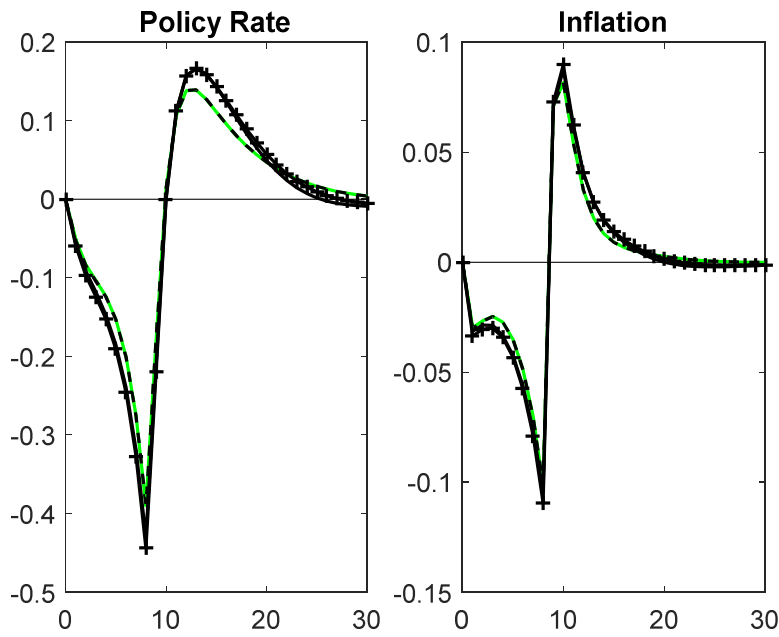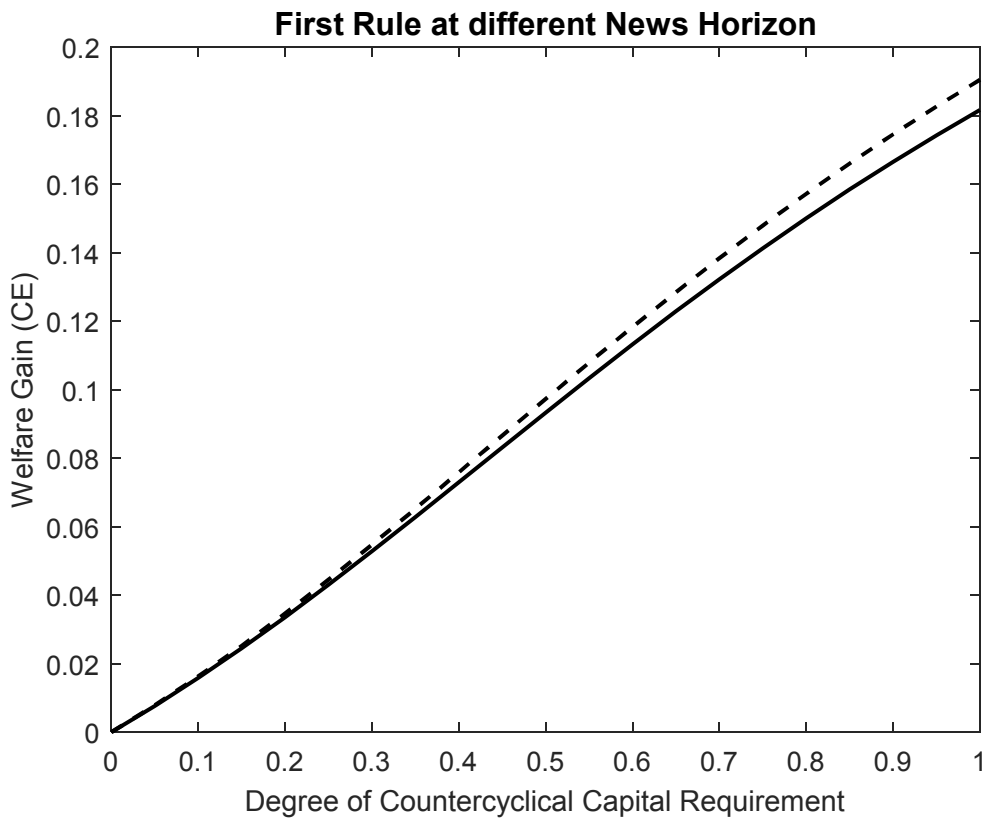
Notes: The black line with crosses represents the first rule (credit to output ratio), the thick black line represents the second rule (credit to its steady state), the black dashed line represents the third rule (credit growth) and the base rule is represented by the green line.
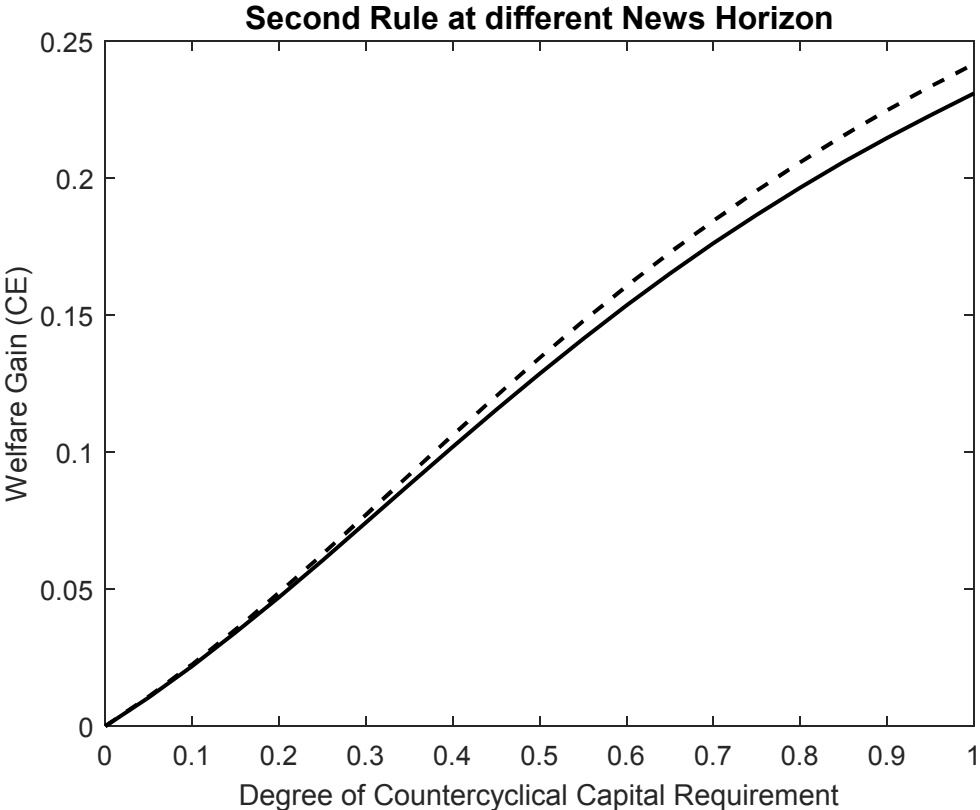
FIGURE 1F
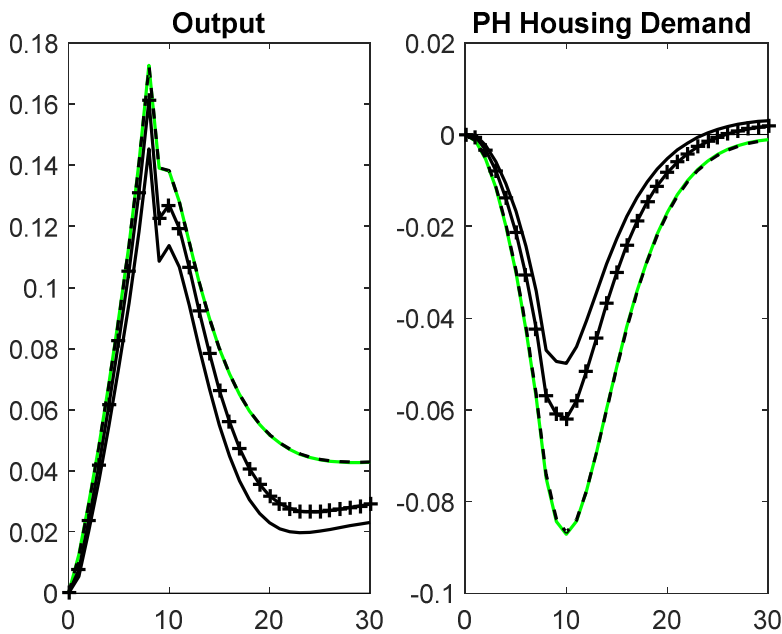
Notes: The black line with crosses represents the first rule (credit to output ratio), the thick black line represents the second rule (credit to its steady state), the black dashed line represents the third rule (credit growth) and the base rule is represented by the green line. PH stands for patient household.

Notes: The black line with crosses represents the first rule (credit to output ratio), the thick black line represents the second rule (credit to its steady state), the black dashed line represents the third rule (credit growth) and the base rule is represented by the green line.

Welfare of Patient Household
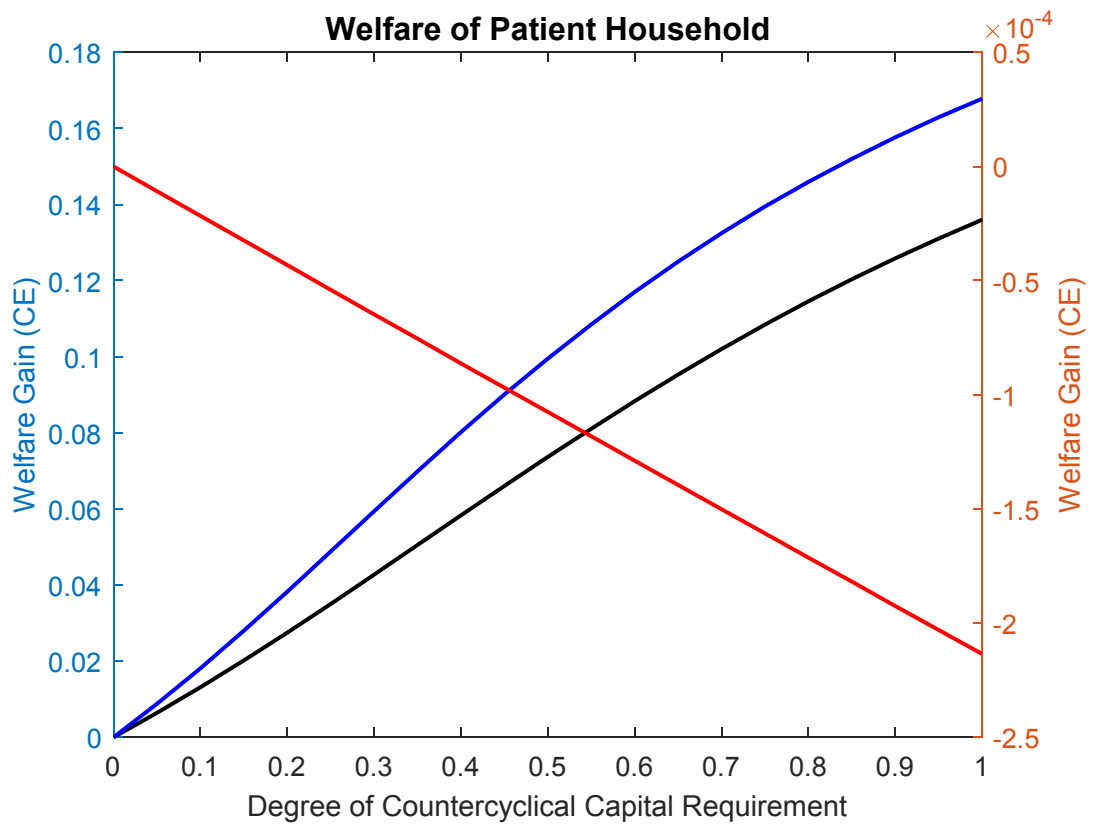
Notes: The black line represents the first rule (credit to output ratio), the blue line represents the second rule (credit to its steady state) and the red line represents the third rule (credit growth).

FIGURE 3: WELFARE OF IMPATIENT HOUSEHOLD

Notes: The black line represents the first rule (credit to output ratio), the blue line represents the second rule (credit to its steady state) and the red line represents the third rule (credit growth).

Notes: The black line represents the first rule (credit to output ratio), the blue line represents the second rule (credit to its steady state) and the red line represents the third rule (credit growth).

**First Rule at different News Horizon**

Notes: We show total household welfare under the first rule at different news horizons. The thick black line represents welfare under anticipated shocks observed 8 periods in advance (as in the previous section) and the dashed black line represents the welfare under anticipated shocks observed 4 periods in advance.

Second Rule at different News Horizon

Notes: We show total household welfare under the second rule at different news horizons. The thick black line represents welfare under anticipated shocks observed 8 periods in advance (as in the previous section) and the dashed black line represents the welfare under anticipated shocks observed 4 periods in advance.

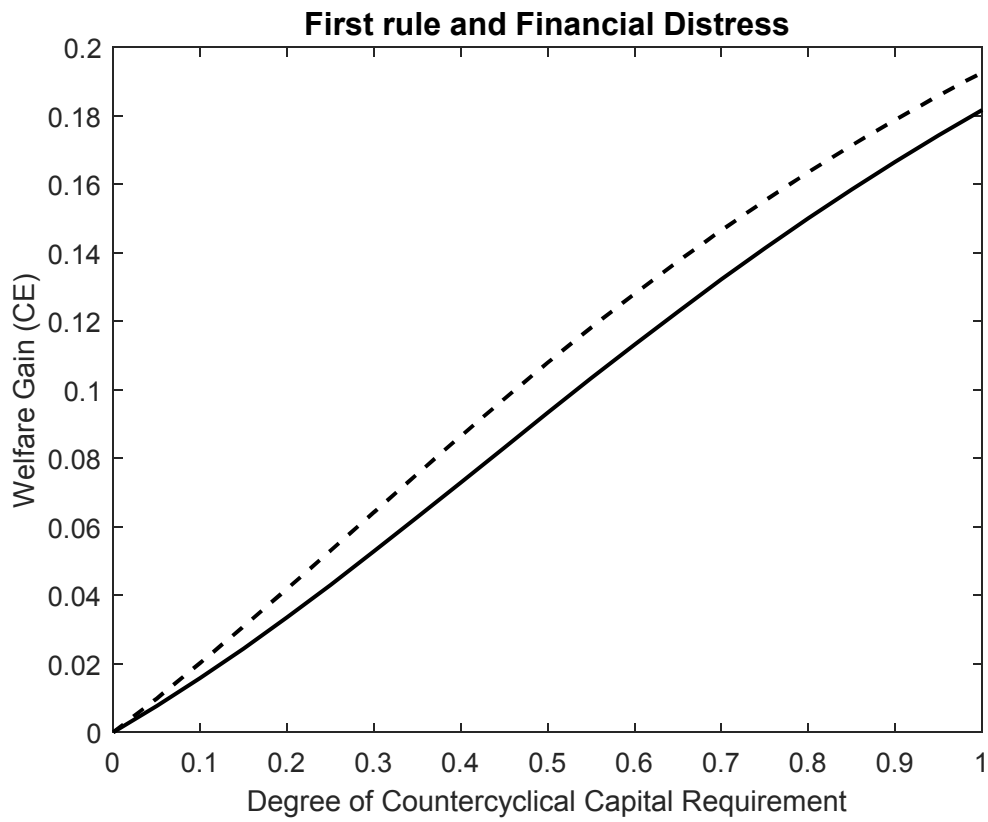**FIGURE 7: TOTAL HOUSEHOLD WELFARE AT DIFFERENT NEWS HORIZONS (3RD RULE)**
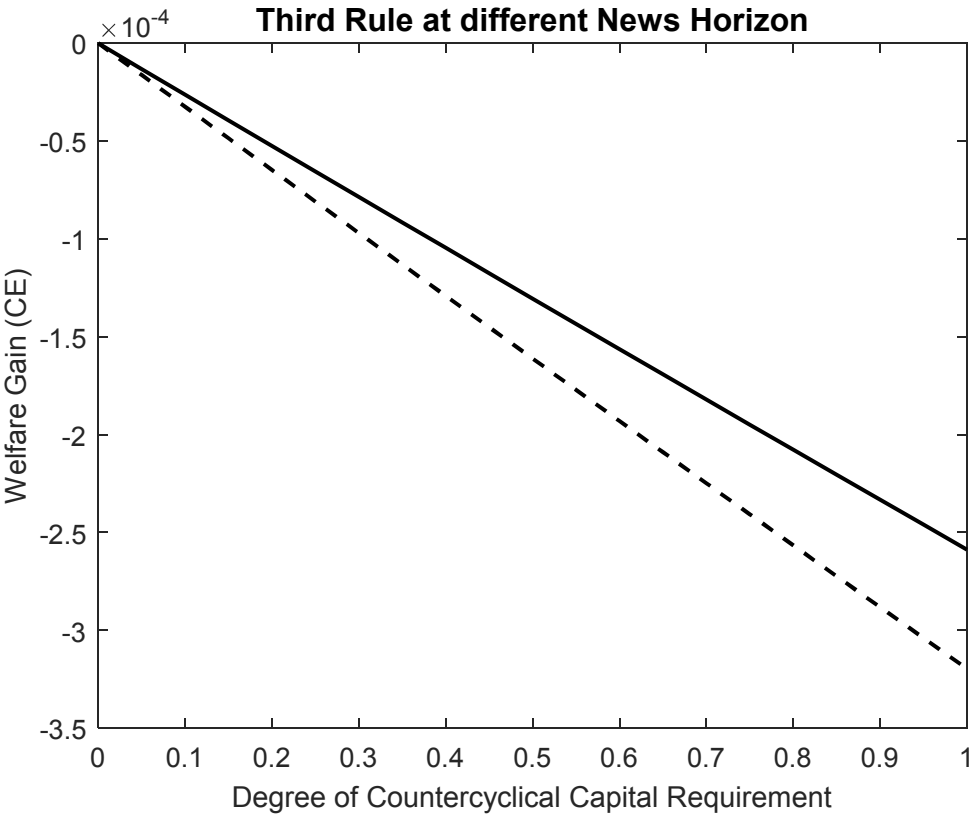
Notes: We show total household welfare under the third rule at different news horizons. The thick black line represents welfare under anticipated shocks observed 8 periods in advance (as in the previous section) and the dashed black line represents the welfare under anticipated shocks observed 4 periods in advance.

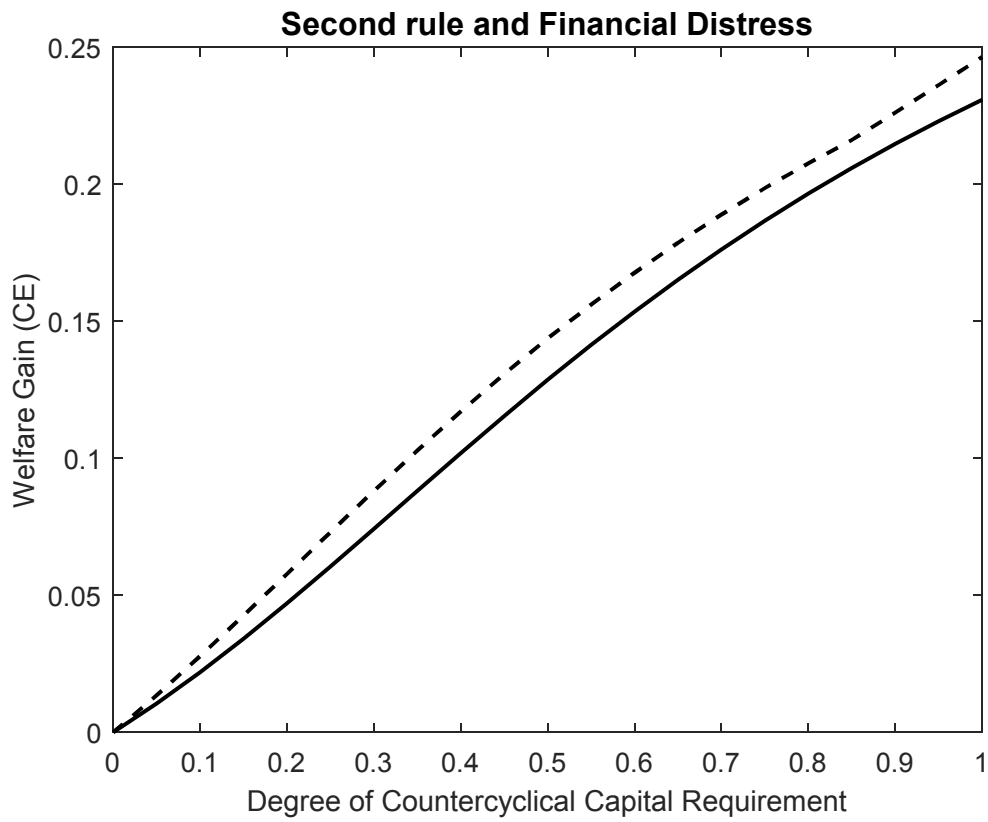**FIGURE 8: TOTAL HOUSEHOLD WELFARE UNDER ALTERNATIVE NEWS SHOCK HORIZONS**
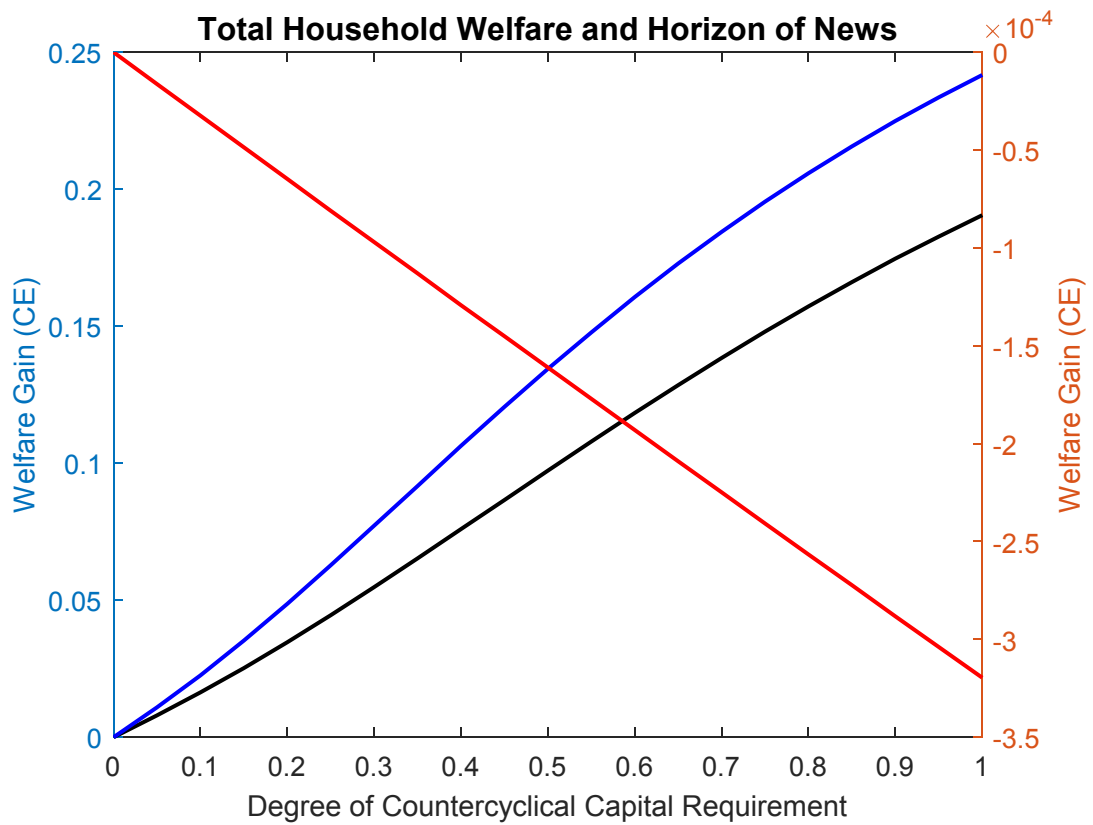
Notes: We show total household welfare under an alternative news shock horizon. The black line represents the first rule (credit to output ratio), the blue line represents the second rule (credit to its steady state) and the red line represents the third rule (credit growth).
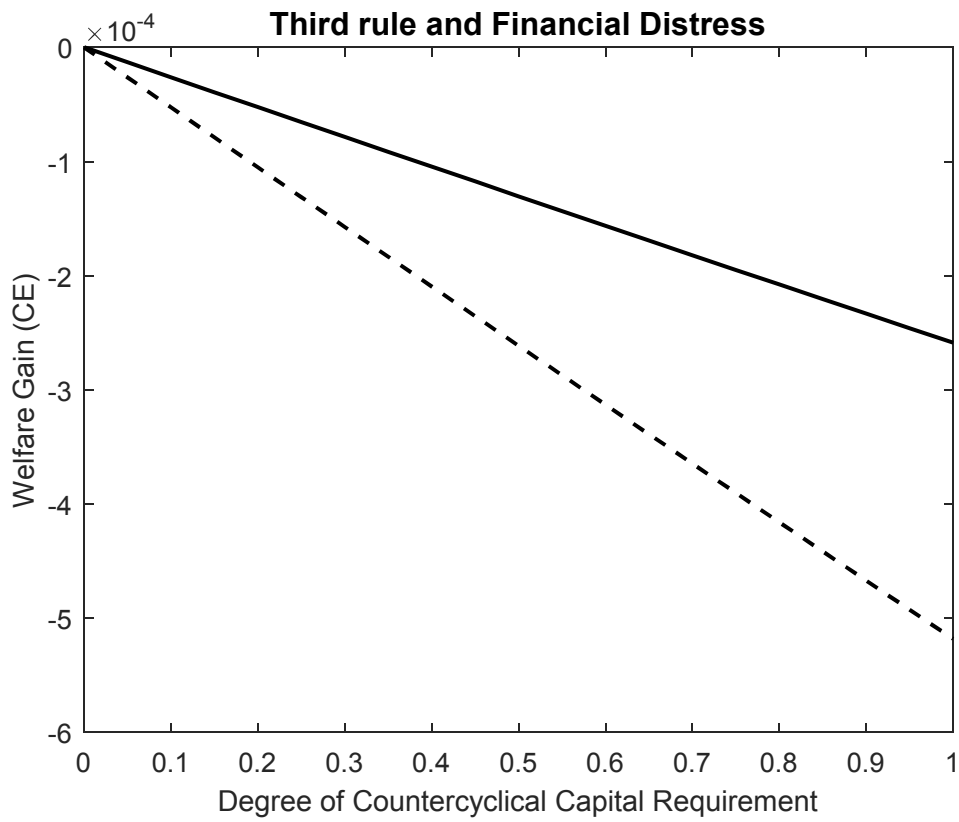
First rule and Financial Distress

Notes: We show total household welfare under the first rule. The thick black line represents welfare under a benchmark calibration financial distress case and the dashed black line represents the welfare under a higher financial distress case.

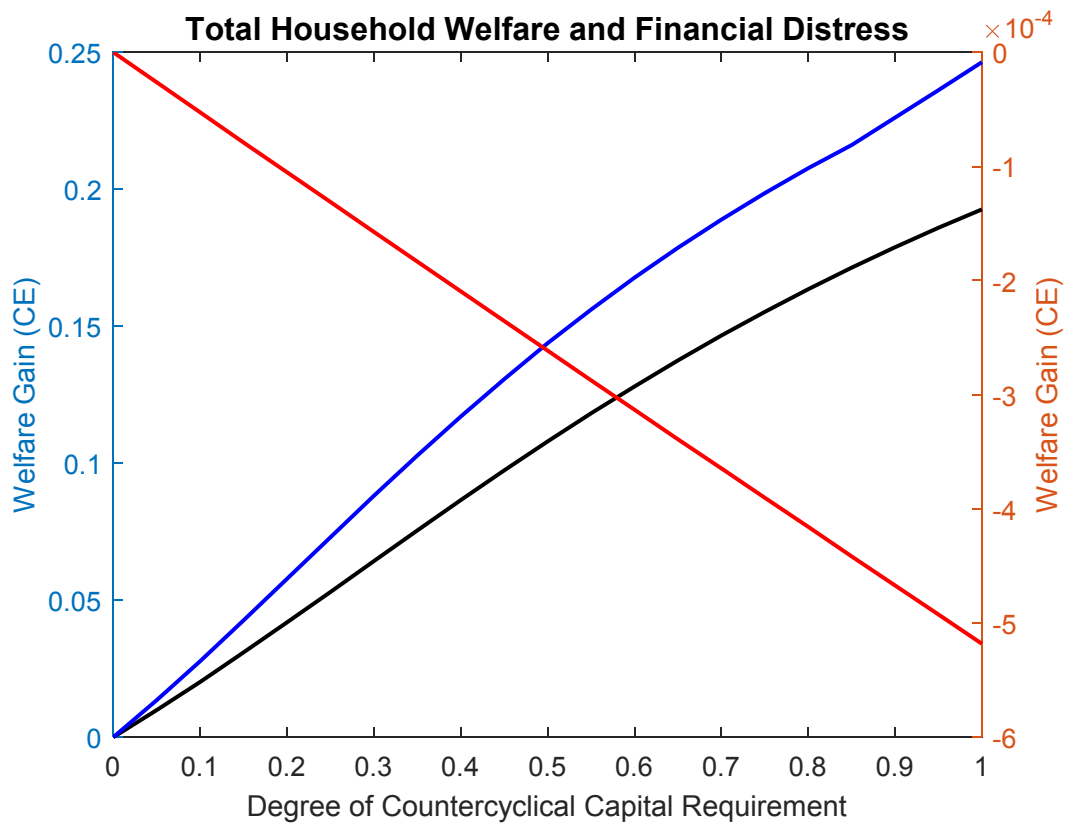**Second rule and Financial Distress**

Notes: We show total household welfare under the second rule. The thick black line represents welfare under a benchmark calibration financial distress case and the dashed black line represents the welfare under a higher financial distress case.

FIGURE 11: TOTAL HOUSEHOLD WELFARE UNDER THE THIRD RULE

Notes: We show total household welfare under the third rule. The thick black line represents welfare under a benchmark calibration financial distress case and the dashed black line represents the welfare under a higher financial distress case.

FIGURE 12: FINANCIAL DISTRESS AND TOTAL HOUSEHOLD WELFARE

Notes: We show total household welfare under financial distress. The black line represents the first rule (credit to output ratio), the blue line represents the second rule (credit to its steady state) and the red line represents the third rule (credit growth).