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Time-varying Bank Capital Requirements with Capital Distribution Constraints: A DSGE Approach*

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We evaluate stabilizing effects of heightened and time-varying minimum capital requirements on the financial sector and the economy. Under the current Basel regulations with time-varying capital requirements, when financial intermediaries incur losses on capital, they can release extra capital accumulated in advance during normal times. As a result, they do not need to contract credit supply in order to keep their capital ratios high enough during bad times. Our simulation results show that a taxing scheme, which works as capital distribution constraints on intermediaries, significantly enhances stabilizing effects of time-varying minimum capital requirements. This evidence partly provides support for the current Basel III counter-cyclical capital buffer regulations.

Keywords: capital requirements, Basel III, DSGE model, capital distribution constraints, counter-cyclical capital buffer

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Ⅰ. Introduction

After the financial crisis of 2007-2008, new macro-prudential capital requirement regimes were proposed in a global regulatory framework for banks, which is called Basel III. Rubioand CarrascoGallego (2016) argue that the macro-prudential regimes of Basel III consist of the two elements: increase in capital requirement ratios in normal times, and introduction of time-varying capital requirement ratios which take into account macro-financial environment of the economy.[1)]

Theoretically, time-invariant capital regulations prevent banks from supplying funds to the economy during a recession, because profit losses of banks reduce the amount of their capital, which leads to lower capital ratios (Repullo and Suarez 2013, Iacoviello 2015). Although the recent theoretical literature discusses the stabilizing effects of time-varying minimum capital requirements on the macroeconomy, the effects have not yet fully been comprehended (Angelini et al 2014, Rubio and Carrasco-Gallego, 2016). In particular, the following important questions have not been answered yet: How do heightened and time-varying minimum capital requirements affect the economy during a recession? How do time-varying minimum capital requirements with capital distribution constraints as introduced in the Basel III framework in a dynamic stochastic general equilibrium (DSGE) model? The goal of this study is to contribute to the theoretical literature on macro-prudential capital requirement regimes by answering these questions.

We consider a DSGE model in which financial intermediaries are subject to time-varying minimum capital requirement constraints. As introduced in Basel III reforms, we consider that a regulatory authority sets the minimum capital requirement ratio responding to the gap of the credit-to-GDP ratio from its long-term trend. In particular, the authority lowers the minimum ratio when the credit-to-GDP ratio falls below its steady-state value, namely during a recession. We refer to such time-varying minimum capital requirement regulations as counter-cyclical minimum capital requirement regulations.

As existing literature argues, when an exogenous disturbance to capital of financial intermediaries triggers a recession, intermediaries incur losses on capital, reducing credit amounts to meet the minimum capital ratios. Then, the declined supply of credit to the production sector leads to the fall in aggregate investment, output, and household consumption.

The simulation results of this study show that the raise in the steady-state minimum capital requirement ratio under the counter-cyclical capital requirement regime has significant stabilizing effects on the economy. Financial intermediaries can release extra capital required by the raise in the steady-state minimum capital requirement ratio, because the government lowers the minimum capital requirement ratio under the counter-cyclical minimum capital requirement regime. For intermediaries, this reduces the necessity of reducing lending and building new capital during periods when they incur losses of capital. Keeping the greater amount of supply of funds in counter-cyclical minimum capital requirement regime than in the time-invariant regime leads to a modest decline in output in the former regime.

The counter-cyclical minimum capital requirement regime enables financial intermediaries to distribute more capital to their owners during a recession than in the time-invariant regime. By taxing on dividend payments by intermediaries to their owners during a recession, the regulator can succeed in lowering incentive of intermediaries to distribute capital. The simulation results show that such taxing scheme significantly enhances the stabilizing effects of the counter-cyclical capital requirement regime. Intermediaries use more capital for supplying funds to the production sector

than in the case without the taxing scheme, not for smoothing the decline in dividend payments to their owners.

Recent theoretical literature examines the effects of counter-cyclical capital requirements by using macroeconomic models.[2] Gertler et al. (2012} and Liu (2016} assess a scheme to subsidize banks' issue of equity as counter-cyclical capital requirements. We contribute to the literature by considering the time-varying minimum capital requirement ratio, which responds to the gap of the credit-to-GDP ratio as proposed in Basel III reforms.

The most related literature is Rubio and Carrasco-Gallego (2016}. They argue that, although counter-cyclical minimum capital requirements mitigate the exogenous fall in bank lending, counter-cyclical minimum capital requirements do virtually not affect the dynamics of aggregate output. Our model differs in considering intermediaries which supply funds to the production sector of the economy, and in providing the results that the counter-cyclical minimum capital requirement regime mitigates the decline in both credit supply and output during a recession. Moreover, we contribute to the literature by illustrating that the time-varying minimum capital requirement rule, which responds to the credit-to-GDP ratio, does not work to mitigate a recession which is triggered by a negative productivity shock.

Angelini et al. (2014), Benes and Kumhof (2015}, and Karmakar (2016} also examine counter-cyclical capital requirements in DSGE models. These models, however, have not yet explicitly considered capital distribution constraints on financial intermediaries as introduced in macro-prudential capital requirement regimes in Basel III. We contribute to the literature by considering a taxing scheme, which works as capital distribution constraints on intermediaries during a recession.

The organization of this paper is as follows. Section 2 presents the macroeconomic framework used in this study. Section 3 presents simulation results of model analysis. Section 4 concludes this study.

Ⅱ. The model

The model of this study builds on a DSGE model developed by Iacoviello (2015).[3] To Iacoviello's model, we add counter-cyclical minimum capital requirement constraints for financial intermediaries. Consider a closed economy comprised of four types of agents: households, entrepreneurs, bankers, and a government. Each entrepreneur manages a final-goods-producing firm. Then, each banker manages a financial intermediary. The sequence of time is expressed in an infinite sequence of discrete periods that is denoted by $t = 0, 1, 2, \cdots$. We describe each component of the model below.

1. Household sector

There is a continuum of identical households of mass of unity. Households consume final goods, own real estate, save, supply labor, and acquire short-term debt (which we call deposits hereafter) issued by financial intermediaries.

Let C_t denote consumption of a representative household at period t, $H_{H,t}$ denote the quantity of real estate that the household owns, and N_t denote time that is spent on working. The preference of the household at any time t is given by

$$E_t\Big\{\sum_{s=t}^{\infty}\beta_H^{s-t}[(1-\eta)\ln(C_s-\eta C_{s-1}) + j\ln H_{H,s}+h\ln(1-N_s)]\Big\}, \qquad (1)$$

with

$$0<\beta_H<1,\ \ 0<\eta<1,\ \ j,h>0,$$

where $E_t\{\cdot\}$ is the expectation operator conditional on information at period t, β_H denotes the discount factor of the household, η measures habit formation in consumption, j denotes the utility weight of real estate, and h denotes the utility weight of labor.[4]

Deposits are defined as real bonds that pay the gross real rate of return denoted by R_t from period $t-1$ to t. Let D_t denote the quantity of deposits that the household acquires, q_t denote the price of real estate, W_t denote the wage rate, and ε_t be a redistribution shock that transfers wealth from the financial sector to the household sector. The budget constraint of the household is given by

$$C_{H,t}+D_t+q_t(H_{H,t}-H_{H,t-1}) = R_{t-1}D_{t-1}+W_tN_t+\varepsilon_t. \quad (2)$$

Following Iacoviello (2015), we introduce the redistribution shock into the model as a way to introduce an exogenous disturbance to capital of financial intermediaries. As we described later, losses on capital of intermediaries trigger a recession. As Iacoviello (2015) argues, wealth of intermediaries is transferred to households by the shock, and therefore, no wealth is created or destroyed in aggregate.

At each period $t, the household chooses consumption, real estate, labor supply, and deposits to maximize the expected discounted utility (1) subject to the budget constraint (2). The first-order conditions for consumption/deposits, real estate, and labor supply are given by

$$u_{C_{H,t}} = \beta_H R_t E_t(u_{C_{H,t+1}}), \quad (3)$$

$$q_t u_{C_{H,t}} = \frac{j}{H_{H,t}}+\beta_H E_t(q_{t+1}u_{C_{H,t+1}}), \quad (4)$$

$$W_t u_{C_{H,t}} = \frac{h}{1-N_t}, \quad (5)$$

where

$$u_{C_{H,t}} \equiv (1-\eta)\frac{1}{C_{H,t}-\eta C_{H,t-1}} -\eta\beta_H(1-\eta)\frac{1}{C_{H,t+1}-\eta C_{H,t}}$$

2. Entrepreneurial sector

There is a continuum of identical final-goods-producing firms of mass of unity. Firms produce homogeneous final goods using real estate and labor, and obtain funds from financial intermediaries. As described later, there are financial market frictions in the process of firms obtaining funds from intermediaries.

Let Y_t denote output of final goods that a representative firm produces at period t, $H_{E,t-1}$ denote real estate purchased by the firm at period $t-1$. At any period t, production is given by

$$Y_t = H_{E,t-1}^{v}N_t^{1-v} \quad \text{with } 0<v<1, \quad (6)$$

where N_t is the labor input.

Let $C_{E,t}$ denote profits of the firm, L_t denote funds (loans) that the firm obtains from financial intermediaries, and $R_{L,t}$ denote the rate of return that the firm pays to creditor-intermediaries. Profits at any time t is given by

$$C_{E,t} = Y_t+L_t-q_t(H_{E,t}-H_{E,t-1})- R_{L,t}L_{t-1}-W_tN_t-ac_{E,t}, \quad (7)$$

with

$$ac_{E,t} \equiv \frac{\phi_E}{2}\frac{(L_t-L_{t-1})^2}{L_E},\ \phi_E>0,$$

where $ac_{E,t}$ is quadratic adjustment costs of loans, and L_E denote the steady-state value of loans.

Following Iacoviello (2015), we introduce borrowing constraints on firms as financial market frictions. In particular, the firm cannot borrow more than a fraction m_H of the expected discounted value of its real estate. The borrowing constraint is given by

$$L_t \le m_H E_t\left(\frac{q_{t+1}H_{E,t}}{R_{E,t+1}}\right)-m_N W_t N_t, \quad (8)$$

with

$$0<m_H<1,\ 0<m_N<1,$$

where Eq. (8) implies that a fraction m_N of wages must be paid in advance.

The entrepreneur who manages the firm uses all the profits of the firm to obtain final goods for his/her consumption. The firm/entrepreneur chooses loans, real estate, and labor input to maximize

$$E_t\left\{\sum_{s=t}^{\infty}\beta_E^{s-t}\ln C_{E,s}\right\},\ \text{with } 0<\beta_E<1, \quad (9)$$

where β_E denotes the discount factor of the entrepreneur, subject to Eqs. (6)-(8). Let $\lambda_{E,t}$ denote the Lagrange multiplier on the borrowing constraint (8). Then, the first-order conditions for loans, real estate, and labor are given by

$$\left(1-\frac{\partial ac_{E,t}}{\partial L_t}\right)\frac{1}{C_{E,t}}-\lambda_{E,t}=\beta_E E_t \left[\left(R_{L,t+1}+\frac{\partial ac_{E,t+1}}{\partial L_t}\right)\frac{1}{C_{E,t+1}}\right], \quad (10)$$

$$q_t-m_H\widehat{\lambda}_{E,t}E_t\left(\frac{q_{t+1}}{R_{L,t+1}}\right)=E_t\left[\Lambda_{t,t+1}\left(q_{t+1}+\frac{vY_{t+1}}{H_{E,t}}\right)\right], \quad (11)$$

$$\frac{(1-v)Y_t}{N_t}=(1+m_N\widehat{\lambda}_{E,t})W_t, \quad (12)$$

with

$$\widehat{\lambda}_{E,t}\equiv\lambda_{E,t}C_{E,t}, \quad (13)$$

$$\Lambda_{t,t+1}\equiv\beta_E\frac{(C_{E,t+1})^{-1}}{(C_{E,t})^{-1}},$$

where $\Lambda_{t,t+1}$ is the entrepreneur's stochastic discount factor. Eq. (10) states that when the borrowing constraint (8) is binding, the marginal gain from expanding borrowing by a unit exceeds the expected discounted marginal costs of doing so, because the constraint limits firm borrowing. Eq. (11) states that the constraint introduces a wedge between the marginal product of real estate and the marginal costs of it. Eq. (12) also states that there is a wedge between the marginal product of the labor input and its marginal costs.

3. Financial sector

There is a continuum of identical financial intermediaries of mass of unity. Each intermediary raises funds from households by supplying deposits. Then, intermediaries supply funds to final-goods-producing firms. As described later, intermediaries are subject to minimum capital requirement constraints.

Let Cap_t denote the amount of net wroth (which we call capital hereafter) that a representative financial intermediary has at the end of period t. The balance sheet of the intermediary at any period t is given by

$$L_t=Cap_t+D_t, \quad (14)$$

where L_t is the quantity of funds that the intermediary supplies to firms, and D_t is deposits that the intermediary obtains from households.

As we noted earlier, deposits that households acquire at period $t-1$ pay the gross rate of return R_{t-1} at period t, and assets that the intermediary has at period $t-1$ earn the gross rate of return $R_{L,t}$ at period t. Let $C_{B,t}$ denote dividends to the banker who manages the intermediary. Then, capital of the intermediary at period t is given by

$$Cap_t=R_{L,t}L_{t-1}-R_{t-1}D_{t-1}-C_{B,t}-ac_{B,t}-\varepsilon_t, \quad (15)$$

with

$$ac_{B,t}\equiv\frac{\phi_B}{2}\frac{(L_t-L_{t-1})^2}{L_E},\ \phi_E>0,$$

where $ac_{B,t}$ is quadratic adjustment costs of loans, and ε_t is the redistribution shock that generates losses on capital.

We now turn to minimum capital requirement regulations for financial intermediaries. The financial intermediary must satisfy the following minimum capital requirement constraint at each period t:

$$\frac{Cap_t}{L_t}\geq 1-\gamma_t, \quad (16)$$

where $1-\gamma_t$ is a regulatory minimum capital requirement ratio. Eq. (16) states that the intermediary is required to hold its capital-to-assets ratio, Cap_t/L_t, greater than or equal to the minimum capital requirement ratio, $1-\gamma_t$.

The banker uses all the dividends to obtain final goods for his/her consumption.
The banker/intermediary chooses deposits and loans to maximize

$$E_t\left\{\sum_{s=t}^{\infty}\beta_B^{s-t}\ln C_{B,s}\right\},\ \text{with}\ 0<\beta_B<1, \quad (17)$$

where β_B is the discount factor of the banker, subject to Eqs. (14)-(15). Let $\lambda_{B,t}$ denote the

Lagrange multiplier on the capital requirement constraint (16). The first-order conditions for deposits and loans are given by

$$\frac{1}{C_{B,t}}-\lambda_{B,t}=\beta_B R_{H,t}E_t\left(\frac{1}{C_{B,t+1}}\right), \tag{18}$$

$$\left[1+\frac{\partial ac_{B,t}}{\partial L_t}\right]\frac{1}{C_{B,t}}=\beta_B E_t \left[\left(R_{L,t+1}-\frac{\partial ac_{B,t+1}}{\partial L_t}\right)\frac{1}{C_{B,t+1}}\right]+\gamma_t\lambda_{B,t}. \tag{19}$$

The term $1/C_{B,t}$ in the left-hand side of Eq. (18) has the interpretation of the marginal gain of obtaining another unit of deposits, and while the right-hand side is the expected discounted marginal costs of doing so. If the intermediary is not subject to the minimum capital requirement constraint, it expands deposits to the point where the marginal gain equals the marginal costs. Eq. (18) states that the marginal gain, however, exceeds the marginal costs to the extent that Eq. (16) is binding, because the constraint limits intermediary obtaining deposits.[5] In particular, given Eq. (14), when the constraint (16) binds, the quantity of deposits that the intermediary can obtain depends on its assets:

$$D_t=\gamma_t L_t. \tag{20}$$

The first-term on the right-hand side of Eq. (19) is the expected discounted marginal gain of expanding loans by a unit, and while the left-hand side is the marginal costs of doing so. Eq. (19) states that the marginal costs exceeds the marginal gain because the binding constraint (20) creates the implicit gain of expanding loans, which is denoted by the term $\gamma_t\lambda_{B,t}$: expanding another unit of loans enables the intermediary to obtain deposit by the unit γ_t.

4. Government sector

We suppose that at each period t, the government sets the minimum capital requirement ratio, $1-\gamma_t$, in response to the gap of the credit-to-GDP ratio from its long-term trend, according to the following rule:

$$\gamma_t=\gamma+m\left(\frac{L_t}{Y_t}-\frac{L}{Y}\right),\ \text{with}\ m<0, \tag{21}$$

where γ is the steady-state minimum capital requirement ratio, L_t/Y_t is the credit-to-GDP ratio at period t, m is a counter-cyclical coefficient, and L/Y is the steady-state credit-to-GDP ratio. Eq. (21) states that the government lowers the minimum capital requirement ratio $1-\gamma_t$ below its steady-state value (i.e., raises the variable γ_t above its steady-state value) when the credit-to-GDP ratio goes below its steady-state value, namely the counter-cyclical coefficient m is negative.[6]

5. Equilibrium

Market clearing in the final goods market requires

$$Y_t=C_{H,t}+C_{E,t}+C_{B,t}+ac_{E,t}+ac_{B,t}, \tag{22}$$

where Y_t is aggregate output; $C_{H,t}$, $C_{E,t}$ and $C_{B,t}$ are aggregate consumption of households, entrepreneurs, and bankers respectively; and $ac_{E,t}$ and $ac_{B,t}$ are aggregate adjustment costs of entrepreneurs and bankers respectively. Following Iacoviello (2015), market clearing in the real estate market requires

$$H_{H,t}+H_{E,t}=1, \tag{23}$$

where the aggregate supply of real estate is normalized to unity. Given the balance sheet constraint of financial intermediaries (14), equilibrium aggregate deposits must equal the aggregate supply of loans minus aggregate capital:

$$D_t=L_t-Cap_t. \tag{24}$$

Finally, market clearing in the loan market requires that the aggregate demand for loans equal their aggregate supply. When the minimum capital requirement constraints (16) bind, this implies

$$L_t=\frac{D_t}{\gamma_t}. \tag{25}$$

In each period t, the 10 equilibrium quantities (Y_t, $C_{H,t}$, $C_{E,t}$, $C_{B,t}$, $H_{H,t}$, $H_{E,t}$, N_t, D_t, L_t,

Cap_t), the four equilibrium prices (W_t, R_t, $R_{L,t}$, q_t), and the three other variables ($\lambda_{E,t}$, $\lambda_{B,t}$, γ_t) are determined by Eqs. (2)-(8), (10)-(15), (18)-(21), (23) as a function of the state variables ($C_{H,t-1}$, R_{t-1}, $H_{H,t-1}$, $H_{E,t-1}$, L_{t-1}, D_{t-1}, ε_t), together with the exogenous stochastic process of the redistribution shock ε_t.

Ⅲ. Model analysis

1. Calibration

There are 11 parameters for which we need to choose values for numerical calculations. Table 1 reports the values of the parameters. Each period is assumed to be a quarter. We use estimates of Iacoviello (2015) to choose the values for most of parameters, which include the discount factors β_H, β_E, and β_B; the utility weight of labor τ and that of real estate j; the habit parameter η; the adjustment parameters ϕ_E and ϕ_B; the share of real estate v; borrowing constraint parameters m_N and m_H. Following Iacoviello (2015), the stochastic process for the redistribution shock, ε_t, is given by

$$\varepsilon_t = 0.9\varepsilon_{t-1} + \iota_t, \tag{26}$$

where l_t is distributed $N(0, \sigma_\varepsilon)$, and $\sigma_\varepsilon = 0.0015$.

Table 2 shows the values of the steady-state equilibrium quantities and prices under our calibration. We consider two different intensities of minimum capital requirement regulations in the steady state. In the first case, the steady-state minimum capital requirement ratio is equal to 8%. We refer to this case as low MCRR case (MCRR denotes ``minimum capital requirement ratio''). In the second case, the steady-state minimum capital requirement ratio is raised to 12.5%. We refer to this case as high MCRR case.

Note first that, in the high MCRR case, the capital of financial intermediaries is approximately 1.3 times as large as that in the low MCRR case. In addition, the aggregate supply of funds declines from 0.344 to 0.283 as the minimum capital requirement ratio increases. These occur because, in the high MCRR case, intermediaries are required to hold more capital relative to the supply of funds and/or to supply less funds relative to the amount of their capital than in the low MCRR case. The decline in the aggregate supply of funds leads to the increase in the equilibrium lending rate. Second, because the aggregate supply of funds to the production sector declines, the increase in the steady-state minimum capital requirement ratio has adverse consequences for real economic activities. In the high MCRR case, the input of real estate into the production de-

Table 1: Parameter values

Households		
β_H	0.9925	Discount factor
h	2	Utility weight of labor
η	0.46	Habit parameter
j	0.075	Utility weight of real estate
Final goods producing		
β_E	0.94	Discount factor of entrepreneurs
ϕ_E	0.25	Adjustment cost parameter
v	0.05	Share of real estate
m_N	1	Borrowing constraint parameter
m_H	0.9	Borrowing constraint parameter
Financial intermediaries		
β_B	0.945	Discount factor of bankers
ϕ_B	0.25	Adjustment cost parameter

Table 2: Steady-state values of equilibrium quantities and prices

		Capital requirement	
		Low MCRR	High MCRR
Output	Y	0.2076	0.2070
Households' consumption	C_H	0.1904	0.1897
Loans	L	0.344	0.283
Deposits	D	0.316	0.248
Financial intermediaries' capital	Cap	0.028	0.035
Dividend payments to bankers	C_B	0.0016	0.0021
Minimum capital requirement ratio (%)	$1-\gamma$	8	12.5
Lending rate	R_L	1.012	1.014
Deposit rate	R	1.008	1.008
Firms' real estate	H_E	0.146	0.132

clines from 0.146 to 0.132, which in turn leads to the fall in both aggregate output and consumption of households.

2. Numerical calculations

Figure 1 shows the impulse responses of the key equilibrium quantities and prices to a redistribution shock. The solid line gives the responses of the model economy. We choose the following parameters of minimum capital requirement regulations: the steady-state minimum capital requirement ratio of 12.5%; and the counter-cyclical coefficient m in the capital requirement rule (21) of -0.1. As a baseline simulation, for comparison, the dotted line gives the responses of the same model except that the minimum capital requirement ratio is constant and equals to 8% through the time. Thus, in the economy, the responses of which are shown by solid line, the steady-state minimum capital requirement ratio is raised by 4.5% from that of 8% in the baseline simulation, and also counter-cyclical minimum capital requirement regime is introduced. We also consider the case that the government does not adjust the minimum capital requirement ratio, and the minimum ratio always equals its steady-state value of 12.5% through the time. The dashed line illustrates this case.

The redistribution shock is the realization of the disturbance l_t in Eq. (26) of one standard deviation at period $t=0$. The shock to the financial sector generates losses on capital of financial intermediaries, which in turn lead to the decline in dividend payments to managers of intermediaries. Intermediaries can offset losses on capital by substantially reducing dividend payments. However, because the dividend payments ($C_{B,t}$) do not decrease as much as the negative shock to bank capital (ε_t), bank capital (CAP_t) decreases. Then, because of the decline in capital, intermediaries reduce supply of funds to firms in order to meet the minimum capital requirement ratio. This leads to the reduction of deposits that intermediaries can obtain from households, which in turn further reduces supply of funds. The shock to the financial sector then affects real economic activity as the decline in aggregate supply of funds to the production sector leads to a fall in aggregate investment. This causes a drop in aggregate output and in consumption of households.

As Figure 1 illustrates, the raise in the steady-state minimum capital requirement ratio with the counter-cyclical minimum capital requirement regime significantly moderates the severity of the recession. The prime reason is that financial intermediaries can release extra capital required by the raise in the steady-state minimum capital requirement ratio, because the government lowers the minimum capital

requirement ratio under the counter-cyclical minimum capital requirement regime. This reduces the necessity to contract lending and build new capital when intermediaries incur losses on capital. Mitigating the fall in the aggregate supply of funds to the production sector then leads to modest decline in both aggregate investment and output.

Without the counter-cyclical capital requirement regime, the raise in the steady-state minimum capital requirement ratio has only slight effects on the declines in aggregate in-

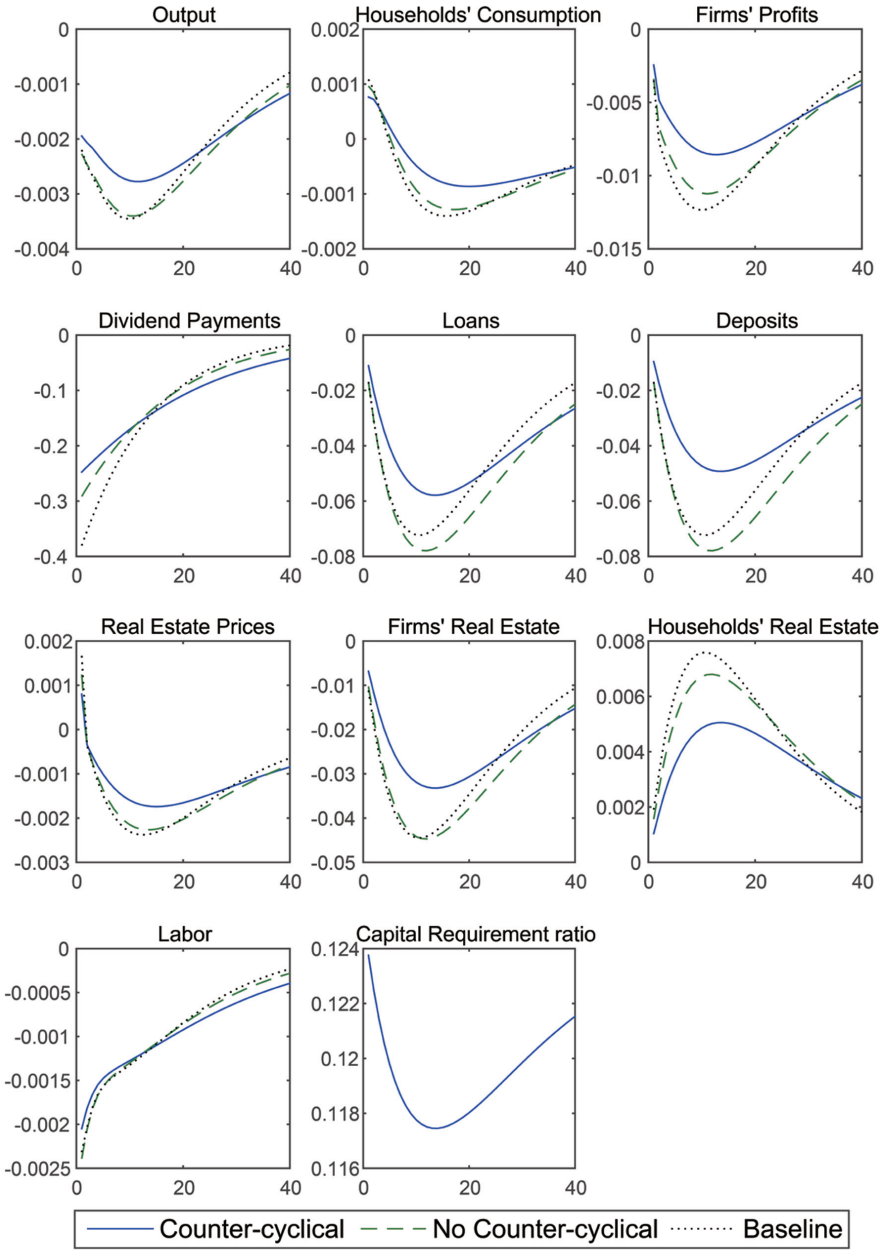

Figure 1: Impulse responses to a redistribution shock. *Note*: Each variable is shown in log-deviations from its steady-state value except for the capital requirement ratio, which is shown at its level.

vestment, output, and household consumption. In this case, extra capital does not work as a buffer because intermediaries have to rebuild capital and reduce lending to meet the minimum capital requirement ratio.

Figure 2 considers two different values of the counter-cyclical coefficient in the capital requirement rule. Note first that the aggressive adjustments of the minimum capital requirement ratio further moderate the severity of the recession. In the case of the counter-cyclical coefficient of −0.2 (shown by the solid line), the

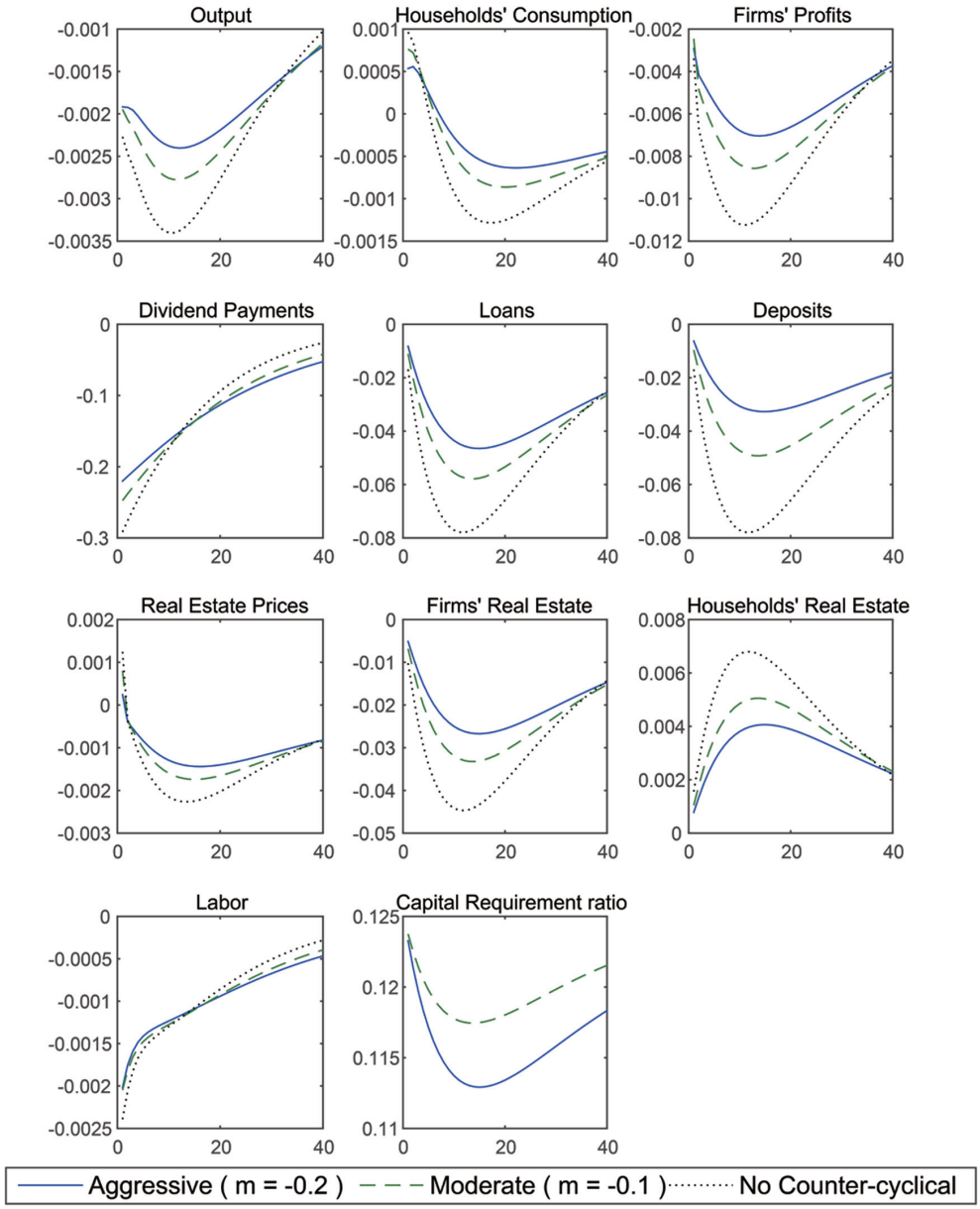

Figure 2: Impulse responses to a redistribution shock in a model with m of-0.2 and with m of -0.1. *Note*: Each variable is shown in log-deviations from its steady-state value except for the capital requirement ratio, which is shown at its level.

declines in both aggregate lending and output are more modest than in the case of the coefficient of −0.1 (shown by the dashed line). This occurs because the aggressive adjustments substantially loosen the minimum capital requirement constraints on financial intermediaries during a recession.

Second, financial intermediaries decrease dividend payment less when counter-cyclical regulations are in place than when they are not. The government's loosening of capital requirement constraints on intermediaries enables them to do so.For example, in the case of aggressive adjustments ($m = -0.2$), the initial decline in dividend payments relative to trend is approximately eight percent smaller than in the case of no adjustments of the minimum capital requirement ratio (shown by the dotted line).

3. Welfare effects of counter-cyclical minimum capital requirements

We now quantify the effects of counter-cyclical minimum capital requirements on the welfare of households, entrepreneurs, and bankers, respectively. Following Rubio and Carrasco-Gallego (2016), the welfare criterion, which we consider, is the function that explains the preference of a representative agent. Specifically, we define the welfare criterion of households, entrepreneurs, and bankers, respectively, as follows:

$$\mathcal{W}_{H,t} \equiv E_t\Big\{\sum_{s=t}^{\infty}\beta_H^{s-t}[(1-\eta)\ln(C_s-\eta C_{s-1})+ j\ln H_{H,s}+h\ln(1-N_s)]\Big\}, \quad (27)$$

$$\mathcal{W}_{E,t} \equiv E_t\Big\{\sum_{s=t}^{\infty}\beta_E^{s-t}\ln C_{E,s}\Big\}, \quad (28)$$

$$\mathcal{W}_{B,t} \equiv E_t\Big\{\sum_{s=t}^{\infty}\beta_B^{s-t}\ln C_{B,s}\Big\}. \quad (29)$$

We write each welfare criterion in recursive form:

$$\mathcal{W}_{H,t} = (1-\eta)\ln(C_t-\eta C_{t-1})+j\ln H_{H,t}+ h\ln(1-N_1)+\beta_H E_t(\mathcal{W}_{H,t+1}), \quad (30)$$

$$\mathcal{W}_{E,t} = \ln C_{E,t}+\beta_E E_t(\mathcal{W}_{E,t+1}), \quad (31)$$

$$\mathcal{W}_{B,t} = \ln C_{B,t}+\beta_B E_t(\mathcal{W}_{B,t+1}). \quad (32)$$

We use Eqs. (30)-(32) to express each welfare criterion as a function of the state variables and the redistribution shock. Then we consider a recession scenario and numerically calculate the value of $\mathcal{W}_{H,t}$, $\mathcal{W}_{E,t}$, and $\mathcal{W}_{H,t}$. In doing these calculations, we take as given the steady-state minimum capital requirement ratio of 12.5% and the realization of the disturbance l_t in Eq. (26) of one standard deviation at period $t = 0$. We consider a range of values for the counter-cyclical coefficient m.

Figure 3 considers values of m ranging from −0.2 to zero. A higher value of the counter-cyclical coefficient m implies less aggressive adjustments of the minimum capital requirement ratio.

The top left panel illustrates the net welfare effects of counter-cyclical minimum capital requirements on households. In the range of values for the counter-cyclical coefficient m from −0.2 to −0.13, the net benefits for households from counter-cyclical minimum capital requirements increase as the value of the counter-cyclical coefficient increases. This is because, as adjustments of the minimum capital requirement ratio become less aggressive, the quantity of real estate held by households increases more sharply. As counter-cyclical minimum capital requirements become less aggressive during a recession, the decline in the credit supply to the production sector becomes more severe. The decline in the credit supply leads to the reduction of the quantity of firms' real estate, which in turn leads to the decline in the real estate prices. Then, as the real estate prices fall more sharply, the demand for real estate in the unproductive sector (i.e., household sector) increases.

When the counter-cyclical coefficient is more than −0.12, the net benefits for households decrease as the value of the counter-cyclical coefficient increases. The reason is that the

benefits from counter-cyclical minimum capital requirements of moderating the contraction of households' consumption decrease as adjustments of the minimum capital requirement ratio become less aggressive.

In addition, a higher value of counter-cyclical coefficient makes counter-cyclical minimum capital requirements less effective to stabilize the fall in entrepreneurs' profits. The top right panel of figure ¥ref{figwel} shows how the benefits for entrepreneurs from counter-cyclical minimum capital requirements decrease as the counter-cyclical coefficient increases.

The bottom left panel of figure 3 illustrates that the benefits for bankers from counter-cyclical minimum capital requirements decrease with the increase in the value of counter-cyclical coefficient. A higher value of counter-cyclical coefficient makes minimum capital requirements on financial intermediaries being more tight during a recession. Thus, intermediaries decrease dividend payments more in the

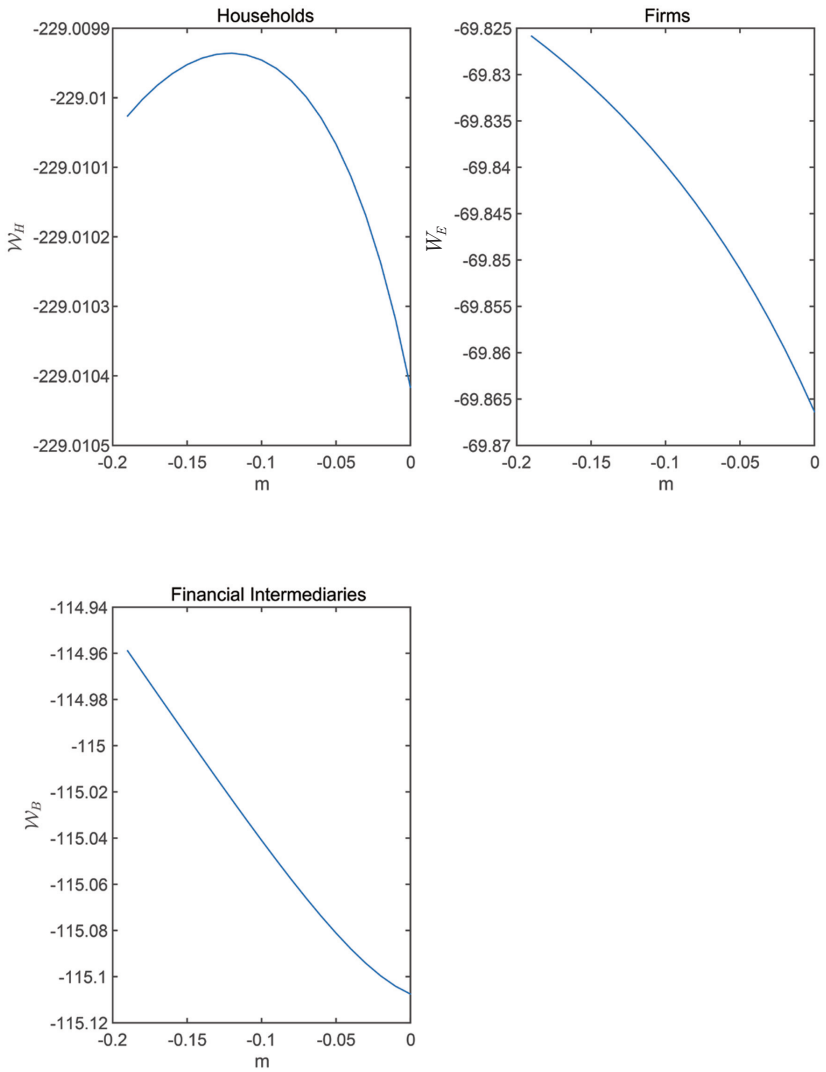

Figure 3: Welfare effects for different values of the counter-cyclical coefficient on households, entrepreneurs, and bankers. *Note*: Each variable is shown at its level.

wake of the redistribution shock as the value of counter-cyclical coefficient becomes higher.

4. Taxation on capital distributions

Within the model economy, there is a motive for a scheme that discourages financial intermediaries from paying dividends to their managers during a recession. As we noted earlier, intermediaries distribute their capital to smooth the decline in dividend payments when a redistribution shock occurs. If intermediaries reduce dividend payments more, their capital is more retained, thus dampening the decline in supply of funds to the production sector of the economy. However, individual intermediary does not take account of this fact when it chooses its dividend payments.

We now proceed to illustrate the effects of a scheme that works to lower incentive of financial intermediaries to distribute their capital during a recession. In particular, we suppose that the government imposes tax of τ_1 per unit of dividend payments of intermediaries and offers them a lump sum subsidy of T_t.
The capital of a representative intermediary is now given by

$$Cap_t = R_{L,t}L_{t-1} - R_{t-1}D_{t-1} - (1+\tau_t)C_{B,t} - ac_{B,t} + T_t - \varepsilon_t, \qquad (33)$$

where the intermediary takes τ_1 and T_t as given. We suppose that the government fully finances the aggregate lump sum subsidy with total tax revenues in order that the net effect of the tax scheme on capital of intermediaries is zero. This tax scheme, however, lowers the attractiveness to the intermediary of paying dividends to its manager.

Furthermore, we suppose that the tax rate τ_1 is set equal to zero in the steady state and varies in response to the change in the capital-to-asset ratio of a representative financial intermediary, according to the following taxation rule:

$$\tau_t = \rho\left[\frac{Cap_t}{L_t} - (1-\gamma)\right], \text{ with } \rho < 0 \qquad (34)$$

where ρ is the feedback coefficient. Eq. (34) states that the government imposes tax on divided payments of the intermediary only when its capital-to-asset ratio goes below its steady-state value, namely the feedback parameter ρ is negative.

The tax scheme which we consider has something in common with the capital distribution constraints, which is introduced in the macro-prudential capital requirement regimes of Basel III reforms.[7] The tax scheme reduces dividend payments of an intermediary only when its capital-to-asset ratio falls below its steady-state value. In this respect, it works as capital distribution constraints.

In Figure 4, we then re-consider the effects of counter-cyclical capital requirement regulations, but in this time, the government imposes tax on dividend payments of financial intermediaries during the recession.[8] We choose the value of the feedback coefficient ρ in the taxation rule (34) of -200. Note that introducing the tax scheme significantly enhances the stabilizing effects of counter-cyclical capital requirement regulations on the declines in the aggregate supply of credit, aggregate investment, and household consumption. In particular, the moderate adjustments of the capital requirement ratio with m of -0.1 (shown by solid line) with the tax scheme moderate the downturn more than the aggressive adjustments without the tax scheme do (shown by dashed line). In case that the tax scheme is in place, financial intermediaries use more capital not for smoothing the decline in dividend payments but for supplying funds to firms than they do in the case without the tax scheme.

In this instance, the tax scheme significantly changes the dynamics of the aggregate output. When the government taxes dividend payments, output drops more initially than when the government does not, although output recovers more quickly. The sharp fall in dividend payments leads to the rapid decline in the demand for final goods in financial sector, which

in turn leads to the initial decline in output. Because the wage rate falls due to the fall in output, households reduce supply of labor and increase consumption during the initial period of the recession. Since the tax scheme enhances the stabilizing effects of counter-cyclical capital requirement regulations on the declines in the aggregate investment, the quantity of output returns to its steady-state value more quickly than when the government does not tax divi-

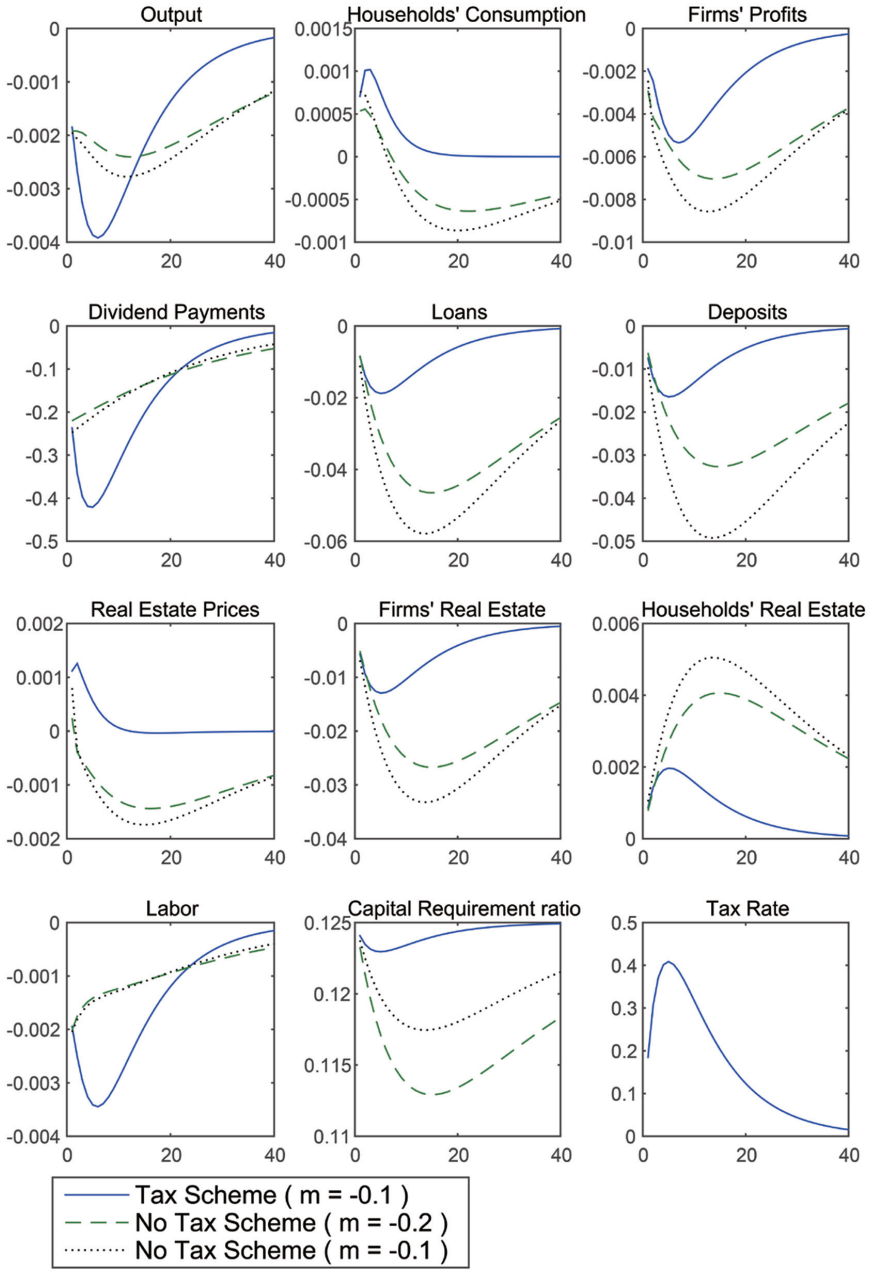

Figure 4: Impulse responses to a redistribution shock in a model with the tax scheme and without it. *Note*: Each variable is shown in log-deviations from its steady-state value except for the capital requirement ratio and the tax rate, which are shown at their level.

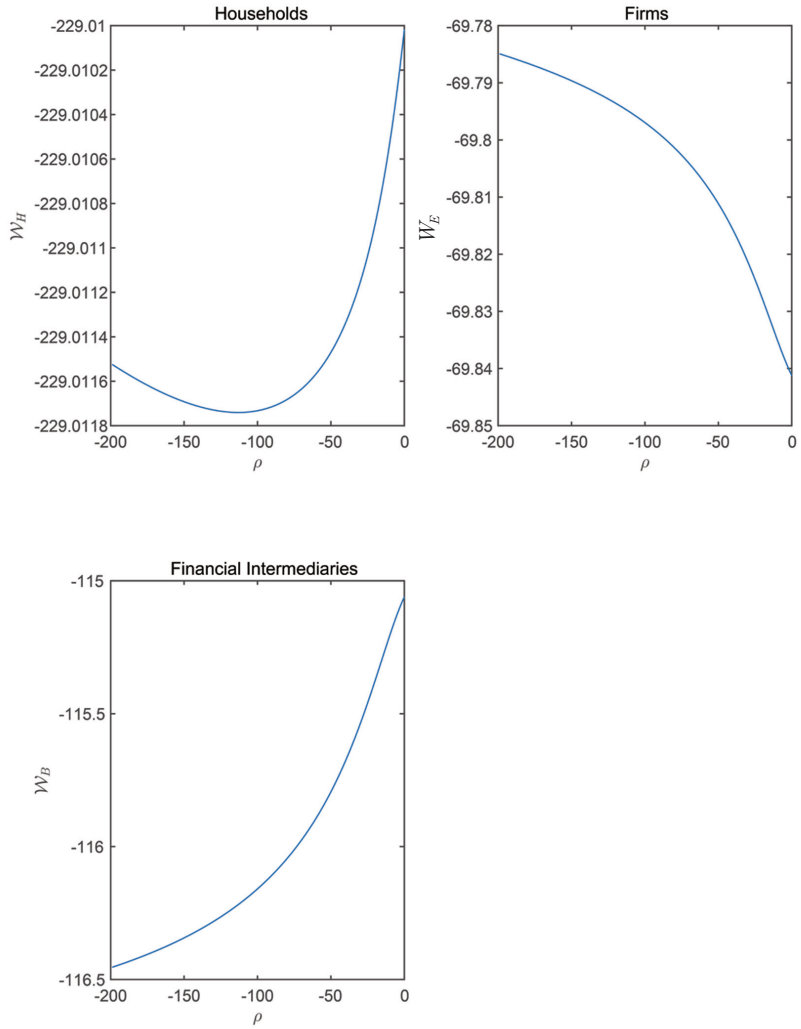

Figure 5: Welfare effects for different values of the feedback coefficient on households, entrepreneurs, and bankers. *Note*: Each variable is shown at its level.

dend payments.

Figure 5 presents the welfare effects of the tax scheme on households, entrepreneurs, and bankers. We take as given the counter-cyclical minimum capital requirement rule (with the counter-cyclical coefficient of -0.1) for setting the minimum capital requirement ratios. The figure considers the values of the feedback coefficient ρ ranging from -200 to zero. A higher value of the feedback coefficient implies less aggressive adjustments of the tax rate.

As indicated in the bottom left panel of figure 5, the tax scheme has negative welfare effects on bankers since it discourages financial intermediaries from paying dividends to their bankers during a recession. The top right panel shows that the benefits for entrepreneurs from the tax scheme of moderating the fall in their profits decrease as the feedback coefficient increases. The top left panel shows the net welfare effects of the tax scheme on households. In the range of values for the feedback coefficient from -200 to -95, the net benefits for households from the tax scheme decrease as

the value of the feedback coefficient increases. The reason is that the benefits from the tax scheme of moderating the contraction of households' consumption decrease as adjustments of the tax rate become less aggressive. When the feedback coefficient is more than −94, the net benefits for households increase as the value of the coefficient increases. This is because, as adjustments of the tax rate become less aggressive, the quantity of real estate held by households increase more sharply.

5. Credit demand shocks

In order to gain some more insight about stabilizing effects of time-varying minimum capital requirements on the economy, we now consider a shock to the productivity of the entrepreneurial sector. Such a shock can serve as a proxy for a credit demand shock. In particular, we modify Eq. (6) to include the productivity of the entrepreneurial sector as follows:

$$Y_t = A_t H_{E,t-1}^{v} N_t^{1-v}, \tag{35}$$

where A_t denotes aggregate productivity. Following Iacoviello (2015), the stochastic process for the aggregate productivity is given by

$$\ln A_t = 0.98 \ln A_{t-1} - \iota_{At}, \tag{36}$$

where ι_{At} is distributed $N(0, \sigma_A)$, and $\sigma_A = 0.007$.

Figure 6 illustrates the effects of a shock to the productivity of the entrepreneurial sector. The productivity shock is the realization of the disturbance ι_{At} in Eq. (36) of one standard deviation at period $t = 0$, namely the negative productivity shock. The solid line gives the responses of the model economy. We choose the following parameters of minimum capital requirement regulations: the steady-state minimum capital requirement ratio of 12.5%; and the counter-cyclical coefficient m in the capital requirement rule (21) of −0.1. For comparison, the dashed line gives the responses of the same model except that the minimum capital requirement ratio is constant and equals to 12.5% through the time. In the numerical calculation of this section, we do not consider the tax scheme which we considered in the previous section.

The negative productivity shock induces the decline in labor demand, which in turn leads to the decline in households' wage income, and their demand for real estate shrinks. Then, because of the decline in households' demand for real estate, the prices of real estate fall. This leads to the reduction of credit demand because firms cannot borrow more than a fraction of the value of real estate that they own. Since the amount of deposits that intermediaries can obtain is limited by the amount of their lending, the negative productivity shock also reduces the equilibrium quantity of deposits.

The key point to note is that the slowdown in the aggregate output—the denominator of the credit-to-GDP ratio—increases the minimum capital requirement ratio above its steady-state value during the recession when counter-cyclical minimum capital requirements are in place. In this instance, the increase in the minimum capital requirement ratio tightens the constraints on financial intermediaries. In order to loosen the constraints and to obtain deposits, which intermediaries can partly transfer to their owners as dividend payments, they supply credit more than when counter-cyclical minimum capital requirements are not in place.[9] Although the contraction in lending is slightly mitigated by the increase in the minimum capital requirement ratio, this does not lead to the significant increase in aggregate investment and recovery of output. Thus, the time-varying minimum capital requirement rule, which responds to the credit-to-GDP ratio, does not work to mitigate a recession which is triggered by a negative productivity shock.[10]

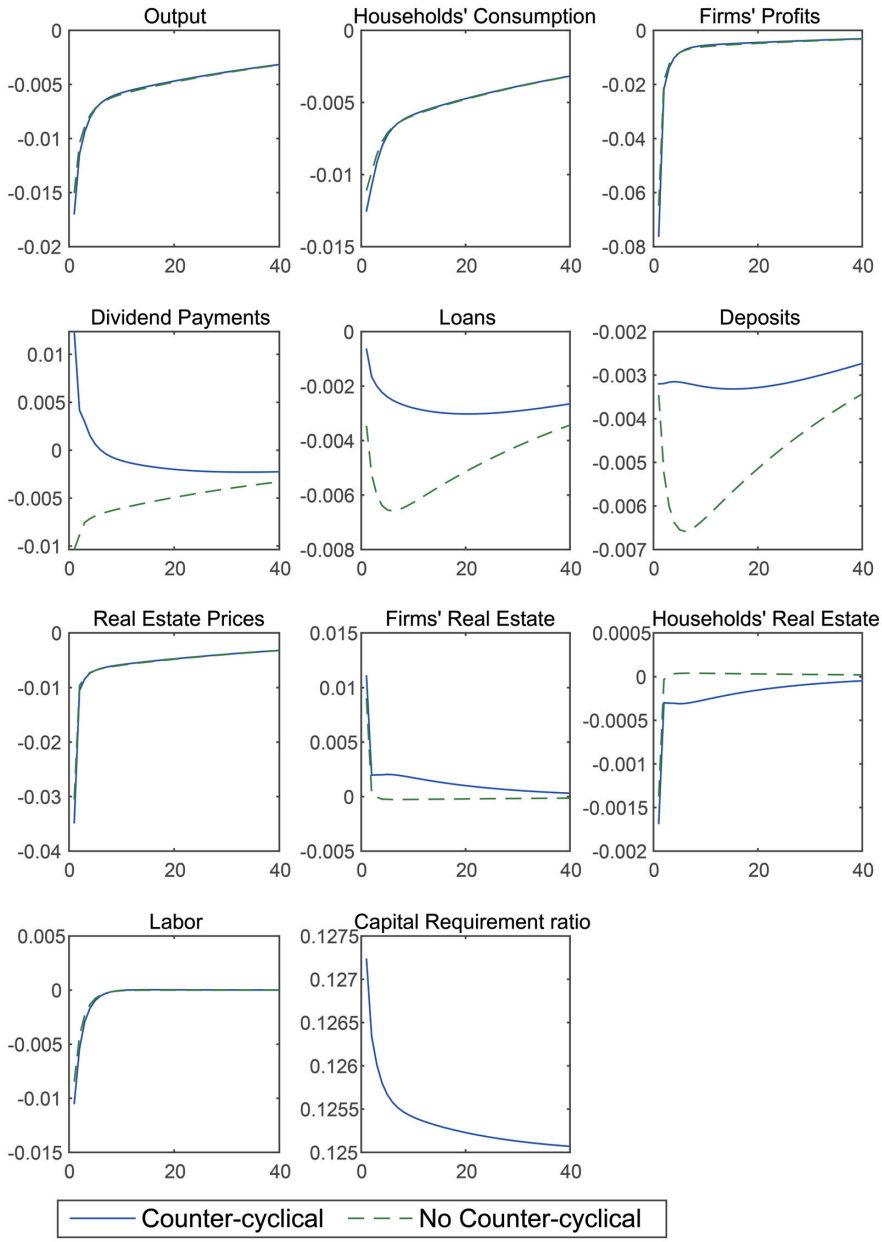

Figure 6: Impulse responses to a productivity shock. *Note*: Each variable is shown in log-deviations from its steady-state value except for the capital requirement ratio, which is shown at its level.

Ⅳ. Conclusions

We consider a DSGE model in which financial intermediaries are subject to time-varying minimum capital requirement constraints. We then use the model to assess how heightened and time-varying minimum capital requirements affect the financial sector and the economy during a recession. As existing literature argues, minimum capital requirement constraints on intermediaries tighten during a recession, preventing intermediaries from

supplying funds to the production sector of the economy. The government then can relax the constraints by lowering the minimum capital requirement ratio. However, the counter-cyclical minimum capital requirement regime enables financial intermediaries to distribute more capital to their owners during a recession than in the time-invariant regime. Our simulation results show that a taxing scheme that works to lower incentives of intermediaries to distribute capital significantly enhances the stabilizing effects of counter-cyclical minimum capital requirements when a recession is triggered by a negative shock to capital of financial intermediaries. This evidence partly provides support for counter-cyclical capital buffer regulations with capital distribution constraints in macro-prudential capital requirement regimes introduced in Basel III reforms.

We also illustrate how counter-cyclical minimum capital requirements stabilize credit and output fluctuations triggered by a negative productivity shock to entrepreneurial sector. The counter-cyclical minimum capital requirement rule, which responds to the credit-to-GDP ratio, does not work to mitigate a recession because the slowdown in the aggregate output－the denominator of the credit-to-GDP ratio－increases the minimum capital requirement ratio during a recession. This result suggests that improvements are required to the current macro-prudential regimes.

Within our framework, capital requirement constraints on financial intermediaries are always binding through the time with reasonable parameters. Thus, we do not consider precautionary motives of intermediaries to hold more capital than regulatory minimum for future losses. In subsequent work, we plan to model the precautionary motives by considering a risk-adjusted steady state and/or occasionally binding constraints in the spirit of (2012) and Brzoza-Brzezina et al (2015).

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Notes

1) See BCBS (2010b), BCBS (2010), and BCBS (2011) for details of macro-prudential capital requirement regimes in Basel III.
2) Clancy and Merola (2017) survey much of this work.
3) See also Iacoviello (2005) for details of the model of this study.
4) For habit formation, see for example Christiano et al (2005) and Smets and Wouters (2007).
5) Under our parameter values, capital requirement constraints on intermediaries are always binding in neighborhood of the steady state.
6) For details of the credit-to-GDP ratio as a indicator for setting counter-cyclical capital regulations, see for example Jokivuolle et al (2015).
7) See BCBS (2011) for details of capital distribution constraints proposed in Basel III
8) The solid line shows the responses with the counter-cyclical coefficient m of -0.1 and with the feedback coefficient ρ in the taxation rule (34) of -200. For comparison, we also plot the instances of the economy without the tax scheme. The dashed line shows the responses with m of -0.2, and the dotted line shows the responses with m of -0.1.
9) Financial intermediaries also use newly obtained deposits to make loans to firms. This further enables intermediaries to obtain deposits.
10) The taxation rule which we considered in the previous section also does not work to mitigate a recession in this instance. The reason is intuitive: the tax rate does not increase above zero because the government does not lower the minimum capital requirement ratio.

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