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Macroeconomic Influences of Counter-cyclical Capital Regulation Rules in a DSGE Model

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ABSTRACT

In the countercyclical capital buffer regime of the Basel III framework, the credit-to-GDP ratio is proposed as a guide to adjusting capital requirements. To date, the effectiveness of the credit-to-GDP guide has not been fully comprehended. We assess the effectiveness of the credit-to-GDP ratio as a guide to implementing counter-cyclical capital requirements by using a simple macroeconomic model. We show the results that the credit-to-GDP ratio is not an effective guide during a recession. A slowdown in aggregate output—the denominator of the credit-to-GDP ratio — requires the authorities to return the capital requirements near to its level in normal times even though the economy is still in a recession. This limits improvement in the supply of funds to the production sector and subsequently leads to an adverse reaction in real economic activity. The results imply possible drawbacks of the countercyclical capital buffer regime.

Key words: Countercyclical capital buffer, Counter-cyclical capital requirements, Basel III, DSGE model

JEL Classification: E32, E44, G28

1. Introduction

In order to address a lesson from the global financial crisis of 2007–2009, the Basel Committee on Banking Supervision (BCBS) proposed a new international regulatory framework for banks. The new framework is called Basel III. There have been a lot of major changes to the Basel III framework from the Basel II framework. Among these major changes, in this study, we focus on a capital requirement regime which is called “countercyclical capital buffer”. Under the countercyclical capital buffer regime, banks are required to build capital as a buffer against future potential losses. Then, financial regulatory authorities lower capital requirements when the entire banking sector incurs losses of bank capital.

As a guide to making decisions on adjustments to capital requirements, deviations of the credit-to-GDP ratio from its long-term trend are proposed in the countercyclical capital buffer regime. To date, there has been no consensus on the effectiveness of the credit-to-GDP ratio as a guide to implementing counter-cyclical capital requirements. The goal of this study is to contribute to filling this gap.[1]

There is a recent theoretical literature which assesses how the counter-cyclical capital requirements mitigate a recession triggered by a credit crunch. Instead of the credit-to-GDP ratio, much of it consider other indicators as a guide to implementing counter-cyclical capital requirements, such as the aggregate amount of credit, aggregate output, and any exogenous shocks to the economy (e.g., Benes & Kumhof, 2015; Karmakar, 2016; Tayler & Zilberman, 2016). Although others such as Angelini et al. (2014) and Clancy & Merola (2017) consider the credit-to-GDP guide, the mechanism of its effectiveness has not been fully explained.

In this study, we assess the effectiveness of the credit-to-GDP ratio as a guide to implementing counter-cyclical capital requirements by using a simple macroeconomic model. The first main contribution of this study is to show the results that the credit-to-GDP ratio is not an effective guide to implementing counter-cyclical capital requirements during a recession triggered by a credit crunch. The authorities can initially mitigate a credit crunch and a subsequent recession by lowering the capital requirements in response to a fall in the credit-to-GDP ratio. By lowering the capital requirements, the authorities can prevent capital requirements from limiting the aggregate supply of funds during a recession. However, when the authorities use the credit-to-GDP ratio as a guide to adjustments to capital requirements, a slowdown in aggregate output—the denominator of the credit-to-GDP ratio—requires the authorities to return the capital requirements near to its level in normal times even though the economy is still in a recession. This limits improvement in the aggregate supply of funds and subsequently leads to an adverse reaction in both aggregate investment and aggregate output.

Much of a theoretical literature in capital requirements suppose counter-cyclical capital requirements for the accumulated retained earnings of banks (e.g., Bekiros et al., 2018; Garcia-Barragan & Liu, 2018; Rubio & Carrasco-Gallego, 2016). However, banks can build not only by conserving internally generated capital but also by raising new capital from the private sector in the equity market. With this background in mind, the second main contribution of this study is methodological: we consider counter-cyclical capital requirements for outside equity of banks.

We employ a macroeconomic framework developed by Gertler et al. (2012), which allows us to address how counter-cyclical capital requirements for outside equity of banks mitigate a recession triggered by a credit crunch in a simple setting. The framework of this study has four main elements. First, the amount of funds which each bank can supply to the production sector is determined by the amount of accumulated retained earnings. This implies that an exogenous decline in earnings on assets of each bank leads to a fall in the aggregate supply of funds to the production sector (i.e., credit crunch).

Second, outside equity of each bank acts as a buffer against fluctuations in earnings on its assets. If the entire banking sector has more buffers against fluctuations in earnings on assets of banks, fluctuations in the aggregate supply of funds are even more dampened. This motivates financial regulatory authorities to implement capital requirements for outside equity.

Third, capital requirements decrease the amount of funds which each bank can intermediate because outside equity issuance is costly for each bank, that is, there is also the cost of implementing capital requirements (see also Angeloni & Faia, 2013; Repullo & Suarez, 2013; Iacoviello, 2015, for the details of pro-cyclicality of capital requirements). This is a rationale for counter-cyclical capital requirements for outside equity: financial regulatory authorities lower capital requirements once a credit crunch occurs in order to prevent capital requirements from limiting the supply of funds by each bank.

1.1. Related literature

As a guide to implementing counter-cyclical capital requirements, Benes & Kumhof (2015) consider aggregate credit, and Karmakar (2016) considers aggregate output. The macroeconomic framework in Tayler & Zilberman (2016) assumes that counter-cyclical capital requirements respond to several exogenous shocks. We differ from them by considering the credit-to-GDP ratio as a guide to implementing counter-cyclical capital requirements.

Others such as Angelini et al. (2014) and Clancy & Merola (2017) consider the credit-to-GDP ratio as a guide to implementing counter-cyclical capital requirements, and argue that counter-cyclical capital requirements have the stabilization effect on a credit crunch and subsequent contraction in real economic activity. Is the credit-to-GDP ratio an effective guide to implementing counter-cyclical capital requirements in any situation? We differ from them by showing that the credit-to-GDP ratio is not an effective guide to adjusting capital requirements during a recession.

The most related literature is Gertler et al. (2012) and Liu (2016). They argue that a subsidy scheme, which provides a subsidy per unit of equity issued to banks, mitigates the severity of a financial crisis. This is because the subsidy scheme motivates banks to issue outside equity, which works as a buffer against losses of retained earnings of banks. How do counter-cyclical capital requirements for outside equity affect the financial sector and the economy? We differ from them by considering counter-cyclical capital requirements for outside equity instead of the subsidy scheme.

2. Model

In this section, we explain the macroeconomic framework of this study. We employ a DSGE model developed by Gertler et al. (2012). They consider the two types of government policies: large-scale asset purchases during a crisis, and a scheme to subsidize the issue of outside equity by banks. Following their framework, we consider counter-cyclical capital requirements instead of those two policies.

Consider a closed economy comprised of five types of agents: households, goods-producing firms, capital-producing firms, financial intermediaries, and a government. The time sequence is expressed as an infinite sequence of discrete periods $t = 0, 1, 2, \cdots$. We describe each element of the model below.

2.1. Household sector

There is a unit-measure continuum of identical households. Each household consumes goods, saves, and supplies labor.

Within a household, there are two types of members: the fraction $1 - f$ of members of the household are "workers" and the remaining fraction f of them are "bankers". Worker supply labor and give wages which they earn to the household. Each banker manages a financial intermediary (i.e., the household owns intermediaries which its bankers manage).

A banker exits and becomes a worker next period with i.i.d. probability $1 - \sigma$. Every period a number of workers of a household randomly become bankers, keeping the relative proportion of workers to bankers in the household fixed. A banker who exits gives retained earnings of its financial intermediary to its household. A new banker, though, receives "start-up" funds from its household as we describe later.

Let C_t be consumption of a representative household at any period t and L_t be household labor hours. Then the preference of the household at any period t is given by

$$\mathcal{U}_t = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{1}{1-\gamma}\left(C_\tau - hC_{\tau-1} - \frac{\chi}{1+\varphi} L_\tau^{1+\varphi}\right)^{1-\gamma}, \tag{1}$$

with $\gamma > 0$, $0 < \beta < 1$, $0 < h < 1$, $\chi > 0$ and $\varphi > 0$. E_t is the expectation operator conditional information at period t, β is the discount factor, h determines habit formation in the consumption-preference of the household, χ is the utility weight of labor and φ determines the elasticity of household labor supply.

The household saves by acquiring non-contingent riskless short term debt which financial intermediaries offer (hereinafter, this is referred to as deposits). Deposits are one period real bonds and pay the gross real rate of return R_t from period $t-1$ to t. The household saves also by acquiring outside equity which intermediaries issue. Each unit of outside equity issued by an intermediary is a claim to the future returns of one unit of the assets which the intermediary holds.

Let D_t be the quantity of deposits which the household acquires, q_t be the price of outside equity, e_t be the quantity of outside equity, W_t be the real wage rate, R_{et} be the gross real rate of return on outside equity. Then the flow-of-funds constraint of the household is given by

$$C_t + D_t + q_t e_t = W_t L_t + \Pi_t - T_t + R_t D_{t-1} + R_{et} e_{t-1}, \tag{2}$$

where T_t is lump sum taxes and Π_t is the net distributions to the household from ownership of financial intermediaries and capital-producing firms.

The household chooses labor hours and consumption/saving to maximize expected discounted utility (1) subject to the flow-of-funds constraint (2). The first order condition for labor hours of the household is given by

$$E_t\left(u_{C_t}\right) W_t = \chi L_t^{\varphi}\left(C_t - hC_{t-1} - \frac{\chi}{1+\varphi} L_t^{1+\varphi}\right)^{-\gamma}, \tag{3}$$

with

$$u_{C_t} \equiv \left(C_t - hC_{t-1} - \frac{\chi}{1+\varphi} L_t^{1+\varphi}\right)^{-\gamma} - \beta h\left(C_{t+1} - hC_t - \frac{\chi}{1+\varphi} L_{t+1}^{1+\varphi}\right)^{-\gamma}.$$

Let $\Lambda_{t,t+1}$ be the stochastic discount factor of the household. Then the first order conditions for consumption/saving are given by

$$E_t(\Lambda_{t,t+1})R_{t+1} = 1, \tag{4}$$

$$E_t(\Lambda_{t,t+1}R_{et+1}) = 1, \tag{5}$$

with

$$\Lambda_{t,t+1} \equiv \beta \frac{u_{C_{t+1}}}{u_{C_t}}. \tag{6}$$

Aggregation

Since the mass of the continuum of households is unity, we regard C_t, D_t, and T_t as aggregate household consumption, aggregate deposits, and aggregate lump sum taxes respectively.

2.2. Goods-producing sector

There is a unit-measure continuum of identical goods-producing firms. Each goods-producing firm produces goods and supplies output to households and capital-producing firms.

The representative goods-producing firm produces goods, using physical capital and labor. Let Y_t denote output, A_t denote total factor productivity and K_t denote physical capital. Then output of the goods-producing firm is expressed as a function of physical capital and labor hours, L_t, as

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{7}$$

with $0 < \alpha < 1$.

Optimal labor input has to satisfy the following condition:

$$W_t = (1-\alpha)\frac{Y_t}{L_t}. \tag{8}$$

Let Z_t be gross profits per unit of physical capital. Eq. (8) implies that gross profits per unit of capital are expressed as follows:

$$Z_t = \alpha A_t \left(\frac{L_t}{K_t}\right)^{1-\alpha}. \tag{9}$$

Let I_t be investment and S_t be the stock of physical capital "in process" at period t for $t + 1$.

The stock of physical capital in process for $t + 1$ is defined as the sum of investment at period t and the stock of undepreciated physical capital:

$$S_t = (1 - \delta)K_t + I_t, \tag{10}$$

where δ is the rate of depreciation of physical capital.

Let ψ_t be a multiplicative shock to the stock of physical capital, which follows a stochastic process with an unconditional mean of unity (hereinafter, this is referred to as capital shock). After the realization of a capital shock, the stock of physical capital at period t for $t + 1$ is transformed into physical capital for production at $t + 1$:

$$K_{t+1} = \psi_{t+1} S_t . \tag{11}$$

The goods-producing firm obtain funds for investment from a financial intermediary by issuing new state-contingent securities. Each unit of the security is a claim to the future returns from one unit of investment. The goods-producing firm issues claims equal to the number of units of capital acquired. In equilibrium, the price of the security at any period t is equal to the price of capital which is created at t.

Aggregation

Since the mass of the continuum of goods-producing firms is unity, we regard Y_t, K_t, L_t and S_t as aggregate output, aggregate physical capital, aggregate labor hours, aggregate physical capital in process respectively.

2.3. Capital-producing sector

There is a unit-measure continuum of identical capital-producing firms. Capital-producing firms produce new physical capital, using output of goods-producing firms.

There are adjustment costs associated with the production of new physical capital. Let Q_t be the price of new physical capital and $f\,(I_t/I_{t-1})$ denote adjustment costs in the rate of change in production. Then discounted profits for the representative capital-producing firm are given by

$$E_t \sum_{\tau = t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau I_\tau - \left[1 + f\left(\frac{I_\tau}{I_{\tau - 1}} \right) \right] I_\tau \right\}, \tag{12}$$

where

$$f\left(\frac{I_t}{I_{t-1}}\right) = \frac{\eta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2.$$

$\Lambda_{t,t+1}$ is the stochastic discount factor of the representative household and I_t is physical capital created at period t. The optimal production has to satisfy the following condition:

$$Q_t = 1 + \frac{\eta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 + \frac{I_t}{I_{t-1}}\eta\left(\frac{I_t}{I_{t-1}} - 1\right) - E_t\left[\Lambda_{t,t+1}\left(\frac{I_{t+1}}{I_t}\right)^2\eta\left(\frac{I_{t+1}}{I_t} - 1\right)\right]. \tag{13}$$

Aggregation

Since the mass of the continuum of capital-producing firms is unity, we regard I_t as the aggregate amount of new physical capital (i.e., aggregate investment).

2.4. Financial sector

There is a unit-measure continuum of identical financial intermediaries. Financial intermediaries supply funds which are obtained from households to goods-producing firms.

Let s_t be the quantity of securities issued by goods-producing firms and held by a representative financial intermediary, n_t be accumulated retained earnings of the intermediary (hereinafter, this is referred to as net worth), and d_t is deposits which the intermediary obtains from households. Then the flow-of-funds constraint of the intermediary is given by

$$Q_t s_t = n_t + q_t e_t + d_t, \tag{14}$$

where Q_t is the price of securities, q_t is the price of outside equity, e_t is the quantity of outside equity issued by the intermediary.

Let R_{kt} denote the gross rate of return on a unit of the assets of the financial intermediary from period $t-1$ to t. Then the net worth of the intermediary evolves as follows:

$$n_t = R_{kt}Q_{t-1}s_{t-1} - R_{et}q_{t-1}e_{t-1} - R_t d_{t-1}, \tag{15}$$

with

$$R_{kt} = \frac{[Z_t + (1-\delta)Q_t]\psi_t}{Q_{t-1}}, \tag{16}$$

$$R_{et} = \frac{[Z_t + (1-\delta)q_t]\psi_t}{q_{t-1}}. \tag{17}$$

R_{et} denotes the gross rate of return on a unit of outside equity from period $t-1$ to t. Eq. (15) implies that outside equity acts as a buffer against the effect of fluctuations in the return on the assets of the intermediary on its net worth.

The objective of a banker who manages the financial intermediary is to maximize the expected present value of the future terminal net worth, which is given by

$$E_t\left[\sum_{\tau=t+1}^{\infty}(1-\sigma)\sigma^{\tau-t-1}\Lambda_{t,\tau}n_\tau\right],$$

where $\Lambda_{t,t+1}$ is the stochastic discount factor of the representative household.

There is an agency problem between the financial intermediary and its depositors. Specifically, after the financial intermediary acquire securities issued by goods-producing firms, the banker can choose to divert the fraction Θ_t of the assets of the intermediary and to transfer them to the household of which he/she is a member, where Θ_t is given by

$$\Theta_t = \theta\left[1 + \varepsilon\frac{q_t e_t}{Q_t s_t} + \frac{\kappa}{2}\left(\frac{q_t e_t}{Q_t s_t}\right)^2\right], \tag{18}$$

with $\theta\ [\varepsilon + \kappa\ (q_t e_t/Q_t s_t)] > 0$. Here, at the margin, the fraction of the assets of the intermediary which the banker can divert depends positively on the fraction of its assets funded by outside equity; that is, it is easier to divert its assets funded by outside equity than by deposits. This is because outside equity issuance weakens the governance of the intermediary and aggravates the agency problem. (see Gertler et al. (2012) for details of the adverse effect of outside equity issuance on the governance of a financial intermediary).

If the banker diverts the assets of the intermediary, it is shut down. We consider an equilibrium where the banker does not choose to divert the assets of the financial intermediary. Let $V_t\ (s_t, e_t, d_t)$ be the maximized value of the expected present value of the future terminal net worth of the banker, given an asset, liability and outside equity configuration at the end of period t. Then the following incentive constraint must be satisfied:

$$V_t(s_t, e_t, d_t) \geq \Theta_t Q_t s_t. \tag{19}$$

The incentive constraint implies that what the banker loses by diverting the assets of the intermediary must be at least as large as his/her gain from doing so.

We can express $V_t\,(s_t, e_t, d_t)$ as follows:

$$V_t(s_t, e_t, d_t) = v_{st}s_t - v_{et}e_t - v_t d_t, \tag{20}$$

where v_{st}, v_{et} and v_t are determined endogenously as we explain detailed derivation in Appendix A.

We consider two cases which provide insight of the workings of the model. In case 1, financial intermediaries do not face capital requirements and bankers choose outside equity issuance to maximize expected present value of their respective future terminal net worth. In case 2, financial intermediaries are subject to capital requirements and issue outside equity to satisfy them. Next, we characterize each of the cases.

2.4.1 Case 1: No capital requirements

When financial intermediaries are not subject to any capital requirements, the financial intermediary chooses outside equity issuance and holding of securities to maximize expected present value of its future terminal net worth subject to the flow-of-funds constraint (14) and the evolution of net worth (15).

Let λ_t be the Lagrangian multiplier for the incentive constraint (19). The optimal holding of securities must satisfy the following condition:

$$(1 + \lambda_t)\left(\frac{v_{st}}{Q_t} - v_t\right) = \theta\left[1 - \frac{\kappa}{2}\left(\frac{q_t e_t}{Q_t s_t}\right)^2\right]\lambda_t, \tag{21}$$

where

$$v_{st} = E_t\left\{\Lambda_{t,t+1}\Omega_{t+1}\left[Z_{t+1} + (1-\delta)Q_{t+1}\right]\psi_{t+1}\right\}, \tag{22}$$

$$v_t = E_t\left(\Lambda_{t,t+1}\Omega_{t+1}\right)R_{t+1}, \tag{23}$$

$$\Omega_{t+1} \equiv (1-\sigma) + \sigma\left(1 + \lambda_{t+1}\right)v_{t+1}\,.$$

The optimal issuance of outside equity must satisfy the following condition:

$$(1+\lambda_t)\left(v_t - \frac{v_{et}}{q_t}\right)q_t = \theta\left(\varepsilon q_t + \kappa \frac{q_t e_t}{Q_t s_t} q_t\right), \tag{24}$$

where

$$v_{et} = E_t\left\{\Lambda_{t,t+1}\Omega_{t+1}\left[Z_{t+1} + (1-\delta)q_{t+1}\right]\psi_{t+1}\right\}. \tag{25}$$

As we explain in Appendix, when the incentive constraint binds, the total value of funds which the financial intermediary can supply depends on its net worth:

$$Q_t s_t = \phi_t n_t, \tag{26}$$

where

$$\phi_t \equiv \frac{(1+\lambda_t)v_t}{\Theta_t}.$$

As we noted earlier, the variable Θ_t depends positively on the fraction of the assets funded by outside equity at the margin. Therefore, Eq. (26) implies that obtaining additional funds by issuing outside equity lowers the amount of funds which the intermediary can intermediate. This is because outside equity issuance aggravates the agency problem.

2.4.2 Case 2: Capital requirements for outside equity

We now suppose that financial intermediaries are subject to capital requirements for outside equity. Let m_t be the capital requirement ratio, which stipulates regulatory requirement ratios of outside equity to asset of financial intermediaries. Then the financial intermediary must satisfy the following condition (hereinafter, this is referred to as capital requirement constraint) at any period t:

$$\frac{q_t e_t}{Q_t s_t} \geq m_t. \tag{27}$$

The intermediary takes the capital requirement ratio as given. We suppose that the capital requirement constraint (27) binds at every period.

In this instance, the financial intermediary chooses outside equity issuance and holding of securities to maximize expected present value of its future terminal net worth subject to the flow-of-funds constraint (14), the evolution of net worth (15), and the capital requirement constraint (27). The optimal holding of securities now must satisfy the following condition:

$$(1+\lambda_t)\left[\left(\frac{v_{st}}{Q_t}-v_t\right)+\left(v_t-\frac{v_{et}}{q_t}m_t\right)\right]=\theta\left(1+\varepsilon m_t\frac{\kappa}{2}m_t^2\right)\lambda_t, \tag{28}$$

where v_{st}, v_t, and v_{et} are determined by Eq. (22), (23), and (25) respectively. Then, the intermediary issue outside equity to satisfy the capital requirement constraint (27).

The total value of funds which the financial intermediary can intermediate is now determined as follows:

$$Q_t s_t = \phi_t n_t, \tag{29}$$

where

$$\phi_t \equiv \frac{(1+\lambda_t)v_t}{\Theta_t},$$

$$\Theta_t = \theta\left[1+\varepsilon m_t + \frac{\kappa}{2}m_t^2\right], \quad \varepsilon + \kappa m_t > 0\,. \tag{30}$$

Here, the maximum ratio of the assets of the intermediary to its net worth depends negatively on the capital requirement ratio m_t. This implies the cost of capital requirements: to require the intermediary to obtain funds by issuing outside equity aggravates its agency problem, lowering the value of funds which it can intermediate. As will become clear later, this motivates the government to impose counter-cyclical capital requirement for outside equity. Eq. (29) also implies that capital requirements for outside equity effectively determines the ratio of net worth (i.e., inside equity) to asset ratio of the intermediary.

Aggregation

Since the mass of the continuum of financial intermediaries is unity, we regard s_t, e_t and d_t as the aggregate number of assets, aggregate number of outside equity and aggregate deposits respectively (i.e., $d_t = D_t$). In equilibrium, the aggregate number of securities issued by goods-producing firms is equal to the aggregate physical capital in process. Thus, $s_t = S_t$.

Let N_t denote the aggregate net worth in the financial sector. Then the aggregate supply of funds is determined as follows:

$$Q_t S_t = \phi_t N_t, \tag{31}$$

where $\phi_t \equiv [(1 + \lambda_t)\ \nu_t]\ /\Theta_t$. The variable Θ is determined by Eq. (18) when financial intermediaries are not subject to any capital requirements and is determined by Eq. (30) when they are subject to capital requirements.

Let N_{ot} denote the net worth of existing bankers and N_{yt} denote that of entering bankers. Then the aggregate net worth of intermediaries is given by

$$N_t = N_{ot} + N_{yt}\,. \tag{32}$$

We aggregate Eq. (15) and obtain the expression of the net worth of existing bankers as follows:

$$N_{ot} = \sigma\big\{[Z_t + (1-\delta)Q_t]\psi_t S_{t-1} - [Z_t + (1-\delta)q_t]\psi_t e_{t-1} - R_t D_{t-1}\big\}, \tag{33}$$

where σ is the fraction of bankers who stay banker until the current period. Each new banker receive the fraction $\xi/(1-\sigma)$ of the total earnings on assets of existing bankers from respective household. Then, the net worth of new bankers is given by

$$N_{yt} = \xi[Z_t + (1-\delta)Q_t]\psi_t S_{t-1}\,. \tag{34}$$

Thus, the aggregate net worth in the financial sector is now given by

$$N_t = (\sigma + \xi)[Z_t + (1-\delta)Q_t]\psi_t S_{t-1} - \sigma[Z_t + (1-\delta)q_t]\psi_t e_{t-1} - \sigma R_t D_{t-1}\,. \tag{35}$$

2.5. Government sector

When the financial sector has more buffers against fluctuations in aggregate net worth, fluctuations in the aggregate supply of funds are even more dampened. However, each intermediary does not take into account this point when it chooses outside equity issuance (see Gertler et al. (2012)). This motivates the government to impose capital requirements for outside equity.

However, there is the cost of capital requirements: to require each intermediary to issue outside equity aggravates its agency problem, lowering the supply of its funds. This is why the government imposes counter-cyclical capital requirements: once an exogenous shock decreases aggregate net worth, the government lowers the capital requirement ratio in order to prevent capital requirements from limiting the aggregate supply of funds.

We consider two types of rules setting the capital requirement ratio as follows:

$$\text{Credit-to-GDP type rule: } m_t = \bar{m} + \rho_1\left(\frac{Q_t S_t}{Y_t} - \frac{\bar{Q}\bar{S}}{\bar{Y}}\right), \ \ \rho_1 > 0, \tag{36}$$

$$\text{Credit growth type rule: } m_t = \bar{m} + \rho_2\left(\frac{Q_t S_t - \bar{Q}\bar{S}}{\bar{Q}\bar{S}}\right), \ \ \rho_2 > 0, \tag{37}$$

where $\bar{m}$ is the steady-state value of the capital requirement ratio; $\bar{S}$ is the aggregate amount of assets of financial intermediaries in the steady state; $\bar{Q}$ is the steady-state asset price; and $\bar{Y}$ is steady-state aggregate output.

In the credit-to-GDP type rule, the government uses the credit-to-GDP ratio from its long-term trend as a guide to setting the capital requirement ratio. Specifically, the government lowers the capital requirement ratio to less than the steady-state value of it when the credit-to-GDP ratio declines to less than its steady-state value. In the credit growth type rule, the government uses the indicator of the growth in the aggregate supply of funds and the capital requirement ratio is a function of deviations of the aggregate supply of funds from its long-term trend.

Let G be the fixed expenditures of the government. Then, the budget constraint of the government at any period t requires that the fixed government expenditures must be equal to lump-sum taxes on households:

$$G = T_t. \tag{38}$$

2.6. Equilibrium

Market clearing in the goods market requires the following condition:

$$Y_t = C_t + \left[1 + \frac{\eta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t + G. \tag{39}$$

Next, market clearing in the outside equity market requires that the ratio of the aggregate value of outside equity to the aggregate supply of funds must be equal to the capital requirement ratio:

$$\frac{q_t e_t}{Q_t S_t} = m_t \,. \tag{40}$$

Finally, we aggregate the flow-of-funds constraint of financial intermediaries in order to obtain the following market clearing condition for the deposit market:

$$D_t = Q_t S_t - q_t e_t - N_t \,. \tag{41}$$

At any period t, an equilibrium for the economy where financial intermediaries are subject to capital requirements consists of the nine quantities (Y_t, C_t, I_t, L_t, K_t, S_t, D_t, e_t, N_t) and the six prices (W_t, Q_t, q_t, R_t, R_{kt}, R_{et}), which are determined by Eqs. (3), (4), (5), (7), (8), (9), (10), (11), (13), (16), (17), (22), (23), (25), (28), (30), (31), (35), the rule setting the capital requirement ratio ((36) or (37)), (39), (40) and (41), together with the other seven endogenous variables (Z_t, v_t, v_{st}, v_{et}, λ_t, Θ_t, m_t). The equilibrium quantities and prices at any period t are recursively determined as a function of the seven state variables (C_{t-1}, I_{t-1}, S_{t-1}, e_{t-1}, D_{t-1}, ψ_t, A_t). In Appendix B, we explain an equilibrium for the economy where financial intermediaries are not subject to any capital requirements.

3. Model Analysis

In this section, we present a simulation designed to assess the effectiveness of the credit-to-GDP ratio as a guide to implementing counter-cyclical capital requirements.

3.1. Calibration

We need to assign values for 17 parameters. Table 1 reports the parameter values. We use parameter values from Gertler et al. (2012) to obtain values for the following 13 parameters: the parameter of risk aversion γ, the discount factor β, the parameter of habit formation in the consumption-preference h, the utility weight of labor χ, the parameter of the labor supply elasticity φ, the parameter of a capital share α, the depreciation rate of physical capital δ, the parameter of the elasticity of investment to the price of capital η, the survival rate of bankers σ, the parameter of transfer to new bankers ξ, and the parameters of the agency problem of the representative financial intermediary (θ, ε and κ). The capital shock which we suppose in our simulation is an unanticipated one-time 5% decline in the value of the multiplicative shock ψ_0 from its steady-state value (from 1 to 0.95).

The three parameters $\bar{m}$, ρ_1 and ρ_2 are specific to this study. Following Gertler et al. (2012), we set $\bar{m}$ = 0.2, implying that, when each financial intermediary is subject to capital requirements, the fraction of its assets funded by outside equity is approximately 10% higher than that which it

Table 1. Parameter values

Household sector		
γ	2	Parameter of risk aversion
β	0.99	Discount factor
h	0.75	Parameter of habit formation in consumption-preference
χ	0.25	Utility weight of labor
φ	1/3	Inverse labor supply elasticity
Goods-producing sector		
α	0.33	Capital share
δ	0.025	Depreciation rate of physical capital
Capital-producing sector		
η	1	Inverse elasticity of investment to the price of capital
Financial sector		
σ	0.9685	Survival rate of bankers
ξ	0.00289	Parameter of transfer to new bankers
θ	0.264	Parameter of agency problem
ε	–1.21	Parameter of agency problem
κ	13.41	Parameter of agency problem
Government sector		
$\overline{m}$	0.2	Steady-state capital requirement ratio
ρ_1	0.15	Coefficient in the credit-to-GDP type rule
ρ_2	0.87	Coefficient in the credit growth type rule
$\overline{G}/\overline{Y}$	0.2	Parameter of steady-state government expenditures

chooses when it is not subject to capital requirements as will become clear later. There are two targets for choosing the value of the coefficient ρ_1 and that of the coefficient ρ_2: First, we choose both values such that, under both the credit-to-GDP type rule and the credit growth type rule, lowering the capital requirement ratio at the occurrence of a capital shock has the stabilizing effect on the fluctuations in the aggregate supply of funds and real economic activities. Second, the government lowers the capital requirement ratio to the same level under both the credit-to-GDP type rule and the credit growth type rule at the occurrence of a capital shock. Our calibration implies that each financial intermediary has the same amount of outside equity as a buffer of its net worth in the steady state under both rules. Then, at the occurrence of a capital shock, each intermediary can stop building a buffer and lower the fraction of its assets funded by outside equity to the same regulatory level under both rules.

3.2. Steady state

Table 2 shows the values of the main steady-state equilibrium quantities and prices under our calibration. In Appendix C, we explain the details of the steady state of the model economy. We consider not only the equilibrium in the economy where financial intermediaries are subject to capital requirements, but also the equilibrium in the economy where they are not subject to any capital requirements. Note first that, in the former economy, the fraction of the assets of each intermediary funded by outside equity is approximately 10% higher than that in the latter

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

	Capital requirements	No capital requirements
$\bar{Y}$	24.898	25.207
$\bar{C}$	14.320	14.462
$\bar{L}$	8.439	8.518
$\bar{D}$	133.117	162.998
$\bar{N}$	46.028	44.555
$\bar{q}$	1.045	1.039
$\bar{K}$	223.932	228.138
$\bar{R}_k$	1.0117	1.0115
$\bar{q}\,\bar{e}/\bar{Q}\bar{S}$	0.2	0.09
$\bar{N}/\bar{Q}\bar{S}$	0.146	0.132

economy. In addition, capital requirements for outside equity effectively raise the fraction of the assets funded by net worth: the fraction in the former economy is 0.6% higher than that in the latter economy.

Second, because capital requirements limit the aggregate supply of funds to the production sector, implementing capital requirements in the steady state has adverse consequences for real economic activity: aggregate output and household consumption in the former economy are smaller than those in the latter economy.

3.3. Simulation

Figure 1 shows the impulse response of the equilibrium to the capital shock: the solid line shows the response of the equilibrium of the model economy where the government follows the credit-to-GDP type rule to implement capital requirements. The dashed line illustrates the response of the equilibrium of the model economy where in this instance the government follows the credit growth type rule. For comparison, the dotted line gives the response of the model economy where financial intermediaries are not subject to any capital requirements.

The capital shock triggers a recession through the following mechanism: the capital shock decreases earnings on the assets of financial intermediaries, and therefore, their net worth decreases. A decline in net worth of intermediaries limits the amount of funds which they can intermediate. This leads to a contraction in the aggregate demand in the security market, and consequently, the prices of each security decline. Then, a fall in the value of the assets of each intermediary further decreases its net worth. This amplification of the capital shock leads to an overall contraction of real economic activity: a fall in the aggregate supply of funds to the production sector leads to a decline in aggregate investment, which in turn decreases aggregate output and household consumption.

Figure 1 indicates that, when financial intermediaries are not subject to any capital requirements, a fall in the aggregate supply of funds at the beginning of a recession is more

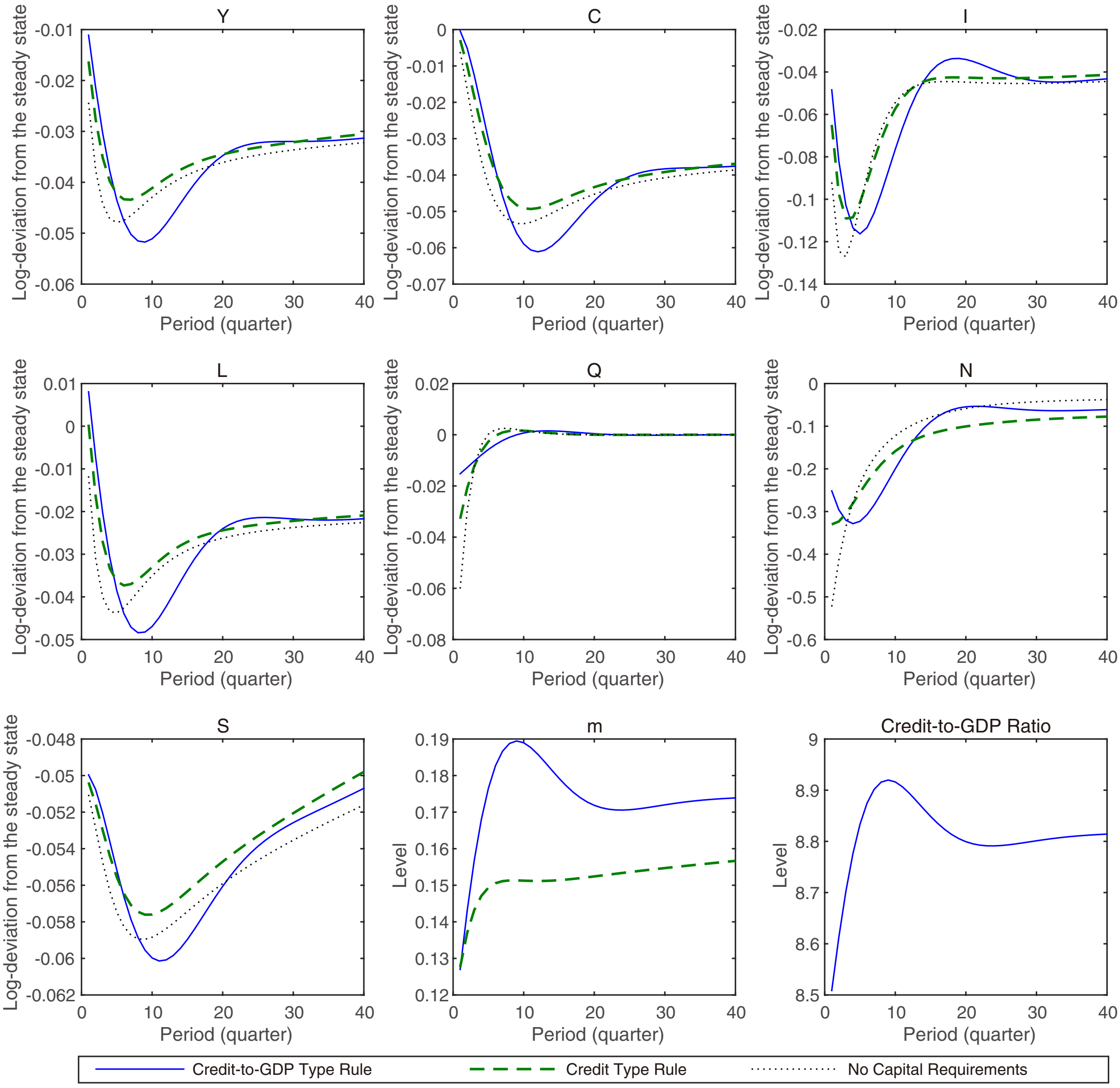

Figure 1.

severe than that in the economy where intermediaries are subject to capital requirements. This is because the financial sector has more buffers against fluctuation in the net worth of intermediaries when they issue outside equity to satisfy capital requirements.

Under the credit growth type rule, the government lowers the capital requirement ratio at the occurrence of the capital shock and keeps the capital requirement ratio low level through a recession. This prevents capital requirements from limiting the aggregate supply of funds, and therefore, mitigates the contraction of real economic activity.

In contrast, the severity of the simulated recession worsens when the government follows the credit-to-GDP type rule to implement capital requirements. Under the credit-to-GDP type rule, a slowdown in aggregate output—the denominator of the credit-to-GDP ratio—requires the government to return the capital requirement ratio near to its steady-state value sooner than does the credit growth type rule. This swift return of the capital requirement ratio under the credit-to-GDP type rule limits the aggregate supply of funds during a recession, which in turn results in slow improvement in the aggregate amount of investment and subsequent sharp downturn in aggregate output and household consumption.

4. Conclusion

Using a simple macroeconomic model, we assess the effectiveness of the credit-to-GDP ratio as a guide to implementing counter-cyclical capital requirements. We suppose that a government uses the credit-to-GDP ratio from its long-term trend as a guide to setting capital requirement ratio, which each financial intermediary must satisfy.

We present the results of a simulation that the government can initially mitigate the contraction of the aggregate supply of funds to the production sector and that of aggregate investment by lowering the capital requirement ratio in response to a fall in the credit-to-GDP ratio. By lowering the capital requirement ratio at the beginning of a recession, the government can prevent capital requirements from limiting the aggregate supply of funds. However, a slowdown in aggregate output—the denominator of the credit-to-GDP ratio—requires the government to return the capital requirement ratio near to its value in normal times even though the economy is in a recession. If intermediaries can not satisfy capital requirements by building new equity, they reduce the supply of funds to satisfy capital requirements. This limits improvement in the aggregate supply of funds and subsequently leads to an adverse reaction in both aggregate investment and aggregate output.

In the countercyclical capital buffer regime, deviations in the credit-to-GDP ratio from its long-term trend are considered to be a guide to making decisions on adjustments to the size of the capital conservation buffer. The results of this study imply possible drawbacks of the countercyclical capital buffer regime: the credit-to-GDP ratio is not an effective guide during a recession.

In the Basel III framework, when the level of capital ratio of a bank falls in the range between the capital conservation buffer and the minimum requirements, capital distribution, such as dividend payments and staff bonus payments, is restricted in order to let the bank make efforts to rebuild buffers of capital. To assess such capital distribution constraints in macroeconomic frameworks is a priority for future research for considering appropriately designed capital requirements for banks.

NOTES

1. In this study, we do not focus on the effect that countercyclical capital buffer suppresses excessive risk-taking by banks during an economic expansion, and exclusively focus on the effectiveness of the credit-to-GDP ratio as a guide to implementing counter-cyclical capital requirements.

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Appendix A. Optimization problem of the representative financial intermediary

We guess that we can express $V_t\,(s_t, e_t, d_t)$ as follows:

$$V_t(s_t, e_t, d_t) = \mathscr{V}_{st}s_t - \mathscr{V}_{et}e_t - \mathscr{V}_t d_t\,.$$

Following Gertler et al. (2012), the Bellman equation for $V_t\,(s_t, e_t, d_t)$ is given by

$$V_t(s_t, e_t, d_t) = \max\ E_t\left\{\Lambda_{t,t+1}\left[(1-\sigma)n_{t+1} + \sigma V_{t+1}(s_{t+1}, e_{t+1}, d_{t+1})\right]\right\}. \tag{42}$$

When the representative financial intermediary is subject to capital requirements, from Eq. (14) and (27), the initial guess of the expression of $V_t\,(s_t, e_t, d_t)$ can be rewritten as follows:

$$V_t(s_t, e_t, d_t) = \left(\frac{\mathscr{V}_{st}}{Q_t} - \mathscr{V}_t\right)Q_t s_t + \left(\mathscr{V}_t - \frac{\mathscr{V}_{et}}{q_t}\right)m_t Q_t s_t + \mathscr{V}_t n_t\,. \tag{43}$$

The Lagrangian is given by

$$\begin{aligned}\mathscr{L} &= V_t(s_t, e_t, d_t) + \lambda_t(V_t(s_t, e_t, d_t) - \Theta_t Q_t s_t),\\ &= (1+\lambda_t)V_t(s_t, e_t, d_t) - \lambda_t\Theta_t Q_t s_t,\\ &= (1+\lambda_t)\left[\left(\frac{\mathscr{V}_{st}}{Q_t} - \mathscr{V}_t\right)Q_t s_t + \left(\mathscr{V}_t - \frac{\mathscr{V}_{et}}{q_t}\right)m_t Q_t s_t + \mathscr{V}_t n_t\right]\\ &\quad -\lambda_t\theta\left[1 + \varepsilon m_t + \frac{\kappa}{2}m_t^2\right]Q_t s_t\,.\end{aligned}$$

When the incentive constraint (19) binds, we have

$$Q_t s_t = \phi_t n_t, \tag{44}$$

$$\phi_t \equiv \frac{\mathscr{V}_t}{\Theta_t - \left[\frac{\mathscr{V}_{st}}{Q_t} - \mathscr{V}_t - \left(\frac{\mathscr{V}_{et}}{q_t} - \mathscr{V}_t\right) m_t\right]}. \tag{45}$$

From Eq. (28), we have

$$\phi_t = \frac{\mathscr{V}_t (1 + \lambda_t)}{\Theta_t}. \tag{46}$$

Combining Eq. (29) and (43) yields the following expression of $V_t\,(s_t, e_t, d_t)$:

$$\begin{aligned} V_t(s_t, e_t, d_t) &= \left[\left(\frac{\mathscr{V}_{st}}{Q_t} - \mathscr{V}_t\right) + \left(\mathscr{V}_t - \frac{\mathscr{V}_{et}}{q_t}\right) m_t\right] \phi_t n_t + \mathscr{V}_t n_t, \\ &= \left\{\mathscr{V}_t + \left[\left(\frac{\mathscr{V}_{st}}{Q_t} - \mathscr{V}_t\right) + \left(\mathscr{V}_t - \frac{\mathscr{V}_{et}}{q_t}\right) m_t\right] \phi_t\right\} n_t. \end{aligned}$$

Substituting this expression into the Bellman equation yields

$$V_t(s_t, e_t, d_t) = E_t\left(\Lambda_{t,t+1} \Omega_{t+1} n_{t+1}\right) \tag{47}$$

where

$$\Omega_{t+1} \equiv 1 - \sigma + \sigma\left\{\mathscr{V}_{t+1} + \left[\left(\frac{\mathscr{V}_{st+1}}{Q_{t+1}} - \mathscr{V}_{t+1}\right) + \left(\mathscr{V}_{t+1} - \frac{\mathscr{V}_{et+1}}{q_{t+1}}\right) m_{t+1}\right] \phi_{t+1}\right\}. \tag{48}$$

From Eq. (28) and (30), Eq. (48) can be rewritten as follows:

$$\Omega_t = 1 - \sigma + \sigma\left(1 + \lambda_{t+1}\right) \mathscr{V}_{t+1}.$$

From the initial guess of the expression of $V_t\,(s_t, e_t, d_t)$ and Eq. (15), Eq. (47) can be rewritten as follows:

$$\mathscr{V}_{st}s_t - \mathscr{V}_{et}e_t - \mathscr{V}_t d_t = E_t\Lambda_{t,t+1}\Omega_{t+1}\left(R_{kt+1}Q_t s_t - R_{et+1}q_t e_t - R_{t+1}d_t\right). \tag{49}$$

From Eq. (49), we learn

$$\begin{aligned}
\mathscr{V}_{st} &= E_t\Lambda_{t,t+1}\Omega_{t+1}R_{kt+1}Q_t,\\
&= E_t\Lambda_{t,t+1}\Omega_{t+1}\left[Z_{t+1} + (1-\delta)Q_{t+1}\right]\psi_{t+1},\\
\mathscr{V}_{et} &= E_t\Lambda_{t,t+1}\Omega_{t+1}R_{et+1}q_t,\\
&= E_t\Lambda_{t,t+1}\Omega_{t+1}\left[Z_{t+1} + (1-\delta)q_{t+1}\right]\psi_{t+1},\\
\mathscr{V}_t &= E_t\Lambda_{t,t+1}\Omega_{t+1}R_{t+1}.
\end{aligned}$$

Now we verify the initial guess of the expression of $V_t\,(s_t, e_t, d_t)$.

Next, when financial intermediaries are not subject to any capital requirements, from Eq. (14), the initial guess of the expression of $V_t\,(s_t, e_t, d_t)$ can be now rewritten as follows:

$$V_t(s_t, e_t, d_t) = \left(\frac{\mathscr{V}_{st}}{Q_t} - \mathscr{V}_t\right)Q_t s_t + \left(\mathscr{V}_t - \frac{\mathscr{V}_{et}}{q_t}\right)q_t e_t + \mathscr{V}_t n_t. \tag{50}$$

The Lagrangian is given by

$$\begin{aligned}
\mathscr{L} &= V_t(s_t, e_t, d_t) + \lambda_t\left(V_t(s_t, e_t, d_t) - \Theta_t Q_t s_t\right),\\
&= (1+\lambda_t)V_t(s_t, e_t, d_t) - \lambda_t\Theta_t Q_t s_t,\\
&= (1+\lambda_t)\left[\left(\frac{\mathscr{V}_{st}}{Q_t} - \mathscr{V}_t\right)Q_t s_t + \left(\mathscr{V}_t - \frac{\mathscr{V}_{et}}{q_t}\right)q_t e_t + \mathscr{V}_t n_t\right]\\
&\quad -\lambda_t\theta\left[1 + \varepsilon\frac{q_t e_t}{Q_t s_t} + \frac{\kappa}{2}\left(\frac{q_t e_t}{Q_t s_t}\right)^2\right]Q_t s_t.
\end{aligned}$$

When the incentive constraint (19) binds, we have

$$Q_t s_t = \phi_t n_t, \tag{51}$$

$$\phi_t \equiv \frac{\mathscr{V}_t}{\Theta_t - \left[\frac{\mathscr{V}_{st}}{Q_t} - \mathscr{V}_t - \left(\frac{\mathscr{V}_{et}}{q_t} - \mathscr{V}_t\right)\frac{q_t e_t}{Q_t s_t}\right]}. \tag{52}$$

From Eq. (21) and (24), we have

$$\phi_t = \frac{\mathscr{V}_t(1+\lambda_t)}{\Theta_t}. \tag{53}$$

Combining Eq. (26) and (43) yields the following expression of $V_t\ (s_t, e_t, d_t)$:

$$\begin{aligned} V_t(s_t, e_t, d_t) &= \left[\left(\frac{\mathscr{V}_{st}}{Q_t} - \mathscr{V}_t\right) + \left(\mathscr{V}_t - \frac{\mathscr{V}_{et}}{q_t}\right)m_t\right]\phi_t n_t + \mathscr{V}_t n_t, \\ &= \left\{\mathscr{V}_t + \left[\left(\frac{\mathscr{V}_{st}}{Q_t} - \mathscr{V}_t\right) + \left(\mathscr{V}_t - \frac{\mathscr{V}_{et}}{q_t}\right)\frac{q_t e_t}{Q_t s_t}\right]\phi_t\right\}n_t. \end{aligned}$$

Substituting this expression into the Bellman equation yields

$$V_t(s_t, e_t, d_t) = E_t\left(\Lambda_{t,t+1}\Omega_{t+1}n_{t+1}\right) \tag{54}$$

where

$$\Omega_{t+1} \equiv 1 - \sigma + \sigma\left\{\mathscr{V}_{t+1} + \left[\left(\frac{\mathscr{V}_{st+1}}{Q_{t+1}} - \mathscr{V}_{t+1}\right) + \left(\mathscr{V}_{t+1} - \frac{\mathscr{V}_{et+1}}{q_{t+1}}\right)\frac{q_{t+1}e_{t+1}}{Q_{t+1}s_{t+1}}\right]\phi_{t+1}\right\} \tag{55}$$

From Eq. (21) and (24), Eq. (55) can be rewritten as follows:

$$\Omega_t = 1 - \sigma + \sigma(1+\lambda_{t+1})\mathscr{V}_{t+1}.$$

From the initial guess of the expression of $V_t\ (s_t, e_t, d_t)$ and Eq. (15), Eq. (54) can be rewritten as follows:

$$\mathscr{V}_{st}s_t - \mathscr{V}_{et}e_t - \mathscr{V}_t d_t = E_t\Lambda_{t,t+1}\Omega_{t+1}\left(R_{kt+1}Q_t s_t - R_{et+1}q_t e_t - R_{t+1}d_t\right). \tag{56}$$

From Eq. (56), we learn

$$\begin{aligned}
\mathscr{V}_{st} &= E_t\Lambda_{t,t+1}\Omega_{t+1}R_{kt+1}Q_t, \\
&= E_t\Lambda_{t,t+1}\Omega_{t+1}\left[Z_{t+1} + (1-\delta)Q_{t+1}\right]\psi_{t+1}, \\
\mathscr{V}_{et} &= E_t\Lambda_{t,t+1}\Omega_{t+1}R_{et+1}q_t, \\
&= E_t\Lambda_{t,t+1}\Omega_{t+1}\left[Z_{t+1} + (1-\delta)q_{t+1}\right]\psi_{t+1}, \\
\mathscr{V}_t &= E_t\Lambda_{t,t+1}\Omega_{t+1}R_{t+1}\,.
\end{aligned}$$

Appendix B. Equilibrium without capital requirements

At any period t, an equilibrium for the economy where financial intermediaries are not subject to capital requirements consists of the nine quantities (Y_t, C_t, I_t, L_t, K_t, S_t, D_t, e_t, N_t) and the six prices (W_t, Q_t, q_t, R_t, R_{kt}, R_{et}), which are determined by Eqs. (3), (4), (5), (7), (8), (9), (10), (11), (13), (16), (17), (18), (21), (22), (23), (24), (25), (31), (35), (39), and (41), together with the other six endogenous variables (Z_t, v_t, v_{st}, v_{et}, λ_t, Θ_t). The equilibrium quantities and prices at any period t are recursively determined as a function of the seven state variables (C_{t-1}, I_{t-1}, S_{t-1}, e_{t-1}, D_{t-1}, ψ_t, A_t).

Appendix C. Steady state

In the non-stochastic steady state of the economy where financial intermediaries are subject to capital requirements, the steady-state value of each endogenous variable is determined by the following equations:

$$\bar{\Lambda}\bar{R} = 1, \tag{57}$$

$$\bar{\Lambda}\bar{R}_e = 1, \tag{58}$$

$$u_{\bar{C}} = (1-\beta h)\left(\bar{C} - h\bar{C} - \frac{\chi}{1+\varphi}\bar{L}^{1+\varphi}\right)^{-\gamma}, \tag{59}$$

$$\bar{\Lambda} = \beta, \tag{60}$$

$$\bar{R}_e = \frac{\bar{Z} + (1-\delta)\bar{q}}{\bar{q}}, \tag{61}$$

$$\bar{Y} = \bar{K}^{\alpha}\bar{L}^{1-\alpha}, \tag{62}$$

$$\bar{Z} = \alpha\left(\frac{\bar{L}}{\bar{K}}\right)^{1-\alpha}, \tag{63}$$

$$\bar{S} = (1-\delta)\bar{K} + \bar{I}, \tag{64}$$

$$\bar{K} = \bar{S}, \tag{65}$$

$$\bar{Q} = 1, \tag{66}$$

$$\bar{R}_k = \bar{Z} + (1-\delta), \tag{67}$$

$$\bar{\Theta} = \theta\left[1 + \varepsilon\frac{\bar{q}\bar{e}}{\bar{Q}\bar{s}} + \frac{\kappa}{2}\left(\frac{\bar{q}\bar{e}}{\bar{Q}\bar{s}}\right)^2\right], \tag{68}$$

$$\frac{\bar{\mathscr{V}}_s}{\bar{Q}} - \bar{\mathscr{V}} + \left(\bar{\mathscr{V}} - \frac{\bar{\mathscr{V}}_e}{\bar{q}}\right)\bar{m} = \frac{\bar{\lambda}}{1+\bar{\lambda}}\bar{\Theta}, \tag{69}$$

$$\bar{Q}\bar{S} = \frac{\bar{\mathscr{V}}\left(1+\bar{\lambda}\right)}{\bar{\Theta}}\bar{N}, \tag{70}$$

$$\bar{\Omega} = 1 - \sigma + \sigma\left(1+\bar{\lambda}\right)\bar{\mathscr{V}}, \tag{71}$$

$$\bar{\mathscr{V}}_s = \bar{\Lambda}\bar{\Omega}\left[\bar{Z} + (1-\delta)\right], \tag{72}$$

$$\bar{\mathscr{V}}_e = \bar{\Lambda}\bar{\Omega}\left[\bar{Z} + (1-\delta)\bar{q}\right], \tag{73}$$

$$\bar{\mathscr{V}} = \bar{\Lambda}\bar{\Omega}\bar{R}, \tag{74}$$

$$\bar{N} = (\sigma+\xi)\left[\bar{Z} + (1-\delta)\bar{Q}\right]\bar{S} - \sigma\left[\bar{Z} + (1-\delta)\bar{q}\right]\bar{e} - \sigma\bar{R}\bar{D}, \tag{75}$$

$$\frac{\bar{q}\bar{e}}{\bar{Q}\bar{S}} = \bar{m}, \tag{76}$$

$$\bar{D} = \bar{S} - \bar{q}\bar{e} - \bar{N}, \tag{77}$$

$$(1-\alpha)\frac{\bar{Y}}{\bar{L}}u_{\bar{C}} = \chi\bar{L}^{\varphi}\left(\bar{C} - h\bar{C} - \frac{\chi}{1+\varphi}\bar{L}^{1+\varphi}\right)^{-\gamma}, \tag{78}$$

$$\bar{Y} = \bar{C} + \bar{I} + G\,. \tag{79}$$

The steady-state value of a variable x_t is denoted by $\bar{x}$. The steady-state value of the variable V_t is given by

$$\bar{\mathscr{V}} = \frac{-P + \left(P^2 - 4HX\right)^{\frac{1}{2}}}{2H}, \tag{80}$$

where

$$H = \frac{\sigma}{\sigma+\xi} - 1, \tag{81}$$

$$P = \left(\frac{\beta-\sigma}{\sigma+\xi}\right)\sigma\bar{\Theta} - \frac{\sigma(1-\sigma)}{\sigma+\xi} + 1 - \sigma - (1-\sigma)\bar{\Theta}, \tag{82}$$

$$X = (1-\sigma)\bar{\Theta}\,. \tag{83}$$

In the non-stochastic steady state of the economy where financial intermediaries are not subject to capital requirements, instead of Eq. (69) and (76), we have

$$\frac{\bar{\mathscr{V}}_s}{\bar{Q}} - \bar{\mathscr{V}} = \theta\frac{\bar{\lambda}}{1+\bar{\lambda}}\left[1 - \frac{\kappa}{2}\left(\frac{\bar{q}\bar{e}}{\bar{Q}\bar{s}}\right)^2\right], \tag{84}$$

$$\bar{\mathscr{V}} - \frac{\bar{\mathscr{V}}_e}{\bar{q}} = \theta\frac{\bar{\lambda}}{1+\bar{\lambda}}\left(\varepsilon + \kappa\frac{\bar{q}\bar{e}}{\bar{Q}\bar{s}}\right). \tag{85}$$

The steady-state value of the variable $\mathscr{V}_t$ is now given by

$$\bar{\mathscr{V}} = \frac{-P' + \left(P'^2 - 4H'X'\right)^{\frac{1}{2}}}{2H'}, \tag{86}$$

where

$$
\begin{aligned}
H' &= \frac{\sigma}{\sigma+\xi} - 1, \\
P' &= \left(\frac{\beta-\sigma}{\sigma+\xi}\right)\sigma\bar{\Theta} - \frac{\sigma(1-\sigma)}{\sigma+\xi} + 1 - \sigma - (1-\sigma)\theta\left[1 - \frac{\kappa}{2}\left(\frac{\bar{q}\bar{e}}{\bar{S}}\right)^2\right], \\
X' &= \theta\left[1 - \frac{\kappa}{2}\left(\frac{\bar{q}\bar{e}}{\bar{S}}\right)^2\right](1-\sigma).
\end{aligned}
$$