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# The effectiveness of countercyclical capital requirements and contingent convertible capital: a dual approach to macroeconomic stability

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## Abstract

This paper studies the effectiveness of countercyclical capital requirements and contingent convertible capital (CoCos) in limiting financial instability, and its associated influence on the real economy. To do this, I augment both features into a standard real business cycle framework with an equity market and a banking sector. The model is calibrated to real U.S. data and used for simulations. The findings suggest that CoCos effectively re-capitalize the banking sector and foster the objectives of countercyclical capital requirements (i.e., Basel III). Under financial shocks, CoCos provide an effective automatic stabilization effect on the financial cycle and the real economy. Conversely, a countercyclical capital adequacy rule dominates CoCos in the stabilization of real shocks.

*JEL* codes: G28, G38, E44

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# 1 Introduction

The purpose of macroprudential policy is to limit systemic financial distress, with the ultimate objective of curtailing macroeconomic costs associated with that financial instability. One such instrument relied on by the Basel Committee on Banking Supervision is that of countercyclical capital requirements (as in Basel III). Indeed, both financial institutions and regulatory authorities are increasingly looking into a dual role for contingent convertible capital instruments (CoCos) and countercyclical capital adequacy (CA) ratios (Avdjiev et al., 2013; Calomiris and Herring, 2013; Galati and Moessner, 2013).<sup>1</sup> Although CoCos are primarily designed to re-capitalize individual bank balance sheets, its adoption within the macroprudential toolkit provides a role for CoCos—alongside Tier 1 equity capital—in mitigating systemic financial distress.

This paper studies the effectiveness of CA ratios and CoCos in limiting financial instability, and its associated influence on the real economy. Moreover, this paper assesses whether CoCos complement the objectives of a Basel III macroprudential policy. To do this, I augment both features into a standard real business cycle (RBC) framework with an equity market and a banking sector. Regulatory capital requirements enter through a quadratic adjustment cost on bank leverage, which includes a time-variant capital adequacy rule. The corporate finance model of Jaffee et al. (2013) provides the core framework to introduce CoCos into the general equilibrium model. The model is calibrated to real U.S. data and used for simulations. To assess the effectiveness of countercyclical capital requirements, a comparison analysis of alternative Basel regimes is done. Here, adopting an RBC framework provides a useful benchmark to observe the dynamic interactions between the financial system and the real economy.

While a capital adequacy rule provides a coherent framework for macroprudential policy, it neglects the barriers to external equity financing. Borio and Zhu (2012, p.238) identify a number of reasons for why banks are reluctant to issue new equity or reduce dividends. For example, the tax shield on debt financing discourages equity financing; and equity issuances may signal weak performance (i.e., adverse selection). The authors also identify distortions related to asymmetric information, agency problems and deposit insurance. Moreover, the return on equity for banks—the maximizing objective for its shareholders—is lowered when new equity is issued or dividends are cut. Conversely, in times of financial distress, the willingness of private investors to *supply* external equity capital can quickly dissipate. As a result, when the banking sector is over-leveraged, a weak macroeconomic outlook will exacerbate financial instability.

That said, contingent convertible debt provides an answer to equity issuances during banking crises and recessions (Avdjiev et al., 2013). CoCos are debt instruments which automatically convert into common equity when, for example, the bank’s capital-asset ratio falls below a predetermined level. At this point of financial distress, equity shares are issued to CoCo holders at their current market price, commensurate to the face value of the original debt instrument. The main objective of CoCos is to therefore replace the lost capital of a financial institution in a timely manner (Calomiris and Herring, 2013). This addresses, in particular, two important financial distress phenomena: one, the amplification of asset fire sales can be curtailed or attenuated; two, the capital-asset ratios of financial institutions are stabilized in a timely

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<sup>1</sup>Both the Basel Committee on Banking Supervision and the Federal Reserve are in the process of formalizing the standards for contingent capital within Basel III regulatory requirements.

manner at the prescribed market value of equity. For example, in the case of systemically important financial institutions (SIFIs), a negative shock to capital-asset ratios (induced by a freeze in the interbank market) results in a fire sale of assets as these SIFIs attempt to stabilize their capital positions. However, the role of CoCos would be to automatically convert into common equity at a prescribed trigger value. As a result, the soundness of bank balance sheets are more readily restored.

The main findings of the paper are as follows. First, a Basel III macroprudential policy improves the balance sheet position of banks and attenuates the effects of shocks on the real economy. That is, relative to simulations of the Basel I and Basel II regimes (akin to fixed and procyclical capital requirements, respectively), a countercyclical CA rule reduces business cycle fluctuations. Second, CoCos effectively recapitalize the banking sector and foster the objectives of countercyclical capital requirements. Under financial shocks, CoCos provide an effective automatic stabilization effect on the financial cycle and the real economy. Whereas, technology shocks produce little variability in bank capital-asset ratios. As a result, a countercyclical CA rule dominates CoCos in the stabilization of real shocks. These findings suggest that CA ratios and CoCos provide an effective dual approach to macroprudential policy. On the one hand, a capital adequacy rule mitigates the build-up of systemic risk through a capital buffer. On the other hand, CoCos are able to reduce the impact of a sudden decline in bank capital. Another result of the paper highlights the robust cyclical properties of the model with respect to the data. Here, financial shocks play a key role in matching financial data variability and reducing the correlation of variables with output.

This paper is related to an expanding literature on the impact of various macroprudential policy tools on the broader economy. Currently, most dynamic stochastic general equilibrium (DSGE) models study either the interaction between monetary policy and macroprudential policy (e.g., Angelini et al., 2012; Angeloni and Faia, 2013; Quint and Rabanal, 2014) or the performance of loan-to-value rules and capital adequacy rules—i.e., the balance sheet channel and the bank lending channel, respectively (e.g., Funke and Paetz, 2012; Brzoza-Brzezina et al., 2013; Lambertini et al., 2013).<sup>2</sup> Although the balance sheet channel forms an important part of the transmission mechanism of financial instability, this paper highlights the bank lending channel in the propagation of shocks to the real economy (e.g., Markovic, 2006; Meh and Moran, 2010). In other words, to satisfy regulatory requirements banks can either raise new capital or reduce their supply of loans. This paper also focuses on the dynamic interactions between the financial system and the real economy, to which two papers are closely related. Firstly, the model setup in Van den Heuvel (2008) is closely related to the one developed here. That is, both models derive a role for debt and equity financing, where firms and banks maximize the return on shareholders' equity. However, in Van den Heuvel (2008), banks and firms only last for one period, and a minimum capital requirement arises to mitigate the moral hazard problem from deposit insurance. Secondly, de Walque et al. (2010) augment an RBC model with a banking sector and similarly study the effects of capital requirements on the business cycle. But instead of incorporating an interbank market with liquidity injections, the model developed here introduces a role for contingent convertible capital.

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<sup>2</sup>Galati and Moessner (2013) provide an extensive literature review on macroprudential policy. Borio and Zhu (2012) also provide an overview of the theoretical studies on the role of bank capital in monetary transmission, and specifically highlight the importance of the “risk-taking channel” of monetary policy.

Lastly, although macroprudential policies are designed to mitigate financial instability, the lack of consensus on a clear definition for financial stability is well-documented (Galati and Moessner, 2013, p.848). Following Borio (2011, p.17), I measure the success of macroprudential policy by its ability to “mitigate the financial cycle”—that is, to reduce the procyclicality of the financial system. On the one hand, the equity premium, the bank capital-asset ratio and the credit spread serve as a measure of financial stability. On the other hand, output, consumption and investment serve as a measure of macroeconomic stability. The “risk” of financial instability is related to the deviation of bank leverage from a target leverage ratio (e.g., Christensen et al., 2011), while the countercyclical CA rule adjusts to output growth (e.g., Angelini et al., 2012; Brzoza-Brzezina et al., 2013).<sup>3</sup>

The remainder of this paper is organized as follows. Section 2 describes the model and introduces a role for contingent convertible capital. Section 3 discusses the calibration of the model and its implied steady-state values. Section 4 compares the model’s numerical simulations with U.S. data and presents the main findings. Section 5 concludes.

## 2 The model economy

This model departs from the standard one-sector, representative agent RBC model in two ways. First, introducing a banking sector creates a market for financial intermediation. More precisely, banks convert household deposits into loanable funds, from which nonfinancial firms borrow to finance their capital input. Second, both nonfinancial firms and banks can raise external equity financing by issuing shares to households. For simplicity, firms and banks are assumed to be wholly-owned by households, and therefore maximize the return on shareholders’ equity. Meanwhile, only banks hold contingent convertible debt as a means to satisfy their capital adequacy ratios.

To ensure that the Modigliani and Miller (1958) theorem no longer holds, frictions arise between the rates of return on deposits, loans and equity. In the real sector, firms face a borrowing constraint and households have a liquidity preference for holding deposits.<sup>4</sup> As a result, the credit spread and the equity premium are linked to the marginal value of installed capital and the marginal utility of liquidity services. In the financial sector, banks face quadratic costs for deviating from a target leverage ratio, such that higher levels of leverage increase the return on equity relative to debt. Here, the target leverage ratio follows a capital adequacy rule, which is either independent from the business cycle (Basel I), or endogenous (Basel II and Basel III). In addition, introducing a capital requirement and a borrowing constraint implies that some proportion of external funding, for both banks and firms, will always comprise of equity.

### 2.1 Households

The representative household maximizes its expected lifetime utility function given by:

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<sup>3</sup>A number of studies promote the credit-to-GDP ratio as a more robust early warning indicator (e.g., Drehmann and Tsatsaronis, 2014). Within the DSGE framework, however, deviations of output from steady-state simplifies the solution of the model, without loss of generality.

<sup>4</sup>Given that households are risk averse and utility maximizing, the latter case is motivated by the greater risk and larger transaction costs associated with stocks compared to deposits. (see, e.g., Van den Heuvel, 2008; Brunnermeier et al., 2012)

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{(\tilde{C}_t)^{1-\gamma}}{1-\gamma} - \frac{(H_t)^{1+\eta}}{1+\eta} + \ln(D_t) \right], \quad (1)$$

where  $\beta^t$  is the discount factor. Consumption ( $\tilde{C}_t = C_t - \phi C_{t-1}$ ) includes habit formation parameterized by  $\phi$ .  $H_t$  is the supply of labor hours. Households' financial wealth is made up of risk-free deposits ( $D_t$ ) and equity investments ( $E_t$ ). Similar to Van den Heuvel (2008) and Christiano et al. (2010) we assume households derive direct utility from the liquidity services of deposits. This drives a positive wedge in the spread between the return on equity and the return on bank deposits.  $\eta$  measures the inverse of the Frisch elasticity of labor supply.  $\gamma$  captures the inverse of the intertemporal elasticity of substitution in consumption.

Eq. 2 gives the household budget constraint:

$$C_t + D_t + Q_t E_t = W_t H_t + R_{t-1} D_{t-1} + (Q_t + V_t) E_{t-1}. \quad (2)$$

The household allocates periodic income from wages ( $W_t$ ), gross real returns on deposits ( $R_{t-1} D_{t-1}$ ), real capital gains/losses ( $Q_t E_{t-1}$ ) and real dividend income ( $V_t E_{t-1}$ ) to current consumption and new financial wealth holdings. In aggregate, the total equity stock  $E_t$  equals the total supply of equity from banks  $E_t^b$  and firms  $E_t^f$ .<sup>5</sup>  $Q_t$  is the equity price in current period  $t$ .

The representative household's first-order conditions for deposits, labor and equity holdings are the following:

$$\frac{1}{D_t} = (\tilde{C}_t)^{-\gamma} - \beta E_t \left[ (\tilde{C}_{t+1})^{-\gamma} R_t \right], \quad (3)$$

$$W_t = (\tilde{C}_t)^{\gamma} (H_t)^{\eta}, \quad (4)$$

$$(\tilde{C}_t)^{-\gamma} = \beta E_t \left[ (\tilde{C}_{t+1})^{-\gamma} R_{t+1}^e \right], \quad (5)$$

where  $R_{t+1}^e = (Q_{t+1} + V_{t+1})/Q_t$ . Eq. 3 is the household's demand for deposits. Eq. 4 gives the standard real wage equation: that is, the real wage equals the marginal rate of substitution between consumption and labor. Eq. 5 gives the consumption Euler equation, based on the standard asset-pricing equation for equity.

Combining Eq. 5 and Eq. 3 illustrates the spread between  $R_{t+1}^e$  and  $R_t$ , based on household liquidity preferences for deposits:

$$\frac{(D_t)^{-1}}{(\tilde{C}_{t+1})^{-\gamma}} = \beta E_t \left[ R_{t+1}^e - R_t \right]. \quad (6)$$

Here Eq. 6 states that the marginal utility of the liquidity services, expressed in units of consumption, equals the equity premium.

## 2.2 Nonfinancial firms

Nonfinancial firms manage the goods producing sector, and are owned by households. A firm's objective is to therefore maximize the value of its shareholders equity.<sup>6</sup> Analogous to Bernanke et al. (1999, p.1349)

<sup>5</sup>  $E_t = E_t^f + E_t^b$  and  $V_t E_t = V_t^f E_t^f + V_t^b E_t^b$ . Later on we see that  $V_t = V_t^f = V_t^b$ .

<sup>6</sup> Equivalent to maximizing the return on shareholders' equity (ROSE).

and Van den Heuvel (2008, p.304), we assume that the firm must borrow an amount  $L_t$  to finance the difference between the value of capital goods and shareholders' equity (net worth):  $L_t = K_t - Q_t E_t^f$ . In other words, the firm finances its new physical capital purchases in the beginning of the period by issuing equity to households ( $Q_t E_t^f$ ) and by borrowing from banks ( $L_t$ ). Firms will continue to issue shares only if the expected return on equity financing is positive.<sup>7</sup>

Firms produce goods using a standard Cobb-Douglas production function described by

$$Y_t = \xi_{z,t} K_{t-1}^\alpha H_t^{1-\alpha}, \quad (7)$$

where  $K_{t-1}$  is physical capital,  $H_t$  is the demand of labor hours, and  $\xi_{z,t}$  is the technology. In addition, nonfinancial firms face a borrowing constraint:

$$R_t^l L_t \leq \nu K_t, \quad (8)$$

where  $\nu$  is the nonfinancial firm's loan-to-value (LTV) ratio.

Therefore, in each period, the firm chooses the desired amount of physical capital, labor and equity issuance to maximize

$$E_0 \sum_{t=0}^{\infty} \beta_f^t \left[ \frac{\Omega_t^f}{R_t^e} \right] \quad (9)$$

subject to the production technology, Eq. 7, the borrowing constraint, Eq. 8, and the flow of funds constraint

$$\Omega_t^f = Y_t - W_t H_t - I_t + Q_t E_t^f + L_t - R_{t-1}^l L_{t-1} - (Q_t + V_t^f) E_{t-1}^f - \Phi_t^i. \quad (10)$$

$\Phi_t^i = (\kappa_i/2\delta)(I_t/K_{t-1} - \delta)^2 K_{t-1}$  captures the capital installation costs, where  $I_t = K_t - (1 - \delta)K_{t-1}$  is investment and  $\delta$  is the rate of depreciation. Using the capital financing identity,  $L_t = K_t - Q_t E_t^f$ , and dividing Eq. 10 by the return on equity,  $R_t^e = (Q_t + V_t^f)/Q_{t-1}$ , gives the maximization problem of the firm:

$$\frac{\Omega_t^f}{R_t^e} = \frac{Y_t - W_t H_t + (1 - \delta)K_{t-1} - R_{t-1}^l (K_{t-1} - Q_{t-1} E_{t-1}^f) - \Phi_t^i}{R_t^e} - Q_{t-1} E_{t-1}^f, \quad (11)$$

defined as the value of shareholders equity (net income over the return on equity) minus the initial equity investment (see, e.g., Van den Heuvel, 2008, p.304).

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<sup>7</sup>That is, if the expected real income from production covers the expected wage, the gross loan repayment and the initial equity investment plus the dividend.

The first order conditions for labor, physical capital, and equity issuances are the following:

$$W_t = \frac{(1 - \alpha)Y_t}{H_t}, \quad (12)$$

$$R_t^l = E_t \left[ \frac{\alpha Y_{t+1}}{K_t} + Q_{t+1}^I (1 - \delta) + \frac{\kappa_i}{\delta} \left( \frac{I_{t+1}}{K_t} - \delta \right) \frac{I_{t+1}}{K_t} - \frac{\kappa_i}{2\delta} \left( \frac{I_{t+1}}{K_t} - \delta \right)^2 \right] - \frac{1}{\beta^f} (Q_t^I - 1) - \frac{\lambda_t^f}{\beta^f} \left( 1 - \frac{\nu}{R_t^l} \right) R_{t+1}^e, \quad (13)$$

$$\lambda_t^f = \beta^f \left( \frac{R_{t+1}^e - R_t^l}{R_{t+1}^e} \right). \quad (14)$$

$Q_t^I = 1 + \kappa_i/\delta(I_t/K_{t-1} - \delta)$  is the shadow value of capital. Eq. 12 is the standard labor demand schedule. Eq. 13 states that the return on loans must equal the expected marginal product of capital plus capital installation costs, taking account for the marginal product of an additional loan  $\lambda_t^f$ . Eq. 14 shows that the marginal product of an additional loan is positively related to the discounted equity financing premium, such that the following holds: if  $R_{t+1}^e > R_t^l$  then  $0 < \lambda_t^f < 1$ ; if  $R_{t+1}^e < R_t^l$  then  $\lambda_t^f < 0$ .

In the frictionless case there are no constraints on credit, and the rates of return on debt and equity are equalized. This implies that both rates of return equal the marginal product of capital. Two important frictions arise from introducing the borrowing constraint: one, a standard Bernanke et al. (1999) financial accelerator effect arises, and two, an increase in the equity financing premium increases the margin product of an additional loan. In addition, the borrowing constraint ensures that the firm must maintain a proportion of capital,  $(R_t^l - \nu)/R_t^l$ , as equity. Combining Eq. 13 with Eq. 14, and ignoring capital installation costs, gives the equity financing margin for nonfinancial firms:

$$R_{t+1}^e = \frac{\alpha Y_{t+1}}{K_t} + (1 - \delta) + \left( \frac{R_{t+1}^e - R_t^l}{R_t^l} \right) \nu. \quad (15)$$

The return on equity is therefore procyclical and linked to the marginal value of installed capital (see also, Christiano and Fisher, 2003).

## 2.3 Banks

Analogous to nonfinancial firms, banks are owned by households and therefore maximize the return on shareholders' equity. Banks issue loans to nonfinancial firms, and fund these assets with deposits and bank capital ( $K_t^b = Q_t E_t^b$ ). Following a recent string of macroprudential studies, banks face a non-binding capital requirement (e.g., Angelini et al., 2012; Angeloni and Faia, 2013; Brzoza-Brzezina et al., 2013). In this paper, quadratic costs arise when the bank's leverage ratio ( $L_t/K_t^b$ ) deviates from the macroprudential instrument: the target leverage ratio  $\tau_t$ . This introduces two important conditions of financial intermediation. Firstly, it drives a wedge between bank lending and funding rates. Secondly, the target leverage ratio can be governed by a macroprudential policy rule to mimic the effects of alternative Basel regimes. Because banks are subject to a binding balance sheet identity,  $L_t = K_t^b + D_t$ , deposits are taken as given. In other words, given households' demand for liquidity services from deposits, the bank will adjust  $L_t$  and  $E_t^b$  to maximize the return on shareholders' equity.



Therefore, the bank chooses loans ( $L_t$ ) and equity ( $E_t^b$ ) to maximize

$$E_0 \sum_{t=0}^{\infty} \beta_b^t \left[ \frac{\Omega_t^b}{R_t^e} \right] \quad (16)$$

subject to the balance sheet identity and the flow of funds constraint

$$\Omega_t^b = R_{t-1}^l L_{t-1} - R_{t-1} D_{t-1} - L_t + D_t + Q_t E_t^b - F(E, L) - (Q_t + V_t^b) E_{t-1}^b, \quad (17)$$

where  $F(E, L) = \kappa/2(L_t/K_t^b - \tau_t)^2 D_t$  is the regulatory cost of intermediation measured by deviations of bank leverage around a target leverage ratio  $\tau_t$ . As with nonfinancial firms, using the balance sheet identity and the return on equity,  $R_t^e = (Q_t + V_t^b)/Q_{t-1}$ , Eq. 17 can be written as follows:

$$\frac{\Omega_t^b}{R_t^e} = \frac{R_{t-1}^l L_{t-1} - R_{t-1} D_{t-1} - F(E, L)}{R_t^e} - Q_{t-1} E_{t-1}^b. \quad (18)$$

The first-order conditions for loans and equity are:

$$R_t^l - R_t = F^l(E, L), \quad (19)$$

$$R_{t+1}^e - R_t = -F^e(E, L) \frac{1}{Q_t}, \quad (20)$$

where  $F^l(E, L) > 0$  and  $-F^e(E, L) > 0$ . In the frictionless equilibrium ( $\kappa = 0$ )  $R_{t+1}^e = R_t^l = R_t$ . This implies that households derive zero utility from the liquidity provision of deposits, and that firms do not face a borrowing constraint.

Combining Eqs. 19 and 20 gives the equity financing margin:

$$R_{t+1}^e - R_t^l = \kappa \left( \frac{L_t}{K_t^b} - \tau_t \right) \left( \frac{D_t}{K_t^b} \right)^2. \quad (21)$$

Eq. 21 states that when bank leverage rises above the target leverage ratio,  $\tau_t$ , the required return on equity increases relative to the return on loans. Comparing Eqs. 14 and 21 implies that the discounted marginal product of an additional loan is proportional to the marginal cost from increasing bank leverage. Subsequently,  $R_t^e \gg R_t^l$  when bank leverage and the marginal product of installed capital are increasing.<sup>8</sup> This captures two key empirical features of the U.S. banking sector. One, as leverage rises the cost of equity financing increases relative to debt financing (Hanson et al., 2010, 2011). Two, in an environment of expanding bank balance sheets and a widening equity premium, bank leverage is procyclical (Adrian and Shin, 2010, 2013). That is, leverage rises during booms and falls during busts.

Additional empirical evidence provided by Adrian and Shin (2010, 2013) shows that U.S. banks tend to adjust debt, rather than equity, to actively manage leverage. In other words, bank capital accumulation is persistent. As it stands in the model setup, leverage requirements create a wedge between the rates of return on equity and loans; however, banks are able to adjust their balance sheet quantities to make this

<sup>8</sup>To be consistent with nonfinancial firms, the bank should face a fixed proportional cost to both equity and debt financing such that the spread,  $R^e - R^l > 0$ . This, however, is not an issue for the log-linearized system of equations.

cost negligible. It is therefore necessary to derive a law of motion for bank capital accumulation.

To begin with, from the optimizing Eqs. 19 and 20, we can re-write the bank's flow of funds constraint as

$$R_t^l L_t - R_t D_t - R_{t+1}^e K_t^b - F(E, L) = 0, \quad (22)$$

where  $K_t^b = Q_t E_t^b$ .<sup>9</sup> Substituting in the balance sheet identity  $L_t = D_t + K_t^b$  and using  $R_{t+1}^e = (Q_{t+1} + V_{t+1}^b)/Q_t$  gives

$$r_t^l L_t - r_t D_t = (Q_{t+1} + V_{t+1}^b) E_t^b - Q_t E_t^b. \quad (23)$$

Eq. 23 states that the net interest margin between the bank's assets and liabilities must cover the expected real capital gains ( $\Delta Q_{t+1} E_t^b$ ) plus the expected real dividend paid to households ( $V_{t+1}^b E_t^b$ ). To introduce a law of motion for bank capital accumulation, we let the RHS of Eq. 23 equal  $K_{t+1}^b - (1 - \delta) K_t^b$ :

$$(Q_{t+1} + V_{t+1}^b) E_t^b - Q_t E_t^b = Q_{t+1} E_{t+1}^b - (1 - \delta_b) Q_t E_t^b \quad (24)$$

$$\therefore Q_{t+1} (E_{t+1}^b - E_t^b) = -(\delta_b Q_t E_t^b - V_{t+1}^b E_t^b). \quad (25)$$

Therefore, Eq. 25 assumes an implicit cost for issuing new shares at price  $Q_{t+1}$ . This cost is equal to a fraction  $\delta_b$  of the initial equity investment less the expected dividend payment. Given this assumption, we can write the law of motion for bank capital accumulation, from Eq. 23, as follows:

$$K_{t+1}^b = (1 - \delta_b) K_t^b + (r_t^l L_t - r_t D_t). \quad (26)$$

## 2.4 Macroprudential policy

Similar to Angelini et al. (2012) and Brzoza-Brzezina et al. (2013), the Basel III target leverage ratio  $\tau_t$  follows a countercyclical capital adequacy rule:

$$\tau_t = \bar{\tau}^{(1-\rho_\tau)} \tau_{t-1}^{\rho_\tau} \left( \frac{Y_t}{\bar{Y}} - 1 \right)^{-\kappa_\tau (1-\rho_\tau)} e^{\epsilon_{\tau,t}}, \quad (27)$$

where  $\epsilon_{\tau,t}$  is an i.i.d shock to the target leverage ratio. The countercyclical policy rule is parameterized by  $\kappa_\tau > 0$  and  $1 > \rho_\tau \geq 0$ . Under a Basel III countercyclical regime, banks accumulate a capital buffer when output deviates above steady-state. This implies that the required leverage ratio of banks is tapered during booms and elevated during busts. Alternatively, when the target leverage ratio is reduced (raised) banks become overleveraged (underleveraged). When banks are overleveraged (underleveraged), the return on equity increases (decreases) relative to the return on loans.

## 2.5 Closing the model

To close the model, the dynamic adjustment path of the risk-free real rate of interest,  $R_t$ , must be specified. As documented by King and Watson (1996, p.48), RBC models tend to fail at reproducing the negative

<sup>9</sup>For simplicity, the regulatory cost term,  $F(E, L)$ , will hereafter be ignored as it falls away in the log-linearized equation.

correlation between the real rate of interest and output for U.S data (see also, Begum, 1998; Christiano and Fisher, 2003; Garnier and Wilhelmsen, 2005).<sup>10</sup> That said, King and Watson (1996, p.48) find that generating a negative correlation is possible at the expense of counterfactual business cycle moments for labor input (see also Table 3 below).

Based on the model setup, it is important to disentangle the influence of the banking sector from the risk-free rate  $R_t$  for two reasons. Firstly, if banks are able to control  $R_t$ , given their optimal responses for loans and equity, the impact of capital requirements on the real economy becomes negligible.<sup>11</sup> Secondly, as the bank capital accumulation equation is derived from the flow of funds constraint, it rules out specifying an equation for the dynamic adjustment of deposits. Therefore, deviations of the risk-free real rate from its steady-state are characterized by the following dynamic rule:

$$R_t = \bar{R}^{(1-\rho_r)} R_{t-1}^{\rho_r} \left( \frac{Y_t}{\bar{Y}} - 1 \right)^{-\kappa_r(1-\rho_r)}, \quad (28)$$

where, for simplicity,  $\rho_r$  is assumed to equal 0.

The aggregate resource constraint for the economy is

$$Y_t = C_t + I_t + F(E, L). \quad (29)$$

## 2.6 Introducing contingent convertible capital (CoCos)

Prior to conversion, CoCos are issued as debt instruments at a fixed rate of return. When the bank's capital-asset ratio falls below a predetermined level CoCos will automatically convert into equity. At this trigger value, defined as the target leverage ratio  $\tau_t$ , CoCo holders' receive a certain value of common equity in exchange for the original debt instrument  $D_t$ . Equity is issued at the current market price, and can be issued up to the face value of the original debt instrument ( $Q_t E_t^X \leq \mu D_t$ ). To introduce CoCos into the model developed here requires three assumptions. First, deposits convert into equity with a probability  $\theta$  at any given value of  $L_t/K_t^b$  above the trigger value  $\tau_t$ . In other words,  $\theta$  is uniformly distributed below  $\tau_t$ . Second, the assumption of perfect markets is relaxed, in which arbitrage implies that the real dividend yield must equal the real rate of return on deposits. As a result, no arbitrage implies that the payoffs of debt and equity instruments (carried over from period  $t-1$ ) may not equate. Third, given the CoCo constraint  $Q_{t-1} E_{t-1}^X \leq \mu D_{t-1}$  the bank must first settle the optimal combination of debt and equity, given the probability  $\theta$  of debt converting into equity. That said, the bank's balance sheet is still binding in period  $t$ .

The bank therefore maximizes the following return on shareholders equity:

$$\frac{\Omega_t^b}{R_t^e} = \frac{R_{t-1}^l L_{t-1} - R_{t-1}(1-\theta\mu)D_{t-1} - F(E, L)}{R_t^e} - Q_{t-1}(E_{t-1}^b + \theta E_{t-1}^X), \quad (30)$$

Combining the first-order conditions for  $L_t$  and  $E_t^b$  gives:

<sup>10</sup>These studies also show that the negative correlation of the real rate of interest is both a leading indicator and contemporaneous.

<sup>11</sup>That is, deriving a rate of returns margin from the bank's first-order conditions: see Eq. A.1 in the Appendix.

$$R_{t+1}^e - R_t^l = \frac{1}{\beta_b} \left[ \kappa \left( \frac{L_t}{K_t^B} - \tau_t \right) \frac{D_t}{K_t^B} \left( \frac{L_t}{K_t^B} - 1 \right) \right], \quad (31)$$

where total bank capital  $K_t^B$  now comprises of the original bank capital  $K_t^b$  plus the value of newly converted CoCo instruments,  $K_t^\chi = Q_t E_t^\chi$ . If  $\theta = 0$  then  $K_t^B = K_t^b$ , and Eq. 31 becomes the original Eq. 21 in the model without CoCos.

Combining the first-order conditions for  $D_t$  and  $E_t^\chi$  gives:

$$(1 - \theta\mu)R_t + \theta\mu R_{t+1}^e = \frac{\theta\mu}{\beta_b} \left[ \kappa \left( \frac{L_t}{K_t^B} - \tau_t \right) \frac{D_t}{K_t^B} \frac{L_t}{K_t^B} \right]. \quad (32)$$

Eq. 32 states that the marginal cost of leverage deviations is proportional to the expected payoff of debt converting into equity at any given leverage ratio ( $L_t/K_t^B$ ) above the trigger value  $\tau_t$ . Conversely, when  $L_t/K_t^B < \tau_t$  then  $\theta = 0$ . Substituting Eq. 32 into Eq. 31 then gives the new marginal cost of leverage deviations in financial intermediation.

The bank capital accumulation equation for  $K_t^b$  can be written as follows:

$$K_{t+1}^b = (1 - \delta)K_t^b + (r_t^l L_t - r_t D_t) + (R_t - R_{t+1}^e)\theta K_t^\chi. \quad (33)$$

The final equation affected from introducing CoCos is the household's demand for deposits, given as:

$$\frac{1}{D_t} = (\tilde{C}_t)^{-\gamma} - \beta E_t \left[ (\tilde{C}_{t+1})^{-\gamma} ((1 - \theta\mu)R_t + \theta\mu R_{t+1}^e) \right]. \quad (34)$$

### 3 Calibration

Households' preferences and nonfinancial firm technology are calibrated in line with the literature. Bank balance sheets are calibrated to represent current U.S. banking conditions, whereas the real rates of return on loans and equity are based on average real quarterly data from 1985Q1–2013Q4. Tables 1 and 2 summarize the calibrated parameters and the implied steady-state values based on the model setup.<sup>12</sup>

The seven preference and technology parameters are calibrated as follows. The inverse of the intertemporal elasticity of substitution in consumption ( $\gamma$ ) and the inverse of the Frisch elasticity of labor supply ( $\eta$ ) are set to 2. Habit formation  $\phi$  equals 0.75. The capital-output share  $\alpha$  is set to 0.3, and the physical capital depreciation rate  $\delta$  is set to 0.025. The parameter governing capital installation costs ( $\kappa_i$ ) is set to 0.5 (see, for example, Bernanke et al., 1999). Lastly, the loan-to-value ratio for firms is set to 0.75.

Based on S&P500 data for equity prices and dividends, the average quarterly real return on equity is 3.5% (Shiller, 2005, updated).  $R^e = 1.035$  matches a 15% annualized real return on bank equity for the period 1985Q1–2008Q1 (Meh and Moran, 2010, p.565). Similar to the value chosen in the RBC setup of de Walque et al. (2010, p.1244), the steady-state values for the quarterly real risk-free rate  $R$  and the real borrowing rate are set to 1.005 and 1.015, respectively.

<sup>12</sup>In the log-linearized equation, the bank's steady-state balance sheet condition offsets the influence of  $\kappa$  in the dynamic adjustment. Rather, the leverage ratio  $\tau$  governs the degree of influence of balance sheet adjustments.

Table 1: Calibrated parameters

Parameter	Description	Value
<i>Households</i>		
$\gamma$	Coefficient of relative risk aversion	2
$\phi$	Habit persistence	0.75
$\eta$	Inverse of the Frisch elasticity	2
<i>Nonfinancial firms</i>		
$\alpha$	Capital share in the production function	0.3
$\delta$	Capital depreciation rate	0.025
$\kappa_i$	Capital installation costs	0.5
$\nu$	Loan-to-value ratio for firms	0.75
<i>Steady-state rates</i>		
$R$	Steady-state return on deposits	1.005
$R^l$	Steady-state return on loans	1.015
$R^e$	Steady-state return on equity	1.035
<i>Banks</i>		
$\tau$	Target leverage ratio	6.67
$\mu$	Ratio of CoCos to total debt	0.015
$\theta$	Debt to equity conversion rate	0.1
$\kappa_r$	Real (natural) rate deviation rule	0.25

Table 2: Implied steady-state values from the model

Parameter	Description	Value
$\beta$	Discount factor	0.966
$\tilde{C}^\gamma/D$	Liquidity services provided by deposits	0.029
$\alpha Y/K$	Marginal production of capital	0.045
$K/Y$	Capital-output ratio	6.634
$I/Y$	Investment-output ratio	0.166
$C/Y$	Consumption-output ratio	0.834
$\delta_b$	Fixed costs for bank capital management	0.072
$K^x/K^B$	Ratio of CoCos to total bank capital	0.1

Note: the steady-state equations based on the model are provided in the appendix.

For the banking sector, the steady-state target leverage ratio  $\tau$  is set to 6.67, which corresponds to an average bank capital-asset ratio of 15%. This is slightly above the average total equity to total assets ratio of 11% for all U.S. commercial banks in 2013, but is similar to the 14% capital adequacy ratio motivated by Meh and Moran (2010) and the 15% effective capital-asset ratio in de Walque et al. (2010). Since 2009, the ratio of CoCos issued to that of non-CoCo subordinated debt plus senior unsecured debt is 1.5% (Avdjiev et al., 2013).  $\mu$  is therefore set equal to 0.015. A reasonable assumption of 1.5% serves the purpose of this paper to study the mitigating effects of CoCos under negative shocks to bank capital. Similarly, given a decline in bank capital, the conversion probability from debt to equity ( $\theta$ ) is fixed at 0.1. A value of 0.25 for  $\kappa_r$  implies that the real interest rate deviates 25 basis points below its steady-state when the output gap increases 1% (e.g., Laubach and Williams, 2003; Garnier and Wilhelmsen, 2005).

The remaining implied steady state values are reported in Table 2. In relation to the RBC literature, the implied steady state values for the capital-output ratio (6.63) and the investment-output ratio (0.17) are slightly below their normally observed values,  $K/Y = 8$  and  $I/Y = 0.2$  (de Walque et al., 2010). As a result, the consumption-output ratio (0.83), is slightly higher than what is observed in the data between 1985Q1 and 2013Q4 (0.66). The discount factor  $\beta$  is the reciprocal of the steady-state return on equity (see Eq. 5). The bank capital management costs parameter  $\delta$  equals 0.072. Based on the approximate estimate for  $\mu$  and given  $\tau$ , the ratio of contingent convertible capital to total bank capital is set at 10%. All autoregressive parameters for exogenous shock processes are standardized to equal 0.75, and innovations are independent and normally distributed. A degree of persistence of 0.75 implies a lifespan of approximately four years for technology and financial shocks.

## 4 Findings

Following the RBC literature, Section 4.1 compares the business cycle moments produced by the model with the stylized facts observed in the data. This exercise also highlights the key role of financial shocks in reproducing business cycle characteristics. Subsequently, Section 4.2 explains the transitional effects of bank capital regulation, from Basel I through to Basel III, on the cyclical properties of the economy. Section 4.3 looks at the effectiveness of CoCos in mitigating negative shocks to bank capital, and whether there is potential for CoCos to complement a Basel III regime with countercyclical capital requirements.

### 4.1 Business cycle moments

Table 3 presents the cyclical properties of the data and the model. The standard deviations and correlations of the U.S. data are calculated from the sample period 1985Q1–2013Q4. Model 1 shows the second moments produced by the model from a productivity shock, whereas, model 2 includes a target leverage ratio shock and an equity premium shock in order to capture financial market properties of the data, not explained by the traditional RBC theory. The productivity shock (1%) and leverage shock (2.14%) correspond to one standard deviation observed in the data. The equity premium shock is set to half a standard deviation (2.7%).

Table 3: Cyclical properties

Variable	standard deviation relative to output			correlation with output		
	data	mod.1	mod.2	data	mod.1	mod.2
Output ( $Y_t$ )	1	1	1	1	1	1
Consumption ( $C_t$ )	0.86	0.85	0.88	0.91	0.85	0.61
Investment ( $V_t$ )	4.97	3.32	4.81	0.93	0.73	0.69
Hours ( $H_t$ )	0.35	0.46	0.66	0.73	-0.99	-0.35
Firm loans ( $L_t$ )	2.08	1.53	1.94	0.38	0.97	0.72
Credit spread ( $R_t^l - R_t$ )	1.35	1.12	1.51	-0.66	-0.88	-0.55
Equity premium ( $R_t^e - R_t$ )	5.30	0.85	3.53	0.02	0.998	0.04
bank capital-asset ratio ( $K_t^b/L_t$ )	2.14	0.05	2.51	-0.28	-0.95	-0.35

Note: model 1 is simulated with a productivity shock. For model 2 a target leverage ratio shock and an equity premium shock are included in order to capture financial market properties in the data not explained by the traditional RBC theory. All variables, except for rates, are in log real terms and are detrended using the HP filter (data list: see Appendix A).

As expected, model 1 reproduces the cyclical moments of the real sector fairly well: consumption is slightly less volatile than output, while investment is over three times as volatile. Although the relative standard deviation of hours worked is consistent with the data, its correlation with output is strongly negative. This counterfactual statistic is a result of the labor market setup being fully-flexible in the model. Similarly, for the financial sector, the productivity shock does reasonably well to capture the relative standard deviations of firm loans and the credit spread, but their correlations with output are significantly overestimated. Conversely, the cyclical properties of the equity premium and bank-capital asset ratio are poorly reproduced.

Including two uncorrelated financial sector shocks (model 2) improves almost all the results of relative standard deviations and correlations. Similar to the results in de Walque et al. (2010), adding the financial shocks raises the volatility of all the variables and reduces their correlation with output. In particular, the statistics for all the financial variables are greatly improved at the expense of lower correlations for consumption and investment.

## 4.2 Business cycle dynamics of the Basel regimes

The purpose of this subsection is to establish the business cycle effects of minimum capital requirements under alternative Basel regimes. Similar to Angelini et al. (2012) and Brzoza-Brzezina et al. (2013), the Basel III target leverage ratio  $\tau_t$  follows a countercyclical capital adequacy rule (Eq. 27) where  $\kappa_\tau = 2.14$  is the standard deviation of the capital-asset ratio relative to output. This means that the target leverage ratio of banks is tapered during booms and elevated during busts. In other words, banks accumulate a capital buffer when output deviates above steady-state. Conversely, Basel II procyclicality can be emulated by inverting the sign for  $\kappa_\tau$  (e.g., Angeloni and Faia, 2013, p.321). This generates the procyclical leverage observed for minimum capital requirements under Basel II. For the Basel I regime, bank capital requirements are exogenous, where  $\kappa_\tau = 0$  and  $\tau_t$  becomes an exogenous AR(1) process. Figures 1 and 2 show the impulse responses of the Basel regimes, under a productivity shock and target leverage ratio shock, respectively.

In Figure 1 we immediately see the exacerbating effect of a procyclical Basel II regime. A positive technology shock raises output, consumption and investment causing banks to expand their balance sheets

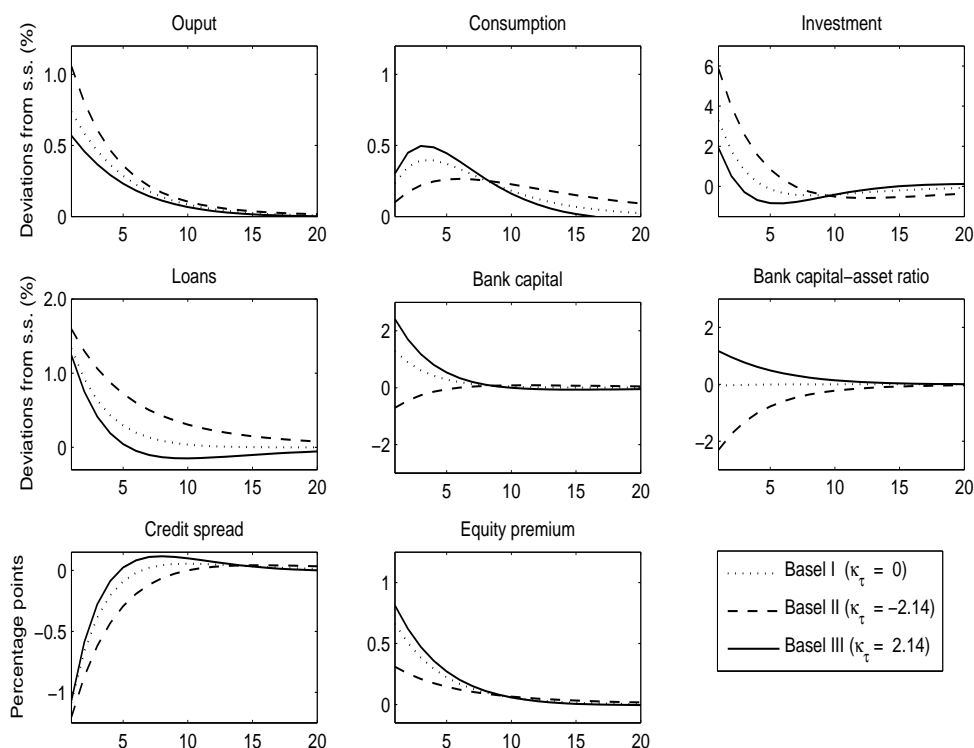


Figure 1: Impulse response to a positive technology shock. From Basel I to Basel III.

by taking on deposits and extending loans to firms. The demand for loans is spurred on by the narrowing credit spread, whilst the rising equity premium reflects the bullish market and the profitability of nonfinancial firms and banks. On the one hand, compared to Basel I, Basel II increases the volatility of bank balance sheets as well as the real economy. In particular, banks become overextended in an environment of higher financing costs and lower returns on assets, causing real investment and production to expand. Households' smooth their consumption paths by increasing savings, whilst a lower return on equity initially dampens consumption. On the other hand, in a Basel I regime banks are required to raise capital to stabilize their leverage ratios, which minimizes adverse bank balance sheet adjustments.<sup>13</sup>

For Basel III, countercyclical capital requirements effectively stabilize bank balance sheets and business cycle fluctuations. By raising a capital buffer, in addition to the Basel I requirements, credit extension is tapered and an overexpansion of the real economy is prevented. In fact, the credit market stabilizes after seven quarters, with the real economy reverting to steady-state within fifteen quarters. Overall, the results for the Basel regimes in Figure 1 confirm the findings in de Walque et al. (2010), Christensen et al. (2011) and Angeloni and Faia (2013).

Figure 2 shows similar results for each alternative Basel regime under the banking sector shock. Basel II is procyclical, and Basel III is countercyclical. Reducing the target leverage ratio of banks, analogous to requiring banks to hold more capital, impacts the business cycle as follows. For Basel II, the effect on loans

<sup>13</sup>With exogenous capital requirements the target leverage ratio remains constant, i.e., Basel I is time-invariant.



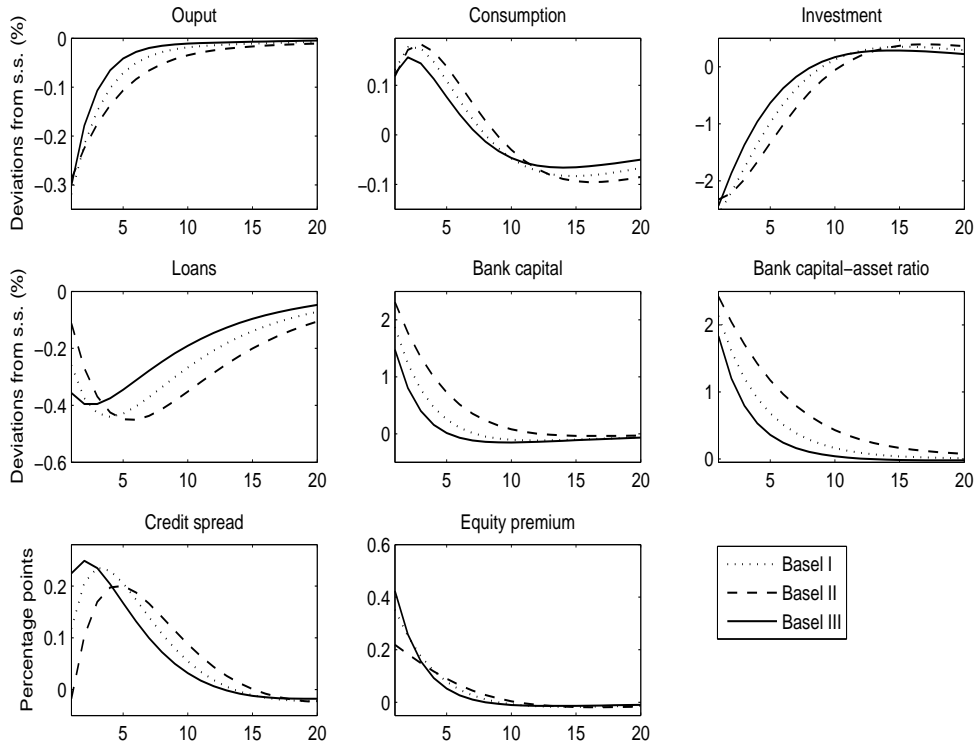


Figure 2: Impulse response to a reduced target leverage ratio. From Basel I to Basel III.

and the credit premium becomes more amplified than Basel I and Basel III after five quarters. In addition, an overcapitalization of bank balance sheets crowds out liquidity supply to and from banks. The result of a worsening credit market and increasing liquidity shortages strengthens the negative effect of higher capital requirements on the real economy. The converse is true for the Basel III regime.

Moreover, the impact of minimum capital requirements is more clearly observed when the *steady-state* target leverage ratio, and not only the dynamic adjustment thereof, changes. This can be interpreted as the effect of an incremental increase in the level of minimum capital requirements from Basel I to Basel III. Figure 3 shows the total equity to total assets ratio for all U.S. banks from 1985Q1 to 2013Q4. The shaded areas correspond with the published (announced) dates of each Basel Accord. The idea here is to roughly illustrate the incremental increase in the steady-state *level* of bank capital-asset ratios after each Basel Accord. Figure 4 shows the impulse response to a reduced target leverage ratio for a low versus high steady-state capital requirement. Simply raising the steady-state capital-asset ratio from 10% to 15% (i.e.,  $\tau = 10$  and  $\tau = 6.67$ , respectively) has a strong exacerbating effect on bank loans and the cost of credit. As a result, investment in production activities declines, further reducing output. Although consumption initially rises because of a better return on equity, it becomes negative after eight quarters.

The reasoning from the model setup is as follows. Based on the bank's optimizing Eqs. 19 and 20, we

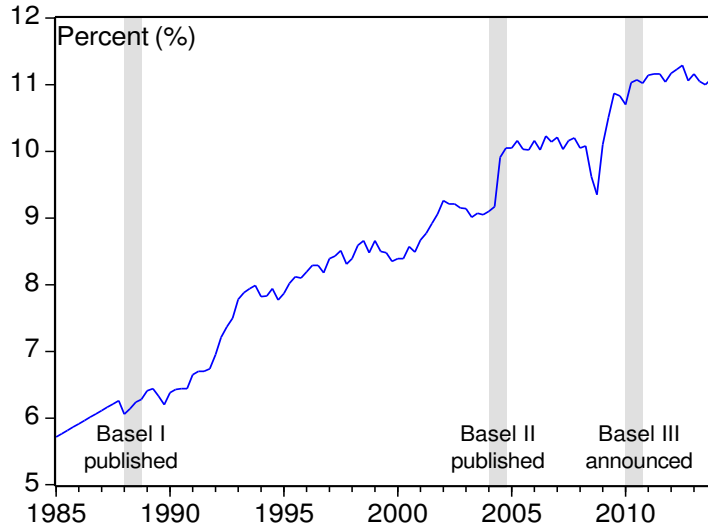


Figure 3: Equity-to-assets ratio for all U.S. banks

can re-write the flow of funds constraint to derive the implied steady-state rate of returns margin

$$R^l = \frac{1}{\tau}R^e + \frac{(\tau - 1)}{\tau}R. \quad (35)$$

Given  $R = 1.005$ ,  $R^l = 1.015$  and  $R^e = 1.035$ , the implied steady-state value for the leverage ratio  $\tau$  equals 3. Its reciprocal gives a 33% bank capital-asset ratio. Therefore, as  $\tau$  tends to 3 (i.e., reducing  $\tau$  from 10 to 6.67) the bank approaches its optimal maximization point. Conversely, given  $R^e$  and  $R$ , the higher the leverage ratio the narrower the steady-state rate of returns margin becomes. In the dynamic equation (21), this also means that the variability of the credit spread and the equity premium is smaller for a given adjustment to the bank capital-asset ratio.

### 4.3 Contingent convertible capital

This subsection shows how contingent convertible capital complements the objectives of a Basel III macroprudential policy. From the above analysis it is clear that the shift from Basel II to Basel III should reduce shocks to both the real economy and the financial sector. However, two important drawbacks are observed. One, shocks to the business cycle are exacerbated by higher steady-state levels of minimum capital requirements. Two, the Basel III regime is not designed to counteract sudden negative shocks to bank capital. Here, contingent convertible capital becomes a useful instrument for bank capital requirements. In that, once the debt instrument converts into common equity the conversion is permanent. State contingent CoCos therefore address permanent shifts in bank capital needs—without requiring banks to hold higher levels of common equity to preempt episodes of financial distress. More importantly, the role of CoCos is to automatically re-capitalize banks, reduce financial distress (in a timely manner), and mitigate knock-on effects to the real economy.

To highlight this role, I compare impulse responses of the model with contingent convertible capital

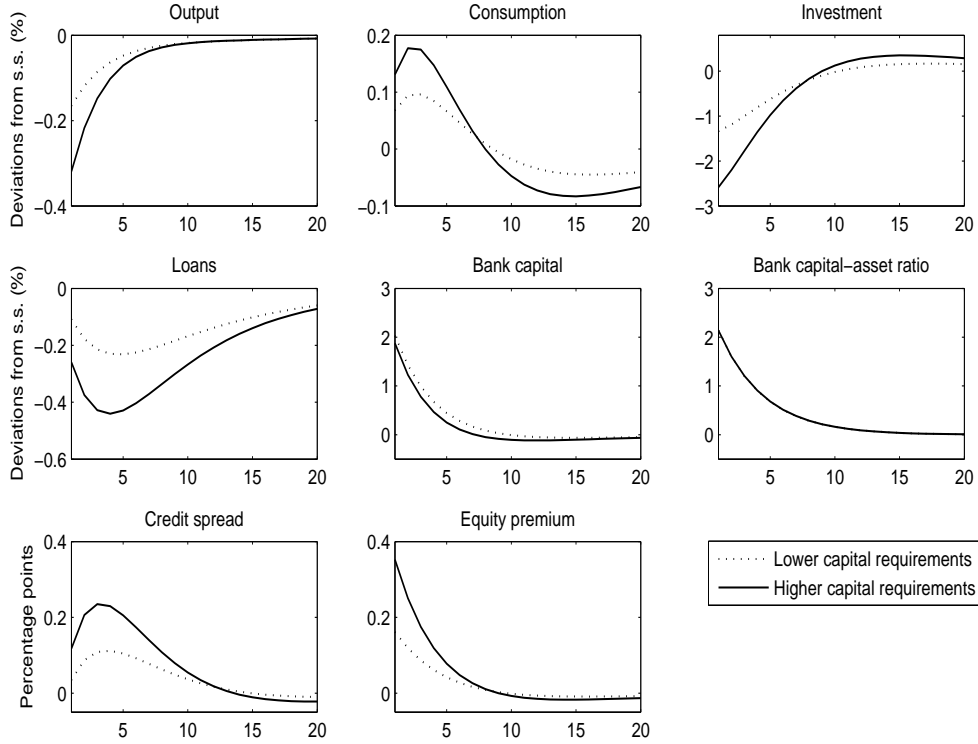


Figure 4: Impulse response to a reduced target leverage ratio for low versus high capital requirements.

to the one without (hereafter No CoCos). Figures 5 and 6 show the attenuating effect of CoCos under a negative target leverage ratio shock and a negative bank capital shock. Figure 7 shows the impulse response to a technology shock. For the leverage shock and the technology shock the target leverage ratio is kept exogenous.<sup>14</sup> For the bank capital shock, the Basel III regime combines with CoCos to highlight the comparative advantage of CoCos over countercyclical capital requirements, in periods of financial distress. In each case, banks are required to raise their capital-asset ratios to satisfy the target leverage ratio. Based on the model setup, CoCos will convert into equity with probability 0.1 when the trigger value ( $L_t/K_t^b$ ) is above the target level ( $\tau_t$ ).

Figure 5 clearly shows the effectiveness of CoCos in mitigating financial distress. On the one hand, for the No CoCos model, a positive shock to capital requirements causes a contraction in loan supply and a widening credit spread. As a result, investment in production activities declines. Although household consumption initially increases due to the positive wealth effect of equity, output falls 0.32%. On the other hand, allowing for banks to hold contingent convertible capital (see CoCos 1) significantly reduces the adverse effect of higher capital requirements, on both the financial sector and the real economy. Firstly, the triggering of CoCos from debt to equity raises overall bank capital and reduces the amount of debt on bank balance sheets. As a result, the contraction in loan supply and the rise in the cost of capital halves. The knock-on effect to the

<sup>14</sup>When the Basel III regime combines with CoCos, the target leverage ratio becomes time-variant and endogenous for all shocks. For this reason, I abstract from showing the combined results in Figures 5 and 7. That said, comparing the impulse responses for Basel III and CoCos (i.e., Fig. 1 with Fig. 7; and Fig. 2 with Fig.5) is indicative of the combined result for both shocks.

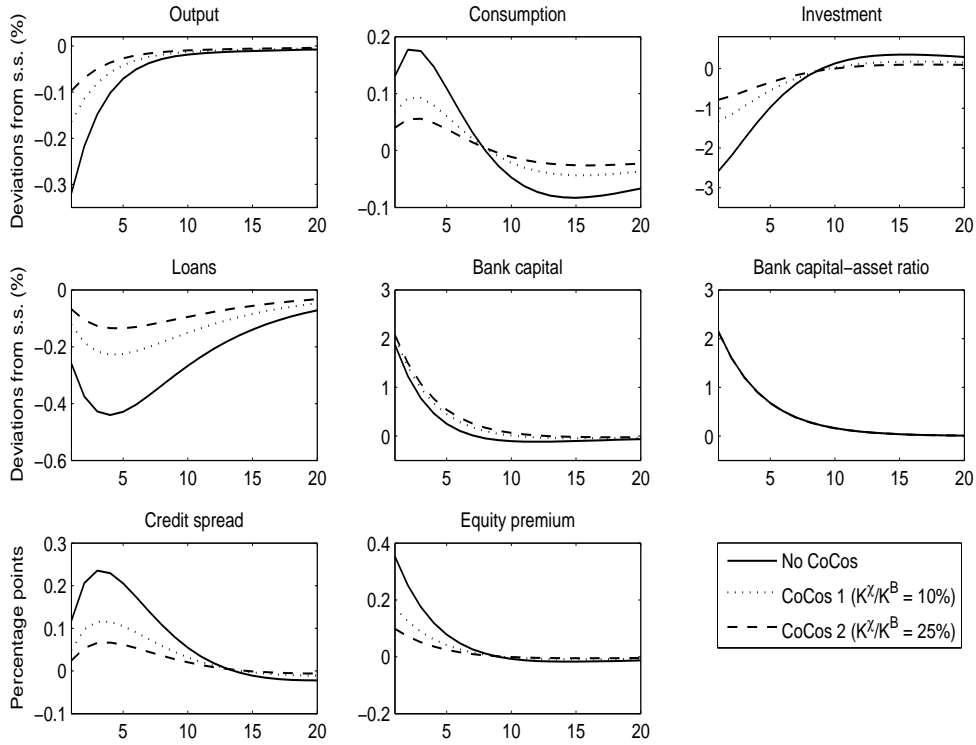


Figure 5: Impulse response to a reduced target leverage ratio. Introducing contingent convertible capital.

real economy is subsequently mitigated, with output now falling only 0.16%. Furthermore, increasing the steady-state ratio of CoCos to total bank capital ( $K^X/K^B$ ) from 10% to 25% further reduces the instability caused by the shock (see CoCos 2). Although illustrative, this result clearly shows a significant stabilization role for CoCos.

Indeed, an exogenous shock to capital requirements may reflect either a market response for holding a capital buffer or a response to Basel regulatory requirements; but as shown for a positive technology shock, an increase in bank leverage may not signal financial distress but rather a build-up of systemic risk (i.e., an overleveraged financial sector with excess credit supply). To therefore test the flexibility of CoCos, Figure 6 illustrates the effectiveness of CoCos under a negative shock to bank capital. Here, we can interpret the trigger value to be linked to bank capital, and not the leverage ratio. In addition, CoCos combine with the Basel III regime to show its relative dominance against financial shocks.

The results in Figure 6 follows closely to that observed for the target leverage ratio shock. But instead of requiring banks to *raise* their capital-asset ratios, they must now attenuate the *costs of a fall* in bank capital. CoCos effectively reduce the collapse in bank equity by half, and reduce the effect of the shock on all the variables. More importantly, when the Basel III regime combines with CoCos the stabilization effect only marginally improves. In particular, when the shock to bank capital reduces credit supply and causes a fall in output, capital requirements are automatically tapered. This means that banks are not required to raise bank capital immediately and, as a result, leverage deviation costs are not transmitted onto the

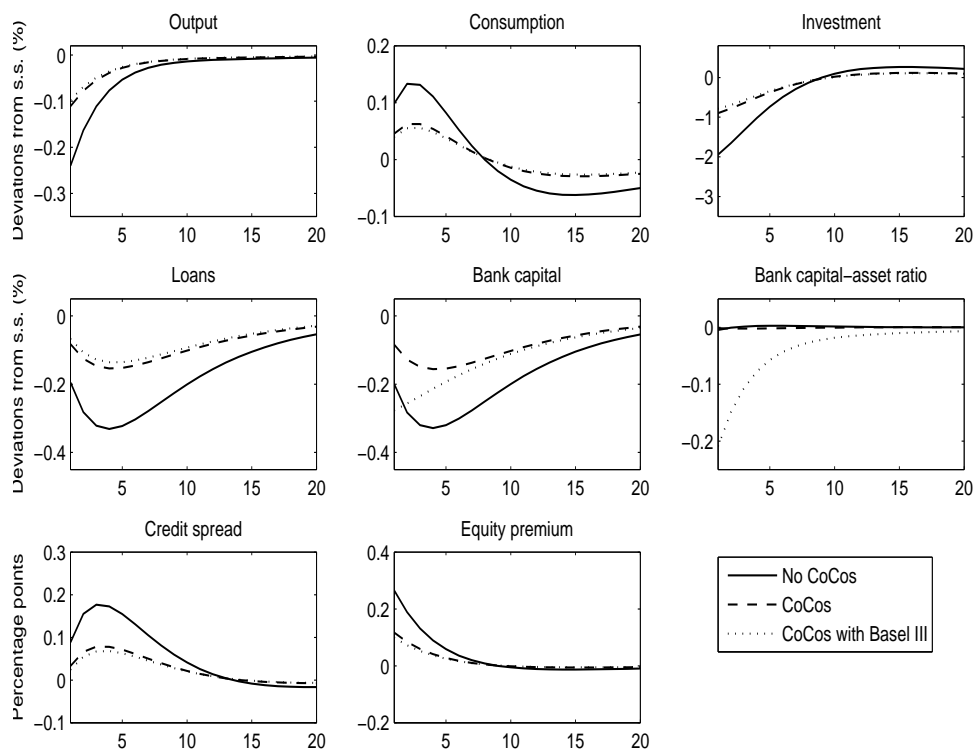


Figure 6: Impulse response to a negative bank capital shock. Introducing contingent convertible capital.

credit spread and the equity premium. This mechanism, however, is not strong enough to improve on the stabilization effect of CoCos.

For the positive technology shock (Figure 7), introducing CoCos raises the aggregate bank capital-asset ratio, but the adjustment is too small to influence the broader economy. Therefore, when banks become overleveraged because of a positive supply shock, a countercyclical capital adequacy rule dominates. That is, the Basel III regime increases the bank capital-asset ratio significantly more, thereby reducing business cycle fluctuations (see Figure 1). This, in fact, is a desirable outcome for the following reasons. Firstly, CoCos are designed to react to negative financial shocks, and not shocks to the real economy. For example, if the trigger value was tied to the share price of common bank equity—and not the leverage ratio—then a positive technology shock will not trigger a conversion of CoCos. Secondly, as positive supply shocks to the real economy tend to be more gradual and persistent, a countercyclical capital adequacy rule dampens the build-up of excess credit supply. Conversely, over shorter horizons, CoCos effectively counteract negative financial shocks.

## 5 Concluding remarks

Using a standard RBC model with an equity market and a banking sector, this paper shows that countercyclical capital requirements (as in Basel III) and contingent convertible capital provide an effective dual

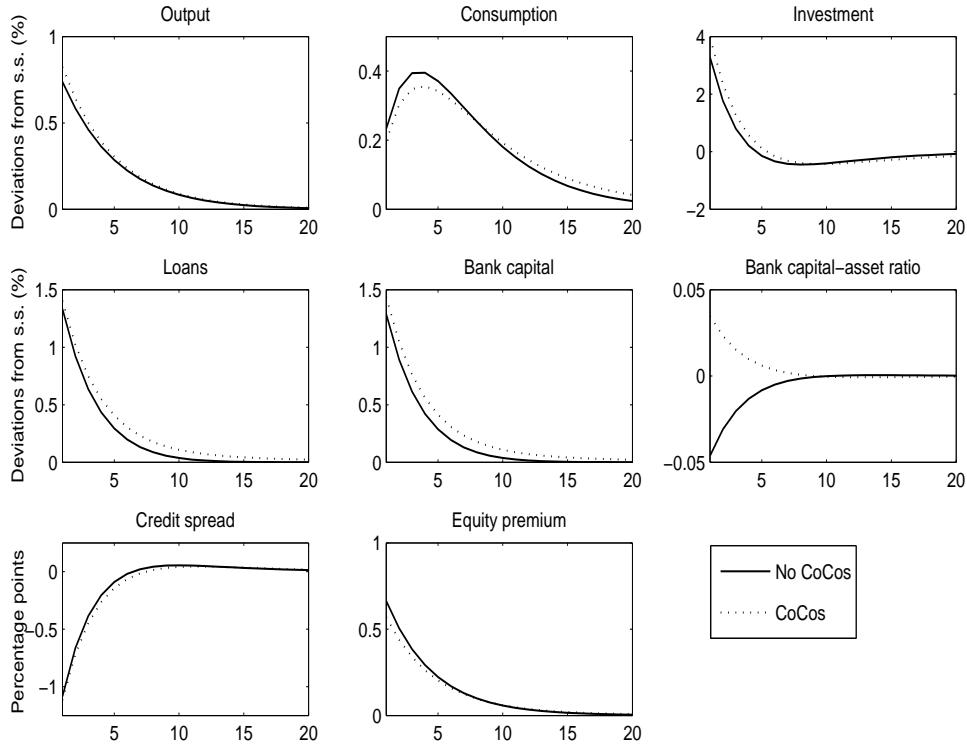


Figure 7: Impulse response to a positive technology shock. Introducing contingent convertible capital.

approach to macroprudential policy. On the one hand, a countercyclical capital adequacy rule dominates CoCos in the stabilization of real shocks. That is, by raising a capital buffer the Basel III regime mitigates the build-up of excess credit supply and, as a result, constrains the expansion of overleveraged banks. On the other hand, CoCos have a strong advantage over the Basel III regime against negative financial shocks. Here, CoCos effectively re-capitalize banks, reduce financial distress in a timely manner, and mitigate knock-on effects to the real economy. Countercyclical capital requirements and contingent convertible capital instruments therefore limit financial instability, and its associated influence on the real economy.

The introduction of contingent convertible capital into the general equilibrium framework comes with two clear shortcomings. One, alternative states cannot be an outcome of the model, but rather imposed through exogenous shocks. Two, the technique used in the model setup to combine bank deposits with subordinated debt (i.e., CoCos) is highly stylized. Given these shortcomings, however, the model does well to capture the mechanism for which CoCos are designed. Furthermore, it is fairly straightforward to include nominal rigidities in the RBC framework, and to observe how monetary policy interacts with macroprudential policy. As it stands, the model does well to capture the cyclical properties of U.S. data, and further research adopting this framework looks promising.

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## A Appendix

### A.1 The rate of returns margin

Based on the optimizing Eqs. 19 and 20, we can re-write the flow of funds constraint to derive the rate of returns margin (the debt financing margin)

$$R_t^l = \frac{K_t^b}{L_t} R_{t+1}^e + \left(1 - \frac{K_t^b}{L_t}\right) R_t + \frac{F(E, L)}{L_t}. \quad (\text{A.1})$$

Therefore, if  $R_t \ll R_t^l$  and  $R_t \ll R_t^e$ , then from Eq. A.1  $R_t^l \ll R_t^e$ .

### A.2 Log-linearized system of equilibrium conditions

- Households

Deposit demand

$$(1 - \beta R) d_t = \frac{\gamma}{(1 - \phi)} (c_t - \phi c_{t-1}) - (\beta R) E_t \left[ \frac{\gamma}{(1 - \phi)} (c_{t+1} - \phi c_t) - r_t \right] \quad (\text{A.2})$$

Wages

$$w_t = \frac{\gamma}{(1 - \phi)} (c_t - \phi c_{t-1}) + \eta h_t \quad (\text{A.3})$$

Equity Euler equation

$$c_t = \frac{\phi}{(1 + \phi)} c_{t-1} + \frac{1}{(1 + \phi)} E_t [c_{t+1}] + \frac{(1 - \phi)}{\gamma(1 + \phi)} r_{t+1}^e \quad (\text{A.4})$$

Steady-state condition:  $\beta = 1/R^e$

- Firms

Labor demand

$$w_t = y_t - h_t \quad (\text{A.5})$$

The equity financing premium

$$R^e r_{t+1}^e = \frac{\alpha Y}{K} (y_{t+1} - k_t) + \nu \frac{R^e}{R^l} (r_{t+1}^e - r_t^l) + \nu \left( \frac{R^e}{R^l} - 1 \right) \nu_t + \kappa_i (i_{t+1} - k_t) - \frac{\kappa_i}{\beta_f} (i_t - k_{t-1}), \quad (\text{A.6})$$

where  $(\alpha Y/K) = R^l - (1 - \delta) - ((R^e - R^l)\nu)/R^l$  and  $R^e > R^l$ .

Borrowing constraint

$$l_t = \nu_t + k_t - r_t^l, \quad (\text{A.7})$$

where  $\nu_t$  is an AR(1) stochastic shock.

Production function

$$y_t = \alpha k_{t-1} + (1 - \alpha) h_t + \xi_{z,t}, \quad (\text{A.8})$$

where  $\xi_{z,t}$  is an AR(1) stochastic shock.

- Banks

The equity financing margin

$$R^e r_{t+1}^e - R^l r_t^l = \tau(\tau - 1)\kappa(l_t - k_t^b - \tau_t), \quad (\text{A.9})$$

where  $R^e > R^l$  ;  $\kappa \approx [\frac{1}{10}; \frac{1}{3}]$  ;  $\tau = (L/K^b) > 1$  and  $(\tau - 1) = (D/K^b)$ .

- Market clearing

Aggregate resource constraint

$$y_t = \frac{C}{Y} c_t + \frac{I}{Y} i_t \quad (\text{A.10})$$

Evolution of state variables

$$k_t = (1 - \delta)k_{t-1} + \delta i_t \quad (\text{A.11})$$

$$k_{t+1}^b = (1 - \delta_b)k_t^b + r^l \tau (r_t^l + l_t) - r(1 - \tau)(r_t + d_t) \quad (\text{A.12})$$

Risk-free real rate of return rule

$$r_t = \rho_r r_{t-1} - \kappa_r (1 - \rho_r) y_t \quad (\text{A.13})$$

- Shock processes

$$\xi_{z,t} = \rho_z \xi_{z,t-1} + \epsilon_{z,t}, \quad (\text{A.14})$$

$$\tau_t = \rho_\tau \tau_{t-1} - \kappa_\tau (1 - \rho_\tau) y_t + \epsilon_{\tau,t}, \quad (\text{A.15})$$

$$\xi_{e,t} = \rho_e \xi_{e,t-1} + \epsilon_{e,t}, \quad (\text{A.16})$$

$$\xi_{k^b,t} = \rho_{k^b} \xi_{k^b,t-1} + \epsilon_{k^b,t}. \quad (\text{A.17})$$

### A.3 Model steady states

$$\beta = \beta_f = \beta_b = \frac{1}{R^e} \quad (\text{A.18})$$

$$\frac{\alpha Y}{K} = R^e - (1 - \delta) - ((R^e - R^l)/R^l)\nu \quad (\text{A.19})$$

$$\frac{K}{Y} = \frac{\alpha}{\alpha Y/K} \quad (\text{A.20})$$

$$\frac{I}{Y} = \delta \frac{K}{Y} \quad (\text{A.21})$$

$$\frac{C}{Y} = 1 - \delta \frac{K}{Y} \quad (\text{A.22})$$

$$\frac{\tilde{C}^\gamma}{D} = (1 - \beta R) \quad (\text{A.23})$$

$$\delta_b = r^l \tau - r(\tau - 1). \quad (\text{A.24})$$

After introducing contingent convertible debt, we include the following steady-state condition:

$$\mu = \frac{K^x}{K^B} \frac{1}{(\tau - 1)}, \quad (\text{A.25})$$

and Eq. A.23 becomes:

$$\frac{\tilde{C}^\gamma}{D} = (1 - \beta((1 - \theta\mu)R + \theta\mu R^e)). \quad (\text{A.26})$$

## A.4 Data and sources

Data source from the St. Louis Federal Reserve Economic Data (FRED).

1. RGDP: Real Gross Domestic Product, 1 Decimal (GDPC1), Billions of Chained 2005 Dollars, Quarterly, Seasonally Adjusted Annual Rate.
2. Inflation: Gross Domestic Product: Implicit Price Deflator (GDPDEF), Index 2005=100, Quarterly, Seasonally Adjusted.
3. Consumption: PCE
4. Investment:
5. Hours:
6. Loans to nonfinancial firms: Commercial and Industrial Loans (BUSLOANS), All Commercial Banks, Billions of Dollars, Quarterly, Seasonally Adjusted plus Real Estate Loans, All Commercial Banks (REALLN), Billions of Dollars, Quarterly, Seasonally Adjusted
7. Bank capital-asset ratio: ETA
8. Short-term rate: 3MTB
9. Return on equity: USROE
10. Loan rate to firms: Moody's seasoned Baa corporate bond yield (BAA), Percent, Quarterly, Not Seasonally Adjusted.
11. Equity: Standard and Poor 500 Index (SP500), Index, Quarterly, Not Seasonally Adjusted.
12. US population: Civilian Noninstitutional Population (CNP16OV), Thousands of Persons, Quarterly, Not Seasonally Adjusted.