A Model of Countercyclical Macroprudential Policy

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May 19, 2019

Abstract

Since the adoption of Basel III bank regulations, countercyclical capital requirements have risen in prominence as a macroprudential tool for mitigating systemic risk and promoting financial stability. In this paper, I develop a model with a social cost of debt, which is addressed by imposing a capital requirement on financial intermediaries that responds countercyclically to aggregate debt and output. I evaluate the economy's responses to simulated financial crises and find that a countercyclical capital requirement reduces the volatility of macroeconomic variables, helping the economy recover after a shock. This smoothing effect can be explained by the degree of the requirement's countercyclicality. In a welfare analysis, I find that a countercyclical capital requirement can lead to greater welfare gains than a debt tax. These results provide strong evidence in favor of the use of countercyclical capital requirements as a policy instrument.

A thesis submitted in partial fulfillment of the requirements for the degree of

Bachelor of Arts in Economics with Honors

Adviser: Harald Uhlig

1 Introduction

The 2008 financial crisis plainly demonstrated to the world the dangers of allowing excess risk to build up in the financial sector. To prevent similar crises in the future, policymakers have increasingly turned to macroprudential policy, which are policies that seek to mitigate systemic risk. At the forefront of this heightened attention toward macroprudential issues was the adoption of Basel III, a global framework for regulating banks and promoting financial stability drafted in 2010. Building on previously-developed regulatory frameworks (Basel I and Basel II), Basel III features several enhancements to rules surrounding banks that have been implemented in developed countries around the world.

A major pillar of Basel III is the strengthening of capital requirements. According to Basel III rules, a certain ratio of banks' risk-weighted assets must be funded by Common Equity Tier 1 (CET1) capital; from 2019 onwards, this minimum CET1 ratio is 7%. The idea behind this requirement is to force banks to maintain a "safety net" which could protect them from bankruptcy if the value of their assets unexpectedly drops. If banks are less likely to fail, then the economy is better protected against financial crises.

In addition, Basel III also introduced a countercyclical capital buffer (CCyB), an extra requirement to be added on to the minimum CET1 ratio that can range between 0% and 2.5%. National policymakers can individually adjust the CCyB within their own borders, allowing them to raise capital requirements during expansions, when high credit growth can lead to increased systemic risk, and lower them during recessions, when credit is needed for the economy to recover. In theory, letting macroprudential policy adapt to credit conditions can smooth the credit cycle, making credit busts less common and less painful. Since its introduction, the CCyB in several countries has been adjusted over time, although the CCyB in the United States has never risen above 0%.

As the policy relevance of macroprudential regulation has surged, much academic work on macroprudential issues has focused on explaining the buildup of systemic risk greater than socially optimal levels. There are four major strands of literature on this topic. First, one idea is that debt imposes a pecuniary externality related to the possibility of fire sales. Lorenzoni (2008) and Korinek (2011) develop a three-period model in which financial contracts are subject to limited commitment. After a negative aggregate shock, banks who borrow to invest in assets may be forced to engage in "fire sales," selling off these assets very cheaply, which decreases equilibrium asset prices and hurts the portfolios of other financial market participants; however, this cost is not internalized by the banks themselves. Thus, macroprudential policy that limits bank borrowing can be welfare-improving.

Second, a friction may arise from banks' reliance on wholesale funds. Kiyotaki and Moore (2012) describe a model featuring assets of varying degrees of liquidity and idiosyncratic liquidity shocks. To maintain their balance sheets, banks must borrow and lend with each other. In such an environment, the failure of one bank can have ripple effects throughout the economy as a whole. However, banks do not internalize this cost, so they expose themselves to more risk than is socially optimal.

Third, another idea is that government policies to prop up banks create a moral hazard problem leading to excessively risky behavior. For example, Kareken and Wallace (1978) examine a model of deposit insurance and conclude that it causes banks to hold riskier portfolios. Additionally, Farhi and Tirole (2012) find that systemic bailouts of failing banks encourage banks to adopt riskier balance sheets.

Fourth, overconfident financial market participants may simply underestimate the riskiness of their assets. This "irrational exuberance," a term used by Shiller (2000) to describe the behavior of investors just prior to the stock market crash of 2000, can lead to the rise and fall of asset price bubbles, which may be harmful to the aggregate economy.

All four of these theories present a case for potential welfare gains from macroprudential intervention. In my model, I take as given the fact that systemic risk in the financial sector imposes an externality. Along this line, I incorporate a "social cost of debt" into my model. This cost can be thought of as an ad hoc representation of any combination of these four theories. In the model, I present the cost as the regulatory expense of supervising financial intermediaries, which is increasing in the level of aggregate debt.

For the rest of my model, I develop a framework based on the financial accelerator model of Bernanke, Gertler, and Gilchrist (1999), which is particularly well-suited for studying macroprudential issues because it features meaningful financial frictions, which magnify the role of financial intermediaries. In this canonical model, firms can either raise funds internally or by borrowing from households, but they have some probability of defaulting that depends on their net worth. As such, external finance is more expensive than internal finance, and this "external finance premium" is inversely related to net worth. When a negative aggregate shock hits, the borrowing capacity of firms may be constrained due to a reduction in their net worth. Then, the negative effects of the shock are amplified, producing the so-called "financial accelerator" effect. Gertler and Karadi (2011) develop a similar model that introduces financial intermediaries, who borrow from households and loan to firms; each period, these intermediaries have the chance to divert their assets and exit the market, which limits how much households are willing to lend to them. As a result, intermediaries face an incentive-based borrowing constraint that depends on their net worth, which generates the financial accelerator effect. Gertler and Kiyotaki (2010) extend this model further by separating firms and intermediaries into islands that experience idiosyncratic investment opportunities, exposing intermediaries to liquidity risks and elevating the importance of interbank borrowing.

The model in this paper features two primary departures from traditional financial accelerator models. The first is the addition of a social cost of debt, described above. Second, I remove the incentive-based borrowing constraint; in its place, intermediaries can be subject to a capital requirement set by policymakers. In essence, I replace the endogenous constraint on intermediary portfolios from Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) with an exogenous one. The capital requirement is time-varying and follows a rule that responds to aggregate debt and output, making it countercylical in the spirit of the minimum CET1 ratio and CCyB outlined in Basel III.

Using this model, I reach two major findings. First, a countercyclical capital requirement is effective in reducing the volatility of macroeconomic variables, helping the economy recover after a crisis. Second, it can lead to significant welfare gains that surpass those from a debt tax.

My paper is not the first to incorporate countercyclical capital requirements into a macroeconomic model. For example, Kannan, Rabanal, and Scott (2012) evaluate their effectiveness at addressing housing booms, Angeloni and Faia (2013) analyze them in an economy featuring bank runs, and Angelini, Neri, and Panetta (2014) develop a complex model with a realistic financial sector to study interactions between monetary and macroprudential policy. All three of these papers conclude that countercyclical capital requirements provide social benefits by smoothing the credit cycle. I re-affirm this conclusion while also contributing to the literature in a few ways. First, I develop a model that is simple and general enough to be applied to a variety of macroprudential research questions. Second, by introducing a social cost of debt, I incorporate both a motivation for macroprudential intervention and an avenue for analyzing its welfare implications.

The rest of this paper proceeds as follows. Section 2 sets up the model by detailing its four sectors: households, financial intermediaries, firms, and capital producers. Section 3 goes over my choices for parameter values and describes the steady states of three variations of the model under different policies. Section 4 presents the economy's responses to two crisis simulations: a negative productivity shock and a negative capital quality shock. Section 5 explores the welfare implications of an optimal debt tax and countercyclical capital requirements. Finally, Section 6 offers concluding remarks and directions for further work.

2 Model

The model in this paper is derived from the financial accelerator model of Gertler and Karadi (2011), which features a financial sector that can be exposed to financial frictions. It takes place in discrete time, with periods indexed by $t = 0, 1, 2, \ldots$. There are four sectors: households, financial intermediaries, firms, and capital producers. Each sector is comprised of a continuum of members of measure unity. Each household owns an intermediary, a firm, and a capital producer.

Figure 1 provides a broad overview of the relationships between the sectors. Households consume, work, and save. Intermediaries borrow savings from households and lend to firms. Firms obtain loans from intermediaries and use labor and capital to produce output. Capital producers convert output into investment goods, which are sold to firms to generate new capital.

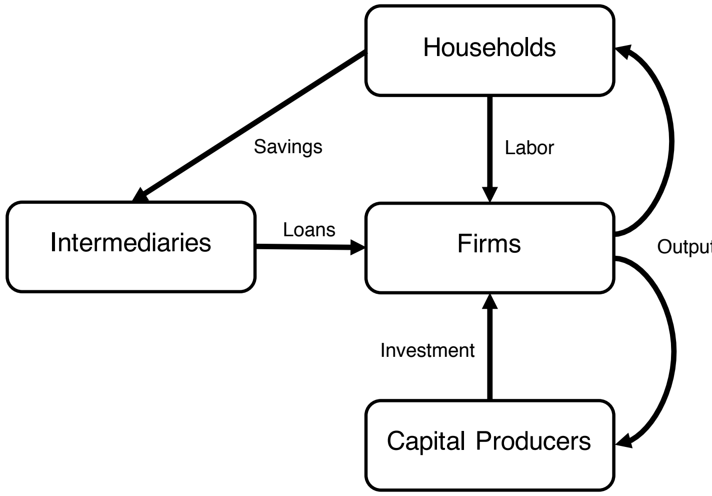

Figure 1: Model overview

Systemic risk is introduced to the model via an ad hoc social cost of debt, which depletes resources from the economy by an amount proportional to the aggregate level of intermediary debt. Because this cost is not internalized by the agents in the model, there is room for welfare gains through macroprudential intervention. Policymakers can choose from two policy instruments: a debt tax, which is imposed on household savings, or a countercyclical capital requirement, which is imposed on intermediary balance sheets.

2.1 Households

Households represent the consumption side of the economy. They consume output produced by firms, provide labor to firms, and offer savings to intermediaries, who repay them with interest after one period.

Let C_t be consumption and L_t be labor. Household prefernces are given by the period utility function

$$U\left(C_t, C_{t-1}, L_t\right) = \log\left(C_t - hC_{t-1}\right) - \frac{1}{1+\phi} L_t^{1+\phi} \tag{1}$$

with $h, \phi > 0$. Following many others in the macroeconomic literature, I allow for habit formation to generate realistic consumption patterns.

Let W_t be wages, B_{t+1} be savings invested in period t that pay out in period $t+1$, R_{t+1} be the gross return on these savings, and Π_t be lump-sum payouts from ownership of other sectors. Furthermore, suppose households are subject to two forms of taxes: a debt tax, which is taken from their savings at rate $\tau \geq 0$, and a lump-sum tax T_t. Each period t, households maximize expected lifetime utility by solving

$$\max_{C_t, L_t, B_{t+1}} E_t \left[\sum_{i=0}^{\infty} \beta^i U \left(C_{t+i}, C_{t+i-1}, L_{t+i} \right) \right] \tag{2}$$

subject to the budget constraint

$$C_t = W_t L_t + R_t B_t - (1+\tau) B_{t+1} + \Pi_t - T_t \tag{3}$$

with $\beta \in (0,1)$. Note that the price of output in period t is normalized to 1.

Let $U_{c,t}$ be the marginal utility of consumption, so

$$U_{c,t} = \frac{1}{C_t - hC_{t-1}} - \beta h E_t \left[\frac{1}{C_{t+1} - hC_t} \right] \tag{4}$$

Let $\Lambda_{t,t+i}$ be the stochastic discount factor, so

$$\Lambda_{t,t+i} = \frac{U_{c,t+i}}{U_{c,t}} \tag{5}$$

Then, first-order conditions give the labor supply equation

$$L_t^{\phi} = W_t U_{c,t} \tag{6}$$

and the Euler equation

$$1 + \tau = \beta R_{t+1} E_t \left[\Lambda_{t,t+1} \right] \tag{7}$$

2.2 Financial Intermediaries

In this model, financial intermediaries represent the entire financial sector, including investment banks, commercial banks, and businesses. They raise funds each period, either from their own net worth or by borrowing savings from households, and they loan these funds to firms in exchange for claims on the firms' future profits. Intermediaries' profits go toward accumulating net worth.

To prevent intermediaries from accumulating so much net worth that the entire intermediary sector becomes fully self-financing, suppose intermediaries exit the market with probability $1 - \theta$ each period, with $\theta \in (0,1)$. An exiting intermediary transfers its net worth to its parent household. Then, the exiting intermediary is replaced with a "newborn" intermediary that receives a start-up fund from its parent household. Intermediaries choose how much to borrow and loan at the end of each period with the objective of maximizing expected terminal net worth.

Consider an arbitrary intermediary j. Let $S_{j,t}$ be its number of claims on firms' future profits, Q_t be the price of these claims, $B_{j,t+1}$ be its savings borrowed from households, and $N_{j,t}$ be its net worth. It is subject to the balance sheet equation

$$Q_t S_{j,t} = N_{j,t} + B_{j,t+1} \tag{8}$$

where $Q_t S_{j,t}$ can be thought of as intermediary j's assets, $N_{j,t}$ as its equity, and $B_{j,t+1}$ as its debt. Let $V_{j,t}$ be its equity-to-assets ratio, so

$$V_{j,t} = \frac{N_{j,t}}{Q_t S_{j,t}} \in (0,1) \tag{9}$$

Let $R_{k,t}$ be the gross return on assets purchased in period t that pay out in period $t+1$, which is stochastic. Then, intermediary j's net worth evolves according to

$$N_{j,t} = (R_{k,t} - R_t) Q_{t-1} S_{j,t-1} + R_t N_{j,t-1} \tag{10}$$

Next, consider the intermediary sector as a whole. Let S_t be the aggregate number of claims on firms' future profits, N_t be aggregate net worth, and B_{t+1} be aggregate debt to households. The aggregate balance sheet equation is

$$Q_t S_t = N_t + B_{t+1} \tag{11}$$

Let V_t be the aggregate equity-to-assets ratio, so

$$V_t = \frac{N_t}{Q_t S_t} \in (0,1) \tag{12}$$

Let the total start-up funds given to newborn intermediaries be equal to a proportion $\omega > 0$ of aggregate assets last period. In other words, when a bank exits, its parent household looks to the value of the assets it was managing to decide how much funding its replacement needs.[1] Then, aggregate net worth evolves according to

$$N_t = \theta[(R_{k,t} - R_t) Q_{t-1} S_{t-1} + R_t N_{t-1}] + \omega Q_{t-1} S_{t-1} \tag{13}$$

If intermediaries are unconstrained, then they borrow until the marginal cost of debt equals the marginal benefit. This implies the no arbitrage condition

$$R_{t+1} = E_t \left[R_{k,t+1} \right] \tag{14}$$

[1] Since there is a measure one of intermediaries, aggregate assets is equivalent to the average assets held by an intermediary. All intermediaries have an equal chance of exiting the market each period, so by the law of large numbers, this is equivalent to the average assets held by an exiting intermediary.

On the other hand, suppose policymakers constrain intermediaries by imposing a capital requirement. This takes the form of a minimum equity-to-assets ratio $\bar{V}_t \in (0,1)$, so

$$V_{j,t} \geq \bar{V}_t \tag{15}$$

for all intermediaries j. If the requirement is binding, then

$$V_t = \bar{V}_t \tag{16}$$

and the no arbitrage condition (Equation 14) does not hold. In my analyses, I choose parameters to ensure that the capital requirement is always binding near steady state.

Let the requirement respond to aggregate debt B_t and output Y_t according to the countercyclical rule

$$\log \bar{V}_t = \log \bar{V}_{ss} + \kappa_b (\log B_t - \log B_{ss}) + \kappa_y (\log Y_t - \log Y_{ss}) \tag{17}$$

where $\bar{V}_{ss}$ is the steady-state value of $\bar{V}_t$, B_{ss} is the steady-state value of B_t, and Y_{ss} is the steady-state value of Y_t. Note that this rule can be countercyclical even if one of the feedback parameters κ_b or κ_y is negative, as long as the other parameter is positive enough to make up for it. For example, a rule with $\kappa_b > 0$ and $\kappa_y = -\kappa_b$ is equivalent to a requirement that responds countercyclically to the debt-to-output ratio. Notably, the credit-to-GDP ratio is one of the main financial indicators proposed in Basel III as a guide for CCyB policy. In my analyses, I examine rules with $\kappa_b, \kappa_y > 0$, which can be thought of as rules that respond countercyclically to both the debt-to-output ratio and the level of output.

2.3 Firms

Firms represent the production side of the economy, hiring labor and accumulating capital to generate output. They obtain all of their funding by issuing claims to intermediaries, and all firm profits are paid back to the intermediaries who purchase these claims.

First, consider the capital accumulation process. At the end of each period t, firms obtain loans from intermediaries by issuing claims S_t, with each claim providing enough funding to purchase one unit of investment goods I_t from capital producers. These investment goods are used to produce new capital K_{t+1} according to the investment equation

$$K_{t+1} = Z_t(1-\delta)K_t + I_t \tag{18}$$

where Z_t is capital quality, which is exogenous. The variable Z_t in the model allows for the possibility of sudden economic depreciation, or obsolescence, of existing capital.

Note that each issued claim translates exactly into one unit of investment goods, which translates exactly into one unit of new capital. Thus, each claim pays out all future profits generated by one unit of capital. Through perfect competition, the price of new capital is equal to the price of claims Q_t. Furthermore, each unit of capital owned by firms is backed by a claim, so

$$Q_t K_{t+1} = Q_t S_t \tag{19}$$

Next, consider the production process. Let A_t be productivity, which is exogenous. Each period t, firms hire labor L_t from households, which is combined with capital to produce output Y_t according to the production function

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \tag{20}$$

with $\alpha \in (0,1)$. They maximize period profits by solving

$$\max_{L_t} \left[Y_t - W_t L_t\right] \tag{21}$$

The first-order condition gives the labor demand equation

$$(1-\alpha)\frac{Y_t}{L_t} = W_t \tag{22}$$

Finally, the return on assets is derived from the marginal product of one unit of capital plus the value of any leftover new capital as

$$R_{k,t} = \frac{\alpha Y_t / K_t + Z_t(1-\delta)Q_t}{Q_{t-1}} \tag{23}$$

2.4 Capital Producers

Capital producers represent the investment side of the economy. Their role in the model is to establish a price for capital. They help firms convert output into investment goods, subject to an adjustment cost. Their profits, which they can earn away from steady state, are transferred to their parent households.

Each period t, capital producers maximize expected lifetime profits by solving

$$\max_{I_t} E_t \left[\sum_{i=0}^{\infty} \beta^i \Lambda_{t,t+i} \left(\left(Q_{t+i} - 1\right) I_t - f\left(\frac{I_{t+i}}{I_{t+i-1}}\right) I_{t+i}\right)\right] \tag{24}$$

where $f(\cdot)$ is an investment adjustment cost function. This form of flow adjustment cost is adopted from the literature to capture realistic investment dynamics. To ensure no adjustment costs at steady state, let $f(\cdot)$ have the functional form

$$f(x) = \frac{\eta}{2}(x-1)^2 \tag{25}$$

with $\eta > 0$.

The first-order condition gives

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - \beta E_t\left[\Lambda_{t,t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 f'\left(\frac{I_{t+1}}{I_t}\right)\right] \tag{26}$$

2.5 Social Cost of Debt & Resource Constraint

To motivate a desire for macroprudential policy, let debt impose a cost on society. This cost is an ad hoc representation of financial frictions that lead to the buildup of systemic risk above socially optimal levels.

One way to think about this cost is to suppose regulators must spend resources to supervise intermediaries, performing tasks (e.g. enforcing contracts, performing stress tests, providing deposit insurance) that are more expensive as more funds are channeled through intermediaries. These regulatory costs are equal to a proportion $\gamma > 0$ of aggregate debt. They are financed by taxes, so

$$\gamma B_{t+1} = \tau B_{t+1} + T_t \tag{27}$$

Finally, to complete the model, the economy-wide resource constraint is

$$Y_t = C_t + I_t + f\left(\frac{I_t}{I_{t-1}}\right) I_t + \gamma B_{t+1} \tag{28}$$

3 Calibration

To prepare the model for quantitative analysis, I calibrate its parameter values and determine the steady states of three different model variations.

My chosen parameter values are listed in Table 1. They are based on the assumption that one period in the model corresponds to one quarter. For β, α, and δ, I choose conventional values. I obtain estimates for h, ϕ, and η from Primiceri, Schaumburg, and Tambalotti (2006). I choose the same value of θ as Gertler and Karadi (2011) and Gertler and Kiyotaki (2010), which is large enough to give intermediaries an average lifespan of around 10 years while being small enough to ensure that steady-state intermediary net worth is finite. Finally, I calibrate ω and τ to hit two targets in my baseline model: a steady-state equity-to-assets ratio of 0.25 and a steady-state consumption-to-output ratio of 0.67. These targets are chosen to roughly capture empirical macroeconomic data from just before the 2008 financial crisis.[2]

Table 1: Parameters

	Value	Interpretation
β	0.990	Discount rate
h	0.815	Habit parameter
ϕ	0.276	Inverse Frisch elasticity of labor supply
θ	0.972	Intermediary survival rate
ω	0.004	Proportional start-up funds for intermediaries
α	0.330	Capital share
δ	0.025	Depreciation rate
η	1.728	Inverse elasticity of investment to price of capital
τ	0.014	Social cost of debt

To compare the effects of different policies, I analyze three variations of my model, whose descriptions are as follows:

1. **Baseline:** $\tau = 0$ and intermediaries are unconstrained. The social cost of debt is funded entirely by a lump-sum tax, so it is not internalized by agents in the model.

2. **Debt tax:** Intermediaries are still unconstrained, but policymakers raise the debt tax to $\tau = \gamma$. Thus, the social cost of debt is equal to the debt tax.

3. **Capital requirement:** The debt tax is kept at $\tau = 0$. Instead of raising the debt tax, policymakers impose a countercyclical capital requirement on intermediaries. The parameters of the countercyclical rule (Equation 17) are set so that $\bar{V}_{ss}$ is equal to the steady-state value of V_t in the debt tax model, and $\kappa_b = \kappa_y = 0.5$. In other words, policymakers target the same steady-state equity-to-assets ratio as in the debt tax model, but they use a different policy instrument.

Using my chosen parameter values, I find the steady states of the three model variations, which are described in Table 2. Note that when either form of macroprudential policy is introduced, the steady-state equity-to-assets ratio rises to 0.917, which is significantly higher than its value of 0.25 in the baseline model. Thus, macroprudential policy has a large impact on intermediary balance sheets.

[2]According to Gertler and Karadi (2011), prior to the 2008 crisis, equity-to-assets ratios were around 0.05 for investment banks, 0.06 for commercial banks, and 0.5 for businesses. They calibrate their own model to hit a steady state equity-to-assets ratio of 0.25 to roughly capture the aggregate data.

Table 2: Steady states

	Baseline	Debt tax	Cap. req.
Y	3.119	2.259	2.295
C	2.090	1.860	1.879
L	1.034	0.880	0.884
W	2.020	1.719	1.739
I	0.733	0.383	0.398
K	29.323	15.306	15.918
B	21.992	1.276	1.327
N	7.331	14.031	14.596
V	0.250	0.917	0.917
R	1.010	1.024	1.010
R_k	1.010	1.024	1.023

4 Crisis Simulations

In this section, I examine the response of the economy to a simulated financial crisis. I compare the three model variations outlined in the previous section, and I observe two unexpected shocks: a negative productivity shock and a negative capital quality shock. My goal is to evaluate the effect of a countercyclical capital requirement on the economy's dynamics. On the one hand, traditional financial accelerator models suggest that imposing a net worth-based borrowing constraint, such as a capital requirement, can lead to increased volatility after a shock. On the other hand, the countercyclical nature of the requirement may smooth the economy's transition path.

I find that a countercyclical capital requirement does serve its intended purpose of reducing volatility and smoothing the path of important macroeconomic variables. For this purpose, it is more effective than a debt tax. I also find that this smoothing effect can be attributed to the requirement's degree of countercyclicality.

4.1 Productivity Shock

My first experiment is a negative productivity shock, which reflects a sudden shift in technology. The shock induces a sudden reduction in the return on assets, triggering a financial crisis. Let productivity follow an AR(1) process

$$\log A_t = \rho_a \log A_{t-1} + \varepsilon_a \tag{29}$$

with $\rho_a = 0.95$. Suppose ε_a is unexpectedly shocked to -0.01 for one period and returns to 0 for all future periods. Figure 2 shows the impulse response functions from conducting this experiment in a first-order approximation of the model.

For major macroeconomic variables, the dynamics of the debt tax model do not differ substantially from those of the baseline model. Output, consumption, and investment follow roughly the same trajectories.

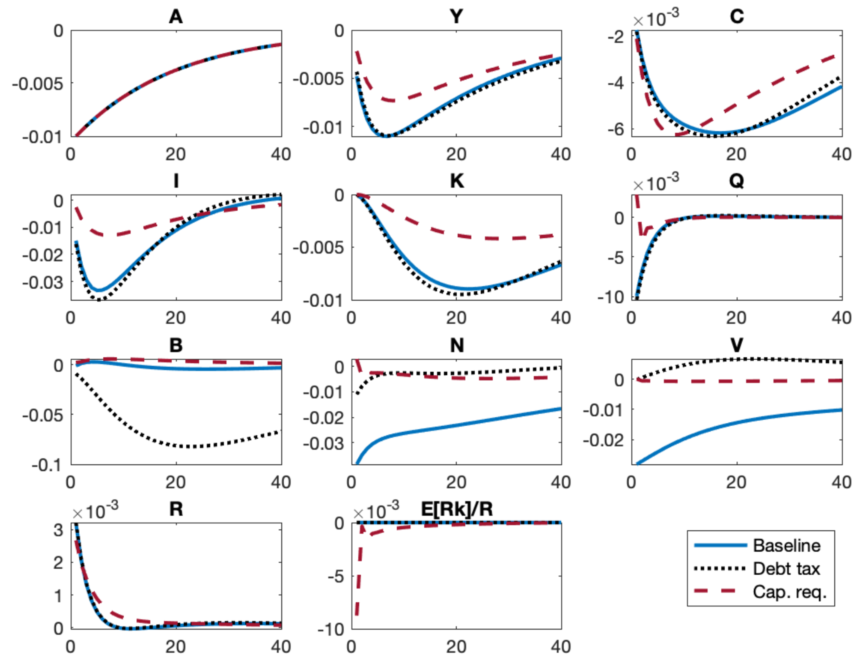

Figure 2: Negative productivity shock

However, the capital requirement model exhibits significant departures from the baseline model. The volatility of output and investment is reduced both on impact and along the transition path. The mechanism for this reduction is the countercyclicality of the requirement. Prior to the shock, intermediaries are prevented from borrowing as much as they would've preferred to in the absence of the requirement. When the shock hits, the drop in output activates the countercyclical rule and allows intermediaries to borrow more, which explains why aggregate debt B does not decrease as much as it does in the debt tax model. As a result, more funds can be channeled toward investment, and the negative impacts of the shock are mitigated. This can be seen by the decrease in the interest rate premium $E[R_k]/R$, which indicates that after the shock, the capital requirement becomes less constraining.

These results illustrate how a countercyclical capital requirement reduces systemic risk. By constraining financial intermediaries during normal times, the economy has more slack that can be released during a crisis. This allows for a smoother recovery. In this way, a countercyclical capital requirement can be thought of as a "financial decelerator."

4.2 Capital Quality Shock

My second experiment is a negative capital quality shock, which reflects the sudden economic depreciation, or obsolescence, of existing capital. This is the main shock used by Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) to simulate a sudden deterioration in asset values, such as the drop in real estate prices prior to the 2008 financial crisis. Its main effect, a reduction in the return on assets, is very similar to that of my first experiment.

Let capital quality follow an AR(1) process

$$\log Z_t = \rho_z \log Z_{t-1} + \varepsilon_z \tag{30}$$

with $\rho_z = 0.95$. Suppose ε_z is unexpectedly shocked to -0.01 for one period and returns to 0 for all future periods. Figure 3 shows the impulse response functions from conducting this experiment in a first-order approximation of the model.

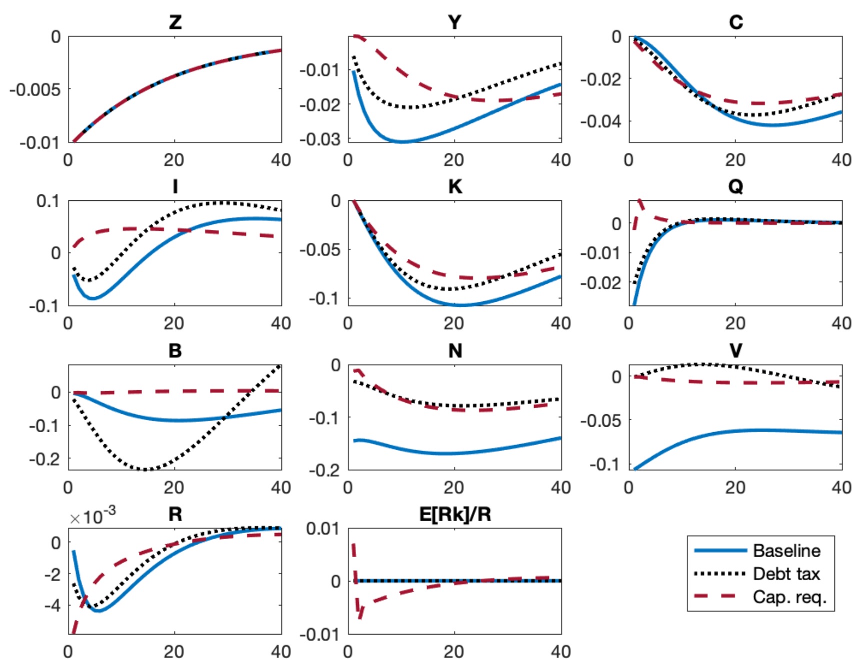

Figure 3: Negative capital quality shock

In this experiment, the debt tax model experiences slightly less volatility in output and investment than the baseline model. However, the capital requirement model still exhibits the least volatility of the three, both on impact and along the transition path. The reasoning for this smoothing effect is the same as in the first experiment — when the shock hits, the countercyclical capital requirement allows intermediaries to borrow more, mitigating the shock's negative effects.

One notable difference between these results and those from the first experiment is that in the capital requirement model, the interest rate premium $E[R_k]/R$ initially jumps up, meaning that the capital requirement becomes more constraining on impact, possibly because the countercyclical rule does not respond quickly enough. This suggests that the traditional financial accelerator effect, increased volatility from a net worth-based borrowing constraint, may still be present in this model. However, it is dominated by the smoothing effect of the countercyclical capital requirement.

4.3 Degree of Countercyclicality

To illustrate the fact that the smoothing effect of the capital requirement can be attributed to its countercyclical nature, I repeat my crisis simulations under capital requirement models with varying degrees of countercyclicality. Specifically, I vary the countercyclical rule's reponse to output: keeping $\kappa_b = 0.5$, I set κ_y equal to 0.5, 2, and 5. Figures 4 and 5 show the impulse response functions from the productivity shock experiment and capital quality shock experiment, respectively.

As expected, increasing κ_y leads to greater reductions in the equity-to-assets ratio V after a crisis, which allows aggregate debt B to rise more dramatically. As a result, output and investment exhibit smaller decreases; in fact, investment after a capital quality shock actually increases. Thus, the greater the responsiveness of the countercyclical capital requirement, the more effective it is at helping the economy recover after a crisis.

5 Welfare Analysis

This section explores the question of welfare to understand how different types of macroprudential policy impact the well-being of agents in the model outside of crisis situations.

To calculate welfare, I simulate a policy shock. Suppose the economy starts out at some steady state; then, policymakers shift the economy to a new model. Let Ω_t be expected household lifetime utility, which is defined recursively according to

$$\Omega_t = U\left(C_t, C_{t-1}, L_t\right) + \beta E_t\left[\Omega_{t+1}\right] \tag{31}$$

Then, the initial jump in Ω_t after a policy shock at time t provides a measure of welfare under the new model. Because this experiment involves analyzing models far from their steady states, first- and second-

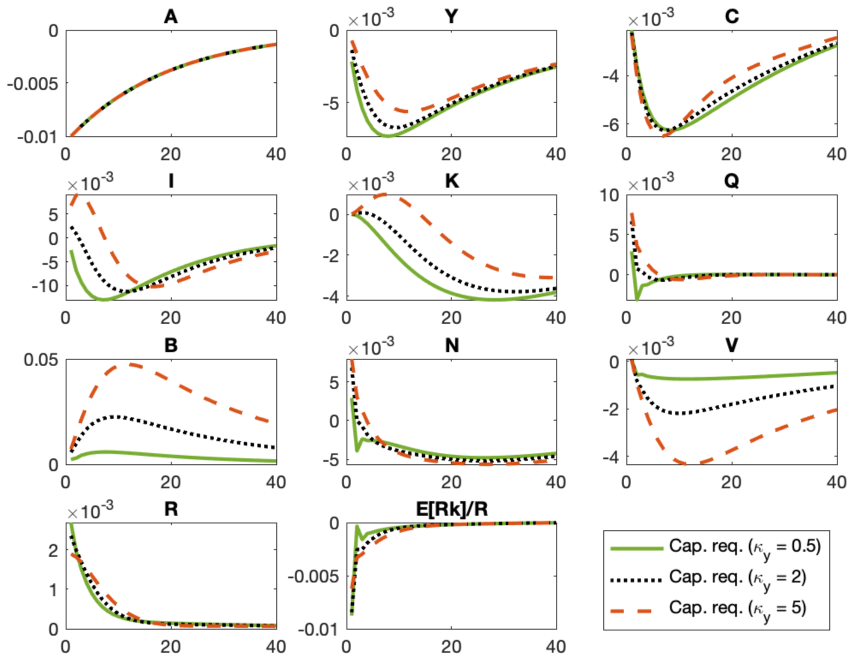

Figure 4: Productivity shock under varying values of κ_y

order approximations would be inaccurate. Hence, I eliminate stochastic shocks and conduct the experiment in a purely deterministic setting.

In this analysis, every simulation must begin from the same initial steady state. For this purpose, I choose the steady state under a capital requirement model with $\kappa_b = \kappa_y = 0.5$ (the capital requirement model described in Section 3).[3] For ease of interpretation, I convert welfare into consumption-equivalent units. In other words, I calculate how much consumption would have to increase or decrease in every period at the initial steady state to grant households an equivalent level of welfare as transitioning to the new model. Thus, welfare is measured in units of consumption at the initial steady state.

My first step is to determine the optimal debt tax. Figure 6 shows consumption-equivalent welfare under debt tax models with varying values of τ. The optimal debt tax is found to be $\tau = \gamma$, which sets the debt tax equal to the social cost of debt. This agrees with intuition: when a debt tax is the only instrument available to policymakers, it makes sense to set it at a level that causes agents in the model to fully internalize the social cost of debt.

My second step is to calculate welfare under some capital requirement models. I examine capital requirement models with various degrees of countercyclicality: keeping $\kappa_b = 0.5$, I set κ_y equal to 0.5, 2, and 5.

[3]I choose this initial condition to ensure that the capital requirement models remain relatively close to their steady states. This is because the capital requirement models blow up far from steady state.

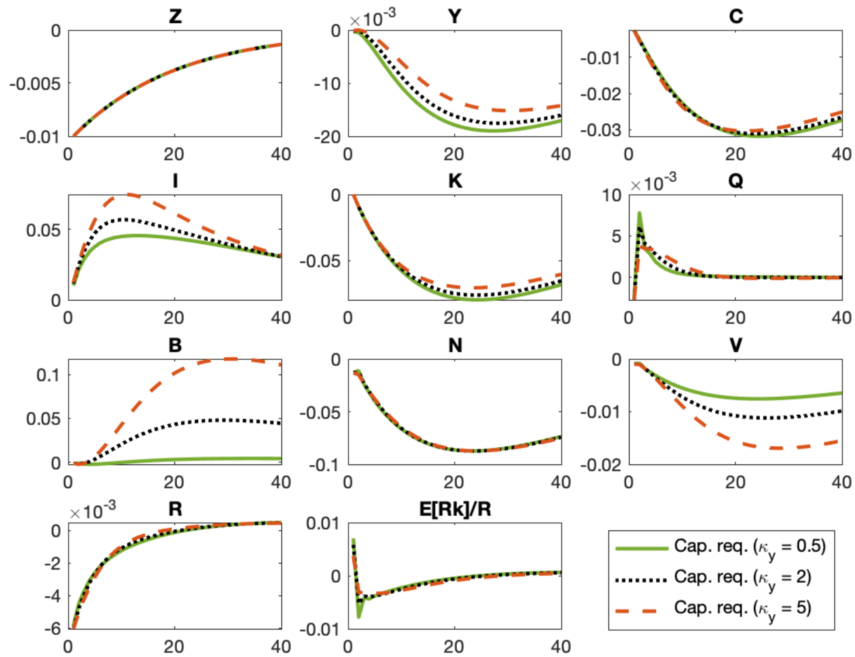

Figure 5: Capital quality shock under varying values of κ_y

Figure 7 shows consumption-equivalent welfare under the baseline model, the optimal debt tax model, and these three capital requirement models. I find that all four models with macroprudential policy represent significant welfare gains over the baseline model. Notably, welfare under any of the three capital requirement models is greater than welfare under the optimal debt tax. Finally, varying the countercyclicality of the capital requirement has no significant effect on welfare. Importantly, these welfare results rely on the assumption that debt imposes a cost on society.

6 Conclusion

This paper provides provide strong evidence for the benefits of countercyclical capital requirements. In my crisis simulations, I find that a countercyclical capital requirement has a "financial decelerator" effect: after both a productivity shock and a capital quality shock, it reduces the volatility of macroeconomic variables and helps the economy recover. It does so by constraining financial intermediaries during normal times, giving the economy more slack that can be released during a crisis. I confirm that this smoothing effect can be attributed to the requirement's degree of countercyclicality. In my welfare analysis, I find that a countercyclical capital requirement can lead to significant welfare gains that surpass those from a debt tax.

These findings suggest that policymakers should consider making greater use of countercyclical macro-

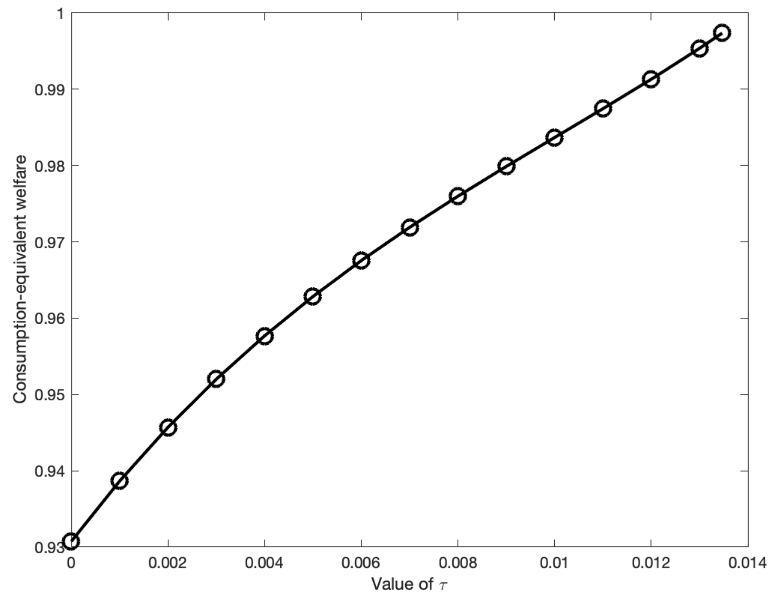

Figure 6: Optimal debt tax

prudential policy tools to address systemic risk and promote financial stability. For instance, in the United States, where the CCyB has never been raised above 0%, it may be advisable to raise the CCyB during periods of high credit growth, setting a precedent for capital requirements to be set by a countercyclical rule similar to the one in my model.

The model in this paper can be extended in several ways. First, while the social cost of debt in its current form is elucidative, it is rather ad hoc and not completely microfounded. The model may be improved by replacing it with some form of an endogenous externality generated by financial intermediary activity.

Second, the model does not differentiate between types of intermediaries, such as investment banks, commercial banks, and businesses. However, capital requirements, like those outlined in Basel III, only apply to banks. Furthermore, intermediaries tend to maintain a wide range of equity-to-assets ratios. Perhaps different types of intermediaries should be modeled separately to capture their peculiarities.

Finally, the model could be easily modified to include nominal rigidities, as done by Gertler and Karadi (2011) and Angelini et al. (2014), which would allow for the study of inflation dynamics and monetary policy. In many countries, the monetary authority is also in control of CCyB policy, so the possibility of coordinating countercyclical capital requirements with monetary policy is particularly relevant.

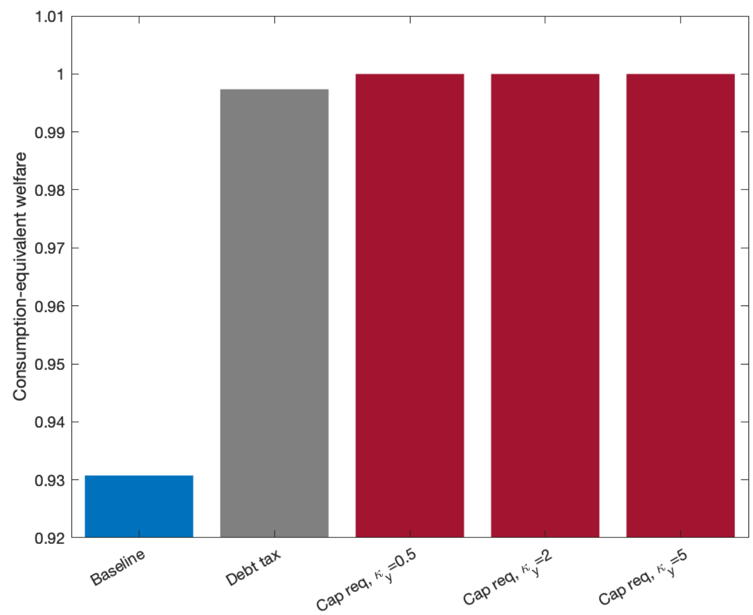

Figure 7: Welfare comparison

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