UNIVERSITY of York

Discussion Papers in Economics

No. 14/18

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Yaprak Tavman

Department of Economics and Related Studies
University of York
Heslington
York, YO10 5DD

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Yaprak Tavman[Υ,Ψ]

July 2014

Abstract

The global financial crisis has clearly shown that macroeconomic stability is not sufficient to guarantee the stability of the financial system. Hence, the recent policy debate has focused on the effectiveness of macroprudential tools and their interaction with monetary policy. This paper aims to contribute to the macroprudential policy literature by presenting a formal comparative analysis of three macroprudential tools: (i) reserve requirements, (ii) capital requirements and (iii) a regulation premium. Utilizing a New Keynesian general equilibrium model with financial frictions, we find that capital requirements are the most effective macroprudential tool in mitigating the negative effects of the financial accelerator mechanism. Deriving welfare-maximizing monetary and macroprudential policy rules, we also conclude that irrespective of the type of the shock affecting the economy, use of capital requirements generates the highest welfare gains.

Keywords: financial crises, monetary policy, macroprudential tools, financial system regulation.

JEL Classification: E44, E58, G21, G28.

[Υ] Department of Economics and Related Studies (DERS), University of York, Heslington, York, YO10 5DD, UK; E-mail: yt594@york.ac.uk.

[Ψ] I would like to thank Martin Ellison, Nobuhiro Kiyotaki, Stephen Millard, Paulo Santos Monteiro, Gulcin Ozkan, Mike Wickens, the participants of the conference on Recent Developments in Money, Macroeconomics and Finance, held at the University of Warwick, 31 March - 1 April 2014, and the seminar participants of the Royal Economic Society Easter School 2014, for useful comments and suggestions.

1 Introduction

The global financial crisis has recast the literature on macroeconomic models and policies. The mainstream dynamic stochastic general equilibrium (DSGE) models used by macroeconomists before the crisis did not contain the role of financial frictions in generating or propagating business cycle fluctuations. Subsequent to the 2007-09 episode, there has been a growing consensus among macroeconomists about the necessity to incorporate financial frictions into macroeconomic models and to examine the significance of financial shocks. Two relevant strands of the literature, based on DSGE models that attempt to overcome these shortcomings, have emerged. The first analyzes monetary policy using models that include financial frictions associated with the constraints of non-financial borrowers, making use of the financial accelerator mechanism designed by Bernanke et. al (1999). The second studies financial frictions linked to financial intermediaries and analyzes the function of bank capital in the monetary transmission mechanism. The framework developed by Gertler and Karadi (2011) is one of the leading examples.

The recent financial crisis has also shown that a single policy objective, inflation stability, to be achieved with the use of a single policy instrument, the interest rate, is not sufficient to guarantee the stability of the financial system. As stated by the well-known "Tinbergen principle", the number of independent instruments should at least be equal to the number of policy objectives. Hence, following the recent experience, the financial accelerator mechanism has been increasingly employed in macroeconomic studies that include supplementary policy instruments, and a common finding emerges from these: to reduce systemic risks and ensure the stability of the financial system, the main monetary policy instrument needs to be supported by additional tools, which are referred to as macroprudential policy instruments (BIS, 2010).

There are, by now, relatively well-defined proposals for macroprudential policy instruments. Counter-cyclical capital requirements and loan-to-value (LTV) ratios are two prominent examples. Some countries have already started using these two instruments that are now requirements as approved by the Basel III reform package. Counter-cyclical reserve requirements are another well-known example of macroprudential tools. In recent years, they have been used by central banks with the purpose of accommodating credit in booms and relaxing liquidity constraints in contractions (Montoro & Moreno, 2011).

In this paper, using a New Keynesian general equilibrium model that incorporates a banking sector, we compare the effectiveness of three macroprudential policies and their interaction with monetary policy. In our study, we include the aforementioned widely-used macroprudential policies; reserve requirements and capital requirements, and a third macroprudential policy tool, a regulation premium, whose formulation is based on the assumption that macroprudential policies in general increase the costs of financial intermediaries, who in turn pass these costs onto borrowers (Unsal, 2013). Our motivation is threefold. First, we complement the studies that analyze the use of reserve requirements as a macroprudential policy tool. To examine the effectiveness of reserve requirements, Glocker and Towbin (2012) use a small open economy model with financial frictions, while Mimir et. al (2013) use a model that includes financial frictions in the banking sector, but does not incorporate a monetary policy rule. In both studies, welfare losses in the presence of reserve requirements are computed using ad-hoc loss functions, whereas we use welfare maximizing monetary and macroprudential policies in our analysis. Second, we also contribute to the literature on bank capital and capital requirements. Even though there are various studies that analyze the use capital requirements employing models with a banking sector[1], they lack a rigorous welfare analysis. The two studies where optimized monetary and macroprudential policy rules are used as in our analysis are by Angeloni and Faia (2013) and by Christensen et. al (2011). However, the modeling of the banking sector in these studies is different from ours. Last but not least, our paper is the first to present a detailed comparative analysis of the given alternative macroprudential policies, in contrast to much of the existing literature where the implications of the use of a single macroprudential policy are analyzed.

To conduct our analysis, we build a monetary DSGE model in which the frictions in the financial intermediation process are as described in Gertler and Karadi (2011). The financial accelerator mechanism built in banks' balance sheet constraints features a pecuniary externality, where bankers do not consider the fact that if they issued more equity, they would decrease the risk of the banking sector. Hence, they accumulate high levels of leverage, which amplifies the negative effects of exogenous shocks to the economy. In other words, bankers' inability to internalize the benefits of equity financing results in a decline in welfare and induces the need for macroprudential regulation (Gertler et. al, 2012). In our framework, reserve requirements and capital requirements both increase the cost of deposits to banks, encouraging them to replace external financing by equity financing. An increase in the regulation premium is reflected in the increase in cost of borrowing to firms. In accordance with the literature, the macroprudential policy tools in our model are assumed to be counter-cyclical. To establish comparability, all three instruments respond to the same financial variable, which is the total nominal credit growth in the economy, with the same intensity.

[1] See, for example, Van den Heuvel (2008), Dib (2010), Christensen et. al (2011), Angelini et. al (2011), Angeloni and Faia (2013).

Our simulation results indicate that when the economy experiences a productivity (TFP) or a financial shock, the use of all the aforementioned macroprudential tools mitigates the negative effects of the given shocks to the economy. Each shock results in a decrease in asset prices, which triggers the financial accelerator mechanism. Since banks are leveraged, the decrease in asset prices results in an amplified decline in their net worth and a downturn in their balance sheets that increases their leverage ratios. The rise in the leverage ratios increases the spread, which is defined as the difference between the gross return to risky loans and the gross riskless return. The increase in the spread, in turn, results in an increase in the cost of capital, which causes a further decline in investment and asset prices. Finally, the decline in investment leads to a decrease in aggregate output. When counter-cyclical reserve requirements or capital requirements are used in combination with monetary policy, the decrease in banks' net worth and hence their leverage ratios is smaller, and so is the increase in the spread. As a result, the negative effects of the shocks on assets prices, investment and output are lower. Counter-cyclical use of the regulation premium, on the other hand, directly results in a smaller increase in the cost of capital. Consequently, the negative effects of the shocks on aggregate output are again lowered.

Comparing the dynamics of both shocks under alternative macroprudential policies, we find that irrespective of the cause of the decline in economy activity, capital requirements perform the best in lowering the negative effects of the given shocks to the spread, asset prices and investment. As a result, they are the most effective macroprudential tool in mitigating the negative effects of the financial accelerator mechanism built in banks' endogenous capital constraints.

Using welfare-maximizing monetary and macroprudential policy rules, we also compute welfare losses and consumption equivalents under each policy alternative. Analyzing productivity and financial shocks separately, we observe that under both shocks, the adoption of each macroprudential policy results in a decrease in the welfare loss. The least effective macroprudential policy tool is the regulation premium under the TFP shock, while it is the reserve requirements under the financial shock. The most effective macroprudential tool is, however, the same under both shocks; capital requirements generate the highest positive effect on welfare, regardless of the type of the shock affecting the economy.

The remainder of this paper proceeds as follows. Section 2 sets out the structure of our model by giving a detailed description of the economic agents, the monetary policy and the macroprudential policies. Section 3 presents our quantitative results, including the discussion of impulse responses, the analysis of macroprudential tools' impact on volatilities and the computation of welfare losses. Finally, Section 4 concludes.

2 The Model

Our framework is a monetary DSGE model with nominal rigidities. It contains a banking sector that is characterized by credit frictions *a la* Gertler and Karadi (2011). The model economy is populated by households, banks, capital goods producers, wholesale firms, retail firms, the fiscal authority and the central bank. We now proceed with a detailed description of the economic agents in the economy.

2.1 Households

The population consists of a continuum of identical households. Within the household, there are 1-p "workers" and p "bankers" who perfectly insure each other. Workers supply labor and earn wages while bankers manage financial intermediaries, i.e., banks and transfer dividends back to households. Households deposit their savings in the banks. Deposits are assumed to be riskless one period securities.

A representative household maximizes expected discounted utility which is a function of consumption, C_t, C_{t-1} and leisure, L_t,

$$E_0 \sum_{t=0}^{\infty} \beta^t U_t(C_t, C_{t-1}, L_t) \tag{1}$$

subject to the following flow of funds constraint,

$$C_t = W_t h_t + \Pi_t - T_t + R_t D_{t-1} - D_t \tag{2}$$

where $0<\beta<1$ is the subjective discount factor and E is the expectation operator. W_t is the wage rate, $h_t(= 1 - L_t)$ denotes hours worked, D_t bank deposits and R_t the gross risk free deposits rate, set in period $t-1$ to pay out interest in period t. T_t is the lump sum taxes remitted by the government and Π_t is the profits earned from the ownership of banks and firms.

Solution of the utility maximization problem of households gives the following optimality conditions,

$$U_{C,t} = \beta R_{t+1} E_t \left[U_{C,t+1}\right] \tag{3}$$

$$\frac{U_{h,t}}{U_{C,t}} = -\frac{U_{L,t}}{U_{C,t}} = -W_t \tag{4}$$

where $U_t = \frac{(C_t - \chi C_{t-1})^{(1-\varrho)(1-\sigma)}(1-h_t)^{\varrho(1-\sigma)} - 1}{1-\sigma}$.

As in Schmitt-Grohe and Uribe (2007), we include habit formation and investment adjustment costs in our model, since empirical work has demonstrated that such real frictions improve the ability of macroeconomic models to explain U.S. business cycles. The given form of the utility function is also adopted from Schmitt-Grohe and Uribe (2007). Various other studies show that non-separable preferences over consumption and leisure explain the aggregate consumption data well[2].

Equation (3) describes the optimal consumption-savings decision. Accordingly, the marginal utility from consuming one unit of income in period t is equal to the discounted marginal utility from consuming the gross income obtained by saving.

Taking expectations on both sides and defining $\Lambda_{t,t+1} = \beta \frac{U_{C,t+1}}{U_{C,t}}$ as the real stochastic discount factor over the interval $[t, t+1]$, we obtain the consumption-Euler equation,

$$1 = R_{t+1} E_t \left[\Lambda_{t,t+1}\right] \tag{5}$$

Equation (4) shows that the marginal rate of substitution between consumption and leisure should be equal to the real wage.

[2] See Kilponen (2009) for a survey of these studies.

2.2 Banks

The modelling of the financial sector closely follows that in Gertler and Karadi (2011). The banking sector's balance sheet has the following form,

$$Q_t s_t = n_t + d_t \tag{6}$$

where s_t denotes loans to non-financial firms, Q_t their price, n_t net worth and d_t household deposits.

The balance sheet of the banks implies an accumulation of net worth according to

$$n_t = R_{k,t} Q_{t-1} s_{t-1} - R_t d_{t-1} \tag{7}$$

To eliminate the case where bankers can accumulate sufficient net worth that makes their financial constraints not binding, we assume that with probability 1-γ, a banker exits and becomes a worker. The bank pays dividends only when it exists. In addition, we assume that (1-γ)p workers randomly become bankers so that the number of both professions stays constant.

Given the fact that the bank only pays dividends when it exists, the banker's objective at the end of period t is to maximize expected discounted terminal net worth, given by

$$V_t = E_t \sum_{i=1}^{\infty} (1-\gamma)\gamma^{i-1} \Lambda_{t,t+i} n_{t+i} \tag{8}$$

Substituting for d_t from Equation (6) in Equation (7) gives another form of net worth accumulation,

$$n_t = R_t n_{t-1} + (R_{k,t} - R_t) Q_{t-1} s_{t-1} \tag{9}$$

Since the returns and Q_t are exogenous to the bank, given n_{t-1} at the beginning of period t, net worth in period t is given by the choice of $\{s_{t+i}\}$ subject to the bank's borrowing constraint.

The financial friction in the banking sector is based on a moral hazard problem between the banks and the households. After a bank obtains funds, the banker's manager may transfer a fraction, Θ of total assets, $Q_t s_t$ for her own benefit. In this case, the bank defaults on its debt, shuts down and the creditors can reclaim the remaining 1-Θ fraction of funds. As households know this possibility, they limit the funds (deposits) that they lend to banks. As a result, the bankers choice of s_t at any time t is subject to the following incentive constraint,

$$V_t \geq \Theta Q_t s_t$$

To solve the bank's optimization problem, we start by guessing that the solution has the following form,

$$V_t = V_t(s_t, d_t) = v_{s,t} s_t - v_{d,t} d_t \tag{10}$$

where $v_{s,t}$ and $v_{d,t}$ are time-varying marginal values of the assets at the end of each period. By eliminating d_t from Equation (10) using Equation (6), we obtain

$$V_t = V_t(s_t, n_t) = \mu_{s,t} Q_t s_t + v_{d,t} n_t \tag{11}$$

and $\mu_{s,t} = \dfrac{v_{s,t}}{Q_t} - v_{d,t}$ is the excess value of the bank's assets over its deposits.

Defining ϕ_t as the leverage ratio that satisfies the binding incentive constraint, we have

$$Q_t s_t = \phi_t n_t \tag{12}$$

where $\phi_t = \dfrac{v_{d,t}}{\Theta - \mu_{s,t}}$.

Using the solution to the banker's optimization problem, we can determine $v_{s,t}$ and $v_{d,t}$ as

$$v_{s,t} = E_t \Lambda_{t,t+1} \eta_{t+1} R_{k,t+1} Q_t$$

$$v_{d,t} = E_t \Lambda_{t,t+1} \eta_{t+1} R_{t+1}$$

where $\eta_t = (1 - \gamma) + \gamma(\mu_{s,t}\phi_t + v_{d,t})$ gives the shadow value of a unit of net worth. As a result, we also have

$$\mu_{s,t} = E_t \Lambda_{t,t+1} \eta_{t+1} \left(R_{k,t+1} - R_{t+1}\right)$$

The difference between the gross return to risky assets/loans, $R_{k,t}$ and the gross riskless return, R_t is defined as the *spread.*

Since ϕ_t is not dependent on bank specific factors, we can aggregate Equation (14) across individual banks to obtain the banking sector balance sheet at the aggregate level,

$$Q_t S_t = \phi_t N_t \tag{13}$$

The evolution of net worth at the aggregate level depends on the net worth of surviving bankers ($N_{o,t}$) and that of new entrants ($N_{e,t}$). Net worth of surviving bankers is given by the earnings on their assets from the previous period minus the cost of deposits, multiplied by the probability that they will survive (γ),

$$N_{o,t} = \gamma(R_{k,t}Q_{t-1}S_{t-1} - R_t D_{t-1}) \tag{14}$$

And net worth of the new bankers is obtained with the assumption that the fraction $\dfrac{\varepsilon}{1-\gamma}$ of the total value of the exiting bankers' assets are transferred to new entrants,

$$N_{e,t} = \varepsilon(R_{k,t}Q_{t-1}S_{t-1}) \tag{15}$$

where ε denotes the proportional transfer to the new bankers. As a result, the evolution of net worth at the aggregate level is given by

$$N_t = R_{k,t}\left(\gamma + \varepsilon\right)Q_{t-1}S_{t-1} - \gamma R_t D_{t-1} \tag{16}$$

2.3 Wholesale Firms

Wholesale firms combine capital and labor to produce output, Y_t^W using the production function

$$Y_t^W = Y_t^W\left(A_t, h_t, K_{t-1}\right) = \left(A_t h_t\right)^{\alpha} K_{t-1}^{1-\alpha} = A_t h_t \left(\frac{K_{t-1}}{Y_t^W}\right)^{\frac{1-\alpha}{\alpha}} \tag{17}$$

Here, it should be noted that K_t is the end-of-period t capital stock and A_t denotes factor productivity. Cost minimization by wholesale firms gives the following labor demand function,

$$\frac{P_t^W}{P_t} Y_{h,t}^W = W_t \tag{18}$$

Equation (18) shows that the marginal product of labor is equal to the real wage. Here P_t^W and P_t are the aggregate price indices in the wholesale and retail sectors, respectively.

To finance its capital purchase each period, the firm obtains funds from banks. The number of claims issued by the firm, S_t is equal to the number of units of capital needed, K_t and hence the price of each claim is also equal to the price of each unit of capital,

$$Q_t S_t = Q_t K_t \tag{19}$$

In obtaining funds from a bank, the wholesale firm does not face any additional financial frictions. However, the credit frictions between the households and the banks have an effect on the amount of funds available to wholesale firms. Because of perfect competition, wholesale firms earn zero profits and hence they completely pay the return on their capital to the banks,

$$R_{k,t+1} = \frac{(1-\alpha)\frac{P_{t+1}^W Y_{t+1}^W}{P_{t+1} K_t} + (1-\delta) Q_{t+1}}{Q_t} \tag{20}$$

where δ is the depreciation rate of capital.

2.4 Capital Producing Firms

Incorporation of capital producers enables us to explore the changes in the price of capital and to introduce the capital quality shock, which is the exogenous shock that initiates the financial crisis in our model. We assume that at time t, I_t of raw output is converted into $(1 - S(X_t)) I_t$ of new capital. Here $S(X_t)$ denotes the investment costs. As a result, capital accumulates according to

$$K_t = [(1-\delta) K_{t-1} + (1 - S(X_t)) I_t] \tag{21}$$

where $X_t = \frac{I_t}{I_{t-1}}$. We assume that investment costs have the following form,

$$S(X_t) = \phi_X X_t^2$$

Accordingly, capital producing firms maximize expected discounted profits with respect to $\{I_t\}$,

$$E_t \sum_{k=0}^{\infty} \Lambda_{t,t+k} \left[Q_{t+k} \left(1 - S\left(X_{t+k}\right)\right) I_{t+k} - I_{t+k} \right] \tag{22}$$

The optimality condition that we achieve as a result of this maximization problem is given by

$$Q_t \left(1 - S\left(X_t\right) - X_t S'\left(X_t\right)\right) + E_t \left[\Lambda_{t,t+1} Q_{t+1} S'\left(X_{t+1}\right) X_{t+1}^2\right] = 1 \tag{23}$$

which indicates a positive relationship between investment and asset prices.

2.5 Retail Firms

The retail sector uses the homogenous wholesale output to produce a basket of differentiated goods for consumption. The consumption demand equation is given as

$$C_t(f) = \left(\frac{P_t(f)}{P_t}\right)^{-\zeta} C_t \tag{24}$$

where ζ is the elasticity of substitution and the aggregate price index, P_t is given by $P_t = \left(\int_0^1 P_t\left(f\right)^{1-\zeta} df\right)^{1/(1-\zeta)}$.

We assume that retail firms set their prices *a la* Calvo(1983). As a result, the optimal price-setting behavior for the typical firm adjusting its price in period

t is obtained by the maximization of the retailer's discounted nominal profits[3],

$$E_t \sum_{k=0}^{\infty} \theta^k D_{t,t+k} Y_{t+k}(f) \left[P_t^a(f) - P_{t+k} MC_{t+k} \right] \tag{25}$$

Here, θ is the probability that a firm cannot adjust its price in a period, MC_t is the real marginal cost, $P_t^a(f)$ is the adjusted price and $D_{t,t+k} = \beta^k \dfrac{U_{C,t+k}/P_{t+k}}{U_{C,t}/P_t}$ is the nominal stochastic discount factor over the period $[t, t+k]$.

Under the given price-setting mechanism, the evolution of the price index is given by

$$P_{t+1}^{1-\zeta} = \theta P_t^{1-\zeta} + (1-\theta) \left(P_{t+1}^a \right)^{1-\zeta} \tag{26}$$

2.6 Monetary Policy

The monetary policy instrument is the gross nominal interest rate, $R_{n,t}$ set in period t to pay out interest in period $t+1$. The relationship between the nominal and real interest rate is given by the following Fisher equation,

$$R_{n,t-1} = R_t E_t \Pi_t \tag{27}$$

We suppose monetary policy is conducted using a simple Taylor rule given by,

$$\log \left(\frac{R_{n,t}}{R_n} \right) = \rho_\pi \log \left(\frac{\Pi_t}{\Pi} \right) + \rho_y \log \left(\frac{Y_t}{Y} \right) \tag{28}$$

where R_n denotes the steady state nominal rate, Π the steady state inflation and Y the steady state level of output.

[3] The optimality conditions that represent the solution to the retail firm's maximization problem are included in Appendix A, where the model equations that describe the competitive equilibrium are presented.

2.7 Macroprudential Policies

In our model we study the implications of using three different macroprudential policies; reserve requirements, capital requirements and a regulation premium. Each policy is characterized by a macroprudential policy rule.

2.7.1 Reserve Requirements (RR)

According to reserve requirements, banks need to hold a portion of their deposits at the central bank, which generally earns zero interest. Hence, such requirements can be regarded as a tax that increases the cost of extending credit. If banks did not need to hold non-interest-bearing reserves, they would probably use the extra funds to supply more loans. This would, in turn, increase their interest income and improve their profitability, as it would result in a larger asset base for them to earn their spread (Hein and Stewart, 2002). As a result, an increase in the central bank's level of reserve requirements can be considered to increase the return to deposits.

The holdings of reserves by banks beyond the required level are called excess reserves. Before the global financial crisis, reserves held with the Fed did not earn any interest so banks had an inclination to minimize their holdings of excess reserves. In 2007, the excess reserves held by U.S. banks were only about 0.3% above the requirement (Keister and McAndrews, 2009). Since there are no gains from holding excess reserves, it can be assumed that the cost of deposits to banks varies only with the level of the required reserves imposed by the central bank. The change in the cost of deposits, in turn, affects the marginal values of a bank's assets, and hence, the leverage of the financial sector (Areosa and Coelho, 2013).

Accordingly, we assume that when the central bank demands banks to hold a required ratio (rr_t) of their deposits as non-interest-earning reserves, the rise in the cost of deposits is reflected as a change from R_t to $\frac{R_t - rr_t}{1 - rr_t}$. As a result, the new accumulation of bank net worth will be given by

$$n_t = R_{k,t} Q_{t-1} s_{t-1} - \left(\frac{R_t - rr_t}{1 - rr_t} \right) d_{t-1} \tag{29}$$

It can be seen that when there is an increase in reserve requirements, the return to deposits increases. Hence, banks are encouraged to substitute internal financing (n_t) for external financing (d_t). To reflect the changes in the bank's maximization problem as a result of the introduction of reserve requirements, we replace R_t, the gross return to deposits with $\frac{R_t - rr_t}{1 - rr_t}$.

Consequently, in the presence of reserve requirements, the marginal value of the bank's loans is given by

$$v_{s,t}^{rr} = E_t \Lambda_{t,t+1} \eta_{t+1}^{rr} R_{k,t+1} Q_t$$

whereas the marginal value of the bank's deposits and the excess marginal value of the bank's loans over its deposits are now represented by

$$v_{d,t}^{rr} = E_t \Lambda_{t,t+1} \eta_{t+1}^{rr} \left[\frac{R_{t+1} - rr_t}{1 - rr_t} \right]$$

$$\mu_{s,t}^{rr} = E_t \Lambda_{t,t+1} \eta_{t+1}^{rr} \left[R_{k,t+1} - \frac{R_{t+1} - rr_t}{1 - rr_t} \right]$$

ϕ_t^{rr} denotes the leverage ratio in the presence of reserve requirements and η_t^{rr}, the shadow value of a unit of net worth, is now equal to $(1-\gamma)+\gamma(\mu_{s,t}^{rr}\phi_t^{rr} + v_{d,t}^{rr})$.

Moreover, the evolution of net worth at the aggregate level changes to

$$N_t = R_{k,t}\left(\gamma + \varepsilon\right) Q_{t-1} S_{t-1} - \gamma \left[\frac{R_t - rr_t}{1 - rr_t}\right] D_{t-1} \tag{30}$$

We assume that the required reserves ratio follows a rule that reacts to the deviations of the total nominal credit from its steady state value,

$$rr_t - rr = \rho_{rr}\left(\frac{Q_t S_t - QS}{QS}\right) \tag{31}$$

Here, variables without any time subscript denote steady state values and we assume that $\rho_{rr} > 0$. Consequently, when the total nominal credit in the economy is increasing, the central bank demands banks to hold higher reserves, which increases the return to deposits and encourages banks to prefer equity financing. Hence, reserve requirements are counter-cyclical. The macroprudential tools in our study respond to the fluctuations in the total nominal credit, since stabilizing the total credit is expected to reduce the deviations in the spread. As the spread is an inter-temporal distortion created by financial frictions, the welfare level is expected to be higher when macroprudential policy rules are used by the central bank.

2.7.2 Capital Requirements (CR)

Different from reserve requirements, macroprudential policy in the form of countercyclical capital requirements focuses on the size of a bank's balance sheet instead of the composition of its assets. Capital requirements deal with the leverage of banks, while reserve requirements address liquidity risk. When a bank's capital ratio is below the capital requirement, the macroprudential authority will enforce corrective measures which can cause serious reputational costs and adverse market reactions. Hence, falling below the capital requirement is extremely costly for a bank. Since capital requirements reduce the ability of banks to supply credit by accepting deposits and limit the percentage of bank assets that can be financed by issuing deposits, the increase in the bank's funding cost in the presence of capital requirements can be regarded as an increase in the cost of deposits (Borio and Zhu, 2011).

As reported in the study by Van den Heuvel (2008), capital adequacy ratios are important determinants of the capital structure of U.S. banks. Majority of U.S. banks hold some buffer of equity above the regulatory minimum since they would like to lower the risk of a negative shock resulting in capital inadequacy. Most bank assets are in U.S. banks with a ratio of at least 3% above the capital requirement. As a result, even though both reserve requirements and capital requirements increase the costs to banks, the way they do so is modelled differently. The cost of capital requirements is given by the first-order derivative of a quadratic cost function of deviations from the required capital/assets ratio. Positive (negative) deviations decrease (increase) the cost of deposits and larger deviations result in higher changes in the cost. In this case, the banker would like to issue as many loans as possible, increasing leverage and thus profits, with the knowledge of the fact that when leverage increases, the capital/assets ratio can fall below the requirement and the bank pays a cost. Consequently, when capital requirements are in place, the banker will choose the bank's optimal capital/assets ratio in line with the profit maximization, while the quantity of reserves is determined essentially by the central bank's decisions.

In line with this interpretation, we formulate the return to deposits in the presence of capital requirements as in Brzoza-Brzezina et. al (2013). In this case, the accumulation of bank's net worth is given by,

$$n_t = R_{k,t} Q_{t-1} s_{t-1} - \left[R_t - \left(\frac{1}{\phi_t^{cr}} - cr_t \right) \left(\frac{1}{\phi_t^{cr}} \right)^2 \right] d_{t-1} \tag{32}$$

where $\dfrac{1}{\phi_t^{cr}}$ is the inverse of the leverage ratio; the ratio of bank's equity to its loans in the presence of capital requirements. As a result, if a bank's capital/assets ratio is lower than the required ratio, it needs to pay a higher return to deposits, which induces the bank to substitute internal financing for external financing.

Incorporating capital requirements in the bank's profit maximization problem is straightforward. This can be done by replacing the gross return to deposits by the new gross return given in Equation (32). Accordingly, in the presence of capital requirements, the marginal value of the bank's loans and deposits are represented by,

$$v_{s,t}^{cr} = E_t \Lambda_{t,t+1} \eta_{t+1}^{cr} R_{k,t+1} Q_t$$

$$v_{d,t}^{cr} = E_t \Lambda_{t,t+1} \eta_{t+1}^{cr} \left[R_{t+1} - \left(\frac{1}{\phi_t^{cr}} - cr_t \right) \left(\frac{1}{\phi_t^{cr}} \right)^2 \right]$$

while the excess marginal value of the bank's loans over its deposits are now given by

$$\mu_{s,t}^{cr} = E_t \Lambda_{t,t+1} \eta_{t+1}^{cr} \left[R_{k,t+1} - R_{t+1} + \left(\frac{1}{\phi_t^{cr}} - cr_t \right) \left(\frac{1}{\phi_t^{cr}} \right)^2 \right]$$

The shadow value of a unit of net worth in the presence of capital requirements is obtained as $\eta_t^{cr} = (1-\gamma) + \gamma(\mu_{s,t}^{cr} \phi_t^{cr} + v_{d,t}^{cr})$.

In addition, the evolution of net worth at the aggregate level changes to

$$N_t = R_{k,t} (\gamma + \varepsilon) Q_{t-1} S_{t-1} - \gamma \left[R_t - \left(\frac{1}{\phi_t^{cr}} - cr_t \right) \left(\frac{1}{\phi_t^{cr}} \right)^2 \right] D_{t-1} \qquad (33)$$

The capital adequacy ratio also follows a rule that reacts to the deviations of total nominal credit from its steady state value,

$$cr_t - cr = \rho_{cr} \left(\frac{Q_t S_t - QS}{QS} \right) \tag{34}$$

where QS is the steady state level of nominal credit and cr is the steady state level of the capital adequacy ratio. Again, the counter-cyclical nature of capital requirements implies that $\rho_{cr} > 0$.

2.7.3 Regulation Premium (RP)

Finally, we turn to a more general representation of macroprudential policy. If banks were competitive in the deposit market but they had market power in the loan market, the marginal cost of deposits would be fixed, while the demand schedule and the marginal revenue for loans would be downward sloping. In this case an increase in the cost of deposits would shift the marginal cost curve up. As a result, at the equilibrium, the interest rate on loans would be higher and the level of credit would be lower. The increase in the lending rates induced by macroprudential policies is called the "regulation premium" (Unsal, 2013). The regulation premium can be interpreted as a tax that increases the cost of borrowers. In the presence of reserve or capital requirements, the costs relating to macroprudential policies are incurred by banks, while in the presence of the regulation premium, these costs are incurred by borrowing firms.

Accordingly, the *spread* in the economy is now given by

$$spread = \frac{R_{k,t} - R_t}{1 + rp_t} \tag{35}$$

where rp_t is the regulation premium. To be able to make a comparative analysis of the three macroprudential policies, rp_t also reacts to the deviations of total nominal credit from its steady state value, in line with rr_t and cr_t,

$$rp_t - rp = \rho_{rp}\left(\frac{Q_t S_t - QS}{QS}\right) \tag{36}$$

where we assume that $\rho_{rp} > 0$. As a result, when the total nominal credit in the economy is lower, the cost of borrowing to firms decreases. Hence, the regulation premium is also counter-cyclical.

2.8 Government Budget Constraint

We assume that government expenditures, G_t, are financed by lump-sum taxes, T_t[4],

$$G_t = T_t \tag{37}$$

2.9 Exogenous Processes

We suppose that the model economy is affected by two exogenous processes, which are total factor productivity (TFP) and capital quality shocks. Both shocks are supposed to follow an AR(1) process,

$$\log A_t - \log A = \rho_A(\log A_{t-1} - \log A) + \varepsilon_A$$

$$\log \psi_t = \rho_\psi(\log \psi_{t-1}) + \varepsilon_\psi$$

By incorporating the capital quality shock into the model, we can conduct a financial crisis experiment. Accordingly, the capital accumulation process (21) is now given by

[4] We also maintain that the proceeds from the use of macroprudential policies are lumped into T_t.

$$K_t = \psi_{t+1}\left[(1-\delta)K_{t-1} + (1 - S(X_t))I_t\right] \tag{38}$$

resulting in the following gross return to capital,

$$R_{k,t} = \psi_t \frac{(1-\alpha)\frac{P_t^W Y_t^W}{P_t K_{t-1}} + (1-\delta)Q_t}{Q_{t-1}} \tag{39}$$

$S_t = [(1-\delta)K_{t-1} + (1 - S(X_t))I_t]$ now gives the capital in process which is by (38) transformed into capital for next period's production according to $K_t = \psi_{t+1} S_t$. As a result, the capital quality shock causes a wedge between capital and the capital in process, where the evolution of capital in process is given by

$$S_t = [(1-\delta)\psi_t S_{t-1} + (1 - S(X_t))I_t] \tag{40}$$

Capital quality shocks in New Keynesian models without any financial sectors only have an effect on the accumulation of and the return to capital. With a banking sector in place, they also have an effect on the evolution of bank's net worth. A negative capital quality shock reduces the net worth, which results in the tightening of the budget constraint. Accordingly, Equation (16) can now be rewritten as

$$N_t = R_{k,t}(\gamma + \varepsilon)\psi_t Q_{t-1} S_{t-1} - \gamma R_t D_{t-1} \tag{41}$$

3 Quantitative Analysis

3.1 Calibration

The parameters used in the calibration of our model are given in Table 1.

Table 1. Parameters

Households		
β	0.987	Discount factor
χ	0.7	Habit parameter
σ	2	Adjustment parameter in the utility function
ϱ	0.876	Preference parameter in the utility function
Wholesale Firms		
α	0.7	Labor share
δ	0.025	Depreciation rate
Capital Producing Firms		
ϕ_X	2	Coefficient of adjustment costs
Retail Firms		
ζ	7	Elasticity of substitution
θ	0.75	Probability of keeping prices constant
Banks		
γ	0.975	Probability that bankers survive
ε	0.001	Proportional transfer to the new bankers
Θ	0.410	Fraction of bank assets that can be diverted
Government		
$\frac{G}{Y}$	0.2	Steady state share of government expenditures
Monetary and Macroprudential Policy Rules		
ρ_π	1.5	Inflation coefficient of the Taylor rule
ρ_y	0.5/4	Output gap coefficient of the Taylor rule
$\rho_{rr} = \rho_{cr} = \rho_{rp}$	1.5	Coefficient of the macroprudential policy rules

We start by calibrating the non-financial parameters. As in Gertler and Karadi (2011), for the labor share α, the elasticity of substitution between goods ζ, and the government expenditure share, we choose conventional values. The steady state depreciation rate δ, the habit parameter χ, and the price rigidity parameter θ are also set in line with the values used by Gertler and Karadi (2011). The parameters that are specific to our model are σ in the utility function and ϕ_X in the investment cost function. The chosen values for these parameters roughly reflect the empirical literature. For calibrating the discount factor β, and the preference parameter ϱ, we use typical U.S. observations of 0.35 for hours worked and 1.01 for the gross interest rate. For calibrating the financial parameters, we again follow values similar to those used by Gertler and Karadi (2011). We choose the value of γ so that the bankers survive 10 years on average. The values of ε and Θ are calibrated so that we will have an economy wide leverage ratio of 4, which will roughly capture the aggregate data and an average credit spread of 100 basis points per year, which is based on pre-2007 spreads between BAA corporate versus government bonds. Finally, the coefficients of the Taylor rule and the macroprudential policy rules are also presented in Table 1. To make our three macroprudential experiments comparable, we assume that the coefficient of the macroprudential policy rule under each macroprudential instrument is the same. At the steady state, required reserves ratio is determined as 0.06, while the capital adequacy ratio is set equal to 0.08, in line with the average values employed by the U.S. Federal Reserve System.[5]

3.2 Model Dynamics

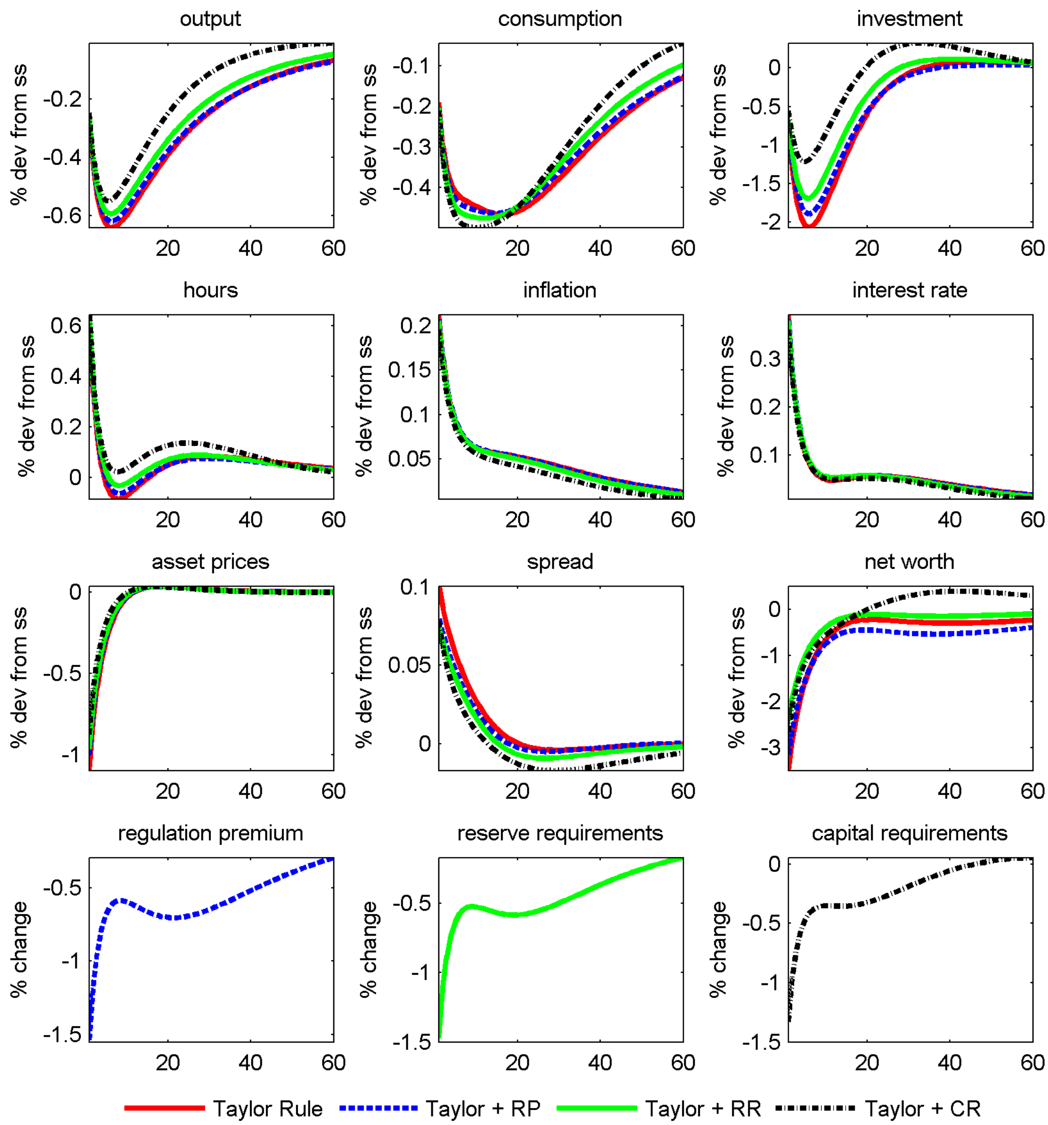
In the following subsections, we start by comparing the dynamics of negative TFP shocks under alternative policy rules. First, we look at the behavior of certain macroeconomic variables when only the monetary policy rule is used by the central bank. We then analyze the behavior of these variables when the monetary policy instrument is used in combination with one of the macroprudential policy tools. Lastly, we conduct a financial crisis experiment, one that is triggered by a negative capital quality shock, and compare the dynamics under the same alternatives.

[5] http://www.federalreserve.gov/econresdata/default.htm

3.2.1 Impulse Responses to TFP Shocks

Figure 1 illustrates the impulse responses under different policy rules when there is a negative one percent change in domestic productivity. The unanticipated decline in domestic productivity decreases investment and reduces asset prices, which triggers the financial accelerator mechanism. Since banks are leveraged, the decrease in asset prices results in a decline in their net worth, which is multiplied by a factor equal to their leverage ratio. As a result, banks experience a downturn in their balance sheets that increases the leverage ratio and pushes up the spread. The rise in the spread increases the cost of capital, which adds on to the decrease in investment and asset prices. The overall decline in investment, in turn, decreases aggregate output. The unanticipated decline in productivity also results in an increase in hours worked, marginal cost and hence inflation. With the use of the monetary policy rule only, since the weight of the movements in inflation is higher than the weight of the fluctuations in output, the interest rate increases. When macroprudential policy rules are used in combination with the monetary policy rule, it can be seen that the negative effects of the financial accelerator mechanism in the economy dampens. According to the reserve requirements rule, the fall in the total nominal credit induced by the decline in productivity results in a decrease in the required reserves. Hence, cost of extending loans for banks declines. As a result, banks' net worth decreases less, leading to a smaller increase in the leverage ratio and the spread. Consequently, the negative effects of the TFP shock on investment & output are lower. In the presence of the capital requirements rule, the decrease in the total nominal credit results in a decrease in the target capital adequacy ratio. Similar to the case under the reserve requirements, this decline lowers the decrease in bank's net worth, which results in the negative effects of the financial accelerator mechanism to be reduced. Finally, when the regulation premium is

Figure 1. Impulse Responses to TFP Shocks under Different Policy Rules

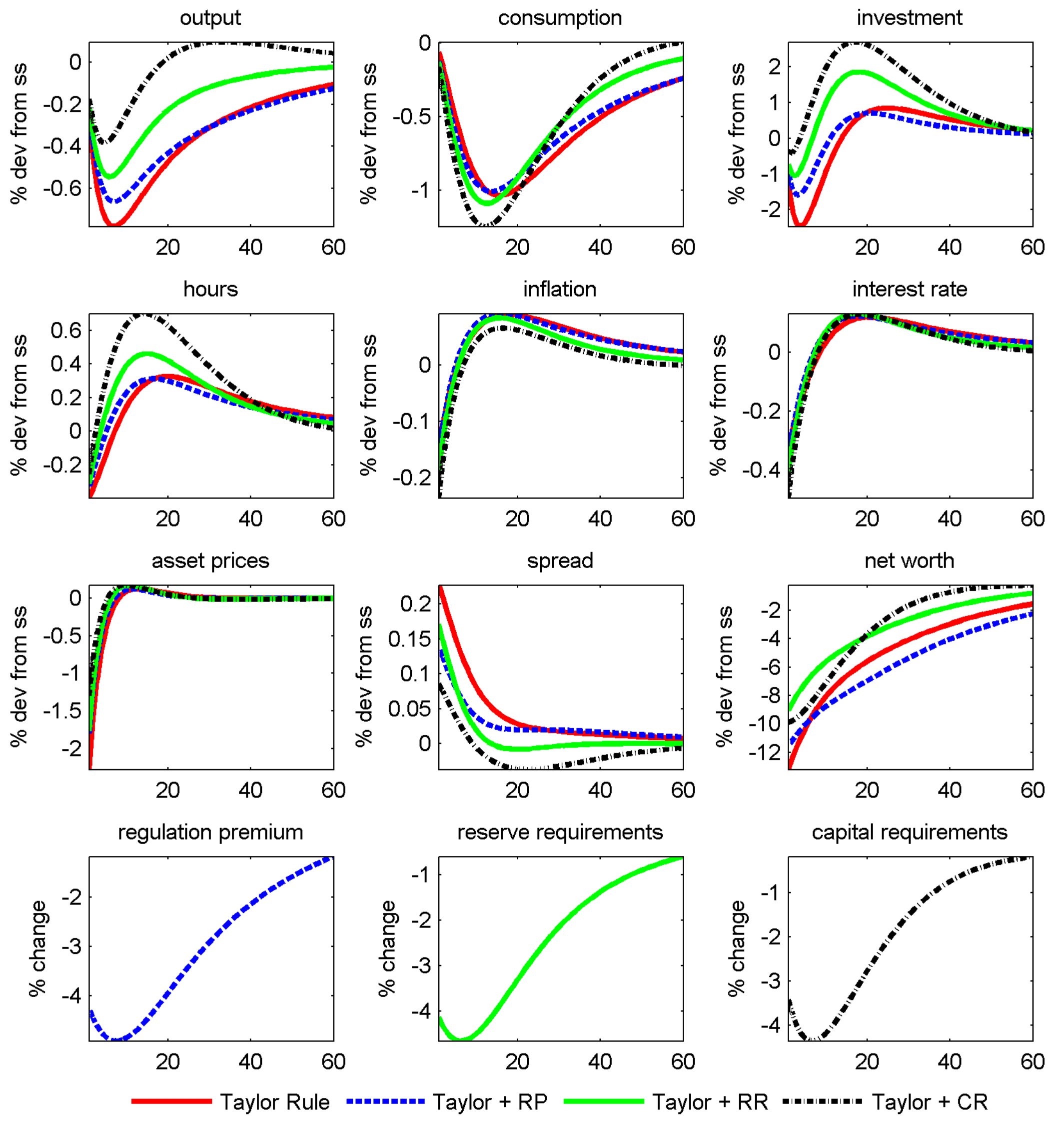


used, the decrease in the total nominal credit lowers the premium. As a result, the cost of borrowing increases less, leading to the depression of the productivity shock's negative effects. When there is a decrease in domestic productivity, it can be observed that counter-cyclical capital requirements are the most effective macroprudential tool in stabilizing output, since their positive effect on the spread, asset prices and investment is the largest.

3.2.2 Financial Crisis Experiment

In our model, we postulate the negative capital quality shock as the origin of the financial crisis as in Gertler and Karadi (2011). The aim is to find a shock that affects the quality of the financial intermediaries' assets, which will cause an amplified decrease in their net worth, because of their high levels of leverage. In this way, we can broadly mimic the dynamics of the sub-prime crisis. Figure 2 demonstrates the impulse responses under alternative policy rules when the economy is affected by a negative one percent change in capital quality. As suggested by Equation (38), the shock results in a decline in capital, which in turn reduces asset prices. In addition to this negative effect, the capital quality shock also causes a decline in banks' net worth, as given by Equation (41). As a result, in the absence of macroprudential measures, banks' leverage ratios increase and so does the spread and the cost of borrowing. The increase in the cost of borrowing results in a further reduction in asset prices and investment. The fall in investment in turn, leads to a decrease in aggregate output, hours worked and marginal cost. Hence, inflation decreases. When used in combination with the monetary policy, all counter-cyclical macroprudential policies dampen the negative effects of the financial accelerator mechanism. They achieve this by lowering the decline in banks' net worth, asset prices and investment. Capital requirements once again, mitigate the negative effects of the financial shock on output the most, since they perform the best in lowering the negative effects to

Figure 2. Impulse Responses to Financial Shocks under Different Policy Rules



the spread, asset prices and investment. When compared with the TFP shock, the capital quality shock results in a higher reduction in asset prices. As a result, all three macroprudential instruments are required to decrease more when the economy experiences a financial crisis.

3.3 Volatility Analysis

Following the analysis of the impulse responses to two different exogenous shocks, we first compare the real and financial statistics in the data and the model. Our aim is to analyze the performance of the model by its ability to mimic the cyclical properties of real and financial variables. In our analysis, we use HP-filtered (smoothing factor: 1600) quarterly U.S. data for the period 1980-2010[6]. To obtain the statistics in the model, we simulate the model 500 times for 100 quarters, with the assumption that both productivity and capital quality shocks affect the model economy. We then compute the business cycle statistics using the cyclical components of the HP-filtered series. In Table 2.a, we report the relative standard deviations of real and financial variables with respect to output and their cross-correlations with output.

Table 2.a. Business Cycle Properties of Real and Financial Variables

	Standard Deviation		Correlation with GDP	
	Data	Model	Data	Model
Consumption	0.69	0.68	0.93	0.78
Investment	3.74	3.92	0.94	0.93
Employment	0.84	0.34	0.74	0.54
Bank assets	1.34	1.81	0.31	0.94
Net Worth	7.08	13.50	0.44	0.69
Leverage Ratio	5.68	10.05	-0.13	-0.64
Spread	0.18	0.28	-0.59	-0.63

[6] Data sources are presented in Appendix B with details.

Examining the real and financial statistics in the data, it can be seen that consumption and employment are less volatile than output, while investment volatility is much higher. In addition, consumption, investment and employment are highly pro-cyclical. These are known as standard business cycle facts (King and Rebelo, 1999). Except the spread, all financial variables are more volatile than output. It can also be noticed that bank assets and net worth are pro-cyclical, while the spread and the leverage ratio are counter-cyclical. These business cycle properties of real and financial variables broadly match the data statistics found in Angeloni and Faia (2013) and Mimir (2013). The pro-cyclicality of bank capital is also reported in these studies. On the other hand, Meh and Moran (2010) and Rannenberg (2013) find that bank net worth and bank capital ratio are counter-cyclical, i.e., bank leverage is pro-cyclical.

We see that the model is able to reproduce the key business cycle facts in the U.S. data and it is able to replicate most of the facts related to financial variables. It nearly matches the relative volatility of consumption and produces pro-cyclical real variables as in the data. However, it underestimates the employment statistics[7]. In addition, net worth and leverage ratio have relatively high volatilities in the model. The higher volatility of bank net worth and leverage ratio within the model is as a result of the direct effect of the changes in asset prices on banks' net worth and leverage. Since the fluctuations in asset prices have a direct and pro-cyclical effect on bank net worth, bank capital is also pro-cyclical. Moreover, when output declines, the greater decrease in bank capital indicates a significant rise in bank leverage, which results in a highly counter-cyclical leverage ratio.

[7] We believe that the performance of the model would improve with the introduction of wage stickiness. Moreover, the relative volatility of employment depends on the preference parameter, ϱ, in the utility function. A higher value of ϱ implies a higher relative volatility.

In this section, we also study each macroprudential policy tool's impact on the volatilities of different macroeconomic variables. In doing so, we employ the methodology used in obtaining the model statistics reported in Table 2.a. Our results are presented in Table 2.b.

Table 2.b Volatilities under Different Policy Rules: Standard Deviations(%)

	Taylor Rule	Taylor + RR	Taylor + CR	Taylor + RP
Real Variables				
Output	1.37	1.15	1.03	1.23
Consumption	0.93	1.15	1.33	1.02
Investment	5.36	3.68	2.90	4.09
Employment	0.46	0.38	0.52	0.36
Financial Variables				
Net Worth	18.47	12.60	14.55	16.30
Spread	0.38	0.28	0.19	0.25
Asset Prices	3.59	2.90	2.30	3.02
Monetary & Macroprudential Variables				
Inflation	0.09	0.09	0.10	0.09
Interest Rate	0.13	0.16	0.24	0.12
Macropru. Tool	-	6.43	5.71	6.58

To start with, we examine the differences in the volatilities of certain real variables. It can be mentioned that all three macroprudential tools are effective in decreasing output volatility, while the adoption of these tools increases the volatility of consumption. The lowest volatility of output and investment are obtained under the capital requirements. When we analyze the volatility of the financial variables, it can be seen that all three macroprudential alternatives are effective in decreasing the volatility of net worth, the spread and asset prices. The lowest volatility of the spread and asset prices are also obtained in the presence of capital requirements. When inflation stability is the main concern, it can be suggested that there is no trade-off between the use of alternative macroprudential tools. Since all three macroprudential tools respond to the fluctuations in total nominal credit, the order of the volatilities of asset prices is reflected in the order of the volatilities of these tools.

3.4 Macroprudential Policies and Welfare

Following Faia and Monacelli (2007) and Gertler and Karadi (2011), we begin our welfare analysis by writing the household's utility function recursively,

$$\Gamma_t = U_t(C_t, C_{t-1}, L_t) + \beta E_t \Gamma_{t+1} \tag{42}$$

We then take a second order approximation of Γ_t around the steady state, under each policy alternative. Using the second order solution of the model, we compute the value of Γ_t, which corresponds to the welfare loss under each alternative. In this computation, we use the values of the monetary and macroprudential policy parameters ($\rho_\pi, \rho_y, \rho_{rr}, \rho_{cr}$ and ρ_{rp}) that optimize Γ_t in response to productivity or financial shocks.[8] By taking the difference of the values of Γ_t obtained under the monetary policy rule only and each macroprudential policy alternative, we can find the welfare gains from using each macroprudential tool. To convert these gains to consumption equivalents (CEs), we then compute the fraction of the steady state consumption required to equate welfare under the monetary policy rule, to the one under each macroprudential alternative. In Table 3, we present the optimized values for the policy parameters and the welfare gain obtained under each macroprudential alternative in terms of the CE. Under both shocks, we find that the optimal parameter for the output gap in the Taylor Rule is equal to zero, as in Schmitt-Grohe and Uribe (2007). As a result,

[8] Schmitt-Grohe and Uribe (2007) provide a detailed discussion on the calculation of the welfare loss in New Keynesian DSGE models.

in our analysis we set this parameter equal to zero and find the optimal parameters for inflation and total nominal credit in the monetary and macroprudential policy rules, respectively.

Table 3. Optimal Parameters & Welfare Gains under Different Policy Rules

	In response to TFP shocks			In response to financial shocks		
	CE	Optimal Parameters		CE	Optimal Parameters	
	(%)	ρ_π	$\rho_{rr}/\rho_{cr}/\rho_{rp}$	(%)	ρ_π	$\rho_{rr}/\rho_{cr}/\rho_{rp}$
Taylor (TR)	-	3.82	-	-	5.00	-
TR + RR	0.0019	5.00	1.26	0.0003	5.00	0.21
TR + CR	0.0429	5.00	1.40	0.1867	4.89	0.96
TR + RP	0.0001	3.82	0.00	0.0034	5.00	1.87

Table 3 shows that the degree of the counter-cyclicality of each macroprudential tool depends on the origin of the shock affecting the economy. However, the adoption of all macroprudential policies results in a decrease in the welfare loss when the economy experiences a TFP or a financial shock. The least effective macroprudential policy tool is the regulation premium under the TFP shock, while it is the reserve requirements under the financial shock. It should be noted that under each shock, the macroprudential tool that has the smallest positive effect on welfare is the one with an optimized macroprudential policy parameter that is closer to zero. When the economy experiences a TFP shock, macroprudential policies improve welfare, but the change is quantitatively small. Under the financial shock, the utilization of the capital requirements and the regulation premium has a higher positive effect on welfare.

It is important to notice that the use of capital requirements has the highest positive effect on welfare irrespective of the type of the shock affecting the economy. This finding is in line with the impulse responses presented in Section 3.2, where it is seen that counter-cyclical capital requirements are the most effective macroprudential tool in mitigating the negative effects of both shocks to the spread, asset prices and investment. As previously mentioned, the financial accelerator mechanism used in our model features a pecuniary externality, where bankers do not consider the fact that if they issued more equity, they would decrease the risk of the banking sector. Consequently, they accumulate high levels of leverage, which amplifies the negative effects of exogenous shocks to the economy and results in a decline in welfare. Since capital requirements directly target banks' leverage (or capital ratio), it is not counter-intuitive to find that they are the most effective macroprudential tool in mitigating the negative effects of the financial accelerator mechanism.

Before concluding our welfare analysis, we also consider the scenario where both monetary and macroprudential policy instruments respond to the fluctuations in the total nominal credit in the economy. In this case, the optimized values for the policy parameters and the value of the CE obtained under each macroprudential alternative are reported in Table 4.

Table 4. Optimal Parameters & Welfare Gains with Credit Growth in the TR

	In response to TFP shocks				In response to financial shocks			
	CE	Optimal Parameters			CE	Optimal Parameters		
	(%)	ρ_π	ρ_{Q^*S}	$\rho_{rr}/\rho_{cr}/\rho_{rp}$	(%)	ρ_π	ρ_{Q^*S}	$\rho_{rr}/\rho_{cr}/\rho_{rp}$
TR + RR	0.0019	5.00	0.00	1.26	0.0006	5.00	0.01	0.19
TR + CR	0.0429	5.00	0.00	1.40	0.1867	4.98	0.00	0.96
TR + RP	0.0001	3.82	0.00	0.00	0.0036	5.00	0.01	1.80

Under financial shocks, there are little welfare gains from including financial market developments in the Taylor rule, when the reserve requirements or the regulation premium are already in place. The optimized coefficient for the total nominal credit in the monetary policy rule is close to zero. In the presence of capital requirements, which are the most effective macroprudential tool in mitigating the negative effects of the financial accelerator mechanism, the monetary authority cannot generate additional welfare gains by responding to the fluctuations in the total nominal credit. When the economy experiences a productivity shock and one of the aforementioned macroprudential tools is in place, the optimal coefficient of the total nominal credit in the Taylor rule is equal to zero. As a result, we conclude that our analysis suggests the use of two different policy instruments, to achieve two distinct but related objectives, namely financial and macroeconomic stability.

In our welfare analysis, we have assumed that the use of the interest rate and the macroprudential tools is assigned to the central bank, or put differently, the monetary and the macroprudential authorities cooperate. In case of non-cooperation, each authority would minimize its own loss function, taking the other's policy rule as given. In this case, we would need to use an exogenously determined loss function for each authority[9].

4 Conclusions

In this paper, utilizing a New Keynesian DSGE model with financial frictions *a la* Gertler and Karadi (2011), we present a comparative analysis of three macroprudential policy tools; reserve requirements, capital requirements and a regulation premium. Our analysis is motivated by the lack of studies in the macroprudential policy literature that make a comparison of alternative policies, using a unified framework.

Running a number of simulations, we find that all of the aforementioned macroprudential tools are successful in lowering the negative effects of exogenous

[9] See Angelini et. al (2011) for a discussion on the topic.

shocks to the economy. They do so by mitigating the negative effects of the financial accelerator mechanism, which is triggered by the decrease in asset prices. As a result of this decrease, banks experience a downturn in their balance sheets, which increases their leverage ratios and raises the spread. The rise in the spread increases the cost of capital, which results in a further decline in investment and asset prices. Finally, the decline in investment lowers the aggregate output. Irrespective of the source of the decline in economic activity, capital requirements are the most effective macroprudential tool in lowering the negative effects of the given shocks to the spread, asset prices and investment. As a result, they perform the best in mitigating the negative effects of the financial accelerator mechanism built in banks' balance sheet constraints.

Computing the welfare loss and the corresponding consumption equivalent under each policy alternative, we can also identify the macroprudential tool that generates the highest positive effect on welfare. It can be seen that under both productivity and financial shocks, all three macroprudential policies are successful in decreasing the welfare loss. Consistent with the results of the simulations, use of capital requirements generates the highest welfare gains, under both shocks.

Before we conclude, it should be mentioned that we have not considered any open economy characteristics in our framework. Consequently, we have excluded the comparison of different macroprudential policies in an open economy setting and the coordination issues between the authorities in different countries. We believe that analyzing these issues will aid us in having a better understanding of the functioning of macroprudential policies and hence should be a subject of further research.

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APPENDIX A. THE COMPETITIVE EQUILIBRIUM

A competitive equilibrium of the model economy is defined by sequences of allocations, prices, shock processes and the government policy (without the use of any macroprudential tools) that satisfy the following optimality and market clearing conditions,

Consumption Euler Equation	$U_{C,t}= \beta R_{t+1} E_t \left[U_{C,t+1}\right]$
Labor Supply	$\frac{U_{h,t}}{U_{C,t}}= -W_t$
Wholesale Output	$Y_t^W= \left(A_t h_t\right)^{\alpha} K_{t-1}^{1-\alpha}$
Labor Demand	$\frac{P_t^W}{P_t} Y_{h,t}^W= W_t$
Return to Capital	$R_{k,t+1}=\frac{(1-\alpha)\frac{P_{t+1}^W Y_{t+1}^W}{P_{t+1} K_t}+(1-\delta) Q_{t+1}}{Q_t}$
Capital Accumulation	$K_t=\left[(1-\delta) K_{t-1}+(1-S(X_t)) I_t\right]$
Investment & Asset Prices	$Q_t\left(1-S(X_t)-X_t S'(X_t)\right)+E_t\left[\Lambda_{t,t+1} Q_{t+1} S'(X_{t+1}) X_{t+1}^2\right]=1$
Price Dispersion in the Retail Sector	$\Delta t=\int_0^1\left(\frac{P_t(f)}{P_t}\right)^{-\zeta} df$
Retail Output[1]	$Y_t=\frac{(1-c) Y_t^W}{\Delta_t}$
Optimal Relative Price	$\frac{P_t^a}{P_t}=\frac{F_t}{H_t}$
Price Dispersion & Inflation	$\Delta_t= \theta \Pi_t^{\zeta} \Delta_{t-1}+(1-\theta)\left(\frac{F_t}{H_t}\right)^{-\zeta}$
Non-linear Phillips Curve[2]	$H_t-\theta \beta E_t\left[\Pi_{t+1}^{\zeta-1} H_{t+1}\right]=Y_t U_{C,t}$
	$F_t-\theta \beta E_t\left[\Pi_{t+1}^{\zeta} F_{t+1}\right]=\mu Y_t U_{C,t} M C_t$
	$\theta \Pi_t^{\zeta-1}+(1-\theta)\left(\frac{F_t}{H_t}\right)^{1-\zeta}=1$
Fisher Equation	$R_{n,t-1}= R_t E_t \Pi_t$
Taylor Rule	$\log\left(\frac{R_{n,t}}{R_n}\right)=\rho_\pi \log\left(\frac{\Pi_t}{\Pi}\right)+\rho_y \log\left(\frac{Y_t}{Y}\right)$
Government Budget Constraint	$G_t= T_t$
Output Equilibrium	$Y_t= C_t+I_t+G_t$

Loans to Non-financial Firms & Capital	$S_t = K_t$
Deposits Held at Banks	$D_t = Q_t S_t - N_t$
Accumulation of Bank Net Worth	$N_t = R_{k,t}(\gamma + \varepsilon) Q_{t-1} S_{t-1} - \gamma R_t D_{t-1}$
Marginal Value of Deposits	$v_{d,t} = E_t \Lambda_{t,t+1} \eta_{t+1} R_{t+1}$
Excess Marginal Value of Loans	$\mu_{s,t} = E_t \Lambda_{t,t+1} \eta_{t+1} (R_{k,t+1} - R_{t+1})$
Leverage Ratio	$\phi_t = \dfrac{v_{d,t}}{\Theta - \mu_{s,t}}$
Banking Sector Balance Sheet	$Q_t S_t = \phi_t N_t$
The Spread	$spread = R_{k,t} - R_t$

[1] c = cost of converting wholesale output to retail output.
[2] μ = steady state mark-up.

APPENDIX B. DATA SOURCES

This appendix presents the details of the data sources used to construct Table 2.a in the main text. All the time series of the nominal macroeconomic and financial variables are deflated using the GDP deflator.

- GDP Deflator: Bureau of Economic Analysis (BEA), NIPA Table 1.1.9. Implicit Price Deflators for Gross Domestic Product.
- Consumption: BEA, NIPA Table 1.1.5. Personal Consumption Expenditures.
- Investment: BEA, NIPA Table 1.1.5. Gross Private Domestic Investment.
- Government Spending: BEA, NIPA Table 1.1.5. Government Consumption Expenditures.

- Gross Domestic Product: BEA, NIPA Table 1.1.5. Sum of Consumption, Investment and Government Spending.

- Hours: Bureau of Labor Statistics, Current Employment Statistics Survey. Multiplication of Average Weekly Hours in Private Sector and Average Number of Workers in Private Sector.

- Bank Assets: Federal Reserve Board (FRB), Data Download Program of Statistical & Historical Database. Bank Credit at the Asset Side of the U.S. Commercial Banks' Balance Sheet.

- Deposits: FRB, Data Download Program of Statistical & Historical Database. Deposits Held at the U.S. Commercial Banks.

- Bank Net Worth: FRB, Data Download Program of Statistical & Historical Database. Bank Credit minus Deposits.

- Leverage Ratio: FRB, Data Download Program of Statistical & Historical Database. Ratio of Bank Credit to Net Worth.

- Spread: Federal Reserve Bank of St. Louis. Moody's Seasoned BAA Corporate Bond Yield minus Effective Federal Funds Rate.