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A Stylized model of European Monetary Union for Analysing coordination games for Monetary and Macroprudential Policy

Joseph Pearlman

City University

joseph.pearlman.1@city.ac.uk

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Abstract

Following on from Quint and Rabanal (2014), who find that coordination between the monetary authority and macroprudential regulators generates virtually identical results to non-coordination, we extend their model in a variety of ways. We address the zero lower bound for nominal interest rates, feedback of the macroprudential tool on the output growth rate, and the role of reserves. In all cases, we find that there is significant impact on the coefficients of the simple rule and on consumption-equivalent welfare effects.

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Contents

1 Introduction

The purpose of this paper is to re-evaluate a recent paper by Quint and Rabanal (2014), which examined the optimal mix of monetary and macroprudential policies in an estimated model of the euro area. There are three additional issues that can most obviously be addressed within the context of their DSGE model. Firstly, although their optimal policies, as evaluated via optimal simple rules, relative to the estimated simple rules show consumption equivalent welfare benefits or losses of the order of 0.6-0.7%, these are evaluated without consideration as to how frequently the zero lower bound (ZLB) for the nominal interest rate is violated. Here we correct for this by penalising deviations from the steady state of the nominal interest rate such that the likelihood of violating the ZLB occurs once every 400 quarters. Secondly, we evaluate whether there is any benefit from using optimal simple rules that include deviations of output from steady state - commonly viewed as countercyclical policy as advocated by by Goodhart; this can be viewed as a feedback that is additional to the standard feedback on either credit growth or on credit/GDP ratios. Finally we also examine the impact of reserve ratios for the financial intermediaries in the model. Quint and Rabanal (2014) assume that the lending-to-deposit ratio is 1 in steady state; although the model is not ideal for examining changes in this ratio, by allowing for the possibility that borrowers in the model have a discount factor that is lower than that assumed by Quint and Rabanal (2014) we are able to evaluate the costs and benefits of banks having a certain required reserve ratio.

The main reasons for focusing so closely on the paper by Quint and Rabanal (2014) is precisely for the reasons documented by Loisel (2014) in his comments on their work, namely that it incorporates European monetary union, it is (mainly) an estimated model, it incorporates a financial accelerator rather than collateral constraints as its financial friction, and that optimal simple rules are designed via maximization of the same welfare function as the one on which the model is based. The main change that we make from their analysis is that we begin with a nonlinear version of their model, and choose optimal policies on the basis of a linear quadratic approximation about the deterministic optimum. These policies are then evaluated through the welfare effects on a second-order approximation to the nonlinear model.

Section 2 provides a brief description of the model, and focuses on how the model with given parameters is not terribly suitable to analyse the effect of reserve ratios, although it is suitable for evaluating loan-to-deposit ratios greater than 1. This latter was suggested by Loisel (2014) as a policy that effectively subsidizes lending by financial intermediaries; however this issue is not tackled in this paper. Section 3 points out the ZLB violations that need to be tackled when designing optimal rules, and also evaluates the gains and losses from including an output term rather than just a credit term in the macroprudential rule. Section 4 then addresses how the model can be used in the case when there are capital constraints and the loan-to-deposit ratio is less than 1. Because of the nature of the model, the interest rate paid by borrowers will be larger than than the discount rate in their utility function, so there is clearly a limit to how large this can be in order to remotely match the data, and this therefore places a constraint on the loan-to-deposit ratio, as we shall see below. Nevertheless a reasonable change in this discount rate is sufficient to generate consumption-equivalent welfare losses that are of the order of those generated by the optimal policies evaluated by Quint and Rabanal (2014).

2 Description of the Model and Steady State Financial Friction Effects

There are two blocs in the economy; we shall only summarise the model for the the 'home' bloc H, and not for the 'foreign' bloc F.

2.1 Households

Households in H are either patient and impatient, with discount factors of β and β^b respectively, where $\beta > \beta^b$. The patient households are savers, while the impatient households are borrowers. Their respective proportions in the population are λ and $1-\lambda$. Saver j maximizes the expected utility function with external habit:

$$E_0 \sum_{t=0}^{\infty} \left[\gamma \xi_t^C log(C_t^j - \epsilon C_{t-1}) + (1-\gamma)\xi_t^D log(D_t^j) - \frac{(L_t^j)^{1+\varphi}}{1+\varphi} \right] \tag{1}$$

where C_t^j is the consumption of non-durable goods, D_t^j the consumption of the stock of housing goods and L_t^j is labour, and ξ_t^C, ξ_t^D are preference shocks. Borrowers have an analogous utility function, with utility dependent on $C_t^{B,j}, D_t^{B,j}, L_t^{B,j}$, and with habit parameter ϵ^B.

Non-durable consumption for savers is an index of home $C_{H,t}^j$ and foreign goods $C_{F,t}^j$ which satisfy

$$(C_t^j)^{1-\frac{1}{\iota^C}} = \frac{1}{\tau^{\iota^C}}(C_{H,t}^j)^{1-\frac{1}{\iota^C}} + \frac{1}{(1-\tau)^{\iota^C}}(C_{F,t}^j)^{1-\frac{1}{\iota^C}} \tag{2}$$

where τ is a measure of home bias. This leads to an overall price index for non-durables P_t^C given by

$$(P_t^C)^{1-\iota_C} = \tau(P_t^H)^{1-\iota_C} + (1-\tau)(P_t^F)^{1-\iota_C} \tag{3}$$

where P_t^H, P_t^F are the price indices of home and foreign produced non-durables, assuming that consumers maximize subject to their budget constraints.

At the household level there is imperfect substitutability between labour supply $L_t^{C,j}$, $L_t^{D,j}$ to the non-durable and non-durable sectors respectively which is represented by the preferences

$$(L_t^j)^{1+\iota_L} = \alpha^{-\iota_L}(L_t^{C,j})^{1+\iota_L} + (1-\alpha)^{-\iota_L}(L_t^{D,j})^{1+\iota_L} \tag{4}$$

For borrowers there are analogous representations of labour supply and non-durable consumption that incorporate the letter B.

The budget constraint of savers in real terms, relative to the price of non-durable goods P_t^C, is given by

$$C_t^j + Q_t I_t^j + S_t^j = \frac{R_{t-1}}{\Pi_t^C} S_{t-1}^j + W_t^C L_t^{C,j} + W_t^D L_t^{D,j} + \Pi_t^j \tag{5}$$

where $Q_t = P_t^C/P_t^D$ is the relative price of durable to non-durable goods, I_t^j is residential investment, S_t^j is real savings, R_t is the gross nominal interest rate, Π_t^C is the inflation rate of non-durable goods, W_t^C, W_t^D are real wages in each sector and Π_t^j is profits. The latter is from intermediate goods producers in both sectors, from domestic and international banks and from the debt collection agencies who intervene for the banks to collect debt from defaulting borrowers.

The budget constraint for borrowers will be described after discussion of the role of the banking sector in the model.

Residential investment I_t^j by savers is used to increase the housing stock:

$$D_t^j = (1-\delta)D_{t-1}^j + (1 - F\left(\frac{I_{t-1}^j}{I_{t-1}^j}\right))I_{t-1}^j \tag{6}$$

where δ is the depreciation rate and F is an adjustment cost given by $F(x) = \frac{\psi}{2}(x-1)^2$.

2.2 Firms

Homogeneous final durable and non-durable goods are produced using a continuum of intermediate goods, indexed by $h \in [0, n]$, $(n < 1)$, in the home bloc, and $h \in (n, 1]$ in the foreign bloc. These intermediate goods are imperfect substitutes and are not traded across blocs.

2.2.1 Final Goods Producers

Final non-durable goods are traded across blocs, but durables are not, and are only used to increase the housing stock. Final goods sectors are perfectly competitive with flexible prices.

Final goods aggregate the intermediate goods according to

$$(Y_t^k)^{1-\frac{1}{\sigma}} = n^{\frac{-1}{\sigma}} \int_0^n Y_t^k(h)^{1-\frac{1}{\sigma}} dh, \quad k = \{C, D\} \tag{7}$$

where σ is the price elasticity. Profit maximization leads to

$$Y_t^C(h) = \left(\frac{P_t^H(h)}{P_t^H}\right)^{-\sigma} Y_t^C \qquad Y_t^D(h) = \left(\frac{P_t^D(h)}{P_t^D}\right)^{-\sigma} Y_t^D \tag{8}$$

where the price indices for home-produced non-durables and durables are given by

$$(P_t^k)^{1-\sigma} = \frac{1}{n}\int_0^n P_t^k(h)^{1-\sigma} dh \qquad k = \{H, D\} \tag{9}$$

2.2.2 Intermediate Goods Producers

Intermediate goods are produced monopolistic competition using labour only:

$$Y_t^C(h) = A_t Z_t^C L_t^C(h) \qquad Y_t^D(h) = A_t Z_t^D L_t^D(h) \tag{10}$$

where the shock A_t is common to both sectors, but there are also sector-specific shocks Z_t^C and Z_t^D. With all these shocks assumed to have an average value of 1, this means that the real wages W_t^C, W_t^D in equilibrium are the same in each sector.

Real marginal cost in each sector is then given by

$$MC_t^C = \frac{W_t^C}{A_t Z_t^C} \frac{P_t^C}{P_t^H} \qquad MC_t^D = \frac{W_t^D}{Q_t A_t Z_t^D} \tag{11}$$

The producers then solve a standard Calvo profit-maximization problem with price indexation that yields the following:

$$J_t^C - \beta\theta^C E_t \left[\left(\frac{\Pi_{H,t+1}}{\Pi_{H,t}^{\phi^C}} \right)^{\sigma} J_{t+1}^C \right] = \frac{MC_t^C Y_t^C}{C_t - \epsilon C_{t-1}} \tag{12}$$

$$H_t^C - \beta\theta^C E_t \left[\left(\frac{\Pi_{H,t+1}}{\Pi_{H,t}^{\phi^C}} \right)^{\sigma-1} H_{t+1}^C \right] = \left(1 - \frac{1}{\sigma}\right) \frac{Y_t^C}{C_t - \epsilon C_{t-1}} \tag{13}$$

$$1 = (1-\theta^C)(J_t^C/H_t^C)^{1-\sigma} + \theta^C(\Pi_{H,t}/\Pi_{H,t-1}^{\phi^C})^{\sigma-1} \tag{14}$$

There are a similar set of equations for durable goods with parameters θ^D, ϕ^D.

2.3 Market Clearing

In the non-durable sector, total supply of goods is equal to the total demand by borrowers and savers in each bloc, taking into account the share of population $(n, 1-n)$ in each bloc and the proportions of savers and borrowers in each bloc $(\lambda, 1-\lambda, \lambda^*, 1-\lambda^*)$. Thus

$$nY_t^C = n(\lambda C_{H,t} + (1-\lambda)C_{H,t}^B) + (1-n)(\lambda^* C_{H,t}^* + (1-\lambda)C_{H,t}^{B*}) \tag{15}$$

For residential investment we have

$$nY_t^D = n(\lambda I_t + (1-\lambda)I_t^B) \tag{16}$$

The evolution of the home bloc's net foreign assets expressed in real terms relative to its non-durable price index is given by

$$n\lambda B_t = n\lambda \frac{R_{t-1}}{\Pi_t^C} B_t + (1-n)\frac{P_{H,t}}{P_t^C}(\lambda^* C_{H,t}^* + (1-\lambda^*)C_{H,t}^{B*}) - n\frac{P_{F,t}}{P_t^C}(\lambda C_{F,t} + (1-\lambda)C_{F,t}^B) \quad (17)$$

The model is closed by assuming the following relationship between home and foreign interest rates, that allows for a risk premium from net foreign assets:

$$log(R_t^*/R_t) = \Theta_t + \kappa^b B_t/Y_t^C \quad (18)$$

where Θ_t is a mean-zero shock. Home GDP is given by $Y_t = Y_t^C + Q_t Y_t^D$, with euro-area GDP and CPI given by

$$Y_t^{EMU} = (Y_t)^n (Y_t^*)^{1-n} \qquad P_t^{EMU} = (P_t^C)^n (P_t^{C*})^{1-n} \quad (19)$$

In addition the interest rate for the home bloc is assumed to be set by the ECB, and is a Taylor rule dependent on euro-area inflation and euro-area output.

2.4 Financial Intermediaries

The model for credit markets of Quint and Rabanal (2014) is virtually identical to that of Zhang (2009), Suh (2012) and Darracq-Paries et al (2011). It allows for default risk in the mortgage market, with borrowers defaulting if the value of their debt is higher than the value of their house. Such default leads of course to an interest spread between borrowers and depositors. The setup is very similar to that of Bernanke et al (1999), but without the agency and asymmetric information aspects.

Financial intermediaries pay depositors a gross interest rate R_t, and extend loans to borrowers at a gross rate R_t^L. Credit is granted backed by the value of the housing stock, and each borrower is subject to an idiosyncratic quality shock to the value of the house ω_t^j. This latter is log-normally distributed, with mean equal to 1, which means that the shock is distributed as $log(\omega_t^j) \sim N(-\frac{1}{2}\sigma_{\omega,t}^2, \sigma_{\omega,t}^2)$. This allows for $\sigma_{\omega,t}^2$ to vary over time, with $log(\sigma_{\omega,t}/\sigma_\omega)$ following an AR(1) process.

Borrowers with high ω_t^j can repay their loans, but values that are 'too' low cause loans to default. If default occurs, banks call in debt-collection agencies which return a proportion $(1-\mu)$ of the realized value of borrower j's housing stock. The agencies retain a proportion μ which is redistributed as profits to the patient consumers.

The ex ante threshold value $\bar{\omega}_t^a$ (to be determined within the context of the model) of default will correspond to that value of ω_t^j where the expected value of the housing stock exactly matches the gross interest payment on the loan. Recalling that D_t^B is the real value of the housing stock, writing S_t^B as the real value of the loan relative to non-durable good price P_t^C, it follows that

$$\bar{\omega}_t^a E_t[Q_{t+1}\Pi_{t+1}^C D_{t+1}^B] = R_t^L S_t^B \tag{20}$$

For borrowers, the ex post threshold value $\bar{\omega}_{t-1}^p$ for which a borrower can just repay the loan is

$$\bar{\omega}_{t-1}^p Q_t D_t^B \Pi_t^C = R_{t-1}^L S_{t-1}^B \tag{21}$$

This means that the budget constraint for borrowers (who receive no income from profits) is different for those hit by a shock above this threshold value, who pay a gross real return to the banks of $R_{t-1}^L S_{t-1}^B/\Pi_t^C$, and those hit by a shock below this threshold, who pay $\omega_{t-1}^j Q_t D_{t-1}^B$. Summing the probability distribution across all these borrowers leads to an aggregate budget identity:

$$\begin{aligned} &C_t^B + Q_t\left[I_t^B + \Phi\left(\frac{log\bar{\omega}_{t-1}^p}{\sigma_{\omega,t-1}} - \frac{\sigma_{\omega,t-1}}{2}\right)D_t^B\right] + \Phi\left(\frac{-log\bar{\omega}_{t-1}^p}{\sigma_{\omega,t-1}} - \frac{\sigma_{\omega,t-1}}{2}\right)R_{t-1}^L S_{t-1}^B \\ &= S_t^B + W_t^C L_t^{C,B} + W_t^D L_t^{D,B} \end{aligned} \tag{22}$$

As Quint and Rabanal (2014) point out, the relevant average interest paid out on the loan S_{t-1}^B should then be expressed as $R_t^D + \Phi\left(\frac{-log\bar{\omega}_{t-1}^p}{\sigma_{\omega,t-1}} - \frac{\sigma_{\omega,t-1}}{2}\right)R_{t-1}^L$ where $R_t^D = Q_t\Phi\left(\frac{log\bar{\omega}_{t-1}^p}{\sigma_{\omega,t-1}} - \frac{\sigma_{\omega,t-1}}{2}\right)D_t^B/S_{t-1}^B$.

The balance sheet of financial intermediaries involves savings S_t by patient consumers, which represents liabilities, net claims on financial intermediaries in the foreign country B_t, loans to impatient consumers S_t^B; in addition there may be reserves and equity. However, we ignore equity, although we shall briefly discuss this below.

Assuming banks are risk-neutral, they require the expected return from credit to be equal to the deposit rate. The expected return depends on the return from the non-defaulters which is fixed at R_t^L and on the expected return from the defaulters which depends on the distribution of ω_t^j below the threshold value $\bar{\omega}_t^a$. Thus, taking into account the properties of the log normal distribution, one can show that this participation constraint is given by

$$n\lambda R_t(S_t - B_t) = n(1-\lambda)E_t[(1-\mu)\Phi(\frac{log\bar{\omega}_t^a}{\sigma_{\omega,t}} - \frac{\sigma_{\omega,t}}{2})Q_{t+1}\Pi_{t+1}^C D_{t+1}^B + \Phi(-\frac{log\bar{\omega}_t^a}{\sigma_{\omega,t}} - \frac{\sigma_{\omega,t}}{2})R_t^L S_t^B] \tag{23}$$

where $\Phi()$ is the cumulative normal distribution.

The macroprudential instrument η_t affects the fraction of liabilities that the bank can lend:

$$n\lambda\frac{1}{\eta_t}(S_t - B_t) = n(1-\lambda)S_t^B \tag{24}$$

2.5 The Steady State

In Appendix A, we outline a minor difference between the calculation of the steady state compared with Quint and Rabanal (2014). In their paper they set the preference parameter γ in the utility function such that the fraction of non-durable to total production is equal to α, one of the preference parameters used for aggregating labour. This is associated with a relative price $Q_t = 1$ of investment to consumption goods. Because we address the possibility that the steady state value of the macroprudential instrument η_t might not be set to 1, $Q_t = 1$ will not necessarily hold in steady state.

2.5.1 Steady State Financial Friction Effects

Given the discount factors β, β^b for savers and borrowers, in steady state each of these will be equated to the inverse of the interest rates faced these two groups of consumers via the steady state of the relevant Euler equations.

In equilibrium, by setting $(1-\tau^*)(1-n) = (1-\tau)n$, the steady state of net foreign assets B_t is 0, so that per capita output and consumption is the same in each bloc. It is then straightforward to obtain the steady state of the the threshold value $\bar{\omega}$ as being satisfied by

$$\frac{\frac{\eta\beta^b}{\beta}-1+\mu}{\bar{\omega}}\Phi\left(\frac{log\bar{\omega}}{\sigma_\omega}-\frac{\sigma_\omega}{2}\right)=(1-\frac{\eta\beta^b}{\beta})\Phi\left(-\frac{log\bar{\omega}}{\sigma_\omega}-\frac{\sigma_\omega}{2}\right) \tag{25}$$

As is well known for financial accelerator models of this sort, a value of $\mu > 0$ is a necessary condition for a solution to the threshold value; otherwise one side of this equation will be positive, and the other negative. As regards the impact of the macroprudential variable, Quint and Rabanal assume throughout that the steady state value of η is 1, implying that on average the loan to deposit ratio is equal to 1. However there is of course no reason for this to be the case. Consider initially the simplest bank balance sheet representation: deposits + equity = loans + reserves, where the LHS represents liabilities and the RHS represents assets. In the absence of equity, loans will be less than or equal to reserves, which corresponds to the case $\eta \geq 1$. Loisel (2014) suggests that it is feasible for $\eta \leq 1$, implying a subsidy for banks, presumably by government taking an equity stake in banks but requiring either no return or a return less than that provided to depositors. Whereas this may be feasible in the short term, it seems unlikely as a long term solution.

A quick glance at (25) indicates that reasonable assumptions about β and β^b will be inconsistent with typical capital or reserve requirements for financial intermediaries of the order of 8%. The model requires $(1-\frac{\eta\beta^b}{\beta})$ to be positive, so that the assumptions of Quint and Rabanal (2014) of $\beta = 0.99$ and $\beta^b = 0.985$ will only permit values of $\eta < 1.005$. Below however, we shall investigate values of $\beta = 0.99$ and $\beta^b = 0.96$ for which $\eta = 1.02$ provides a reasonable comparison with $\eta = 1$. Since $\beta^b = 0.96$ implies that the lending rate is over 4% per quarter, this value is at the outer limits of borrowing rates, given that credit card borrowing rates are of the order of 18% per annum.

3 Impact of the Zero Lower Bound for Interest Rates

Quint and Rabanal (2014) estimate some of the parameters of the model above, and also include estimates of a Taylor Rule

$$log(R_t/\bar{R})=\gamma_r log(R_{t-1}/\bar{R})+(1-\gamma_r)[\gamma_\pi log(\Pi_t^{EMU}/\bar{\Pi}^{EMU})+\gamma_y log(Y_t^{EMU}/Y_{t-1}^{EMU})] \tag{26}$$

as well as macroprudential rules for each bloc:

$$log(\eta_t/\bar{\eta}) = \gamma_{\eta,sb} log(\Upsilon_t) \qquad log(\eta_t^*/\bar{\eta}) = \gamma_{\eta,sb}^* log(\Upsilon_t^*) \tag{27}$$

where Υ_t is either the ratio of credit to GDP (relative to its steady state value) or else the growth of credit. The authors evaluate the welfare gains from optimized values of these parameters, and find that for credit/GDP there are benefits to savers and losses for borrowers in the two blocs, with an average benefit of 0.12% in consumption equivalent terms for feedback on credit growth all consumers benefit, with an average benefit of 0.06% consumption equivalent.

However in both of these cases the standard error of the nominal interest rate, which is not reported in the paper, is around 6% for each quarter. Since the steady state value of the nominal interest rate is 1.01% per quarter, this implies continual violations of the zero lower bound on interest rates.

Levine et al (2008) have shown how to get round the zero lower bound problem without requiring occasionally binding constraint software. The simplest solution is to add a penalty $-w_r((R_t - \bar{R})^2 + (R_t^* - \bar{R})^2)$ to the utility function, and to increase the value of w_r until the standard errors of the interest rates are sufficiently small. Here we have selected standard errors of 0.36% which implies a violation of the ZLB once every 400 quarters on average, assuming that interest rates are approximately normally distributed.

In Table 1 we give the values of the optimizing coefficients in two cases; in each case we allow for smoothing (with coefficients $\gamma_\eta, \gamma_\eta^*$) of the instruments η_t, η_t^* via feedback on their lagged values, and feedback on credit growth. We also allow in the second case for the instruments to feed back on output growth (with coefficients $\gamma_{\eta,y}, \gamma_{\eta,y}^*$); this has come to be associated with Goodhart's recommendations that macroprudential rules should respond to the business cycle, and we compare the consumption equivalent benefits across these two regimes.

The foreign (*) bloc represents the periphery countries Greece, Ireland, Italy, Portugal and Spain, so it is not so surprising that policy for that bloc should be somewhat more active. However the expected loss to lenders compared with the gain for borrowers is likely to ensure that the response to output growth is so large as not to be pursued.

Rule	$\gamma_r, \gamma_\pi, \gamma_y$	$\gamma_\eta, \gamma_{\eta,sb}, \gamma_{\eta,y}$	$\gamma^*_\eta, \gamma^*_{\eta,sb}, \gamma^*_{\eta,y}$	W^S	W^B	W^{S*}	W^{B*}
Simple	0.9,1.014,0.097	0.99, 0.43, 0	0.99,0.43,0	-	-	-	-
Simple with ΔY	0.9,1.014,0.097	0.99, 0.446,0	0.99,1,0.203	-0.02%	0.04%	-0.68%	1.06%

Table 1: **Optimized Simple Rules, with and without response to output growth.** Final columns compare the benefits for savers S and borrowers B in each bloc.

4 The Impact of Reserve Requirements

As observed earlier, the model that we are handling is too basic to allow for reserve requirements (or provisioning or capital ratios) as high as 8%. In order to get a handle on the importance of this, even at levels as low as 2%, we modify the model with regard to two parameters only, namely the steady state level σ_ω, which characterizes the distribution of the idiosyncratic quality shock to housing, and the discount rate of borrowers β^b.

As regards the two discount factors, whereas Quint and Rabanal assume discount factors of 0.99 and 0.985, Angelini and Gerali (2012) assume 0.996 and 0.975, Beau et al (2012) assume 0.994 and 0.975, and Iacoviello (2013) assumes 0.9925 and 0.94. For this section we assume 0.99 and 0.96, and change the value of σ_ω from 0.1742 to 0.05. This enables us to use a steady state value of $\eta = 1.02$ to compare with $\eta = 1$.

The main deterministic characteristics of this comparison are the values of the long term interest rates, the threshold value $\bar{\omega}$, the total credit S^B, and how these affect the consumption equivalent gains or losses of patient and impatient consumers. In Table 2, we show how these vary. Firstly, we see that with the proportion of loans coming down as η increases, the total credit decreases, which lowers the risk of default, so that the interest rate spread decreases; as a consequence the threshold value for non-performing loans comes down as well. The lowered interest rates paid by borrowers therefore increase their utility. However total savings by patient consumers are lower, which can be seen by comparing savings per borrower when $\eta = 1$, equal to $3.475\frac{1-\lambda}{\lambda}$ compared with $\eta = 1.02$ when they are $3.389 \times 1.02\frac{1-\lambda}{\lambda} = 3.457\frac{1-\lambda}{\lambda}$. This lowers consumption, so that savers are worse off.

We also examine the effects of optimal simple rules in each of these cases, and these appear in Table 3. As can be seen from this table, the main effect is to welfare in the

η	R^L	$\bar{\omega}$	S^B	W^S and W^{S*}	W^B and W^{B*}
1	1.046	0.949	3.475	-	-
1.02	1.043	0.922	3.389	-0.25%	0.42%

Table 2: **Effect of Loan to Deposit Ratio Less than 1.** Final columns compare the benefits for savers S and borrowers B.

η	$\gamma_r, \gamma_\pi, \gamma_y$	$\gamma_\eta, \gamma_{\eta,sb}$	$\gamma^*_\eta, \gamma^*_{\eta,sb}$	W^S	W^B	W^{S*}	W^{B*}
1	0.9,1.014,0.097	0.99, 0.55	0.99,0.99	-	-	-	-
1.02	0.9,1.014,0.097	0.99, 1	0.99,0.99	-0.27%	0.47%	0%	0%

Table 3: **Optimized Simple Rules, without response to output growth.** Final columns compare the benefits for savers S and borrowers B in each bloc.

home bloc.

5 Conclusions

The contribution of this paper has been to assess the importance of additional cyclical features in the macroprudential rule, and to assess the effect of reserve requirements and/or provisioning and/or capital requirements, with the latter being indistinguishable within the model of the paper. In addition we have investigated rules that satisfy the ZLB constraint for nominal interest rates at virtually every period.

The results have shown that macroprudential rules that respond to growth rates of output have potentially significant effects. The reason for this is that in a recession, when credit growth has become negative, the rule will try and compensate for this; however, any subsequent small positive growth in credit will then immediately dampen this effect, so a further reaction to negative output growth is needed in order to stimulate the economy further by additional credit.

We have also demonstrated that there are gains and losses to each of borrowers and savers respectively when reserve requirements are increased, which means that it is a political decision as to the exact level which can be regarded as optimal. However, coupled with this, one needs to take account of financial stability; our analysis has only examined the ZLB for interest rates, so further account must be taken of the volatility of reserves as measured by the macroprudential variables η_t.

Finally, when one accounts for the ZLB on the interest rate, it is clear that both interest rate rules and the macroprudential rules are very different from those obtained by Quint and Rabanal (2014).

As regards further work, although the model is a general equilibrium one with sticky prices, it needs further refinement in order to introduce the levels of reserves and capital requirements that are currently under discussion by regulators. In addition, this paper has not studied the gains from coordination, which were not found to be of importance in the initial working paper of Quint and Rabanal. Clearly the effects of the ZLB may play a role here, so this needs further investigation.

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Appendix

A Additional Steady State Equations

The equations below for Q and L are required in addition to the steady state equations derived by Quint and Rabanal (2014) when the parameters are such that Q is not equal to 1:

$$\gamma\left(1-\frac{1}{\sigma}\right)\left(\frac{\lambda}{1-\epsilon}+\frac{1-\lambda}{1-\epsilon^b}(L/L^B)^{\varphi}\right)\left(\alpha+(1-\alpha)Q^{1+\frac{1}{\iota_L}}\right)=\alpha L^{\varphi}((1-\lambda)L^B+\lambda L) \tag{A.1}$$

$$\left(1-\alpha+\alpha Q^{-1-\frac{1}{\iota_L}}\right)\gamma\delta\left(1-\frac{1}{\sigma}\right)\left(\frac{\lambda}{(1-\epsilon)\Gamma}+\frac{1-\lambda}{(1-\epsilon^b)\Gamma^b}(L/L^B)^{\varphi}\right)=(1-\alpha)L^{\varphi}((1-\lambda)L^B+\lambda L) \tag{A.2}$$

where

$$\Gamma=\frac{\gamma(1-\beta(1-\delta))}{\beta(1-\gamma)(1-\epsilon)} \qquad \Gamma^B=\frac{\gamma(1-\beta^B(1-\delta))}{\beta^B(1-\gamma)(1-\epsilon^B)} \tag{A.3}$$

Note that these two equations are not analytically equivalent to one another when $Q=1$. However Quint and Rabanal (2014) calibrate the value of γ in such a way that these are consistent with one another numerically when $Q=1$.