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Macro Effects of Capital Requirements and Macroprudential Policy

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Macro effects of capital requirements and macroprudential policy

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Abstract

I investigate macro effects of higher bank capital requirements on the Norwegian economy and their use as a macroprudential policy instrument under Basel III. To this end, I develop a macroeconometric model where the capital adequacy ratio, lending rates, asset prices and credit interact with each other and with the real economy. The empirical results suggest that changes in capital requirements are primarily transmitted via lending rates to the other variables in the model. The proposed increases in capital requirements under Basel III are found to have significant effects especially on house prices and credit. I also derive optimal paths for the countercyclical capital buffer in response to various shocks. The buffer is found to equal its imposed ceiling of 2.5% in response to most of the shocks considered while its duration varies in the range of 1–12 quarters depending on the shock and its persistence.

Keywords: Basel III; capital requirements; macroprudential policy.

JEL Codes: *C52, C53, E52, G38.*

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1 Introduction

I investigate macroeconomic effects of higher capital requirements on the Norwegian economy and their use as a macroprudential policy instrument. Macroprudential policy aims at financial stability partly by e.g. managing growth in asset prices and credit. Excess growth in these variables over extended periods may be seen as a necessary condition for financial instability (see e.g. Borio and Lowe (2002), Reinhart and Rogoff (2009) and Schularick and Taylor (2012)). A number of studies have argued for time-varying capital requirements to avoid destabilizing credit growth (see e.g. Bank of England (2009) and Brunnermeier et al. (2011)). I investigate in particular possible effects of the capital requirements recently proposed by the Basel Committee on Banking Supervision (BCBS), which are referred to as Basel III (see BCBS (2010a)). The new regulatory framework proposes a permanent increase in the common equity ratio by 2.5 percentage points (conservation buffer) and a systemic-risk dependent variation in the common equity ratio in the range of 0–2.5 percentage points (countercyclical buffer).[1] Furthermore, I shed light on the implementation of the countercyclical capital buffer in response to various shocks with different persistence.

I employ a quarterly macroeconometric model of the Norwegian (mainland) economy to conduct the analyses. The model includes empirical relationships between several real and financial variables, including those between house prices and credit to households, and between banks' capital adequacy ratio and lending rates. The latter relationship is among the novel features of this model, as an explicit account of capital requirements in macroeconometric models is rare (see BCBS (2010b), Angelini et al. (2011) and the references therein). To my knowledge, this is the first

[1] Basel III also entails more stringent requirements for the level of and the quality of bank's core capital. It also proposes restrictions on the maturity structure of banks' assets and liabilities to ensure sufficient liquidity and hedge against particularly large withdrawals of liabilities. These restrictions are formulated as two quantitative liquidity requirements: a liquidity coverage ratio (LCR) and a net stable funding ratio ($NSFR$). The liquidity coverage ratio concerns the required level of liquid assets a bank must have in order to be able to withstand periods of downturn in the markets for funding while the net stable funding ratio concerns the composition of sources of funding or the stability of the funding. These restrictions may have additional effects on banks' funding costs and thereby lending rates which are not accounted for in the following analyses. The Basel III is expected to be be phased in gradually over the period 2013–2019, see www.bis.org/bcbs/basel3.htm for more details.

such model based on Norwegian data. The model employed is essentially a smaller version of a model maintained by Norges Bank which has been further developed, updated and adapted to conduct the analyses of interest to this paper.[2]

The literature on the design and effectiveness of macroprudential policy tools as well as the development of appropriate models for their investigation is still in its infancy. In general, there is a lack of theoretically well-founded models for policy analyses that account for key relationships between the financial economy and the real economy in a satisfactory way (see e.g. Tovar (2008) and Galati and Moessner (2011) and the references therein). Obtaining precise estimates of how the economy would have performed or how it will perform under alternative capital requirements is inherently difficult. It is not possible to say whether and to what extent the model's parameters will shift with new policy changes. However, I proceed under the assumption that the macroeconomic effects of changes in capital requirements will be comparable to those observed historically.

In the analysis of the countercyclical capital buffer as a macroprudential policy tool, the policymaker is assumed to minimize excess fluctuations in aggregate credit growth while taking into account the effects of policy decisions on economic activity (cf. Haldane (2012)). I use aggregate credit growth as an indicator of systemic risk, for the sake of simplicity and because growth rates of credit and GDP are relatively more robust to data revisions than their levels (see e.g. Orphanides and Norden (2002)and Edge and Meisenzahl (2011)). In response to a given shock, the policymaker is assumed to minimize the loss function by deciding on a future path for the countercyclical capital buffer. The path is defined by the size and duration of the countercyclical capital buffer. I derive such paths in response to various shocks for different degrees of persistence. I also investigate the sensitivity of such paths to the strength of the policymaker's concern for fluctuations in economic activity, and alternatively for fluctuations in the inflation rate.

The paper is organized as follows. Section 2 presents the empirical framework, while Section 3 employs the model to investigate the effects of increases in capital

[2]The model at use in Norges Bank is documented in Hammersland and Træe (2012). It is mainly based on Bårdsen et al. (2003) and Bårdsen et al. (2005).

requirements on the Norwegian economy. In Section 4, capital requirements are used as a macroprudential policy tool within the Basel III framework in response to various shocks. Section 5 contains the main conclusions. Finally, the appendix contains data definitions, model documentation and sensitivity analyses.

2 The empirical framework

I first develop a system of dynamic equations for the capital adequacy ratio, lending rates, house prices, credit to households and credit to (non-financial) firms to investigate their interaction with one another.[3] This equation system is then integrated into a macroeconometric model briefly presented in Section 2.4. This model contains dynamic equations for a number of other financial and real economic variables including short-term interest rates, equity returns, the nominal effective exchange rate, inflation and output. It was not feasible to develop a closed system of dynamic equations for a relatively large number of variables of interest to investigate how changes in capital requirements are transmitted to the economy. The macroeconometric model is therefore composed of a few small equation systems as well as single equation models, while conditioning on variables such as oil prices, foreign interest rates and foreign GDP.

2.1 Capital ratio, lending rates, house prices and credit

The system of dynamic econometric equations for the capital adequacy ratio, lending rates, house prices, credit to households and credit to firms has been derived in two steps. In the first step, long-run relationships between a given set of variables in levels were established by testing for cointegration between the variables. The variables in levels were found to be unit-root non-stationary. Upon finding evidence of cointegrating relationships between the variables, a Vector Equilibrium Correction Model (VECM) was formulated, estimated by FIML, tested and, if required, respecified

[3]Capital adequacy ratio is defined as the sum of common equity, hybrid equity and additional equity (Tier 2), divided by risk weighted assets. I also made an attempt to develop econometric models of the main subcomponents of the capital adequacy ratio but without much success.

to satisfy a number of statistical model diagnostic tests (cf. Hendry (1995)). The model has been estimated on quarterly data for the Norwegian (mainland) economy over the period 1992Q2–2010Q4.

In the following, I first present the estimated long-run relationships and then the VECM in Table 1. Unless stated otherwise, variable names in small letters denote the natural log of the corresponding variables, while Greek letters without subscript t represent parameter values. Δ and Δ_4 denote first- and fourth-difference operators, respectively.

2.2 Long-run relationships

The quarterly time series of the capital adequacy ratio (CAR) suggests that it fluctuates around a fairly stable value over the sample period 1992Q4–2010Q4; ADF tests reject the null hypothesis of a unit root in CAR. That is,

$$\begin{aligned} CAR_t &= \alpha_1 + \varepsilon_{1,t}, \\ &= \kappa + \mu + \varepsilon_{1,t}, \end{aligned} \tag{1}$$

where $\varepsilon_{1,t}$ represents a zero mean stationary process.

I estimate the stable value of CAR, α_1, which can be interpreted as it equilibrium value, by its sample average, 12.5% (see Equation (1)). The equilibrium value of CAR may be decomposed into the minimum common equity ratio required by Basel regulations (κ) and the equilibrium value of other capital components (μ), including hybrid capital, Tier 2 capital and additional capital held by banks beyond that required by capital adequacy rules. Banks may choose to hold capital in addition to that required by regulations as a hedge against credit and liquidity risk (see Booth et al. (2001), Peura and Keppo (2006) and Flannery and Rangan (2006)).

When modeling lending rates (i^L), I assume they reflect funding costs of banks in the long run which depend on (short-term) money market rates (i) and costs of equity. The latter costs are assumed to depend on banks' return on equity and

other possible costs of equity associated with e.g. issuing equity, monitoring and asymmetric information (see e.g. Jensen (1986), Kashyap et al. (2008), Holmstrom and Tirole (1997), Repullo and Suarez (2000) and Bolton and Freixas (2006)). The following long-run relationship for lending rates may be specified:

$$i_t^L = (1 - CAR_t)i_t + CAR_t(\Delta_4 be) + \gamma_1 CAR_t + \alpha + \varepsilon_{2,t}. \tag{2}$$

This equation expresses that lending rates (per annum) reflect a weighted average of money market rates (i) and return on bank equity ($\Delta_4 be$). The weights depend on the capital adequacy ratio, which is also used to represent other possible costs of equity. α and $\varepsilon_{2,t}$ denote an intercept term and a stochastic error term, respectively.

However, access to quarterly data on return on bank equity is limited in Norway, as only a few Norwegian banks are listed on the stock exchange. I therefore assume that excess return on bank equity ($\Delta_4 be - i$) is proportional to excess return on the overall Oslo Stock Exchange ($\Delta_4 ose - i$), consistent with the capital asset pricing model (CAPM). Accordingly, the long-run relationship for lending rates can be expressed as a function of the return on the overall Oslo Stock Exchange ($\Delta_4 ose$):

$$\begin{aligned} i_t^L &= (1 - CAR_t)i_t + CAR_t(i_t + \beta(\Delta_4 ose_t - i_t)) + \gamma CAR_t + \alpha + \varepsilon_{3,t}, \\ &= i_t + \beta CAR_t(\Delta_4 ose_t - i_t) + \gamma CAR_t + \alpha + \varepsilon_{3,t}. \end{aligned} \tag{3}$$

I estimate the value of β to be 0.10 and that of γ to be 0.14 (see Table 1).

For the sake of simplicity, I assume β to be invariant to changes in the capital adequacy ratio, in contrast with reasoning based on the Modigliani-Miller theorem, which implies a negative relationship between β and capital adequacy ratio. The evidence of such a negative relationship is inconclusive, in general. A few recent studies suggesting a negative relationship include Miles et al. (2011) and Hanson et al. (2011). Accordingly, the effects of changes in capital requirements on lending

rates and other variables may be smaller than those presented in this study.

The empirical analysis suggests that credit to firms in real terms ($crf - p$) depends on real GDP (y) and real lending rates ($i^L - \Delta_4 p$) in the long run:

$$\widehat{crf - p} = 2.16y - 4.67(i^L - \Delta_4 p). \tag{4}$$

Here, the income elasticity of real credit to firms is greater than one and suggests that the ratio between real credit to firms and income ($crf - p - y$) increases with real GDP and falls with real interest rates. The long-run relationship may be interpreted as a combination of two stationary terms. The relationship between the non-stationary variables real credit to firms and GDP is assumed to be stationary through cointegration, while real lending rates are assumed to be stationary by themselves.

Credit to households in real terms ($crh - p$) has been found to depend on real GDP and real house prices ($ph - p$) in the long run (see Equation (5)). I did not find evidence of a direct effect of real lending rates on credit to households in the long run, only an indirect effect through real house prices (see Equation (6)).

$$\widehat{crh - p} = 1.00y + 1.00(ph - p). \tag{5}$$

The long-run relationship for credit to households (5) suggests that the ratio between real credit to households and income ($crh - p - y$) depends on real house prices. Another interpretation of this relationship is that the (real) household-credit-to-value ratio ($crh - ph$) depends on real income. The long-run relationship is interpreted as a cointegrating relationship between non-stationary real credit to households, GDP and house prices.

Finally, I find evidence of a long-run relationship between real house prices, real GDP and real lending rates:

$$\widehat{ph - p} = 1.8y - 3.8(i^L - \Delta_4 p). \tag{6}$$

This long-run relationship may also be interpreted as a linear combination of

two stationary terms: real house prices and real GDP through cointegration and real lending rates, which are assumed to be stationary (cf. Equation (4)).

2.3 Dynamic relationships

Table 1 presents a system of dynamic equations for the capital adequacy ratio, lending rate, house prices, credit to households and credit to (non-financial) firms. This system formulated as a VECM, is based on the long-run relationships presented above. Initially, a rather general VECM was formulated by including several lagged difference terms and/or levels of the variables included in the long-run relationships and other potentially relevant variables. I then simplified the general VECM by excluding most of the statistically insignificant variables from the model and obtained the VECM presented. Statistically insignificant variables that have been retained represent short-term effects of variables usually expected to be relevant. They have been retained to avoid a possible erroneous neglect of their effects.

Tests of the statistical properties of the system suggest that it has been adequately specified. There is no violation of the standard assumptions regarding residuals of these equations, especially when I control for some outliers by using impulse dummies.[4] In particular, the null hypotheses of no autocorrelation and normally distributed errors are not rejected at the standard levels of significance.

The (econometric) equation for the capital adequacy ratio suggests that it fluctuates around a fairly constant value over the sample period, the average sum of κ and μ, which is 12.5%. The capital adequacy ratio increases following a decline in the actual capital adequacy ratio below its average value and decreases when it has been above the average value. One simplifying assumption is that a change in the long-run average value of the capital adequacy ratio would have the same effect on capital-ratio adjustment irrespective of whether it is due to a regulatory change

[4]Impulse dummies for the following quarters have been included: In the equation for CAR: 1993Q4 and 2010Q4; in the equation for i^L: 1998Q3, 2000Q3 and 2009Q1; in the equation for crh: 1994Q2 and 1995Q2; and in the equation for crf: 1992Q4 and 2000Q3. The impulse dummies are mostly associated with the exchange rate fluctuations and/or the associated changes in interest rates during the ERM-crisis in 1992Q4, the oil price fall in the autumn of 1998, and the recent financial crisis.

Table 1: *A VECM of the capital adeq. ratio, lending rate, house prices and credit*

$$
\begin{aligned}
\Delta CAR_t &= \underset{(-4.46)}{-0.19}\,[CAR_{t-1}-\kappa-\mu] + \underset{(4.07)}{0.01}\,\Delta u_{t-3} - \underset{(-4.67)}{0.05}\,\Delta y_{t-2} \\
&\quad - \underset{(-2.16)}{0.02}\,\Delta y_{t-3} + \underset{(2.55)}{0.01}\,\Delta(ose-p)_{t-3} + \underset{(3.13)}{0.19}\,\Delta CAR_{t-4} \\
&\quad + \widehat{\varepsilon}_{CAR,t}; \qquad \widehat{\sigma}_{CAR} = 0.28\ \% \\
\Delta i^L_t &= \underset{(-12.1)}{-0.36}\,\{i^L - i - 0.10CAR \times (\Delta_4 ose - i)\}_{t-1} + \underset{(18.3)}{0.42}\,\Delta i_t \\
&\quad + \underset{(9.94)}{0.05}\,CAR_{t-1} + \widehat{\varepsilon}_{i^L,t}; \qquad \widehat{\sigma}_{i^L} = 0.16\ \% \\
\Delta(ph-p)_t &= \underset{(-4.47)}{-0.10}\,\{(ph-p) - 1.8y + 3.8(i^L - \Delta_4 p)\}_{t-1} - \underset{(-6.19)}{1.20}\,\Delta i^L_t \\
&\quad + \underset{(3.26)}{0.06}\,\Delta(ose-p)_t + \underset{(4.62)}{0.43}\,\Delta(ph-p)_{t-1} \\
&\quad + \underset{(1.87)}{0.27}\,\Delta(crh-p)_{t-2} + \underset{(2.35)}{0.16}\,\Delta(crf-p)_{t-2} - \underset{(-4.47)}{2.37} \\
&\quad + \widehat{\varepsilon}_{ph,t}; \quad \widehat{\sigma}_{ph} = 2.3\ \% \\
\Delta(crh-p)_t &= \underset{(-2.69)}{-0.01}\,\{(crh-p) - (ph-p) - y\}_{t-1} + \underset{(2.15)}{0.07}\,\Delta(ph-p)_{t-1} \\
&\quad - \underset{(-3.47)}{0.25}\,\Delta(i^L - \Delta_4 p)_{t-2} - \underset{(-4.58)}{0.31}\,\Delta(i^L - \Delta_4 p)_{t-3} \\
&\quad + \underset{(6.97)}{0.52}\,\Delta(crh-p)_{t-4} + \underset{(3.21)}{0.02} + \widehat{\varepsilon}_{crh,t}; \qquad \widehat{\sigma}_{crh} = 0.89\ \% \\
\Delta(crf-p)_t &= \underset{(-4.84)}{-0.09}\,[(crf-p) - 2.16y]_{t-1} - \underset{(-1.51)}{0.34}\,\Delta(i^L - \Delta_4 p)_{t-1} \\
&\quad - \underset{(-4.46)}{0.42}\,(i^L - \Delta_4 p)_{t-4} + \underset{(4.43}{0.40}\,\Delta(e + p^f - p)_t + \underset{(3.08)}{0.16}\,\Delta y_{t-2} \\
&\quad + \underset{(1.84)}{0.14}\,\Delta(crf-p)_{t-4} - \underset{(-4.70)}{1.14} + \widehat{\varepsilon}_{crf,t}; \qquad \widehat{\sigma}_{crf} = 1.77\ \%
\end{aligned}
$$

Sample:	1992Q4–2010Q4	
Method:	FIML	
Vector SEM-AR 1-5 test,	F(125,187)	= 0.90 [0.73]
Vector Normality test,	$\chi^2(10)$	= 7.60 [0.67]

Note: Parentheses below the coefficient estimates include t-values. Estimates of sigma associated with each of the equations are the standard errors of the corresponding residuals. See Table 6 for details about the tests.

affecting κ or by a change in banks' internal target affecting μ. Some evidence in the relevant literature suggests the speed of adjustment may be relatively lower in the former case (see e.g. Ediz et al. (1998)). Another simplifying assumption is that the speed of adjustment is symmetric around the average value and not dependent on the state of the economy. Arguably, it could be more demanding to raise equity

in recessions than in expansions.

Business cycle fluctuations represented by lagged GDP growth rate (Δy) and unemployment rate (u) contribute to a higher capital adequacy ratio in downturns and a lower one in upturns. This is consistent with banks increasing their capital buffers to weather potential losses on e.g. loans to firms and households in (macroeconomic) downturns. Such a countercyclical response of the capital adequacy ratio may contribute, however, to reduce credit growth during economic recessions and increase credit growth during expansions and thereby to an amplification of business cycles. Such procyclical implications of the relationship between the capital adequacy ratio and business cycle indicators are consistent with much previous evidence (see e.g. Drumond (2009)). In this model, the procyclical implications are due to the positive relationship between the capital adequacy ratio and lending rates (shown next) and the negative relationship between lending rates and economic activity. One of the main motivations for introducing a countercyclical capital buffer is to moderate the procyclicality of capital requirements (see BCBS (2010a)).[5]

The equation for lending rates suggests that lending rates mainly follow money market rates in both the short run and the long run. Costs of capital requirements are found to affect lending rates in addition to money market interest rates.

The equation for house prices implies that they mainly follow variables representing income, lending rates and credit to both households and firms. House prices and credit to households affect each other in the short run as well as in the long run. In the short run, they are also affected by stock market returns (Δose), and changes in lending rates (Δi^L). Stock market returns as well as growth of credit to firms may reflect upturns in business activity and hence higher demand for commercial property, which tend to be highly correlated with house prices. The effects of stock market returns could also reflect their wealth effects on house prices through

[5]However, the observed relationship could be partly due to e.g. recessions contributing to lower credit growth, which can reduce the volume of (risk weighted) assets, and thereby lead to an increase in the equity ratio by lowering the denominator in the capital-to-risk-weighted-assets ratio (CAR). The latter explanation could be somewhat less relevant after the introduction of Basel II, as risk weights tend to increase during recessions, counteracting some of the effects of a reduction in assets owing to a fall in credit growth. Moreover, banks' equity also tends to decline in downturns due to reduced cash flows and higher loan defaults.

a higher demand for housing.

The equation for credit to households implies a short-run and long-run interaction between credit to households and house prices. House prices may have collateral effects on (real) credit to households. Credit also depends on income (represented by GDP) and changes in real lending rates ($\Delta(i^L - \Delta_4 p)$). I did not find evidence of direct effects of changes in the capital adequacy ratio on credit to households. Hence, these effects seem to be transmitted through lending rates only.

To test explicitly for possible direct effects of changes in the capital adequacy ratio on credit to households, I included up to 4 lags of ΔCAR in the equation for credit to households jointly and individually and tested for their statistical significance. In all cases, I found statistically insignificant effects of changes in the capital adequacy ratio on credit to households using standard levels of significance. For example, in the test of the null hypothesis of no effects of the contemporaneous and lagged effects (up to 4) of ΔCAR in the credit to households equation, the Wald test gave a Chi-square statistic ($\chi(5)$) equal to 6.37 with a p-value of 0.27.[6]

As shown above, credit to (non-financial) firms reflects movements in GDP and real lending rates in the long run. In the short run, GDP growth and changes in the real lending rate and the real exchange rate ($\Delta(e + p^f - p)$) also affect credit growth to firms. The real lending rate has a relatively strong negative effect on credit to firms. As in the case of credit to households, changes in the capital adequacy ratio do not appear in the equation for credit to firms due to their statistically insignificant effects. For example, the null hypothesis of no contemporaneous and lagged effects (up to 4) of ΔCAR in the equation for credit to firms was not rejected at standard levels of significance. The outcome of the Wald test was a Chi-square statistic equal to 5.65 with a p-value of 0.34.

[6]Another hypothesis of interest is that of a possible negative relationship between changes in the capital adequacy ratio and credit growth during downturns only. Accordingly, higher capital requirements can make banks lower their loans supply and thereby their assets to meet the regulatory capital ratio if it proves difficult to raise equity during downturns. There does not seem to be sufficient information in the data set used to firmly test this hypothesis, however.

2.4 The macroeconometric model: An overview

To investigate the macroeconomic effects of changes in capital requirements, I include the VECM presented above in a macroeconometric model.[7] In addition to the five-equation VECM, the macroeconometric model contains systems as well as single-equation dynamic models for ten financial and real variables (see Appendix B). These variables are returns on the Oslo Stock Exchange, the nominal effective exchange rate, import prices, aggregate demand, unemployment, productivity, wages, domestic consumer prices, core consumer price inflation and the short-term money market rate. The key monetary policy rate is represented by the short-term money market rate, which is therefore modelled in accordance with a Taylor-type interest rate rule. Specifically, the short-term interest rate adjusts in response to deviations from the (core) inflation target, a measure of the unemployment gap and lagged short-term interest rate.[8] Norway adopted a flexible inflation targeting regime in March 2001, under which explicit weight is attached to output stabilization while targeting inflation. Foreign GDP, a world stock price index (MSCI-World), foreign consumer prices and interest rates, crude oil prices, domestic government expenditures and electricity prices are all treated as exogenous variables.

The macroeconometric model characterizes a linear stable (economic) system where the effects of nominal shocks eventually die out. This applies to monetary policy as well as macroprudential policy shocks. Moreover, even permanent changes in banks' capital requirements tend to have persistent but not permanent effects in the model. This is consistent with evidence based on long time series e.g. from the UK, where no clear relationship has been found between banks' equity ratio and economic growth (see Miles et al. (2011)).

A linear stable model may be considered appropriate for analysing policy deci-

[7] This model builds on a macroeconometric model for the Norwegian economy that has been developed and applied in e.g. Bårdsen et al. (2003), Bårdsen et al. (2005) and Akram and Eitrheim (2008). The main difference with the models used in these studies is that the model used here characterizes the capital adequacy ratio and takes into account its effects on banks' lending rates and thereby on the rest of the economy. In addition, the current model has been somewhat respecified and reestimated on recent and revised data.

[8] The use of the unemployment gap is motivated by relatively large uncertainty in real time measures of GDP gaps (cf. Orphanides and Norden (2002)).

sions aimed at promoting monetary policy and/or financial stability in the normal course of policymaking than in situations of crises or near-crises. Non-linear models are required to model the latter situations.[9]

Figure 1 presents an overview of the macroeconometric model sketching the main linkages between different endogenous variables in the model.

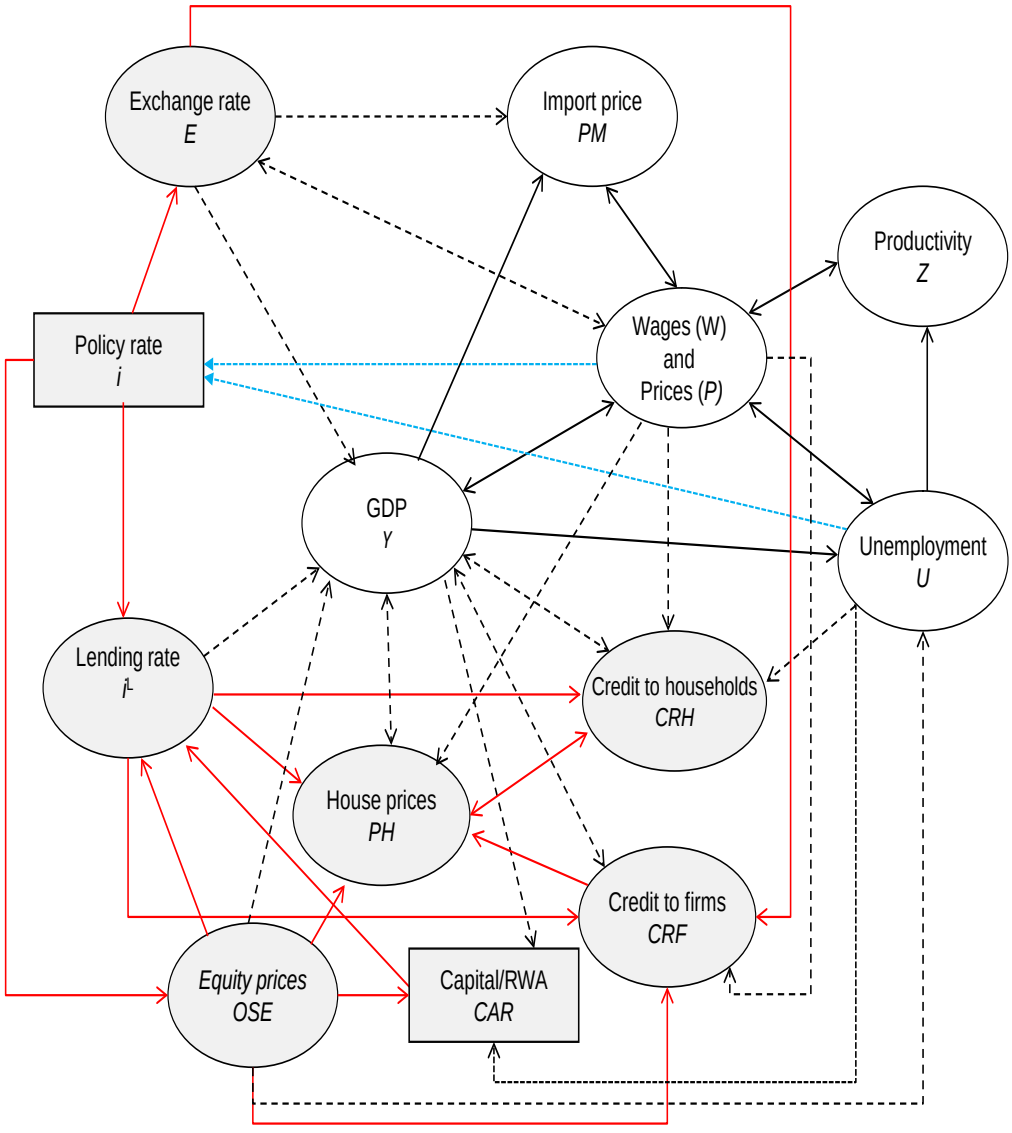

Figure 1: *Main linkages between the endogenous variables in the macroeconometric model. Two-way arrows between variables indicate direct interactions between them.*

The different system and single-equation models constituting the macroecono-

[9]Another argument for using non-linear models becomes relevant if one considers financial stability as a property of a system rather than a state of affairs (see Allen and Wood (2006)). In the former case, a stable linear model would be unsuitable for studying financial stability since financial instability would be ruled out *a priori* by model design.

metric model are largely econometrically well-specified. Specifically, for most of the equations the null hypotheses of no autocorrelation, normally distributed residuals and no heteroscedasticity are not rejected at the standard levels of significance (see Appendix B for details).

The estimated parameters in most of the equations have been found to be stable in response to various policy and structural changes over the sample period (see Appendix C). Notably, only some parameter estimates in equations that have been directly affected by changes in policy have been found to vary over time. Other model equations appear to be quite robust to these changes. Such a lack of evidence for significant parameter instability in the face of shifts in policy is in line with most empirical investigations on the importance of the Lucas critique (see Ericsson and Iron (1995), Leeper and Zha (2003) and Rudebusch (2005)).[10]

In particular, I have not found significant effects on the model's parameters of changes in the regulatory regime in Norway. The regulatory changes could be associated with the move from Basel I to Basel II in 2007, and with the expectations of the gradual implementation of Basel III over the period 2013–2019. For example, Figure 7 in Appendix C shows the relative stability of the estimates of key parameters in the equations for the capital adequacy ratio.

Although the parameter estimates of the model have been found to be invariant to actual and expected changes in the regulatory regime in-sample, changes in the parameters cannot be ruled out when Basel III is implemented. Therefore, more uncertainty may be associated with the effects of the policy analyses than indicated by the standard confidence intervals.

[10] How much parameters of a reduced form econometric model vary with changes in policy mainly depends on three factors: (a) the importance of forward-looking expectations, (b) the size of the policy shift, and (c) the responsiveness of the economy to the policy shift (see e.g. Rudebusch (2005)). In particular, up to a moderate degree of forward-looking expectations combined with relatively weak response of the economy to policy shifts may lead to negligible changes in reduced form parameters.

3 Macro effects of higher capital requirements

Regulatory proposals following the recent financial crisis have mainly focused on the common equity to risk-weighted assets ratio. I conduct response analyses by varying the minimum common equity ratio κ. A variation in any of the other components in the total capital held by banks would have identical effects in the model used, however, as both κ and μ enter the model symmetrically in Table 1. This is a simplification as possible differences between the effects of changes in κ and μ can not be distinguished empirically here. While investigating the effects of a higher equity ratio, I assume that monetary policy will respond in line with the estimated Taylor-type rule (see Table 11 in Appendix B).

Figure 2 plots responses of the modelled variables to a one percentage point permanent increase in the minimum common equity ratio (κ) implemented linearly over four quarters. The overall impression is that the increase in the common equity ratio affects the capital adequacy ratio and thereby the lending rate, which directly affects house prices, credit to households, credit to firms and aggregate demand. The initial negative responses of these variables are then amplified by their mutual interactions. There are no first-round effects on the other variables of the increase in the equity ratio, as they do not directly respond to lending rates. In particular, both the nominal exchange rate and equity returns do not respond directly to the lending rate but to the short-term money market rate, which responds to changes in the inflation and unemployment gaps. The second-round effects on the other variables may also be considered negligible because of relatively small direct effects on aggregate output and thereby on unemployment, productivity, wages, consumer prices and the nominal exchange rate. All of the variables respond as expected to the increase in the lending rate following a higher equity ratio.

In detail, the increase in the common equity ratio is for the most part transmitted (84%) to the capital adequacy ratio within a year after its full increase. The lending rate rises by at most 14 basis points, within 4.5 years since the start of the increase in the common equity ratio. House price growth per annum fall by about 25 basis

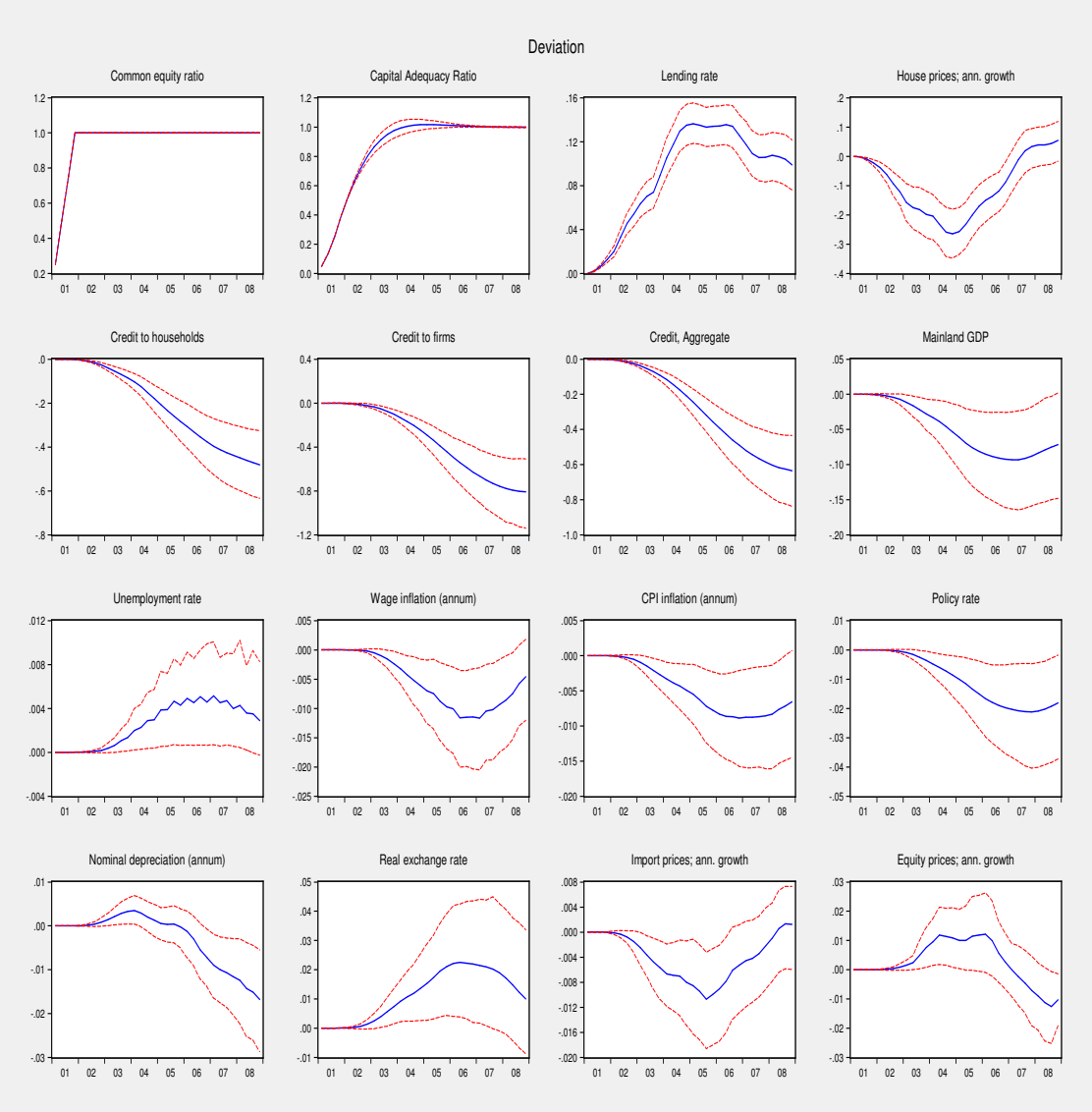

Figure 2: *Responses (+/- SE) to a one percentage point permanent increase in the common equity ratio when monetary policy follows a Taylor-type rule. The implementation period is four quarters and the simulation period is of 32 quarters. The vertical axes denote values in percentage points for the common equity ratio, capital adequacy ratio, lending rate, key policy rate and unemployment rate. For the other variables, the vertical axes denote values in percent.*

points while credit to households and firms decline, by around 25 and 35 basis points, respectively, within 4.5 years. As a result, aggregate credit falls by around 28 basis points over the same time span. The effects on aggregate credit after eight years and beyond are at most –65 basis points. GDP falls at most by 9 basis points over the simulation horizon and only 7 basis points after eight years. The unemployment rate increases only by a negligible amount. By simulating the model for a sufficiently long period, it can be shown that the real economic effects are reversed in the very

long run.

The effects on the other macro variables are for the most part quite small. Notably, inflation and wage growth fall at most by 1 basis point, while the short-term money market rate, which represents the key policy rate, falls by 2 basis points. The nominal exchange rate depreciates slightly due to the fall in the interest rate, but thereafter tends to appreciate because of the fall in the inflation rate. Equity returns increase somewhat due to the fall in the short-term interest rate.

The monetary policy rule serves to dampen effects of the higher capital requirements in the model. If short-term interest rates had not fallen as prescribed by the estimated Taylor-type rule, the effects of changes in the common equity ratio on key macroeconomic variables such as real and nominal lending rates, credit to households, credit to firms and GDP would have been a few basis points greater (in absolute terms). The effects would also have been somewhat greater if capital requirements had also been increased in Norway's trading partners, contributing to a fall in the foreign GDP and thereby in domestic GDP and other macroeconomic variables.

I have found the macroeonometric model and the main results to be generally invariant to changes in the sample period, which covers changes in the structure of the economy, the introduction of inflation targeting in 2001, the introduction of Basel II framework in Norway in 2007 as well as the recent financial crisis and the accompanying changes in monetary policy and actual and/or expected changes in financial regulation (see Appendix C for details). In particular, responses to higher capital requirements based on the macroeconometric model when estimated partly on data until the end of 2006Q4 are comparable to those based on the full sample estimation of the macroeconometric model (see Figure 9). The impulse responses of the different variables in Figure 9 can be interpreted as representing the possible effects of changes in the common equity ratio under Basel I, which has been gradually being replaced since the end of 2006.

3.1 Comparison with international evidence

The regulatory response to the recent financial crisis has motivated a number of empirical studies on the possible effects of higher capital requirements on banks' funding costs, lending rates, credit and economic activity (see e.g. BCBS (2010b), Angelini et al. (2011), Hanson et al. (2011), Miles et al. (2011), Slovik and Cournède (2011) and Elliott et al. (2012)). Their findings, however, are generally quite dependent on their approach and underlying assumptions. For the sake of brevity, I will only compare some of the results with those from the study by the Macroeconomic Assessment Group (MAG): BCBS (2010b). This study reports evidence based on 89 models for 15 advanced economies. The relatively large range of variation in estimated effects across these models, which is reported in Table 2, are likely to cover even estimated effects based on models not utilized by the MAG study.

Table 2: *Comparing effects of higher equity with the MAG study*

	I. This study: Norwegian evidence			
1 pp over 8 qtrs	*After 18 qtrs*		*After 32 qtrs*	
Lending rate	14	{12, 16}	12	{10, 13}
Credit	–23	{–31, –16}	–71	{–97, –45}
GDP	–7	{–11, –2}	–10	{–20, –2}
	II. MAG study: International evidence			
1 pp over 8 qtrs	*After 18 qtrs*		*After 32 qtrs*	
Lending rate	17	[5, 25]	15	[5, 26]
Credit	–140	[–360, –6]	–190	[–360, –80]
GDP	–12	[–96, 39]	–10	[–314, 3]
GDP; *std*	–12	[–96, 39]	–10	[–314, 3]
GDP; *dsge*	–11	[–41, –1]	–7	[–25, –2]
GDP; *rf*	–30	[–87, 18]	–24	[–88, 2]

Note: The effects are measured in basis points. Panel I presents the means and the 68% confidence intervals (in curly brackets) of the effects of a 1 percentage point increase in the equity ratio on selected Norwegian variables 18 and 32 quarters after the start of implementing the equity increase. Panel II presents median estimates from the MAG study and the ranges of estimated effects across models defined by minimum and maximum effects in hard brackets. The results reported come from Graph 1 and Tables 1 and 2 in BCBS (2010b). *std* denotes the standard approach where implications for lending rates are derived using an accounting approach and the implications for GDP are obtained by implementing the change in the lending rate in the national models; *dsge* denotes an integrated approach where a group of DSGE models with banks are used. Finally, *rf* refers to an integrated approach where a group of reduced-form models is used.

For ease of comparison with the MAG study, I implement a one percentage point increase in capital requirements while letting the key policy rate remain unresponsive to changes in inflation and economic activity. I also implement higher capital requirements gradually over eight quarters and study their effects after 18 and 32 quarters from the start of implementation; the 32nd quarter was the end point of the simulation period in the MAG study. As in the MAG study, I focus on the estimated response of lending rates, (aggregate) credit and GDP. Allowing for an implementation period of 16 quarters did not substantially affect the conclusion from the comparative analysis reported below. In some of the models employed in the MAG study, the length of the implementation period seems to matter to a relatively larger extent.

Panel I of Table 2 presents estimated responses of the key variables, measured as deviations from the baseline paths in basis points together with their 68% confidence intervals (see Figures 11 in Appendix D for complete paths and confidence bands for all of the variables). Panel II of the table reports median estimates for the responses of key variables from the MAG study together with ranges of variation across models used. For GDP, I report median estimates and ranges based on all 89 models, and with models divided into three subgroups. The relatively wide ranges of estimated effects on the three key variables reveal relatively large differences in the estimated effects across the models. I therefore compare the estimated effects of this study with the MAG's median effects on the three variables at selected periods.

The point estimates of this study are lower than the (MAG's) median estimates in Panel II at both the 18-quarters and 32-quarters horizons. The differences in the estimated effects are smaller in the long run than in the short run. That is, in the present study lending rates increase by 3 basis points less than the median estimates, irrespective of the horizon. The effects on credit, however, are substantially smaller than the corresponding median estimates. For example, credit falls by 23 basis points 18 quarters after the start of implementation in the present model, while the median estimate is –140 basis points. After 32 quarters, credit falls by 71 basis points in this model, while the median estimate is –190 basis points. In the case of

effects on GDP, it declines by 7 basis points at the horizon of 18 quarters, which is 5 basis points less than the median estimate at this horizon. At the horizon of 32 quarters, however, GDP declines by 10 basis points, which is equal to the median estimate of –10 basis points.

Note also that the responses of GDP estimated by this study are closer to the (MAG's) median estimates based on the standard approach and DSGE models, and differs substantially from those based on many of the reduced form models used in the MAG study. The latter models suggest substantially greater effects on GDP. The group of reduced form models includes a relatively large number of VAR models. Results comparable to those based on VAR models have also been reported using a VAR model with identified shocks on Norwegian data (see Jacobsen et al. (2011)).

Statistically, however, in all but one case, estimates of this study are not significantly different from the median estimates at the standard levels of significance. Even the 68% confidence intervals presented in curly brackets (nearly) include the corresponding median estimates from the MAG study. One exception is the case of the estimated effect on aggregate credit after 18 quarters where neither the reported 68% confidence interval nor a 95% confidence interval would include the median estimates in Panel II. Another such exception is the case of the median of estimated effects on GDP implied by the reduced form models used by the MAG study.

3.2 Macro effects of Basel III

The Basel III framework entails a permanent 2.5 percentage point increase in the minimum common equity ratio (conservation buffer) and a systemic risk-dependent variation in the common equity ratio in the range of 0–2.5 percentage points (countercyclical buffer). In the following, I investigate the effects of such general increases in the minimum common equity ratio. I assume an implementation period of eight quarters. Because the model is linear, the effects of a 2.5 percentage point higher equity ratio would be a multiple of those presented above for the case of a 1 percentage point increase in the equity ratio for the same implementation period.

Figure 3 shows the effects of the introduction of the conservation buffer. It is

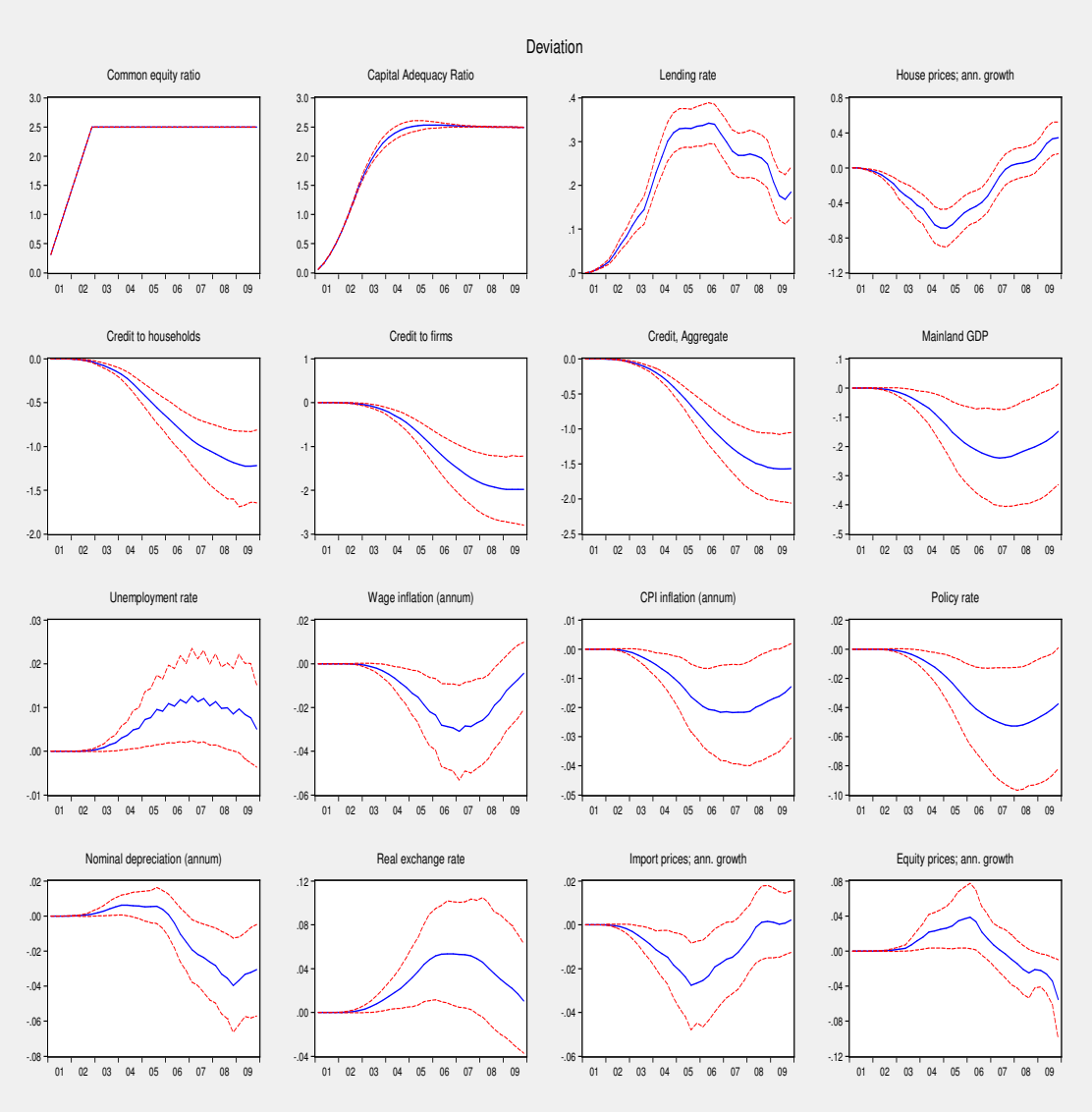

Figure 3: *Effects of the conservation buffer under Basel III. Responses (+/- SE) to a 2.5 percentage point permanent increase in the common equity ratio, when monetary policy follows a Taylor-type rule. The implementation period is 8 quarters and the simulation period is 36 quarters. The vertical axes denote values in percentage points for the common equity ratio, capital adequacy ratio, lending rate, key policy rate and unemployment rate. For the other variables, the vertical axes denote values in percent.*

seen that the nominal lending rate increases by about 35 basis points at most, while GDP falls by 24 basis points. House prices fall by 70 basis points, while credit to households and firms declines by 123 and 200 basis points at most, respectively, implying a fall in aggregate credit by 157 basis points. The effects of the higher equity requirement have been moderated somewhat by the 5 basis point reduction in the key policy rate in response to lower inflation and lower economic activity (higher unemployment gap).

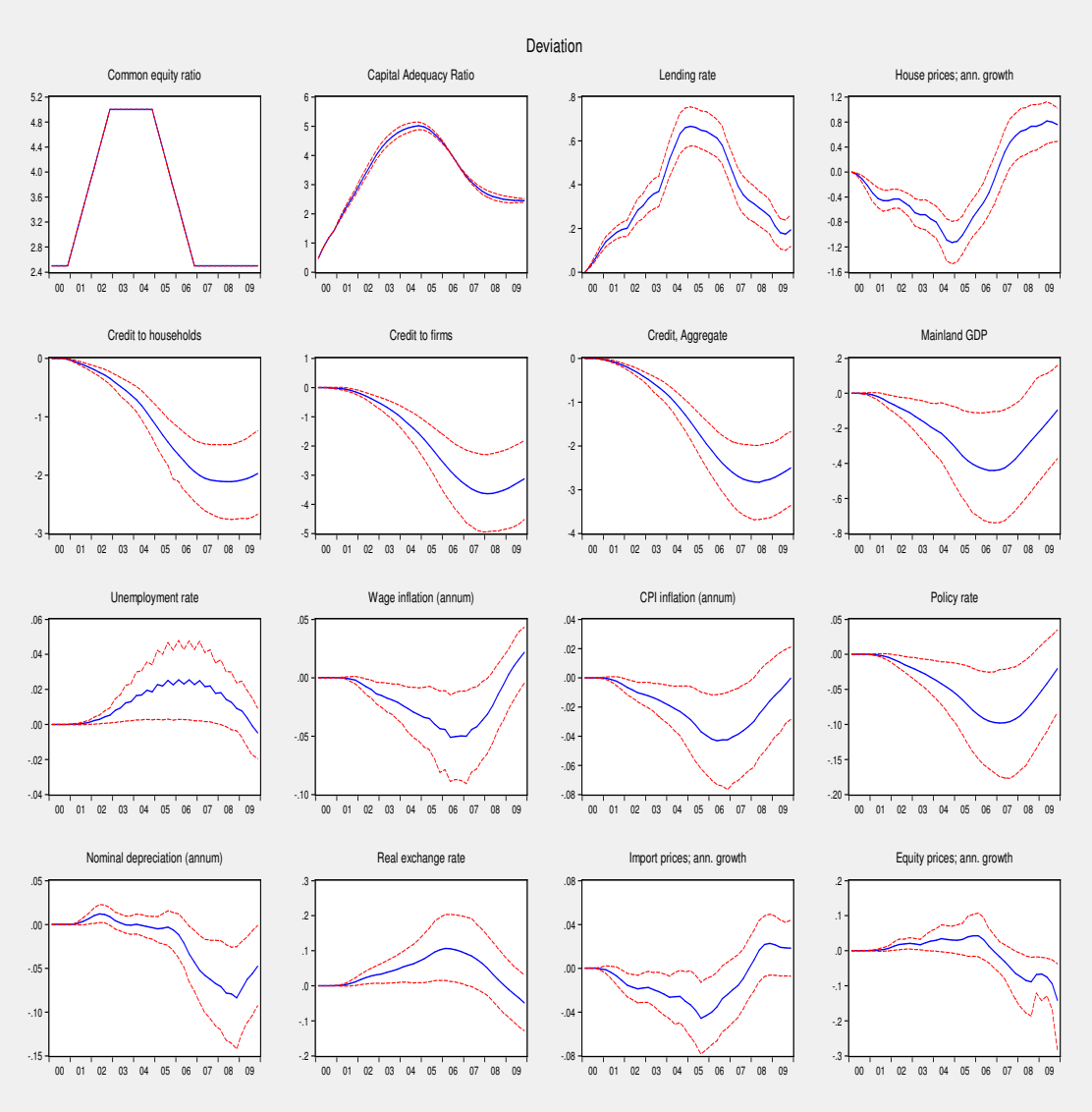

Figure 4: *The effects of the countercyclical and conservation buffers under Basel III. Responses (+/- SE) to a gradual change over eight quarters of the common equity ratio of up to 2.5 percentage points, when the conservation buffer as been raised immediately by 2.5 percentage points to a permanently higher level. Monetary policy follows a Taylor-type rule. The simulation period is 36 quarters. The vertical axes denote values in percentage points for the common equity ratio, capital adequacy ratio, lending rate, key policy rate and unemployment rate. For the other variables, the vertical axes denote values in percent.*

Figure 4 shows the effects in a scenario where the conservation buffer has been fully implemented and the countercyclical buffer is increased by its maximum value (2.5 percentage points) for two years. Thus, for two years the common equity ratio is 5 percentage points higher than it would have been in the absence of Basel III. I assume a symmetric implementation period for both the increase to the maximum value and the decrease to the minimum value (zero) for the countercyclical buffer.

It is seen that lending rates increase by around 67 basis points while GDP falls by

44 basis points, at most. House price inflation falls by 113 basis points, while credit to households and firms falls by 210 and 360 basis points, at most, respectively. Hence, aggregate credit falls at most by about 280 basis points. As above, the effects of the relatively high capital requirements are moderated by the reduction in the key policy rate, which falls by up to 10 basis points in response to lower inflation and economic activity.

The effects of the temporary increase in the countercyclical capital buffer diminishes over time, and the effects on the macroeconomic variables converge towards those presented in Figure 3 for the case of the higher conservation buffer. Ultimately, however, even effects of the higher conservation buffer die out due to the equilibrium correction properties of the model's equations and the monetary policy rule.

4 Implementing the countercyclical capital buffer

In the following, I investigate how much and for how long equity requirements should be changed in response to different shocks of a transitory or persistent nature. I assume that a forward-looking macroprudential policymaker facing a certain shock will minimize the following loss function by choosing a path for the countercyclical capital buffer:

$$L_t = Var(CRgr) + \lambda Var(Ygr). \tag{7}$$

The loss function depends on the variance of growth in aggregate credit and output, *Var(CRgr)* and *Var(Ygr)*. It is a reformulation of a quadratic loss function assuming that the discount factor is close to one. Subscript t indicates that the fluctuations in credit and output growth will depend on the properties of the given shock at time t, in addition to the model and the policy response.[11] λ indicates the degree of concern for fluctuations in output growth relative to that for fluctuations

[11] Such an analysis is, of course, a considerable simplification of the actual conduct of policy as the economy is continuously buffeted by combinations of shocks that vary in magnitude with different sizes and degrees of persistence. However, the procedure can be easily adapted to a more realistic case by providing multiple new shocks to the model economy while taking into account the effects of the previous shocks.

in credit growth.

The policymaker aims to reduce systemic risk by stabilizing aggregate credit around its presumably sustainable value, while avoiding to some extent possible excess volatility in output growth (cf. Haldane (2012)). The objective function has been formulated in terms of annual rates of aggregate credit growth and (mainland) GDP growth instead of the aggregate credit-to-GDP ratio gap, which is implied by e.g. BCBS (2010a). The choice of growth rates over levels is due to substantially smaller data revisions to GDP growth relative to revisions of the level of GDP, in particular (see e.g. Orphanides and Norden (2002) and Edge and Meisenzahl (2011)). Changes in the capital buffer stabilize aggregate credit growth and other macro variables by reducing the procyclicality of the capital adequacy ratio and thereby of lending rates. I assume that the key policy rate follows the Taylor-type rule presented in Table 11, while macroprudential policy is conducted as outlined below.

I assume that in response to a given shock, the policymaker chooses a path for the countercyclical capital buffer by deciding simultaneously on the change in the capital requirement within a given range of 0–2.5% and on its duration. For the sake of simplicity, I assume that the capital requirement is changed only when the shock appears in period t and remains effective for q quarters. That is, the capital requirement relative to a given fixed level $(\kappa_{t+i} - \kappa)$ is changed by $\delta \in [0,\ 2.5]$ for q quarters:

$$\begin{aligned} \kappa_{t+i} - \kappa &= \delta \qquad ; i = 0,\ 1,\ 2, ...q-1, \qquad (8) \\ &= 0 \qquad ; i = \ q,\ q+1,\ q+2, ... \qquad (9) \end{aligned}$$

A given shock (ε_v) may follow an AR(1) process with the degree of persistence denoted by ϕ:

$$\varepsilon_{v,\ t+i} = \phi \varepsilon_{v,\ t+i-1} + \eta_{v,\ t}, \qquad (10)$$

where $\phi \in [0,\ 0.9]$. Precisely, ε_v denotes the residual in the econometric equation of a variable v while $\eta_{v,\ t}$ is an impulse shock implying a percentage point change in v.

Table 3: *Optimal δ and q in response to various shocks with different persistence*

v:	*ph*		*crh*		*crf*		*ose*		y		i	
ϕ	δ	q	δ	q	δ	q	δ	q	δ	q	δ	q
0	*2.5*	2	*2.5*	4	*0.5*	1	*0.5*	1	*2.5*	2	*2.5*	5
0.1	*2.5*	2	*2.5*	4	*0.5*	1	*1.0*	1	*2.5*	3	*2.5*	5
0.2	*2.5*	2	*2.5*	5	*0.5*	1	*1.0*	1	*2.5*	3	*2.5*	5
0.3	*2.5*	2	*2.5*	5	*0.5*	1	*1.0*	1	*2.5*	3	*2.5*	5
0.4	*2.5*	2	*2.5*	5	*1.5*	1	*1.5*	1	*2.5*	3	*2.5*	5
0.5	*2.5*	3	*2.5*	6	*2.0*	1	*2.0*	1	*2.5*	4	*2.5*	6
0.6	*2.5*	3	*2.5*	6	*2.0*	1	*2.5*	1	*2.5*	5	*2.5*	6
0.7	*2.5*	4	*2.5*	7	*2.5*	1	*2.5*	1	*2.5*	6	*2.5*	7
0.8	*2.5*	6	*2.5*	9	*2.5*	3	*2.5*	2	*2.5*	7	*2.5*	9
0.9	*2.5*	8	*2.5*	12	*2.5*	5	*2.5*	3	*2.5*	10	*2.5*	9

Note: The top row indicates the shocked variables while the first column contains the degree of persistence (ϕ) in the corresponding shocks (see Equation (10)). The shocked variables increase initially by one percentage point, except the short term money market rate which declines. Values of δ (in percentage points) and q (in quarters) minimize the loss function (7) for a given shock with a specified degree of persistence. The weight on the variance of the GDP growth gap in the loss function, i.e. λ, has been set equal to 0.4. The optimal values of δ and q have been obtained by simulating the macroeconometric model over 32 quarters.

To derive optimal paths for the buffer in response to different shocks, I expose the model to a specific shock with persistence ϕ and then minimize the loss function (7) with respect to δ and q. When deriving values of the loss function, the value of λ has been set equal to 0.4. The optimal values of δ and q have been obtained by undertaking a grid search within the ranges 0–2.5, with step size 0.50 percentage point, and 1–16 quarters, with step size 1 quarter, respectively. In every case, the model has been simulated over a sufficiently long period for convergence to the steady state; in many cases, 32 quarters were found to be more than sufficient.

Table 3 presents optimal changes/additions in capital requirements, δ, and their duration, q, in response to different shocks with persistence values of 0–0.9 degrees. The following variables have been shocked in turn to (temporarily) increase their value by one percentage point: house prices, credit to households, credit to firms, return on equity and aggregate demand. In contrast, short term money market rates have been shocked to obtain a reduction of one percentage point.

Table 3 suggests that optimal changes in capital requirements and their duration tend to increase with the degree of persistence of the shocks. This is especially the

case for the duration of higher capital requirements. The optimal change in capital requirements is 2.5 percentage points for most shocks, irrespective of their degrees of persistence. The exceptions to this pattern are shocks to credit to firms and return on equity. In these cases, the capital requirement increases gradually to 2.5 percentage points with increases in the degree of persistence.

Given that the upper boundary (2.5 percentage points) for changes in capital requirement has been selected (through simulations) for most of the shocks, only duration of higher capital requirements increases when the persistence of shocks increases. Shocks to firm credit and return on equity reveal that the optimal change in capital requirements increases with the degree of persistence without an accompanying change in its duration as long the change is lower than the upper boundary. When in response to a shock, changes in capital requirements have reached the ceiling, duration increases with the degree of persistence.

There appears to be a non-linear relationship between the degree of persistence of shocks and the duration of higher capital requirements. The duration tends to increase gradually, if at all, with persistence in the range of 0–0.7, but rises with bigger steps to higher levels when the degree of persistence increases from 0.7. The duration is one to five quarters for various kinds of strictly transitory shocks (with $\phi = 0$), and still in the range of one to six quarters for degrees of persistence up to 0.5. In contrast, when the degree of persistence is 0.9, the duration varies in the relatively high range of eight to twelve quarters for shocks to house prices, credit to households, aggregate demand and short-term interest rates. The duration for shocks to return on equity and credit to firms increases to two and four quarters, respectively.

The next subsection indicates that the optimal paths of the countercyclical capital buffer in response to different shocks are quite robust to the parameter representing the policymaker's concern for output fluctuations, and even inflation volatility. This result owes mainly to the relatively strong correlation between the variances of credit growth, output growth and inflation under the set of shocks considered.

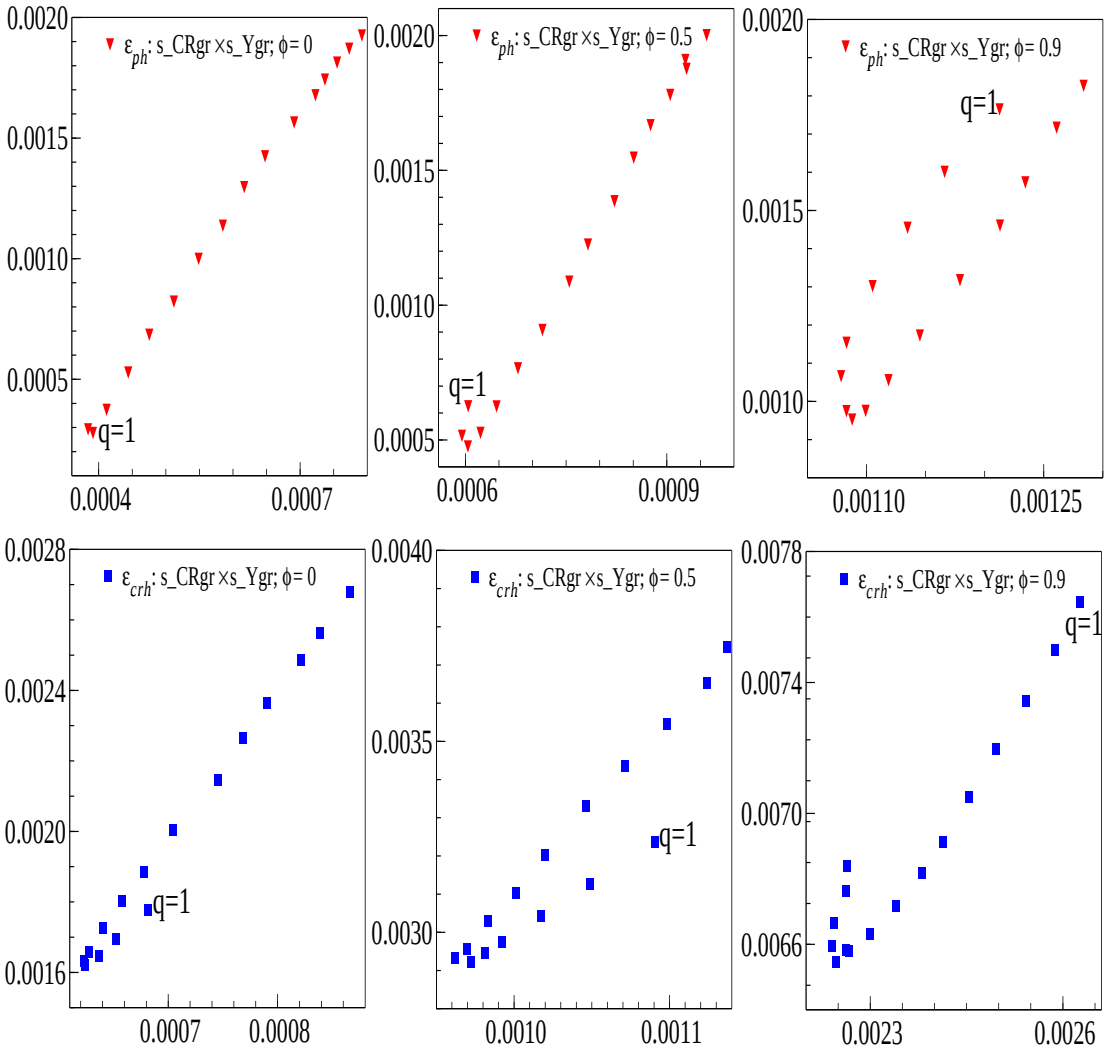

Figure 5: *Cross plots between the standard deviations of aggregate credit growth (s_CRgr) and GDP growth (s_Ygr) implied by different durations (q=1,2...,16) for the buffer size (δ) = 2.5 percentage point. q = 1 refers to the outcome implied by duration of 1 quarter and δ=2.5. The subsequent points correspond to outcomes associated with q=2,3,4,...,16 (and δ=2.5). The three charts in the upper panel show the cross plots of the standard deviations implied by specific durations (and buffer size = 2.5 pp) in response to house price shocks with three different degrees of persistence: 0, 0.5 and 0.9. The lower panel shows corresponding cross plots for the case of shocks to credit to households.*

4.1 Optimal capital buffer paths and the loss function

Optimal choices of δ and q in response to different shocks and their properties presented in Table 3 are based on the assumption of $\lambda = 0.4$, where λ indicates the policymaker's concern for output stabilization while pursuing credit growth stabilization. To investigate how sensitive the optimal values of δ and q are to changes in the value of λ in the loss function, I have redone the analysis above with λ values

equal to 0, 0.2, 0.6, 0.8 and 1. For $\lambda = 0$, minimizing the loss function amounts to minimizing the variance of aggregate credit growth, while for $\lambda = 1$, minimizing the loss function equals the minimization of the sum of the variances of aggregate credit growth and GDP growth.

Table 4: *Alternative loss function: optimal δ and q when shocks with different persistence*

v:	*ph*		*crh*		*crf*		*ose*		*y*		*i*	
ϕ	δ	q	δ	q	δ	q	δ	q	δ	q	δ	q
0	*2.5*	2	*2.5*	4	*0.5*	1	*0.5*	1	*2.5*	2	*2.5*	5
0.1	*2.5*	2	*2.5*	4	*0.5*	1	*1.0*	1	*2.5*	3	*2.5*	5
0.2	*2.5*	2	*2.5*	5	*0.5*	1	*1.5*	1	*2.5*	3	*2.5*	5
0.3	*2.5*	2	*2.5*	5	*0.5*	1	*1.5*	1	*2.5*	3	*2.5*	5
0.4	*2.5*	3	*2.5*	6	*1.0*	1	*1.5*	1	*2.5*	4	*2.5*	5
0.5	*2.5*	3	*2.5*	6	*1.0*	1	*2.0*	1	*2.5*	4	*2.5*	6
0.6	*2.5*	4	*2.5*	7	*2.5*	1	*2.0*	1	*2.5*	5	*2.5*	6
0.7	*2.5*	5	*2.5*	8	*2.5*	1	*2.5*	1	*2.5*	6	*2.5*	7
0.8	*2.5*	6	*2.5*	9	*2.5*	3	*2.5*	2	*2.5*	8	*2.5*	8
0.9	*2.5*	8	*2.5*	11	*2.5*	5	*2.5*	3	*2.5*	11	*2.5*	10

Note: Optimal paths for countercyclical capital buffers under a loss function which is defined by the sum of the variances of the aggregate credit growth gap and the inflation gap. The top row indicates the shocked variables while the first column contains the degree of persistence (ϕ) in the corresponding shocks (see Equation (10)). The shocked variables increase initially by one percentage point, except the short term money market rate which declines. Values of δ (in percentage points) and q (in quarters) minimize the loss function for a given shock with a specified degree of persistence.

In brief, the variation of λ within the range of 0–1 does not generally affect the optimal choices of δ and q in response to the different shocks considered. This is because of the relatively high correlation between the variance of aggregate credit growth and the variance of GDP growth in the cases of the shocks considered (see Figure 5).[12] Besides that, changes in capital requirements represented by δ and q have relatively small effects on the variance of GDP growth relative to the variance of aggregate credit growth (see Figures 2 and 5). Therefore, changes in the variance of aggregate credit growth in response to different values of δ and q dominate the influence of changes in the variance of GDP growth on the loss function, even when the weight of the latter is 1.

In cases where an increase in the value of λ from 0 to 1 matters, δ and q change by only 0.5 percentage point and/or 1 quarter, respectively. Such exceptions to the

[12]See also Olsen et al. (2003) for evidence on the strong relationship between output and credit in Norwegian data.

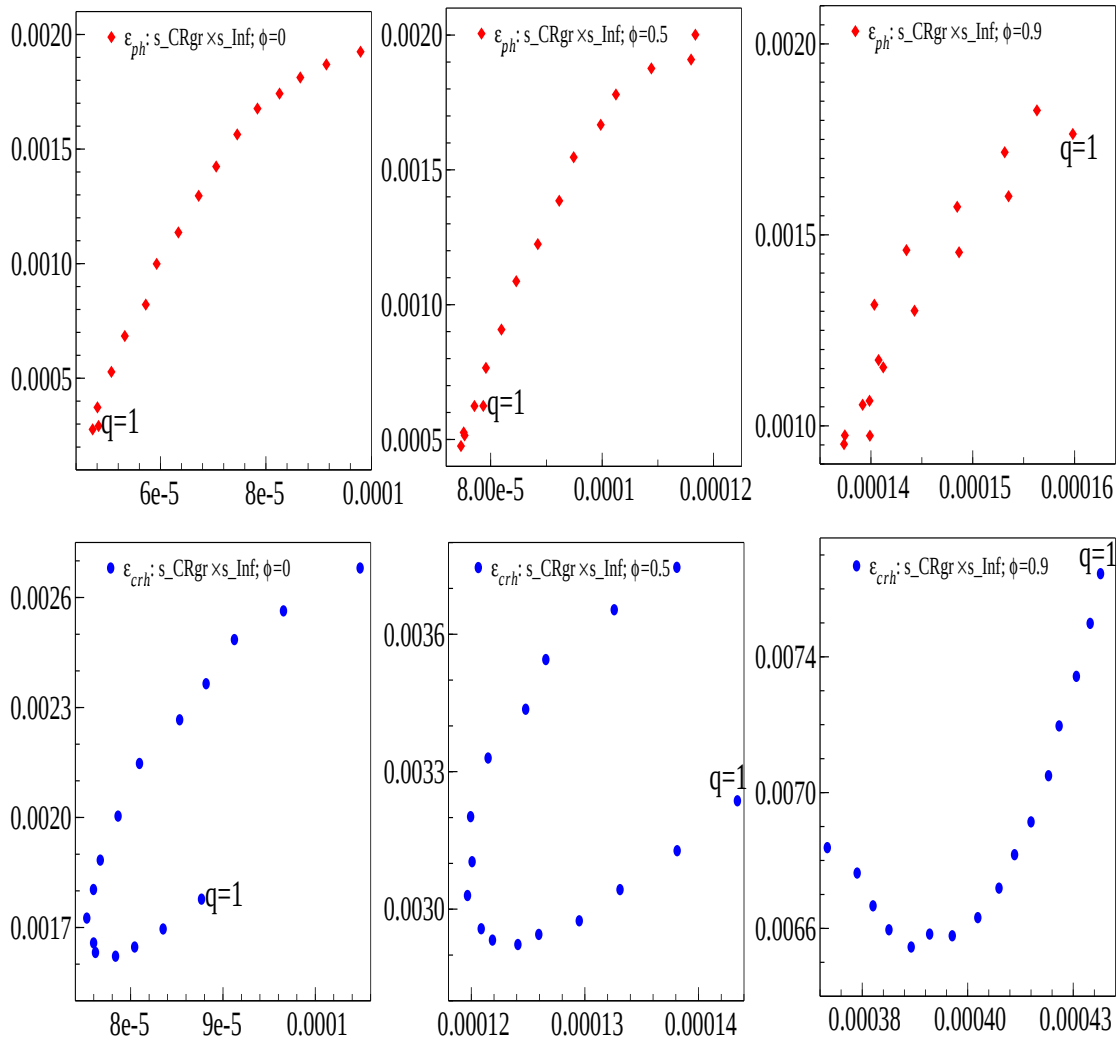

Figure 6: *Cross plots between the standard deviations of aggregate credit growth (s_CRgr) and inflation gap (s_Inf) implied by different durations (q=1,2...,16) for the buffer size (δ) = 2.5 pp. q = 1 refers to the outcome implied by duration of 1 quarter and δ=2.5. The subsequent points correspond to outcomes associated with q=2,3,4,...,16 (and δ=2.5). The three charts in the upper panel show the cross plots of the standard deviations implied by specific durations (and buffer size = 2.5 pp) in response to house price shocks with three different degrees of persistence: 0, 0.5 and 0.9. The lower panel shows corresponding cross plots for the case of shocks to credit to households.*

general pattern are found in the cases of shocks to credit to firms, return on equity and GDP. In the latter case, $\lambda = 1$ entails a different δ-value than $\lambda < 1$.[13]

If I instead assume that the decision maker cares about the variance of the inflation gap rather than that of the GDP growth gap while pursuing stabilization

[13]In the case of shocks to credit to firms, for degrees of persistence equal to 0.2 and 0.9, δ increases by 0.5 percentage point while duration increases by 1 quarter relative to values in Table 3. In the case of shocks to return on equity, q remains invariant but δ increases by 0.5 percentage point, when λ is reduced. That is, $\delta = 0.5$ for $\lambda \geq 0.4$, while $\delta = 1$ for $\lambda \leq 0.2$.

of the credit growth gap, the optimal values of the δ and q are also unaffected in most cases (see e.g. Table 4). In cases where they are affected, the values do not differ by more than one percentage point and/or one quarter relative to the values presented in Table 3, where the loss function includes concern for fluctuations in GDP growth. As above, the changes in the optimal values of δ and q occur mostly for shocks to credit to firms and return on equity. For other shocks, optimal values of δ do not change while the optimal values of duration may differ by one quarter from those presented in Tables 3.[14]

The relatively minor differences between the outcomes presented in Tables 3 and 4 is mainly due to the relatively strong correlation between the variances of the aggregate credit growth and inflation gap for the shocks considered (see Figure 6).

5 Conclusions

I have investigated the effects of higher bank capital requirements on key Norwegian macroeconomic variables and their implications for macroprudential policy under Basel III. To this end, I have further developed and updated a quarterly macroeconometric model of the Norwegian (mainland) economy. To shed light on the countercyclical capital buffer as a macroprudential policy instrument, it is assumed that the policymaker stabilizes aggregate credit growth while taking into account possible destabilizing effects on output growth. The policymaker is also assumed to respond to a given shock by choosing a path for the countercyclical capital buffer characterized by the size and duration of the countercyclical capital buffer.

I would like to highlight the following results. First, higher capital requirements affect credit growth, house prices and other macroeconomic variables through their effects on lending rates. I do not find statistically significant direct effects of changes in capital requirements on credit to households and firms.

[14]The optimal values in Table 4 are based on the assumption that the decision maker minimizes the variance of the aggregate credit growth gap while placing equal weight on the variance of inflation gap. It can be shown that it is the replacement of the variance of the GDP growth gap with the variance of the inflation gap rather than the change in λ from 0.4 to 1 that accounts for the differences between Tables 3 and 4.

Second, the effects on credit growth and house prices are found to be of considerable size, especially when capital requirements are increased by as much as 2.5 percentage points or more. The effects on the other variables such as GDP and inflation are relatively modest. The macroeconomic effects could have been somewhat larger than those presented if one had taken into account possible recessionary effects of a simultaneous imposition of capital requirements in Norway's trading partners.

Third, the analysis of the countercyclical capital buffer in response to various shocks suggests that the buffer increases by 2.5 percentage points in response to most of the shocks considered, while its duration varies in the range of 1–12 quarters depending on the persistence of the shock.

And fourth, the size and duration of the countercyclical capital buffer in response to different shocks do not vary notably with the parameter representing the policymaker's concern for output stabilization while stabilizing aggregate credit growth. Accordingly, the countercyclical capital buffer that minimizes the variance of credit growth also minimizes a combination of the variances of credit growth and output growth. Moreover, comparable results are obtained even when the variance of output growth in the loss function is replaced by the variance of the inflation gap. This outcome is primarily due to the relatively strong correlation between credit growth, output growth and inflation in the model for the shocks considered, and the relatively stronger effects of changes in the capital buffer on credit growth compared to effects on output growth and inflation. It follows that stabilization of aggregate credit growth in response to selected shocks may not conflict with output stabilization or inflation stabilization. It remains to be investigated, however, whether this outcome is supported by other models.

Finally, I would like to stress that the analyses presented in this paper are based on a number of heroic assumptions, particularly about the out-of-sample relevance of the model and results under a different regulatory framework. They should therefore be treated more cautiously than suggested by the confidence intervals and significance values presented in the paper.

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Appendix

A. Data

The primary source of most of the series is Statistics Norway. Unless another source is given, the time series have been extracted from the database HISTDATA maintained by Norges Bank (Central Bank of Norway). Variables as named in the database are noted in hard brackets [.] below. Where relevant, the base year is 1991 and the unit of measurement is NOK million. The mainland economy is defined as the total Norwegian economy excluding oil and gas production and international shipping. In the text, except for interest rates, variable names in small letters are natural logs of the corresponding variables listed below. Impulse dummies are denoted as iyyqx, where e.g. i80Q2 is 1 in 1980Q2 and 0 else.

CG Public consumption in NOK million; [CO].

CRH Domestic credit to households. Stock in NOK million; [KFC2H].

CRF Credit to non-financial firms, mainland Norway. Stock in millions of NOK; [KFC3EMN].

CR Aggregate credit: CRH + CRF.

Qj Seasonal dummy variable for the jth quarter.

E Import-weighted nominal exchange rate relative to Norway's 44 main trading partners; [SI44].

CAR Capital adequacy ratio, i.e. capital to risk-weighted assets. Capital consists of both Tier 1 and Tier 2 capital, where Tier 1 capital is composed of common equity and hybrid equity while Tier 2 capital is additional capital; [Netto ansvarlig kapital]. Source: ORBOF database.

i The 3 months effective nominal money market rate. NIBOR (ask); [RN3M].

i^f The 3 months effective nominal money market rate, euro area. EURIBOR; [RN3M_EURO].

i^L Nominal lending rate; Average of floating interest rate for bank loans (total); [RNBL].

IT A step dummy that is 0 before 2001Q1 and 1 afterwards.

$MSCIW$ MSCI-World share index; Source: Datastream.

$OILP$ Brent Blend crude oil prices in USD per barrel; [POILUSD].

OSE Oslo Stock Exchange All Share Index; [OSEAX].

P Consumer price index; [PCPI].

PC Consumer price index adjusted for indirect taxes and energy prices; [PCPIJAE].

PEL Electricity prices, subcomponent of CPI; [PCPIEL].

P^f Consumer price index for Norway's main trading partners (25 countries); [PCPI_F25].

PH House prices: NOK thousand per square meter; [PHN].

PM Deflator of total imports; [PB].

PX Producer price index for Norway's trading partners in foreign currency, a proxy for deflator of export prices in foreign currency; [PPIKONK].

$PD1$ Composite dummy for introduction and removal of direct price controls. 1 in 1971Q1, 1971Q2, 1976Q4, 1979Q1; -1 in 1975Q1, 1980Q1, 1981Q1, 1982Q1; and zero otherwise.

U Unemployment rate (registered); [URR].

W Wage income per hour, mainland Norway; [WILMN].

$WD1$ and Composite dummy for wage freeze: 1 in 1979Q1, 1979Q2, 1988Q2 and 1988Q3.

Y Mainland real GDP of Norway, measured in NOK million at fixed market prices; [YMN].

Y^f Gross domestic product index for Norway's 26 main trading partners; [Y_F26].

Z Productivity: value added per man hour at factor costs for mainland economy; [ZYF].

B. The macroeconometric model

In addition to the VECM for the capital adequacy ratio, lending rates, house prices, credit to households and credit to firms, the macroeconometric model contains single equations and systems of econometric equations for a number of other variables. These equations are briefly described in the following and presented in Tables 5–11.

Nominal equity returns based on the all share index of the Oslo Stock Exchange are modelled in light of the capital asset pricing model (CAPM) by treating the Norwegian stock market portfolio as a single asset and the international stock market portfolio as the market portfolio. The model in Table 5 suggests that excess returns on the Norwegian stock market portfolio ($\Delta ose - i$) move closely with excess returns on the international market portfolio. There is a strong negative relationship between changes in short-term interest rates and excess returns on the domestic stock market. In addition, an increase in oil prices has a positive effect on equity prices, and thereby on e.g. aggregate demand, credit growth and house prices (see Tables 1 and 9).

I model the nominal effective exchange rate (e) and aggregate import prices (pm) as a simultaneous equation system in order to take into account possible contemporaneous interdependence between them (see Table 6). The nominal effective exchange rate reflects the difference between domestic and foreign prices, a possible difference between domestic and foreign interest rates and oil prices in the long run; a lower value of the exchange rate indicates appreciation. Accordingly, domestic prices becomes fully reflected in the nominal exchange rate in the long run. The nominal exchange rate reacts to correct deviations from the purchasing power parity

Table 5: *Return on the Oslo Stock Exchange*

$$(\Delta ose - i)_t = \underset{(0.086)}{0.47}\ (\Delta msciw - i)_t + \underset{(0.083)}{0.42}\ (\Delta msciw - i)_{t-1} + \underset{(0.057)}{0.43}\ \Delta oilp_t - \underset{(0.905)}{2.74}\ \Delta i_t + \widehat{\varepsilon}_{ose,t}$$

$$\widehat{\sigma}_{ose} = 0.070$$

Summary statistics				
AR 1-5	F(5,63)	=	0.993	[0.429]
ARCH 1–4:	F(4,64)	=	0.117	[0.976]
Hetero test	F(8,63)	=	4.681	[0.000]**
Normality	$\varkappa^2(2)$	=	2.323	[0.313]
RESET23	F(2,66)	=	6.577	[0.003]**
Sample period:	1992Q4–2010Q3			
Estimation method:	OLS			

Note: Parentheses below the coefficient estimates include standard errors. *AR* 1-5 denotes an LM test of the null hypothesis of no autocorrelation up to order 5 in the errors (see Harvey (1990)). *ARCH* 1–4 is an LM test for the null hypothesis of unconditional homoscedasticity of errors against the alternative hypothesis of autoregressive conditional heteroscedasticity up to order 4 of errors (see Engle (1982)). *Hetero* test, tests the null of unconditional homoscedasticity of errors against the alternative hypothesis of heteroscedasticity, as proposed by White (1980). *Normality* tests the null hypothesis of normally distributed errors as suggested by Doornik and Hansen (1994). *RESET23*, a general regression specification test based on Ramsey (1969), tests the null of correct specification of the specified model by testing the significance of the 2. and 3. power of the fitted value of the left-hand-side variable. p-values are presented in square brackets. An $*$ indicates rejection of the null hypothesis at the 5% level, while two $*$s denote rejection at the 1% level. The estimation and tests of this model and of the other models have been undertaken using the PcGive module of OxMetrics 6.20 (see www.doornik.com).

relationship and thereby contributes to stabilizing the real exchange rate. In the short run, the nominal exchange rate appreciates when the interest rate and/or the interest rate differential increases, ceteris paribus. Also, higher oil prices tend to appreciate the nominal exchange rate in the short run as well as in the long run. This is as expected given the relatively large volume of Norwegian petroleum exports, which constitute more than half of Norwegian exports.

There is a complete pass-through of the nominal exchange rate and foreign export prices (px) to aggregate import prices in the long run (see Table 6). In the short run, cost-push variables such as higher growth in real wages relative to growth in labour productivity ($\Delta(w-p-z)$) and domestic economic activity (Δy) contribute to higher import prices. Such effects could be reflecting a procyclical mark-up on import costs, perhaps owing to pricing-to-market behaviour by exporters.

Table 6: *A system of the nominal effective exchange rate and import prices*

$$
\begin{aligned}
\Delta e_t \quad = \quad & \underset{(0.066)}{-\ 0.29}\ (e-(p-p^f))_{t-1} + \underset{(0.207)}{\ 0.51}\ \Delta_4 p_{t-1} - \underset{(0.138)}{\ 0.33}\ (i-i^f)_t \\
& \underset{(0.714)}{-\ 2.17}\ \Delta(i-i^f)_t \times \mathrm{IT} \ - \underset{(0.002)}{\ 0.009}\ oilp_t \times \mathrm{IT} \\
& + \underset{(0.016)}{\ 0.09}\ \mathrm{id08Q4}_t \ + \underset{(0.298)}{\ 1.32}\ + \widehat{\varepsilon}_{e,t} \\
& \widehat{\sigma}_e = 0.0150 \\
\Delta pm_t \quad & \underset{(0.033)}{-\ 0.056}\ [pm-(e+px)]_{t-1} \ + \underset{(0.135)}{\ 0.56}\ \Delta px_t + \underset{(0.136)}{\ 0.48}\ \Delta px_{t-1} \\
& + \underset{(0.076)}{\ 0.43}\ \Delta e_t \ + \underset{(0.074)}{\ 0.30}\ \Delta[(w-p)-z)]_{t-1} + \underset{(0.0817)}{\ 0.46}\ \Delta y_{t-1} \\
& \underset{(0.006)}{-\ 0.03}\ Q1 - \underset{(0.152)}{\ 0.27}\ + \widehat{\varepsilon}_{pm,t} \\
& \widehat{\sigma}_{pm} = 0.0111
\end{aligned}
$$

Summary statistics				
Vector SEM-AR 1-5	F(20, 98)	=	0.74	[0.783]
Vector Normality test:	$\mathrm{Chi}^2(4)$	=	4.08	[0.395]
Vector Hetero test:	F(63,129)	=	1.23	[0.166]
Sample period:	1994Q2–2010Q4			
Estimation method:	FIML			

Note: *Vector SEM-AR* 1-5, is a vector error autocorrelation test of the null hypothesis of no autocorrelation up to order 5 of errors. *Vector Normality test* and *Vector Hetero test* are the multivariate equivalent tests of the single equation normality test and heteroscedasticity test, respectively. See Tables 5 for information about model estimation and tests.

Wages (w), consumer prices (p) and labour productivity (z) are also modelled as a simultaneous equation system (see Table 7). The wage equation suggests a partial pass-through of consumer price inflation to nominal wage growth in the short run. In each period, nominal wages also adjust towards their long-run relationship where there is a full pass-through of consumer prices and productivity. However, the mark-up of wages on prices and productivity falls with the unemployment rate.

In the short run, consumer price inflation varies with changes in aggregate demand and to some extent nominal wage growth (see Table 7). In addition, it adjusts to correct deviations from the long-run relationship for consumer prices. In the long run, consumer prices reflect a weighted average of domestic and imported costs, represented by unit labor costs and import prices.

The equation for labour productivity is rather rudimentary, as it is inherently

Table 7: *A system of wages, consumer prices and labour productivity*

$$
\begin{aligned}
\Delta w_t \;=\; & \underset{(0.028)}{-\,0.13} \;-\; \underset{(0.054)}{0.59}\,\Delta w_{t-1} \;-\; \underset{(0.068)}{0.36}\,\Delta w_{t-2} - \underset{(0.064)}{0.15}\,\Delta w_{t-3} \\
& - \underset{(0.038)}{0.13}\,\Delta w_{t-4} + \underset{(0.19)}{0.58}\,\Delta p_{t-1} + \underset{(0.115)}{0.46}\,\Delta z_t \;-\; \underset{(0.035)}{0.21}\,[w-p-z]_{t-1} \\
& - \underset{(0.005)}{0.026}\,u_{t-1} \;+\; \underset{(0.011)}{0.066}\,\mathrm{Q3} \;+\; \underset{(0.020)}{0.13}\,\mathrm{Q4} \;+\; \underset{(0.016)}{0.044}\,\mathrm{WD1}_t \\
& - \underset{(0.003)}{0.018}\,\mathrm{WD2}_t \\
& \qquad \widehat{\sigma}_w = 0.019
\end{aligned}
$$

$$
\begin{aligned}
\Delta p_t \;=\; & \underset{(0.013)}{0.19}\,\Delta_3 p_{t-2} + \underset{(0.013)}{0.098}\,\Delta y_{t-1} \;+\; \underset{(0.011)}{0.15}\,\Delta_2(w-z)_t \;-\; \underset{(0.015)}{0.07}\,\Delta z_{t-3} \\
& + \underset{(0.012)}{0.028}\,\Delta pm_t - \underset{(0.010)}{0.029}\,[p - 0.78(w-z) - 0.22pm \;- 0.72]_{t-1} \\
& + \underset{(0.004)}{0.051}\,\Delta pel_t - \underset{(0.002)}{0.020}\,\mathrm{Q4} + \underset{(0.004)}{0.012}\,\mathrm{id80Q1} - \underset{(0.004)}{0.017}\,\mathrm{PD1}_t \\
& \qquad \widehat{\sigma}_p = 0.0046
\end{aligned}
$$

$$
\begin{aligned}
\Delta z_t \;=\; & \underset{(0.047)}{0.39}\,\Delta z_{t-4} + \underset{(0.035)}{0.26}\,\Delta y_{t-4} \;+\; \underset{(0.020)}{0.34}\,\Delta(w-p)_t \\
& - \underset{(0.048)}{0.22}\,[z - \{0.49(w-p) + 0.04u + 0.0021t + 3.171\}]_{t-1} \\
& + \underset{(0.003)}{0.013}\,Q1 + \underset{(0.004)}{0.02}\,Q4 - \underset{(0.010)}{0.041}\,id06Q1 \\
& \qquad \widehat{\sigma}_z = 0.010
\end{aligned}
$$

Summary statistics				
Vector SEM-AR 1-5	F(45, 297)	=	1.619	[0.011]
Vector Normality test:	$\mathrm{Chi}^2(6)$	=	9.954	[0.127]
Vector Hetero test:	F(372, 361)	=	1.657	[0.000]**
Sample period:	1979Q2–2010Q4			
Estimation method:	FIML			

Note: A system of three equations estimated by FIML using time series data over the period 1992Q4–2010Q4. See Tables 5-6 for more information.

difficult to explain productivity growth. One interpretation of the equation derived is that the productivity level follows a deterministic trend as well a real wages in the long run, which also have positive short-run effects on productivity. A positive relationship between real wages and productivity is consistent with efficiency wage models. The latter models can also explain positive effects of the unemployment rate. I also find that labour productivity tends to be procyclical in the short run as it tends to increase in booms and fall in recessions. This could be a reflection of labour hoarding in firms, which implies that output falls more than labour in

downturns and increases by more than employment in upturns.

The model of core inflation (Δpc) in Table 8 reflects its definition, which is CPI inflation adjusted for energy prices (i.e. electricity and oil prices) and indirect taxes.

Table 8: *Core CPI inflation*

$$\begin{aligned}\Delta_4 pc_t = {} & \underset{(0.176)}{0.9}\ \Delta_4 p_t - \underset{(0.012)}{0.028}\ \Delta pel_t - \underset{(0.012)}{0.031}\ \Delta pel_{t-1} - \underset{(0.010)}{0.035}\ \Delta pel_{t-2} \\ & - \underset{(0.012)}{0.038}\ \Delta pel_{t-3} - \underset{(0.012)}{0.019}\ \Delta oilp_t - \underset{(0.009)}{0.025}\ \Delta oilp_{t-1} \\ & - \underset{(0.01)}{0.035}\ \Delta oilp_{t-2} - \underset{(0.011)}{0.033}\ \Delta oilp_{t-3} + \underset{(0.003)}{0.0043} + \widehat{\varepsilon}_{pc,t}\end{aligned}$$

$$\widehat{\sigma}_{pc} = 0.0046$$

Summary statistics				
AR 1-5	F(5,12)	=	4.562	[0.015]*
ARCH 1–4:	F(5,19)	=	0.327	[0.856]
Hetero test	F(18,8)	=	0.744	[0.715]
Normality	$\varkappa^2(2)$	=	0.603	[0.740]
RESET23	F(2,15)	=	0.616	[0.553]
Sample period:	2001Q2–2007Q4			
Estimation method:	OLS			

Note: A technical equation for determining core inflation. See Table 5 for information about model estimation and the tests.

Aggregate demand in the relatively open Norwegian economy follows foreign GDP (y^f), real exchange rate movements and real lending rates (see Table 9). Moreover, real equity returns and house prices, in particular, have effects on aggregate demand which may be interpreted as wealth effects. I also find effects on aggregate demand of credit to households and firms. There are also positive short-run effects on aggregate demand of growth in government expenditures.[15]

The (registered) unemployment rate follows output growth in the short run, as in the Okun's law relationship (see Table 10). In addition, it reverts slowly towards a constant rate. The unemployment also falls with higher real equity returns which could be interpreted as an effect of current and/or expected higher earnings in financial and non-financial firms.

[15] I have not found any significant direct effect of oil prices on aggregate demand (in the mainland economy). However, oil prices indirectly affect aggregate demand through their positive effects on equity prices and the nominal exchange rate. One reason for the absence of direct oil price effects could be that the effects of oil prices are already taken into account by the government consumption variable. Norwegian oil revenues are invested abroad, while the return on the petroleum assets abroad is spent by the central government in accordance with a fiscal policy rule.

Table 9: *A single equation model of Norwegian (mainland) GDP*

$$
\begin{aligned}
\Delta y_t \;=\; & -\underset{(0.088)}{0.52}\,\Delta y_{t-1} - \underset{(0.053)}{0.13}\,(y-y^f)_{t-1} + \underset{(0.061)}{0.18}\,\Delta(e+p^f-p)_t \\
& - \underset{(0.094)}{0.04}\,(i^L-\Delta_4 p)_{t-1} + \underset{(0.057)}{0.59}\,\Delta cg_t + \underset{(0.079)}{0.28}\,\Delta cg_{t-1} \\
& + \underset{(0.014)}{0.036}\,\Delta(\text{ose}-p)_t + \underset{(0.013)}{0.041}\,\Delta(\text{ose}-p)_{t-1} + \underset{(0.048)}{0.13}\,\Delta(ph-p)_{t-3} \\
& + \underset{(0.101)}{0.29}\,\Delta(crh-p)_{t-3} + \underset{(0.05)}{0.051}\,\Delta(crf-p)_{t-5} \\
& + \underset{(0.44)}{1.05} - \underset{(0.006)}{0.049}\,\text{Q1} - \underset{(0.007)}{0.054}\,\text{Q3} - \underset{(0.006)}{0.034}\,\text{Q4} + \widehat{\varepsilon}_{y,t}
\end{aligned}
$$

$\widehat{\sigma}_y = 0.0107$

Summary statistics				
AR 1-5	F(5,56)	=	2.135	[0.075]
ARCH 1–4:	F(4,68)	=	0.633	[0.641]
Hetero test	F(25,50)	=	0.968	[0.521]
Normality	$\varkappa^2(2)$	=	1.691	[0.429]
RESET23	F(2,59)	=	1.139	[0.327]
Sample period:	1991Q1–2009Q4			
Estimation method:	OLS			

Note: See Table 5 for information about estimation and model evaluation.

Table 10: *A single equation model of the registered unemployment rate*

$$
\begin{aligned}
\Delta u_t \;=\; & \underset{(0.063)}{0.32}\,\Delta u_{t-1} + \underset{(0.070)}{0.43}\,\Delta u_{t-4} - \underset{(0.015)}{0.038}\,u_{t-1} + \underset{(0.017)}{0.059} \\
& - \underset{(0.234)}{0.59}\,\Delta_2 y_{t-1} - \underset{(0.025)}{0.13}\,\Delta_3(ose-p)_t - \underset{(0.193)}{0.38}\,\Delta cg_t \\
& + \underset{(0.031)}{0.23}\,\text{Q1} + \underset{(0.024)}{0.14}\,\text{Q4} + \widehat{\varepsilon}_{u,t}
\end{aligned}
$$

$\widehat{\sigma}_u = 0.051$

Summary statistics				
AR 1-5	F(5,95)	=	0.999	[0.422]
ARCH 1–4:	F(4,101)	=	0.491	[0.741]
Hetero test	F(14,94)	=	1.468	[0.139]
Normality	$\varkappa^2(2)$	=	4.425	[0.109]
RESET23	F(2,98)	=	4.104	[0.019]*
Sample period:	1983Q4–2010Q4			
Estimation method:	OLS			

Note: See Table 5 for information about estimation and model evaluation.

Finally, I let the short-term money market interest rate represent the key policy rate and model it as a Taylor-type interest rate rule with interest rate smoothing (see Table 11). The short run rates respond to deviations between core inflation and the inflation target of 2.5%, and deviations from the natural unemployment

Table 11: *Interest rate rule for short-term money market rates*

$$i_t = (1-0.69)(\underset{(0.005)}{0.06} + \underset{(0.266)}{2.15}\,(\Delta_4 pc - 0.025)_t - \underset{(0.012)}{0.04}\,\log(\tfrac{U_t}{3.5})) + \underset{(0.059)}{0.69}\,i_{t-1} + \widehat{\varepsilon}_{i,t}$$

$\widehat{\sigma}_i = 0.0029$

Summary statistics				
AR 1-3	F(3, 20)	=	4.117	[0.020]*
ARCH 1–3:	F(3, 21)	=	0.484	[0.697]
Hetero test	F(6, 20)	=	1.182	[0.355]
Normality	$\varkappa^2(2)$	=	2.999	[0.223]
Sample period:	2001Q2–2007Q4			
Estimation method:	NLS			

Note: See Table 5 for information about estimation and model evaluation.

rate, assumed to 3.5%. I use the unemployment gap instead of the output gap, which may be more prone to measurement errors than the unemployment rate. I include one lag of the interest rate to take into account interest rate smoothing. When estimating the coefficient estimates, I also limited the sample period to the period of 2001Q2–2007Q4, as inflation targeting in Norway was formally introduced in March 2001 and to avoid influencing coefficient estimates with the turbulence in the money market rate during the recent financial crisis and the associated monetary policy actions.

C. Robustness to changes in the sample period?

I have tested the stability of each of the equations in the macroeconometric model by estimating them recursively on increasingly larger data samples and examining estimates of their (main) parameters for changes. I have also conducted a number of break point tests (cf. Chow (1960)). In the latter tests, one looks for unusually large one-step or several-step ahead prediction errors after estimating the model each time. Such prediction errors can reflect shifts in parameter estimates;

Overall, I find parameter estimates in equations of variables that have not been directly affected by policy changes to be fairly stable over time. In particular, there is no evidence of changes in parameter estimates coinciding with the introduction of inflation targeting in 2001 and the introduction of Basel II framework in 2007.

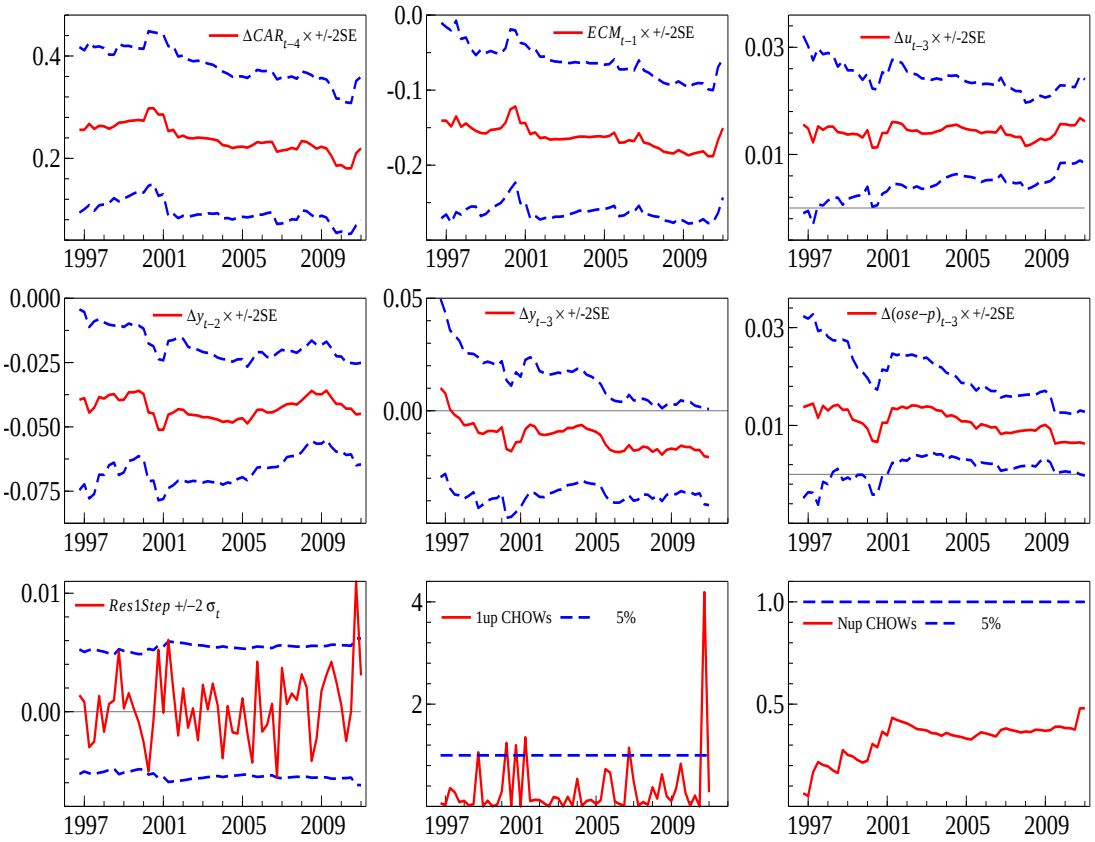

Figure 7: *Recursive OLS estimates (+/- 2SE) of main parameters in the equation for the capital adequacy ratio (see Table 1). The initial estimates are based on the sample period 1992Q4–1997Q1, which is extended by one observation at at time until the full sample 1992Q4–2010Q4 is used to obtain the final estimates. In the bottom panel: recursive one-step ahead prediction errors and recursive estimate of the standard errors of residuals, followed by plots of recursively obtained statistics of break point Chow tests scaled by their critical values at the 5% percent level. Values higher than one indicate rejection of the null hypothesis of parameter stability at the 5% level of significance.*

Parameter estimates in equations of variables that have been directly affected by regulations such as capital adequacy ratio also seem to be remarkably stable over time, even around period of the regulatory changes.

For example, Figure 7 shows recursive estimates for the main parameters in the equations for capital adequacy ratio (CAR). It is seen that the parameter estimates do not display significant changes over the sample periods; they are well within the 95% confidence bands over increasingly larger samples. The lack of evidence against the null hypothesis of parameter stability in the equation for capital adequacy ratio is notable given the introduction of Basel II in 2007 as well as the recent financial crisis. It is too early, however, to conclude on possible effects of the recent financial crisis on

the parameter estimates of this equation. So far, I have observed a relatively large increase in the capital adequacy ratio in 2010Q4 whose effect has been controlled for by including an impulse dummy in the equation for the capital adequacy ratio.

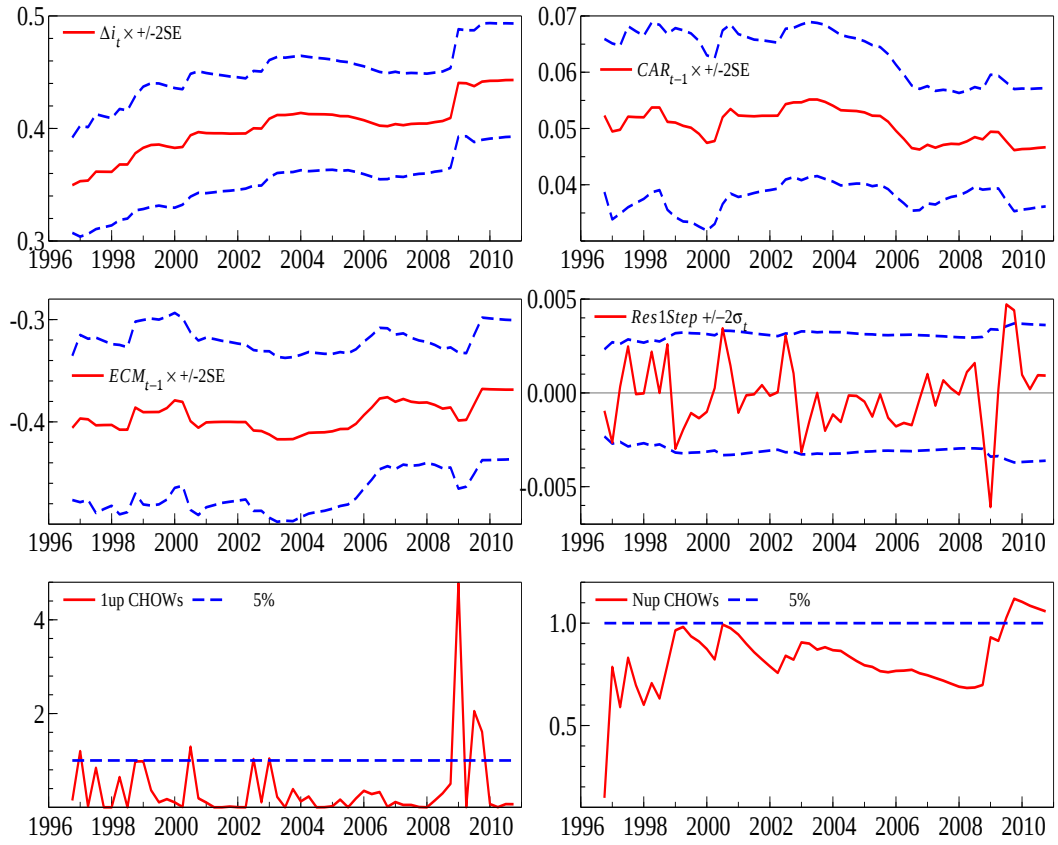

Figure 8: *Recursive OLS estimates (+/- 2SE) of main parameters in the lending rate equation (see Table 1). The initial estimates are based on the sample period 1992Q4–1997Q1, which is extended by one observation at a time until the full sample 1992Q4–2010Q4 is used to obtain the final estimates. The middle panel displays recursive one-step ahead prediction errors and recursive estimate of the standard errors of residuals. The bottom panel shows plots of recursively obtained statistics of break point Chow tests scaled by their critical values at the 5% percent level. Values higher than one indicate rejection of the null hypothesis of parameter stability at the 5% level of significance.*

However, in equations of variables that have been directly affected by changes in policy, some parameter estimates display shifts in periods coinciding with the policy changes. This applies to equations for the nominal effective exchange rate, wages, consumer prices, the short-term interest rate and the lending rate. The parameter instabilities associated with policy changes have been reduced by using dummy variables for the relevant periods, or by discarding observations under previous policy regimes, to simplify the relevant equations.

In the nominal effective exchange rate equation, the effects of the interest rate differential and oil prices become stronger after the formal move from exchange rate targeting to inflation targeting in 2001Q1. This has been taken into account by a multiplicative step dummy (IT), which changes its value from zero to 1 in 2001Q1. While the parameter estimates in the equations for wages and prices do not display any shift coinciding with the change in the monetary policy regime, the wages and prices seem to be affected by the introduction and the subsequent removal of several wage and price freezes during the 1970s and the 1980s. I have controlled for their effects by dummy variables. The behaviour of the short-term interest rate also changes around the time of the shift in the monetary policy regime. The Taylor-type interest rate rule has therefore been estimated using observations from 2001Q1 onwards.

I have also found small but statistically significant changes in the coefficient estimate associated with the short-term interest rate in the equation for the lending rate. The shifts seem to occur quite abruptly in the autumn of 2008 (see Figure 8). The break point tests in the lower panel of the figure also indicate possible changes in the parameter estimate from the autumn of 2008 onwards. The change in the pass-through of the short-term rates to the lending rate may be associated with the possible effects of the recent financial crisis on the money market and on the accompanying changes in monetary policy and regulatory policy proposals. The Norwegian money market was affected by the Lehman default in mid-September 2008 and the defaults in late September and October 2008 of two Icelandic banks, Glitnir and Kaupthing, respectively, which also had branches in Norway.

Finally, I have examined to what extent the impulse responses of financial and real economic variables presented in Figure 2 are influenced by data observations from the period since early 2007. To this end, I have reestimated the VECM presented in Table 1 using data only up to 2006Q4 and implemented it in the macroeconometric model. Figure 9 shows that the responses are comparable to those presented in Figure 2, which is based on the full sample.

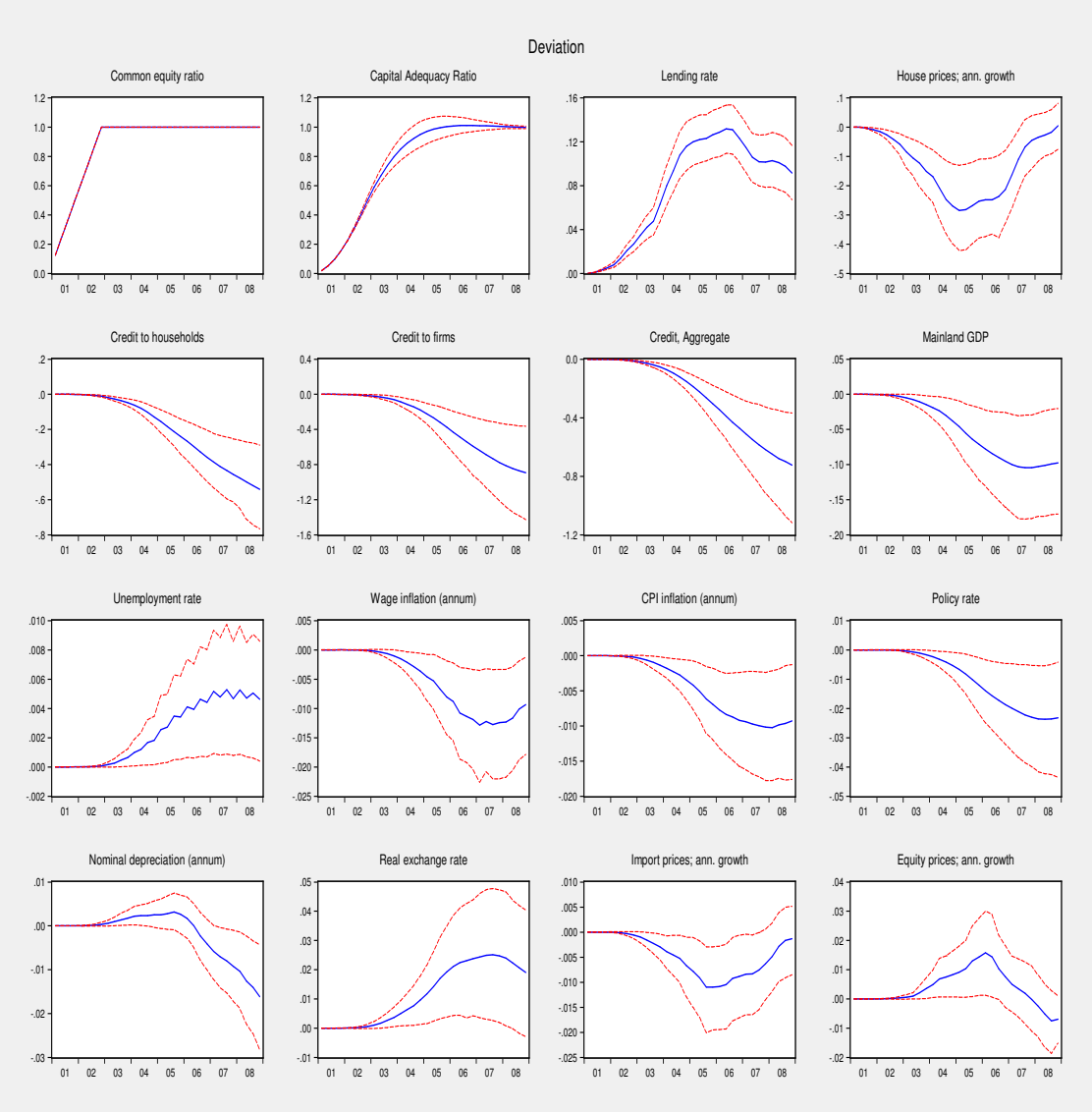

Figure 9: *Response analyses under Basel I; the VECM in Table 1 has been estimated using data only up to 2006Q4. Graphs show responses (+/- SE) to a one percentage point permanent increase in the common equity ratio when monetary policy follows a Taylor-type rule. The implementation period is of 8 quarters and the simulation period is of 32 quarters. The vertical axes denote values in percentage points for the common equity ratio, capital adequacy ratio, lending rate, key policy rate and unemployment rate. For the other variables, the vertical axes denote values in percent.*

D. Effects of higher capital requirements

Figure 10 shows the effects of a temporary increase in capital requirements. Figure 11 shows the effects of a permanent increase when monetary policy does not respond to macroeconomic changes owing to higher capital requirements, as in one of the main exercises in the MAG study.

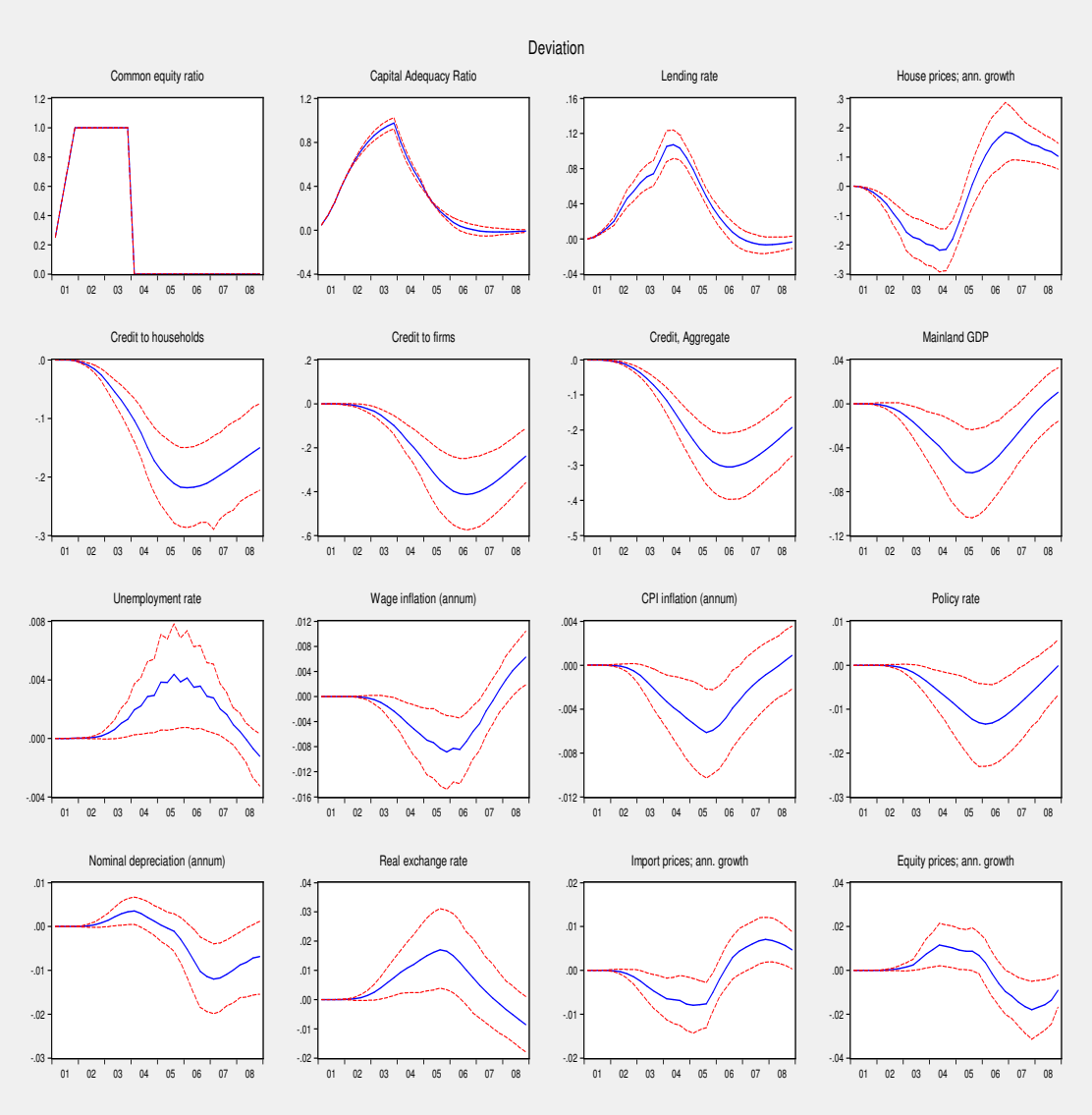

Figure 10: *Responses (+/- SE) to a one percentage point temporary increase in the common equity ratio for two years when monetary policy follows a Taylor-type rule. The implementation period is of 4 quarters and the simulation period is of 32 quarters. The vertical axes denote values in percentage points for the common equity ratio, capital adequacy ratio, lending rate, key policy rate and unemployment rate. For the other variables, the vertical axes denote values in percent.*

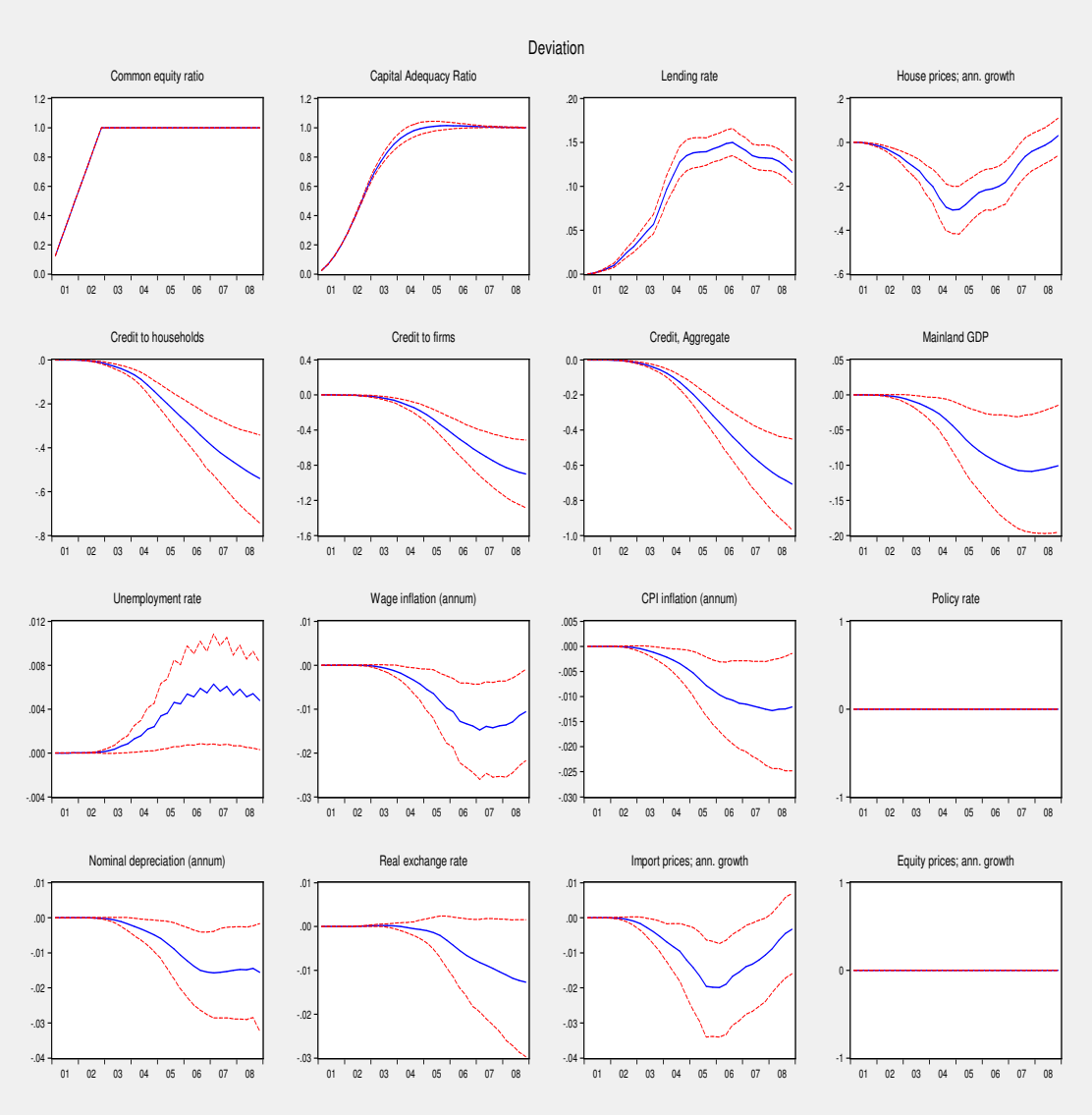

Figure 11: *Responses (+/- SE) to a one percentage point permanent increase in the common equity ratio when monetary policy rate is given. The implementation period is of 8 quarters and the simulation period is of 32 quarters. The vertical axes denote values in percentage points for the common equity ratio, capital adequacy ratio, lending rate, key policy rate and unemployment rate. For the other variables, the vertical axes denote values in percent.*