

The effects of a countercyclical capital buffer in a DSGE model for Switzerland

Master Thesis

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Date of submission:	14.07.2017

Abstract

This thesis explores the impact of a countercyclical capital buffer on the economy. A small open economy DSGE model is estimated using Swiss data.

The analysis of the impulse response functions during a build-up phase after a positive return on equity shock shows how the buffer leads to a higher equity-to-loans ratio given a positive deviation of the credit-to-GDP gap. Furthermore, a dampening effect on the credit-to-GDP gap, serving as an indicator for the state of the financial sector, is observed. The amount of loans and deposits given a positive deviation of the gap lies below the one of an economy where no countercyclical capital buffer is implemented. The same conclusions are reached when looking at shocks from other sectors. The shock from the financial sector also has a mitigating effect on the main macroeconomic variables outside the financial sector. The analysis showed that the buffer reaches the goal in enhancing the resistance of the banking sector by building up the equity-to-loans ratio. Furthermore it dampens the imbalances during the build-up phase.

The thesis also looks at the welfare costs which are according to the results -0.02% in terms of consumption. Therefore, the countercyclical capital buffer is welfare enhancing.

Furthermore, the analysis of the volatilities of the main financial variables and the credit-to-GDP gap showed that the buffer exerts a dampening effect. The impact on typical macroeconomic variables depends on the variable. The buffer does also not induce any sign change in the correlations of the absorption respectively the GDP with the main macroeconomic and financial variables.

Finally it is shown that the buffer is robust to monetary policy.

Acknowledgments

My special gratitude goes to Prof. Dr. Collard who supervised this thesis. I thank him for his advices and the several constructive feedback.

Furthermore, I would like to thank my family and Alvaro for their support during my Bachelor and Master studies.

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1 Introduction

This master thesis explores the effects of a countercyclical capital buffer in a DSGE model for Switzerland. The countercyclical capital buffer is part of the Basel III regulations and was introduced into Swiss legislation in 2012 (ERV, 2012 [33] and SNB, 2014 [51]). The countercyclical capital buffer enhances the resistance of the banking sector against excessive credit growth and leans against those imbalances (ERV, 2012 [33] and SNB, 2014 [51]).

The financial crisis revealed the necessity and importance of regulation in the banking sector. For Switzerland with its large banking sector, regulation is especially important. Regarding the countercyclical capital buffer Switzerland takes a forerunner role with its early introduction (SNB, 2014 [51]).

Assessing how the countercyclical capital buffer would have influenced the Swiss economy in the past is challenging. How the buffer is implemented in Swiss legislation it would for example have been activated in the late 1980s and the early 1990s. According to the Swiss National Bank (SNB) the countercyclical capital buffer would have substantially increased the resilience of the banking system. Next to a moderating effect on the market in the second half of the 1980s it would have absorbed a large part of the losses due to the crisis (SNB, 2014 [51]).

Furthermore, in 2013 a sectoral countercyclical capital buffer targeting the residential real estate in Switzerland was announced (SNB, 2017 [52]). According to the report of the SNB in January 2014 the activation let several banks, among them also important ones, to take actions regarding their capital. This contributed to the strength of the sector. Furthermore, Danthine (2012, [24]) points out that even if banks hold a significant capital cushion before the activation of the countercyclical capital buffer, the effect of the countercyclical capital buffer may be weaker but it can still be useful if it shifts lending from relatively weak banks constrained by the buffer to more resilient banks who benefit from a sufficient capital buffer.

The effects of the countercyclical capital buffer is currently researched by many and this thesis contributes to the exploration of its impact.

More specifically, the aim of this thesis is to a) explore how impulse response functions change, b) quantify the welfare costs, c) explore the impact on volatilities

and correlations and d) analyse the robustness to monetary policy, all with respect to the countercyclical capital buffer.

Analysation is done with a DSGE model of a small open economy which is calibrated and estimated using Swiss data. Dynare is used for the computations.

Section 3 discusses separately the related literature. While there exists worldwide a solid basis of literature regarding the countercyclical capital buffer almost none research exists for the Swiss case. Three studies focusing on Switzerland are Basten and Koch (2015 [11]), Junge and Kugler (2013 [40]) and Auer and Ongena (2016 [9]) which are shortly discussed in the mentioned section.

The thesis is structured as such that after a first part giving an overview over the regulation and the literature, the model is solved in a second part and the results are discussed in the last part. In more detail: In section 2 the Basel III regulations regarding the countercyclical capital buffer are described and the implementation of the buffer is discussed. Section 3 gives an overview over related literature. In section 4 the model is described and section 5 shows the deflated general equilibrium. Section 6 shortly describes the calculation of the welfare costs. Information regarding calibration and estimation can be found in section 7. In section 8 results are discussed. Finally section 9 concludes.

2 Regulation and implementation

2.1 Overview

The countercyclical capital buffer is a macroprudential instrument and an integral part of the Basel III banking regulations (Basel Committee on Banking Supervision (BC), 2011 [13]).

According to article 44 ERV (2012 [33]) and stated by the SNB (2014 [51]) the goal of the buffer is to enhance the resistance of the banking sector against excessive credit growth and to lean against those imbalances. In periods of excessive credit growth, associated with an increase in system-wide risk, the buffer is activated and if the cycle turns the buffer is released. Depending on the situation the release can happen promptly or gradually.

As history showed excessive aggregate credit growth was often associated with the build-up of system-wide risk. The countercyclical capital buffer helps to ensure that the banking sector in aggregate growth the necessary capital to absorb losses and help maintain the credit flow in times of stress in the broader financial system after excessive credit growth without risking insolvency of the banks. Furthermore, like this the risk of undermining the performance of the real economy and therefore of additional credit losses in the banking system due to constraints on the supply of credit by regulatory capital requirements may be prevented.

The countercyclical capital buffer is added on top of the capital conservation buffer. Depending on the assessment of the system-wide risks the relevant authority in each jurisdiction determines whether the buffer increases or decreases over time. The buffer size is always within the range of 0% to 2.5% of risk weighted assets (BC, 2010 [12]). Banks have to fulfill the capital requirements with common equity tier 1 (CET 1) or other fully loss absorbing capital. Otherwise the banks will be subject to restrictions on distributions (BC, 2011 [13]). Authorities monitor indicator variables and have to use their judgment when taking decisions about the buffer. Furthermore, they should follow the guidance by the Basel Committee where also main principles regarding the setting of the buffer are described.¹

Banks can have credit exposure in different jurisdictions. Therefore, each bank

¹There exist different guides and one can for example also have a look at the one for the European Union (ESRB, 2014 [34]).

has to calculate the countercyclical capital buffer it is supposed to have. It is a weighted average of the buffers in effect in the jurisdictions where a bank has credit exposure.²

Authorities review relevant information on a quarterly or more frequent basis. Communication on the stance of the buffer takes place at least once a year or more frequent when buffer actions are taken. Buffer increases are preannounced by up to 1 year before while reductions can take place immediately. The Basel Committee stresses the importance of proper explanation regarding decisions taken.

There are no restrictions on the distribution of the capital surplus when the buffer is turned off. However if the supervisory authority assesses a distribution of released capital as imprudent it can prohibit it (BC, 2010 [12]).

The countercyclical capital buffer is worldwide gradually phased in between the beginning of 2016 and the end of 2018. This does not mean that the buffer must be in action during this time period but it can with a possible maximum size growing gradually during the phase in (Bank for International Settlements (BIS), 2011 [13]).

2.2 Indicator

In this part, indicator variables for guiding the Basel III countercyclical capital buffer with a special focus on the credit-to-GDP gap are shortly discussed.³ Due to the inherent importance of finding the right indicators for the success of the buffer, quite a lot of empirical research was conducted in that direction. For example Behn et al. (2013 [14]) point out, that it is important to take a broad approach regarding indicators used for setting the countercyclical capital buffer. They conclude that next to credit variables, other domestic and global financial factors as well as banking sector variables have prediction power for vulnerable

²In Switzerland banks with a balance sheet of at least 250 billions, of which at least 10 billions correspond to their total foreign exposure, or with a total foreign exposure of at least 25 billions Swiss Francs have to hold a so called extended countercyclical capital buffer. The size of this buffer is a weighted average of the buffers in place in the jurisdictions where they have exposure to the private sector. The maximum lies at 2.5% of risk-weighted assets. The countercyclical capital buffer of Switzerland described before is eligible to the extended buffer. No extended countercyclical capital buffer exists in the context of a sectoral buffer (ERV, 2012 [33]).

³A sectoral buffer uses other or additional variables for assessment of the situation. Which indicator variables are useful for a sectoral buffer are not discussed in this section.

economic states. Drehmann et al. (2010 [27]) come to the conclusion that a system-wide approach would be preferable and that not the same variables are useful as signals for the pace and size of the accumulation of the buffer and the timing and intensity of the release. The credit-to-GDP ratio for example is well suited to indicate the build-up phase while measures of aggregate losses with a possible combination with indicators of credit conditions can signal well the release phase. Drehmann et al. (2011 [28]) come to similar conclusions.

Lozej et al. (2016 [43]), where this thesis takes the banking sector from, look at the credit-to-GDP gap and house prices as indicators for guiding the countercyclical capital buffer. Regarding rules linked to the credit-to-GDP gap, they show that the buffer has a dampening effect on the economy after a boom and bust cycle in the housing market as well as an AR(1) type housing demand shock. The same conclusion holds for exogenous unexpected shock losses on the bank portfolio. When a shock triggers an acyclical or countercyclical credit gap response the countercyclical capital buffer linked to the gap can not attenuate the shock or even amplifies it. An example for such a shock is a temporary decline in export demand. The rule responding positively to house prices reacts to all shocks they looked at procyclically and therefore, they suggest to not only look at the credit-to-GDP gap but also to take house prices into account.

Gete and Tiernan (2014 [36]) suggest to implement a countercyclical capital requirement with a value at risk rule. Edge and Meisenzahl (2011 [32]) focus on exploring the reliability of the credit-to-GDP ratio as a real time measure and find that mismeasurement and ex post revisions are sizable and can trigger incorrect shrinkage of lending volume. Finally, Drehmann and Tsatsaronis (2014 [30]) agree that there are relevant measurement issues concerning the credit gap but still, the credit-to-GDP ratio is in general the best single indicator in the countercyclical capital buffer framework.

As research shows there is not the one and only indicator variable and guidance can be based on different variables. The credit-to-GDP ratio is a repeatedly mentioned useful indicator and also recommended by the Basel Committee on Banking Supervision (2011 [13]). As the buffer in the model is also based on this ratio, in the following, figures plotting the evolution of this ratio, its trend and the gap for Switzerland and the US are shown.

Figure 1 shows the evolution of the credit-to-GDP ratio, its trend and the corresponding gap between the ratio and its trend for Switzerland. Furthermore,

an average yearly gap is calculated (smoothed gap) and the corresponding buffer that would have been in place according to this gap. Regarding interpretation of the buffer it is important to keep in mind, that the influence of the buffer itself on the gap is missing and that from 2013 on the sectoral buffer may have influenced the gap.

We notice that the credit-to-GDP ratio trend increased strongly over the last 45 years from originally around 120 percent to around 210 percent. The first two lines in the third figure indicate the reaching of the buffer maximum of 2.5% in 1978 Q3 resp. 1988 Q4. We can see that the maxima were reached before the slow down of GDP growth in Switzerland in the beginning of the 80ties (Data: Trading economics) and the outburst of the crisis in the 90ties (Bodmer, 2004 [17]).

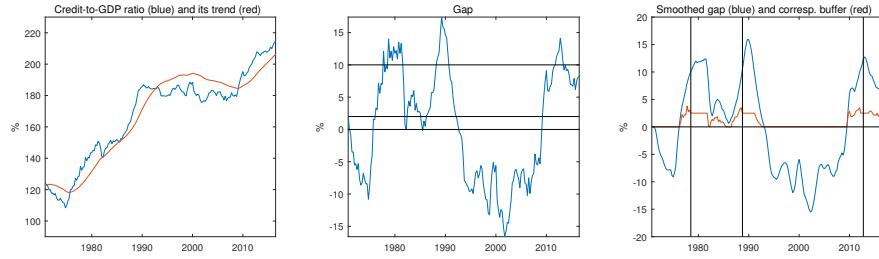


Figure 1: Credit-to-GDP ratio, gap and counter-cyclical capital buffer for Switzerland from 1970Q4-2016Q3 (Data: BIS)

For the recent financial crisis evidence is less clear. In Switzerland the recent financial crisis mainly brought the large and internationally focused Swiss banks under pressure but the regional banks were hardly affected (Jordan, 2014 [39]).

Having a look at figure 2 which shows the same data for the US where the financial crisis originated, we can see that the credit-to-GDP ratio was clearly above the trend before the outburst of the crisis. The third line indicates the first quarter of 2007 where the buffer would have reached its maximum just before the TED spread jumped up and the \$Libor rates and the Fed Funds rate were falling (Data: FRED). The evolution of the US buffer would have also been of significance for Swiss banks with credit exposure in the US due to the jurisdictional reciprocity. As discussed above, for the release of the counter-cyclical capital buffer, research showed that macro variables may not be ideal as indicators.

The last line in figure 1 indicates the last quarter in 2012, just before in the first

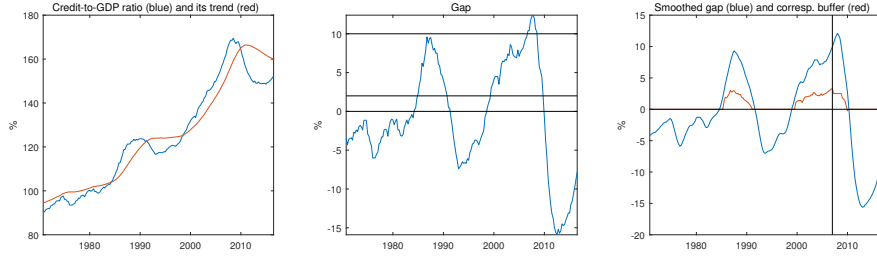


Figure 2: Credit-to-GDP ratio, gap and countercyclical capital buffer for the US from 1970Q4-2016Q3 (Data: BIS)

quarter 2013 the sectoral buffer was announced (SNB, 2017 [52]). We can see that the years before the credit-to-GDP ratio was above its trend and rising strongly. A more detailed assessment would show that the credit-to-GDP ratio was rising due to an increase in the mortgage-to-GDP ratio (SNB, 2017 [52]). After 2012 the gap slightly decreases. How much of this evolution is due to the countercyclical capital buffer is left open. Basten and Koch (2015 [11]) as well as Auer and Ongena (2016 [9]) evaluated the effects of this buffer. Their results are shortly described in section 3.

2.3 Buffer calculation

In the guidance for national authorities operating the countercyclical capital buffer (BC, 2011 [13]) the credit-to GDP ratio is also recommended as a useful common reference point for guiding buffer decisions. They suggest to calculate the buffer as follows:

$$Ratio_t = Credit_t / GDP_t * 100\%$$

$$Gap_t = Ratio_t - Trend_t$$

First the credit-to-GDP ratio in percent is calculated. For the calculation of the ratio according to the guide (BC, 2011 [13]), the annual size of GDP is used. Although this is not that clearly described in the guide, the used data for GDP can be recalculated from the reported data by the BIS.

Afterwards the long term trend is subtracted. They suggest to use the one sided HP filter with a smoothing parameter lambda of 400'000 for its calculation.

At last defined thresholds come into play for setting the buffer. The thresholds were empirically evaluated and an overview over the results can be found in the

guidance from the Basel Committee on Banking Supervision (2011 [13]). The buffer is set to zero if the gap is below 2%. If the gap is above 10% the buffer is set at its maximal size of 2.5% of risk-weighted assets. Between 2% and 10% the size of the buffer rises linearly with the gap. It is for example set to 1.25% when the gap is 6%, thus in half-way between 2% and 10%.

A broad definition of credit that includes all sources of debt funds for the private sector (including funds raised abroad) is used. Ideally all credit given to households and other non-financial private entities in an economy independent of form and supplier should be included.

Reasons for using such a broad definition are prediction precision, prevention of giving wrong incentives and the fact that also banks not directly driving credit growth can suffer from its consequences. The last fact is also the reason why the buffer applies to all banks having credit exposure in a certain jurisdiction.

According to the Basel Committee on Banking Supervision (2011 [13])⁴ looking at the past performance, the credit-to-GDP ratio would have often been a useful guide in taking buffer decisions. Furthermore, it takes into account the size of the economy, the stage of development of the financial system, it is smoother than other variables, minimizes spurious volatility and directly targets the objective wanted to be reached. But they also stress the importance of judgment, discretion and adequate communication as also the credit-to-GDP ratio did not correctly signal the imbalances at all times in all places. Additionally, as already mentioned, research also showed that macro variables may not be optimal indicator variables for signaling the release phase (BC 2011 [12]). Indicators of banking sector conditions, asset prices and spreads are named in the guidance by the Basel Committee on Banking Supervision (2011 [12]) as possible indicators. Results from the evaluation of these variables are mixed and a summary can be found in the guidance for national authorities.

2.4 Implementation in Switzerland

Switzerland introduced the countercyclical capital buffer ahead of schedule (SNB, 2014 [51]). Since July 2012 the buffer can be activated according to Art. 44

⁴They base their recommendation on the results from the BIS Working Paper of Drehmann et al. (2010 [27]).

ERV (ERV, 2012 [33] and SNB, 2014 [51]). The countercyclical capital buffer is implemented as such that it can target the whole credit market (consistent with the Basel III rules) or just a sector of the credit market (SNB, 2017 [52]). The buffer applies to all Swiss Banks as well as to subsidiary companies of foreign banks in Switzerland and has to be fulfilled with CET1 capital.

The SNB consults the Swiss Financial Market Supervisory Authority (FINMA) before it makes an official proposal to the Federal Council. The Federal Council then takes a final decision.

The SNB uses a “guided discretion” approach for building its opinion. Guidance corresponds to the systematic analysis and aggregation of main quantitative indicators while discretion especially plays a role when the main indicators do not indicate a homogeneous picture of the situation. In the latter case a broader set of quantitative and qualitative indicators is taken into account. The buffer size is set proportional to the extent of imbalances. Historical experiences help in assessing the situation. In normal times the buffer should be zero (SNB, 2014 [51]).

Switzerland already made first experience in using the countercyclical capital buffer. A sectoral countercyclical capital buffer of 1% of relevant risk-weighted positions targeting the residential real estate situated in Switzerland was announced in February 2013. The buffer was subsequently increased to 2% (SNB, 2017 [52]). As mentioned in the introduction, the activation contributed to the strength of the sector as several banks took actions regarding their capital (SNB, [51]).

3 Literature overview

Due to the worldwide importance of the Basel regulations, research regarding the countercyclical capital buffer was conducted in different institutions all over the world and with different goals and approaches to reach them. The following section gives an overview with some focus on the impact on volatility and welfare as well as the effects of the buffer given the conduct of monetary policy. Also three studies focusing on the Swiss case are mentioned.

Research on the impact of the buffer was mainly conducted using theoretical models as the countercyclical capital buffer was in most countries not yet introduced and data was therefore not available.

Agénor et al. (2014 [2]) use a small open economy DSGE model to assess the effects of a countercyclical capital buffer on macroeconomic and financial stability. According to them countercyclical capital buffers are able to strength both types of stability. However they also point out that due to diminishing returns countercyclical capital buffers should be complemented with other macroprudential policies. Agénor et al. (2015 [3]) also study the effects of countercyclical capital buffering and come to the conclusion that a buffer helps mitigating macroeconomic and financial volatility. Angelini et al. (2015 [6]) use several macroeconomic and econometric models to explore long-lasting effects of the Basel III reform. Regarding the countercyclical capital buffer they come to the conclusion that it can enhance the dampening effect on output volatility the Basel III reform exerts. Clancy and Merola (2017 [22]) conclude that it helps limiting the damage in economic downturns if banks are forced to build up capital in an economic upswing driven by over-optimistic expectations. The economies ability to absorb negative shocks can furthermore be boosted with a more aggressive action during the release phase. Lastly, de Carvalho and Castro (2015 [25]) show that results may depend on the origin of the shocks. Their research reveals that countercyclical capital buffers help mitigating the effects of adverse shocks to the credit market when the shocks originate in the financial system. If the shock comes from the real sector, the power of the buffer is much lower.

Christensen et al. (2011 [21]), Mimir and Sunel (2015 [45]) and Angelini et al. (2014 [7]) also include the interaction of the countercyclical capital buffer with monetary policy in their research. Christensen et al. (2011 [21]) conclude regarding monetary policy that there may exist strong interactions with banking

regulation policy. Especially the stabilizing effects of the countercyclical capital buffer after a productivity shock is depending on the policy response of monetary authorities. Mimir and Sunel (2015) [45] study the quantitative performance of lean-against-the-wind-type monetary policy rules and reserve requirement rules after shocks on macroeconomic, domestic and external financial stability. Regarding countercyclical reserve requirements targeting a stabilization of credit spreads they find that in combination with a conventional Taylor-type rule it can effectively reduce welfare costs. Effects are especially pronounced under external financial shocks. Angelini et al. (2014 [7]) come to the conclusion that in “normal times” macroprudential policy in the form of a countercyclical requirement could damage rather than enhance macroeconomic stability if there is a lack of cooperation with monetary policy. In the case of financial shocks a countercyclical requirement reduces the volatility of output and the loans-to-output ratio no matter if authorities cooperate or not. De Resende et al. (2013 [26]) show that key stabilizing effects on key macroeconomic variables are most pronounced after financial shocks.

Several researches also focus on the analysis of welfare. For example Aliaga-Diaz et al. (2011 [4]) come to the conclusion that anticyclical capital requirements improve welfare. The reason is that it makes consumption more stable although it can make investment more volatile. Karmakar (2013 [41]) concludes that a countercyclical capital requirement regime can help reduce fluctuations and raise welfare. He comes to the conclusion that the household has welfare gains of about 1.11% of consumption under the countercyclical scheme in contrast to a fixed capital requirement regime. The gains stem from the bank having to adjust less in economic downturn to remain solvent and the household anticipating this benefit. Benes and Kumhof (2015 [16]) also find that a countercyclical capital buffer induces a significant increase in welfare. Rubio and Carrasco-Gallego (2015 [48]) differentiate between the welfare gains of borrowers, savers and the bank. They come to the conclusion that borrowers and savers gain from the implementation of the countercyclical capital buffer while the bank loses welfare given optimal monetary policy.

As already shortly mentioned, empirical research exploring the effects of an introduced countercyclical capital buffer was only done to a limited extent due to the lack of experience. Spain is an exception in that regard. Spain introduced in 2000 “dynamic” provisioning, modified it four times and tested it in its counter-

cyclicality during the crisis, (Jimenez et al. 2015 [38]). Jimenez et al. (2015 [38]) analyse the experience of Spain. They find that dynamic provisioning dampens credit supply cycles and has pronounced positive aggregate firm-level credit, employment and survival effects in crisis times. Furthermore, they describe important compositional effects in credit supply.

Drehman and Gambacorta (2012 [29]) focus as well on Spain. They find a dampening effect when doing a counterfactual simulation using Spanish data.

One empirical study was also done for the case of Switzerland. Basten and Koch (2015 [11]) analyse how the countercyclical capital buffer affected mortgage pricing after Switzerland activated it. For this they explore the supply and demand side of the mortgage market. Basten and Koch (2015 [11]) come to the conclusion that the countercyclical capital buffer has reached its intended goal in shifting mortgages from less resilient to more resilient banks. Especially capital-constrained banks with small capital cushions and banks with a specialization in mortgage lending showed pronounced reactions. They furthermore conclude that banks seek to pass on the extra costs of previously issued and also by the buffer affected mortgages to the new customers. In addition they find that risk-weighting does not amplify the buffer's impact.

Another study focusing on the Swiss case was written by Junge and Kugler (2013 [40]) who look at the cyclical component of leverage. They come to the conclusion that when the trend leverage is on a higher level a measure that could reduce the cyclical component of leverage becomes more effective. Good timing and the ability to effectively stop the cyclical build-up of leverage are crucial. They furthermore point out that the countercyclical capital buffer may slow the build up of leverage but whether it is able to prevent excess is questionable.

Auer and Ongena (2016 [9]) as well focus on the implementation of the countercyclical capital buffer in Switzerland and find like Basten and Koch (2015 [11]) shifts in lending behavior. They come to the conclusion that the squeeze of lending in one place has led to an expansion in another. More specifically they show that the activation of the buffer targeting residential lending led to an increase in the amount and the cost of lending to corporations especially to small firms and those active in the commercial real estate market. It is important to point out that they also write that such an expansion may not be suboptimal or unexpected but it needs to be taken into account.

The countercyclical capital buffer leaves as a new instrument a lot of questions

in diverse directions open. Within the next years, due to the introduction of the buffer in several countries, research will most probably be boosted, simply due to the availability of empirical data.

4 The model

4.1 Literature sources

The following model is based on Lozej et al. (2016 [43])⁵ and Collard et al. [23] with own adjustments and extensions where necessary.

While the banking sector is mainly based on Lozej et al. (2016 [43]), the firm sector is taken from Collard et al. [23]. The household and other building blocks of the model base on elements from both papers.

4.2 The household

The maximization problem

The representative household maximizes lifetime utility with respect to consumption c , hours h , investment i /capital k , housing H , domestic deposits D , loans L and money M subject to its budget constraint and the evolvement of capital. P is the general price level. $\zeta_H, \zeta_{d^d}, \zeta_m$ denote the relative importance of the respective elements in the utility function and β is the discount factor. η, ι and Φ^m denote the inverse elasticity of labour supply, real domestic deposits and real money.

$$\begin{aligned} & \max_{\{c_{t+i}, h_{t+i}, H_{t+i}, D_{t+i}^d, i_{t+i}, k_{t+i+1}, L_{t+i}, M_{t+i}\}_{i=0}^{\infty}} \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i \left(\log(c_{t+i}) - \zeta_{h,t} \frac{h_{t+i}^{(1+\eta)}}{(1+\eta)} \right. \\ & \left. + \zeta_H \log(H_{t+i}) + \zeta_{d^d} \frac{\left(\frac{D_{t+i}^d}{P_{t+i}} \right)^{(1-\iota)}}{(1-\iota)} + \zeta_m \frac{\left(\frac{M_{t+i}}{P_{t+i}} \right)^{(1-\Phi_m)}}{(1-\Phi_m)} \right) \end{aligned}$$

⁵Note that Clancy and Merola (2017 [22]) published a paper in May where they use a slightly modified version of the model as in Lozej et al. (2016 [43]). As the model of this thesis was already implemented and analysed at this point in time, it was decided to stay with the version from Lozej et al. (2016 [43]). Clancy and Merola (2017 [22]) made several adjustments regarding the banking sector and also changed the rule of the regulatory requirement. Clancy and Merola (2017 [22]) made the model more detailed but the model by Lozej et al. (2016 [43]) is still valid. Clancy and Merola (2017 [22]) and Lozej et al. (2016 [43]) did not explore the same aspects of the countercyclical capital buffer. A comment about the paper by Clancy and Merola (2017 [22]) can be found in section 3. See section 2.2 for details about the paper by Lozej et al. (2016 [43]). As the thesis takes the banking sector from this paper but does not do a replication of the paper itself, the summary of the paper by Lozej et al. (2016 [43]) is a bit longer as other ones but it is not exhaustive.

s.t.

$$P_t c_t + P_t i_t + P_{H,t} H_t + R_{l1,t} L_{t-1} + D_t^d + E_t + M_t + \Theta_t = P_t w_t h_t + P_t z_t k_t + P_{H,t} H_{t-1} + L_t + R_{t-1} D_{t-1}^d + R_{e,t} E_{t-1} + M_{t-1} + \Pi_t^f + P e_{t-1}$$

and

$$k_{t+1} = i_t + (1 - \delta) k_t$$

L are loans, E is equity and D are domestic deposits. R_{l1} is the gross interest rate the household pays on loans after having accounted for defaults. R is the gross interest rate the household gets on deposits. R_e denotes the gross return on equity.

Investment is denoted by i and k is the capital stock. The capital stock evolves according to the equation written down above. δ denotes the depreciation rate and z is the net rental rate of capital.

P_H is the price of housing and H denotes the housing stock. The wage the household gets per hour worked is denoted by w . M stands for money. Θ are lump sum taxes which are paid to the government. Π^f are the profits of the firm sector which are rebated to households. $P e_t$, denoting the amount of penalty the bank has to pay (see section 4.3), is as well given to the household.⁶ See section 4.3 for further information regarding the latter.

First order conditions

Solving the problem⁷ of the household yields the following first order conditions:

Consumption decision

$$\Lambda_t P_t = \frac{1}{c_t}$$

Labor supply

$$\Lambda_t P_t w_t = \zeta_{h,t} h_t^\eta$$

Housing demand

$$\Lambda_t P_{H,t} = \zeta_H \frac{1}{H_t} + \beta \mathbb{E}_t \Lambda_{t+1} P_{H,t+1}$$

⁶The general equilibrium is the same, no matter if the amount of penalty is given to the household or, as another possibility, to the government.

⁷See section A.1 for the Lagrangian.

Deposit demand

$$\Lambda_t = \zeta_{d^d} \left(\frac{D_t^d}{P_t} \right)^{-\iota} \left(\frac{1}{P_t} \right) + \beta \mathbb{E}_t \Lambda_{t+1} R_t$$

Money demand

$$\Lambda_t = \zeta_m \left(\frac{M_t}{P_t} \right)^{-\Phi_m} \left(\frac{1}{P_t} \right) + \beta \mathbb{E}_t \Lambda_{t+1}$$

Investment supply

$$\Lambda_t P_t = Q_t$$

$$Q_t = \beta \mathbb{E}_t [\Lambda_{t+1} P_{t+1} z_{t+1} + Q_{t+1} (1 - \delta)]$$

Loan demand

$$\Lambda_t = \beta \mathbb{E}_t \Lambda_{t+1} R_{l1,t+1}$$

Having domestic deposits in the utility function is a way to implement that the household holds deposits as well as loans at the same time as we also see it in the real world. Without the term coming from the utility function in the first order condition of domestic deposits, the first order conditions of domestic deposits and loans would be the same except of the different interest rates. We know that the interest rate on loans is higher than the one of domestic deposits. Therefore, the two conditions couldn't hold at the same time if the term from the utility function would be missing.

Default

In each period some of the households default. Default happens if the following inequality holds:

$$\exp(u_{i,t}) F_{i,t} < \overline{F_{i,t-1}}$$

$$\text{with } F_t = \mu H_{t-1} P_{H,t} + (1 - \mu) P_t w_t h_t$$

$$\text{and } \overline{F_t} = \frac{L_t R_{l,t}}{\psi}$$

The term $\exp(u_{i,t})$ is an idiosyncratic shock term. u_t is $\mathcal{N}(0, \sigma)$. $\overline{F_{t-1}}$ is proportional to the value of loans times the gross interest rate. ψ is an inverse proportionality factor. We call $\overline{F_{t-1}}$ the relevant minimum wealth for default calculation. The individual composite wealth is a weighted sum of the value of housing and income by work. ϕ denotes the weight of housing.

The probability to default at the beginning of period t on the loan from the previous period is given by $J_t = \kappa + (1 - \kappa)\Phi\left(\frac{\log(\bar{F}_{t-1}) - \log(F_t)}{\sigma_B}\right)$. σ_B is a risk measure and Φ denotes the standard normal cumulative distribution function. κ is the proportion of households that default regardless of the state of the economy.

After defaults have taken place, resources are redistributed among households such that the composite wealth is identical for all households. Only after redistribution consumption and saving decisions take place. By the law of large numbers the probability to default is also the share of households that default.

Of a non-performing loan only a proportion χ is lost while the proportion $(1 - \chi)$ can be recovered.

4.3 The banking sector

The maximization problem

The banks balance sheet consists out of four components: loans L , domestic deposits D , foreign deposits B and equity E .

$$L_t = D_t^d + D_t^f + E_t$$

Equity evolves exogenously according to $E_t = E_{t-1} \frac{R_{e,t}}{R_e}$. R_e denotes the steady state value of R_e . Equity is only raised from returned earnings as the costs of raising equity on the financial markets are too high.

Foreign deposits evolve according to $D_t^f = R_{t-1}D_{t-1}^f - P_{x,t}x_t + P_t y_t$. See section A.13 for details about the derivation. According to the equation, the level of foreign deposits is determined by two dynamics. First, the stock of foreign deposits is augmented each period by the received interest on it. Second, the level of foreign deposits is directly influenced by the current account of the home country.

Given that E_t and D_t^f evolve exogenously and the balance sheet constraint has to hold, the bank solves the following maximization problem⁸:

⁸One could also add the term $-R_t B_t - E_t$ but as equity and foreign deposits evolve exogenously and are additive terms, they do not matter for the decision of the bank. On the same time they have to be taken into account when calculating the return on equity.

$$\begin{aligned} & \max_{L_t} \mathbb{E}_t \left(R_{l,t}(1 - \chi J_{t+1})L_t - R_t \underbrace{(L_t - D_t^f - E_t)}_{D_t^d} \right. \\ & \left. - \left(v + \frac{v_2}{2} \left(\log \left(\frac{E_t/L_t}{rcr_t} \right) \right)^2 \right) L_t \right) \end{aligned}$$

The bank optimally chooses loans to maximize its profits. R_l denotes the gross return on loans before accounting for losses due to defaults. The term $v \left(\frac{E_t}{L_t}, rcr_t \right) \equiv \left(v + \frac{v_2}{2} \left(\log \left(\frac{E_t/L_t}{rcr_t} \right) \right)^2 \right)$ is a penalty term. The bank has to pay a penalty for deviating from the regulatory capital ratio. Note that in the maximization problem the penalty is multiplied by L and so the total penalty payment is proportional to the banks balance sheet. v and v_2 are parameters. rcr is the regulatory capital ratio which should be met. See section 4.5 for details about rcr . The penalty function is a way of how to implement that the bank has an incentive to meet the requirement. In comparison to a model in which the equity-to-loans ratio is just fixed, the model with the penalty function leaves the bank more flexibility as it is also the case in the real world.

Meeting the regulations and therefore having a low penalty should be the common case. A high penalty due to a too low equity-to-loans ratio can be associated with the consequences to the bank when not meeting the requirements. Furthermore, one part of the Modigliani-Miller-theorems (1958 [46] and 1961 [44]) is that the capital structure does not matter for the value of a firm. As the assumptions underlying this theorem do not hold in the real world, capital structure matters (2010 [5]). Therefore, the penalty function can also be interpreted in this way. Karmakar (2013 [41]) uses as well a penalty function.

The first order condition

Solving the maximization problem yields the following first order condition:

$$\mathbb{E}_t(R_{l,t+1}) = R_t + v - v_2 \log \left(\frac{E_t/L_t}{rcr_t} \right) + \frac{v_2}{2} \left(\log \left(\frac{E_t/L_t}{rcr_t} \right) \right)^2$$

$$\text{with } \mathbb{E}_t(R_{l,t+1}) = \mathbb{E}_t[R_{l,t}(1 - \chi J_{t+1})]$$

$\mathbb{E}_t(R_{l,t+1})$ is the *expected* gross return on loans after losses due to defaults have been accounted for. See section A.2 for the calculation of the first order condition.

Return on equity

The profits the bank earns are added to equity. Given equity evolves as specified above, R_e is therefore as follows:

$$R_{e,t} = R_{t-1} + (R_{l1,t} - R_{t-1}) \frac{L_{t-1}}{E_{t-1}} - \left(v + \frac{v_2}{2} \left(\log \left(\frac{E_{t-1}/L_{t-1}}{rcr_{t-1}} \right) \right)^2 \right) \frac{L_{t-1}}{E_{t-1}} + (\varepsilon_{Re,t} - 1)$$

with $R_{l1,t} = R_{l,t-1}(1 - \chi j_t)$

R_{l1} is the gross return on loans after having accounted for losses due to defaults. $\varepsilon_{Re,t}$ is a shock process. See section A.3 for details.

4.4 The firm sector

In this section only the main results are written down. For details about the derivation of the results see section A.

Producer of y

The retailer firm combines the inputs x^d (domestic good) and x^f (foreign good) and produces the non-tradable final good y . The firm maximizes profits with optimally choosing x^d and x^f . $P_{x,t}$ respectively $P_{x,t}^*$ is the price of the domestic respectively the foreign good denominated in the currency of the seller.

$$\max_{x_t^d, x_t^f} P_t y_t - P_{x,t} x_t^d - N e_t P_{x,t}^* x_t^f \text{ with } y_t = \left(\omega^{(1-p)} x_t^{d\rho} + (1-\omega)^{(1-p)} x_t^{f\rho} \right)^{\frac{1}{\rho}}.$$

The parameter ρ determines the substitutability between the domestic and the foreign good and ω is 1 minus the import share. The two first order conditions $x_t^d = \left(\frac{P_{x,t}}{P_t} \right)^{\frac{1}{(\rho-1)}} \omega y_t$ and $x_t^f = \left(\frac{N e_t P_{x,t}^*}{P_t} \right)^{\frac{1}{(\rho-1)}} (1-\omega) y_t$ represent the optimal demand for the inputs. Foreign equivalence is assumed and therefore $x_t^{d*} = \left(\frac{P_{x,t}}{N e_t P_t^*} \right)^{\frac{1}{(\rho-1)}} (1-\omega) y_t^*$.

The general price index $P_t = \left(\omega P_{x,t}^{\frac{\rho}{(\rho-1)}} + (1-\omega) (N e_t P_{x,t}^*)^{\frac{\rho}{(\rho-1)}} \right)^{\frac{(\rho-1)}{\rho}}$ can be derived by plugging the demand functions into profits (given the assumption of free entry in the final good sector).

Producers of x^d , x^{d*} , x^f

x^d is a combination of inputs denoted by $x^d(i)$ according to the following function: $x_t^d = \left(\int_0^1 x_t^d(i)^{\frac{(\theta-1)}{\theta}} di \right)^{\frac{\theta}{(\theta-1)}}$. The parameter θ determines the elasticity of substitution between the various inputs. For x^f the equivalent holds, so $x_t^f = \left(\int_0^1 x_t^f(i)^{\frac{(\theta-1)}{\theta}} di \right)^{\frac{\theta}{(\theta-1)}}$.

The firm producing x^d maximizes profits with optimally choosing $x^d(i)$:

$$\max_{x_t^d(i)} P_{x,t} x_t^d - \int_0^1 \tilde{P}_{x,t}(i) x_t^d(i) di.$$

This yields the first order condition $x_t^d(i) = \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t}} \right)^{-\theta} x_t^d$. Equivalently, the demand function of the firm producing x^f is as follows: $x_t^f(i) = \left(\frac{\tilde{P}_{x,t}^*(i)}{P_{x,t}^*} \right)^{-\theta} x_t^f$. Equivalent behavior of foreign firms is assumed when they demand domestic products. Therefore, the following demand function holds: $x_t^{d*}(i) = \left(\frac{\tilde{P}_{x,t}(i)}{ne_t P_{x,t}^*} \right)^{-\theta} x_t^{d*}$.

Plugging the demand functions for x_t^d and x_t^f into profits yields the general price index $P_{x,t} = \left(\int_0^1 \tilde{P}_{x,t}(i)^{(1-\theta)} di \right)^{\frac{1}{(1-\theta)}}$.

Producer of $x(i)$

The production function of an input $x(i)$ is $x_t(i) = a_t k_t(i)^\alpha h_t(i)^{(1-\alpha)}$. The parameter α denotes the capital elasticity. The firms have local monopoly power and minimize real costs subject to their production functions:

$$\min_{k_t(i), h_t(i)} z_t k_t(i) + w_t h_t(i) \text{ s.t. } x_t(i) = \overline{x_t(i)}.$$

It follows that the real marginal cost, s_t , is given by $s_t = \frac{\partial c_t}{\partial \overline{x_t}} = \frac{\frac{1}{a_t} z_t^\alpha w_t^{(1-\alpha)}}{\alpha^\alpha (1-\alpha)^{(1-\alpha)}}$. The total minimized real costs are $s_t x_t(i)$.

The firm sets its prices such as to maximize the expected profit flow subject to the demand it faces:

$$\max_{\tilde{P}_{x,t}(i)} \mathbb{E}_t \sum_{j=0}^{\infty} \Phi_{t,t+j} \xi^j \Pi(\tilde{P}_{x,t}(i))$$

with $\Pi(\tilde{P}_{x,t}(i)) = (\tilde{P}_{x,t}(i) - P_{t+j} s_{t+j}) x_{t+j}(i)$ and $\Phi_{t,t+j} \propto \beta^j \frac{\Lambda_{t+j}}{\Lambda_t}$

$$\text{s.t. } x_t(i) = \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t}} \right)^{-\theta} x_t \text{ with } x_t = x_t^d + x_t^{d*}$$

$\Phi_{t,t+j}$ is the discount factor and ξ is the probability that the firm can adjust its price. The maximization problem yields the following first order condition:

$$\mathbb{E}_t \left[\sum_{j=0}^{\infty} (\beta \xi)^j \frac{\Lambda_{t+j}}{\Lambda_t} \left((1 - \theta) \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t+j}} \right)^{-\theta} x_{t+j} + \theta \frac{P_{t+j}}{\tilde{P}_{x,t}(i)} \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t+j}} \right)^{-\theta} s_{t+j} x_{t+j} \right) \right] = 0.$$

As all firms that are able to reset their price choose the same price, $\tilde{P}_{x,t}(i) = \tilde{P}_{x,t}$ holds for all $i \in (0, 1)$. The first order condition can be restated as

$$\tilde{P}_{x,t} = \frac{P_{x,t}^n}{P_{x,t}^d}$$

$$\text{with } P_{x,t}^n = \mathbb{E}_t \left[\sum_{j=0}^{\infty} (\beta \xi)^j \Lambda_{t+j} \frac{\theta}{(\theta-1)} P_{t+j} P_{x,t+j}^{\theta} s_{t+j} x_{t+j} \right]$$

$$\text{and } P_{x,t}^d = \mathbb{E}_t \left[\sum_{j=0}^{\infty} (\beta \xi)^j \Lambda_{t+j} P_{x,t+j}^{\theta} x_{t+j} \right].$$

$P_{x,t}^n$ and $P_{x,t}^d$ can also be stated in recursive representation as follows:

$$P_{x,t}^n = \frac{\theta}{(\theta-1)} \Lambda_t P_t P_{x,t}^{\theta} s_t x_t + \beta \xi \mathbb{E}_t P_{x,t+1}^n \text{ and } P_{x,t}^d = \Lambda_t P_{x,t}^{\theta} x_t + \beta \xi \mathbb{E}_t P_{x,t+1}^d$$

Aggregate price level

Using the price index $P_{x,t}$ the aggregate price level can be expressed as the average of all surviving contracts:

$$P_{x,t} = \left(\sum_{j=0}^{\infty} (1 - \xi) \xi^j \tilde{P}_{x,t-j}^{(1-\theta)} \right)^{\frac{1}{(1-\theta)}} \text{ or expressed recursively}$$

$$P_{x,t} = \left((1 - \xi) \tilde{P}_{x,t}^{(1-\theta)} + \xi P_{x,t-1}^{(1-\theta)} \right)^{\frac{1}{(1-\theta)}}.$$

Aggregate output

Using $\frac{k_t(i)}{h_t(i)} = \frac{k_t(j)}{h_t(j)} = \frac{k_t}{h_t}$ and inserting it into the production function of $x_t(i)$ yields

$x_t(i) = a_t \left(\frac{k_t}{h_t} \right)^\alpha h_t(i)$. From integration across firms it follows that

$\int_0^1 x_t(i) di = a_t \left(\frac{k_t}{h_t} \right)^\alpha \int_0^1 h_t(i) di$. Inserting for $x_t(i)$ its demand function yields

$\int_0^1 \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t}} \right)^{-\theta} di x_t = a_t k_t^\alpha h_t^{(1-\alpha)}$ with h_t denoting $\int_0^1 h_t(i) di$. Furthermore, we define

$\Delta_t = \int_0^1 \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t}} \right)^{-\theta} di$, rearrange and get $\Delta_t = (1 - \xi) \left(\frac{\tilde{P}_{x,t}}{P_{x,t}} \right)^{-\theta} + \xi \pi_{x,t}^\theta \Delta_{t-1}$.

Inserting Δ_t in the equation above yields the aggregate output $\Delta_t x_t = a_t k_t^\alpha h_t^{(1-\alpha)}$.

Combining the aggregate output and the real marginal cost yields the real wage

$w_t = \frac{(1-\alpha)s_t p_{x,t} x_t}{h_t}$ and the real interest rate on investment $z_t = \frac{\alpha s_t p_{x,t} x_t}{k_t}$.

4.5 The countercyclical capital buffer

Regulatory requirement without countercyclical capital buffer (Option 1)

In the base case the regulatory capital ratio requirement, this means the regulatory equity-to-loans ratio, is set to a constant. No countercyclical term is implemented.

$$rcr_t = crcr$$

Regulatory requirement with countercyclical capital buffer (Option 2)

The decision about the size of the countercyclical capital buffer is based on the credit-to-GDP gap. The credit-to-GDP gap is calculated as follows:

$$gap_t = \left(\frac{\gamma L_t}{4P_{x,t} x_t} - \frac{\gamma L}{4P_{x,x}} \right)$$

The variables without time index denote the steady state values. Therefore the credit-to-GDP gap is defined as the deviation of the “loan-to-GDP ratio” from its long term trend, e.g. the steady state. γ is a parameter that adjusts the total amount of credit to the relevant one. See section 7.1 for details.

The regulatory capital ratio is then calculated as follows:

$$rcr_t = crcr + \nu_g gap_t - \nu_c$$

So additionally to the constant minimum requirement there is now the credit-to-GDP gap dependent term which lowers or increases the requirement.

As a first order approximation around the steady state is taken when using Dynare, an implementation of a step function is not possible. Therefore, the rule is a linear function with no minimum or maximum. See section 7.1 for details about the calibration of ν_g and ν_c .

4.6 Monetary policy

Exogenous money supply (Option 1)

In the base case, exogenous money supply is assumed. Money demand is implemented as money in the utility function (see section 4.2).

$$M_t = M_{t-1}$$

Taylor rule (Option 2)

To study the robustness of the countercyclical capital buffer to monetary policy, the exogenous money supply and the money in the utility function term are taken out of the model and replaced by a Taylor rule.

$$\log(R_t) = \rho_r \log(R_{t-1}) + (1 - \rho_r)(\log(R) + \gamma_\pi(\log(\pi_t) - \log(\pi)) + \gamma_y(\log(y_t) - \log(y)) + \gamma_{rer}(\log(rer_t) - \log(rer)))$$

4.7 Shock processes

Return on equity shock

$$\log(\varepsilon_{Re,t}) = \rho_{Re} \log(\varepsilon_{Re,t-1}) + \epsilon_{Re,t}$$

Shock to the preference for hours

$$\log(\zeta_{h,t}) = \rho_{\zeta_h} \log(\zeta_{h,t-1}) + (1 - \rho_{\zeta_h}) \log(\bar{\zeta}_h) + \epsilon_{\zeta_h,t}$$

Fiscal shock

$$\log(g_t) = \rho_g \log(g_{t-1}) + (1 - \rho_g) \log(\bar{g}) + \epsilon_{g,t}$$

Technology shock

$$\log(a_t) = \rho_a \log(a_{t-1}) + \epsilon_{a,t}$$

4.8 Other

Foreign deposits

The foreign deposits evolve as follows (see section A.13 for details):

$$D_t^f = R_{t-1} D_{t-1}^f + P_t y_t - P_{x,t} x_t$$

with the absorption

$$y_t = P_t c_t + P_t i_t + P_t g_t$$

For details about the derivation see section A.13.

Government spending/Lump sum tax

The government raises a lump sum tax in each period and spends it in the same period. Government spending does not give the household any utility nor is it productive in any way. Π_t^M denotes the gains from seigniorage.

$$\Theta_t + \Pi_t^M = P_t g_t$$

Capital stock

$$k_{t+1} = i_t + (1 - \delta)k_t$$

Housing supply

The housing supply is fixed to 1 and only house prices can fluctuate.

$$H = 1$$

Inflation $\pi_{x,t}$

$$\frac{P_{x,t}}{P_{x,t-1}} = \pi_{x,t}$$

Uncovered interest rate parity

$$R_t = R_{w,t} E_t \frac{Ne_{t+1}}{Ne_t} + \phi \frac{D_t^f}{P_{x,t} x_t}$$

Foreign economy

Foreign absorption equals the domestic absorption in the steady state $y^* = y$. Furthermore, it is assumed that $P_t^* = 1$ and $P_{x,t}^* = P_t^*$. As these variables do not vary over time, they are inserted as parameters in the model.

Change in the nominal exchange rate

$$\Delta_t^e = \frac{Ne_t}{Ne_{t-1}}$$

GDP

$$GDP_t = P_{x,t} x_t$$

Equity-to-loans ratio

$$ratio_t = \frac{E_t}{L_t}$$

Penalty

$$pe_t = v + \frac{v_2}{2} \left(\log \left(\frac{E_t/L_t}{rcr_t} \right) \right)^2$$

5 The deflated general equilibrium

Household

$$\lambda_t = \frac{1}{c_t}$$

$$\lambda_t w_t = \zeta_{h,t} h_t^\eta$$

$$\lambda_t p_{H,t} = \zeta_H \frac{1}{H} + \beta \mathbb{E}_t \lambda_{t+1} p_{H,t+1}$$

$$\lambda_t = \zeta_{d^d} d_t^{d-\iota} + \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\pi_{t+1}} R_t$$

$$\lambda_t = \zeta_m m_t^{-\Phi^m} + \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\pi_{t+1}}$$

$$\lambda_t = \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\pi_{t+1}} R_{l1,t+1}$$

$$\lambda_t = q_t$$

$$q_t = \beta \mathbb{E}_t \left[\lambda_{t+1} \alpha s_{t+1} \frac{p_{x,t+1} x_{t+1}}{k_{t+1}} + q_{t+1} (1 - \delta) \right]$$

$$\overline{f_t} = \frac{l_t R_{l,t}}{\psi}$$

$$f_t = \mu H p_{H,t} + (1 - \mu) w_t h_t$$

$$J_t = \kappa + (1 - \kappa) \Phi \left(\frac{\log(\overline{f_{t-1}}) - \log(f_t) - \log(\pi_t)}{\sigma_B} \right)$$

Banking sector

$$\mathbb{E}_t(R_{l1,t+1}) = R_t + v - v_2 \log \left(\frac{e_t/l_t}{rcr_t} \right) + \frac{v_2}{2} \left(\log \left(\frac{e_t/l_t}{rcr_t} \right) \right)^2$$

$$R_{e,t} = R_{t-1} + (R_{l1,t} - R_{t-1}) \frac{l_{t-1}}{e_{t-1}} - \left(v + \frac{v_2}{2} \left(\log \left(\frac{e_{t-1}/l_{t-1}}{rcr_{t-1}} \right) \right)^2 \right) \frac{l_{t-1}}{e_{t-1}} + (\varepsilon_{Re,t} - 1)$$

$$e_t = \frac{e_{t-1}}{\pi_t} \frac{R_{e,t}}{R_e}$$

$$l_t = d_t^d + d_t^f + e_t$$

$$R_{l1,t} = R_{l,t-1}(1 - \chi j_t)$$

Firm sector

$$\Delta_t x_t = a_t k_t^\alpha h_t^{(1-\alpha)}$$

$$x_t^d = p_{x,t}^{\frac{1}{(p-1)}} \omega y_t$$

$$x_t^{d*} = \left(\frac{p_{x,t}}{rer_t} \right)^{\frac{1}{(p-1)}} (1 - \omega) y_t^*$$

$$x_t^f = (rer_t p_{x,t}^*)^{\frac{1}{(p-1)}} (1 - \omega) y_t$$

$$x_t = x_t^d + x_t^{d*}$$

$$1 = \omega p_{x,t}^{\frac{p}{(p-1)}} + (1 - \omega) (rer_t p_{x,t}^*)^{\frac{p}{(p-1)}}$$

$$rer_t = \frac{\Delta_t^e p_t^*}{\pi_t p_{t-1}^*} rer_{t-1}$$

$$p_{x,t} = \frac{\pi_{x,t}}{\pi_t} p_{x,t-1}$$

$$p_{x,t}^n = \frac{\theta}{(\theta - 1)} \lambda_t p_{x,t}^\theta s_t x_t + \beta \xi \mathbb{E}_t [p_{x,t+1}^n \pi_{t+1}^\theta]$$

$$p_{x,t}^d = \lambda_t p_{x,t}^\theta x_t + \beta \xi \mathbb{E}_t [p_{x,t+1}^d \pi_{t+1}^{\theta-1}]$$

$$p_{x,t} = \left((1 - \xi) \left(\frac{p_{x,t}^n}{p_{x,t}^d} \right)^{(1-\theta)} + \xi \left(\frac{p_{x,t-1}}{\pi_t} \right)^{(1-\theta)} \right)^{\frac{1}{(1-\theta)}}$$

$$\Delta_t = (1 - \xi) \left(\frac{p_{x,t}^n}{p_{x,t} p_{x,t}^d} \right)^{-\theta} + \xi \Delta_{t-1} \pi_{x,t}^\theta$$

$$w_t = (1 - \alpha) \frac{s_t p_{x,t} x_t}{h_t}$$

Countercyclical capital buffer

Regulatory requirement without countercyclical capital buffer (Option 1)

$$rcr_t = crcr$$

Regulatory requirement with countercyclical capital buffer (Option 2)

$$gap_t = \left(\frac{\gamma l_t}{4p_{x,t} x_t} - \frac{\gamma l}{4p_x x} \right)$$

$$rcr_t = crcr + \nu_g gap_t - \nu_c$$

Monetary Policy

Exogenous money supply (Option 1)

$$m_t \pi_t = m_{t-1}$$

Taylor rule (Option 2)

$$\begin{aligned} \log(R_t) = & \rho_r \log(R_{t-1}) + (1 - \rho_r)(\log(R) + \gamma_\pi(\log(\pi_t) - \log(\pi)) \\ & + \gamma_y(\log(y_t) - \log(y)) + \gamma_{rer}(\log(rer_t) - \log(rer))) \end{aligned}$$

Shock processes

$$\log(\varepsilon_{Re,t}) = \rho_{Re} \log(\varepsilon_{Re,t-1}) + \epsilon_{Re,t}$$

$$\log(\zeta_{h,t}) = \rho_{\zeta_h} \log(\zeta_{h,t-1}) + (1 - \rho_{\zeta_h}) \log(\zeta_h) + \epsilon_{\zeta_h,t}$$

$$\log(g_t) = \rho_g \log(g_{t-1}) + (1 - \rho_g) \log(g) + \epsilon_{g,t}$$

$$\log(a_t) = \rho_a \log(a_{t-1}) + \epsilon_{a,t}$$

Other

$$d_t^f = R_{t-1} \frac{d_{t-1}^f}{\pi_t} - p_{x,t} x_t + y_t - (\varepsilon_{Re,t} - 1) \frac{e_{t-1}}{\pi_t}$$

$$R_t = R_{w,t} \mathbb{E}_t \frac{rer_{t+1} \pi_{t+1}}{rer_t \pi_{t+1}^*} + \phi \frac{d_t^f}{p_{x,t} x_t}$$

$$k_{t+1} = i_t + (1 - \delta)k_t$$

$$y_t = c_t + i_t + g_t$$

$$gdp_t = p_{x,t}x_t$$

$$ratio_t = \frac{e_t}{l_t}$$

$$pe_t = v + \frac{v_2}{2} \left(\log \left(\frac{e_t/l_t}{rcr_t} \right) \right)^2$$

with

$$\lambda_t = \Lambda_t P_t, \, p_{x,t} = \frac{P_{x,t}}{P_t}, \, p_{x,t}^n = \frac{P_{x,t}^n}{P_t^n},$$

$$p_{x,t}^d = \frac{P_{x,t}^d}{P_t^{(\theta-1)}}, \, p_{H,t} = \frac{P_{H,t}}{P_t}, \, \pi_t = \frac{P_t}{P_{t-1}}, \, p_{x,t}^* = \frac{P_{x,t}^*}{P_t^*}, \, \pi_{x,t} = \frac{P_{x,t}}{P_{x,t-1}}, \, rer_t = Ne_t \frac{P_t^*}{P_t}$$

6 Welfare costs

For the calculation of the welfare costs a second order Taylor approximation of the lifetime utility function is taken.

The welfare of the household in a system without implementation of a countercyclical capital buffer is compared to one with buffering. More exactly, it is calculated how much extra consumption in percent the household would need to be willing to live in an economy with a countercyclical capital buffer.

This extra consumption in percent is the welfare cost and is denoted by Ω . See appendix C for details.

$$\begin{aligned} W^{ccyb} \{c_{t+i}(1 + \Omega), h_{t+i}, H_{t+i}, D_{t+i}, M_{t+i}\}_{i=0}^{\infty} \\ = W^{no\ ccyb} \{c_{t+i}, h_{t+i}, H_{t+i}, D_{t+i}, M_{t+i}\}_{i=0}^{\infty} \end{aligned}$$

7 Calibration and estimation

7.1 Calibration

The table below gives an overview over calibrated steady state values of variables, steady state ratios and parameters. The longest possible time horizons within 1987Q1 and 2016Q3 were used. See section D for an overview of the sources. The model is in quarterly frequency.

The values in the first block of the table are calibrated according to Swiss data. In the second block in the table are parameters which are calibrated according to common used values and assumptions. The parameters ζ_{ad} , H , μ and κ in that block are calibrated according to Lozej et al. (2016 [43]), the parameters η , δ , ω , y^* , p^* and p_x^* correspond to the ones in Collard et al. ([23]). The utility weight of money ζ_m is as in Brázdik (2006 [18]). The parameter ϕ is part of the uncovered interest rate parity. As the foreign deposits are zero in the steady state the uncovered interest rate parity could not be exactly implemented as in Lozej et al. (2016 [43]), but similar. The parameter ϕ is calibrated to a low value. The Taylor Rule exchange rate coefficient γ_{rer} is calibrated to 0 in the base case and to 1000 if the exchange rate is wanted to be held fixed. For the first four parameters see the comment below.

Regarding the first block of parameters some important points should be mentioned. First, the value of loans in the steady state loans-to-GDP ratio corresponds to the whole size of the balance sheet of banks. This is due to the fact that in the model the asset side of the balance sheet only consists of loans. To make the calculation again consistent with the guidelines for national authorities (BC, 2010 [12]) a coefficient γ is inserted. When computing the gap the coefficient γ accounts for the risk-weighting and the fact, that not all loans resp. all bank assets are relevant for the calculation of the gap. The parameter is a ratio. The numerator is the average credit-to-GDP ratio which is used by the BIS to calculate the gap. The denominator is the credit-to-GDP gap when the total unweighted size of the banks balance sheet is counted as loans. As GDP is the same in both ratios, it cancels out. What is left is a coefficient that accounts for the relevant risk-weighted amount of credit.

For the return on equity the growth rate of the SPI was used. The default threshold parameter is calculated as the interest rate on loans (ex-ante) divided by 1

minus the average loan-to-value ratio. For the calculation of an approximation of the typical loan to value ratio, data of the housing stock (Data: Federal Statistical Office (FSO)) and mortgages (Data: SNB) were used.

Regarding the second block it is important to mention that the CET1-to-loans ratio is an assumption. Next to the lack of data for the whole banking sector⁹, another reason for this value is that the steady state value should lie below the steady state value of the capital requirement. This makes sure that the first order approximation of the penalty function is taken in a part where not having enough capital leads to a penalty.

The parameter $crcr$ is set to 7%. The 7% correspond to the minimum CET1 value of 4.5% plus 2.5% stemming from the part of the minimum conservation buffer which has to be fulfilled with CET1 as well and holds for banks of category 5 (ERV 2012, [33]).¹⁰ The slope coefficient ν_g and the intercept ν_c are set according to the guidance for national authorities (BC, 2010 [12]). The idea is that the buffer shall vary linearly between 0% and 2.5% when the gap is between 2 and 10 percentage points (BC, 2010 [12]).

7.2 Estimation

Estimation is done in Dynare. The mode of the standard deviations and the parameters are used afterwards as values when running the model to get impulse response functions, volatilities and correlations with and without countercyclical capital buffer. The model is estimated twice. One time with exogenous money supply and a second time with a Taylor Rule (without fixed exchange rate). An estimation of the model with a Taylor rule and a fixed exchange rate was not done as we know that historically the exchange rate was not fixed and a fixed exchange rate has quite some impact on the data.

Estimation is in both cases done for the economy without a countercyclical capital buffer.

As mentioned above, the model is in quarterly frequency and Swiss data over the time horizon 1987Q1-2016Q3 is used. The data series taken for estimation

⁹For example Credit Suisse had in the first quarter of 2012 a CET1 ratio of 4.4% (SNB, 2013 [50]).

¹⁰See ERV (2012 [33]) for information about other categories and legislation regarding systemically relevant banks.

Parameter	Description	Value
h	Hours	0.19
g/GDP	Government spending-to-GDP ratio	0.34
$p_H H/GDP$	Housing stock-to-GDP ratio	6.70
wh/GDP	Labor share	0.57
l/GDP	Loan-to-GDP ratio	17.17
R	Interest rate on deposits	1.002135571
R_l	Interest rate on loans	1.008956426
R_e	Return on equity	1.022621833
$diffR$	Banking sector profit margin	0.0022771
ψ	Default threshold	3.57
γ	Credit adjuster	0.43
$crcr$	Constant regulatory capital requirement	0.07
ν_g	Parameter in the c. c. buffer rule	0.3125
ν_c	Parameter in the c. c. buffer rule	0.00625
e/l	CET1-to-loan ratio	0.05
η	Inverse labor supply elasticity	0.1
ζ_{ad}	Utility weight of deposits	0.3526
ζ_m	Utility weight of money	0.005
H	Housing	1
μ	Weight on pledgeable housing wealth	1
κ	Non-contingent default rate	0
δ	Depreciation rate	0.025
ϕ	Parameter in UIRP	0.0025
θ	Determ. of the elast. of subst. btw. inputs	6
ω	1-import share	0.85
y^*	Foreign absorption	y
p^*	Foreign price level	1
p_x^*	Foreign price of x^*	1
γ_{rer}	Taylor rule exchange rate coefficient	0 resp. 1000

Table 1: Calibrated parameters

are inflation, the return on equity and investment¹¹. Before usage the natural logarithm is taken, a linear trend is taken out to make the series stationary and the intercept is set to the steady state value of the variable in the model.¹² The priors of the standard deviations of the shocks and the structural parameters are listed below.

The standard deviation and persistence priors are set as in Smets and Wouters (2007 [49]). The prior mean of ξ is set in between the prior mean according to Adolfson et al. (2007 [1]) and Balke et. al. (2012 [10]). The standard deviation was set to 0.05 as in Adolfson et al. (2007 [1]). The prior mean of θ was chosen according to the calibration in Collard et al. ([23]). The standard deviation was set to half of the mean. The prior mean of χ is the calibrated value in Lozej et al. (2016 [43]). The standard deviation is 0.1. The standard deviation of ρ is as well 0.1 and the mean is chosen according to the calibrated value in Collard et al. ([23]). The prior mean and standard deviation of Φ_m is in line with Benchimol (2011 [15]).

The prior mean of the reaction to output is a typical value and is used for example in Cantore et al. (2014 [20]). The standard deviation is as well as in Cantore et al. (2014 [20]). The prior mean and standard deviation in the reaction to inflation are as well typical prior values and are used for example in Gehrke (2015 [35]). The prior distributions of the last two mentioned parameters are gamma as in Kliem and Kriwoluzky (2013 [42]). The prior mean of the interest rate coefficient was set to 0.8 as in Cantelmo and Melina (2017 [19]). Anguyo et al. (2017 [8]) use the same value. The standard deviation is set according to the last mentioned paper.

A jscale of 0.7 in the case with exogenous money supply and a jscale of 0.475 for the estimation with Taylor rule was used. This gave an overall acceptance ratio of around 24.4% in the case with exogenous money supply and around 24% in the case with a Taylor Rule. This is in line with Roberts (1997 [47]) who find an optimal acceptance rate of 23.4% under quite general conditions.

¹¹Government investment is not taken out of the data of total investment. The reason is that quarterly data is not available. As the mean of the series is anyway adjusted to the mean of the variable in the model, it should only have a neglectable impact.

For the return on equity data of the SPI was used.

¹²Due to the estimation of the parameter θ the steady state of investment slightly changes but to a negligible amount. The steady state in logs is still the same until 2 decimals behind the comma and therefore we can use the same data.

St. dev.	Description	Prior		
		Distr. fct.	Mean	St. dev.
$\sigma_{\varepsilon_{Re}}$	St. dev. of the return on equity shock	inv. gamma	0.1	2
σ_{ζ_h}	St. dev. of the preference shock to hours	inv. gamma	0.1	2
σ_g	St. dev. of the fiscal shock	inv. gamma	0.1	2
σ_a	St. dev. of the technology shock	inv. gamma	0.1	2

Table 2: Priors of the standard deviations

250'000 replications are done with two parallel chains. The first observation is 1. No prefiltering is done. The type of initialization of the Kalman filter is set to 1 (lik_init) and presample is set to 4. The first 20% of the draws from the Metropolis-Hastings are discarded. As optimizer for the mode computation Chris Sim's csminwel is used. Have a look at the Dynare user guide by Griffoli (2013 [37]) and the Dynare reference manual ([31]) for detailed information.

The estimation results are listed below. Figure 4 and 5 show the results for the case with exogenous money supply and figure 6 and 7 the ones in the case with a Taylor rule. In the appendix E the MCMC univariate convergence diagnostic, the multivariate convergence diagnostic, the priors and posteriors as well as the smoothed shocks can be found.

Parameter	Description	Prior		
		Distr. fct.	Mean	St. dev.
$\rho_{\varepsilon_{Re}}$	Persistence of the return on equity shock	beta	0.5	0.2
ρ_{ζ_h}	Persistence of the preference shock to hours	beta	0.5	0.2
ρ_g	Persistence of the fiscal shock	beta	0.5	0.2
ρ_a	Persistence of the technology shock	beta	0.5	0.2
χ	Loss given default	beta	0.5	0.1
ξ	Probability that a price contract is not ending	beta	0.675	0.05
ρ	Substitutability btw. domestic and foreign good	normal	0.33	0.1
θ	Determinator of elast. of subst. btw. various inputs	gamma	6	3
Φ_m	Inverse elasticity of real money	gamma	1.25	0.1
ρ_r	Persistence of the Taylor Rule	beta	0.8	0.05
γ_π	Taylor Rule inflation coefficient	gamma	1.7	0.1
γ_y	Taylor Rule absorption coefficient	gamma	0.125	0.05

Table 3: Priors of the structural parameters

St. dev.	Posterior				
	Mode	St. dev.	Mean	90% HPD int.	
$\sigma_{\varepsilon_{Re}}$	0.0871	0.0057	0.0882	0.0786	0.0974
σ_{ζ_h}	0.0197	0.0025	0.0199	0.0157	0.0241
σ_g	0.0296	0.0045	0.0313	0.0235	0.0391
σ_a	0.0159	0.0016	0.0160	0.0133	0.0186

Table 4: Posteriors of the standard deviations, exogenous money supply

Parameter	Posterior				
	Mode	St. dev.	Mean	90% HPD int.	
ρ_{Re}	0.0717	0.0441	0.0864	0.0189	0.1481
ρ_{ζ_h}	0.8302	0.0458	0.8120	0.7310	0.8991
ρ_g	0.9686	0.0107	0.9655	0.9479	0.9831
ρ_a	0.8383	0.0311	0.8299	0.7775	0.8847
χ	0.4990	0.1067	0.5003	0.3340	0.6625
Φ_m	1.2701	0.0700	1.2776	1.1147	1.4484
ξ	0.4814	0.0242	0.4822	0.4415	0.5231
ρ	0.3191	0.0916	0.3165	0.1679	0.4643

Table 5: Posteriors of the structural parameters, exogenous money supply

St. dev.	Posterior				
	Mode	St. dev.	Mean	90% HPD int.	
$\sigma_{\varepsilon_{Re}}$	0.0837	0.0054	0.0848	0.0758	0.0937
σ_{ζ_h}	0.0344	0.0100	0.0430	0.0219	0.0639
σ_g	0.0493	0.0076	0.0507	0.0388	0.0626
σ_a	0.0295	0.0081	0.0381	0.0183	0.0585

Table 6: Posteriors of the standard deviations, Taylor Rule

Parameter	Posterior				
	Mode	St. dev.	Mean	90% HPD int.	
ρ_{Re}	0.1081	0.0582	0.1228	0.0336	0.2069
ρ_{ζ_h}	0.4095	0.1775	0.3525	0.1648	0.5355
ρ_g	0.8310	0.0350	0.8152	0.7534	0.8794
ρ_a	0.3539	0.1133	0.3324	0.1813	0.4862
ρ_r	0.8333	0.0329	0.8125	0.7572	0.8673
γ_π	1.6646	0.0921	1.6778	1.5254	1.8251
γ_y	0.2263	0.0366	0.2527	0.1819	0.3230
χ	0.5194	0.1042	0.5197	0.3589	0.6789
ξ	0.7205	0.0345	0.7452	0.6840	0.8096
ρ	0.4909	0.0905	0.5093	0.3647	0.6606
θ	5.9629	0.0572	5.9649	5.8708	6.0605

Table 7: Posteriors of the structural parameters, Taylor Rule

8 Evidence

8.1 Impulse response functions

8.1.1 General

In this section the focus lies on the differences in the impulse response functions (IRFs) due to the countercyclical capital buffer. For a discussion of how the shocks in general affect the economy see section F in the appendix.

Four shocks were chosen for the discussion of the effect of the countercyclical capital buffer. The first shock is the shock to the return on equity which should represent a typical shock in the banking sector. Other shocks in the banking sector like a shock to the probability to default, the loss given default or the risk measure would also have been possible. When looking at the IRFs due to these shocks one can see that they look similar to the ones due to the shock to the return on equity. As a second shock a preference shock was chosen. A shock to the preference for hours was chosen as it is a typical preference shock and when looking at the variance decomposition of the gap due to several preference shocks it shows that this shock is relevant. A shock to the preference for consumption, housing or domestic deposits would also have been possible. The third shock is the fiscal shock. This shock was chosen as it is too an important driver according to the analysis of the variance decomposition. The last shock is the shock to technology because it is important for explaining the data in the estimation process. Note that we therefore have four different shocks stemming from four different sectors (banking, household, government, production). The shock from the financial sector may be the most relevant with respect to the analysis of the countercyclical capital buffer. The other shocks furthermore allow to enhance the analysis and draw a bigger picture of how the buffer would influence the economy. The focus in the analysis lies on the build-up phase where the buffer reacts on a positive deviation of the gap. Note that the deviations are mirrored if the same shock hits in the opposite direction. The conclusions from the results in such a case correspond not exactly to the modeling of a downturn phase as first, the buffer is in reality a step function which reacts only to positive deviations and secondly the effects from a prephase with a positive deviation of the gap where the buffer directly impacts on the economy is partially missing. Still one could draw conclusion about the effect of a capital requirement which is lowered given

a negative deviation of the gap.

Dynare is used for the calculations. All variables are log-transformed. When Dynare linearizes the model in terms of the log-transformed variables, it does the log-linearization of the model in terms of the original variables. The impulse response functions therefore show the deviations from the steady state in percent. Before reading the interpretation of the impulse response functions one should be aware that if a variable influences another then the other variable most probably influences the first directly or indirectly as well and all effects finally lead to an equilibrium. The interpretation points out the most important and direct argumentation lines but a full description with all back effects is not possible nor desired as not to lose the overview.

Furthermore, it should be pointed out that it is possible to add for example deposit or capital adjustment costs to the model. Additionally we could also smooth the gap or the GDP in the countercyclical capital buffer rule. For analysis this was omitted as not to blur the pure effect of the buffer and thus its interpretation. Before starting with the analysis of the different shocks, shortly the household demand for deposits and loans should be explained as one can be confused because the first order conditions look similar.

The first order condition for domestic deposits says that the marginal utility of wealth today has to equal the marginal utility of domestic deposits today plus the expected discounted marginal utility of wealth tomorrow times the interest rate on deposits. Furthermore it is accounted for expected inflation. If the interest rate is *ceteris paribus* higher, the household forgoes more interest tomorrow for example when consuming today and therefore, the marginal utility of wealth has to be higher today. This leads the household to save more.

The first order condition of loans is similar. The marginal utility of wealth today has to equal the expected discounted marginal utility of wealth tomorrow times the expected ex-post interest rate on loans. Expected inflation is taken into account. If the interest rate on loans is *ceteris paribus* higher, the marginal utility of wealth today has to be higher as it has to be worth to incur the higher costs of interest tomorrow. Note that the interest rate on loans is higher than the interest rate on deposits. Therefore, it is necessary that domestic deposits give utility today such that both conditions can hold. As mentioned this is a way of how to implement that the household both wants to hold loans and deposits at the same time. The domestic deposits in the utility function term can be reasoned for example with

the fact that people can get utility from the safety feeling they get when they know that they have deposits.

Given the interest rates, the household decides how much he wants to save. The amount the household saves each period with loans and deposits is actually $d_t - l_t$. The household can save more if it takes more deposits or if it lowers the amount of loans. Therefore, loans are just another way of how savings can be adjusted. The interest rates guide the households optimal decision of how much deposits and loans it wants to have. Furthermore, investment, housing and money are other means which shift budget from one to another period.

Lastly before analyzing it should be pointed out that the gap and the regulatory requirement have the same time index. The gap influences the requirement which itself influences again the gap etc. If they have the same time index this process happens within the same period, otherwise the IRFs would reflect this fact in a jagged evolution until the variables are back in their steady state.

8.1.2 Return on equity shock

The shock to the return on equity opens up the gap. Due to this the regulatory capital requirement goes up when the countercyclical capital buffer is implemented. This affects the banks decision making as it has to pay a penalty for a deviation of the equity-to-loans ratio from the regulatory ratio. The bank chooses loans as such that the expected interest spread equals the marginal penalty with respect to loans. A higher regulatory requirement implies that the marginal penalty with respect to loans is *ceteris paribus* higher. Therefore, given an expected interest spread and equity the marginal penalty with respect to loans equals the interest spread at a lower amount of loans. With the countercyclical capital buffer implemented the bank therefore wants to supply less loans even if the higher equity already contributes to the adjustment on the higher regulatory capital requirement. Given an amount of foreign deposits and equity the banks wants to supply less domestic deposits when it supplies less loans as the balance sheet has to equalize. As the household is not directly affected by the requirement, demand for loans and deposits given interest rates stay on impact the same. Therefore, given the change in the supply, the amount of loans and domestic deposits is lower. The interest rate on loans (ex-post) lies above the one in the case without buffer from the second period on and the interest rate on

deposits is below. Mainly due to the lower interest rate on deposits, the amount of foreign deposits is lower.

The probability to default lies above the one in the case without buffer in the first period because the relevant wealth for default calculation is lower and the for the calculation relevant minimum wealth is still in the steady state. Inflation is slightly higher.

The relevant wealth for default calculation is lower as the marginal utility of wealth is higher (see below). From the second period on the probability to default is less high as the evolution of the minimum wealth for default calculation dominates. The minimum wealth for default calculation is lower because of the lower amount of loans and the lower interest rate on loans ex-ante (not shown).

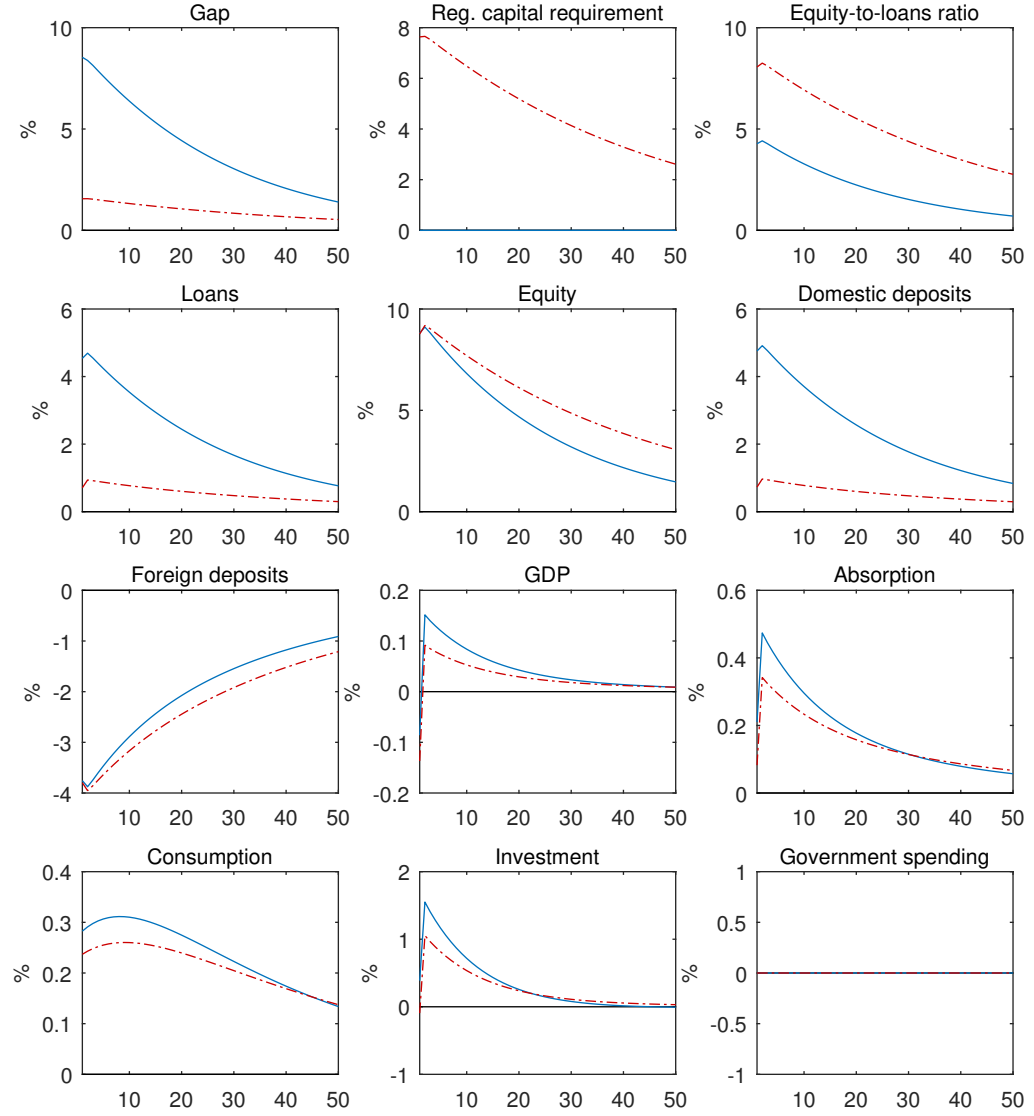
Due to the higher probability to default, the interest rate on loans (ex-post) lies in the first period below the one of the economy without buffer. The penalty is higher due to the higher regulatory requirement.

Equity evolves exogenously and is higher due to the higher interest spread and the evolution of loans. Given the evolution of equity and loans it follows that the equity-to-loans ratio is higher when the countercyclical capital buffer is implemented as it should be.

The marginal utility of domestic deposits falls by less with a lower amount of domestic deposits. The marginal utility of wealth shows a dampened evolution. Hours, investment and consumption also show on the whole a dampened evolution as the marginal utility of wealth does. They themselves again influence back on the marginal utility of wealth. Hours and investment directly affect the evolution of the GDP which deviates on the whole less from the steady state with the countercyclical capital buffer except in the first period. In the first period we have the case that GDP falls below the steady state and therefore moves in opposite direction to the gap. As the buffer leads to a lower GDP, the fall in GDP is even more pronounced. Absorption which follows the evolution of consumption and investment shows a dampened evolution. Government spending stays the same. The evolution of inflation is slightly dampened due to the dampened evolution of the marginal utility of wealth which dampens the demand of money.

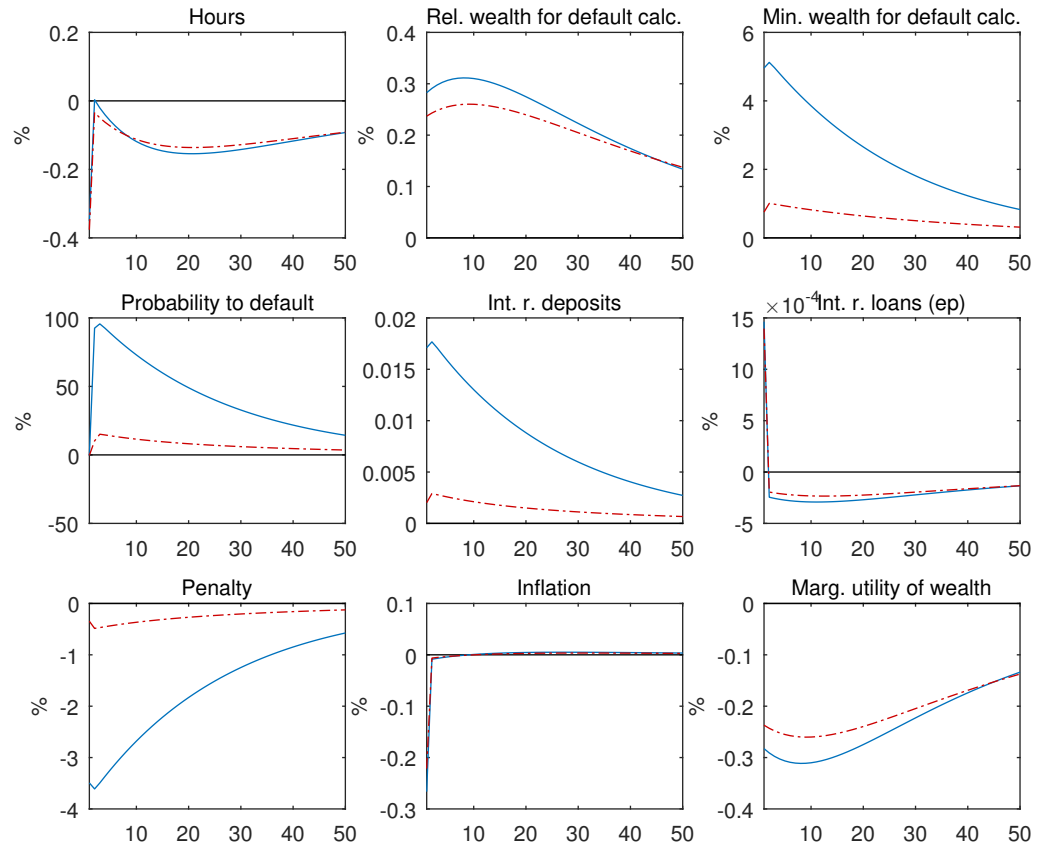
Summarizing, we can see that the countercyclical capital buffer stabilizes the gap. As the gap rises due to the shock, the equity-to-loans ratio is higher with the countercyclical capital buffer due to the impact from the changed regulatory requirement.

Furthermore we can see the dampening side effect the buffer exerts on the financial sector. The deviation from the steady state of loans and domestic deposits are lower. The gap itself is lower in the case with the countercyclical capital buffer due to the dampening effect of the buffer on loans which dominates the effect of the mitigated GDP. But not only the financial but also typical macroeconomic variables are smoother. As one can see also the GDP, the absorption, consumption, hours and investment deviate on the whole less from the steady state in the case with a countercyclical capital buffer.



blue solid = without c. c. buffer and red dashed = with c. c. buffer

Figure 3: Deviations after a positive temporary return on equity shock, 50 quarters (1/2)



blue solid = without c. c. buffer and red dashed = with c. c. buffer

Figure 4: Deviations after a positive temporary return on equity shock, 50 quarters (2/2)

8.1.3 Preference shock to hours

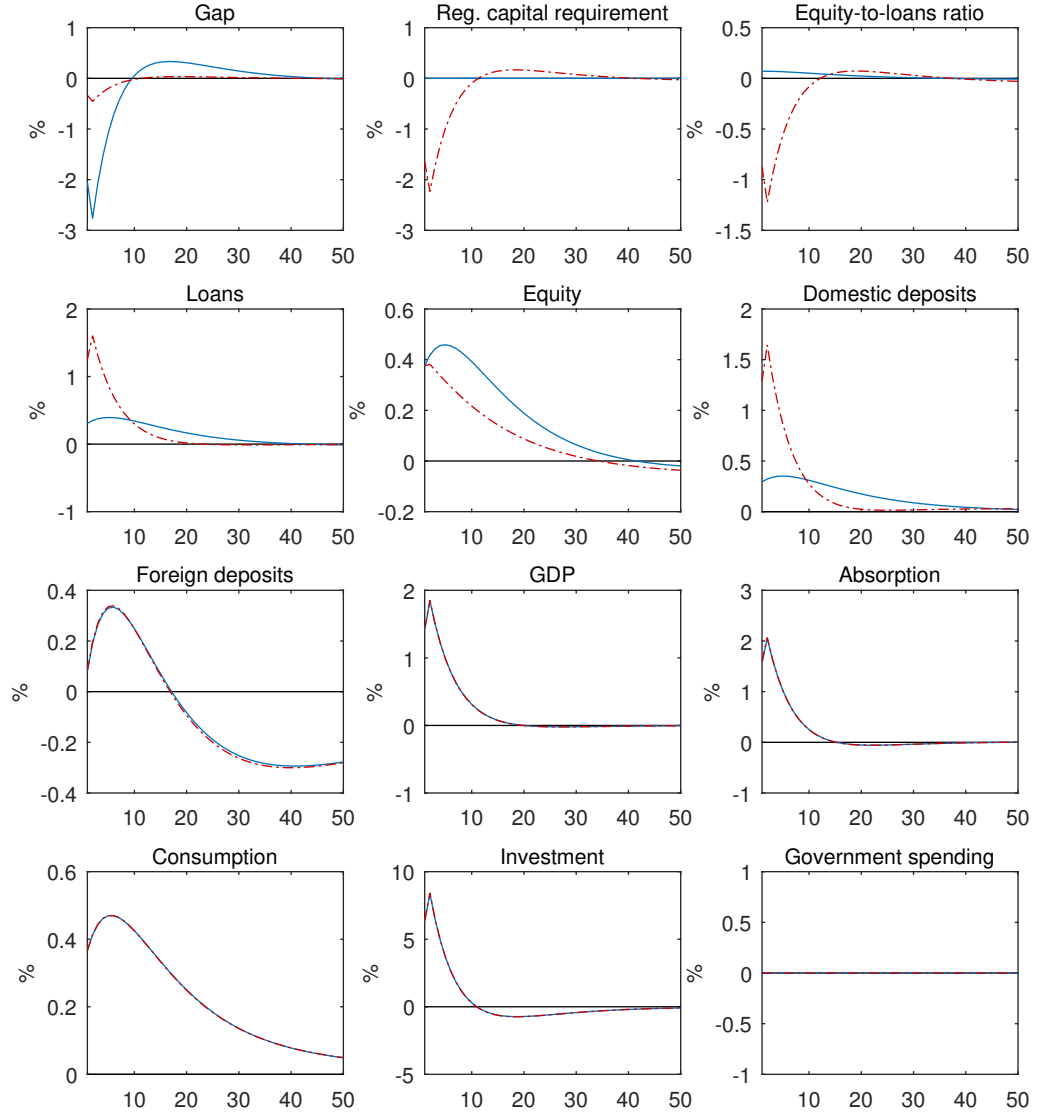
The description of the impact of the buffer is for the following three shocks shorter as the mechanisms are always the same. The focus lies more on pointing out what the shock can learn us additionally about the buffer.

The shock to the preference for hours illustrates how the equity-to-loans ratio is able to adjust to the evolution of the gap even if it moves from below the steady state to above within a short time frame. As equity depends on the specified exogenous rule it is less flexible in adjustment. Therefore, a large part of the fast adjustment of the equity-to-loans ratio stems from the adjustment of loans.

In the beginning the gap falls below the steady state due to the pronounced rise in the GDP which dominates the effect of the loans. Due to this the requirement also falls below the steady state. As the marginal penalty with respect to loans is *ceteris paribus* lower, the bank wants to supply more loans given an expected interest spread and equity. The same mechanisms as described at the shock to the return on equity come into play. Later GDP is almost back at its steady state while loans are still positively affected by the shock. The gap is therefore positive and we are in a typical situation of a high aggregate credit amount in comparison to GDP. The requirement therefore rises from below to above the steady state and now the bank wants to supply less loans. As loans have a duration of one period in the model, the whole amount of loans can be adjusted without time lag. In reality the adjustment would be more time lagged as contracts are made for several periods. The evolution of domestic deposits follows the one of loans. The bank takes its balance sheet into account when taking decision about the supply of loans.

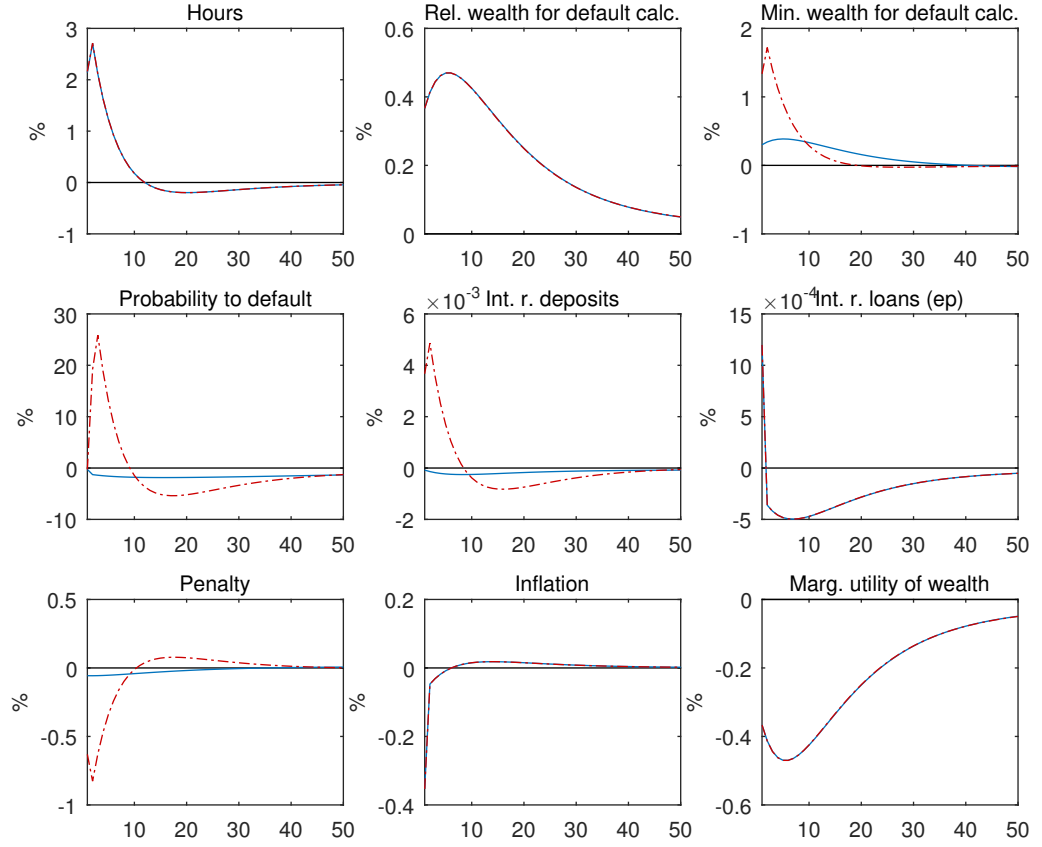
What may look oddly at a first sight is the evolution of the probability to default. But given that the probability to default is affected by the minimum wealth with a time lag and the minimum wealth falls fast after the second period due to the fall in loans the evolution is explainable.

In comparison to the shock on the return on equity we can almost not see an effect of the buffer on the typical macroeconomic variables as GDP, absorption, consumption, investment, hours and inflation.



blue solid = without c. c. buffer and red dashed = with c. c. buffer

Figure 5: Deviations after a negative temporary preference shock to hours, 50 quarters ($1/2$)



blue solid = without c. c. buffer and red dashed = with c. c. buffer

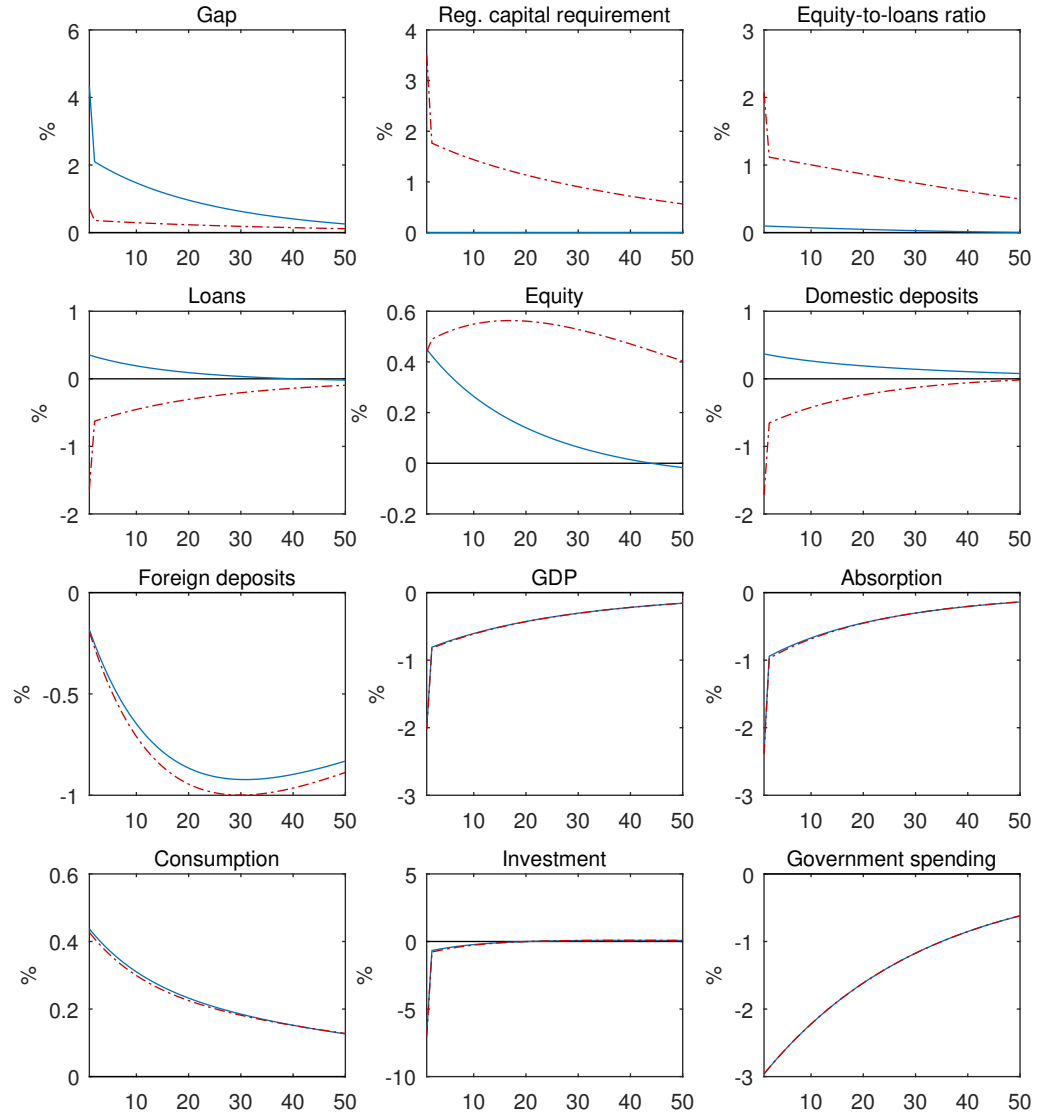
Figure 6: Deviations after a negative temporary preference shock to hours, 50 quarters (2/2)

8.1.4 Fiscal shock

The fiscal shock is outstanding due to its high persistence. Due to the high persistence of the gap also the rise in the regulatory requirement is very persistent. What is interesting to see is that the effect on loans and domestic deposits is so pronounced that they are below the steady state and not anymore above it with the buffer in action. This outstanding evolution is due to the fact that in the case without buffer GDP and loans move in opposite directions due to the shock which is not the case at the other shocks and loans do not deviate that much from the steady state. Furthermore, we have the situation that not only the evolution of loans determines the evolution of the gap in later periods but also the effect of GDP, which given its value below the steady state lifts up the value of the gap at any given value of loans *ceteris paribus*. For an optimal reaction of the bank to the regulatory capital requirement loans have to adjust so much that they fall below the steady state and the evolution is very persistent. We can see the different evolution of loans with the countercyclical capital buffer reflected in the dampened evolution of the gap which is due to the evolution of GDP still above the steady state even if loans fall below it.

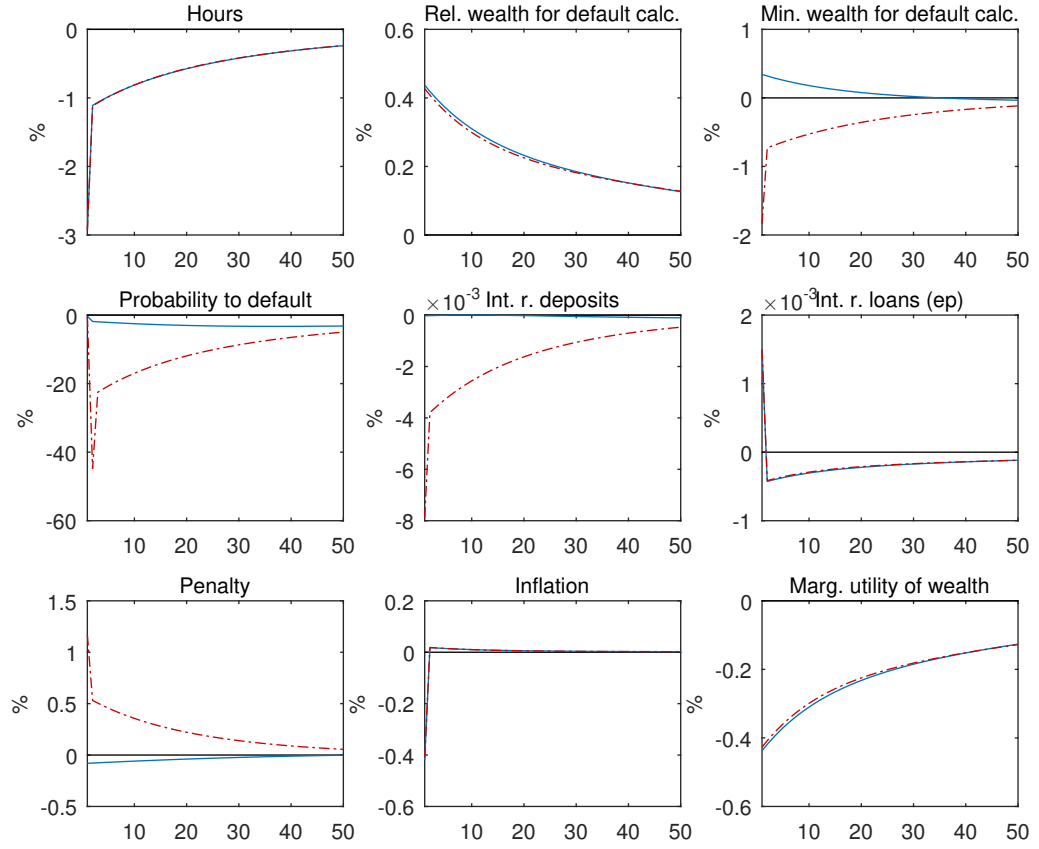
Although the effect of the buffer for example on GDP and absorption is neglectable we can see a slight effect on consumption and house prices (relevant wealth for default calculation). Especially due to the fall in domestic deposits the marginal utility of wealth falls by a lower amount. This affects other variables and the most pronounced impact (although still small) it has on consumption and house prices. Their deviation from the steady state is less pronounced.

Lastly it is left to point out that the buffer causes an even more pronounced fall in foreign deposits due to the pronounced and persistent fall in the interest rate on deposits.



blue solid = without c. c. buffer and red dashed = with c. c. buffer

Figure 7: Deviations after a negative temporary fiscal shock, 50 quarters (1/2)



blue solid = without c. c. buffer and red dashed = with c. c. buffer

Figure 8: Deviations after a negative temporary fiscal shock, 50 quarters (2/2)

8.1.5 Technology shock

The shock to technology causes similar reactions as the shock to the preference for hours. Therefore, the reaction of the buffer is as well similar and not commented again. As the technology shock has a slightly stronger impact, also the deviation of the regulatory capital requirement is slightly more pronounced.

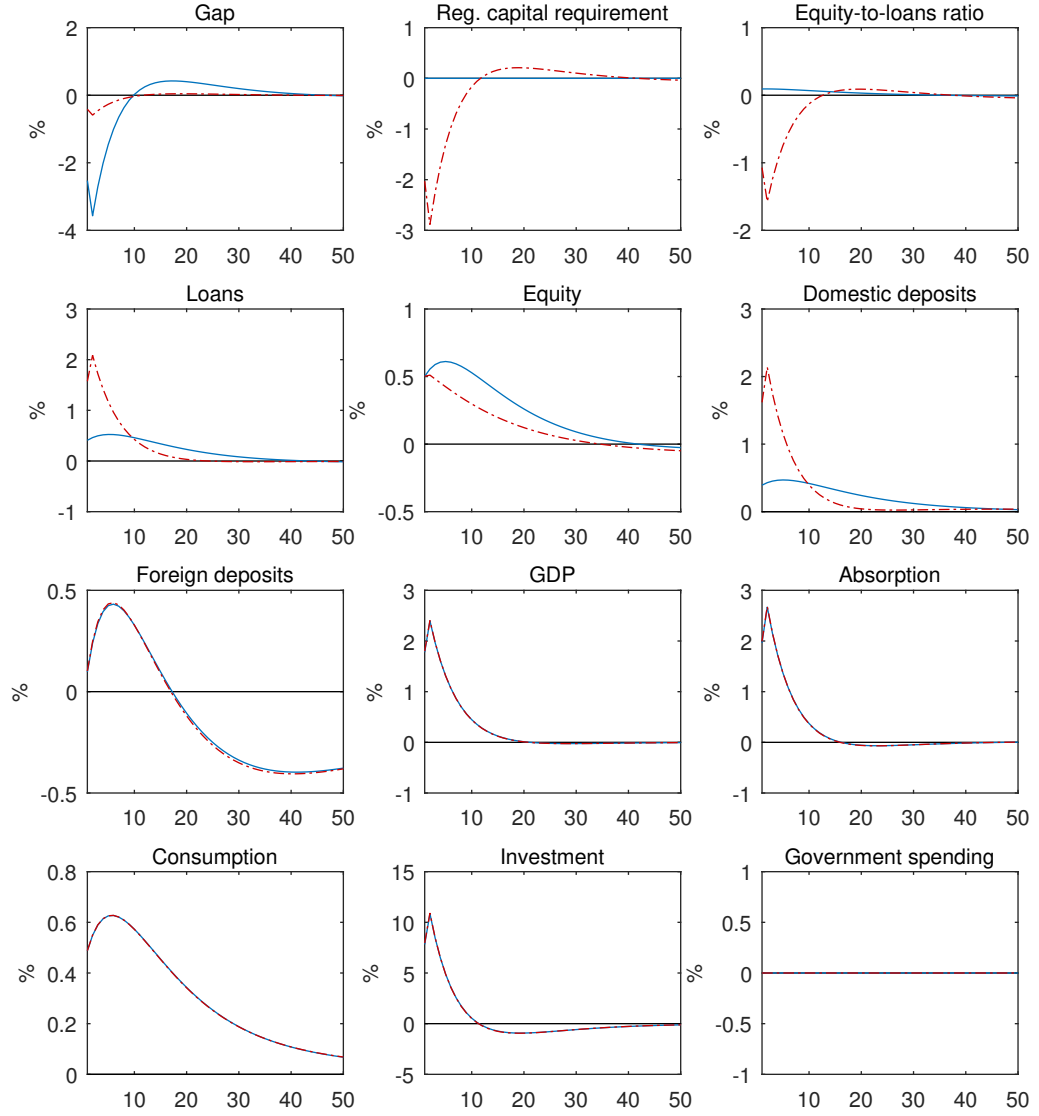
8.1.6 Summary

After having looked at all four shocks we can summarize a few important facts. First we can see in the case of all four shocks a dampened evolvement of the gap. Given that the credit-to-GDP gap is a good indicator for the imbalances and excessive aggregate credit growth we can therefore say that the buffer exerts a dampening effect on it. Secondly, we observe that the targeted equity-to-loans gap in the case with buffer is higher than the one in the economy without buffer if the gap is opened up positively. This goal is reached with a higher amount of equity and a lower amount of loans.

The results of the opposite case when the gap initially falls below the steady state are rather an issue of implementation. According to the guidelines, the countercyclical capital buffer has always a value between 0% and 2.5% and only reacts to a positive deviation of the gap from its trend (BC, 2010 [12]). As we take a first order approximation when doing the calculations in Dynare, an implementation of a step function is not possible. Therefore, in reality the reaction to the fall of the gap below the steady state due to the rise in GDP in the first few quarters after the preference shock and the technology shock would in reality fall away.

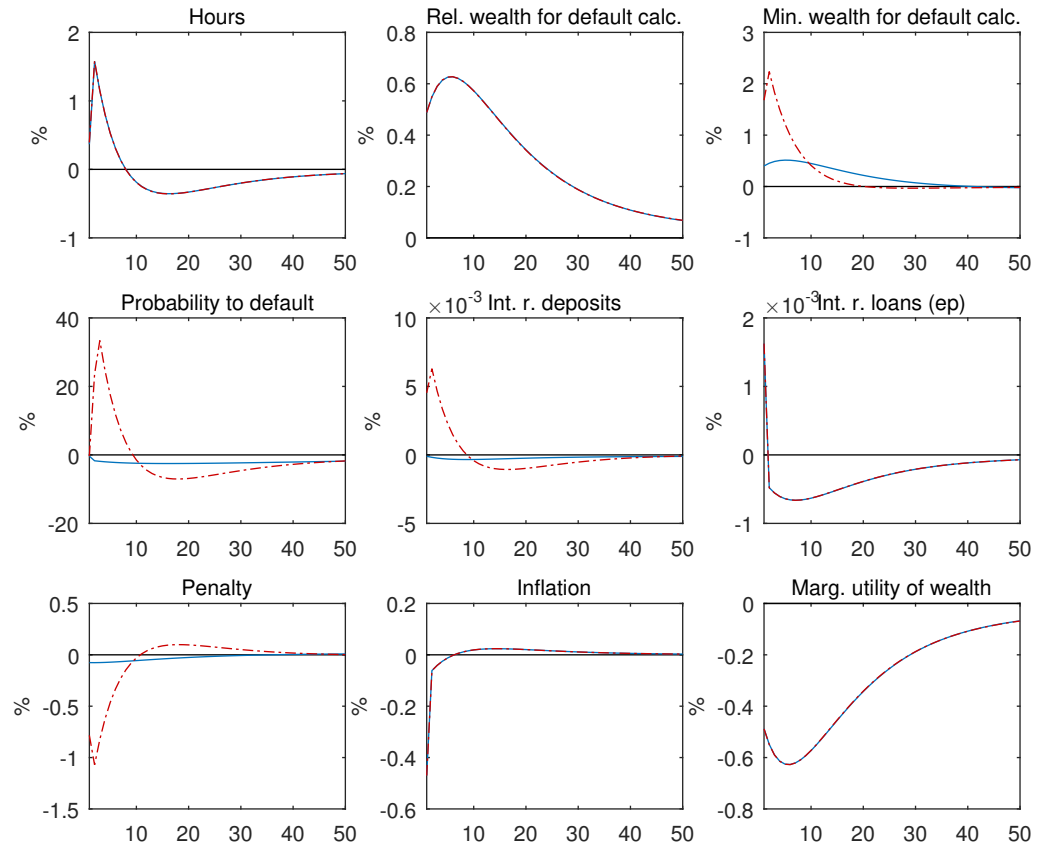
Additionally it is left to point out that the buffer always leads to a lower amount of loans given a positive deviation of the gap. This therefore also means that if the loans are already below their steady state values, they even fall further below it. An authority can but does not have to implement a countercyclical capital buffer in such a situation as they follow a guided discretion approach (BC, 2010 [12])

What should furthermore shortly be once again mentioned is the vice versa dependence of the gap and the requirement which causes a repeating up and down behavior which is not seen in the impulse response functions because it happens all in the same period. When looking at the absolute numbers we have to keep



blue solid = without c. c. buffer and red dashed = with c. c. buffer

Figure 9: Deviations after a positive temporary technology shock, 50 quarters (1/2)



blue solid = without c. c. buffer and red dashed = with c. c. buffer

Figure 10: Deviations after a positive temporary technology shock, 50 quarters (2/2)

this in mind. If the gap for example initially opens up by 6% this implies a requirement of 1.25%. As the banking sector reacts on it already in the same period, this lowers the gap and the authorities can set a lower requirement.

Lastly what should be mentioned is the observation that it partly matters from which sector the shock stems. On the one hand we have a shock in the financial sector. This shock represents a typical shock in the financial sector. The shock represents also the typical case for which the countercyclical capital buffer got implemented. First we have the case that due to higher returns especially the amount of loans is higher. The credit-to-GDP gap opens up positively. Now the buffer comes into play and dampens the evolution of the gap, loans and domestic deposits in the financial sector and an extra equity cushion is build up. The equity-to-loans ratio is higher. What we secondly observe is that also the other typical macroeconomic variables as GDP, absorption, consumption, hours, investment and inflation are on the whole dampened. Therefore, not only regarding financial variables but also macroeconomic variables in general the buffer has the side effect of mitigating the responses to the shock.

When the shock does not stem from the financial sector but from the household (preference shock), firm sector (technology shock) or from the government sector (government spending shock) the buffer also fulfills its goal in enlarging the equity-to-loans ratio when the gap is above the steady state. Furthermore, we observe the dampened evolution of the gap and a lower amount of loans and domestic deposits. In difference to the financial shock the buffer has only a neglecting impact on the evolution of other macroeconomic variables as GDP or consumption. This is similar to the conclusion by Carvalho and Castro (2015 [25]) who observe that the buffer helps to mitigate the effects of the shock stemming from the financial system but its power is much lower when the shock originates elsewhere. Also De Resende et al. (2013 [26]) show that key stabilizing effects on key macroeconomic variables are most pronounced after financial shocks.

Summarizing we can say that the buffer is able to fulfill the goals listed in article 44 ERV (2012 [33]) and stated by the SNB (2014 [51]) in enhancing the resistance of the banking sector against excessive credit growth by building up the equity-to-loans ratio and leaning against those imbalances (represented by the credit-to-GDP gap).

8.2 Welfare costs

The welfare costs are -0.02% of consumption. The values of the relevant variables in the steady state and the relevant parameters are the same with and without the countercyclical capital rule. Therefore, the welfare costs stem from the differences in the volatilities. The volatilities are taken from a stochastic simulation in Dynare when all four shocks hit the economy at the same time.

If a term is concave, more volatility is lowering welfare costs. More volatility makes welfare costs higher if the term is convex. This is the case because given a point on a convex function, one can gain more when marginally moving up than one loses when marginally moving down. In the case of a concave function the opposite holds. In the case of a logarithmic function less volatility is as well enhancing welfare gains.

Therefore, the household has higher welfare gains the lower the volatility of consumption, real domestic deposits and real money. As the supply of the housing stock is fixed, the volatility of the housing stock is zero in any case. In the case of hours, the lower the volatility, the higher the welfare gains as well. Although the function is convex, due to the negative sign in front of the term, more utility lowers welfare.

We have a lower volatility of consumption, real domestic deposits and real money and a higher volatility of hours in the case with the countercyclical capital rule. On the whole the household is better off in an economy with a countercyclical capital rule.

The results are in line with the conclusions of the researchers listed in section 3.

8.3 Volatilities and correlations

8.3.1 Volatilities

The following table shows the volatilities¹³ of different variables and how these volatilities change when a countercyclical capital buffer is in action. The results stem from a stochastic simulation in Dynare when all four shocks hit the economy at the same time.

As expected the volatility of the gap on which the countercyclical capital buffer

¹³In the Dynare model the variables are log-transformed. The volatilities and correlations are approximations to the ones of the not log-transformed variables.

reacts is clearly less volatile. This means that the loan-to-GDP gap can be stabilized. Given that the loan-to-GDP gap is a good indicator of imbalances, the countercyclical capital buffer exerts a dampening effect. The mitigating effect on the financial sector can also be seen when looking at the volatilities of loans and domestic deposits which are lower with a countercyclical capital buffer implemented. Also the volatility of equity is lower. With a countercyclical capital buffer the volatility of consumption is as well smaller although to a very small extent. We can furthermore observe a negative negligible difference in the volatility of the absorption. This corresponds to the findings by Lozej et al. (2016 [43]) who come to the conclusion that a buffer guided by the credit-to-GDP gap can not attenuate or even amplify the response of the economy to shocks if the gap and the GDP deviate not into the same direction. Also Angelini et al. (2014 [7]) conclude that in “normal times” a countercyclical requirement could damage rather than enhance macroeconomic stability if there is a lack of cooperation with monetary policy. An exception is the shock to the financial sector which reduces the volatility of output anyway.

Our difference in the volatility of absorption is negative because investment and hours are to a negligible amount more volatile. The evolution of investment and hours are coupled to some extent as their marginal products depend on each other. The effect of the buffer on hours and investment can almost not be seen in the impulse response functions except we have the case of a shock to the return on equity. In this case the countercyclical capital buffer actually exerts on the whole rather a dampening effect. Also Aliaga-Diaz et al. (2011 [4]) come to the conclusion that anticyclical capital requirements make consumption more stable and can make investment more volatile. Finally, we observe that inflation is less volatile with the buffer but also here as well the difference is small.

Our conclusions regarding welfare costs, volatilitites and correlations can give a reference point about the impact of the countercyclical capital buffer represented by our formulated rule. On the same time one should be conscious about the fact that in reality the countercyclical capital buffer is a step function and with a full modeling of cycles we would get more precise results.

Volatilities		
σ_{gap}	no ccyb	0.134539
	ccyb	0.023861
	Difference	0.110679
σ_l	no ccyb	0.063205
	ccyb	0.038929
	Difference	0.024276
σ_e	no ccyb	0.121783
	ccyb	0.120873
	Difference	0.000911
σ_{dd}	no ccyb	0.065989
	ccyb	0.040131
	Difference	0.025859
σ_y	no ccyb	0.049063
	ccyb	0.049379
	Difference	-0.000316
σ_c	no ccyb	0.012252
	ccyb	0.012008
	Difference	0.000244
σ_i	no ccyb	0.191767
	ccyb	0.193104
	Difference	-0.001337
σ_h	no ccyb	0.049237
	ccyb	0.049489
	Difference	-0.000252
σ_π	no ccyb	0.007465
	ccyb	0.007282
	Difference	0.000183

ccyb = countercyclical capital buffer

Table 8: Volatilities (EMS)

Correlations		
σ_{ygap}	no ccyb	-0.437052
	ccyb	-0.425327
σ_{yl}	no ccyb	0.176037
	ccyb	0.970927
σ_{ye}	no ccyb	0.151187
	ccyb	0.116515
σ_{yd^d}	no ccyb	0.165953
	ccyb	0.972350
σ_{yc}	no ccyb	0.426015
	ccyb	0.420596
σ_{yi}	no ccyb	0.976590
	ccyb	0.976825
σ_{yh}	no ccyb	0.903964
	ccyb	0.908519
$\sigma_{y\pi}$	no ccyb	-0.144526
	ccyb	-0.151157

ccyb=countercyclical capital buffer

Table 9: Correlations (EMS)

8.3.2 Correlations

Table 9 shows the correlations with absorption. As we can see from the table, the countercyclical capital buffer does not induce any sign changes in front of them. One could have also looked at the correlations with GDP and would have come to the same conclusions.

8.4 Robustness to monetary policy

The following graphs show the evolvement of the gap and of the equity-to-loans ratio in the case of exogenous money supply, a Taylor Rule and a Taylor Rule which holds the real exchange rate fixed.

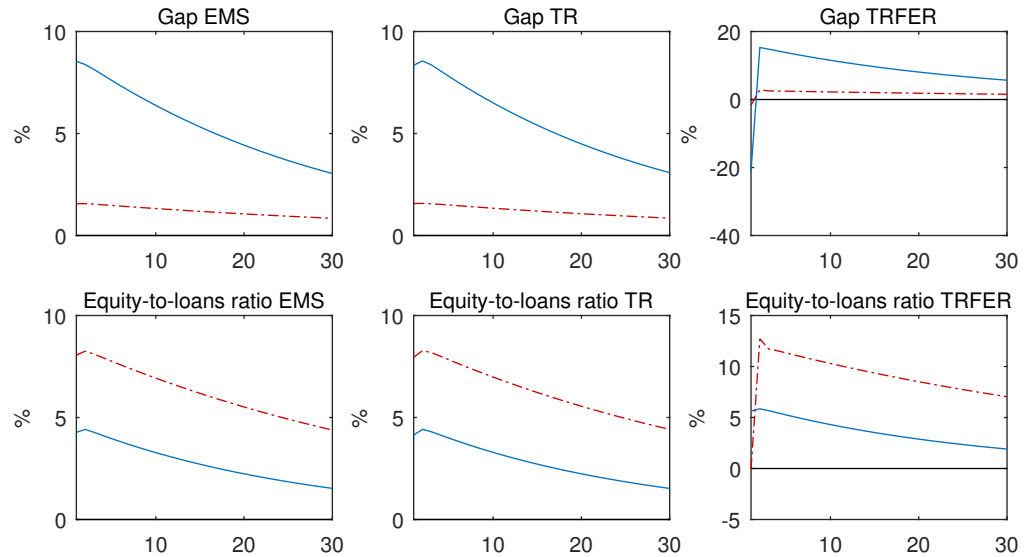
As one can see, the effect from the countercyclical capital buffer on the equity-to-loans ratio is robust to monetary policy. The equity-to-loans ratio reacts ade-

quately to the evolution gap and we can also see the dampening effect on the gap. The reaction of the economy (without a countercyclical capital buffer) to the shock itself changes to some extent when monetary policy changes. The analysis of how an economies reaction changes with the change from exogenous money supply to a Taylor rule is another research question and is not part of this thesis. The welfare costs in the case of a Taylor rule and a floating exchange rate are -0.03%. This is in line with Mimir and Sunel (2015 [45]) who find that a countercyclical reserve requirement in combination with a conventional Taylor-type rule can effectively reduce welfare costs.

In the case of a model with a Taylor rule which holds the real exchange rate fixed the costs lie at -0.22%.

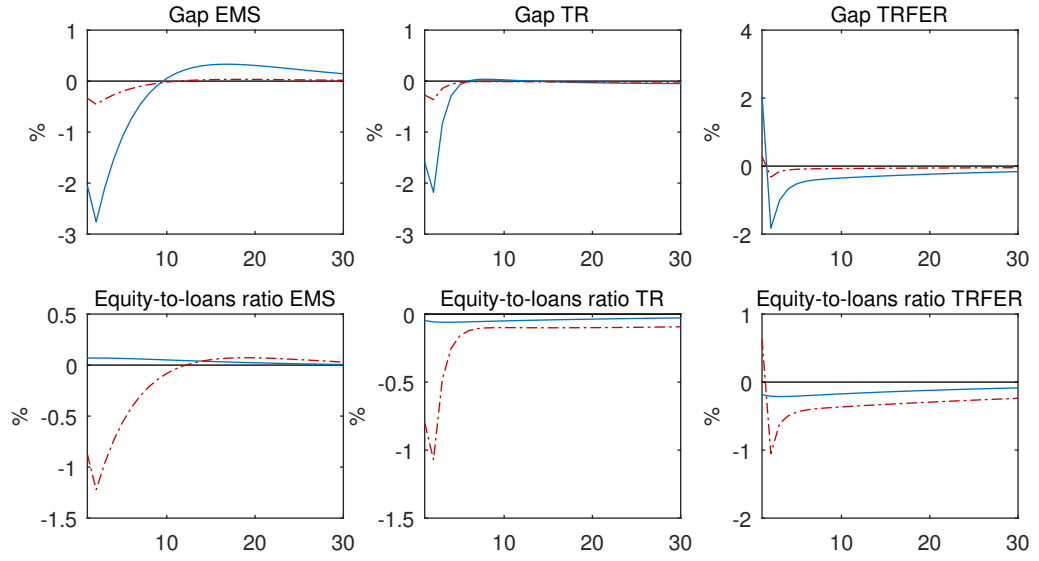
The buffer therefore further enhances welfare if monetary policy can be represented by a conventional Taylor Rule, respectively a Taylor Rule which holds the real exchange rate fixed. Note that when calculating the welfare costs the term stemming from the money in the utility function falls away in the case of a Taylor rule.

An overview over the volatilities and the correlations in the case with a Taylor rule (and a fixed exchange rate) can be found in the appendix G.



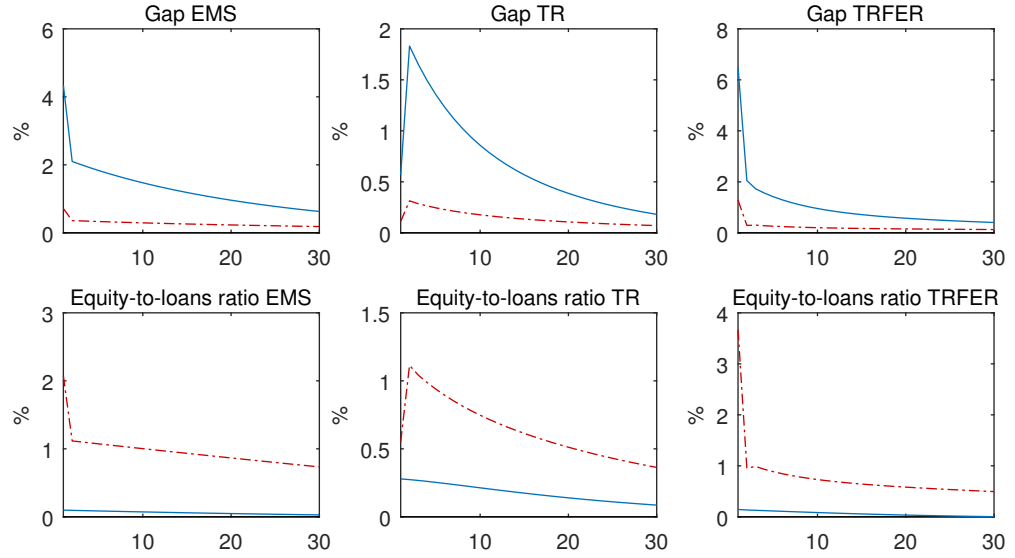
blue solid = without c. c. buffer and red dashed = with c. c. buffer

Figure 11: Robustness to monetary policy, return on equity shock, 30 quarters



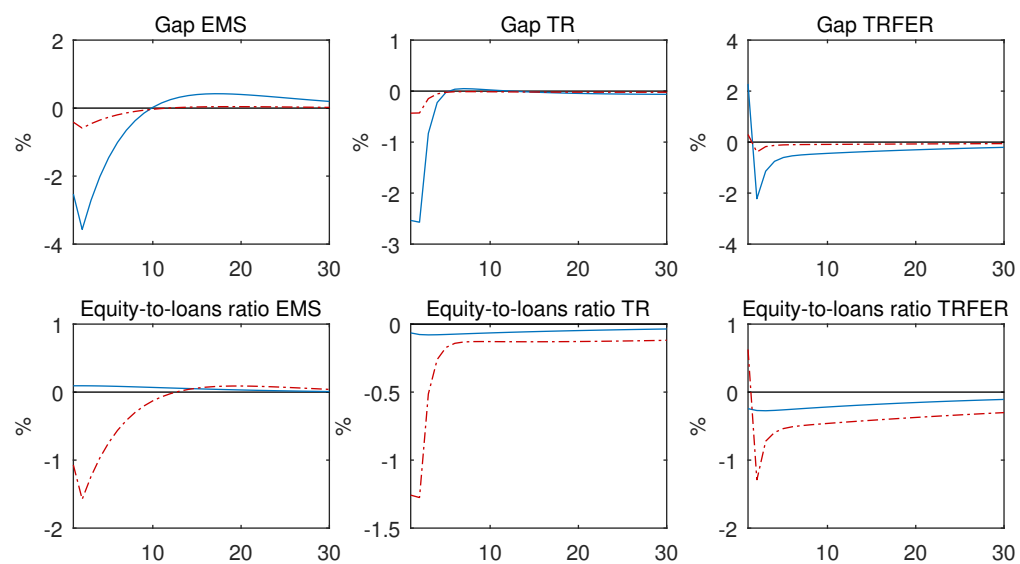
blue solid = without c. c. buffer and red dashed = with c. c. buffer

Figure 12: Robustness to monetary policy, preference shock to hours, 30 quarters



blue solid = without c. c. buffer and red dashed = with c. c. buffer

Figure 13: Robustness to monetary policy, fiscal shock, 30 quarters



blue solid = without c. c. buffer and red dashed = with c. c. buffer

Figure 14: Robustness to monetary policy, technology shock, 30 quarters

9 Conclusion

This thesis explored the effects of a countercyclical capital buffer on the economy. A small open economy DSGE model estimated with data of the Swiss economy was used. The buffer was implemented in line with the rule suggested by the Basel Committee in the guidance for national authorities operating the countercyclical capital buffer (BC, 2010 [12]). The buffer reacts on the credit-to-GDP gap, which serves as indicator of the state of the financial sector. In a first step the impulse response functions of the main financial and macroeconomic variables after four different shocks from four different sectors were analyzed. The focus in the analysis lied on the build-up phase. The countercyclical capital buffer always led to a higher equity-to-loans ratio given a rise of the credit-to-GDP gap above the steady state. The goal is reached by a lower amount of loans and partially by a higher equity. Furthermore, due to the countercyclical capital buffer the credit-to-GDP gap showed a dampened evolution. Therefore, the buffer shows the positive side effect in dampening the imbalances. Furthermore given a positive deviation of the gap from the steady state the amount of loans and deposits is lower. If the buffer dampens important macroeconomic variables depends on the origin of the shock. Given a typical financial shock the buffer shows a mitigating effect not only on financial variables but also on typical macroeconomic ones. If the shock stemmed from other sectors the buffer almost has no influence.

Summarizing we can say that the buffer is able to fulfill the goals outlined in article 44 ERV (2012 [33]) and stated by the SNB (2014 [51]). It enhances the resistance of the banking sector against excessive credit growth by building up the equity-to-loans ratio and leans against the imbalances.

In a second step the welfare costs were calculated. The implementation of our countercyclical capital buffer rule enhances welfare and the welfare gains in terms of consumption are -0.02%. The welfare gains stem from the differences in the volatilities.

In a third step the effects of the countercyclical capital buffer on standard deviations and correlations were explored. The implementation of the rule lowers the volatilities of the main financial variables as well as the one of consumption and inflation. The volatilities of absorption, hours and investment are higher but of a neglectable size. Therefore the volatilities of these variables mainly stay the same. The countercyclical capital rule does not change any correlation of absorption re-

spectively GDP with the main macroeconomic and financial variables in the sense that it inverts the sign in front.

Furthermore, analysis also showed that the countercyclical capital buffer is robust to monetary policy. The exogenous money supply and the money in the utility function term in the base case economy were replaced by a conventional Taylor rule and a Taylor rule which holds the exchange rate fixed. The impulse response functions showed that the equity-to-loans ratio is higher given a positive deviation of the credit-to-GDP gap from the steady state in the case with a countercyclical capital buffer. Also the dampening effect on the credit-to-GDP gap is present. The welfare costs lie at -0.03% (conventional Taylor rule) and -0.22% (Taylor rule and fixed exchange rate). The buffer therefore even further enhances the welfare given those two cases.

As mentioned, the focus when analysing the impulse response functions lied on the impact of the buffer during the build-up of the imbalances. This is the time when the buffer is activated and leads to the build-up of the equity-to-loans ratio and a dampening of the growing imbalances. In a future research project one could focus more on modeling a whole cycle and look at the aftereffects of the countercyclical capital buffer after the build-up phase. Furthermore the implementation of the countercyclical capital buffer as a step function would enhance the research. Maybe second order approximations are a possibility.

The modeling of whole cycles and the implementation of a step function would also allow preciser results regarding the welfare costs, volatilities and the correlations. Regarding the model itself an implementation of a more complex banking sector would allow to explore a variety of shocks from this sector. One could for example think about including interbank lending. Also to add lending from the banking to the firm sector is another possibility. This would maybe allow to model a tighter interconnectedness between the financial and the economic cycle. Furthermore, one could differentiate more with respect to lending. A possibility would be to implement two banks of which one is specialized in mortgage lending. Excessive credit growth in the housing sector would then maybe induce compositional effects as empirically evidenced by Basten and Koch (2015 [11]) and Auer and Ongena (2016 [9]).

Within the next years research regarding the countercyclical capital buffer will be further enhanced due to the availability of data from the first experiences with the

buffer in different countries. The available literature which draws its conclusions from theoretical models will be enriched in its variety by empirical research results.

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A Selected model calculations

A.1 Lagrangian of the maximization problem of the household

The Lagrangian of the maximization problem of the household (see section 4.2) is as follows:

$$\begin{aligned} \mathcal{L} = \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i & \left(\log(c_{t+i}) - \zeta_{h,t} \frac{h_{t+i}^{(1+\eta)}}{(1+\eta)} + \zeta_H \log(H_{t+i}) + \zeta_{d^d} \frac{\left(\frac{D_{t+i}^d}{P_{t+i}}\right)^{(1-\iota)}}{(1-\iota)} + \zeta_m \frac{\left(\frac{M_{t+i}}{P_{t+i}}\right)^{(1-\Phi_m)}}{(1-\Phi_m)} \right. \\ & + \Lambda_{t+i} (P_{t+i} w_{t+i} h_{t+i} + P_{t+i} z_{t+i} k_{t+i} + P_{H,t+i} H_{t-1+i} + L_{t+i} + R_{t-1+i} D_{t-1+i}^d + R_{e,t+i} E_{t-1+i} \\ & + M_{t-1+i} + \Pi_{t+i}^f + P e_{t-1+i} - P_{t+i} c_{t+i} - P_{t+i} i_{t+i} - P_{H,t+i} H_{t+i} - R_{l1,t+i} L_{t+i-1} \\ & \left. - D_{t+i}^d - E_{t+i} - M_{t+i} - \Theta_{t+i}) + Q_{t+i} (i_{t+i} + (1-\delta)k_{t+i} - k_{t+1+i}) \right) \end{aligned}$$

When taking the derivative with respect to $c_{t+i}, h_{t+i}, H_{t+i}, D_{t+i}^d, i_{t+i}, k_{t+i+1}, L_{t+i}, M_{t+i}$ we get the first order conditions written down in section 4.2.

A.2 Optimal bank behavior

The bank maximizes profits. It solves the following maximization problem:

$$\max_{L_t} \mathbb{E}_t \left(R_{l,t} (1 - \chi J_{t+1}) L_t - R_t \underbrace{(L_t - D_t^f - E_t)}_{D_t^d} - \left(v + \frac{v_2}{2} \left(\log \left(\frac{E_t/L_t}{rcr_t} \right) \right)^2 \right) L_t \right)$$

Taking the first order condition with respect to L_t yields

$$\begin{aligned} \mathbb{E}_t & \left(R_{l,t} (1 - \chi J_{t+1}) - R_t - \left(v + \frac{v_2}{2} \left(\log \left(\frac{E_t/L_t}{rcr_t} \right) \right)^2 \right) \right. \\ & \left. - \left(v_2 \log \left(\frac{E_t/L_t}{rcr_t} \right) \frac{rcr_t}{E_t/L_t} (-1) \frac{E_t/L_t^2}{rcr_t} \right) L_t \right) = 0 \end{aligned}$$

We can rearrange it to

$$\mathbb{E}_t \left(R_{l,t} (1 - \chi J_{t+1}) - R_t - \left(v + \frac{v_2}{2} \left(\log \left(\frac{E_t/L_t}{rcr_t} \right) \right)^2 \right) + v_2 \log \left(\frac{E_t/L_t}{rcr_t} \right) \right) = 0$$

Using $\mathbb{E}_t(R_{l1,t+1}) = \mathbb{E}_t[R_{l,t}(1 - \chi J_{t+1})]$ we get

$$\mathbb{E}_t(R_{l1,t+1}) = R_t + v - v_2 \log\left(\frac{E_t/L_t}{rcr_t}\right) + \frac{v_2}{2} \left(\log\left(\frac{E_t/L_t}{rcr_t}\right)\right)^2$$

A.3 Return on equity

The household is the shareholder of the bank and therefore, it gets the profits.

$R_{e,t}$ is the gross return on equity and is therefore as follows:

$$\begin{aligned} R_{e,t}E_{t-1} &= R_{l1,t}L_{t-1} - R_{t-1}(D_{t-1}^d + D_{t-1}^f) - \left(v + \frac{v_2}{2} \left(\log\left(\frac{E_{t-1}/L_{t-1}}{rcr_{t-1}}\right)\right)^2\right) L_{t-1} \\ &+ (\varepsilon_{Re,t} - 1)E_{t-1} \end{aligned}$$

Using $L_t = D_t^d + D_t^f + E_t$ yields

$$\begin{aligned} R_{e,t}E_{t-1} &= R_{l1,t}L_{t-1} - R_{t-1}(L_{t-1} - E_{t-1}) - \left(v + \frac{v_2}{2} \left(\log\left(\frac{E_{t-1}/L_{t-1}}{rcr_{t-1}}\right)\right)^2\right) L_{t-1} \\ &+ (\varepsilon_{Re,t} - 1)E_{t-1} \end{aligned}$$

We rearrange and get the following equation:

$$\begin{aligned} R_{e,t} &= R_{t-1} + (R_{l1,t} - R_{t-1}) \frac{L_{t-1}}{E_{t-1}} - \left(v + \frac{v_2}{2} \left(\log\left(\frac{E_{t-1}/L_{t-1}}{rcr_{t-1}}\right)\right)^2\right) \frac{L_{t-1}}{E_{t-1}} \\ &+ (\varepsilon_{Re,t} - 1) \end{aligned}$$

A.4 Demand for the domestic and foreign goods x_t^d and x_t^f

The maximization problem is

$$\max_{x_t^d, x_t^f} P_t y_t - P_{x,t} x_t^d - N e_t P_{x,t}^* x_t^f \text{ with } y_t = \left(\omega^{(1-p)} x_t^{dp} + (1 - \omega)^{(1-p)} x_t^{fp}\right)^{\frac{1}{p}}$$

which can be rewritten to

$$\max_{x_t^d, x_t^f} P_t \left(\omega^{(1-p)} x_t^{dp} + (1 - \omega)^{(1-p)} x_t^{fp}\right)^{\frac{1}{p}} - P_{x,t} x_t^d - N e_t P_{x,t}^* x_t^f$$

Taking the first order condition with respect to x_t^d yields

$$\begin{aligned} P_t^{\frac{1}{p}} \left(\omega^{(1-p)} x_t^{dp} + (1 - \omega)^{(1-p)} x_t^{fp}\right)^{\frac{1}{p}-1} p \omega^{(1-p)} x_t^{d(p-1)} - P_{x,t} &= 0 \\ y_t^{(1-p)} \omega^{(1-p)} x_t^{d(p-1)} &= \frac{P_{x,t}}{P_t} \end{aligned}$$

$$y_t^{-1} \omega^{-1} x_t^d = \left(\frac{P_{x,t}}{P_t} \right)^{\frac{1}{(p-1)}}$$

$$x_t^d = \left(\frac{P_{x,t}}{P_t} \right)^{\frac{1}{(p-1)}} \omega y_t$$

The equation $x_t^f = \left(\frac{Ne_t P_{x,t}^*}{P_t} \right)^{\frac{1}{(p-1)}} (1 - \omega) y_t$ can be derived equivalently.

A.5 Price index P_t

Given free entry in the final good sector, firms make zero profits. Therefore,

$$P_t y_t - P_{x,t} x_t^d - Ne_t P_{x,t}^* x_t^f = 0$$

Inserting the demand functions $x_t^d = \left(\frac{P_{x,t}}{P_t} \right)^{\frac{1}{(p-1)}} \omega y_t$ and $x_t^f = \left(\frac{Ne_t P_{x,t}^*}{P_t} \right)^{\frac{1}{(p-1)}} (1 - \omega) y_t$ yields

$$P_t y_t - P_{x,t} \left(\frac{P_{x,t}}{P_t} \right)^{\frac{1}{(p-1)}} \omega y_t - Ne_t P_{x,t}^* \left(\frac{Ne_t P_{x,t}^*}{P_t} \right)^{\frac{1}{(p-1)}} (1 - \omega) y_t = 0$$

$$P_t P_t^{\frac{1}{(p-1)}} - P_{x,t} P_{x,t}^{\frac{1}{(p-1)}} \omega - Ne_t P_{x,t}^* (Ne_t P_{x,t}^*)^{\frac{1}{(p-1)}} (1 - \omega) = 0$$

$$P_t^{\frac{p}{(p-1)}} - P_{x,t}^{\frac{p}{(p-1)}} \omega - (Ne_t P_{x,t}^*)^{\frac{p}{(p-1)}} (1 - \omega) = 0$$

$$P_t = \left(\omega P_{x,t}^{\frac{p}{(p-1)}} + (1 - \omega) (Ne_t P_{x,t}^*)^{\frac{p}{(p-1)}} \right)^{\frac{(p-1)}{p}}$$

A.6 Demand for the intermediate goods $x_t^d(i)$, $x_t^{d*}(i)$ and $x_t^f(i)$

The maximization problem looks as follows:

$$\max_{x_t^d(i)} P_{x,t} x_t^d - \int_0^1 \tilde{P}_{x,t}(i) x_t^d(i) di \text{ with } x_t^d = \left(\int_0^1 x_t^d(i)^{\frac{(\theta-1)}{\theta}} di \right)^{\frac{\theta}{(\theta-1)}}$$

respectively,

$$\max_{x_t^d(i)} P_{x,t} \left(\int_0^1 x_t^d(i)^{\frac{(\theta-1)}{\theta}} di \right)^{\frac{\theta}{(\theta-1)}} - \int_0^1 \tilde{P}_{x,t}(i) x_t^d(i) di$$

Taking the first order condition with respect to $x_t^d(i)$ yields

$$\begin{aligned}
& \frac{\theta}{(\theta-1)} P_{x,t} \left(\int_0^1 x_t^d(i)^{\frac{(\theta-1)}{\theta}} di \right)^{\frac{\theta}{(\theta-1)}-1} \frac{(\theta-1)}{\theta} x_t^d(i)^{\frac{(\theta-1)}{\theta}-1} - \tilde{P}_{x,t}(i) = 0 \\
& P_{x,t} \left(\int_0^1 x_t^d(i)^{\frac{(\theta-1)}{\theta}} di \right)^{\frac{1}{(\theta-1)}} x_t^d(i)^{\frac{(\theta-1)}{\theta}-1} - \tilde{P}_{x,t}(i) = 0 \\
& P_{x,t} x_t^{\frac{1}{\theta}} x_t^d(i)^{\frac{(\theta-1)}{\theta}-1} = \tilde{P}_{x,t}(i) \\
& x_t^d(i) = \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t}} \right)^{-\theta} x_t^d
\end{aligned}$$

The demand functions for $x_t^{d*}(i)$ and $x_t^f(i)$ can be derived equivalently.

A.7 Price index $P_{x,t}$

Firms make zero profits as there is free entry in the final good sector. Therefore,

$$P_{x,t} x_t^d - \int_0^1 \tilde{P}_{x,t}(i) x_t^d(i) di = 0$$

Inserting the demand function $x_t^d(i) = \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t}} \right)^{-\theta} x_t^d$ yields

$$P_{x,t} x_t^d - \int_0^1 \tilde{P}_{x,t}(i) \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t}} \right)^{-\theta} x_t^d di = 0$$

Rearranging yields

$$\begin{aligned}
P_{x,t} &= \int_0^1 \tilde{P}_{x,t}(i) \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t}} \right)^{-\theta} di \\
P_{x,t}^{(1-\theta)} &= \int_0^1 \tilde{P}_{x,t}(i)^{(1-\theta)} di \\
P_{x,t} &= \left(\int_0^1 \tilde{P}_{x,t}(i)^{(1-\theta)} di \right)^{\frac{1}{(1-\theta)}}
\end{aligned}$$

A.8 Real marginal cost

We know that

$$cost(i)_t = z_t k_t(i) + w_t h_t(i)$$

and

$$x_t(i) = a_t k_t(i)^\alpha h_t(i)^{(1-\alpha)}$$

The intermediaries have local monopoly power. Therefore, the firms minimize

real costs with respect to the production function stated above.

$$\min_{k_t(i), h_t(i)} z_t k_t(i) + w_t h_t(i) \text{ s.t. } x_t(i) = \overline{x_t(i)}$$

We can rewrite it to

$$\min_{k_t(i), h_t(i)} z_t k_t(i) + w_t h_t(i) + \Upsilon(a_t k_t(i)^\alpha h_t(i)^{1-\alpha} - \overline{x_t(i)})$$

There are two first order conditions. The first is

$$z_t + \Upsilon(\alpha a_t k_t(i)^{\alpha-1} h_t(i)^{1-\alpha}) = 0$$

Rearranging yields

$$z_t + \Upsilon \alpha a_t \left(\frac{h_t(i)}{k_t(i)} \right)^{1-\alpha} = 0$$

The second first order condition is

$$w_t + \Upsilon((1-\alpha)a_t k_t(i)^\alpha h_t(i)^{-\alpha}) = 0$$

We can rearrange it to

$$w_t + \Upsilon(1-\alpha)a_t \left(\frac{k_t(i)}{h_t(i)} \right)^\alpha = 0$$

When we combine the two first order conditions, we get

$$\frac{z_t}{w_t} = \frac{\alpha}{(1-\alpha)} \frac{h_t(i)}{k_t(i)}$$

For the next step we need the following three equations

$$\begin{aligned} \overline{x_t(i)} &= a_t k_t(i)^\alpha h_t(i)^{1-\alpha} \\ h_t(i) &= k_t(i) \frac{(1-\alpha)}{\alpha} \frac{z_t}{w_t} \\ k_t(i) &= \frac{\alpha}{(1-\alpha)} h_t(i) \frac{w_t}{z_t} \end{aligned}$$

We can insert the third equation into the second and then insert the new equation

into the first. We get

$$\begin{aligned}\overline{x_t(i)} &= a_t \left(\frac{\alpha}{(1-\alpha)} h_t(i) \frac{w_t}{z_t} \right)^\alpha h_t(i)^{(1-\alpha)} \\ \overline{x_t(i)} &= a_t \left(\frac{\alpha}{(1-\alpha)} \frac{w_t}{z_t} \right)^\alpha h_t(i) \\ h_t(i) &= \overline{x_t(i)} \frac{1}{a_t} \left(\frac{\alpha}{(1-\alpha)} \frac{w_t}{z_t} \right)^{-\alpha}\end{aligned}$$

The same way we can also derive the equation for $k_t(i)$.

$$k_t(i) = \overline{x_t(i)} \frac{1}{a_t} \left(\frac{\alpha}{(1-\alpha)} \frac{w_t}{z_t} \right)^{(1-\alpha)}$$

We insert $k_t(i)$ and $h_t(i)$ into the cost function. This yields

$$c_t = z_t \overline{x_t(i)} \frac{1}{a_t} \left(\frac{\alpha}{(1-\alpha)} \frac{w_t}{z_t} \right)^{(1-\alpha)} + w_t \overline{x_t(i)} \frac{1}{a_t} \left(\frac{\alpha}{(1-\alpha)} \frac{w_t}{z_t} \right)^{-\alpha}$$

Then we can take the derivative with respect to $\overline{x_t}$.

$$\begin{aligned}\frac{\partial c_t}{\partial \overline{x_t}} &= \frac{1}{a_t} z_t^\alpha w_t^{(1-\alpha)} (1-\alpha)^{-(1-\alpha)} \alpha^{(1-\alpha)} + \frac{1}{a_t} z_t^\alpha w_t^{(1-\alpha)} (1-\alpha)^\alpha \alpha^{-\alpha} \\ \frac{\partial c_t}{\partial \overline{x_t}} &= \frac{1}{a_t} z_t^\alpha w_t^{(1-\alpha)} \left((1-\alpha)^{-(1-\alpha)} \alpha^{(1-\alpha)} + (1-\alpha)^\alpha \alpha^{-\alpha} \right) \\ \frac{\partial c_t}{\partial \overline{x_t}} &= \frac{1}{a_t} z_t^\alpha w_t^{(1-\alpha)} \alpha^{-\alpha} (1-\alpha)^\alpha \left((1-\alpha)^{-1} \alpha + 1 \right) \\ \frac{\partial c_t}{\partial \overline{x_t}} &= \frac{1}{a_t} z_t^\alpha w_t^{(1-\alpha)} \alpha^{-\alpha} (1-\alpha)^\alpha \left(\frac{\alpha}{(1-\alpha)} + \frac{(1-\alpha)}{(1-\alpha)} \right) \\ \frac{\partial c_t}{\partial \overline{x_t}} &= \frac{1}{a_t} z_t^\alpha w_t^{(1-\alpha)} \alpha^{-\alpha} (1-\alpha)^{\alpha-1}\end{aligned}$$

Finally we get

$$s_t = \frac{\partial c_t}{\partial \overline{x_t}} = \frac{\frac{1}{a_t} z_t^\alpha w_t^{(1-\alpha)}}{\alpha^\alpha (1-\alpha)^{(1-\alpha)}}$$

A.9 Calvo Fairy

The price setting behavior is represented by a typical Calvo Fairy

$$\max_{\tilde{P}_{x,t}(i)} \mathbb{E}_t \sum_{j=0}^{\infty} \Phi_{t,t+j} \xi^j \Pi(\tilde{P}_{x,t}(i))$$

$$\text{with } \Pi(\tilde{P}_{x,t}(i)) = (\tilde{P}_{x,t}(i) - P_{t+j} s_{t+j}) x_{t+j}(i)$$

and

$$x_t(i) = \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t}} \right)^{-\theta} x_t$$

$\Phi_{t,t+j}$ is the discount factor and $\Phi_{t,t+j} \propto \beta^j \frac{\Lambda_{t+j}}{\Lambda_t}$. Rewriting yields

$$\max_{\tilde{P}_{x,t}(i)} \mathbb{E}_t \sum_{j=0}^{\infty} (\beta\xi)^j \frac{\Lambda_{t+j}}{\Lambda_t} (\tilde{P}_{x,t}(i) - P_{t+j} s_{t+j}) \left(\frac{\tilde{P}_{x,t}(i)}{\tilde{P}_{x,t+j}} \right)^{-\theta} x_{t+j}$$

Taking the first order condition with respect to $\tilde{P}_{x,t}(i)$ yields

$$\mathbb{E}_t \left[\sum_{j=0}^{\infty} (\beta\xi)^j \frac{\Lambda_{t+j}}{\Lambda_t} \left((1-\theta) \left(\frac{\tilde{P}_{x,t}(i)}{\tilde{P}_{x,t+j}} \right)^{-\theta} x_{t+j} + \theta \frac{P_{t+j}}{\tilde{P}_{x,t}(i)} \left(\frac{\tilde{P}_{x,t}(i)}{\tilde{P}_{x,t+j}} \right)^{-\theta} s_{t+j} x_{t+j} \right) \right] = 0$$

All firms which reset their prices in period t , set it at the same level and therefore, $\tilde{P}_{x,t}(i) = \tilde{P}_{x,t}$ for all $i \in (0, 1)$.

$$\begin{aligned} \mathbb{E}_t \left[\sum_{j=0}^{\infty} (\beta\xi)^j \Lambda_{t+j} \left(P_{x,t+j}^{\theta} x_{t+j} - \frac{\theta}{(\theta-1)} \frac{P_{t+j}}{\tilde{P}_{x,t}} P_{x,t+j}^{\theta} s_{t+j} x_{t+j} \right) \right] &= 0 \\ \mathbb{E}_t \sum_{j=0}^{\infty} (\beta\xi)^j \Lambda_{t+j} P_{x,t+j}^{\theta} x_{t+j} - \mathbb{E}_t \sum_{j=0}^{\infty} (\beta\xi)^j \Lambda_{t+j} \frac{\theta}{(\theta-1)} \frac{P_{t+j}}{\tilde{P}_{x,t}} P_{x,t+j}^{\theta} s_{t+j} x_{t+j} &= 0 \\ \frac{1}{\tilde{P}_{x,t}} \mathbb{E}_t \sum_{j=0}^{\infty} (\beta\xi)^j \Lambda_{t+j} \frac{\theta}{(\theta-1)} P_{t+j} P_{x,t+j}^{\theta} s_{t+j} x_{t+j} &= \mathbb{E}_t \sum_{j=0}^{\infty} (\beta\xi)^j \Lambda_{t+j} P_{x,t+j}^{\theta} x_{t+j} \\ \frac{\mathbb{E}_t \sum_{j=0}^{\infty} (\beta\xi)^j \Lambda_{t+j} \frac{\theta}{(\theta-1)} P_{t+j} P_{x,t+j}^{\theta} s_{t+j} x_{t+j}}{\mathbb{E}_t \sum_{j=0}^{\infty} (\beta\xi)^j \Lambda_{t+j} P_{x,t+j}^{\theta} x_{t+j}} &= \tilde{P}_{x,t} \end{aligned}$$

A.10 Recursive representation of $P_{x,t}^n$, $P_{x,t}^d$ and $P_{x,t}$

$P_{x,t}^n$ is defined as follows:

$$P_{x,t}^n = \mathbb{E}_t \left[\sum_{j=0}^{\infty} (\beta\xi)^j \Lambda_{t+j} \frac{\theta}{(\theta-1)} P_{t+j} P_{x,t+j}^{\theta} s_{t+j} x_{t+j} \right]$$

For the recursive representation we first take out the term at $j = 0$.

$$P_{x,t}^n = \mathbb{E}_t \left[\Lambda_t \frac{\theta}{(\theta-1)} P_t P_{x,t}^{\theta} s_t x_t + \sum_{j=1}^{\infty} (\beta\xi)^j \Lambda_{t+j} \frac{\theta}{(\theta-1)} P_{t+j} P_{x,t+j}^{\theta} s_{t+j} x_{t+j} \right]$$

We rewrite the equation as such that the sum starts at $j = 0$.

$$P_{x,t}^n = \mathbb{E}_t \left[\Lambda_t \frac{\theta}{(\theta-1)} P_t P_{x,t}^\theta s_t x_t + \sum_{j=0}^{\infty} (\beta\xi)^{j+1} \Lambda_{t+j+1} \frac{\theta}{(\theta-1)} P_{t+j+1} P_{x,t+j+1}^\theta s_{t+j+1} x_{t+j+1} \right]$$

We take out $\beta\xi$ of the sum.

$$P_{x,t}^n = \mathbb{E}_t \left[\Lambda_t \frac{\theta}{(\theta-1)} P_t P_{x,t}^\theta s_t x_t + \beta\xi \sum_{j=0}^{\infty} (\beta\xi)^j \Lambda_{t+j+1} \frac{\theta}{(\theta-1)} P_{t+j+1} P_{x,t+j+1}^\theta s_{t+j+1} x_{t+j+1} \right]$$

We can rewrite it to

$$P_{x,t}^n = \frac{\theta}{(\theta-1)} \Lambda_t P_t P_{x,t}^\theta s_t x_t + \beta\xi E_t P_{x,t+1}^n$$

The recursive representation of $P_{x,t}^d$ and $P_{x,t}$ can be derived the same way.

A.11 The term Δ_t

We define Δ_t as follows:

$$\Delta_t = \int_0^1 \left(\frac{\tilde{P}_{x,t}(i)}{P_{x,t}} \right)^{-\theta} di$$

We can rewrite it to

$$\Delta_t = \sum_{j=0}^{\infty} (1-\xi) \xi^j \left(\frac{\tilde{P}_{x,t-j}}{P_{x,t}} \right)^{-\theta}$$

Rearranging yields

$$\begin{aligned} \Delta_t &= (1-\xi) \left(\frac{\tilde{P}_{x,t}}{P_{x,t}} \right)^{-\theta} + \sum_{j=1}^{\infty} (1-\xi) \xi^j \left(\frac{\tilde{P}_{x,t-j}}{P_{x,t}} \right)^{-\theta} \\ \Delta_t &= (1-\xi) \left(\frac{\tilde{P}_{x,t}}{P_{x,t}} \right)^{-\theta} + \sum_{n=0}^{\infty} (1-\xi) \xi^{n+1} \left(\frac{\tilde{P}_{x,t-n-1}}{P_{x,t}} \right)^{-\theta} \end{aligned}$$

$$\begin{aligned}
\Delta_t &= (1 - \xi) \left(\frac{\tilde{P}_{x,t}}{P_{x,t}} \right)^{-\theta} + \xi \left(\frac{P_{x,t-1}}{P_{x,t}} \right)^{-\theta} \sum_{n=0}^{\infty} (1 - \xi) \xi^n \left(\frac{\tilde{P}_{x,t-n-1}}{P_{x,t-1}} \right)^{-\theta} \\
\Delta_t &= (1 - \xi) \left(\frac{\tilde{P}_{x,t}}{P_{x,t}} \right)^{-\theta} + \xi \left(\frac{P_{x,t-1}}{P_{x,t}} \right)^{-\theta} \Delta_{t-1} \\
\Delta_t &= (1 - \xi) \left(\frac{\tilde{P}_{x,t}}{P_{x,t}} \right)^{-\theta} + \xi \pi_{x,t}^{\theta} \Delta_{t-1}
\end{aligned}$$

A.12 Real wage and real interest rate on investment

Inserting $\frac{w_t}{z_t} \frac{\alpha}{(1-\alpha)} = \frac{k_t}{h_t}$ into $p_{x,t}x_t = a_t \left(\frac{k_t}{h_t} \right)^{\alpha} h_t$ yields

$p_{x,t}x_t = a_t \left(\frac{w_t}{z_t} \frac{\alpha}{(1-\alpha)} \right)^{\alpha} h_t$. We know that $a_t \frac{s_t}{w_t} (1 - \alpha) = \frac{z_t^{\alpha} w_t^{(-\alpha)}}{\alpha^{\alpha} (1-\alpha)^{(-\alpha)}}$. Therefore,

$p_{x,t}x_t = a_t \left(a_t \frac{s_t}{w_t} (1 - \alpha) \right)^{-1} h_t$. Rearranging yields $w_t = (1 - \alpha) s_t \frac{p_{x,t}x_t}{h_t}$.

Inserting the equation for the real wage into $\frac{w_t}{z_t} \frac{\alpha}{(1-\alpha)} = \frac{k_t}{h_t}$ yields $z_t = \alpha s_t \frac{p_{x,t}x_t}{k_t}$.

A.13 Foreign deposits

For deriving the foreign deposits we start with the budget constraint of the household:

$$\begin{aligned}
P_t c_t + P_t i_t + P_{H,t} H_t + R_{l1,t} L_{t-1} + D_t^d + E_t + M_t + \Theta_t &= P_t w_t h_t + P_t z_t k_t + P_{H,t} H_{t-1} \\
+ L_t + R_{t-1} D_{t-1}^d + R_{e,t} E_{t-1} + M_{t-1} + \Pi_t^f + P e_{t-1}
\end{aligned}$$

Rearranging and using $\Theta_t + \Pi_t^M = P_t g_t$ and $L_t = D_t^d + D_t^f + E_t$ we get

$$\begin{aligned}
P_t c_t + P_t i_t + P_t g_t + R_{l1,t} L_{t-1} - R_{t-1} D_{t-1}^d - R_{e,t} E_{t-1} - P e_{t-1} &= P_t w_t h_t + P_t z_t k_t \\
+ D_t^f + \Pi_t^f
\end{aligned}$$

From the banking sector we know that $R_{e,t} E_{t-1} = R_{t-1} E_{t-1} + (R_{l1,t} - R_{t-1}) L_{t-1} - \left(v + \frac{v_2}{2} \left(\log \left(\frac{E_{t-1}/L_{t-1}}{rcr_{t-1}} \right) \right)^2 \right) L_{t-1} + (\varepsilon_{Re,t} - 1) E_{t-1}$. Inserting it into the equation yields

$$\begin{aligned}
P_t c_t + P_t i_t + P_t g_t + R_{l1,t} L_{t-1} - R_{t-1} D_{t-1}^d - R_{t-1} E_{t-1} - (R_{l1,t} - R_{t-1}) L_{t-1} \\
+ \left(v + \frac{v_2}{2} \left(\log \left(\frac{E_{t-1}/L_{t-1}}{rcr_{t-1}} \right) \right)^2 \right) L_{t-1} - (\varepsilon_{Re,t} - 1) E_{t-1} - P e_{t-1} &= P_t w_t h_t + P_t z_t k_t \\
+ D_t^f + \Pi_t^f
\end{aligned}$$

We use $L_t = D_t^d + D_t^f + E_t$ and $Pe_t = \left(v + \frac{v_2}{2} \left(\log \left(\frac{E_t/L_t}{rcr_t}\right)\right)^2\right) L_t$, rearrange and get

$$P_t c_t + P_t i_t + P_t g_t + R_{t-1} D_{t-1}^f - (\varepsilon_{Re,t} - 1) E_{t-1} = P_t w_t h_t + P_t z_t k_t + D_t^f + \Pi_t^f$$

We know that $P_t w_t = (1 - \alpha) s_t \frac{P_{x,t} x_t}{h_t}$ and $P_t z_t = \alpha s_t \frac{P_{x,t} x_t}{k_t}$. Inserting yields

$$P_t c_t + P_t i_t + P_t g_t + R_{t-1} D_{t-1}^f - (\varepsilon_{Re,t} - 1) E_{t-1} = (1 - \alpha) s_t \frac{P_{x,t} x_t}{h_t} h_t + \alpha s_t \frac{P_{x,t} x_t}{k_t} k_t + D_t^f + \Pi_t^f$$

After rearranging we finally get

$$D_t^f = R_{t-1} D_{t-1}^f + P_t y_t - P_{x,t} x_t - (\varepsilon_{Re,t} - 1) E_{t-1}$$

with

$$P_t y_t = P_t c_t + P_t i_t + P_t g_t$$

B The steady state

In the steady state the values of the variables do not change over time. Therefore, it is the case that $var_t = var_{t-1} = \dots = var_0$.¹⁴

$$a = 1$$

$$\varepsilon_{Re} = 1$$

$$\pi = 1$$

$$\pi_x = 1$$

$$p_x = 1$$

$$h = \overline{h}$$

$$R_e = \overline{R_e}$$

$$R = \overline{R}$$

$$R_l = \overline{R_l}$$

$$R_{l1} = R + \overline{diffR}$$

$$gap = 0$$

¹⁴When implementing the model in Dynare the gap and foreign deposits are defined as such that they are 1 and not 0 in the steady state. In the equations one gets distracted where necessary such that the equations are equal to the original ones. This adjustment is necessary because the logarithm of 0 is not defined.

without countercyclical capital buffer

$$rcr = crcr$$

with countercyclical capital buffer

$$rcr = crcr - \nu_c$$

$$J = \frac{1 - (\frac{R_M}{R_t})}{\chi}$$

$$\Delta_t^e = 1$$

$$rer = 1$$

$$\Delta = 1$$

$$s = \frac{(\theta - 1)}{\theta}$$

$$\alpha = 1 - \frac{\overline{\frac{wh}{gdp}}}{s}$$

$$\beta = \frac{1}{R_{l1}}$$

$$\frac{k}{x} = \frac{\alpha \beta s}{1 - \beta(1 - \delta)}$$

$$x = \frac{k^{(\frac{\alpha}{1-\alpha})}}{x} h$$

$$y=x$$

$$y^*=y$$

$$\frac{i}{x}=\delta \frac{k}{x}$$

$$\frac{c}{y}=1-\frac{i}{x}-\frac{\overline{g}}{gdp}$$

$$c=\frac{c}{y}y$$

$$k=\frac{k}{x}x$$

$$i=\frac{i}{x}x$$

$$g=\frac{\overline{g}}{gdp}y$$

$$x^d=\omega y$$

$$x^{d*}=(1-\omega)y^*$$

$$x^f=(1-\omega)y$$

$$\lambda=\frac{1}{c}$$

$$q=\lambda$$

$$p_x^d=\frac{(\lambda x)}{(1-\beta \xi)}$$

$$p_x^n=p_x^d$$

$$w=\frac{\overline{wh}}{gdp}\frac{y}{h}$$

$$\zeta_h=\frac{\lambda w}{h^\eta}$$

$$l=\frac{\overline{l}}{gdp}y$$

$$e=\frac{\overline{e}}{\overline{l}}l$$

$$d^f=0$$

$$R_w=R$$

$$v_2=\frac{-(R_e-R)\frac{e}{\overline{l}}}{\log\left(\frac{e/l}{rcr}\right)}$$

$$v=Rl1_t-R_t+v_2\log\left(\frac{e/l}{rcr}\right)-\frac{v_2}{2}\left(\log\left(\frac{e/l}{rcr}\right)\right)^2$$

$$p_H=\frac{\overline{p_H\overline{H}}}{gdp}\frac{y}{\overline{H}}$$

$$f=\mu Hp_H+(1-\mu)wh$$

$$\overline{f}=\frac{lR_l}{\psi}$$

$$\sigma^b=\frac{(\log(\overline{f})-\log(f))}{\Phi^{-1}\left(\frac{J-\kappa}{1-\kappa}\right)}$$

$$\zeta_H = p_H \lambda (1-\beta) H$$

$$d^d=l-e$$

$$\iota=\frac{\log\left(\frac{\zeta_{d_d}}{\lambda(1-R\beta)}\right)}{\log(d^d)}$$

$$gdp=p_x x$$

$$ratio=\frac{e}{l}$$

$$pe=v+\frac{v_2}{2}\left(\log\left(\frac{e/l}{rcr}\right)\right)^2$$

The following value is only part of the steady state
in the case of exogenous money growth

$$m=\left(\frac{\lambda(1-\beta)}{\zeta_m}\right)^{\left(-\frac{1}{\phi_m}\right)}$$

C Calculation of welfare costs

This section shows the calculation steps. For a summary about the concept see section 6.

The lifetime utility function looks as follows:

$$\mathbb{E} \sum_{i=0}^{\infty} \beta^i \left(\log(c_{t+i}) - \zeta_{h,t} \frac{h_{t+i}^{(1+\eta)}}{(1+\eta)} + \zeta_H \log(H_{t+i}) + \zeta_{d^d} \frac{\left(\frac{D_{t+i}^d}{P_{t+i}}\right)^{(1-\iota)}}{(1-\iota)} + \zeta_m \frac{\left(\frac{M_{t+i}}{P_{t+i}}\right)^{(1-\Phi_m)}}{(1-\Phi_m)} \right)$$

The second order Taylor approximation of the utility function is

$$\begin{aligned} \mathbb{E} \sum_{i=0}^{\infty} \beta^i & \left(\log(c) + \left(\frac{c_t-c}{c}\right) - \frac{1}{2} \left(\frac{c_t-c}{c}\right)^2 - \zeta_h \frac{h^{(1+\eta)}}{(1+\eta)} - \zeta_h h^\eta h \left(\frac{h_t-h}{h}\right) \right. \\ & - \frac{1}{2} \zeta_h \eta h^{(\eta-1)} h^2 \left(\frac{h_t-h}{h}\right)^2 + \zeta_H \log(H) + \zeta_H \left(\frac{H_t-H}{H}\right) - \frac{1}{2} \zeta_H \left(\frac{H_t-H}{H}\right)^2 \\ & + \zeta_{d^d} \frac{d^{d(1-\iota)}}{(1-\iota)} + \zeta_{d^d} d^{d(-\iota)} d^d \left(\frac{d_t^d-d^d}{d^d}\right) + \frac{1}{2} \zeta_{d^d} (-\iota) d^{d(-\iota-1)} d^{d^2} \left(\frac{d_t^d-d^d}{d^d}\right)^2 \\ & \left. + \zeta_m \frac{m^{(1-\Phi_m)}}{(1-\Phi_m)} + \zeta_m m^{(-\Phi_m)} m \left(\frac{m_t-m}{m}\right) + \frac{1}{2} \zeta_m (-\Phi_m) m^{(-\Phi_m-1)} m^2 \left(\frac{m_t-m}{m}\right)^2 \right) \end{aligned}$$

Let us denote any given variable with var . We can write $\left(\frac{var_t-var^*}{var^*}\right) = e^{\hat{var}_t} - 1$ with $\hat{var}_t = \ln(var_t) - \ln(var^*)$. The Taylor series for $e^{\hat{var}_t}$ is $1 + \hat{var}_t + \frac{1}{2} \hat{var}_t^2 + \dots$. Neglecting higher order terms and inserting it into the first equation yields $\left(\frac{var_t-var^*}{var^*}\right) \simeq \hat{var}_t + \frac{1}{2} \hat{var}_t^2$. As an approximation we therefore have that $\left(\frac{var_t-var^*}{var^*}\right)^2 \simeq \hat{var}_t^2$. Inserting it into the second order Taylor approximation yields

$$\begin{aligned} \mathbb{E} \sum_{i=0}^{\infty} \beta^i & \left(\left[\log(c) + \hat{c}_t + \frac{1}{2} \hat{c}_t^2 - \frac{1}{2} \hat{c}_t^2 \right] - h^{1+\eta} \zeta_h \left[\frac{1}{(1+\eta)} + \hat{h}_t + \frac{1}{2} \hat{h}_t^2 + \frac{1}{2} \eta \hat{h}_t^2 \right] \right. \\ & + \left[\zeta_H \log(H) + \zeta_H \hat{H}_t + \zeta_H \frac{1}{2} \hat{H}_t^2 - \zeta_H \frac{1}{2} \hat{H}_t^2 \right] + d^{d(1-\iota)} \zeta_{d^d} \left[\frac{1}{(1-\iota)} \right. \\ & \left. \left. + \hat{d}_t^d + \frac{1}{2} \hat{d}_t^{d^2} + \frac{1}{2} (-\iota) \hat{d}_t^2 \right] + m^{(1-\Phi_m)} \zeta_m \left[\frac{1}{(1-\Phi_m)} + \hat{m}_t + \frac{1}{2} \hat{m}_t^2 + \frac{1}{2} (-\Phi_m) \hat{m}_t^2 \right] \right) \end{aligned}$$

We know that $\mathbb{E}[v\hat{a}r_t] \simeq \mathbb{E}\left(\frac{var_t - var^*}{var^*}\right) - \mathbb{E}\left[\frac{1}{2}v\hat{a}r_t^2\right]$, respectively $\mathbb{E}[v\hat{a}r_t] \simeq -\frac{1}{2}\mathbb{E}[v\hat{a}r_t^2]$. Furthermore, $\sigma_{var}^2 \equiv \sigma_{\ln(var_t)}^2 = \sigma_{\ln(var_t) - \ln(var)}^2 = \mathbb{E}[v\hat{a}r_t^2] - [\mathbb{E}[v\hat{a}r_t]]^2$. Rearranging yields $\mathbb{E}[v\hat{a}r_t^2] \simeq \sigma_{var}^2 + [-\frac{1}{2}\mathbb{E}[v\hat{a}r_t^2]]^2$. As $[-\frac{1}{2}\mathbb{E}[v\hat{a}r_t^2]]^2 \simeq 0$ we have that $\mathbb{E}[v\hat{a}r_t^2] \simeq \sigma_{var}^2$ and $\mathbb{E}[v\hat{a}r_t] \simeq -\frac{1}{2}\sigma_{var}^2$. Inserting it into the equation above yields

$$\begin{aligned} & \frac{1}{(1-\beta)} \left(\overbrace{\log(c) - \frac{1}{2}\sigma_c^2}^a - \overbrace{h^{(1+\eta)}\zeta_h \left[\frac{1}{(1+\eta)} + \frac{1}{2}\eta\sigma_h^2 \right]}^b + \overbrace{\zeta_H \log(H) - \zeta_H \frac{1}{2}\sigma_H^2}^c \right. \\ & \left. + \overbrace{d^{d(1-\iota)}\zeta_{dd} \left[\frac{1}{(1-\iota)} + \frac{1}{2}(-\iota)\sigma_{dd}^2 \right]}^d + \overbrace{m^{(1-\Phi_m)}\zeta_m \left[\frac{1}{(1-\Phi_m)} + \frac{1}{2}(-\Phi_m)\sigma_m^2 \right]}^e \right) \end{aligned}$$

Finally the second order approximation of the utility function in the economy with a countercyclical capital buffer is set equal to the one of the economy without, using the parameter Ω to equalize.

$$\begin{aligned} & \frac{1}{(1-\beta)} \left(a^{ccyb} + b^{ccyb} + c^{ccyb} + d^{ccyb} + e^{ccyb} + \log(1 + \Omega) \right) = \\ & \frac{1}{(1-\beta)} \left(a^{no\ ccyb} + b^{no\ ccyb} + c^{no\ ccyb} + d^{no\ ccyb} + e^{no\ ccyb} \right) \end{aligned}$$

Solving for Ω yields

$$\Omega = e \left(a^{no\ ccyb} + b^{no\ ccyb} + c^{no\ ccyb} + d^{no\ ccyb} + e^{no\ ccyb} - a^{ccyb} - b^{ccyb} - c^{ccyb} - d^{ccyb} - e^{ccyb} \right) - 1$$

D Data sources

Table 10 gives an overview of the used data sources for the model calibration. Most data was not available within the whole time horizon of 1987Q1-2016Q3 which was used for estimation. As long series as possible were taken. As the data is “only” used to calibrate the steady state and all data series have some reasonable length, the difference in the length of the series is neglectable. Furthermore, most data is not available in quarterly series, but as for steady state calibration only a mean is needed, the mean of the yearly data is taken and adjusted to quarterly frequency. Lastly, note that the interest rates were all taken over the same time horizon as consistency among them is crucial.

Parameter	Data source and time horizon
h	OECD (1991-2015)
g/GDP	FSO, SECO (1990-2014)
$p_H H/GDP$	FSO, SECO (1990-2015)
wh/GDP	SECO (1990Q1-2016Q3)
l/GDP	FSO, SECO (1987-2015)
R	World Bank (1995-2012)
R_l	World Bank (1995-2012)
R_e	SIX (1995-2012)
$diffR$	FRED (1995-2012)
ψ	FSO, SNB (1990-2015)
γ	BIS, FSO, SECO (1987Q1-2016Q3)

BIS = Bank for International Settlements, FFA = Federal Finance Administration,
 FRED = Federal Reserve Economic Data, FSO = Federal Statistical Office,
 SECO = State Secretariat for Economic Affairs, SNB = Swiss National Bank

Table 10: Data

E Additional estimation results

E.1 Results model with exogenous money supply

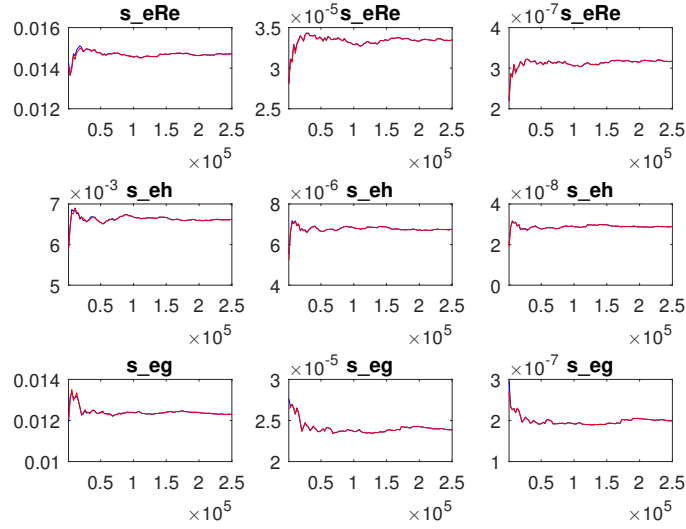


Figure 15: MCMC univariate convergence diagnostic - interval, m2, m3 (1/4 EMS)

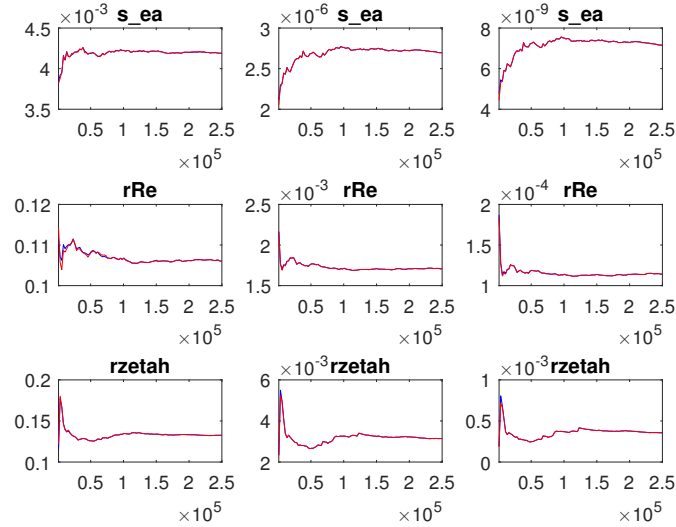


Figure 16: MCMC univariate convergence diagnostic - interval, m2, m3 (2/4 EMS)

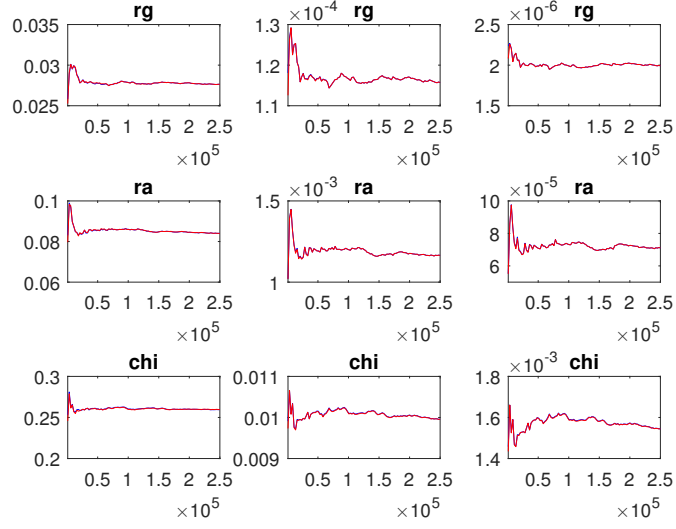


Figure 17: MCMC univariate convergence diagnostic - interval, m2, m3 (3/4 EMS)

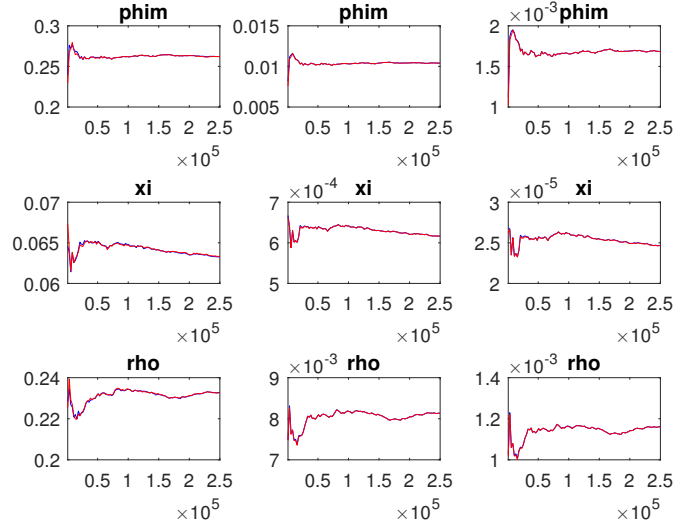


Figure 18: MCMC univariate convergence diagnostic - interval, m2, m3 (4/4 EMS)

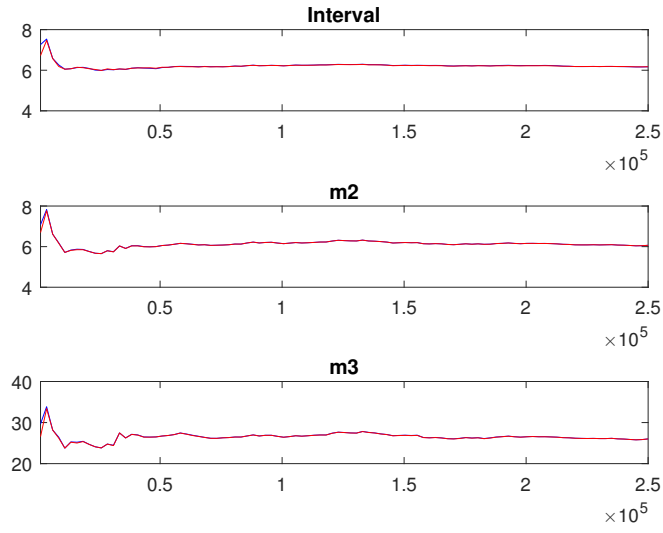


Figure 19: Multivariate convergence diagnostic (EMS)

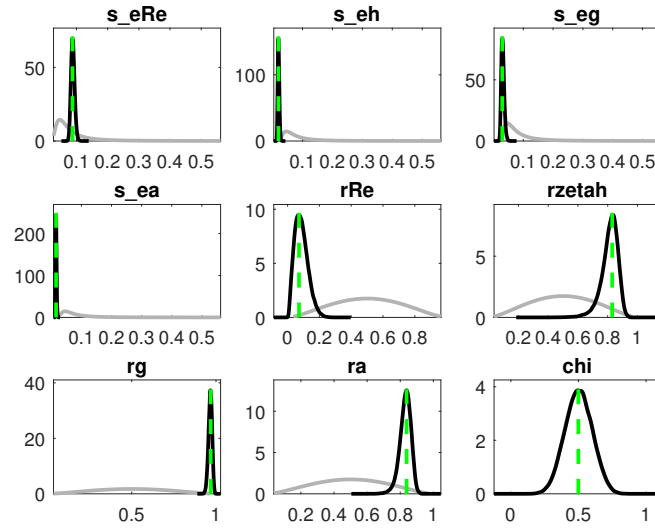


Figure 20: Priors and posteriors (1/2 EMS)

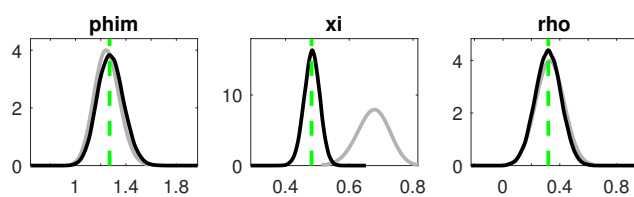


Figure 21: Priors and posteriors (2/2 EMS)

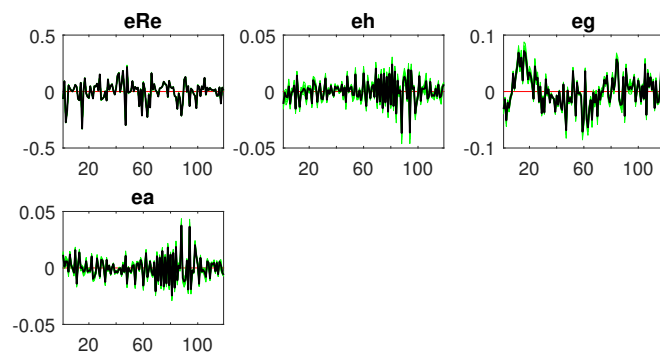


Figure 22: Smoothed shocks (EMS)

E.2 Results model with a Taylor Rule

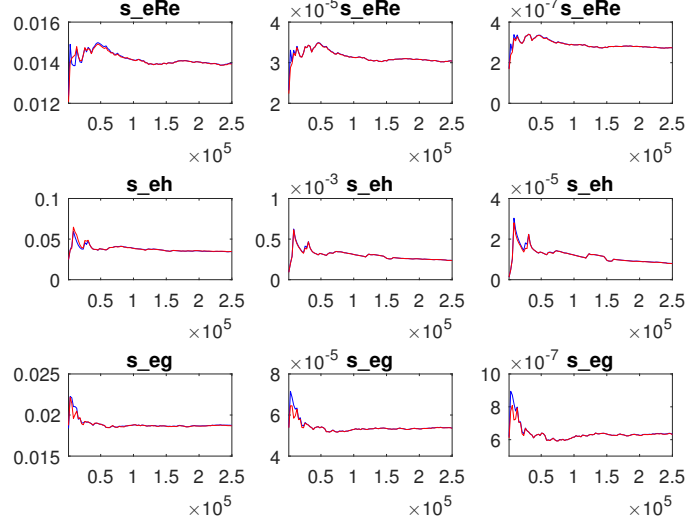


Figure 23: MCMC univariate convergence diagnostic - interval, m2, m3 (1/5 TR)

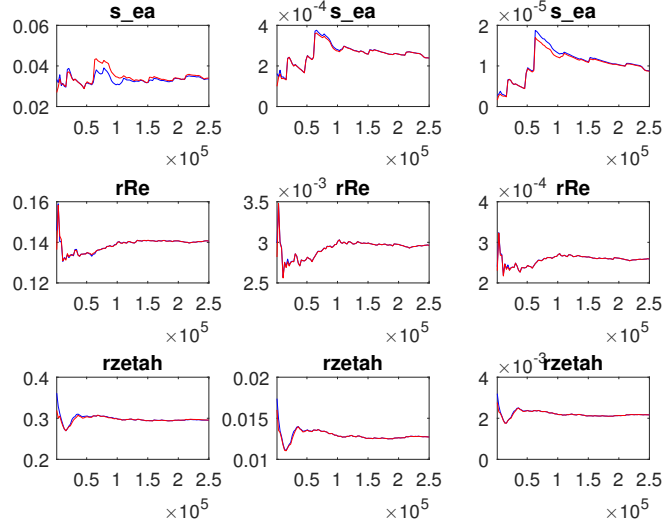


Figure 24: MCMC univariate convergence diagnostic - interval, m2, m3 (2/5 TR)

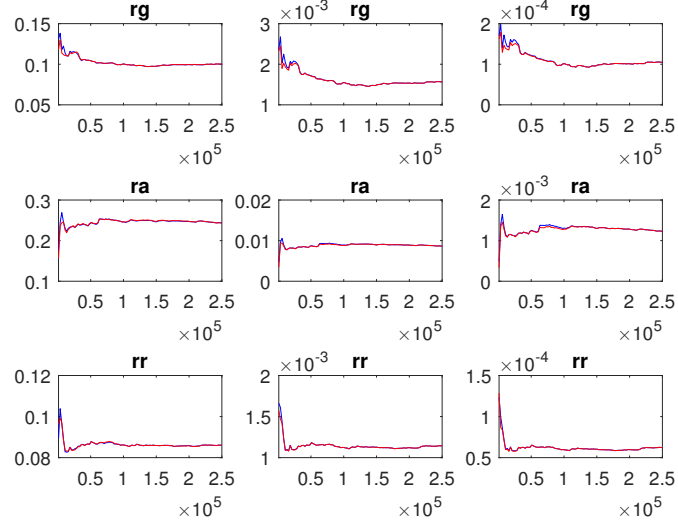


Figure 25: MCMC univariate convergence diagnostic - interval, m2, m3 (3/5 TR)

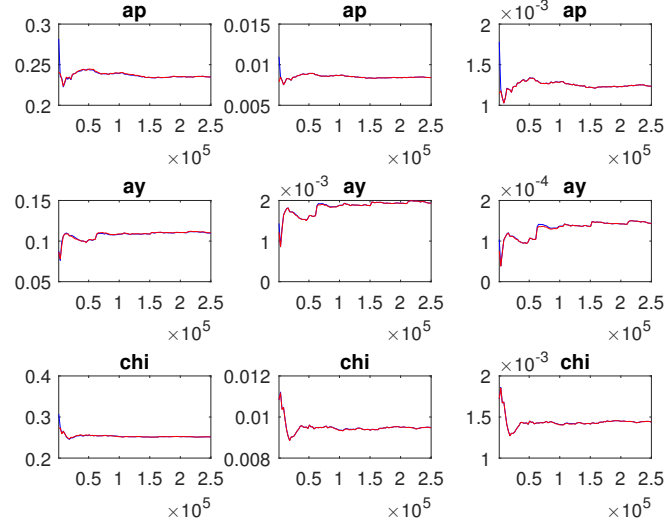


Figure 26: MCMC univariate convergence diagnostic - interval, m2, m3 (4/5 TR)

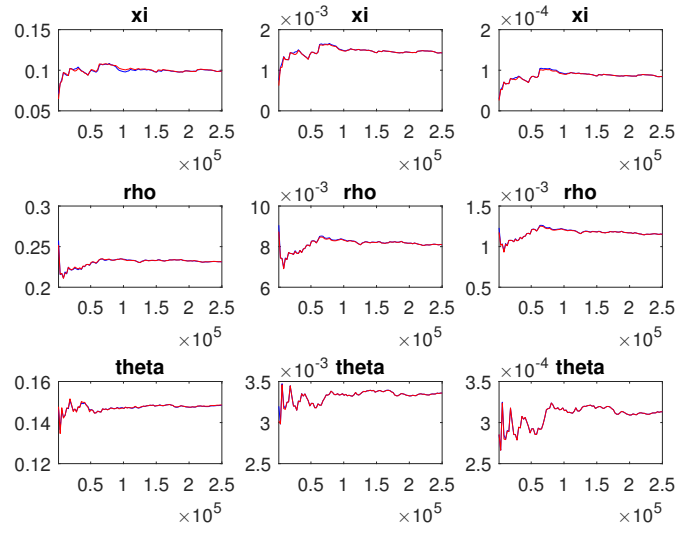


Figure 27: MCMC univariate convergence diagnostic - interval, m2, m3 (5/5 TR)

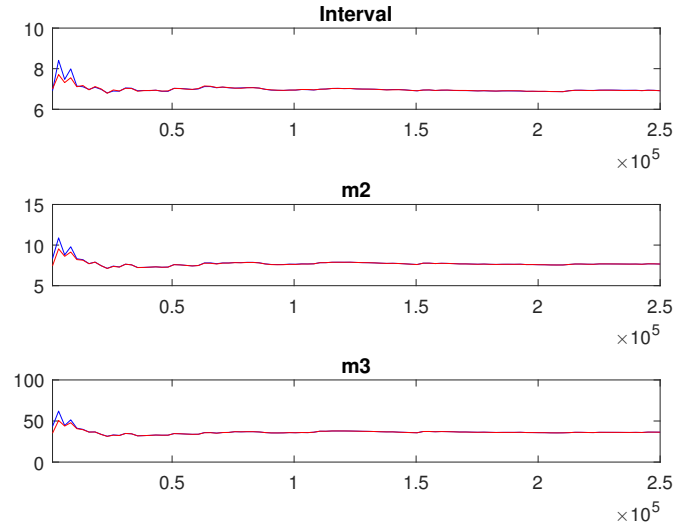


Figure 28: Multivariate convergence diagnostic (TR)

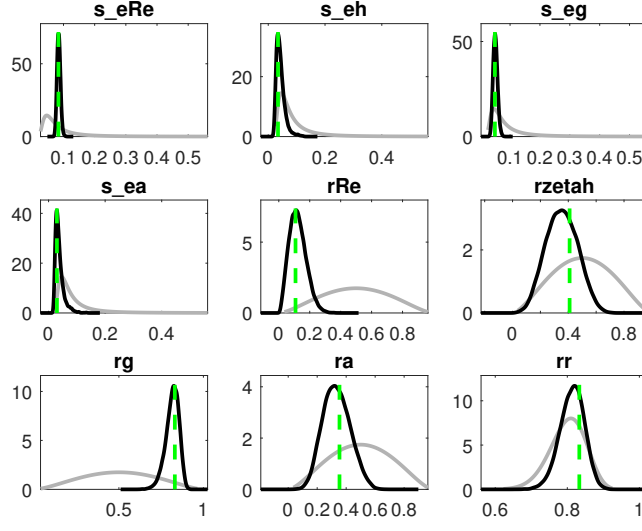


Figure 29: Priors and posteriors (1/2 TR)

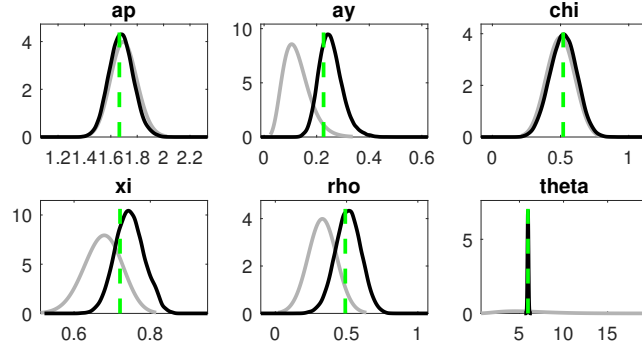


Figure 30: Priors and posteriors (2/2 TR)

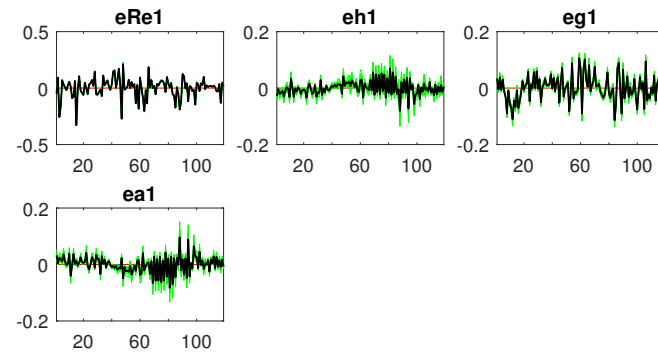


Figure 31: Smoothed shocks (TR)

F Description of the impulse response functions

F.1 Return on equity shock

As the return on equity is instantly higher due to the shock, equity as well rises mainly because the household invests more into it as the ratio $\frac{R_{e,t}}{R_e}$ is higher. Equity is even to a higher extent above the steady state as variables not influencing the return on equity on impact do it from the second period on. Loans and domestic deposits rise as well. The household has a higher budget as the shock induces a direct social gain¹⁵ and the return on equity is higher than for example the return on deposits. As the household invests more into equity, it also gets back a higher return in absolute terms *ceteris paribus*. The household has more demand for deposits and less for loans. The bank wants to supply as many loans until the expected interest spread equals the marginal penalty with respect to loans. In this decision the bank takes into account how domestic deposits have to adjust due to its decision. As equity is higher the marginal penalty with respect to loans is lower *ceteris paribus* and the bank wants to supply more loans for a given expected interest spread. The amount of deposits and loans lie above their steady state values. Given supply and demand the interest rate on deposits lies above the steady state too. Due to the higher supply and lower demand the interest rate on loans (ex-post) is lower from the second period on. In the first period the interest rate on loans (ex-post) is above the steady state as the interest rate on loans (ex-ante) was fixed the period before and the economy gets surprised by the shock which in the first period lowers the probability to default.

The relevant wealth for default calculation is higher as the prices on houses are higher when the demand for housing rises due to the shock. The variables influencing the minimum wealth for default calculation are loans and the ex-ante interest rate (not shown). As both are above the steady state, the value of the minimum wealth for default calculation is higher as well. Given these evolutions and the evolution of inflation the probability to default lies above the steady state from the second period on. In the first period the probability to default lies slightly below the steady state as the house prices are higher. The minimum wealth for default calculation influences the probability to default with a lag and does not influence

¹⁵The results are similar also when the gain from the return on equity shock is not part of the rule guiding the foreign deposits.

it in the first period. From the second period on the evolution of the minimum wealth then dominates the effect from the evolution of the relevant wealth and later of the inflation.

As the household has more budget it wants to consume more and work less. Investment is another mean to save and if the household on the whole wants to save more, also investment rises. This evolution of investment and hours and the evolution of the price of x is reflected in the GDP. As we have a social gain, foreign deposits fall below the steady state. Absorption rises as consumption as well as investment rise above their steady state values and government spending doesn't change. Inflation first goes down as nominal money supply is fixed and demand rises. Later it is above the steady state. The value of the marginal utility of wealth is below the steady state.

As the evolution of loans dominates the effect from GDP, the gap is above the steady state. The same holds for the equity-to-loans ratio. The effect from the rise in equity overtops the effect from the rise in loans. The penalty falls below the steady state due to the higher equity to loans ratio.

F.2 Preference shock to hours

The negative shock to the preference for hours instantly leads the household to work more. As investment is therefore more profitable it rises as well. Due to the rise in hours and investment, GDP rises. The negative shock to the preference for hours influences the marginal utility of wealth as such that it deviates negatively from its steady state. Therefore, the marginal utility of consumption has to fall and thus consumption itself rises. As consumption and investment lie above their steady state values absorption is as well above its steady state. Government spending stays the same. As there is more demand for money, real money is above its steady state value. As inflation is 1 divided by $1 + \text{real money growth}$ it first falls below its steady value before it later rises above it.

Given the evolution of the GDP, the absorption and the interest rate foreign deposits are first above the steady state before they negatively deviate from it. The household demands more deposits and less loans. Given an expected interest spread loan supply depends on the evolution of equity as the equity-to-loans ratio is relevant for the calculation of the penalty. Given that the probability to default lies below its steady state in the first period, the return on equity is above

the steady state in the first period. Together with the lower inflation, the last mentioned effect leads to a rise in the equity. In later periods the interest rate on deposits, the interest spread, the amount of loans as well as the value of the penalty influence the evolution of equity. Given that equity is above its steady state value, the bank wants to supply more loans given an expected interest spread (see argumentation at the shock to the return on equity) . Given supply and demand the amount of loans rises above the steady state value and the interest rate on it (ex-post) falls below it (from the second period on). Domestic deposits in the home country rise as well. The interest rate on deposits rises above the steady state and later falls below it.

As housing supply is fixed and the demand for houses is enlarged, the house prices are higher and therefore the relevant wealth for default calculation. Due to the higher amount of loans the minimum wealth for default calculation rises as well. Given the evolution of the relevant wealth, the minimum wealth and the inflation, the probability of default lies below the steady state from the first period on.

The gap is first mainly influenced by the evolution of the GDP and later by the evolution of loans. Therefore, it first deviates negatively from the steady state and later is above it. The equity-to-loans ratio is in the first half of the horizon above the steady state as the evolution of equity is the dominating effect. The penalty falls slightly below the steady state due to the higher equity-to-loans ratio.

F.3 Fiscal shock

A negative temporary fiscal shock triggers wealth effects. Government is not producing anything in this model. Therefore, lower government spending induces lower tax payments. Therefore, the household has a higher budget respectively is more wealthy. That is why the household consumes more. Supply of hours falls while demand stays the same on impact. From there it follows that hours fall. Investment shows a similar evolution as hours but is after some quarters above the steady state. Absorption falls below the steady state because government spending and partially investment are below their steady state values. Due to less hours worked and the lower capital stock, the GDP is lower. Inflation is directly connected to real money growth.

As the fall in the GDP is lower than the one in absorption, net exports are positively affected and foreign deposits fall. Equity rises above the steady state in

the first period because the probability to default and inflation lie below it. Equity stays above the steady state also after the first period implied by the evolution of the loans and the penalty. As equity rises the bank wants to supply more loans as the higher equity lowered the marginal penalty with respect to loans *ceteris paribus*. The household wants to hold more deposits and less loans. Given supply and demand, the amount of loans and domestic deposits in the economy both rise above the steady state. Given the higher supply and lower demand the ex-post interest rate on loans (from the second period on) falls below the steady state. In the first period the ex-post interest rate on loans lies above the steady state due to the lower level of default which comes as a surprise. The interest rate on deposits falls below the steady state.

The marginal utility of wealth falls below the steady state. Due to the higher demand for housing, the house prices are above the steady state (rel. wealth for default calc.). Due to the higher amount of loans the minimum wealth lies over a long time horizon above the steady state. The probability to default is lower (see argumentation at the return on equity or the preference shock).

The gap rises due to the rise in the loans and the fall in the GDP. Due to the rise in equity, the equity-to-loans ratio lies above the steady state too. The penalty lies below the steady state due to the higher equity-to-loans ratio.

The fiscal shock is outstanding due to its high persistence. One factor leading to a high persistence is the high persistency of the shock process itself. Furthermore the shock almost directly affects absorption, which itself affects netexports. Net-exports affect the foreign deposits which deviations from the steady state are very persistent.

F.4 Technology shock

Due to the higher marginal products demand and supply for hours and investment initially rise. Therefore they lie above their steady state values. The GDP is above the steady state as technology, hours and the capital stock (from the second period on) are above the steady state.

Due to the shock the household is more wealthy and therefore consumes more. As consumption and investment are higher the absorption is higher. Government spending stays the same. Foreign deposits rise initially above the steady state as net exports are lower and the interest rate on deposits is higher. One can see the

first effect from the comparison of the GDP and absorption. Later the foreign deposits fall below the steady state.

The marginal utility of wealth falls below the steady state. The value of the relevant wealth for default calculation is above the steady state as more housing is demanded while supply is fixed and therefore, house prices are above their steady state value. The minimum wealth is above its steady state value too as although the interest rate on loans ex-ante (not shown) is below its steady state value, the amount of loans is above it. The probability to default lies below the steady state as the effect from the evolution of house prices and later also inflation are dominating.

Equity lies above its steady state value. In the first period it jumps up due to the lower probability to default which enlarges the return on equity and the low inflation. Later the interest rate on deposits, the interest spread, the amount of loans as well as the value of the penalty influence the evolution of equity. The household wants to hold more deposits and less loans. The bank wants to supply more loans given the evolution of equity. The amount of loans rises and the interest rate on loans (ex-post) falls in the second period below the steady state. Note that in the first period the ex-post interest rate on loans is above the steady state as the ex-ante interest rate was already fixed the period before and then the economy is surprised by the shock which lowers the probability to default. The amount of domestic deposits is also above the steady state and given supply and demand the interest rate on deposits falls below the steady state.

The gap falls initially below the steady state due to the high GDP. As the effect on loans is more persistent than the one on the GDP the gap is after a few quarters above its steady state. The equity-to-loans ratio is above the steady state as although the amount of loans is above its steady state value, equity is too. The latter effect dominates. The penalty lies below the steady state due to the higher equity to loans ratio.

Real money evolves similar to consumption. As real money growth is first positive and afterwards negative, inflation first falls below the steady state while it is later above it.

G Volatilities and correlations in the case with a Taylor rule (and a fixed exchange rate)

Correlations		TR	TRFER
σ_{ygap}	no ccyb	-0.219939	-0.806760
	ccyb	-0.271661	-0.671019
σ_{yl}	no ccyb	0.140783	0.398929
	ccyb	0.924171	0.990234
σ_{ye}	no ccyb	0.139820	0.395884
	ccyb	0.058947	0.371276
σ_{yda}	no ccyb	0.139107	0.395923
	ccyb	0.928901	0.994263
σ_{yc}	no ccyb	0.203754	0.412616
	ccyb	0.162216	0.395005
σ_{yi}	no ccyb	0.802394	0.995752
	ccyb	0.806309	0.992862
σ_{yh}	no ccyb	0.219131	0.988528
	ccyb	0.243357	0.981045
$\sigma_{y\pi}$	no ccyb	-0.665139	0.651638
	ccyb	-0.661393	0.540387

ccyb = countercyclical capital buffer

Table 11: Correlations (TR and TRFER)

Volatilities		TR	TRFER
σ_{gap}	no ccyb	0.124072	0.337514
	ccyb	0.022380	0.045309
	Difference	0.101692	0.292205
σ_l	no ccyb	0.062026	0.117816
	ccyb	0.022728	0.130474
	Difference	0.039298	-0.012658
σ_e	no ccyb	0.120630	0.195938
	ccyb	0.119416	0.182918
	Difference	0.001215	0.013021
σ_{dd}	no ccyb	0.064792	0.117101
	ccyb	0.023629	0.134318
	Difference	0.041164	-0.017217
σ_y	no ccyb	0.027836	0.228829
	ccyb	0.028310	0.171337
	Difference	-0.000475	0.057491
σ_c	no ccyb	0.007289	0.021037
	ccyb	0.006865	0.015415
	Difference	0.000424	0.005622
σ_i	no ccyb	0.137766	1.003978
	ccyb	0.138868	0.746790
	Difference	-0.001102	0.257188
σ_h	no ccyb	0.032786	0.294932
	ccyb	0.032736	0.223460
	Difference	0.000050	0.071471
σ_π	no ccyb	0.006436	0.044824
	ccyb	0.006356	0.049247
	Difference	0.000080	-0.004423

ccyb = countercyclical capital buffer

Table 12: Volatilities (TR and TRFER)

Statement of Authorship

I hereby declare that I have written this thesis without any help from others and without the use of documents and aids other than those stated above. I have mentioned all used sources and cited them correctly according to established academic citation rules. I am aware that otherwise the Senat is entitled to revoke the degree awarded on the basis of this thesis, according to article 36 paragraph 1 letter o of the University Act from 5 September 1996.

Bern, 14.07.2017

A handwritten signature in cursive script, appearing to read 'Schneider', is written in dark ink.