A Model with Bank Lending and the US Housing Bubble in the Financial Crisis 2007/2008

Stefan Dürmeier*

(Version of February 28, 2018)

Abstract

The paper addresses the topic of the conference, explaining and forecasting the great recession and its aftermath with structural models, by outlining first the origins of the financial crisis 2007/2008. It disentangles the financial channels occurring in boom and bust phases. A New Keynesian DSGE model incorporates the bank lending channel, a principal agent problem between banks and entrepreneurs as well as the collateral channel for housing with a feedback loop in order to study the effects of a shock to the monitoring costs of the households considering the capital requirements of banks and of an increase in the demand for housing. In a scenario of unfulfilled expectations, the housing boom is followed by the bust. The model displays the spikes in the yields on housing, in rising bank balance sheets, wages, consumption and inflation, with the output of the entrepreneurs exhibiting the reverse dynamics. It calls for a monetary policy explicitly targeting the credit and property price gaps in the realm of financial stability.

*Email: stefan.duermeier.econ@gmail.com. Stefan Dürmeier – Makroökonomische Forschung und Mathematik Nachhilfe (Macroeconomic Research and Mathematics Tutoring). The paper was written on the call for papers for the 2nd Research Conference of the CEPR Network on Macroeconomic Modelling and Model Comparison (MMCN), June 7-8, 2018, at Stanford University, and was not selected. The views expressed in this paper are those of the author. In part it is based on the master's thesis "Monetary Policy and Capital Requirements" under supervision of Prof. G. Sorger, University of Vienna. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. In equation (44) and thus equation (64), the subjective discount factor is missing for the expectation on the stochastic discount factor.

1. Introduction

The Fed has initialized three quantitative easing programs since the financial crisis 2007/2008 to stem against the outcomes. On top of the accommodative monetary policy, a boost through fiscal stimulus is on the way by the tax reform of the current US administration, which is expected to amount to 1.5 trillion USD, and by additional spending of 300 billion USD. It is now forecast that the Fed will further raise the interest rates four times this year and two times in 2019, on the back of stronger growth and the economy at full employment. Although there were signs of an upswing in wages and inflation this month,[1] central bankers still puzzle over the loose connection of unemployment, wage growth and inflation. This accounts as well for the Eurozone, where, at the current stage, the economy shows very strong momentum and rising employment. After having phased out the quantitative easing, interest rate increases will follow in sequence. In the last meeting, it was decided to lower the monthly purchase of assets to 30 billion USD.[2] The amount of bonds on the balance sheet of the ECB, mainly sovereign debt, passed 2.3 trillion EUR.[3] Government bond rates have been pushed down by the programs and the announcement of the head of the ECB Draghi to do "whatever it takes", while the overly indebted countries do not seem to have significantly changed or are going to change their long term behaviour towards reducing the debt burden. The debt-to-GDP ratio of Greece as of today fluctuates around 177 percent,[4] that of Italy around 134 percent,[5] and that of Portugal around 131 percent,[6] in spite of the boundary of 60 percent it was agreed on, artificially as it turns out. In June 2016, the British voted to leave the European Union.

The paper addresses the topic of the conference, explaining and forecasting the great recession and its aftermath with structural models, by outlining first the origins of the financial crisis 2007/2008. It disentangles the financial channels occurring in boom and bust phases. A New Keynesian DSGE model incorporates the bank lending channel, a principal agent problem between banks and entrepreneurs as well as the collateral channel for housing with a feedback loop in order to study the effects of a shock to the monitoring costs of the households considering the capital requirements of banks and an increase in the demand for housing. In a scenario of unfulfilled expectations, the housing boom is followed by the bust.

2. The Origins of the Financial Crisis 2007/2008

The financial crisis was originated in the US housing market, specifically the subprime mortgage sector. A housing bubble was created which bust and along with collapsing stock markets. The severest banking crisis, ongoing dried up or subdued lending and mistrust between banks, affected the real economy. Consumption and investment dropped.[7] In

[1] https://www.bloomberg.com/news/articles/2018-02-20/upon-further-review-fed-may-finallysay-what-that-word-meant (accessed 20 February 2018)
[2] http://www.ecb.europa.eu/press/pressconf/2018/html/ecb.is180125.en.html (accessed 17 February 2018)
[3] http://www.bundesbank.de/Redaktion/DE/Interviews/2018_01_17_weidmann_faz.html (accessed 17 February 2018)
[4] http://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=325.GFS.Q.N.GR.W0.S13.S1.C.L.LE.GD.T._Z.XDC_R_B1GQ_CY._T.F.V.N._T (accessed 17 February 2018)
[5] http://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=325.GFS.Q.N.IT.W0.S13.S1.C.L.LE.GD.T._Z.XDC_R_B1GQ_CY._T.F.V.N._T (accessed 17 February 2018)
[6] http://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=325.GFS.Q.N.PT.W0.S13.S1.C.L.LE.GD.T._Z.XDC_R_B1GQ_CY._T.F.V.N._T (accessed 17 February 2018)
[7] Eakins and Mishkin (2011: 204 ff.)

expectation of higher yields on housing in the future, credit was provided to persons unworthy of credit and the value of the housing served as the collateral. While the yields kept on rising, the bank could seize the property in case the loan was not repaid, resulting in a profitable investment. When the bubble bust, however, there was no other income to be seized and the issuer of the loan incurred losses, triggering to an unprecedented extent several downward spirals through financial channels. The expectations of higher prices were unfulfilled.[8] More technically, financial innovation such as the FICO-scores to measure the credit worthiness, Mortgage-Backed-Securities intended to finance the mortgage and, based on these securities, Collateralized-Debt-Obligations instead accelerated losses and spurred contagion.[9] Readily the securities were also absorbed by German Landesbanken. The assumption of the mortgages bundled together being uncorrelated or nearly so did not hold, thereby not diversifying but increasing risk, the different risk classes underlying the product were not accurate and the riskiest part of the mortgage was sold to special vehicles, or subsidiaries, of the banks thus remaining in them.[10] Underlying it, credit was made available due to non-core funding, i.e. interbank liabilities and marketed-based funding apart from retail deposits. Not only were financial institutions linked via the products, also hedging against idiosyncratic risk lead to the institutions being exposed to the same risks.[11] Creating moral hazard, it was insured against the default on these securities in a market of hundreds of billions USD of credit default swaps. Moreover, the brokers of the mortgages were solely remunerated based on the amount of contracts concluded, regardless of the risk inherent. Contracts included teaser rates initially, followed by adjustable rate mortgages overburdening the holder of the mortgage. Rating agencies as well relied on the past data to presume an ongoing profitable development of the mortgage market and they rated products of companies which constituted at the same time their clients, giving rise to conflicts of interest.[12]

It is argued, though to different extent, that the monetary policy of the Fed contributed to the housing bubble by providing too cheap credit over the years preceding the crisis (Streissler (2011), Taylor cit. in Eakins and Mishkin (2011), Weidmann (2015).[13] US policy effectively promoted and further shored up the housing market.[14] Sreissler (2011) further extends the scope of the analysis to state that the finance around the housing sector, together with consumption credit and government finance, was the only profitable investment left in the US.[15] This time, the realised, excess investment in the US limited the savings, largely imported from outside the US: with the realised losses on the investment in the US, savings channelling through to other parts of the world with demand for profitable investment was hindered, as ex-post realised investment and savings must equalize globally.[16] In the macro view of Borio (2014), monetary policy needs not only to be concerned with the risks out of a financial bubble but with the general build up of macroeconomic risks. The inclusion of the financial variables of credit and property prices into the objective needs to be part of the interest rate policy, which has all the more signalling effect. While the main focus in on monetary policy, financial stability needs to be targeted further by prudential policy and fiscal policy. The approach for the central bank is to pursue a more symmetric policy, i.e. in the

[8] Eakins and Mishkin (2011: 213), Streissler (2011: 34 f.) and course material of Wood (2008)
[9] Eakins and Mishkin (2011: 211) and Streissler (2011: 37 f.)
[10] Streissler (2011: 37 f.)
[11] Deutsche Bank Research (2012: 4) with reference to Adrian and Shin (2010) for the change in the structure of financial intermediation.
[12] Eakins and Mishkin (2011: 212), Streissler (2011: 38) and course material of Wood (2008)
[13] Eakins and Mishkin (2011: 214), Weidmann (2015: 38), Streissler (2010: 26 f.)
[14] Eakins and Mishkin (2011: 2012), Streissler (2011: 34 ff.) and Deutsche Bank Research (2012: 4)
[15] Streissler (2011: 23 and 36)
[16] Streissler (2011: 19, ff.)

boom phase to tighten more and in the bust phase after an immediate crisis management to be less accommodative. [17]

Finally, it is pointed on the missing restructuring mechanism for banks and non-transparent balance sheets. Regulation of banks via liquidity and capital requirements was insufficient for the banks to be capable of bearing the losses accrued instead of shifting the liability to others.[18]

3. The Channels of the Financial Cycle

Externalities might arise on the side of financial intermediaries. In the context of the financial cycle, the external effects of the decisions of financial institutions are not internalized in the boom and bust phase if credit and asset prices do not reflect the effect of one decision maker on the others: in a downturn spiral, the individual decisions of selling off assets simultaneously have an higher negative impact system-wide than the aggregation of them in isolation would imply. The liquidation of assets pose an externality on the other institution via prices and the balance sheets are impaired indirectly in the contagion. Thereby, the constraints of financial actors are shifted, the pecuniary externalities are also called fire-sale externalities.[19]

The bank lending channel is essentially a supply side channel, which incorporates the capital position of the bank. The funding conditions and the supply of loans are impaired if the financial intermediaries face problems on their capital position. By a shock to the capital base, relating possibly to a liquidity spiral or a tighter capital requirement, the bank has to resort to a different composition of deposits and equity. The issuance of equity is bounded in the market and in consequence, the provision of loans is affected. In the literature, the bank lending channel is also called the bank capital channel and the liquidity spiral. If the assets are sold by the bank exhibiting a liquidity shortage, possibly at fire sale prices, the deterioration of capital continues, which sets off the spiral. Moreover, the volatility in the market rises and although the price decrease of equity might be temporary, the mechanism is accelerated by the liquidity mismatch inherent in the assets of the banks which comove in a financial crisis.[20] The period of high funding problems is accompanied by creditors subtracting to lower leverage ratios to be safe. Furthermore, higher haircuts, or equivalently higher margins, are required due to asymmetric information and in order to guard against the adverse effects of falling prices of the assets in future. In line with the higher risk in the financial markets, higher margins or haircuts are pledged on the collateral comprised of the value of the asset in the next period, which intersects with the collateral channel. In the precautionary behaviour of market participants, the formation of expectations is therefore crucial. It is also called the margin/haircut or leverage spiral, which leads to a further acceleration in the downturn. The two liquidity channels are both moving together aggravating the crisis with spillover effects.[21]

---

[17] Borio (2014: 9 ff.). For empirical evidence on the indicators for banking crises, i.e. credit together with the property price deviations from historical trends, reference is made in Borio (2014) to Borio and Drehmann (2009) and Drehmann et al. (2012). The approach is seemingly adopted in Weidmann (2015: 41), yet putting more emphasis on macroprudential policy as the first guard for financial stability.

[18] http://www.cesifo-group.de/de/ifoHome/events/seminars/Muenchner-Seminare/Archive/mucsem_20140127_Dombret.html (accessed 17.06.2016)

[19] Brunnermeier and Oehmke (2013: 30 ff.)

[20] Deutsche Bank Research (2012: 3) and Brunnermeier and Oehmke (2013: 40 ff.). Modeling can be found in Kiley and Sim (2014: 177 ff.), Alpanda et al. (2014: 9 ff.) and Gambacorta and Signoretti (2014: 148 ff.).

[21] Brunnermeier and Oehmke (2013: 40 ff.)

Elementary in the credit cycle are in addition the balance sheet effects on the side of the borrower, which can be categorized by the different models of the collateral channel and the agency-cost models. The collateral channel defines the relation between the value of the collateral and the credit market. If the value of the assets on the side of the borrowers improves, equivalently to a lower leverage, then so does the value of the collateral. This relaxes the borrowing constraint of households and in general also of firms.[22] Relating this effect to the boom phase of the financial cycle, the creation of financial imbalances is then characterised by the build up of overburdened private sector balance sheets and aggressive risk taking.[23] The agency-cost models go further in that lending is determined endogenously by shifts in the value of the underlying assets with feedback effects. Not only is the borrowing activity spurred but also the investment, it is further explicitly grounded on asymmetric information between lenders and borrowers.[24] A common name of the feedback loop in the downturn of the economy is the debt-deflation mechanism: it is triggered by a fall in asset prices in the deflation, spreading over to a lower value of the collateral and a lower exposure on credit.[25]

In a sense, all the different mechanisms and channels described are subject to the risk channel, i.e. the factor risk goes beyond it. Most often in the modeling literature covered, it is explicitly resorted to the mathematical toolbox, rather than pointing on the occurrence of a certain event, such as the bank default or bank runs.[26]

4. Model

The model is populated by representative agents of households, final and intermediate goods producing firms, banks and a central bank. Households consume goods and have the option to save by depositing their money with a bank. They take out loans in order to finance housing. They work for the intermediate goods producer, provide capital to them and receive in turn the wage for labor as well as the rent on capital. Capital adjustment costs are introduced. There is monopolistic competition in the markets of the respective inputs and the producers face price adjustment costs. Demand for credit is created on the side of these entrepreneurs for the purpose of funding their activities. In addition, there are final goods producer using the intermediate goods while acting in perfect competition. The demand for deposits emerges on the side of the banking sector, which accrues profits from the supply of loans issued to entrepreneurs and households. Both the intermediate goods producing sector and the financial sector are owned in aggregate by the households and distribute dividends to them. Monetary policy by the central bank follows the Taylor rule and the policy rate represents the price of savings.

Financial frictions are introduced in the form of monitoring costs: the depositors face monitoring costs when supplying funds to the financial sector. The costs depend on the

[22] Alpanda et al. (2014: 4) and the model for Brazil in de Carvalho et al. (2014: 6 ff.). In the latter, the collateral of the household constitutes labor income, the one of the entrepreneur capital.
[23] Borio (2014: 8)
[24] Alpanda et al. (2014: 14 ff.) and Gambacorta and Signoretti (2014: 148 ff.). Also the model of Lozey et al. (2016: 4 ff.) features a feedback loop between the lending rate and the probability of default.
[25] Deutsche Bank Research (2012: 3)
[26] Kara (2012: 2), Angeloni and Faia (2012 : 8), Kiley and Sim (2014: 179 f.), de Carvalho et al. (2014: 7), Dewachter and Wouters (2014: 243 ff.) and Brunnermeier and Oehmke (2013: 60 ff.)

leverage of the banks measured by a certain deviation from the capital requirement, the higher the deviation the higher the costs. The friction can be subsumed under the bank lending channel. Besides, the financial sector faces monitoring costs when issuing loans to the entrepreneurs. These costs depend on the leverage position of the entrepreneur incorporating an agency-cost problem. The costs on lending to the household depend on the value of the housing, which serves as the collateral, relative to the whole loan exposure, reinforcing each other.[27]

The model extends the covered literature in various ways: it combines the bank lending channel and a principal agent problem similar to Alpanda et al. (2014) and Gambacorta and Signoretti (2014) with the default modeling of Lozey et al. (2016) for housing. Moreover, in the principal agent problem between banks and entrepreneurs, not the capital serves for computing the net worth of the entrepreneurs but the dividends, which channel through to households. Banks do optimize with respect to capital and the built up of capital by reinvesting profits versus distributing them is modelled differently. Finally in comparison, the New Keynesian Model applied for the real economy similar to Pichler (2008) is of rather simple form.

Households

The representative household maximizes the utility function with respect to consumption c_t, housing hou_t and labor h_t:

$$\max U = Exp_0 \sum_{t=0}^{T} \beta^t [\frac{c_t^{1-\tau} - 1}{1-\tau} + \frac{\chi_{hou} hou_t^{1-\iota}}{1-\iota} d_t + \chi_h (1-h_t)] \tag{1}$$

where β is the discount factor, χ_{hou} and χ_h are parameters equal to the weights of preference given to housing and to leisure, d_t is an AR(1) process increasing the demand for housing.

The budget constraint is:

$$\begin{aligned} &\frac{q_t hou_{t-1}}{\pi_t} + w_t h_t + r_t k_t + div_t + divbank_t + \frac{s_{t-1} dep_{t-1}}{\pi_t} + loanh_t \geq \\ &c_t + q_t hou_t + x_t + \tfrac{\gamma}{2}(\tfrac{x_t}{k_t} - \delta)^2 k_t + (1+\mu) dep_t + \frac{lh_{t-1} loanh_{t-1}}{\pi_t} \end{aligned} \tag{2}$$

w_t is the wage, h_t are the hours of labor, div_t are the dividends of producers, $divbank_t$ the dividends of the bank both reasoned by the ownership, r_t is the rent on capital k_t, investment

$$x_t = k_{t+1} - (1-\delta) k_t \tag{3}$$

where δ is the depreciation rate of present physical capital. γ is a cost parameter for the capital adjustment costs, such that they take the following form accounting for the law of motion of capital:

[27] Source of the simplified New Keynesian Model without a financial sector: course material of Pichler (2014), identical to the model in Pichler (2008). The modeling of the financial frictions is mainly derived from Alpanda et al. (2014) and Gambacorta and Signoretti (2014), the modeling of the household default from Lozey et al. (2016). All the optimality conditions and the symmetric equilibrium conditions are listed in the Annex.

$$x_t + \tfrac{\gamma}{2}(\tfrac{x_t}{k_t} - \delta)^2 k_t = k_{t+1} - (1-\delta)k_t + \tfrac{\gamma}{2}(\tfrac{k_{t+1}}{k_t} - 1)^2 k_t \qquad (4)$$

s_t is the gross savings rate on the real market value of the deposits dep_t. The savings rate is assumed to be a perfect substitute to the interest rate on overnight loans of reserves from one bank to another, i.e. the policy rate. All variables are in real terms. p_t is the price of final goods at time t, $\pi_t = p_t / p_{t-1}$ is the gross rate of inflation, q_t is the gross rate of returns on housing, derived from the prices of housing. The value of the property of the household is reset every period, while the return on savings and the costs on the loan are bound to the period the decision on deposits and loans are made.

The monitoring costs have the following form:

$$(1+\mu) = \chi d1 (\nu \tfrac{loan_t}{kbank_t})^{\chi d2} a_t \qquad (5)$$

ν is a capital requirement target defining a ratio of the required capital to the total assets, which are comprised of the loans in real terms $loan_t$. $\chi d1$ is a level parameter accounting for the spread in the costs in the steady state, $\chi d2$ an elasticity changing the costs with respect to the deviation from the capital requirement. a_t is an AR(1) process.[28] As it is created on the supply side via the financial sector and in equilibrium affects the expected lending rate of the firm, the current lending rate on housing and thereby the provision of credit, it is subsumed under the bank lending channel.[29] The optimal decision regarding deposits for both households and banks in the equilibrium yields the following relation:

$$s_t = \frac{1}{c_t^{\tau}}(1+\mu)_t \frac{1}{\beta} Exp_t(c_{t+1}^{\tau} \pi_{t+1})$$

There is asymmetric information between the household and the bank with respect to the solvency of the bank, or at least to the quality of deposits and assets within the banking sector, for which reason monitoring costs incur. A lower capital ratio than required would go together with a higher perceived risk of the deposits and, hence, with higher costs for the household. Finally, the household has an incentive in the long run that the bank makes profits because of accruing at least partly the dividends. The household is aware of this by requiring the bank to fulfil the capital requirement, i.e. has some capital buffer: the monitoring costs rise with a deviation from the target such that in equilibrium, the positioning of the bank with respect to the capital requirement influences the costs of its funding and thus the funding itself. Furthermore: “Although this formulation abstracts from bank default per se, these monitoring costs can be interpreted as the fraction of funds that are defaulted upon by the banks (i.e., "bad loans"), following Curdia and Woodford (2011). Another interpretation of these monitoring costs is that they reflect the cost of purchasing default insurance on funds extended to banks, similar to a credit default swap (Amdur, 2010).” (Alpanda, Meh and Cateau 2014: 10)[30]

[28] For the modeling of the monitoring costs, Alpanda et al. (2014) refer to Curdia and Woodford (2011). In Signoretti and Gambacorta (2014), the banking sector directly has to pay the costs associated with the deviation from the target.

[29] The effects are analytically discussed at the description of the banking sector.

[30] Alpanda et al. (2014: 9 ff.). Reference is made to Curdia and Woodford (2011) and Amdur (2010) respectively.

The equilibrium condition for housing reveals that the returns today depend positively on the discounted expected returns in the future and on the shock process d_t:[31]

$$q_t = c_t^{\tau} \chi_{hou} hou_t^{-\iota} d_t + \beta Exp_t (\frac{q_{t+1}}{c_{t+1}^{\tau} \pi_{t+1}})$$

In addition to the control variables c_t, hou_t, h_t, k_{t+1} and dep_t, the household decides upon the loan $loanh_t$.

Final-goods producer

The firms are split into producers of final and intermediate goods. The final goods producer are assumed to be perfectly competitive, i.e. no profits are made such that no dividends are disbursed. They use the intermediate goods yj_t as inputs. The intermediate producers are indexed $j \in [0,1]$. It is further assumed a constant returns-to-scale technology:

$$y_t = (\int_0^1 yj_t^{\frac{\theta-1}{\theta}} dj)^{\frac{\theta}{\theta-1}} \tag{6}$$

where θ is the elasticity of substitution between two intermediate inputs and y_t is the output: with respect to the final good, the firm will not able to produce as much if it has to substitute one input with another. The imperfect substitutability gives the intermediate goods producer market power because each intermediate good producer is a monopolist for the single input who sets the price instead of taking it as given.

Intermediate-goods producer

The representative agent maximizes the discounted value of expected real dividends:

$$\max Exp_0 \sum_{t=0}^{T} \beta f^t \lambda_t div_t \tag{7}$$

with βf^t the time discount factor which differs from the one of households and banks due to asymmetric information. λ_t denotes the Lagrangean multiplier from the budget constraint of the households, in other words the shadow price of one unit of additional wealth. It gives the change in the value of the objective function, i.e. the maximization of the utility function, if the budget constraint is changed by one unit, i.e. by one unit of additional wealth. The stochastic discount factor of the household is valid for the firm because of its ownership structure, the firm is assumed to behave in the best interest of its owner.

$$div_t = \frac{pj_t yj_t}{p_t} + loan_t - r_t kj_t - w_t hj_t - \frac{lf_t loanf_{t-1}}{\pi_t} - pac_t \tag{8}$$

by which pj_t denotes the price of the intermediate goods. lf_t is the gross lending rate on loans updated to the current period and $loanf_{t-1}$ is the real market value of the loans taken out in the last period. The loans are used to finance the production with the inputs provided by the household.

[31] Equilibrium condition (54). Reference in Lozey et al. (2016) is made in general to Clancy and Merola (2014), in turn based on Beneš et al. (2014). Note: In equilibrium, the aggregate housing stock is fixed.

The intermediate goods producing firm exhibits a constant returns to scale Cobb-Douglas production function:

$$yj_t = kj_t^{\alpha}(z_t hj_t)^{1-\alpha} \tag{9}$$

yj_t is the output of intermediate goods producer, z_t is a technology shock.
They act in monopolistic competition such that each firm j can set the price of each input pj_t, revealing market power. Moreover, the firms are subject to quadratic price adjustment costs according to Rotemberg (1982). Price changes are costly while compared to the steady state inflation π^*. The underlying assumption is that, varying from industry to industry, price changes are costly, as customer relationships are destructed or due to menu costs. The costs are given in real terms, i.e. adjusted for the general price level in the economy p_t:

$$pac_t = \tfrac{\varphi}{2}\left(\tfrac{pj_t / pj_{t-1}}{\pi^*} - 1\right)^2 y_t \tag{10}$$

In the interpretation of the results, the implied version of a New Keynesian Phillips curve is crucial:[32]

$$0 = \frac{1}{c_t^{\tau}}[1-\theta+\theta\frac{w_t h_t}{(1-\alpha)y_t} - \varphi(\frac{\pi_t}{\pi^*}-1)\frac{\pi_t}{\pi^*}] + \beta f Exp_t[\frac{1}{c_{t+1}^{\tau}}(\frac{\pi_{t+1}}{\pi^*}-1)\varphi\frac{\pi_{t+1}}{\pi^*}\frac{y_{t+1}}{y^*}]$$

It is forward-looking due to the price adjustment costs. It features an expression for the costs of production in terms of labor, a gap in inflation, and additionally the expected deviations in both inflation and output from their steady states.

Banking sector

The financial intermediaries maximize the discounted value of expected dividends:

$$\max Exp_0 \sum_{t=0}^{T} \beta^t \lambda_t divbank_t \tag{11}$$

The time preference factor as well as the stochastic discount factor is the one of the shareholders. The balance sheet constraint of a bank is comprised of loans to the firms $loanf_t$ and the loan to the households $loanh_t$ on the asset side, $loan_t = loanf_t + loanh_t$, corresponding quantitatively to the deposits of the household dep_t and the capital $kbank_t$ on the liability side. At the end of the period t, the following condition holds:

$$loan_t = dep_t + kbank_t \tag{12}$$

In the optimization, the stochastic discount factor ψ_t is introduced in order to account for the costs associated with deviating from the balance sheet identity. $kbank_{t+1}$ will be determined via reinvested profits, in addition banks choose to distribute a fraction of the profits to the households in the form of dividends. The accumulation of bank capital thus follows the law of motion:

$$kbank_{t+1} = (1-consb)kbank_t + reinvpr_t \tag{13}$$

[32] Equilibrium condition (59)

whereas *consb* is the parameter owing to the consumption of bank capital and $reinvpr_t$ are the reinvested profit of the bank in the current period.[33] In order to improve the capital base and thereby diminish the monitoring costs of the households, the banks are obliged to reinvest a higher share of the profits accrued. In the following cash flow, the dividends and the reinvested profits are separate variables:

$$divbank_t = \frac{lf_t loanf_{t-1}}{\pi_t} + \frac{lh_{t-1}(1-\xi j_t)loanh_{t-1}}{\pi_t} + dep_t - \frac{s_{t-1}dep_{t-1}}{\pi_t} - (1+\varsigma)loanf_t - loanh_t - reinvpr_t \tag{14}$$

The dividends consist of the profits accrued from the interest on loans to the households and entrepreneurs minus the interest on deposits paid to the households. The extension of the loans to firms is captured by $loanf_t$ with the monitoring costs imposed:

$$(1+\varsigma) = \chi l1\left(\frac{loanf_t}{div_t}\right)^{\chi l2} b_t \tag{15}$$

$(1+\varsigma)$ are the monitoring costs for the banks when contracting the loans. The costs arise due to the monitoring of the leverage position of the borrower of the funds, i.e. the intermediate goods producer. The agency-cost problem is introduced. $\chi l1$ is the level parameter, $\chi l2$ the elasticity. The AR(1) process b_t might account for the variance in the net worth of the firm,[34] and additionally for the risk of the loans not reasoned by the leverage of the entrepreneur.[35] In equilibrium, higher monitoring costs on both sides thus channel through to an higher expected discounted lending rate:[36]

$$\beta Exp_t\left[\frac{1}{c_{t+1}^{\tau}}\frac{lf_{t+1}}{\pi_{t+1}}\right] = \frac{1}{c_t^{\tau}}[\chi l2(1+\varsigma)_t + (1+\varsigma)_t] - \frac{1}{c_t^{\tau}} + \frac{1}{c_t^{\tau}}(1+\mu)_t$$

The crucial element in the financial crisis of households defaulting on their loans for housing is modeled by examining a threshold for which this is the case. In particular, a negative idiosyncratic shock $u_t \sim N(0, \sigma u)$ hits the value of the collateral of the loan of the previous period, i.e. the housing stock at current prices, to the extent that the household defaults:

$$\exp(u_t)\frac{q_t hou_{t-1}}{\pi_t} < lh_{t-1}loanh_{t-1} \tag{16}$$

$= \exp(u_t)f_t < fbar_{t-1}$, with $f_t = \frac{q_t hou_{t-1}}{\pi_t}$ and $fbar_{t-1} = lh_{t-1}loanh_{t-1}$. Isolating u_t on the left hand side, one arrives at the probability of default j_t:

$$j_t = \Phi\left(\frac{\log\left(\frac{fbar_{t-1}}{f_t}\right)}{\sigma u}\right) \tag{17}$$

[33] In an extension of the model, adjustment costs can be placed at the law of motion for bank capital, in order to better model the associated problems the banks faced in the crisis.
[34] Boivin et al. (2010) cit. in Alpanda et al. (2014: 15)
[35] Christiano et al. (2010) cit. in Alpanda et al. (2014: 15). For the modeling of the monitoring costs, the authors refer to Curdia and Woodford (2011).
[36] Equilibrium condition (65)

where Φ is the cumulative standard normal distribution function and σu accounts for the idiosyncratic risk. Given default, roughly half of the loan exposure is lost for the bank, captured by the parameter ξ, while the rest can be recovered.[37] Due to the Law of Large Numbers, the probability of default can also be interpreted as the share of non-performing loans. When the bank decides upon the loan to the household, it takes the probability of default as given. The equilibrium condition yields: [38]

$$lh_t = \frac{1}{c_t^{\tau}}(1+\mu)_t \frac{1}{\beta} Exp_t[\frac{c_{t+1}^{\tau}\pi_{t+1}}{(1-\xi j_{t+1})}]$$

The current lending rate that the banks require rises with the expected probability of household default, reinforcing each other, and with the monitoring costs for the household implied by the deviation from the capital requirement. The banks require to be compensated for the higher risk of the households defaulting on the loan.

Central bank

The central bank follows a Taylor rule comprising deviations from the steady state for the policy rate, output and inflation:

$$\log(\frac{s_t}{s^*}) = \rho s \log(\frac{s_{t-1}}{s^*}) + \rho y \log(\frac{y_t}{y^*}) + \rho \pi \log(\frac{\pi_t}{\pi^*}) + \varepsilon s_t \qquad (18)$$

5. Calibration

In part, the parameters of the related literature are used in the model:[39] Following Angeloni and Faia (2011), φ amounts to 30. γ is set to 10, as in Pichler (2008), Gerali et al. (2010) and Alpanda, Cateau and Meh (2014). δ is set at 0.025, in line with most of the covered literature. Following Pichler (2008), τ is 2, the parameter θ for the labor costs in the version of the New Keynesian Phillips curve is 6 and the typical Taylor rule parameter ρs, ρy and $\rho\pi$ are 0.7, 0.5 and 1.5 respectively. $\chi l2$ is set at 0.05, similar to Bernanke et al. (1999) cit. in Alpanda, Cateau and Meh (2014). $\chi d2$ is at 0.01 for the illustration of the bank capital channel, v at 0.1 as in Alpanda, Cateau and Meh (2014) and α is at 0.36. The persistence parameter ρa is set to 0.9 as in Alpanda, Cateau and Meh (2014), σa to 0.07, ρd to 0.95 and σd is the estimated 0.14 of Lozey et al. (2017) for the Irish housing boom in lack of the estimation for the US, ξ is roughly 0.5 as in Lozey et al. (2016). ι is 1 as in Lozey et al. (2016).

The rest of the parameters is calibrated. The calibration is based on the averages in the data for the US from 2000 to 2007. The source is the FRED Database of the St. Louis Fed.[40] The

[37] ξ is assumed to be exogenous and can be subject to shocks. In an extension of the model, ξ can rise with the severity of the crisis.

[38] Equilibrium condition (66). Note: the optimization with respect to the credit as in Lozey et al. (2016), contrary to Lozey et al. (2017), takes the probability of default as an independent variable.

[39] The parameter can be found in Pichler (2008: 13 f. and 16), Gerali et al. (2010: 21 f. and 44), Signoretti and Gambacorta (2014: 155 f.), Alpanda et al. (2014: 25 ff. and 39) and Angeloni and Faia (2011: 13 ff.), Lozey et al. (2016: 42) and Lozey et al. (2017: 33). An overview of all parameter values is provided in the Annex.

[40] A description of the data is provided in the Annex.

following targets are met: j = 0.0107, *loanh/y* = 0.19, *loanf/y* = 0.09, *hou/y* = 0.82, *lf* = 1.064, s = 1.034, q = 1.024. Due to missing data for the non-performing loans in the real estate sector, the average was borrowed from the ratio of non-performing loans to all loans. No data was available for *lh*. In order to roughly match the ξ of 0.5 as in Lozey et al. (2016), it amounts to 1.04. Inflation derived from the GDP deflator amounts roughly to 1 percent per quarter, i.e. π is 1.01.

The calibration of the time discount factors results in somewhat lower values than usually found in the DSGE literature because the averages of 6.4 percent for the lending rate of firms and 4 percent for households are relatively high, respectively. For the gauge of the monitoring costs of the household in the steady state, i.e. in order to arrive at the savings rate of 3.4 percent, the level of bank capital which is consumed by the bank is close to zero but negative at the steady state. It means that without any interference, the banks build up equity every period in order to reduce the monitoring costs implied by their leverage, resulting in reinvested profits close to zero but negative in the steady state. Overall, the calibration in accordance with the target levels yields only barely positive dividends of the banks which in fact was not the state in the US preceding the crisis.

Caveats

As appears in the previous section, the model lacks a thorough calibration or estimation of the parameter, in particular might the persistence parameters and the intensities of the shock processes or the parameters of the monitoring costs not set accordingly such that a close fit to the actual development results. Related to this issue is the one of over-fitting parameter.

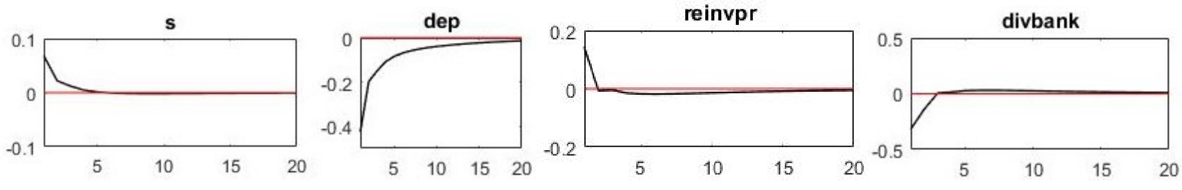
Besides, non-linearities are claimed to play a larger role when modeling the behaviour in the financial markets, in particular explosive price paths.

A feature not modelled explicitly is that the financing of firms in the US happened to be more self-finance, capital market based, rather than resorting to financial intermediaries.[41] Financial securitization is not modelled per se, and an open-economy perspective could account for the international trade balance, exchange rate and spill-over effects, and further contagion risk.

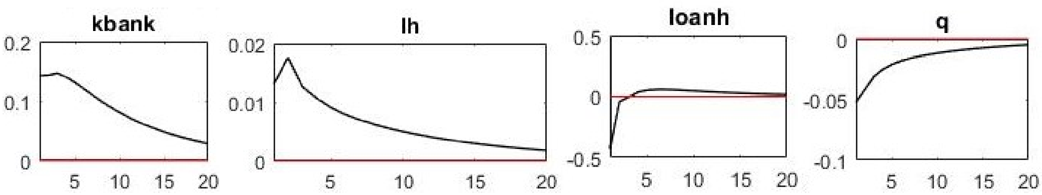
6. Interpretation of the Results

Shock to the monitoring costs of the household

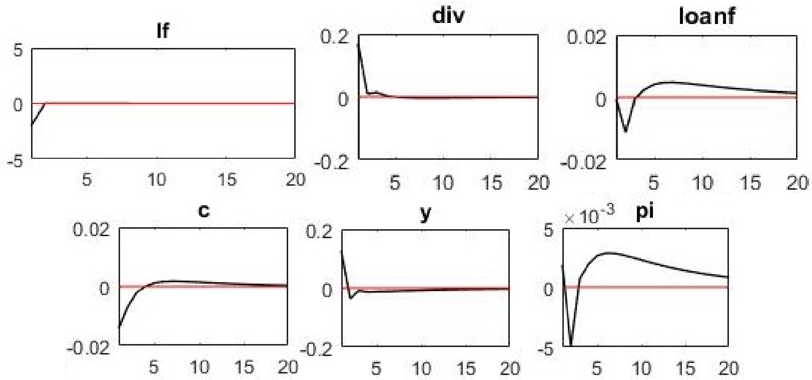
The shock to the standard deviation of the shock process related to the capital requirement pushes the savings rate required by the household inducing a drop in deposits. In order to reduce the monitoring costs, banks reinvest heavily in rebuilding capital and incur losses which affect the cash flow of households.



[41] Streissler (2011: 23)



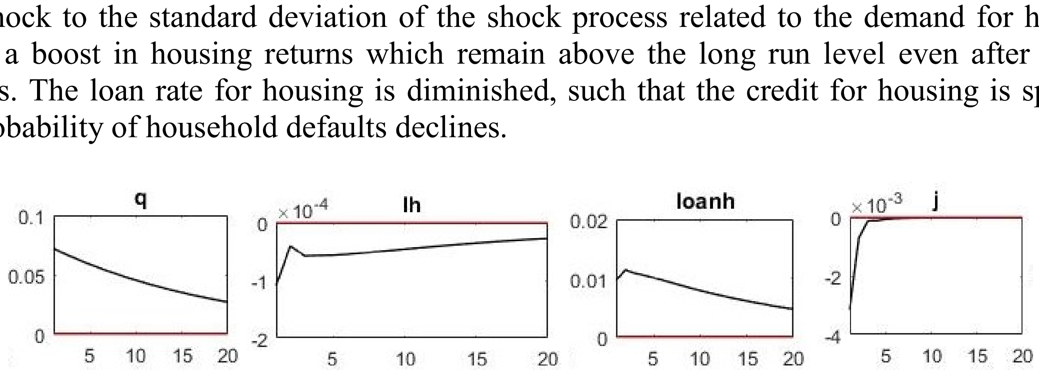
The higher funding costs further channel through to a higher lending rate for households and a lower level of credit for housing, leading to a fall in non-performing loans. The returns on housing are depressed, which overall reveals the dampening effects on the housing market. The current loan rate for firms drops, only in expectation lead the higher monitoring costs to a higher rate which is counteracted by the considerable increase in dividends and the immediate drop in loans for firms, thereby alleviating the principal agent problem of banks and firms. After roughly two quarters, however, the rate is back at the long run level and the loans for the firms turn into positive territory to remain there even after the 20 quarters considered.



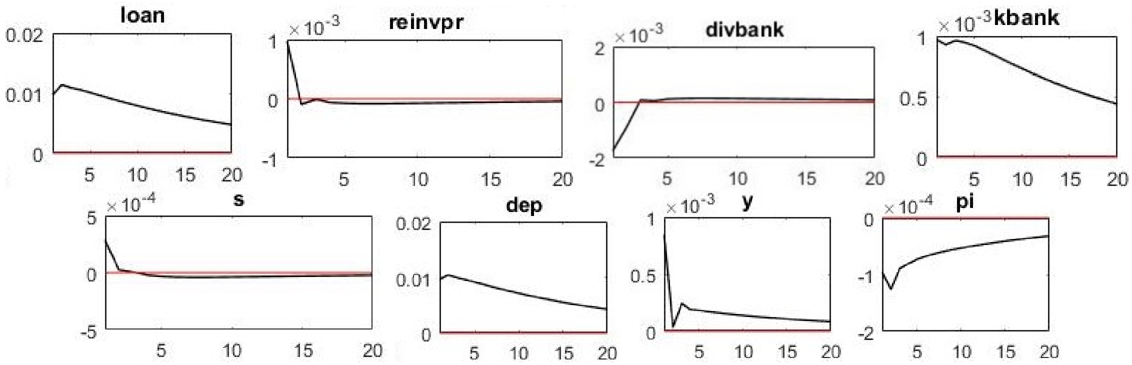
Output approaches quickly its steady state and after the initial drop inflation, with lowered wages and consumption, rebounds roughly after two quarters to remain above the steady state, though quantitatively of minor importance.

Shock to the demand for housing

The shock to the standard deviation of the shock process related to the demand for housing yields a boost in housing returns which remain above the long run level even after the 20 periods. The loan rate for housing is diminished, such that the credit for housing is spurred, the probability of household defaults declines.



The total credit in the economy rises and, along with higher reinvested profits on the expense of bank dividends, the capital stock is increased to drive down the costs for banks to deviate from the capital requirement. Accordingly, the costs of funding via deposits rise initially while at the same time the balance sheet of the bank is enlarged by an higher level of funding.

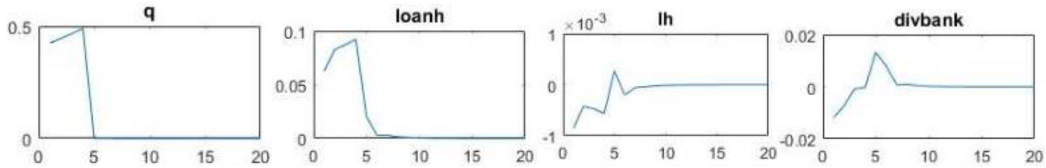


The principal agent problem between banks and firms is alleviated due to a spike in dividends and the reduction of credit to the firms, similar to the response described for the shock to the monitoring costs for households. Output is levelled up initially and remains above the steady state over the time horizon, and along with wages and consumption falling, inflation is depressed, though quantitatively of minor importance.

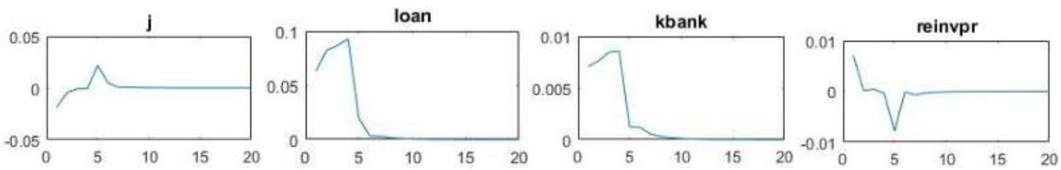
Boom and bust scenario of the housing market

In order to model the boom and bust scenario of the housing market in the US, market participants expect an housing boom to occur in one year, i.e. anticipate the development of rising prices for housing. When the point of time is reached, however, the expectations are unfulfilled and the demand for housing does not materialize, which leads to the bust. It is coded like a "pure" news shock and the development of the variables represent the deviations from the steady state.[42]

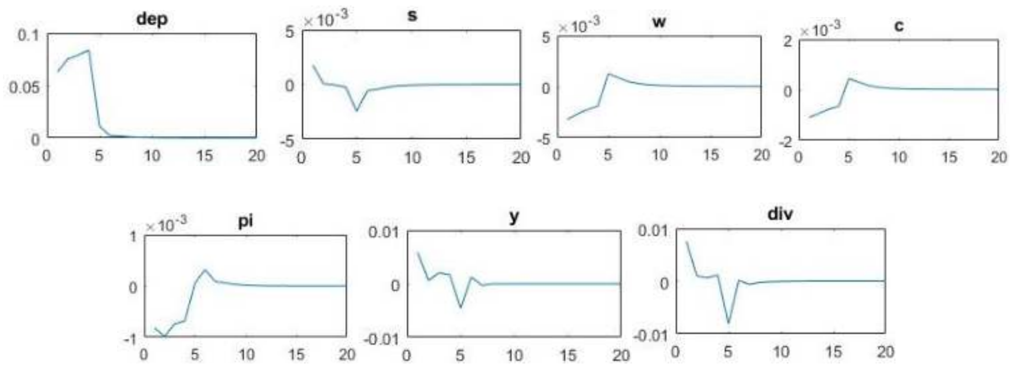
The expectations of higher demand for housing in the future are accompanied by rising yields on housing and an higher respective credit. The loan rate remains depressed until the bubble bust. The dividends of banks rise.



The amount of non-performing loans for housing approaches its long run trend towards the end of the first year. Also the total credit in the economy is expanded as is the bank capital, initially by reinvesting profits. The balance sheet of banks is enlarged by additional funding. The savings rate falls, while the central bank does not target the credit and the property price gaps.



[42] The boom and bust scenario is similar to Lozey et al. (2016), the coding is from Pfeifer (2013) referring to Portier (2004), for example, as appears in the forum of Dynare (2013).

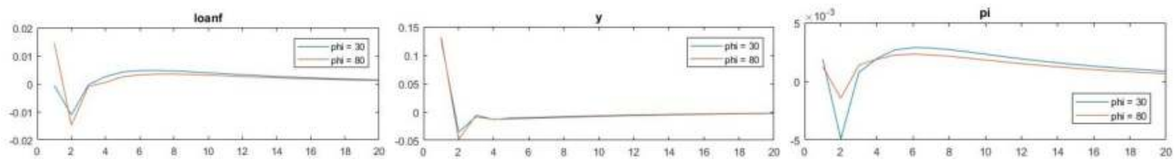


Wages and consumption are spurred constantly, culminating at around four quarters. It takes longer for inflation to reverse its upwards trend. The output of entrepreneurs in line with the disbursed dividends bounces back when completing the first year. The unfulfilled expectations reverse the effects, resulting in a drop in the yields on housing and the dividends of banks, a shrinking balance sheet of banks, falling lending rates and falling inflation.

7. Sensitivity Analysis

Price adjustment costs

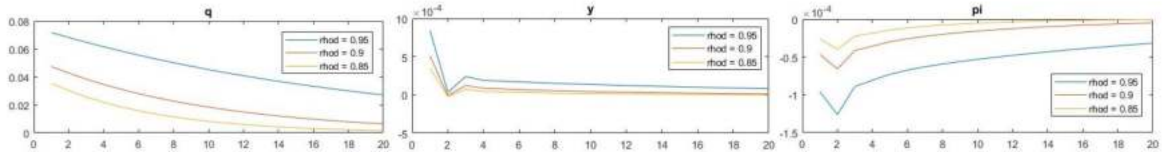
The parameter φ provides the gauge of price stickiness in the model, i.e. how costly it is for intermediate goods producer to change prices. It thus enters the New Keynesian Phillips curve in front of the inflation and the output gaps. φ amounts to 30, which corresponds both to the estimated value of Gerali et. al. (2010) in the Eurozone, i.e. the baseline model for Signoretti and Gambacorta (2014), and to the value of Angeloni and Faia (2011): “a value that matches, in the Rotemberg framework, the empirical evidence on the frequency of price adjustments obtained using the Calvo-Yun approach.” (Angeloni and Faia 2011: 13 f.) In the baseline New Keynesian Model of Pichler (2008), φ however amounts to 80, in turn based on the estimates of Ireland (2001) for the US. The following figures display the sensitivities for the shock to the monitoring costs of the household:



The higher gauge of price stickiness is accompanied by a larger drop in credit to the entrepreneurs and in output, contrary to the measure of price increases, which exhibits lower volatility.

Shock persistence

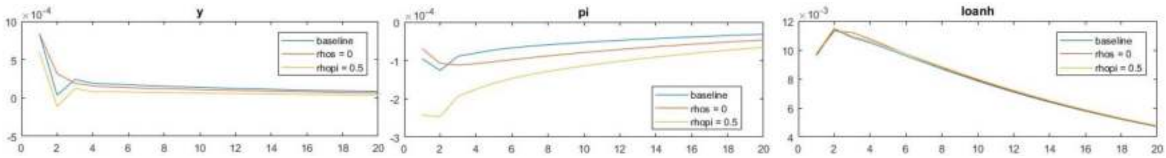
The persistence parameter of the shock process pushing the demand for housing ρd is varied from 0.95 to 0.9 and 0.85:



Accordingly, the impact on the yields on housing, output and inflation and is less pronounced.

Taylor rule

More sensitivity analyses are pursued for the parameters of the Taylor rule. The smoothing parameter *ρs* is set to 0, such that the central bank fully adjusts to deviations in inflation and output. In addition, the parameter *ρπ* is set to 0.5 to consider a more accommodative monetary policy within the given targeting approach. The shock pushing the demand for housing yields the following dynamics:



If the central bank does not adjust the policy rate gradually, output follows a higher path in the beginning and the deflation is less targeted over time. Output is below the baseline scenario when the monetary policy is more accommodative and the deflation is more severe. In every case, there is a very close match in the dynamics of the credit for housing, owing to the missing link between the firms and the housing market.

8. Summary

The boom and bust scenario for housing is able to replicate some crucial dynamics associated with the financial crisis 2007/2008. Within the given framework, the main task is to estimate the parameter to better fit the data quantitatively. Furthermore, higher-order dynamics need to be included and with respect to the elements, the model needs to feature an open economy in order to account for the international dimension.

Annex

Optimality conditions

Household

The Lagrangean function set up from (1) and (2), λ_t is the Lagrange multiplier:

$$Lagrange = Exp_0 \sum_{t=0}^{T} \beta^t \{[\frac{c_t^{1-\tau}-1}{1-\tau} + \frac{\chi_{hou} hou_t^{1-\iota}}{1-\iota} d_t + \chi h(1-h_t)] + \lambda_t [\frac{q_t hou_{t-1}}{\pi_t} + w_t h_t + r_t k_t + div_t$$
$$+ divbank_t + \frac{s_{t-1} dep_{t-1}}{\pi_t} + loanh_t - q_t hou_t - c_t - x_t - \frac{\gamma}{2}(\frac{x_t}{k_t} - \delta)^2 k_t - (1+\mu) dep_t - \frac{lh_{t-1} loanh_{t-1}}{\pi_t}]\} \quad (19)$$

Control variables are c_t, h_t, dep_t, k_{t+1}, hou_t and $loanh_t$:

$$0 = \frac{1}{c_t^{\tau}} - \lambda_t \quad (20)$$

$$0 = -\chi h + \lambda_t w_t \quad (21)$$

$$0 = -\lambda_t (1+\mu) + s_t \beta Exp_t \lambda_{t+1} \frac{1}{\pi_{t+1}} \quad (22)$$

$$0 = \lambda_t [1 + \gamma(\frac{k_{t+1}}{k_t} - 1)] - \beta Exp_t \lambda_{t+1} [r_{t+1} + 1 - \delta - \frac{\gamma}{2}(\frac{k_{t+2}}{k_{t+1}} - 1)^2 + \gamma(\frac{k_{t+2}}{k_{t+1}} - 1)\frac{k_{t+2}}{k_{t+1}}] \quad (23)$$

$$0 = \chi_{hou} hou_t^{-\iota} d_t - q_t \lambda_t + \beta Exp_t (\lambda_{t+1} \frac{q_{t+1}}{\pi_{t+1}}) \quad (24)$$

$$0 = \lambda_t - lh_t \beta Exp_t (\frac{\lambda_{t+1}}{\pi_{t+1}}) - \lambda_t \chi d1 \chi d2 (v \tfrac{loan_t}{kbank_t})^{\chi d2 - 1} a_t dep_t \tfrac{v}{kbank_t} \quad (25)$$

The budget constraint:

$$0 = \frac{q_t hou_{t-1}}{\pi_t} + w_t h_t + r_t k_t + div_t + divbank_t + \frac{s_{t-1} dep_{t-1}}{\pi_t} + loanh_t$$
$$- q_t hou_t - c_t - x_t - \frac{\gamma}{2}(\frac{x_t}{k_t} - \delta)^2 k_t - (1+\mu) dep_t - \frac{lh_{t-1} loanh_{t-1}}{\pi_t} \quad (26)$$

Final-goods producer

The objective function, plugging in (6):

$$\max_{yj_t} [y_t p_t - \int_0^1 yj_t pj_t dj] = \max_{yj_t} [(\int_0^1 yj_t^{\frac{\theta-1}{\theta}} dj)^{\frac{\theta}{\theta-1}} p_t - \int_0^1 yj_t pj_t dj] \quad (27)$$

The optimality condition wrt. yj_t, using (6):

$$yj_t = (\frac{pj_t}{p_t})^{-\theta} y_t \tag{28}$$

The objective function, plugging in (28):

$$\max_{y_t}[y_t p_t - \int_0^1 yj_t pj_t dj] = \max_{y_t}[(y_t p_t - \int_0^1 (\frac{pj_t}{p_t})^{-\theta} y_t pj_t dj] \tag{29}$$

The optimality condition wrt. y_t:

$$p_t = (\int_0^1 pj_t^{1-\theta} dj)^{\frac{1}{1-\theta}} \tag{30}$$

Intermediate-goods producer

The Lagrangean set up from (7)-(10), in real terms and using (28), ω_t is the Lagrangean multiplier:

$$\begin{aligned} Lagrange = Exp_0 \sum_{t=0}^{T} \beta f^t \{\lambda_t[(\frac{pj_t}{p_t})^{1-\theta} y_t + loanf_t - w_t hj_t - r_t kj_t - \frac{lf_t loanf_{t-1}}{\pi_t} \\ - \frac{\varphi}{2}(\frac{pj_t / pj_{t-1}}{\pi *} - 1)^2 y_t] + \omega_t[kj_t^{\alpha}(z_t hj_t)^{1-\alpha} - (\frac{pj_t}{p_t})^{-\theta} y_t]\} \end{aligned} \tag{31}$$

The control variables are hj_t, kj_t, $loanf_t$ and pj_t:

$$0 = -\lambda_t w_t + \omega_t (1-\alpha) kj_t^{\alpha} z_t^{1-\alpha} hj_t^{-\alpha} \tag{32}$$

$$0 = -\lambda_t r_t + \omega_t \alpha kj_t^{\alpha-1}(z_t hj_t)^{1-\alpha} \tag{33}$$

$$0 = \lambda_t - \beta f Exp_t \lambda_{t+1} \frac{lf_{t+1}}{\pi_{t+1}} \tag{34}$$

$$\begin{aligned} 0 = \lambda_t[(1-\theta)(\frac{pj_t}{p_t})^{-\theta} \frac{y_t}{p_t} - (\frac{pj_t}{\pi * pj_{t-1}} - 1)\frac{\varphi y_t}{\pi * pj_{t-1}}] \\ + \beta entr Exp_t \lambda_{t+1}[(\frac{pj_{t+1}}{\pi * pj_t} - 1)\frac{\varphi y_{t+1} pj_{t+1}}{\pi * pj_t^2}] + \omega_t[(\frac{pj_t}{p_t})^{-\theta-1} \theta \frac{y_t}{p_t}] \end{aligned} \tag{40}$$

The production technology constraint:

$$0 = kj_t^{\alpha}(z_t hj_t)^{1-\alpha} - (\frac{pj_t}{p_t})^{-\theta} y_t \tag{41}$$

Banking sector

The Lagrangean set up from (11), (12) and (14), ψ_t is the Lagrangean multiplier for the balance sheet:

$$Lagrange = Exp_0 \sum_{t=0}^{T} \beta^t \{\lambda_t [\frac{lf_t loanf_{t-1}}{\pi_t} + \frac{lh_{t-1}(1-\xi j_t) loanh_{t-1}}{\pi_t} + dep_t - \frac{s_{t-1} dep_{t-1}}{\pi_t}$$
$$-(1+\varsigma) loanf_t - loanh_t - reinvpr_t] + \psi_t (loanf_t + loanh_t - dep_t - kbank_t)\} \quad (42)$$

The control variables are dep_t, $kbank_{t+1}$, $loanf_t$ and $loanh_t$:

$$0 = \lambda_t - s_t \beta Exp_t \lambda_{t+1} \frac{1}{\pi_{t+1}} - \psi_t \quad (43)$$

$$0 = -\lambda_t + \beta Exp_t \lambda_{t+1}(1-consb) - \psi_{t+1} \quad (44)$$

$$0 = -\lambda_t [\chi l2(1+\varsigma) + (1+\varsigma)] + \beta Exp_t \lambda_{t+1} \frac{lf_{t+1}}{\pi_{t+1}} + \psi_t \quad (45)$$

$$0 = -\lambda_t + lh_t \beta Exp_t \lambda_{t+1} \frac{(1-\xi j_{t+1})}{\pi_{t+1}} + \psi_t \quad (46)$$

The balance sheet constraint:

$$0 = -dep_t - kbank_t + loanf_t + loanh_t \quad (47)$$

The symmetric competitive equilibrium

$\pi_t = p_t / p_{t-1}$
$hou_t = hou$
$hj_t = h_t$
$kj_t = k_t$
$pj_t = p_t$

Equilibrium conditions

From (20):

$$\lambda_t = \frac{1}{c_t^{\tau}} \quad (48)$$

From (21) and (48):

$$0 = -\chi h + \frac{w_t}{c_t^{\tau}} \quad (49)$$

From (22) and (48), or alternatively from (43), (48) and (61):

$$0 = -\frac{1}{c_t^{\tau}}(1+\mu)_t + s_t \beta Exp_t (\frac{1}{c_{t+1}^{\tau} \pi_{t+1}}) \quad (50)$$

From (23) and (48):

$$0 = \frac{1}{c_t^\tau}[1+\gamma(\frac{x_t}{k_t}-\delta)] - \beta Exp_t\{\frac{1}{c_{t+1}^\tau}[r_{t+1}+1-\delta-\frac{\gamma}{2}(\frac{x_{t+1}}{k_{t+1}}-\delta)^2+\gamma(\frac{x_{t+1}}{k_{t+1}}-\delta)(\frac{x_{t+1}}{k_{t+1}}-\delta+1)]\} \quad (51)$$

From (26), (8) and (14):

$$0 = y_t - \frac{\varphi}{2}(\frac{\pi_t}{\pi*}-1)^2 y_t + loanf_t - (1+\varsigma)_t loanf_t + dep_t - (1+\mu)_t dep_t + \frac{q_t hou}{\pi_t}$$
$$- q_t hou + \frac{lh_{t-1}(1-\xi j_t) loanh_{t-1}}{\pi_t} - \frac{lh_{t-1} loanh_{t-1}}{\pi_t} - c_t - x_t - \frac{\gamma}{2}(\frac{x_t}{k_t}-\delta)^2 k_t - reinvpr_t$$
(52)

From (3):

$$0 = k_{t+1} - (1-\delta)k_t - x_t \quad (53)$$

From (24):

$$0 = \chi_{hou} hou^{-\iota} d_t - \frac{q_t}{c_t^\tau} + \beta Exp_t(\frac{q_{t+1}}{c_{t+1}^\tau \pi_{t+1}})$$
(54)

From (25) and (48):

$$0 = \frac{1}{c_t^\tau} - lh_t \beta Exp_t(\frac{1}{c_{t+1}^\tau \pi_{t+1}}) - \frac{1}{c_t^\tau}\chi d1 \chi d2 (\nu \frac{loan_t}{kbank_t})^{\chi d2-1} a_t dep_t \frac{\nu}{kbank_t} \quad (55)$$

From (9):

$$0 = k_t^\alpha (z_t h_t)^{1-\alpha} - y_t \quad (56)$$

From (32) and (33):

$$0 = \alpha w_t h_t - (1-\alpha) r_t k_t \quad (57)$$

From (8)

$$0 = y_t + loanf_t - r_t k_t - w_t h_t - \frac{lf_t loanf_{t-1}}{\pi_t} - \frac{\varphi}{2}(\frac{\pi_t}{\pi*}-1)^2 y_t - div_t \quad (58)$$

From (40), (32), (9) and (48):

$$0 = \frac{1}{c_t^\tau}[1-\theta+\theta\frac{w_t h_t}{(1-\alpha)y_t} - \varphi(\frac{\pi_t}{\pi*}-1)\frac{\pi_t}{\pi*}] + \beta f Exp_t[\frac{1}{c_{t+1}^\tau}(\frac{\pi_{t+1}}{\pi*}-1)\varphi\frac{\pi_{t+1}}{\pi*}\frac{y_{t+1}}{y*}] \quad (59)$$

From (34) and (48):

$$0=\frac{1}{c_t^{\tau}}-\beta f Exp_t[\frac{1}{c_{t+1}^{\tau}}\frac{lf_{t+1}}{\pi_{t+1}}] \quad (60)$$

From (22) and (43):

$$\psi_t=\lambda_t-\lambda_t(1+\mu)_t \quad (61)$$

From (14):

$$0=\frac{lf_t loanf_{t-1}}{\pi_t}+\frac{lh_t(1-\xi j_t)loanh_{t-1}}{\pi_t}+dep_t-\frac{s_t dep_{t-1}}{\pi_t}-(1+\varsigma)_t loanf_t-loanh_t$$
$$-reinvpr_t-divbank_t \quad (62)$$

From (13):

$$0=(1-consb)kbank_t+reinvpr_t-kbank_{t+1} \quad (63)$$

From (44), (48) and (61):

$$0=-\frac{1}{c_t^{\tau}}+\beta Exp_t\frac{1}{c_{t+1}^{\tau}}(1-consb)-\frac{1}{c_{t+1}^{\tau}}+\frac{1}{c_{t+1}^{\tau}}(1+\mu)_{t+1} \quad (64)$$

From (45), (48) and (61):

$$0=\beta Exp_t[\frac{1}{c_{t+1}^{\tau}}\frac{lf_{t+1}}{\pi_{t+1}}]-\frac{1}{c_t^{\tau}}[\chi l2(1+\varsigma)_t+(1+\varsigma)_t]+\frac{1}{c_t^{\tau}}-\frac{1}{c_t^{\tau}}(1+\mu)_t \quad (65)$$

From (46), (48) and (61):

$$0=lh_t\beta Exp_t[\frac{1}{c_{t+1}^{\tau}}\frac{(1-\xi j_{t+1})}{\pi_{t+1}}]-\frac{1}{c_t^{\tau}}(1+\mu)_t \quad (66)$$

From (47):

$$0=-dep_t-kbank_t+loanf_t+loanh_t \quad (67)$$

From (17):

$$0=\Phi\left(\frac{\log\left(\frac{fbar_{t-1}}{f_t}\right)}{\sigma u}\right)-j_t \quad (68)$$

From (18):

$$0 = \rho s \log(\frac{s_{t-1}}{s*}) + \rho y \log(\frac{y_t}{y*}) + \rho\pi \log(\frac{\pi_t}{\pi*}) + \varepsilon s_t - \log(\frac{s_t}{s*}) \tag{69}$$

From the definition of f_t:

$$0 = \frac{q_t hou_{t-1}}{\pi_t} - f_t \tag{70}$$

From the definition of $fbar_t$:

$$0 = lh_{t-1} loanh_{t-1} - fbar_{t-1} \tag{71}$$

From the definition of $loan_t$:

$$0 = -loanh_t - loanf_t + loan_t \tag{72}$$

Shocks

The two shocks processes for the analysis follow AR1 processes, with $\varepsilon a_t \sim N(0, \sigma a^2)$ and $\varepsilon d_t \sim N(0, \sigma d^2)$:

$$0 = \rho a \log a_{t-1} + \varepsilon a_t - \log a_t$$

$$0 = \rho d \log d_{t-1} + \varepsilon d_t - \log d_t$$

Parameter values

Parameter	Value
β	0.9625
βf	0.9492
τ	2
χh	1.6406
χhou	0.0509
γ	10
θ	6
δ	0.025
α	0.36
φ	30
v	0.1
consb	-0.0541
$\chi d1$	0.9854
$\chi d2$	0.01
$\chi l1$	1.0087
$\chi l2$	0.05
ρs	0.7
$\rho \pi$	1.5
ρy	0.5
ρa	0.9
ρd	0.95
σa	0.07
σd	0.14
σu	0.793
ξ	0.5365
hou	0.82
ι	*1*

References

Data for calibration (Citation as suggested in the FRED database):

Board of Governors of the Federal Reserve System (US), Bank Prime Loan Rate [MPRIME], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/MPRIME, February 1, 2018.

Board of Governors of the Federal Reserve System (US), Commercial and Industrial Loans, All Commercial Banks [BUSLOANS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/BUSLOANS, February 1, 2018.

Board of Governors of the Federal Reserve System (US), Effective Federal Funds Rate [FEDFUNDS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/FEDFUNDS, January 31, 2018.

Board of Governors of the Federal Reserve System (US), Households; Owners' Equity in Real Estate, Level [OEHRENWBSHNO], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/OEHRENWBSHNO, February 2, 2018.

Board of Governors of the Federal Reserve System (US), Real Estate Loans, All Commercial Banks [REALLN], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/REALLN, February 2, 2018.

Federal Financial Institutions Examination Council (US), Nonperforming Total Loans (past due 90+ days plus nonaccrual) to Total Loans [NPTLTL], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/NPTLTL, February 1, 2018.

S&P Dow Jones Indices LLC, S&P/Case-Shiller U.S. National Home Price Index [CSUSHPISA], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CSUSHPISA, February 1, 2018.

U.S. Bureau of Economic Analysis, Gross Domestic Product: Implicit Price Deflator [GDPDEF], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GDPDEF, January 31, 2018.

U.S. Bureau of Economic Analysis, Gross Domestic Product [GDP], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GDP, January 31, 2018.

Literature and data:

- Alpanda, S., Cateau, G., Meh, C., 2014: A policy model to analyze macroprudential regulations and monetary policy. *BIS Working Papers,* [Online]. No 461. Available at: http://www.bis.org/publ/work461.pdf [accessed 02 February 2015]
- Angeloni, I. and Faia, E., 2011: *Capital Regulation and Monetary Policy with Fragile Banks*. [Online]. Goethe Universität Frankfurt. Available at: http://www.wiwi.uni-frankfurt.de/profs/faia/welcome_files/AF_revision.pdf [accessed 02 February 2015]
- Borio, C., 2014: Monetary policy and financial stability: what role in prevention and recovery? *BIS Working Papers*, [Online]. No 440. Available at: http://www.bis.org/publ/work440.pdf (accessed 17 June 2016)

- Borio, C. and Drehmann, M., 2009: Assessing the risk of banking crises – revisited. *BIS Quarterly Review*, [Online]. March 2009. Available at: http://www.bis.org/publ/qtrpdf/r_qt0903e.pdf (accessed 06 June 2016)
- Brunnermeier, M. K. and Oehmke, M., 2013: *Bubbles, Financial Crises and Systemic Risk.* [Online]. Chapter for the Handbook of the Economics of Finance, p. 1-32, 40-71. Available at: https://www0.gsb.columbia.edu/faculty/moehmke/papers/BrunnermeierOehmkeHandbookSystemicRisk.pdf (accessed 29 July 2014)
- Bundesbank. 2018. Das Anleihekaufprogramm soll 2018 auslaufen. Interview in der Frankfurter Allgemeinen Zeitung. [internet]. Available at: http://www.bundesbank.de/Redaktion/DE/Interviews/2018_01_17_weidmann_faz.html (accessed 17 February 2018)
- DB Research, Weistroffer, C., 2013: *Macroprudential supervision. In search of an appropriate response to systemic risk*. [Online]. Current Issues, Global financial markets, May 24, 2014. Available at: https://www.dbresearch.com/PROD/DBR_INTERNET_EN-PROD/PROD0000000000288812/Macroprudential_supervision%3A_In_search_of_an_appro.PDF (accessed 19 June 2016)
- de Carvalho, F. A., Castro, M. R., Costa, S. M. A., 2014: Traditional and matter-of-fact financial frictions in a DSGE model for Brazil: the role of macroprudential instruments and monetary policy. *BIS Working Papers*, [Online]. No 460. Available at: http://www.bis.org/publ/work460.pdf (accessed 02 February 2015)
- Dewachter, H. and Wouters, R., 2014: Endogenous risk in a DSGE model with capital-constrained financial intermediaries. *Journal of Economic Dynamics & Control*, [Online]. No. 43 (2014), p. 241-268. Available at: http://econpapers.repec.org/article/eeedyncon/v_3a43_3ay_3a2014_3ai_3ac_3ap_3a241-268.htm (accessed 19 June 2016)
- Dombret, A., 2014: *Das Streben nach Stabilität - Märkte und Regeln im Spiegel der Krise*. Speech given at the Münchner Seminar. [Online]. Available at: http://www.cesifo-group.de/de/ifoHome/events/seminars/Muenchner-Seminare/Archive/mucsem_20140127_Dombret.html (accessed 17 June 2016)
- Dynare, 2011. *Plotting IRFs from different model in the same figure*. [Online]. Available at: https://forum.dynare.org/t/plotting-irfs-from-different-models-in-the-same-figure/2139/2 (accessed 26 February 2018)
- Dynare, 2013. *Unrealized Expectations*. [Online]. Available at: https://forum.dynare.org/t/unrealized-expectations/3265 (accessed 11 February 2018)
- Dynare, 2014. *Q: combining IRFs into subplotted figures & iterating?* [Online]. Available at: https://forum.dynare.org/t/q-combining-irfs-into-subplotted-figures-iterating/3609 (accessed 26 February 2018)
- Eakings, S.G. & Mishkin, F.S., 2011: *Financial Markets and Institutions*, p. 204 – 218. 7th ed. Prentice Hall.
- European Central Bank. 2018. *Press Conference*. [internet]. Available at: http://www.ecb.europa.eu/press/pressconf/2018/html/ecb.is180125.en.html (accessed 17 February 2018)
- European Central Bank – Statistical Data Warehouse – Quick View. 2018. *Government debt (consolidated) (as % of GDP), Greece*. [Online]. Available at: http://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=325.GFS.Q.N.GR.W0.S13.S1.C.L.LE.GD.T._Z.XDC_R_B1GQ_CY._T.F.V.N._T (accessed 17 February 2018)
- European Central Bank – Statistical Data Warehouse – Quick View. 2018. *Government debt (consolidated) (as % of GDP), Italy*. [Online]. Available at: http://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=325.GFS.Q.N.IT.W0.S13.S1.C.L.LE.GD.T._Z.XDC_R_B1GQ_CY._T.F.V.N._T (accessed 17 February 2018)

- European Central Bank – Statistical Data Warehouse – Quick View. 2018. *Government debt (consolidated) (as % of GDP), Portugal.* [Online]. Available at: http://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=325.GFS.Q.N.PT.W0.S13.S1.C.L.LE.GD.T._Z.XDC_R_B1GQ_CY._T.F.V.N._T (accessed 17 February 2018)
- Gambacorta, L. and Signoretti, F. M., 2014. Should monetary policy lean against the wind? An analyis based on a DSGE model with banking. *Journal of Economic Dynamics & Control*, [Online]. No. 43 (2014), p. 146-174. Available at: http://econpapers.repec.org/article/eeedyncon/v_3a43_3ay_3a2014_3ai_3ac_3ap_3a146-174.htm (accessed 19 June 2016)
- Gerali, A., Neri, S., Sessa, L. and Signoretti, F. M., 2010: Credit and Banking in a DSGE Model of the Euro Area. *Journal of Money, Credit and Banking*, [Online]. Supplement to Vol. 42, No. 6 (September 2010), p. 121. Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1538-4616.2010.00331.x/abstract (accessed 20 June 2016)
- Kara, A. H., 2012. Monetary Policy in Turkey After the Global Crisis. *Working Paper Series, Central Bank of the Republic of Turkey*, [Online]. No. 12/17. Available at: http://www.tcmb.gov.tr/wps/wcm/connect/cae05ae6-46c5-44a1-9ed8-bba3a6ccb2e1/WP1217E.pdf?MOD=AJPERES&CACHEID=ROOTWORKSPACEcae05ae6-46c5-44a1-9ed8-bba3a6ccb2e1 (accessed 20 June 2016)
- Kiley, M. T. and Sim, J. W., 2014: Bank capital and the macroeconomy: Policy considerations. *Journal of Economic Dynamics & Control*, [Online]. No. 43 (2014), p. 175-198. Available at: http://econpapers.repec.org/article/eeedyncon/v_3a43_3ay_3a2014_3ai_3ac_3ap_3a175-198.htm (accessed 19 June 2016)
- Lozej, M., Onorante, L. and Rannenberg, A., 2016. Countercyclical Capital Regulation in a Small Open Economy DSGE Model. *New Methods for Macroeconomic Modelling, Model Comparison and Policy Analysis*. Frankfurt, Germany 5-6 April 2016.
- Lozey, M., Onorante, L., Rannenberg, A., 2017: Countercyclical Capital Regulation in a Small Open Economy DSGE Model. *Central Bank of Ireland Research Technical Paper*, [online]. No 03/RT/2017. Available at: https://centralbank.ie/docs/default-source/publications/research-technical-papers/03rt17-countercyclical-capital-regulation-in-a-small-open-economy-dsge-model.pdf?sfvrsn=6 [accessed 05 February 2018]
- Matthews, S., 2018. Fed Minutes May Give Clues to 2018 Interest Rate World Puzzle. *BloombergMarkets*, [internet]. 20 February. Available at: https://www.bloomberg.com/news/articles/2018-02-20/upon-further-review-fed-may-finally-say-what-that-word-meant (accessed 20 February 2018)
- Pichler, P., 2008: Forecasting with DSGE Models: The Role of Nonlinearities. *The B.E. Journal of Macroeconomics*, [Online]. Vol. 8, Issue 1, Article 20. Available at: http://www.bepress.com/bejm/vol8/iss1/art20 (accessed 21 June 2016)
- Pichler, P., University of Vienna, 2014. *Macroeconomic Forecasting with Theory-Based Models*. December 2014. [Course material].
- Streissler, E. W., 2011: Honi soit qui mal y pense? *Report to the Austrian Academy of Sciences on Questions Pertaining to the Recent International Financial Crisis*. Available at: http://homepage.univie.ac.at/sylvie.hansbauer/WS%202010%20und%202011/Finanzkrise%20%20FCIR.pdf (accessed 03.02.2012)
- Weidmann, J., 2015: *Zur Rolle der Finanzstabilität für die Geldpolitik*. [Online]. Münchner Seminar. Available at: www.cesifo-group.de/DocDL/ifosd_2015_07_3.pdf (accessed 09 September 2015)
- Wood, G., CASS Business School, City University London, 2008. *Topics in Money, Banking and Finance*. May 2008. [Course material].