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Asset prices, collateral, and unconventional monetary policy in a DSGE model

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Non-technical summary

The way central banks conduct monetary policy changed with the onset of the crisis. Central banks do no longer rely exclusively on traditional interest rate policy but also prolong the maturities of repurchase agreements ("Repo"), widen the set of collateral accepted in Repo transactions, and reduce the haircut applied to specific types of assets. Those measures can be subsumed under the heading of unconventional monetary policy measures. To enable economists to analyze the macroeconomic consequences of a central bank resorting to a richer set of monetary policy tools that are targeted to change the liquidity situation among banks, requires to implement an interbank market in modern macroeconomic models. In recent times a couple of DSGE models emerged which explicitly incorporate an active banking sector (Gerali, Neri, Sessa, and Signoretti (2010), deWalque, Pierrard, and Rouabah (2010), Dib (2009)).

In this paper we set up a New-Keynesian model that features a heterogenous financial sector that consists of two different types of banks: a borrowing bank and a lending bank which interact on an interbank market. Whereas the interbank borrowing bank invests its funds together with interbank loans in a loan to a firm, the interbank lending bank invests in a riskless asset which it can exchange against liquidity in repurchase agreements with the central bank. Moreover, we introduce a borrowing constraint in a borrower-lender relationship as in Iacoviello (2005) and more recently in Gerali et al. (2010) by assuming that the interbank borrowing bank's ability to obtain liquidity on the interbank market is limited by the asset portfolio she can offer as collateral. Furthermore, to account for the recently observed enhancement of the monetary policy toolkit we introduce an additional instrument, namely, the size of the haircut applied to securities which the central bank accepts as collateral in repurchase agreements with interbank lending banks. In addition, we follow Bernanke and Gertler (1999) and distinguish between the fundamental price of capital, Q, equivalent to Tobin (1969)'s q and the market price of capital, S. The latter enters the borrowing constraint and influences the interbank lending volume. Given an exogenous shock to the market price of capital, the model is used to analyze the effectiveness of both conventional and unconventional monetary policy instruments in affecting the business cycle.

We can show that in our model the effect of a shock to the conventional monetary policy instrument on the real economy is dampened by the presence of an interbank market. Similarly, we show that the same market amplifies an exogenous shock to asset prices. Moreover, the haircut instrument has a positive effect on the level of interbank lending activity whose increase has the potential to stimulate the economy. However, this comes at the risk of increased inflation in the first periods after a negative shock to haircuts.

Given that our model contains an interbank market we argue that central banks should react to asset price movements. Our results support a central bank which resorts to the haircut instrument and not to an interest rate instrument if an asset price shock happens. In terms of a stabilization policy our results show that for a given magnitude of an asset price shock a haircut policy is able to reduce the macroeconomic volatility substantially.

However, given that a central bank decides to implement a haircut policy it has to think about the exit from such an unconventional monetary policy tool if inflationary pressures become too high. In line with the monetary policy literature the model implies that a central bank should prefer to communicate the exit date in advance and then credibly stick to it to ensure a smooth evolution of macroeconomic aggregates resulting from the agents' expectations formation. In case it decides not to define an exit from such a policy, the volatility of key macroeconomic variables is low at the cost of higher inflation in the long-run as liquidity provided by the central bank to the interbank market is growing over time.

Nicht-technische Zusammenfassung

Seit Beginn der aktuellen Finanzkrise hat sich die Geldpolitik grundlegend gewandelt, da sich Zentralbanken nicht länger ausschließlich auf die traditionelle Zinspolitik beschränken, um ihre geldpolitischen Ziele zu erreichen. Deshalb verlängerten sie die Laufzeiten der Offenmarktgeschäfte ("Repos"), erweiterten den Kreis der zugelassenen Sicherheiten für diese Transaktionen und reduzierten auch die Abschläge ("Haircuts") für ausgewählte Wertpapierklassen in Repo-Geschäften. Diese Maßnahmen kann man unter dem Oberbegriff der unkonventionellen Geldpolitik zusammenfassen. Damit Volkswirte in der Lage sind, die makroökonomischen Folgen zu beurteilen, die ein Zurückgreifen der Zentralbank auf dieses erweiterte Instrumentarium hat, ist es notwendig, einen Interbankenmarkt in moderne makroökonomische Modelle zu integrieren. In letzter Zeit wurden einige DSGE-Modelle entwickelt (siehe z.B. Gerali et al. (2010), deWalque et al. (2010), Dib (2009)), in welche explizit ein solcher Interbankenmarkt integriert worden ist.

In diesem Papier stellen wir ein Neu-Keyensianisches Modell mit einem heterogenen Finanzsektor auf, der aus zwei verschiedenen Arten von Banken besteht. Während die eine Bank Liquidität nachfragt, bietet die andere überschüssige Liquidität auf dem Interbankenmarkt an. Erstere verwendet die Depositen von Haushalten zusammen mit Interbankkrediten dafür, Kredite an Firmen zu vergeben. Die zweite Bank investiert ihre Mittel in risikolose Anlagen, deren Angebot exogen gegeben ist und welche im Rahmen von Repo-Geschäften gegen Zentralbankliquidität eingetauscht werden können. Darüber hinaus enthält unser Modell eine Friktion wodurch die Höhe des Kreditvolumens zwischen den beiden Banken davon abhängt, über welche Sicherheiten der Kreditnehmer verfügt (siehe Iacoviello (2005) oder Gerali et al. (2010)) und welcher Wert für die Sicherheiten in der nächsten Periode erwartet wird. Das Instrumentarium der Zentralbank erweitern wir, indem wir eine "Haircut-Regel" einführen, welche angewendet wird, um den Gegenwert der Sicherheiten für die kreditgebende Bank in Offenmarktgeschäften festzulegen. Desweiteren folgen wir Bernanke and Gertler (1999) und unterscheiden zwischen dem Fundamentalpreis für Kapital, Q, welcher Tobin (1969)'s q entspricht, und dem Marktpreis für Kapital S. Letzterer spielt im Rahmen der oben genannten Friktion eine Rolle und hat Einfluss auf die Höhe des Kreditvolumens auf dem Interbankenmarkt. Wir analysieren die Effektivität von konventioneller und unkonventioneller Geldpolitik auf den Konjunkturzyklus bei einem exogenen Schock auf den Marktpreis für Kapital.

Wir können mit unserem Modell einerseits die Ergebnisse anderer Studien bestätigen, dass ein heterogener Bankensektor dazu führt, dass die Wirkung eines geldpolitischen Schocks auf den realen Sektor durch den Interbankenmarkt reduziert wird. Andererseits können wir zeigen, dass im Falle von Vermögenspreisübertreibungen das Vorhandensein eines Finanzsektors den Effekt auf die Realwirtschaft im Vergleich zu einer Modellierung ohne einen solchen Sektor sogar erhöht. Hinsichtlich der Effektivität des Haircut-Instruments stellen wir fest, dass eine Senkung des Abschlags auf Wertpapiere in Repo-Geschäften sowohl einen positiven Effekt auf das Kreditvolumen auf dem Interbankenmarkt hat als auch in der Lage ist die Realwirtschaft zu stimulieren. Allerdings geht dieses zu Lasten höherer Inflation.

Nach unserem Modell ist es möglich, die Auswirkungen einer Vermögenspreisänderung auf die Volatilität makroökonomischer Variablen deutlich zu verringern, wenn die Notenbank in solchen Fällen den Haircut verändert, statt einer dementsprechend die Zinsen anzupassen.

Sofern sich eine Zentralbank entscheidet, das Haircut-Instrument einzusetzen, sollte sie sich auch damit auseinandersetzen, wie sie dessen Einsatz wieder beenden kann. Das gilt insbesondere im Hinblick auf damit verbundene steigende Inflationsrisiken. Die Antwort unseres Modells auf diese Frage ist, dass im Hinblick auf die Volatilität sowohl realwirtschaftlicher als auch finanzmarktbezogener Variablen eine Strategie zu bevorzugen ist, welche explizit ein Ausstiegsdatum für die Beendigung einer solchen Maßnahme nennt und an diesem festhält. Dadurch wird mittels der Erwartungsbildung der Agenten eine gleichmäßige Entwicklung der makroökonomischen Variablen unterstützt. Falls die Zentralbank die Entscheidung fällt, das Haircut-Instrument auf unbestimmte Zeit anzuwenden, führt dieses zwar zu einer anhaltend niedrigen Volatilität der makroökonomischen Variablen jedoch auf Kosten von höherer Inflation in der Zukunft, da die Liquidität, welche dem Interbankenmarkt durch die Zentralbank zugeteilt wird, wächst.

Asset Prices, Collateral, and Unconventional Monetary Policy in a DSGE Model*

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Abstract

In this paper we set up a New-Keynesian model with a heterogenous banking sector to analyze liquidity problems on the interbank market. The presence of an interbank market is essential to consider a situation where an increased liquidity supply by the central bank is only partially passed on to the interbank market. Moreover, this framework allows us to examine the implications of an unconventional monetary policy tool modeled as a haircut rule applied to eligible assets in repurchase agreements ("Repos") on the interbank market. We can show that this tool is suited to bring down the interest rate charged among banks on the interbank market. Furthermore an exogenous bubble process is modeled to evaluate the effects of the haircut rule for a central bank which decides to implement a "leaning-against-the-wind"-policy. Finally, we analyze the long-run consequences of reacting to asset price movements and examine the effects of different exit strategies. We find that the central bank can stabilize all variables at the cost of higher inflation and that macroeconomic volatility is smallest if the central bank communicates the exit date in advance and credibly commits to it.

Keywords: New-Keynesian Model, Monetary Policy, Business Cycle, Collateral, Haircuts

JEL classification: E4, E5, E61, G21

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What appears to be in substance a direct transfer of mortgage and mortgage-backed securities of questionable pedigree from an investment bank to the Federal Reserve seems to test the time honored central bank mantra in time of crisis-"lend freely at high rates against good collateral"-to the point of no return, (Volcker (April 8, 2008), Remarks by Paul Volcker at a Luncheon of the Economic Club of New York)

1 Introduction

In the twenty years preceding the current financial crisis all major economies have witnessed an environment with low macroeconomic volatility known as the 'Great Moderation'.[1] During this time central banks in industrialized countries set the policy rate to anchor the inflation expectations around a specified level. The twenty years of quietness before the Great Recession are by and large attributable to good policy but according to some studies (see for example the studies Primiceri (2005) and Justiniano, Primiceri, and Tambalotti (2010)) also to good luck. Once this steady macro environment changed with the onset of the crisis, central banks were required to change their conduct of monetary policy as well. For example, they no longer relied exclusively on traditional interest rate policy but also prolonged the maturities of repurchase agreements ("Repo"), widened the set of collateral accepted in Repo transactions, and reduced the haircut applied to specific types of assets. Those measures can be subsumed under the heading of unconventional monetary policy. So far these measures have been confined to crisis times and were aimed at reviving the interbank market and stabilizing the financial systems as a whole. If, however, the period of good luck is over and the economy is experiencing higher macroeconomic volatility, unconventional measures might remain in place longer than initially intended. Therefore it is important to discuss and analyse those additional instruments with their costs and benefits.

The interbank market is important for a central bank because it is the market which is most directly affected by monetary policy decisions and hence is the preferred channel to implement the monetary policy strategy of a central bank. To enable economists to analyze the macroeconomic consequences of a central bank resorting to a richer set of monetary policy tools that are targeted to change the liquidity situation among banks requires to implement an interbank market in modern macroeconomic models. In models of Bernanke, Gertler, and Gilchrist (1999) or Markovic (2006) banks are financial intermediaries who channel funds from borrowers to lenders. Although they assume profit maximizing behavior, banks in these models are assumed to break-even each period. Only in recent times a couple of DSGE models emerged which explicitly incorporate an active banking sector (Gerali et al. (2010), deWalque et al. (2010), Dib (2009)).

Our model features a heterogenous financial sector that consists of two different types of banks whose behavior is the outcome of explicit optimization problems. Both types of banks accept deposits from the household sector but their investment decisions are different. Whereas one grants loans to firms the other invests its funds completely in safe assets which are eligible as collateral at the central bank. In addition, the first bank with its risky exposure needs interbank funding from the other bank to be secured by collateral stemming from its loan business to the firm sector. The way the interbank market is modeled in our setup is different from the literature. Dib (2009) for example splits up the responsibilities of a bank by assuming two

[1] The term 'Great Moderation' goes back to a paper by Stock and Watson (2003) to describe the decline in the output volatility in the United States since the early 1980s.

separate entities: a savings and a lending bank. In our model each commercial bank borrows and lends. While both borrow from the household sector, one type of commercial bank lends to the firm sector while the other type lends to banks on the interbank market. While Gerali et al. (2010) claim to model an interbank market, in their model in equilibrium no interaction among wholesale banks takes place. Other studies that examine interbank liquidity flows are, for example Eisenschmidt and Tapking (2009), Allen, Carletti, and Gale (2009) and Freixas and Jorge (2008), however, these do not incorporate their microeconomic model into a DSGE framework.

By assumption an interbank borrowing bank can only offer risky assets as collateral in return for interbank liquidity. The volume of interbank lending depends on the expected value of the collateral in the next period. If the value of the underlying collateral is expected to rise an interbank lending bank accepts the risky asset as collateral for an interbank loan independent of the collateral policy of the central bank. However, if the collateral value is expected to decline and the central bank is unwilling to accept this risky asset as eligible asset in a main refinancing operation, the volume of interbank lending will decline. Hence, within this model the central bank faces a situation where the decline in interbank lending activity is not caused by concerns about direct counterparty risk but due to concerns about the value of the collateral pledged by a commercial bank in return for an interbank loan.

Only recently Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) incorporate unconventional monetary policy into a DSGE model to assess the effects of these policies on the macroeconomy.[2] We allow for unconventional monetary policy in our model by introducing a haircut rule in addition to the interest rate rule to analyze the role of collateral in repurchase agreements with the central bank. To differentiate between different qualities of collateral the central bank is able to apply different haircuts to the securities within the set of eligible collateral. Recent papers which incorporate a haircut into their models are Ashcraft, Gârleanu, and Pedersen (2011), Gorton and Metrick (2009), Adrian and Shin (2009), Cúrdia and Woodford (2011), and Schabert (2010). Within our framework we analyze the impact of such a haircut policy on the lending activity on the interbank market. Because a central bank can vary the haircut on certain asset classes in our model, it is in the position to increase or decrease the liquidity supply to the banking sector even if the interest rate is at or near the zero lower bound. This policy constitutes an alternative to direct liquidity provision to commercial banks and has the advantage of not completely crowding out the lending activity on the interbank market.

Another feature that distinguishes our study from other studies mentioned above is the distinction between the fundamental price of capital which is equivalent to Tobin (1969)'s q and the market price of capital. The latter is used to determine the value of the collateral a borrowing bank can offer to an interbank lending bank in return for an interbank loan or to a central bank as eligible collateral in repurchase agreements. If one value deviates from the other permanently we refer to it as a bubble (or bust) process. The effect of such a bubble is an increase in the amount of collateral available for borrowing in the interbank market. To model these two variables we rely on the setup introduced by Bernanke and Gertler (1999) who extend the framework of Bernanke et al. (1999). By including an exogenous bubble process we try to contribute to the ongoing debate in the literature whether central banks should respond to asset prices as well.

Our results confirm the results of other studies with an interbank market that a financial sector

[2] A study of unconventional monetary policy which also places a big emphasis on the central bank's balance sheet has recently been conducted by Cúrdia and Woodford (2011).

helps to dampen monetary policy shocks to the real economy. In addition, we illustrate that if bubbles inflate the prices used to determine the value of the collateral the presence of a financial sector amplifies shocks to the real economy. Moreover, by lowering the haircut, or equivalently by enlarging the set of admissible collateral, the central bank has a significant and positive impact on the whole economy in the short run. The only drawback is an increase in inflation after the liquidity supply in the interbank market has increased.
In addition, we shed new light on the argument of financial stability and the question if central banks should target asset prices. Knowing that this is primarily a political decision we follow a purely economic line of argument and deem it appropriate to follow a "leaning-against-the-wind"-policy. Given that a change in market prices increases the volatility of the economy in our model we find that both the interest rate rule as well as the collateral policy can be used to dampen a boom-bust cycle. According to our metric, however, the haircut rule is more appropriate for this task.
Within the same setup we are enable to analyze the long run effects of "leaning-against-the-wind"-policy and contribute to the ongoing research on the exit strategy of a central bank engaged in unconventional monetary policy. Conditional on a reduction of the haircut on eligible collateral in Repo transactions we simulate the long run effects of such unconventional monetary policy on the economy and give recommendations about the preferable strategy based on the variances of output, inflation and financial market variables computed across different exit scenarios. Based on this metric our model recommends to communicate the exit date in advance and stick to the announced exit date. If the central bank sticks to its asset price targeting policy, all variables can be stabilized with the important exception of inflation which is positive throughout. This is due to the fact that keeping the haircut low for a prolonged period of time, the amount of liquidity provided to the interbank market is rising over time.
This paper is structured in the following way. In Section 2 the model setup is explained. The calibration to the data is shown in Section 3. We proceed in Section 4 by stating important results such as impulse response functions, comparative statics and the long run effects of asset price targeting. Section 5 finally concludes.

2 Model

The model economy consists of three major blocks: the real sector, the financial sector, and the central bank. A figure that explains the sectors and their interactions can be found in Appendix A. The real sector comprises the household sector and the production sector and is very similar to Bernanke et al. (1999) and Christensen and Dib (2008). Each household consumes a final good sold by the retailer and supplies labor to entrepreneurs. Entrepreneurs combine household labor with capital bought from capital good producers to produce an intermediate good which is sold to retailers. To transfer wealth across periods, households can save by holding deposits at both types of banks. The interbank borrowing bank uses these deposits together with interbank liquidity obtained from the interbank lending bank to grant loans to entrepreneurs. In the relationship between the commercial bank and the entrepreneur a demand side friction is incorporated, which results in an external finance premium that depends on the net worth an entrepreneur has accumulated.
The financial sector consists of two different types of banks where both types of banks accept deposits from the household sector but their investment decisions are different. Whereas one

grants loans to firms the other invests its funds completely in safe assets which are eligible as collateral at the central bank. In addition, the first bank with its risky exposure needs interbank funding from the other bank to be secured by collateral stemming from its loan business to the firm sector. It is assumed that commercial banks are heterogenous with respect to their balance sheet structure. One type of commercial bank has highly liquid assets on its balance sheet while the balance sheet of the other type of commercial bank contains less liquid, risky assets. In case the latter bank has a liquidity need it prefers to demand additional liquidity from the interbank market. In return it offers the illiquid, risky asset as collateral to avoid having to forgo profitable investment opportunities. In the following we will refer to the former group as interbank lending banks and to the latter group as interbank borrowing banks. The interbank lending volume depends crucially on both the expected value of the collateral as well as the haircut applied to the collateral in Repo transactions with the central bank.
In the following subsections the model setup and the optimization problems faced by each agent are explained. For the model's first order conditions we refer the reader to Appendix B.1.

2.1 Household

Households are infinitely lived and maximize consumption and leisure subject to a budget constraint. Throughout the model h is attached to variables and parameters to denote an individual household quantity. The instantaneous utility function has the following form

$$U_t = \frac{C_t(h)^{1-\gamma_c}}{1-\gamma_c} + \frac{(1-L_t(h))^{1-\gamma_h}}{1-\gamma_h} \tag{1}$$

The infinite sum of discounted utility is maximized by the household under the following budget constraint which is expressed in real terms

$$C_t(h) + D_t(h) = W_t L_t(h) + \frac{R^D_{t-1}}{\pi_t} D_{t-1}(h) + P_t(h) - T_t(h) \tag{2}$$

The household's savings are transferred across periods by depositing it with commercial banks. The gross return paid on household's deposits is denoted by R^D_t. W_t is the wage in real terms that the household gets from the entrepreneur in exchange for its labor supply $L_t(h)$. Finally, $P_t(h)$ denotes transfer payments stemming from profits made by commercial banks, the central bank and retailers. $T_t(h)$ are the lump sum taxes that the government collects from household h. $D_t(h)$ refers to real deposits.

2.2 Entrepreneur

The entrepreneur is perfectly competitive and produces output that is sold to retailers. As input factors in production they use homogenous labor (L_t) supplied from households and capital (K_t) purchased from capital producers. The production function is assumed to be of the Cobb-Douglas type

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \tag{3}$$

Technology which is denoted by A_t follows an AR(1) process.
Each period the entrepreneur purchases capital K_{t+1} to be used in production at the beginning of the next period. The difference between the value of capital $Q_t K_{t+1}$ (with Q_t being the price

of capital[3]) and the net worth N_t needs to be financed by a loan B_t taken out from the interbank borrowing bank.

$$B_t = Q_t K_{t+1} - N_t \tag{4}$$

The interest rate charged by banks for loans to the entrepreneur is R_t^B.
Bernanke et al. (1999) show that an external finance premium results from the financial contract signed between a bank and the firm. Dib (2009) implemented this financial contract in a model with a banking sector. The expected external marginal financing costs are defined as a mark up over the lending rate. The size of the markup depends on the ratio of the market value of capital S_t over the net worth N_t and is given by the following function

$$\mathbb{E}_t R_{t+1}^S = \frac{R_t^B}{\pi_{t+1}} \left(\frac{S_t K_{t+1}}{N_t} \right)^{\psi} \tag{5}$$

The external finance premium $(S_t K_{t+1}/N_t)^{\psi}$ depends on the entrepreneur's leverage ratio which is defined as $S_t K_{t+1}/N_t$. If the leverage ratio increases, the entrepreneur increasingly relies on debt financing which increases its probability of default.[4] The aggregate net worth position of entrepreneurs is evolving as

$$N_t = \nu \left[R_t^S S_{t-1} K_t - \left(R_t + \frac{\mu \int \omega \mathrm{d}F(\omega) R_t^S S_{t-1} K_t}{S_{t-1} K_t - N_t} \right) (S_{t-1} K_t - N_t) \right] + (1-\alpha)(1-\Omega) A_t K_t^{\alpha} H_t^{(1-\alpha)\Omega} \tag{6}$$

with ν and ω being the survival probability of the entrepreneur and the default probability of the project the entrepreneur invests in, respectively. Moreover, $1 - \Omega$ denotes the share of entrepreneurial labor CE_t in the amount of total labor H_t and μ is the parameter of the supervising costs of the bank.
Note that the loan contract between the entrepreneur and the commercial bank is conditioned on the market price of capital S_t and not on the fundamental price Q_t. The distinction between the market price S_t and the fundamental price Q_t has been proposed by Bernanke and Gertler (1999) in an extension of the model by Bernanke et al. (1999) [5] and allows to model exogenous asset price bubbles.[6] R_t is the short rate that is set by the central whose behavior will be explained in Section 2.7.
If a unit of capital is valued at the fundamental price Q_t, optimal demand for capital guarantees that the marginal external financing costs equal the marginal return on capital

$$R_t^Q = \frac{\left(R_t^k + (1-\delta)Q_t\right)}{Q_{t-1}} \tag{7}$$

[3] Q denotes the ratio of the market value of the capital stock relative to the replacement cost of capital. In equilibrium the adjustment costs are equal to one. In the absence of adjustment costs, the entrepreneur is able to adjust its capital stock instantaneously, However, this behavior is not in line with empirical observations which rather point towards a sluggish behavior of investment. That is, adjustment in the level of capital takes place over several periods. For that reason adjustment costs at the level of the capital producer are introduced (see Section 2.3). As a result Q will not be equal to one during periods where the level of the capital stock is not equal to its equilibrium value

[4] The size of the elasticity parameter ψ that has originally been calibrated by Bernanke et al. (1999) to be 0.05 depends on the standard deviation of the distribution of the entrepreneurs idiosyncratic shocks, agency costs, and the entrepreneurs' default threshold. If the parameter ψ is set to zero, the financial accelerator vanishes and the mark up is zero.

[5] The deviation of the fundamental value Q_t from the market price S_t is denoted by u_t. It holds that $S_t = Q_t u_t$

[6] For an introduction on asset price bubbles we refer to the seminal paper by Blanchard and Watson (1982).

Analogously, if a unit of capital is valued at the market price S_t and $S_t \neq Q_t$, optimal demand for capital satisfies

$$R_t^S = \frac{\left(R_t^k + (1-\delta)S_t\right)}{S_{t-1}} \tag{8}$$

where δ is the depreciation rate whose parameter value is discussed in the calibration section. Actually the latter condition is the relevant optimally condition for the capital demand by the entrepreneur.

The fundamental return and the market return on capital are related as follows

$$R_t^S = R_t^Q \left\{ b + (1-b)\left[1 - (1-a)\frac{(S_{t-1} - Q_{t-1})}{S_t}\right] + \epsilon_t^{SQ} \right\} \tag{9}$$

The parameter a determines the speed of convergence back to the fundamental price Q_t and b is given by $b \equiv a(1-\delta)$.[7] The shock to the fundamental value ε_t^{SQ} is normally distributed with variance σ_S^2. In the absence of shocks the market price S_t moves in line with Q_t.

2.3 Capital Producer

Capital producers provide the capital purchased by entrepreneurs. They use a linear technology to produce capital and maximize the following objective function

$$\max_{I_t} E_t \sum_{t=0}^{\infty} \beta^t \lambda_t \left[Q_t \left[I_t - \frac{\kappa_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \right] - I_t \right]. \tag{10}$$

The aggregate capital stock evolves according to

$$K_{t+1} = (1-\delta)K_t + \left(1 - \frac{\kappa_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right) I_t \tag{11}$$

where δ determines the depreciation rate and investment is subject to quadratic adjustment costs with κ_i denoting the parameter of those costs. This maximization problem is standard and a detailed description can be found for example in Dib (2009).

2.4 Retailer

To introduce sticky prices we assume that retailers are Calvo (1983) price setters. This is a common assumption in the New-Keynesian literature and implies that each period there is an exogenous probability of $1 - \xi_p$ that a retailer is able to adjust its price. The rest of the retailers index their prices to current inflation. As in Bernanke et al. (1999) monopolistic retailers buy the product of the entrepreneur, transform it into final output at no cost and sell it to households or capital goods producers. The expected discounted profit function that the retailer maximizes takes the form:

$$\Pi_t^R = \sum_{k=0}^{\infty} \xi_p^k E_{t-1} \left[\Lambda_{t,k} \frac{P_t^* - P_{t+k}^w}{P_{t+k}} Y_{t+k}^*(R) \right] \tag{12}$$

where $\Lambda \equiv \beta \frac{C_t}{C_{t+k}}$ denotes the stochastic discount factor of households as those benefit from the profits of the retailer. Finally $P_t^w \equiv \frac{P_t}{Z_t}$ is the nominal price of wholesale goods with Z_t being the gross markup.

[7] In the case of rational bubbles this value would be one, see Blanchard and Watson (1982).

2.5 Interbank Borrowing Bank j

A commercial bank j has market power and maximizes over both the deposit rate R_t^D and the loan rate R_t^B while taking the interest rate prevailing on the interbank market R_t^{IB} as given. The liability side of commercial bank j comprises deposits $D_t(j)$ and interbank Loans ($IB_t(j)$). These funds are invested in loans to entrepreneurs $B_t(j)$. A commercial bank j by assumption is limited to invest in risky loans to the entrepreneur which are assumed to be less liquid. The balance sheet of a commercial bank j is then given by

Assets	Liabilities
Loans to Entr. $B_t(j)$	Deposits $D_t(j)$
	Interbank Loans $IB_t(j)$

Table 1: Balance Sheet of a Commercial Bank j

Each commercial bank *j* maximizes its profit which is given by the following equation

$$\Pi_t(j) = \frac{R_{t-1}^B}{\pi_t} B_{t-1}(j) - \frac{R_{t-1}^D}{\pi_t} D_{t-1}(j) - \frac{R_{t-1}^{IB}}{\pi_t} IB_{t-1}(j) \tag{13}$$

$$- \frac{\kappa_d}{2}\left(\frac{R_{t-1}^D}{R_{t-2}^D} - 1\right)^2 \frac{R_{t-1}^D}{\pi_t} D_{t-1}(j) - \frac{\kappa_b}{2}\left(\frac{R_{t-1}^B}{R_{t-2}^B} - 1\right)^2 \frac{R_{t-1}^B}{\pi_t} B_{t-1}(j) \tag{14}$$

with κ_b and κ_d being the adjustment cost parameter for the respective interest rates which are introduced to increase the stickiness in the adjustment of both loans and deposits.
As deposits and loans of different commercial banks j are imperfect substitutes for households, the maximization is subject to the following demand functions for household deposits and entrepreneurial loans (see also Gerali et al. (2010)).

$$D_t(j) = \left(\frac{R_t^D(j)}{R_t^D}\right)^{\epsilon_d} D_t \tag{15}$$

$$B_t(j) = \left(\frac{R_t^B(j)}{R_t^B}\right)^{-\epsilon_h} B_t = f(j)B_t = f(j)(Q_t K_t - N_t) \tag{16}$$

In return for the loan $B_t(j) = f(j)(Q_t K_t - N_t)$ to the entrepreneur, a commercial bank j obtains collateral worth $f(j)Q_t K_t$. It is assumed that a commercial bank j possesses a technology to transform the illiquid capital stock into a marketable security. In the following we will refer to the financial instrument generated in this process as asset-backed security. In contrast to the value of the capital stock $f(j)Q_t K_t$, the value of the asset-backed security portfolio of bank j is given by

$$ABS_t(j) = f(j)S_t K_t \tag{17}$$

The assumption that the risky asset $ABS_t(j)$ depends on the market price S_t and not on the fundamental price Q_t allows us to consider the effect of asset price movements on the behavior of banks in the interbank market where these securities serve as collateral.
Our model also features a borrowing constraint in a borrower-lender relationship in the form proposed by Kiyotaki and Moore (1997). However, in our model the financial friction arises

between the commercial bank j and an interbank lending bank k. The borrowing constraint of a commercial bank vis-a-vis an interbank lending bank takes the following form[8]

$$R_t^{IB} IB_t \leq m_t E_t S_{t+1} K_t \tag{18}$$

In order to obtain interbank liquidity $IB_t(j)$ at the interbank interest rate R_t^{IB} the commercial bank j offers its asset backed securities (ABS) as collateral. The commercial bank j's ability to obtain interbank liquidity is limited by the expected value of the asset portfolio in the next period. However, an interbank lending bank k encounters transaction costs which are proportional to the collateral value, $(1 - m_t)S_{t+1}K_t$. These transaction costs comprise the time to find a buyer for the collateral and legal fees paid in the process of liquidating the pledged assets. Hence, to ensure full repayment in the case of a default of the commercial bank j, the maximum amount of interbank liquidity granted by a commercial bank k is given by $m_t E_t S_{t+1} K_t$ where m_t is the loan-to-value ratio which responds to deviations of the market price of capital from the fundamental price, u_t, to account for the reluctance of an interbank lending bank to provide interbank loans in the presence of asset price bubbles. As $m_t < 1$ is assumed, the size of the interbank loan to a bank j will always be strictly lower than the value of the asset portfolio in the next period. In log-linearized terms m_t is set according to the following rule[9]:

$$m_t = \rho_m m_{t-1} - \chi \cdot u_t + \epsilon_t^m \tag{19}$$

Finally, the balance sheet identity has to hold in all periods t.

$$B_t(j) = D_t(j) + IB_t(j) \tag{20}$$

2.6 Interbank Lending Bank k

The activities performed by a commercial bank k vis-a-vis the private sector are identical to those of a commercial bank j. However, compared to a commercial bank j, a commercial bank k invests its funds in a liquid asset G_t and not in a risky asset. The liquid asset G_t can be always exchanged against central bank liquidity if a commercial bank k is willing to supply liquidity on the interbank market. Because the funding structure is identical across interbank lending banks the interest rate paid on deposits will be the same across commercial banks. Moreover, we assume that the difference between the interest rate paid on deposits and the interest obtained from the investment in the liquid asset G_t is negligible and we are able to ignore it in the optimization problem of the commercial bank k.
The interest rate on the interbank market R_t^{IB} is endogenously determined by the profit maximizing behavior of interbank lending banks and interbank borrowing banks. Hence, a commercial bank k which considers lending to a commercial bank j takes the policy rate R_t set by the central bank as given and decides optimally about the amount of liquidity supplied on the interbank market. Each commercial bank k maximizes its profit function which has the following form

$$\Pi_t^{IB}(k) = R_t^{IB} IB_t(k) - R_t(M_t^D(k) - X_t(k)) \tag{21}$$

[8]We assume that the borrowing constraint is satisfied with equality because the size of the shock is sufficiently small such that the economy remains in the neighborhood of the steady-state. See Iacoviello (2005)

[9]In section 4.3 we assume that the loan-to-value ratio is controlled by a supervisory authority and therefore the deviation of the market price from its fundamental value has to be included

where R_t denotes the policy rate which is set by the central bank (see Section 2.7), $M_t^D(k)$ is the demand for central bank liquidity and $X_t(k)$ a deposit opportunity for the interbank lending bank k at the central bank. Defining a spread prevailing in the interbank market as

$$R_t^{Spread} = R_t^{IB} - R_t \tag{22}$$

we can restate the profit function (21) as follows:

$$\Pi_t^{IB}(k) = R_t^{Spread}\left(IB_t(k) + M_t^D(k) - X_t(k)\right) + R_t IB_t(k) - R_t^{IB} M_t^D(k) + R_t^{IB} X_t(k) \tag{23}$$

Equation 23 emphasizes that the commercial bank k not only cares about the absolute interbank rate but equivalently about the spread between the interbank interest rate and the policy rate set by the central bank. In this way we capture the fact of the spread being a multivariate function of (1) the tension in the interbank market (volume IB_t) (2) the liquidity supply decision of the central bank (M_t and h_t) and (3) the financial stability stance (m_t). We assume that commercial bank k's demand for central bank liquidity depends on the optimally chosen value for interbank lending and riskless asset as follows

$$M_t^D(k) = IB_t(k)^{\zeta} X_t(k)^{1-\zeta} \tag{24}$$

Unlike the Cobb-Douglas production function which takes labor and capital as input factors and yields goods as output, here the only input factor is the supply of central bank liquidity M_t whose division among interbank funds and deposits is governed by the parameter ζ. If ζ is equal to one, there is a one-to-one relationship between the additional liquidity supply of the central bank and the supply of interbank liquidity on the interbank market. However, ζ is assumed to be strictly smaller than one to account for the effect of the money multiplier.
In exchange for an interbank loan $IB_t(k)$ a commercial bank k receives collateral $ABS_t(k)$ from a commercial bank j which is subject to a haircut h_t in liquidity operations of the central bank. In addition, a commercial bank k possesses an exogenously given amount of liquid assets $G_t(k)$ fully eligible as collateral in repurchase agreements with the central bank. Hence, the commercial bank k faces the following collateral constraint

$$M_t^D(k) = G_t(k) + (1 - h_t)ABS_t^{PD}(k) \tag{25}$$

If $h_t = 1$ the central bank does not accept asset-backed securities.[10] The lower the haircut, the lower the discount applied to the risky asset by the central bank and hence the higher the volume of liquidity obtainable per unit of asset-backed securities.
In equilibrium the supply of central bank liquidity has to equal the demand for interbank liquidity given in equation (24).

2.7 Central Bank

A central bank sets the monetary policy rate R_t in response to deviations of output and expected inflation. Moreover, we allow for interest rate smoothing on part of the central bank.

$$R_t = \rho_r R_{t-1} + \phi_\pi(E_t\pi_{t+1} - \bar{\pi}) + \phi_y(Y - \bar{Y}) + \epsilon_t^R \tag{26}$$

[10] This would be the case of the Fed before the crisis. In Europe the haircut was lower than one even before the crisis and were lowered even more during the crisis.

In addition, we assume that the central bank is interested in financial market stability and especially in a liquid interbank market. In this context the central bank decides which assets are eligible as collateral in repurchase agreements and through this device it is able to vary the liquidity supply to the banking sector directly. The haircut h_t set by the central bank is specified by the following process

$$h_t = \rho_h h_{t-1} - \varepsilon_t^h \tag{27}$$

and is negatively related to a central bank's liquidity, that is, if the central bank decreases the haircut h_t, the liquidity supply increases.

We do not postulate that the haircut rule should substitute the interest rate rule. The haircut rule, however, is suited to fine-tune the liquidity situation on the interbank market once the interest rule policy does not have the desired effect anymore because, for example, of the zero lower bound. In addition to that it is another tool that helps to smooth the business cycle. We can show that a decrease in the haircut can stimulate both the interbank market and the real economy.

The profit function of the central bank consists of seigniorage minus the payment on deposits a commercial bank k holds in its account with the central bank:

$$\Pi_t^{CB} = \frac{R_{t-1}}{\pi_t} M_{t-1}^{cb} - \frac{R_{t-1}}{\pi_t} X_{t-1} \tag{28}$$

The profits of the central bank are distributed among the households.

2.8 Aggregate Conditions

In equilibrium the following aggregate conditions have to hold.

The amount borrowed by an entrepreneur across commercial bank j has to equal the amount of loans granted to the entrepreneur by the commercial bank sector. γ^X denotes the relative mass of agent X.

$$B_t = \gamma^j B_t(j) \tag{29}$$

The same holds true for the savings of households and deposits accepted by commercial banks

$$\gamma^j D_t(j) = \gamma^P D_t(h) \tag{30}$$

Total interbank lending has to satisfy

$$\gamma^j IB_t(j) = \gamma^k IB_t(k) \tag{31}$$

Money provided by the central bank has to equal the total money demand by commercial banks k.

$$M_t^{CB} = \gamma^k M_t^k(k) \tag{32}$$

The total supply of asset-backed securities is constrained by the available capital stock K and the market price of capital S.

$$ABS_t = S_t K_t \tag{33}$$

The maximum amount of collateral the commercial banks j can offer to commercial banks k is then given by (33). Summing across the demand for collateral by commercial banks k and the supply of collateral by commercial banks j the following condition holds

$$ABS_t = \gamma^k ABS_t(k) = \gamma^j ABS_t(j) \tag{34}$$

Finally, goods market clearing requires

$$Y_t = C_t + G_t + CE_t + Q_t \left(K_t^h - (1-\delta) K_{t-1}^h\right) + \text{Adj. costs} \tag{35}$$

3 Calibration

One crucial task of calibrating this model is to deal both with a real sector where one period usually corresponds to one quarter as macroeconomic aggregates like GDP are updated on a quarterly basis and a financial sector where information about financial variables are updated at a much higher frequency. Hence, as a compromise we decide to calibrate the model to monthly data[11]. So most of the parameters on which the literature agreed on and that are calibrated to quarterly data are adjusted to a monthly frequency. The discount rate of households β is set to 0.997 which corresponds to a yearly interest rate of 3.6%, which is in line with other studies which assume 4% per year. For the instantaneous household utility we assume log preferences in both consumption and labor. The fraction of capital employed in the production process α is set to 0.33 which is a value commonly found in the literature. With respect to the rate of depreciation which is commonly calibrated to be 10% per year, we set the monthly depreciation rate to a value of 0.008. The coefficient determining the mark-up ϵ_p is time-invariant and set to 6 as for example in Bernanke et al. (1999). However, the fraction of retailers being able to set prices each period is set slightly lower than in the quarterly specification. In a quarterly setting it is usually assumed (as in Bernanke et al. (1999)) that $(1-\xi_p)$ is equal to 0.25. In our context we set this value to 0.15 to account for the monthly frequency. Both the elasticities of the demand functions for entrepreneurial loans and household deposits and the adjustment cost parameters for both interest rates are taken from Gerali et al. (2010) and are multiplied by three as the values used in Gerali et al. (2010) are calibrated to a quarterly model. Thus, the values are 852 and 759 for the deposit and loan demand elasticities, respectively, and 540 and 1125 for the adjustment cost parameter κ_d and κ_b, respectively.

The financial friction parameter ψ which is calibrated by Bernanke et al. (1999) to be 0.05 is recalibrated with our parameters from above and equals 0.0506. Two parameters are important for the development of the bubble process, a and b. Those are exactly set as in Bernanke and Gertler (1999), to 0.98 and 0.97216 (which equals $a(1-\delta)$). The amount of entrepreneurial labor is chosen to be 0.01 as is common in the literature, see Bernanke et al. (1999). The elasticity of Tobin's q with respect to investment is set to 0.5 as in Bernanke and Gertler (2001). The leverage of the entrepreneurs is assumed to be 2. Finally, in line with Bernanke and Gertler (1999) the survival rate of entrepreneurs is set to 0.95.

The values in the interest rate rule are set in accordance with Taylor (1993). With respect to the autoregressive parameters in the AR(1) shock processes we increase all values in comparison to existing studies as those were chosen to match quarterly time series dynamics. Thus, in our study they take on values in the range from 0.95 in the case of government expenditure to 0.99 in the case of the haircut and the policy rate set by the central bank.

The single parameter that is completely unknown in the literature is the intensity of interbank loans or deposits in the production function of a commercial bank k denoted by ζ. We set it to $\zeta = 0.9$ which seems reasonable and is in line with most of the banks' balance sheets. In addition the robustness checks indicate that the results are robust to higher values for this parameter. The haircut is set in steady state to be 0.2, as the ECB paid a little more than 80 percent for BBB ranked assets.

A comprehensive summary of all parameter and imposed steady state values can be found in Appendix C.

[11] This approach is also often used in the macro-finance literature, see for example Borgy, Mesonnier, Laubach, and Renne (2011)

4 Results

In this section we discuss the results of the model. In the impulse response analysis of Section 4.1 we discuss how the model developed in Section 2 reacts to a set of shocks. Furthermore, we compare the impulse responses for the same set of shocks both in a model setup with and without an interbank market. In the case without an interbank market we assume that the commercial bank k does not exist. As the commercial bank j is then in direct contact with the central bank no interbank lending occurs in equilibrium and the interbank rate is identical to the policy rate.[12] This enables us to study the implications of incorporating an interbank market on the model dynamics. In Section 4.2 we answer the question whether in our model framework central banks should "lean against the wind", that is, if a central bank should react to asset prices or not. Boom-bust cycles caused by market price fluctuations are simulated following the procedure laid out in Bernanke and Gertler (1999). Finally, in Section 4.3 three different exit strategies for the central bank are analyzed within the model framework proposed in Section 2.

4.1 Impulse Response Analysis

In this section we examine the model dynamics in response to four types of shocks: a monetary policy shock, a shock to the haircut h_t applied to risky assets, a shock to technology A_t and to the market price of capital S_t. The impulse responses are expressed in percentage deviations from steady state and one period corresponds to one month. All corresponding figures can be found in Appendix D.1.

Figure 2 shows the impulse response functions to an unanticipated 25 bp increase (3 pp in annualized terms) in the nominal interest rate. As the policy rate rises, liquidity demanded by the commercial bank k declines and the interest rate for interbank loans increases. This in turn lets the commercial banks demand less interbank funds. At the same time a higher interest rate induces the commercial bank k to hold more deposits at the central bank. This countercyclical movement of interbank loans and deposits is due to the specification of the production function of the commercial bank k.[13] As a result the fundamental price of capital Q_t decreases on impact before returning gradually to its steady state. Because the loan rate R_t^B increases as well, demand for capital by the entrepreneur decreases. Thus the capital stock declines and output declines. Hence, our model recommends to raise interest rates in response to a boom in asset prices.

An interbank market smoothes the responses of the economy to a monetary policy shock compared to the case without an interbank market. Taking for example output and inflation, the impulse responses are all qualitatively the same but the initial impact is much more pronounced. Liquidity decreases more than in the case where an interbank market is not present. Moreover, the decline in the fundamental price of capital and thus the decline in the value of asset-backed securities is stronger if the interbank market is shut down.

If the central bank lowers the haircut on asset-backed securities temporarily, the liquidity supply increases on impact and converges slowly back to its steady-state (see Figure 3). This is due to the fact that the autoregressive parameter of the haircut is chosen to be very close to one and

[12] Even in the model without an interbank market the results will differ from Bernanke and Gertler (1999) due to the presence of an profit maximizing commercial bank

[13] The percentage increase in deposits is much higher because its steady state value is very low.

one time period corresponds to one month.[14] As expected both output and inflation increase on impact in response to a 10% decrease in the haircut applied by the central bank. The lowering of the haircut has a positive effect on the fundamental price of capital which then increases the value of the asset-backed securities. As the total value of collateral offered by the commercial banks in return for interbank loans increases, the interbank lending rate decreases which stimulates interbank lending. Besides rising interbank lending also deposits go up. This is the only time that both quantities move in the same direction.[15] This stimulus, however, comes at a cost of higher inflation.[16]

In Figure 4 technology increases by 1%. As this shock originates in the real sector the responses of the real variables (output, inflation, fundamental price of capital) are in line with other studies that incorporate a financial accelerator (see Bernanke et al. (1999) and Christensen and Dib (2008)). As the technology shock leads to a decrease in the policy rate, the interbank lending rate decreases as well which in turn stimulates interbank lending activity. In the case of a technology shock the two setups deliver similar responses for output and consumption. If the interbank market is missing the price of capital and therefore the asset-backed securities are deviating a bit more from their respective steady states. The same holds true for liquidity. If anything, then a shock to technology is dampened by the presence of the interbank market, although not by as much as in the case of a monetary policy shock.

Finally, we analyze a shock which leads to a 10% increase in the market price S_t.[17] In this case, for the first time, the impulse responses of market price and fundamental price are not identical (see Figure 5). While both prices increase, the market value rises by ten percent more, driving up the value of the asset-backed securities above their fundamental value as their value depends on the market price S_t. Although the liquidity supply by the central bank rises with the value of the asset backed securities, banks are reluctant to increase their interbank lending and rather invest in riskless deposits. Hence, in our model banks become more cautious in their investment behavior in response to sharp increases in asset prices. Although the increase in the value of the asset-backed securities results from a shock to the market price and not from an increase in the liquidity supplied by the central bank, the model resembles the behavior of the banks in the aftermath of the financial crisis. Namely, that in response to an increase in liquidity banks are reluctant to lend in the interbank market and rather invest in riskfree assets.

A shock to the market price S_t exhibits a significantly different evolution of variables. Without an interbank market the size of the market price increase is only about a third compared to its impact in the setup that features an interbank market. Asset-backed securities and liquidity show similar responses across model specifications. After all volatility is nevertheless greatly reduced once the interbank market is eliminated. In this case the interbank market amplifies shocks to the market price of capital S_t.

[14]In a period of forty months liquidity as well as the other persistent financial variables converge back to their steady states

[15]Compare on the real side the increase of both labor and capital after a technology shock using the same production function specification.

[16]A comparison between the model with and without an interbank market is not very meaningful here as the haircut policy in our setup only works with an interbank market. The assumption hinges on the fact that the commercial bank k gets liquidity from the central bank in exchange for government bonds and asset-backed securities. Once the interbank market is eliminated, the Central Bank has full control over the liquidity supply to the banking sector.

[17]The deviation of the fundamental value Q_t from the market price S_t is denoted by u_t

4.2 Boom-Bust Cycles

In this subsection we apply the methodology of Bernanke and Gertler (1999) and Bernanke and Gertler (2001) to a model framework with a microfounded interbank market and where the central bank has an additional central bank instrument, namely, the haircut rule given in equation (36). The question we try to answer is whether central banks should 'lean against the wind', that is, if a central bank should respond to deviations of asset prices from their fundamental value. To account for this possibility we incorporate both in the Taylor rule as well as in the haircut rule deviations of the market value from its steady state if we consider reactions to the asset price.

$$R_t = \rho_r R_{t-1} + \phi_\pi(E_t\pi_{t+1} - \bar{\pi}) + \phi_y(Y - \bar{Y}) + d(S_t - \bar{S}) + \epsilon_t^R \tag{36}$$

$$h_t = \rho_h h_{t-1} + c(S_t - \bar{S}) - \varepsilon_t^h \tag{37}$$

The parameter c determines the sensitivity of the central bank to asset price deviations from its fundamental value $\bar{S}$ which is equal to $\bar{Q}$ in equilibrium. As a "leaning-against-the-wind"-policy is considered $c > 0$ is assumed. Thus the central bank will decrease the haircut if the market price of capital S_t is below its steady-state. We plot six variables[18]: Output and inflation to analyze the impact on macroeconomic volatility, interbank loans and the external finance premium to consider financial markets and the fundamental market price as well as the market price of capital.
In this subsection we compare five different cases which are specified in Table 2. These cases differ in the central bank's reaction to asset price deviations when deciding about the setting of their policy instruments. In case 1 the central bank only reacts to inflation and output with the Taylor rule. The haircut rule is autoregressive. Asset prices are not targeted at all. Compared to this, case 2 includes asset prices in the Taylor rule with the same coefficient used in Bernanke and Gertler (1999). The haircut rule is not responding to the market price of capital. Cases 3 to 5 reflect no asset price targeting in the interest rate rule but responding to deviations of the market price of capital with the haircut rule where c is increasing from 0.1 to 0.5.

Cases	Values			
	ρ_π	ρ_y	c	d
Case 1:TR	2	0.5	0	0
Case 2:TR-LATW	2	0.5	0	0.1
Case 3:HR-LATW I	2	0.5	0.1	0
Case 4:HR-LATW II	2	0.5	0.25	0
Case 5:HR-LATW III	2	0.5	0. 5	0

Table 2: Boom-Bust Cycle Analysis: Cases

Figure 6 resembles the analysis of Bernanke and Gertler (1999) and Bernanke and Gertler (2001) within our model setup and compares conventional monetary policy with and without a central bank following a "leaning-against-the-wind"-policy. In this case the haircut rule is a

[18] Bernanke and Gertler (1999) also plot only six variables: output, inflation, the market price of capital, the fundamental price of capital, the return on capital and the external finance premium

simple AR(1) process that does not react to asset prices. To assess the quantitative importance of the stability gains we calculate the variances for each of the six variables shown in Figure 6.

	Output	Inflation	Fundamental Price Q	Market Price S	Interbank Loans	Ext.Fin.Premium
Case 1:TR	0.0062	0.0033	0.0312	0.0772	0.1900	0.00019
Case 2:TR-LATW	0.0048	0.0021	0.0226	0.0632	0.1957	0.00016

Table 3: Stabilization Gains I

The results for cases 1 and 2 indicate that it does not make a difference if the monetary authority is targeting asset prices or not. If anything, however, the evolution of inflation for example is a bit more dampened if the interest rate rule reacts to asset prices. This is different from Bernanke and Gertler (1999) and is likely to stem from the fact that the interbank market amplifies market price shocks. Hence, if they are mitigated by a rule, boom-bust cycles are less pronounced. However, even more important is the answer to the question, which instrument is more appropriate to target asset prices. Therefore we plot in Figure 7 once again the Taylor rule which incorporates asset prices and also the haircut rule with different reaction coefficients on market prices of capital. To assess the quantitative importance of the stability gains we calculate the variances for each of the six variables shown in Figure 7.

	Output	Inflation	Fundamental Price Q	Market Price S	Interbank Loans	Ext.Fin.Premium
Case 2:TR-LATW	0.0048	0.0021	0.0226	0.0632	0.1957	0.00016
Case 3:HR-LATW I	0.0041	0.0016	0.0179	0.0552	0.1997	0.00012
Case 4:HR-LATW II	0.0020	0.00058	0.0073	0.0347	0.2119	0.000075
Case 5:HR-LATW III	0.0011	0.000018	0.0022	0.0214	0.2260	0.000034

Table 4: Stabilization Gains II

Based on the results in Table 4 which depicts the variances of the variables plotted in Figure 7 we can confirm the result of Cecchetti, Genberg, and Wadhwani (2002) who argue in favor of including asset prices in the set of instruments by the monetary authority. But the overall performance can be dramatically improved if the haircut rule is allowed to respond to asset prices. The stronger the coefficient, the larger the macro-stabilization gains. As a result, our model predicts that macroeconomic stability is higher if a central bank uses a haircut policy and not the interest rate policy to increase its liquidity supply.

4.3 Exit Strategies

In the aftermath of a crisis exit strategies and primarily the timing of the exit are very important questions for central banks. We are not able to determine the optimal exit date within our model. Nevertheless we are able to analyze the response of the economy to an exit. Methodologically we follow Winkler and Angeloni (2011) who examine exit strategies at the government level in a deterministic environment. However, we perform this exercise in connection with exit strategies of the monetary authority. In our scenario we examine three cases: (1) the exit from a haircut policy by which risky assets are purchased at lower haircuts than normal and (2) the simultaneous exit from both the above mentioned haircut policy and an interest rate policy that keeps the interest rate close to its zero lower bound and (3) an exit from a policy that keeps the loan-to-value ratio at a level above normal.[19]

In Figure 8 we depict four variables and their reactions if the market price is shocked negatively. One path shows how the economy evolves if the central bank can credibly commit not to exit from its haircut policy ("no exit"). Given a negative shock to the market price, the haircut decreases which keeps output and the prices of capital close to their steady state values. However, inflation rises before stabilizing at a higher level. Another path exemplifies how the variables evolve if agents are surprised by the fact that the central bank ignores deviations of the market price of capital from period twenty-five onwards ("unanticipated exit") and the haircut returns back to its steady-state value at a pace governed by the AR-coefficient ρ_h. It is obvious that until the time of the unanticipated exit the economy's response is identical to the "no exit"-case. Afterwards, given that the haircut is no longer responding to the asset price, output and inflation drop immediately and considerably, as liquidity is reduced sharply. In addition, the prices of capital reduce unexpectedly before returning gradually to the steady state value. The last path depicted in Figure 8 belongs to a situation where the agents anticipate correctly from the very beginning that after twenty-four periods the central bank is no longer stimulating the economy with its haircut instrument ('anticipated exit'). Hence, for all variables this path has to differ from period one onwards as the expectation of the central bank abandoning the liquidity provision drives up output after a few periods and lets inflation fall from the very beginning. Once the haircut rule is actually shut down, the prices of capital and output experience a sudden but only slight dip before returning quickly to their steady states. Only inflation takes longer to adjust. Table 5 shows the variances of the four variables plotted in Figure 8. The variances are lowest for the case of a constant haircut. Moreover, the variances are significantly lower if the central bank exits its constant haircut policy as anticipated by the agents in the model.

	Output	Inflation	Fundamental Price Q	Market Price S
No Exit	0.0039	0.0014	0.0191	0.0335
Anticipated Exit	0.0484	0.0052	0.0552	0.0779
Unanticipated Exit	0.2622	0.0032	1.1972	1.3867

Table 5: Exit from Haircut Policy

Figure 9 shows the results of a central bank which exits its haircut policy after twenty-four periods and simultaneously increases the interest rate to a level implied by the Taylor-rule. The results are more mixed in this example. For output and inflation the anticipated response is much closer to the unanticipated one. Unlike in the previous case where only an exit from the low haircut regime rule was examined the response to inflation looks much smoother with an initial huge spike in the beginning when the interest rate is allowed to increase above the zero lower bound. But the response of both prices of capital is less pronounced in the case of an anticipated exit.

[19] One could assume that the loan-to-value is controlled by a supervisory authority whose only objective is to keep excesses on the interbank market at bay. Note that both the haircut rule and the loan-to-value ratio respond to asset price deviations.

	Output	Inflation	Fundamental Price Q	Market Price S
No Exit	8.2629	10.2129	2.8563	3.4686
Anticipated Exit	9.3231	8.5345	4.9132	5.7406
Unanticipated Exit	8.0824	10.7364	10.8665	11.9479

Table 6: Exit from Haircut Policy plus Taylor-Rule

The conclusion drawn from the variances in Table 6 is that less volatility in inflation comes at the cost of more volatility in the other variables. While overall the level of the variances is higher, again the anticipated exit is preferable to an unanticipated exit.
Finally, in Figure 10 we assume that the central bank is able to control the loan-to-value ratio and acts as a supervisory authority. The setup is the same as in the previous cases with the instrument being shut down after twenty-four periods and letting it return to its steady-state value at a speed governed by a pure AR(1) process afterwards. In the 'no exit'-case the loan-to-value ratio would be constantly above its steady-state value which leads to very little macroeconomic volatility as can be seen in Figure 10. After a shock to the market price output decreases and inflation increases slightly. In the case of an anticipated exit, the reaction of output and and inflation is stronger. After the exit, output as well as the prices for capital increase sharply whereas inflation drops considerably because we assumed that the loan-to-value ratio runs countercyclical to the development in the asset-backed securities. Once the loan-to-value ratio returns to its normal level, the value of asset-backed securities increases and overall demand in the real sector drives up the price of capital and output. If the exit is unanticipated by the agents, output and the price of capital increase even stronger. This is confirmed by the variances produced by the simulation and which are depicted in Table 7.

	Output	Inflation	Fundamental Price Q	Market Price S
No Exit	0.0039	0.0014	0.0191	0.0335
Anticipated Exit	0.0442	0.006	0.066	0.0726
Unanticipated Exit	0.0484	0.0045	0.1742	0.1437

Table 7: Exit from Constant Loan-to-Value Ratio

5 Conclusion

The financial crisis has changed the way economists have to think about modeling and describing monetary policy. This paper tries to take a step in the right direction by modeling an interbank sector with optimizing banks in the presence of an interbank market. By this modeling device unconventional monetary policy can be analyzed which includes not only a simple interest rate rule but also a collateral policy. This unconventional monetary policy has important implications for the characteristics of business cycles. Furthermore, we are able to take up the debate on leaning against the wind and argue whether it is advisable to include asset prices in the monetary policy setup and enhance the debate by analyzing a second monetary instrument, namely the haircut.
We find that the interbank market matters for the economy as a whole as it decreases macroeconomic volatility if an interest rate shock hits the economy and amplifies it if an asset price

bubble occurs. Once this market is drying up or risks to be malfunctioning, central banks are able to react and stimulate the liquidity situation on this market by resorting to an additional instrument besides traditional interest rate policy. The haircut as an additional instrument can be assumed to be even more important if the policy rate set by the central bank is already close to the zero lower bound and restricts the leeway of a central bank. Decreasing haircuts is the instrument we analyzed and it works fine to boost interbank lending and increase output in total. This comes at the risk of increased inflation in the first periods after a negative shock to haircuts. With respect to the ongoing debate in the literature we back the position of Bernanke and Gertler (1999) and claim that asset prices should not be incorporated in the interest rate rule. However, in this model framework both financial and macroeconomic volatility are lowest if asset price deviations are taken into consideration in the haircut rule. After a negative shock to the market prices of financial assets, central banks can reduce the macroeconomic volatility further if they commit to exit at a pre-announced date. Agents' expectations formation contributes then to a smoothing of key variables. If they do not exit at all from this policy, all other macro variables are nevertheless well stabilized at the cost of higher inflation.

An interesting way to extend the model would be first to implement default probabilities on the interbank market which certainly would increase the responses in a financial crisis setup. Secondly, having already some type of shocks included both in the real as well as in the financial sector, one further possibility would be to estimate the model to match certain country characteristics more accurately.

Appendix

A Model Graph

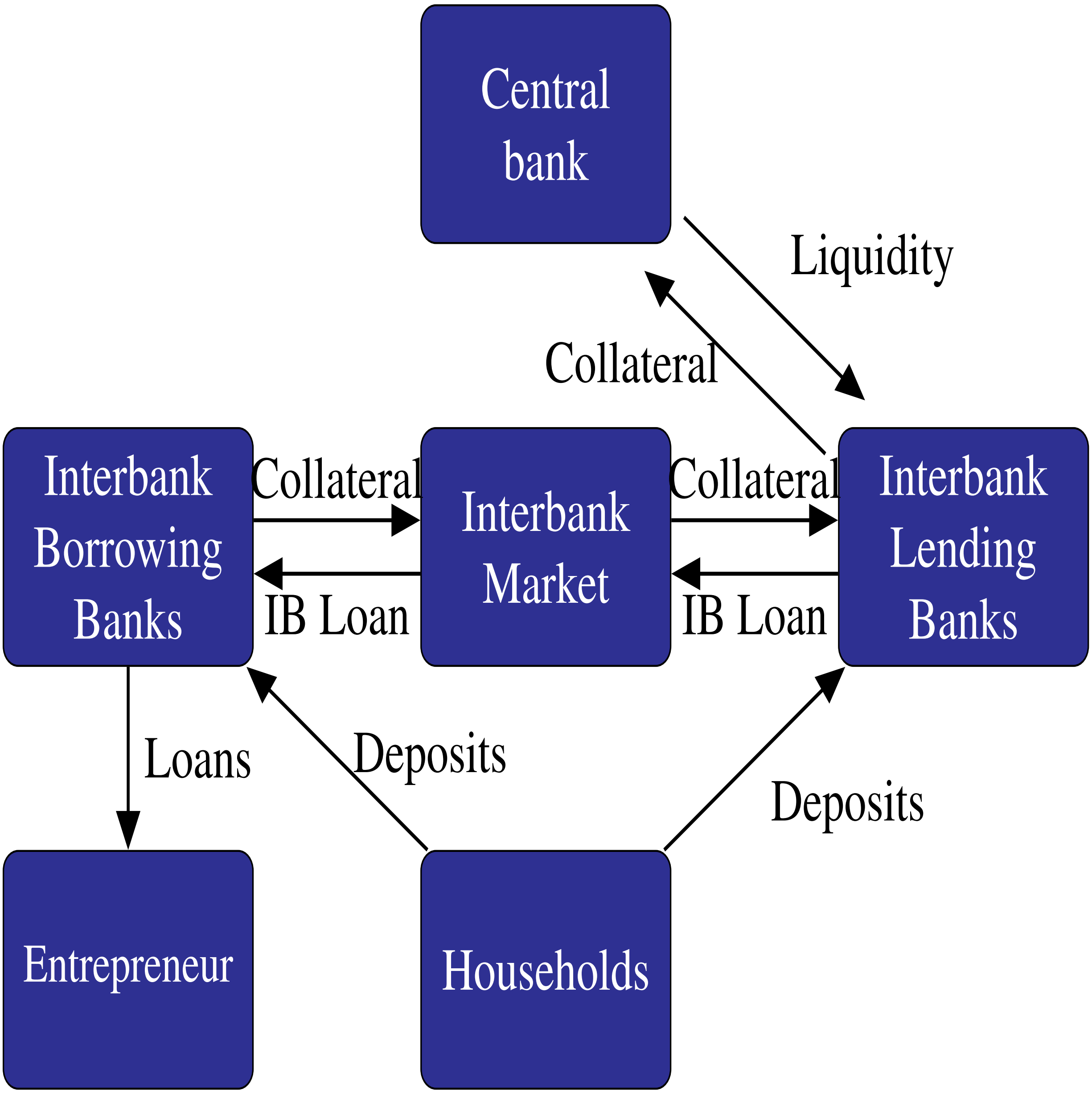

Figure 1: Structure of the economy

B Model Equations

B.1 First-order Conditions

Patient Households

$$\begin{aligned}
\lambda_t &= (C_t(h))^{-\gamma} \\
\lambda_t &= \beta \lambda_{t+1} \frac{R_t^D}{\pi_{t+1}} \\
\lambda_t W_t &= \eta \frac{1}{(1 - L_t(h))^{\gamma_l}}
\end{aligned}$$

Entrepreneurs

$$\begin{aligned}
R_t^k &= \alpha MC_t \frac{Y_t}{K_t} \\
W_t &= (1 - \alpha) MC_t \frac{Y_t}{L_t}
\end{aligned}$$

Capital Producers

$$\begin{aligned}
& Q_t \left(1 - \frac{\kappa_i}{2} \left(\frac{K_t}{K_{t-1}} - 1 \right)^2 - \kappa_i \left(\frac{K_t}{K_{t-1}} - 1 \right) \frac{K_t}{K_{t-1}} \right) \\
+ \quad & \beta \kappa_i \left(\frac{\lambda_{t+1}}{\lambda_t} \right) Q_{t+1} \left(\frac{K_{t+1}}{K_t} - 1 \right) \left(\frac{K_{t+1}}{K_t} \right)^2 = 1
\end{aligned}$$

Retailer

$$\sum_{k=0}^{\infty} \theta^k E_{t-1} \left\{ \Lambda_{t,k} \left(\frac{P_t^*}{P_{t+k}} \right)^{-\epsilon_y} Y_{t+k}^*(R) \left[\frac{P_t^*}{P_{t+k}} - \left(\frac{\epsilon_y}{\epsilon_y - 1} \right) \frac{P_{t+k}^w}{P_{t+k}} \right] \right\} = 0$$

Interbank Borrowing Bank *j*

$$
\begin{aligned}
& -(1+\epsilon_d)D_t(j) + \left(1+\lambda_t^{CoB}\right)\epsilon_d \frac{R_t^{IB}}{R_t^D} D_t(j) - \kappa_d \left(\frac{R_t^D}{R_{t-1}^D} - 1\right)\frac{R_t^D}{R_{t-1}^D} D_t(j) \\
+ \quad & \beta^P \kappa_d \frac{\lambda_{t+1}^P}{\lambda_t^P}\left(\frac{R_{t+1}^D}{R_t^D} - 1\right)\left(\frac{R_{t+1}^D}{R_t^D}\right)^2 D_{t+1}(j) = 0 \\
& (1-\epsilon_h)B_t(j) + \left(1+\lambda_t^{CoB}\right)\epsilon_h \frac{R_t^{IB}}{R_t^H} B_t(j) - \kappa_h \left(\frac{R_t^H}{R_{t-1}^H} - 1\right)\frac{R_t^H}{R_{t-1}^H} B_t(j) \\
+ \quad & \beta^P \kappa_h \frac{\lambda_{t+1}^P}{\lambda_t^P}\left(\frac{R_{t+1}^H}{R_t^H} - 1\right)\left(\frac{R_{t+1}^H}{R_t^H}\right)^2 B_{t+1}(j) = 0
\end{aligned}
$$

Interbank Lending Bank *k*

$$
X_t(k) = \left(\frac{R_t^{Spread} - R_t^{IB}}{\lambda_t(1-\alpha)}\right)^{-\frac{1}{\alpha}} IB_t(k)
$$

$$
IB_t(k) = X_t(k)\left(\frac{R_t^{Spread}\left(1+\frac{1-h_t}{m_t}R_t^{IB}\right) + R_t - \lambda_t \frac{1-h_t}{m_t} R_t^{IB}}{\lambda_t \alpha}\right)^{\frac{1}{\alpha-1}}
$$

B.2 Log-linearized Equations

Real Sector

$$
\begin{aligned}
Y_t &= \frac{C_{ss}}{Y_{ss}}C_t + \frac{G_{ss}}{Y_{ss}}G_t + \frac{I_{ss}}{Y_{ss}}I_t \\
\pi_t &= \frac{(1-\xi)(1-\xi\beta)}{\xi}MC_t + \beta\pi_{t+1} \\
K_t &= (1-\delta)K_{t-1} + \delta I_t \\
Y_t &= A_t + \alpha K_{t-1} + (1-\alpha)(1-\omega)LH_t \\
Q_t &= \varphi(I_t - K_{t-1}) \\
Y_t &= \frac{LH_{ss}}{1-LH_{ss}}LH_t + C_t + LH_t - MC_t \\
C_t &= \frac{h}{1+h}C_{t-1} + \frac{1}{1+h}C_{t+1} - \frac{1-h}{(1+h)\sigma}\left(R_t^D - \pi_{t+1}\right) + \\
&\quad + \frac{1-h}{(1+h)\sigma}\left(\epsilon_t^P - \epsilon_{t+1}^P\right) \\
R_t^Q &= (1-\vartheta)(MC_t + Y_t - K_{t-1}) + \vartheta Q_t - Q_{t-1} \\
R_{t+1}^Q &= R_t^B - \pi_{t+1} - \psi(N_t - (Q_t + U_t) - K_t) \\
N_t &= \nu\frac{R_{ss}^Q K_{ss}}{N_{ss}}\left\{R_t^Q - \left(1 - \frac{N_{ss}}{K_{ss}}\right)\left(R_{t-1}^B - \pi_t\right) - (1 - \frac{N_{ss}}{K_{ss}})\psi(K_{t-1} + Q_{t-1})\right. \\
&\quad \left. - \left[1 + \left(1 - \frac{N_{ss}}{K_{ss}}\right)[\psi - (1-b)]\right] + \vartheta U_t + \left[\left(1 - \frac{N_{ss}}{K_{ss}}\right)\psi + \frac{N_{ss}}{K_{ss}}\right]N_{t-1}\right\}
\end{aligned}
$$

Financial Sector

$$
\begin{aligned}
R_t^B &= \frac{\left(\kappa_b R_{t-1}^B + \beta\kappa_b R_{t+1}^B + (\epsilon_b - 1)R_t^{IB}\right)}{(\epsilon_b - 1 + \kappa_d(1+\beta))} \\
R_t^D &= \frac{\left(\kappa_d R_{t-1}^D + \beta\kappa_d R_{t+1}^D + (1 + \epsilon_d)R_t^{IB}\right)}{(1 + \epsilon_d + \kappa_d(1+\beta))} \\
B_t &= \frac{Q_{ss}K_{ss}}{B_{ss}}(Q_t + K_t) - \frac{N_{ss}}{B_{ss}}N_t \\
D_t &= \frac{B_{ss}}{D_{ss}}B_t - \frac{IB_{ss}}{D_{ss}}IB_t
\end{aligned}
$$

Financial Sector (cont.)

$$
\begin{aligned}
MBS_t^{CoB} &= (1-o)\frac{Q_{ss}K_{ss}}{MBS_{ss}^{CoB}}\left[(Q_{t+1}+U_{t+1})+K_t\right] - o\frac{N_{ss}}{MBS_{ss}^{CoB}}N_t \\
M &= \frac{G_{ss}}{M_{ss}}G_t - HC_{ss}\frac{MBS_{ss}^{CoB}}{M_{ss}}HC_t + (1-HC_{ss})\frac{MBS_{ss}^{CoB}}{M_{ss}}MBS_t^{CoB} \\
R_t^{spread} &= \frac{R_{ss}^{IB}}{R_{ss}^{spread}}R_t^{IB} - \frac{R_{ss}}{R_{ss}^{spread}}R_t \\
M_t &= \zeta IB_t + (1-\zeta)X_t \\
X_t &= \frac{1}{\zeta}\left(\frac{R_{ss}^{spread}}{R_{ss}^{spread}-R_{ss}^{IB}}R_t^{spread} - \frac{R_{ss}^{IB}}{R_{ss}^{spread}-R_{ss}^{IB}}R_t^{IB} - \lambda_t\right) + IB_t \\
IB_t &= \frac{1}{\zeta}\left[\left(R_{ss}^{spread}\left(1+\frac{(1-HC_{ss})}{m_{ss}}R_{ss}^{IB}\right) + R_{ss} - \left(R_{ss}^{IB}\right)^2\frac{1-HC_{ss}}{m_{ss}}\right.\right. \\
&\quad \left.\left. +\lambda_{ss}\frac{1-HC_{ss}}{m_{ss}}R_{ss}^{IB}\right) / \left(\lambda_{ss}\zeta X_{ss}^{(1-\zeta)}\right)\right]^{-1} \\
&\quad \left\{\frac{1+m_{ss}-HC_{ss}}{m_{ss}}R_{ss}^{IB}R_{ss}^{spread}R_t^{spread}\right. \\
&\quad + \left(R_{ss}^{spread}+\lambda_{ss}-2R_{ss}^{IB}\right)\frac{1-HC_{ss}}{m_{ss}}R_{ss}^{IB}R_t^{IB} \\
&\quad \left. + R_{ss}R_t + \left[\left(R_{ss}^{spread}+\lambda_{ss}-R_{ss}^{IB}\right)\frac{R_{ss}^{IB}}{m_{ss}}\right]HC_{ss}HC\right\} \\
&+ \frac{1-\zeta}{\zeta}X_{ss}X_t
\end{aligned}
$$

Shocks

$$
\begin{aligned}
A_t &= \rho_a A_{t-1} + \varepsilon_t^A \\
G_t &= \rho_g G_{t-1} + \varepsilon_t^G \\
U_t &= b\frac{R_{ss}^Q}{(1-\delta)}U_{t-1} + \varepsilon_t^U \\
R_t &= \phi_r R_{t-1} + \phi_\pi \pi_t + \phi_y Y_t(+dS_t) + \varepsilon_t^R \\
HC_t &= \rho_h HC_{t-1}(+cS_t) - \varepsilon_t^{HC} \\
m_t &= \rho_m m_{t-1} - 2 * U_t + \varepsilon_t^m
\end{aligned}
$$

C Calibrated Parameters

Parameters	Values	Parameters	Values
β	0.997	ϵ_d	852
α	0.33	ϵ_b	759
δ	0.008	ϵ_y	6
κ_d	540	ψ	0.0506
κ_b	1125	ν	0.95
ξ_p	0.85	a	0.98
om	0.01	ϖ	0.5
ζ	0.9	ϑ	0.9792
γ^p	1	ρ_g	0.9
γ^i	1	ρ_m	0.9
γ^{CoB}	1	ρ_r	0.99
γ^{pd}	1	ρ_a	0.95
γ^l	1	ρ_h	0.98
γ^h	1	ρ_π	1.5
τ	0.15	ρ_y	0.5
$b = a \cdot (1-\delta)$	0.9722	c	0
A^{ss}	1	d	0
π^{ss}	1	Ω	0.01
HC^{ss}	0.2	Lev	2
LH^{ss}	0.25	$\frac{G^{ss}}{Y^{ss}}$	0.2
$\frac{CE^{ss}}{Y^{ss}}$	0.04	χ	2

Table 8: Calibrated Model Parameters

D Dynamic Analysis

D.1 Impulse Response Analysis

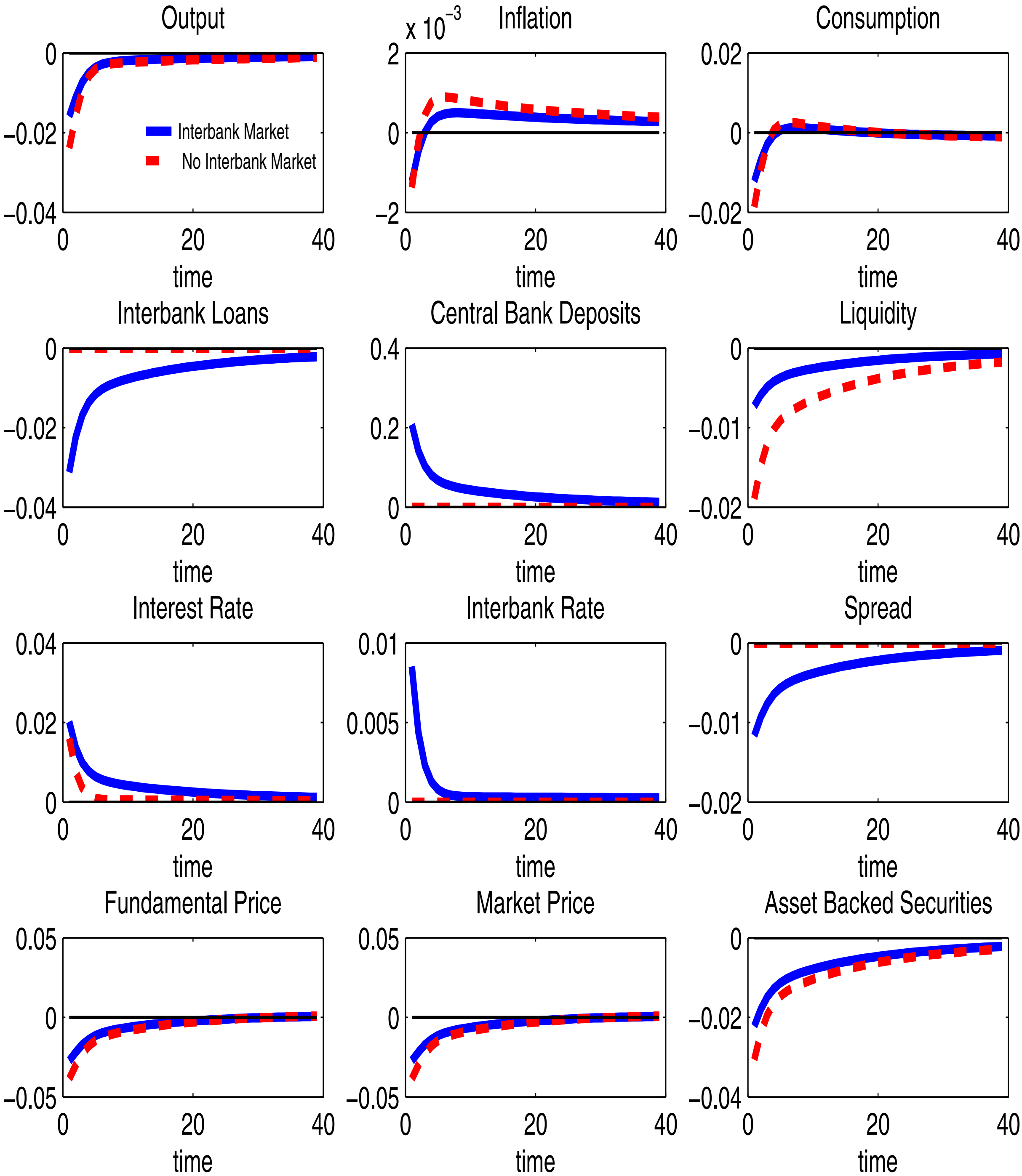

Figure 2: Interest Rate Shock

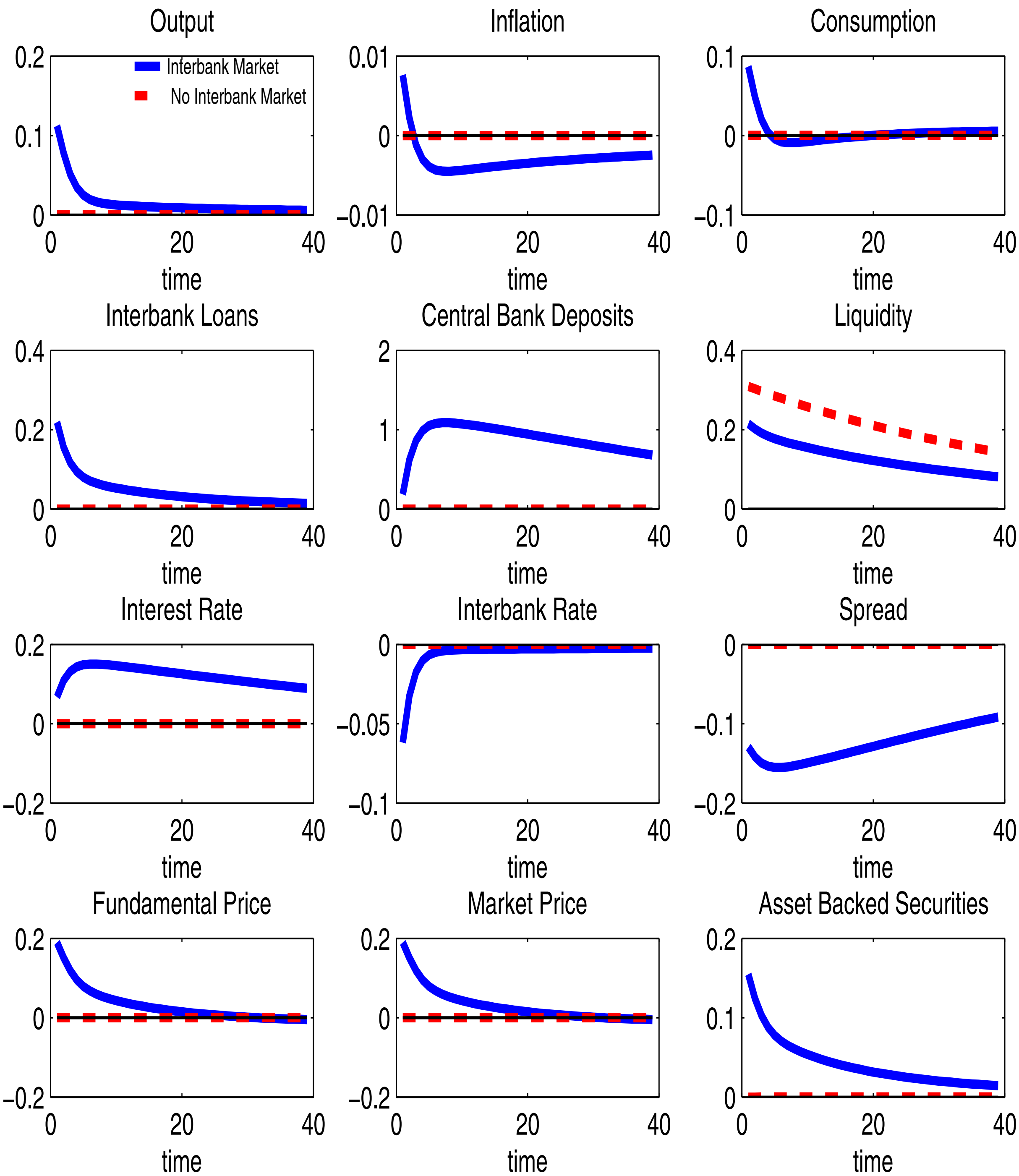

Figure 3: Haircut Shock

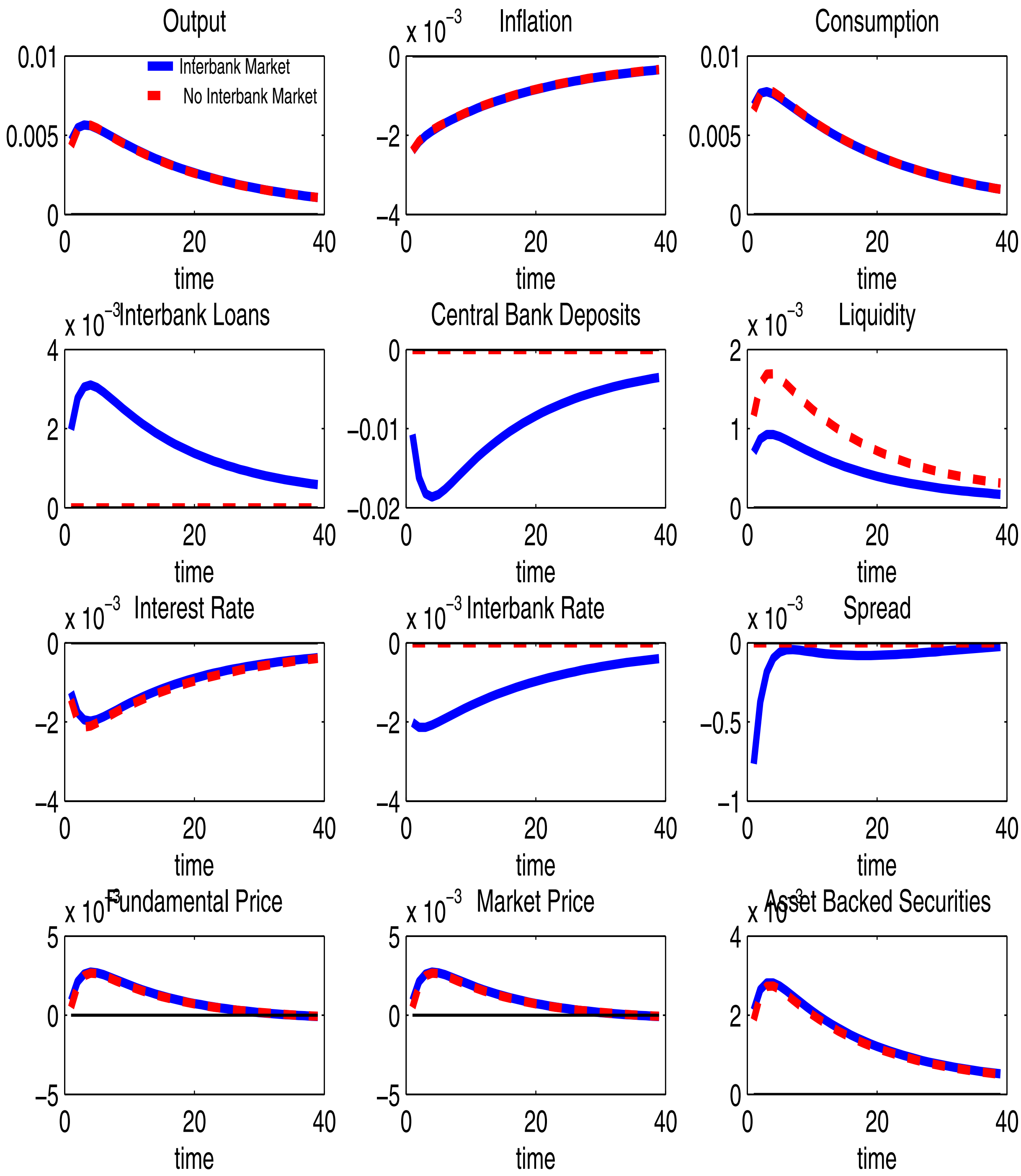

Figure 4: Technology Shock

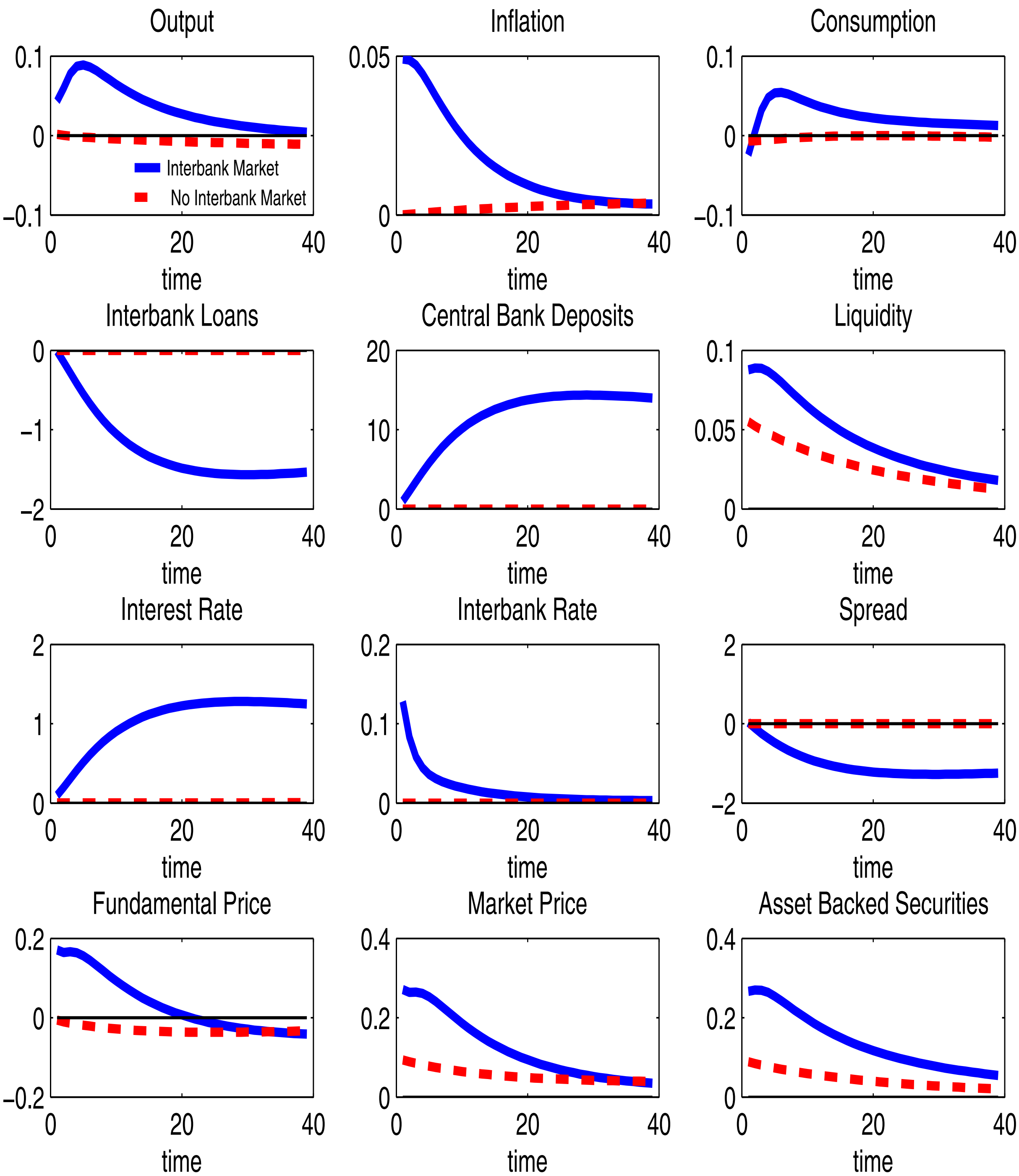

Figure 5: Market Price Shock

D.2 Boom-Bust Cycles

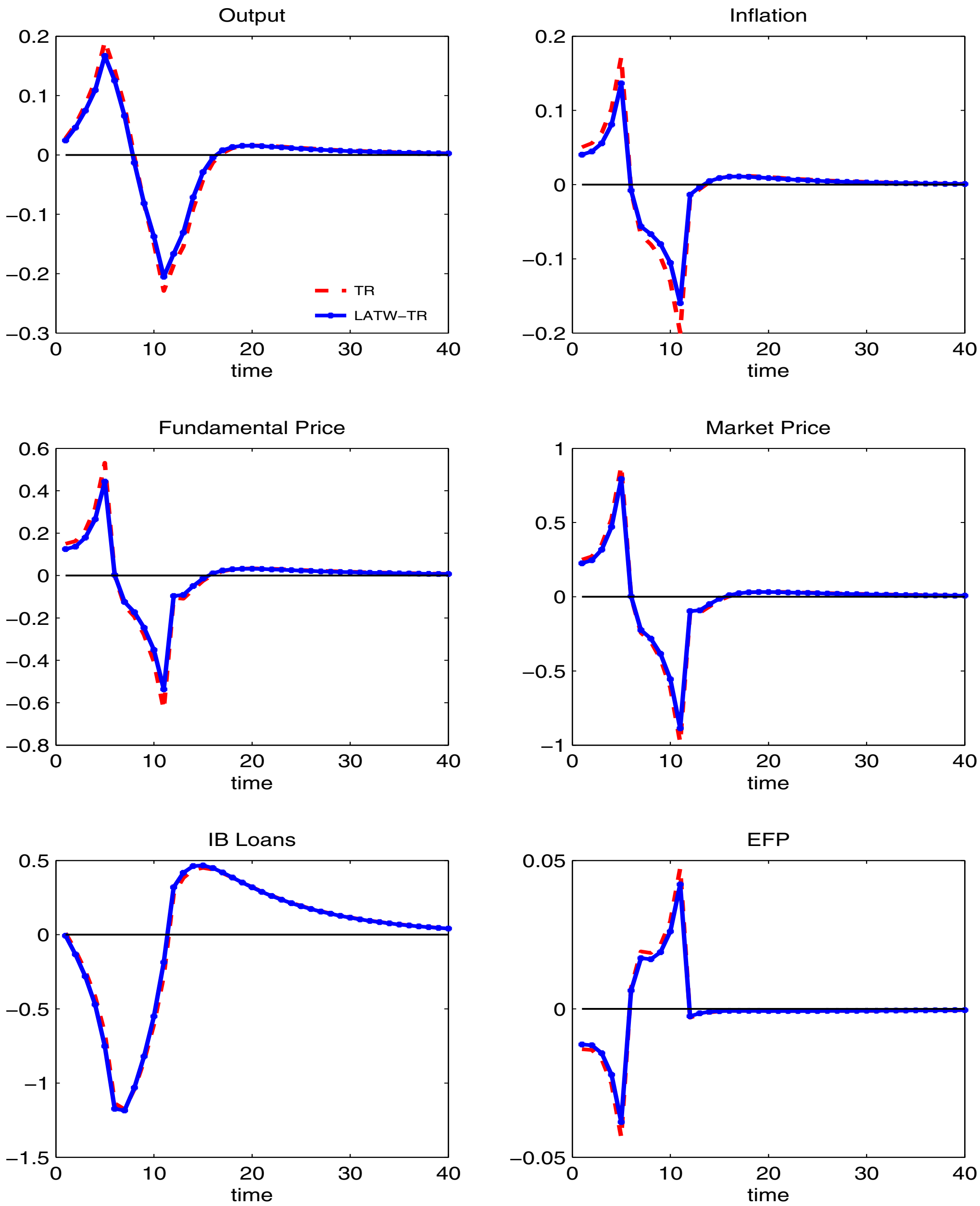

Figure 6: Boom-Bust Cycles I

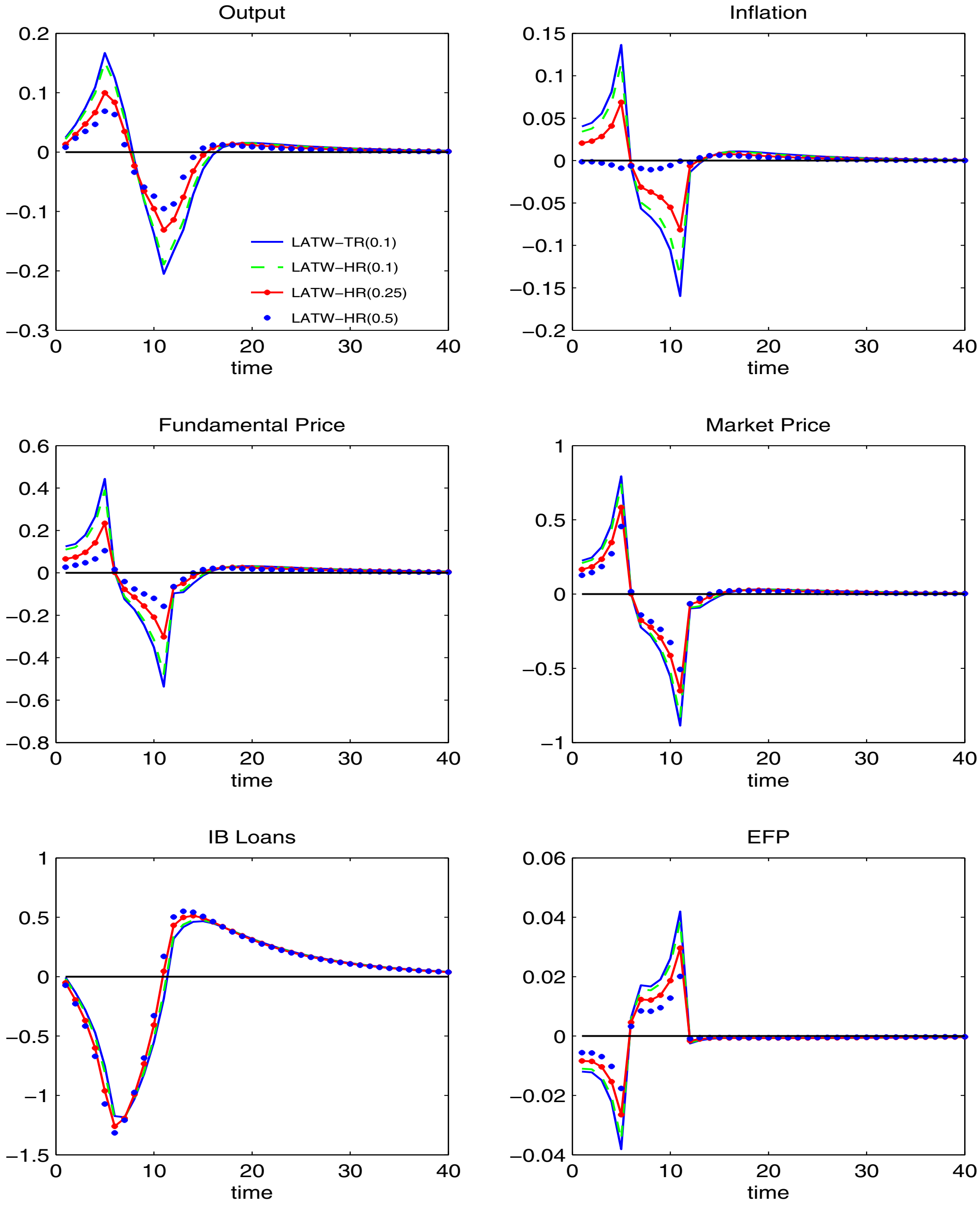

Figure 7: Boom-Bust Cycles II

D.3 Exit strategy

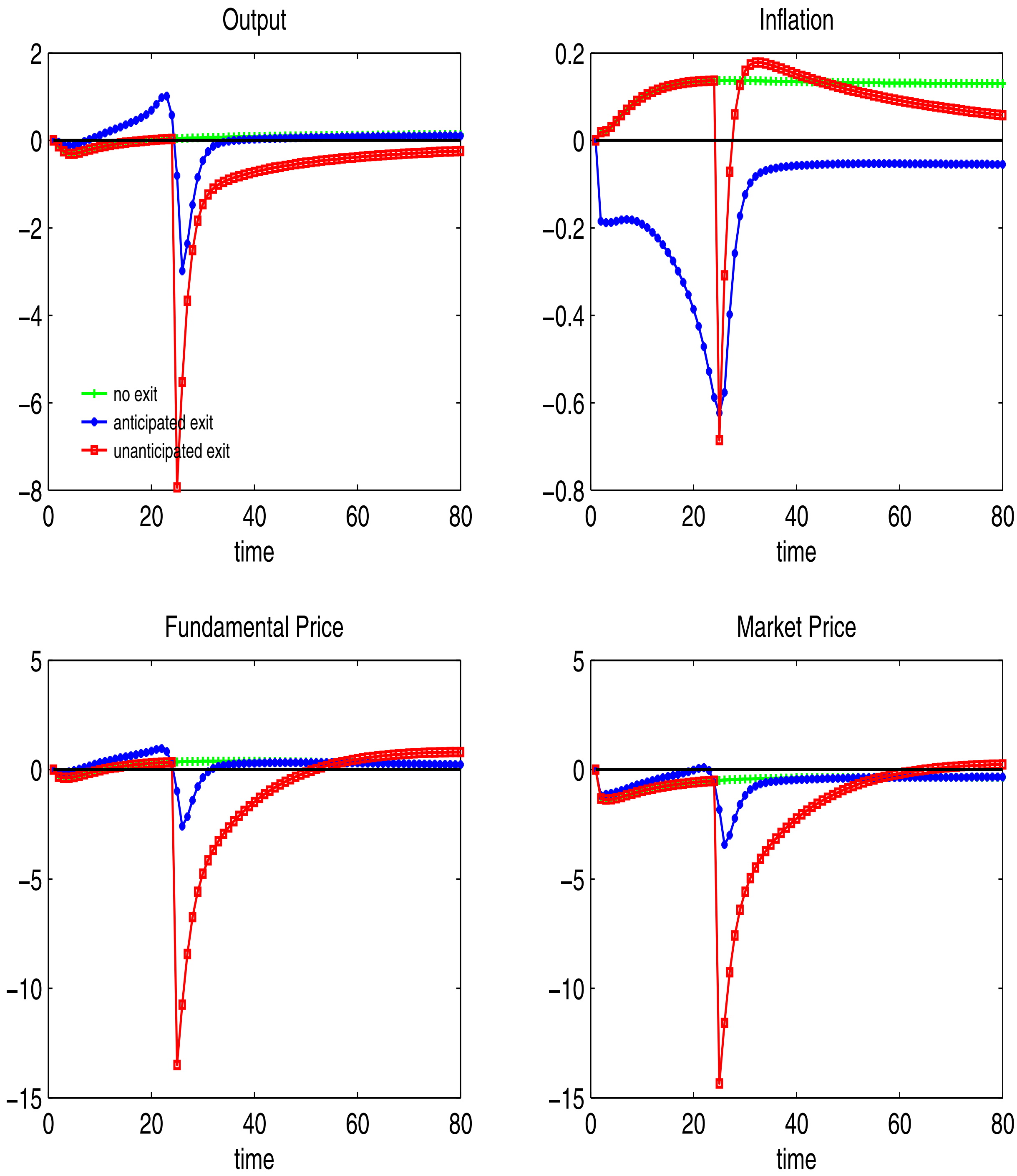

Figure 8: Exit Strategy: Haircut

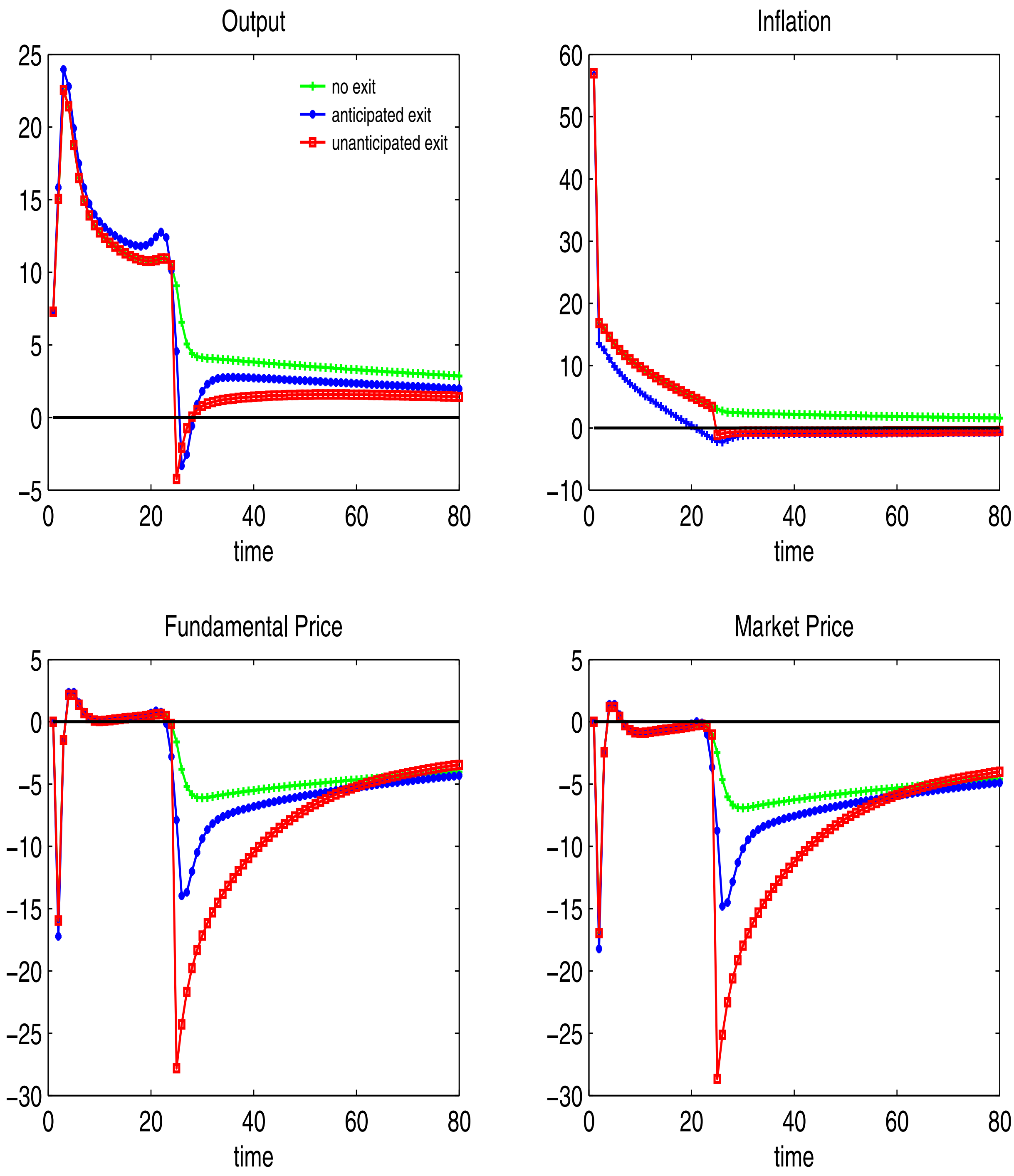

Figure 9: Exit Strategy: Haircut plus Taylor-Rule

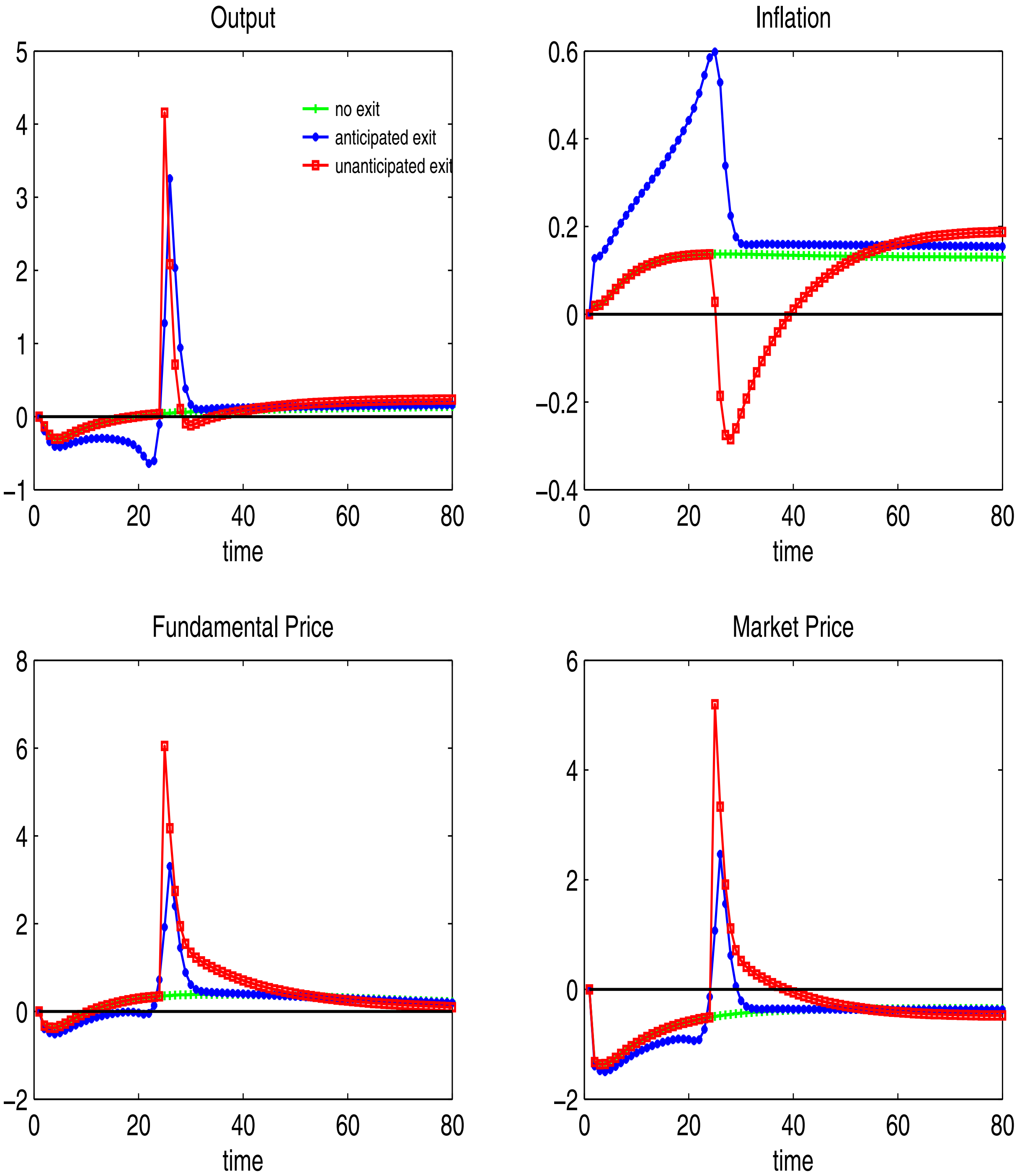

Figure 10: Exit Strategy: Loan-to-Value Ratio

References

Adrian, T. and H. S. Shin (2009). Money, liquidity, and monetary policy. *American Economic Review:Paper&Proceedings 99:2*, 600–605.

Allen, F., E. Carletti, and D. Gale (2009). Interbank liquidity and central bank intervention. *Working Paper*.

Ashcraft, A., N. Gârleanu, and L. H. Pedersen (2011, August). Two monetary tools: Interest rates and haircuts. In *NBER Macroeconomics Annual 2010, Volume 25*, NBER Chapters, pp. 143–180. National Bureau of Economic Research, Inc.

Bernanke, B. and M. Gertler (1999). Monetary policy and asset price volatility. *Economic Review*, 17–51.

Bernanke, B. and M. Gertler (2001). Should central banks respond to movements in asset prices. *American Economic Review Papers and Proceedings 91*(2), 253–257.

Bernanke, B., M. Gertler, and S. Gilchrist (1999). *The financial accelerator in a quantitative business cycle framework*, Volume 1, Chapter 21, pp. 1341–1393. Handbook of Macroeconomics.

Blanchard, O. J. and M. Watson (1982). *Bubbles, Rational Expectations and Financial Markets*. Wachtel, Crises in the Economic and Financial Structure.

Borgy, V., J.-S. Mesonnier, T. Laubach, and J.-P. Renne (2011). Fiscal policy, default risk and euro area sovereign bond spreads. *Working Paper*.

Calvo, G. (1983). Staggered prices in a utility maximizing framework. *Journal of Monetary Economics 12*, 383–398.

Cecchetti, S. G., H. Genberg, and S. Wadhwani (2002). Asset price in a flexible inflation targeting framework. *NBER Working Paper Series* (8970).

Christensen, I. and A. Dib (2008). The financial accelerator in an estimated new keynesian model. *Review of Economic Dynamics 11*, 155–178.

Cúrdia, V. and M. Woodford (2011, January). The central-bank balance sheet as an instrument of monetarypolicy. *Journal of Monetary Economics 58*(1), 54–79.

deWalque, G., O. Pierrard, and A. Rouabah (2010, December). Financial (in)stability, supervision and liquidity injections: A dynamic general equilibrium approach. *Economic Journal 120*(549), 1234–1261.

Dib, A. (2009). Banks, credit market frictions and business cycles. *Working paper*.

Eisenschmidt, J. and J. Tapking (2009, March). Liquidity risk premia in unsecured interbank money markets. Working Paper Series 1025, European Central Bank.

Freixas, X. and J. Jorge (2008). The role of interbank markets in monetary policy: A model with rationing. *Journal of Money, Credit and Banking 40*(6), 1151–1176.

Gerali, A., S. Neri, L. Sessa, and F. M. Signoretti (2010, 09). Credit and banking in a dsge model of the euro area. *Journal of Money, Credit and Banking 42*(s1), 107–141.

Gertler, M. and P. Karadi (2011, January). A model of unconventional monetary policy. *Journal of Monetary Economics 58*(1), 17–34.

Gertler, M. and N. Kiyotaki (2010). Financial intermediation and credit policy in business cycle analysis. *Hankbook of Monetary Economics*.

Gorton, G. and A. Metrick (2009). Haircuts. *Yale ICF Working Paper No. 09-15*.

Iacoviello, M. (2005, June). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review 95*(3), 739–764.

Justiniano, A., G. E. Primiceri, and A. Tambalotti (2010, March). Investment shocks and business cycles. *Journal of Monetary Economics 57*(2), 132–145.

Kiyotaki, N. and J. Moore (1997). Credit cycles. *Journal of Political Economy 105*(2), 211–48.

Markovic, B. (2006, November). Bank capital channels in the monetary transmission mechanism. Bank of England working papers 313, Bank of England.

Primiceri, G. E. (2005). Time varying structural vector autoregressions and monetary policy. *Review of Economic Studies 72*, 821–852.

Schabert, A. (2010, June). Optimal central bank lending. Tinbergen Institute Discussion Papers 10-057/2, Tinbergen Institute.

Stock, J. H. and M. W. Watson (2003, August). Has the business cycle changed and why? In *NBER Macroeconomics Annual 2002, Volume 17*, NBER Chapters, pp. 159–230. National Bureau of Economic Research, Inc.

Taylor, J. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Series on Public Policy 39*, 195–214.

Tobin, J. (1969, February). A general equilibrium approach to monetary theory. *Journal of Money, Credit and Banking 1*(1), 15–29.

Winkler, R. and I. Angeloni (2011). Exit strategies. 2011 Meeting Papers 241, Society for Economic Dynamics.