MODELING STOCK MARKET BOOMS*

Martin Kliem†
Deutsche Bundesbank

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Abstract

This paper examines a DSGE model which covers the observed co-movements of stock market boom and bust episodes in the 1980's and 1990's and the economy. The boom episodes within the model are triggered by news shocks about the future technology. By including nonseparable preferences and nominal rigidities, the model explains the simultaneous rise of consumption, output, investments, hours worked, and wages during a boom and the subsequent bust. Furthermore, featuring a standardized monetary authority, the model also replicates the observed fact of a declining inflation during the boom episodes. As a result the model allows for a more fundamental discussion of central bank activism during stock market booms. The paper concludes that a monetary authority which is not only "strict" inflation-targeting can reduce the welfare losses through stock market booms.

JEL classification: E32, E44, E52
Keywords: stock market boom, monetary policy, nonseparability, news shock

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† Deutsche Bundesbank, Economic Research Center, Wilhelm-Epstein-Straße 14, D-60431 Frankfurt am Main, Germany, email: martin.kliem@bundesbank.de, phone: +49 69 9566 2830

1 Introduction

During the last decades a strand of monetary policy research tends to question, whether the monetary authority should respond to asset pricing movements. This interest seems obvious with respect to the recent history, but in the case the answer is yes, how exactly should central banks respond to asset price movements? To answer this question it is necessary to have a model at hand which helps to understand the co-movements of stock market booms and busts and the real economy in more detail. Given such a model the investigation and evaluation of policy instruments can help to resolve the aforementioned question.

The derivation of such a model and the investigation of monetary policy are the purposes of the present paper. First, the paper evaluates a New-Keynesian DSGE model which can replicate the movements of some key macro variables during the asset market boom at the end of the 1980's and 1990's. Afterwards different monetary policy regimes are investigated, and optimized rules are used to illustrate the possibilities of the monetary authority to reduce the distortions during the boom-bust episode.

For the boom and bust episodes of the 1980's and 1990's it can be empirically disclosed that during an asset market boom output, investments, consumption, and hours worked are all rising, followed by an overall reduction during the bust episode. Additionally, real wages are rising during the boom and later fall. The present model's ability to recapitulate this additional fact makes the model more applicable to detailed policy investigations than similar models in the literatures. The investigated episodes of booming equity markets have gone along with decreasing interest rates and decreasing inflation. These stylized fact are widely discussed in the recent literature (e.g., Adalid and Detken, 2007) and contradict the model findings of Bernanke and Gertler (2000) that inflation tends to rise during asset market booms. Furthermore, the conclusion of Bernanke and Gertler (2000) that an inflation-targeting monetary authority automatically stabilizes the stock market seems not longer obvious. Moreover, as mentioned by e.g. Cecchetti, Genberg, Lipsky, and Wadhwani (2000) a 'leaning against the wind' monetary policy could prevent an additional heating-up of the boom due to a reduction of interest rates.

In order to investigate policy decisions it is necessary to discuss the source of the rapidly increasing stock market. The problematic identification of a boom and its source is the basis for further policy suggestions and the reason for the variaty of suggestions, namely from preemptive approaches to a reactive approaches (see Bean, 2004; Greenspan, 2002). Within the literature rapidly increasing asset prices are usually classified into fundamental or non-fundamental, into a boom or a bubble. The approaches solving for the appearance of huge asset prices movements vary from irrational exogenous shocks (see e.g. Bernanke and Gertler, 2000, 2001; Tetlow, 2006) to rational but wrong expectations about the future (Beaudry and Portier, 2006; Christiano, Ilut, Motto, and Rostagno, 2007; Gilchrist and Saito, 2006). To shed light on the debate, it seems essential to investigate the interdependencies between asset market booms and the rest of the economy in more detail.

The model presented in this paper is an extension of Christiano et al. (2007). In contrast to the authors, the model in this paper can also simulate the simultaneous increase of wages and hours worked during asset market booms due to the use of nonseparable preferences between consumption and leisure. Furthermore, the representative agent has habitually formed preferences with respect to her former level of consumption and leisure. This makes the agent more unwilling to change her leisure over time. Moreover, the individual concurrently demands a higher wage for an increase of her hours on the job due to a small Frisch elasticity. The model shows that the nominal wages are slightly increasing as a reaction of the overoptimistic anticipated shift of technology, which is in line with the data. Of course, this effect is also supported by nominal wage rigidities and is a necessary fact in the model, but cannot soley resolve the simultaneous increase of real wages and hours worked (Christiano et al., 2007). Finally, the increase of real wages depends on the decrease in inflation. As mentioned by Christiano et al. (2007) the interaction of real wages and inflation targeting in the form of a standard Taylor rule can trigger a boom episode. By capturing this fact more accurate, the model is more accurate to the observed boom and bust episodes, which increases the ability of the model to investigate policy activities.

In the contrast to most of the literature, the present paper does neither investigate additional features of the monetary policy rule nor argues for optimal monetary policy rules. Instead, the main interest is to investigate the reactions of a standardized monetary policy rule during asset market booms and busts. Especially, the ability of this monetary policy rule to stabilize the economy under different monetary policy regimes is focused. For example, as previous discussed, in the present model with an anticipated increase of technology, the increasing real wages tend to down-shift inflation due to the nominal rigidities in the economy. An inflation-targeting regime would cut the nominal interest rate followed by a credit boom which in turn is heating-up the boom episode (see Christiano et al., 2007).

In order to investigate the consequences of different regimes from "strict" inflation-targeting to a more "flexible" inflation-targeting regime, I assume that the monetary authority is interested in stabilizing the economy with respect to fluctuations in inflation, output gap, and changes of the nominal interest rate. For a comparison I calculate optimized monetary policy rules based on the loss function of the central bank (e.g. Levin and Williams, 2003). Under these optimized rules only small differences between the regimes are discovered. However, it can be concluded that a monetary authority should increase the nominal interest rates during the boom. This finding confirms the 'leaning-against the wind' policy as suggested by Cecchetti, Genberg, and Wadhwani (2002). Additionally, a monetary policy regime which accounts more for a steady interest rate and small output fluctuations is welfare-enhancing. With respect to the debate about central bank activism this finding suggests that a continuous and moderate monetary policy is favorable.

As mentioned above, the paper is closely related to Christiano et al. (2007). Comparable to their approach, my model is triggered by an over-optimized anticipated future technology and motivated by the findings of Beaudry and Portier (2006). A similar approach is proposed by Gilchrist and Saito (2006). The authors argue that asset price booms occur because agents do not know the true state of technology growth but learn about it over time instead. Under these circumstances, there exists a motivation to respond to the gap between observed asset prices and their potential level, in order to reduce the distortions of resource allocations. However, the imperfect information in the economy also affects the policymaker's decision about the potential asset price, which results in a welfare-reducing monetary policy.

Another strand of the literature investigates stock market booms as non-fundamental bubbles and studies the effects of allowing monetary policy to respond to asset price movements. Bernanke and Gertler (2000, 2001) and Tetlow (2006) show that an irrational exogenous shock to the asset price increases the aggregate demand within the economy. They conclude that a strong inflation-targeting regime is sufficient. The extension by Gilchrist and Leahy (2002) also suggests a "strict" inflation-targeting monetary authority if exogenous bubbles have a persistent effect on technology growth. However, in a similar model framework, Cecchetti et al. (2000) show that there may be some benefits to responding to asset prices and that a monetary policy can avoid an overshooting asset prices bubble. The contrasting results within similar model frameworks are due to different assumptions about what exactly can be observed by the policymaker (Cecchetti et al., 2002). Dupor (2002, 2005) finds similar results and he suggests that in response to inefficient shocks to investment demand, optimal policy reduces both price fluctuations as well as non-fundamental asset price movements.

This raises the importance of both as targets of the monetary authority. Furthermore, Mishkin and White (2002) suggest that the central bank should only respond to a stock market crash in order to prevent financial instability. In this case the stock market crash is unlikely to result in changes of aggregate demand and the policy maker should not directly react to stock market movements.

The paper is organized as follows. Section two presents the stylized facts of the identified boom and bust episodes during the last decades. The third section introduces the model including financial frictions and nominal rigidities. In section four, the benchmark simulation of the model is presented and the responses to different shocks within the economy are discussed. The ensuing section compares the benchmark solution to the data of the known shocks of the 1980's and 1990's. Afterwards, section six investigates different monetary policy regimes and compares these regimes based on optimized rules with respect to their ability to stabilize the economy throughout boom episodes and their unexpected busts. Section seven concludes the paper and discusses implications.

2 Stylized Facts

To investigate the relationship between asset price booms and busts and key macroeconomic variables, I identify boom episodes on the US equity market. I use real equity prices of the S&P 500 in quarterly frequency, starting at 1948.[1] That method is similar to the one used by Detken and Smets (2004) or Lowe and Borio (2002) for annual data and Adalid and Detken (2007) for quarterly data. Following Adalid and Detken (2007), I define an asset price boom as a period, in which real asset prices differ from their trend by more than ten percent for a minimum of four quarters. Because of the end-point problem of a standard HP-filter, which occurs due to the fact that such a filter also has a forward-looking part, I decide to follow the cited literature and use a one-sided HP-filter to estimate the trend of real equity prices. The one-sided HP filter is estimated recursively by taking into account only data available at that time.[2] Furthermore, I use an observation period of 40 quarters to estimate the first trend. Finally, I calculate the

[1]The time series for equity prices bases on the data collection of Robert J. Shiller. I am very thankful to him for making the data available on his website. The finally used real prices of the S&P 500 are calculated from these nominal values and a corresponding consumption deflator. For more details see appendix B.

[2]For a discussion and an alternative approach to calculate an one-sided HP-filter see Stock and Watson (1999). For completeness, I should mention that there, of course, exits different approaches to identify asset market gaps or booms (see, e.g., Bordo and Jeanne, 2003).

trend for equity prices during 1958 and 2007. The one-sided HP filter is implemented using a $\lambda = 10000$; this implies the trend to adjust slowly and allows to identify episodes of deviations. The chosen value for λ is smaller compared to the related literature (e.g. Adalid and Detken, 2007, uses a value of $\lambda = 100000$), but still larger than the usually used value for quarterly data of $\lambda = 1600$ as postulated by Hodrick and Prescott (1997).

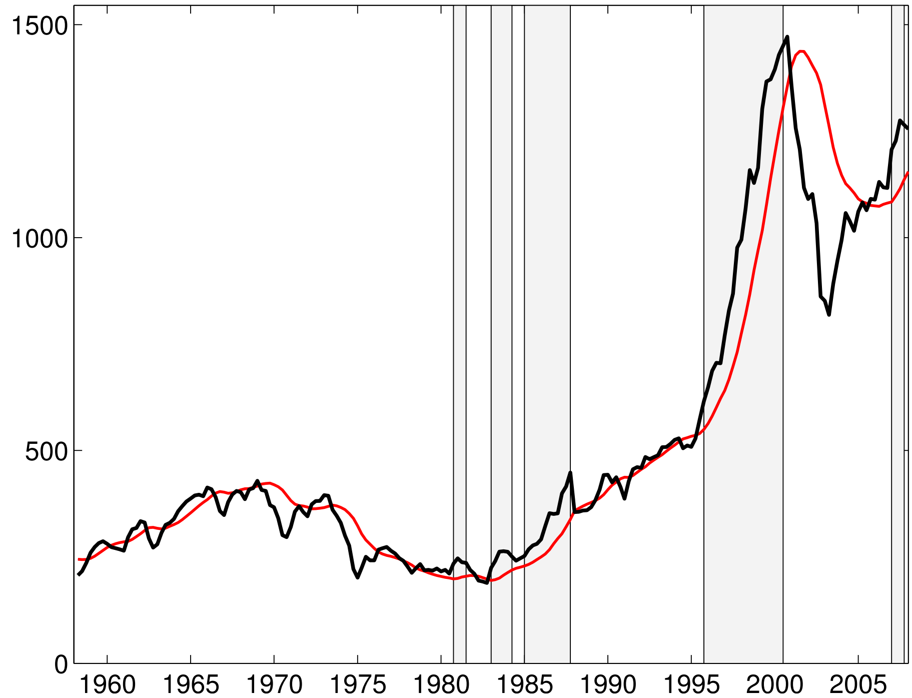

Figure 1: Real price of equity based on S&P 500 (black line), its estimated HP-trend (red line), and identified boom episodes (shaded areas).

Figure 1 shows the real price of the S&P 500, its trend (red line) and the identified boom episodes (shaded areas) for the last 50 years. Moreover, Figure 1 shows identified short boom episodes at the beginning of the 80s' and during 2007. These episodes ended all after a duration of four or six quarters. Additionally, I identify two longer boom episodes from 1984-Q4 to 1987-Q3 and between 1995-Q3 and 2000-Q2. The first boom ended after twelve quarters while the second one has a duration of 20 quarters. These results are not surprising and in line with the literature (see Adalid and Detken, 2007).

In order to investigate the association with macroeconomic variables, I have a more detailed view on the two longer boom episodes. I use the ending dates of both booms (1987-Q3 vs. 2000-Q2) as reference points and analyze how the business cycle components of the macroeconomic time series have changed during the four years before and after the reference point.[3]

The investigated time series include real GDP, real consumption, real private investment, hours worked, and real wages. All these data are per capita and in current dollars using the same consumption deflator as mentioned above.[4] Additionally, the consumption deflator as well the return of the treasury bill are also investigated during and after the boom episodes. Moreover, I detrend each time series with its corresponding trend estimated with a one-sided HP-filter by using $\lambda = 1600$. Additionally, I calculate the averages over both booms for 16 quarters before and after the reference point.

Figure 2 shows the resulting Burns-Mitchell diagram, which plots the detrended data as percentage deviations from their trends, except for hours worked. Because hours worked are assumed to be stationary, I plot the deviation of hours worked from its average over the investigated quarters.

The figure 2 confirms that during an asset market boom output, investments, consumption, hours worked, and real wages rise and afterwards begin to decrease. Both episodes of a booming equity market go along with a decreasing inflation. This fact is widely discussed in the recent literature (e.g., Adalid and Detken, 2007) and contradicts the model findings of Bernanke and Gertler (2000) that inflation tends to rise during asset market booms. Consequently, the conclusion of Bernanke and Gertler (2000) that an inflation-targeting monetary authority automatically stabilizes the stock market seems no longer obvious. The main point the present paper addresses is to simulate the co-movements of these macroeconomic variables during asset market booms. Especially, the simultaneous increase of real wages per capita together and hours worked seems hard to fix (Christiano et al., 2007). However, to start an educated discussion about central bank activism with respect to asset price movements it is necessary to have a model at hand which is able to simulate stock market booms and their association with macroeconomic variables as good as possible.

Figure 3 illustrates the time series with trend by normalizing all time series to the same starting point of unity. The Burns-Mitchell diagram illustrates that the boom and especially the bust have not decreased the levels dramatically. However, neither the boom nor the bust have influence an impact on the long-run, but the distortions in the short run around their trends are obvious and generates welfare distortions.

[3] The related literature - Detken and Smets (2004), Lowe and Borio (2002), or Adalid and Detken (2007) - often defines the peak within a boom episode, at the point where the deviation from the trend is the highest. For the model investigated in this paper, it is more interesting to use the end of a boom as peak or reference point.

[4] For detailed information on the used data (e.g. source and adjustments) see appendix B.

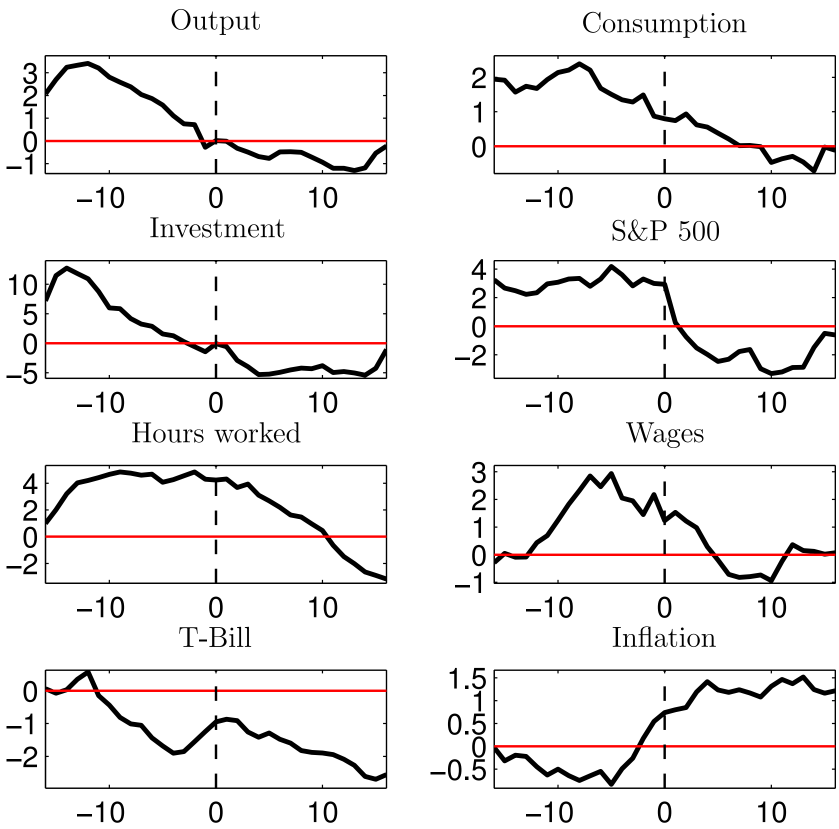

Figure 2: Percentage deviation of macroeconomic time series from their trend during and after asset market booms.

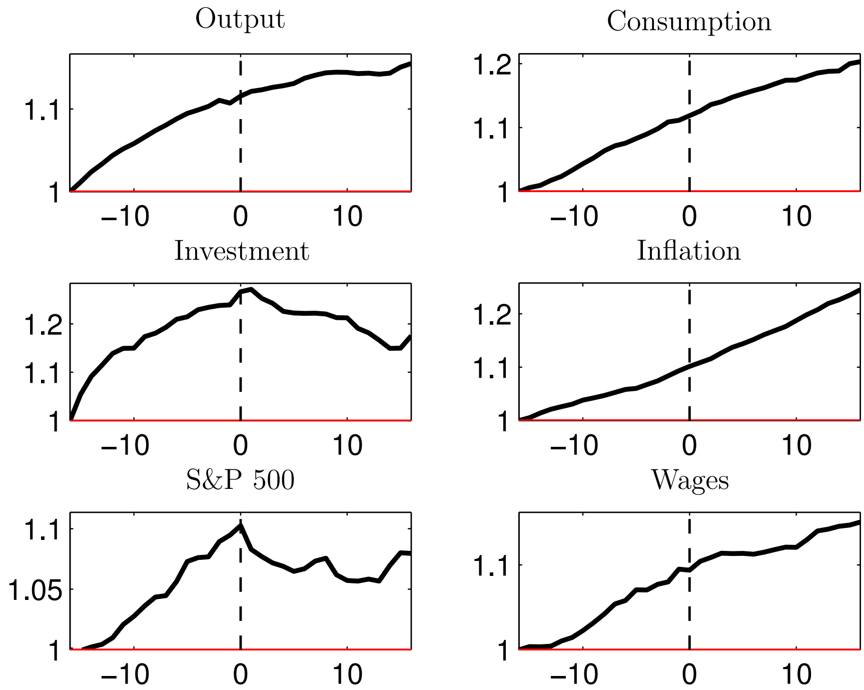

Figure 3: Normalized macroeconomic time series during and after asset market booms.

3 Model

In this section, I describe the economy investigated in this paper. The economy as a whole is similar to the one in Christiano et al. (2007) and Gilchrist and Saito (2006) it includes financial frictions modeled through a "financial accelerator" mechanism as postulated by Carlstrom and Fuerst (1997) and Bernanke, Gertler, and Gilchrist (1999). Following Uhlig (2007) the preferences of the households are modeled in a more general way than in the foregoing papers. Basu and Kimball (2002) show that a nonseparability of consumption and leisure explains the data much better than the standard separable utilities. Separable preferences a often used in the literature can only be a proxy because these are rigid assumptions, which investigate only subsequences.

3.1 Households

In the economy exists a continuum of households indexed by $i \in (0,1)$. Each household i consumes or holds one-period riskless deposits with a nominal return known at the time of purchase. Furthermore, each household purchases securities with payments contingent upon whether it can reoptimize its wage decision. Additionally, the wage rate is set after learning about if it is allowed to optimize wages. Finally, the household decides about the fraction of money balances held in form of currency. The preferences of the representative household are similar to the specification in Uhlig (2007):

$$E_0 \sum_{t=0}^{\infty} \left[\beta^t \frac{\left(\left(C_t(i) - \chi C_{t-1} \right) \left(A + \left(L_t(i) - \psi L_{t-1} \right)^{\nu} \right) \right)^{1-\eta} - 1}{1-\eta} + \upsilon \left(\frac{M_t(i)}{P_t} \right) \right], \tag{1}$$

where $C_t(i)$ is the individual consumption of the household i in period t, which is chosen in each period to maximize the households utility. Leisure $L_t(i)$ is given by the total time endowment of the household minus working hours $H_t(i)$ offered to the entrepreneurs. For simplicity the total time endowment is scaled up to unity, which implies that the leisure of the household in period t is given by:

$$L_t(i) = 1 - H_t(i) \tag{2}$$

Furthermore, the preferences are characterized by the discount factor β, the power utility parameter η, and ν the impact of leisure on the utility. The parameters χ and ψ measure the habit persistence regarding consumption or leisure respectively. Both habits are assumed to be externally formed and depend either on the aggregate past level of consumption or on the past level of leisure. Because of monotonicity and concavity constraints the preference parameter have to fulfil the following conditions:

$$\eta > 0\,,\ \nu > 0 \qquad \text{and} \qquad \eta > \frac{\nu}{\nu+1} \tag{3}$$

In each period, the households consume and invest a part of their income into a nominal one-period riskless deposit, D_t. They receive a nominal labor income, $W_t\,(i) \cdot H_t\,(i)$ and receive the deposit invested in period $t-1$ in addition to the interest rate for this riskless deposit. Moreover, they also receive $S_t\,(i)$ the net cash flow from the insurance market. Additionally, they obtain real dividends Π_t from the retail firms and pay lump-sum taxes T_t to the government. Finally, the budget constraint of the household is characterized by

$$C_t\,(i) + \frac{D_t\,(i)}{P_t} + T_t = \frac{W_t\,(i)}{P_t} H_t\,(i) + \frac{R_{t-1}^N D_{t-1}\,(i)}{P_t} + \Pi_t + S_t\,(i) - \frac{M_t\,(i) - M_{t-1}\,(i)}{P_t}. \tag{4}$$

The first-order condition regarding consumption can be expressed as:

$$\lambda_t = \left(C_t\,(i) - \chi C_{t-1}\right)\left(A + \left(L_t\,(i) - \psi L_{t-1}\right)^{\nu}\right)^{1-\eta}, \tag{5}$$

where λ is the multiplier of the budget constraint in the Lagrangian representation of the household's problem. The first-order condition with respect to D_t is given by the Euler equation:

$$1 = E_t\left[\beta \frac{\lambda_{t+1}}{\lambda_t} R_t^N \frac{P_t}{P_{t+1}}\right]. \tag{6}$$

Following Erceg, Henderson, and Levin (2000), I model the wage setting analogously to staggered price setting introduced by Calvo (1983). Each household supplies a differentiated type of labor service, $h_t(i)$, which is aggregated into a homogenous labor good by a representative competitive firm. This firm uses the following technology:

$$H_t = \left[\int_0^1 H_t\,(i)^{\frac{\varepsilon_w - 1}{\varepsilon_w}}\right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}},$$

where $\varepsilon_w > 1$ is the elasticity of substitution. Finally, the demand for labor of type i is given by,

$$H_t(i) = \left[\frac{W_t\,(i)}{W_t}\right]^{-\varepsilon_w} H_t, \tag{7}$$

where $W_t\,(i)$ is the nominal wage demanded by labor of type i and W_t is the wage index defined as

$$W_t = \left[\int_0^1 W_t(i)^{\varepsilon_w - 1} \right]^{\frac{1}{\varepsilon_w - 1}}.$$

Given the demand curve of labor, each household supplies as many labor services as demanded at this wage. The household has to set his wage. In each period the household can optimize his wage with probability $1-\theta_w$ and with probability θ_w he cannot. If the household can not optimize its wage, the wage rate in t is given by:

$$W_t(i) = \bar{\pi} W_{t-1}(i), \tag{8}$$

where $\bar{\pi}$ is the steady-state inflation rate of the economy. The household optimizes its wage $W_t(i)$ by maximizing the following objective function:

$$E_t \left[\sum_{j=0}^{\infty} (\theta_w \beta)^j \left[\lambda_{t+j} \bar{\pi}^j \frac{W_t(i)}{P_{t+j}} H_{t+j}(i) - U\left(H_{t+j}(i), C_{t+j}(i)\right) \right] \right] \tag{9}$$

The corresponding first order condition of the household is given by:

$$E_t \left[\sum_{j=0}^{\infty} (\theta_w \beta)^j \left[\bar{\pi}^j \frac{W_t(i)}{P_{t+j}}(i) - \frac{\varepsilon_w - 1}{\varepsilon_w} MRS_{t+j}\left(H_{t+j}(i), C_{t+j}(i)\right) \right] \right] = 0 \tag{10}$$

In the following I restrict the analysis of the influences of the nonseparability between consumption and leisure to the individual consumption and wage decision. As stated by Christiano, Eichenbaum, and Evans (2005), the uncertainty of the household whether it can reoptimize its wages or not is idiosyncratic because each household supplies a different amount of labor and earns a different wage rate. As a consequence, the households are also heterogenous in consumption and asset holdings. A widely used argument in the staggered-wage-setting literature (see Erceg et al., 2000; Woodford, 2003) is that the existence of an insurance market implies the equalization of the marginal utility of wealth across households. Using separable preferences, this assumption allows to assume that the households are homogenous with respect to consumption and asset holdings, but heterogenous with respect to wages and labor supply (Christiano et al., 2005).

Since, this paper uses a preference structure which is nonseparable in consumption and leisure, I want to illustrate the effects of nonseparability in more detail. The presentation follows Guerron-Quintana (2007). In particular, I reproduce the results for the preferences applied in this present paper.

In general, the assumption of an insurance market because of the complete market hypothesis imposes that the following condition has to hold:

$$U_c\left(C_t\left(i\right), H_t\left(i\right)\right) = U_c\left(C_t\left(i'\right), H_t\left(i'\right)\right) \qquad \forall\, i, i' \in (0,1) \tag{11}$$

This condition implies that the households differ in their ex-post consumption levels because of their labor schedules, resulting from different wage schedules. Guerron-Quintana (2007) conclude, that the relative consumption of the household is a linear function of the relative wage. This can be illustrated by the following function,

$$\hat{c}_{R,t}\left(i\right) = \Upsilon\, \hat{w}_{R,t}\left(i\right), \tag{12}$$

where Υ is a constant, $\hat{c}_{R,t}\left(i\right)$, and $\left(\hat{w}_{R,t}\left(i\right)\right)$ are the log-linear approximation of the individual consumption or individual wage relative to aggregate consumption or economy-wide wage respectively. Of course, the log-linear approximation requires that this relation only holds for small changes around the steady state.

To specify Υ, I evaluate the log-linear approximation of equation (11). The evaluation can be written in terms conditioning on deep parameters, the relative consumption, and the individual labor supply of a household:

$$\Theta_1 \hat{c}_{R,t}\left(i\right) + \Theta_2 \hat{h}_t\left(i\right) = \Theta_1 \hat{c}_{R,t}\left(i'\right) + \Theta_2 \hat{h}_t\left(i'\right). \tag{13}$$

Given the labor demand function (7) and equation (12), it is easily verified that the complete market condition of equal marginal utilities across households only holds for

$$\Upsilon = \varepsilon_w \cdot \frac{\Theta_2}{\Theta_1} = \varepsilon_w \cdot \frac{\bar{H}}{1-\bar{H}} \frac{\nu\left(1-\eta\right)\left(1-\chi\right)}{\eta\left(1+\Gamma\right)\left(1-\psi\right)}, \tag{14}$$

where $\bar{H}$ is the steady state labor supply and $\Gamma = A\left(1-\psi\right)^{-\nu}\left(1-\bar{H}\right)^{-\nu}$ is another helpful steady state condition.[5] Because the aggregate nominal wage is given by $\hat{w}_t = \theta_w \hat{w}_{t-1} + \left(1-\theta_w\right)\hat{w}_t\left(i\right)$ and the wage inflation is evaluated as $\hat{\pi}_t^w = \hat{w}_t - \hat{w}_{t-1}$, it is obvious that

$$\hat{w}_{R,t} = \frac{\theta_w}{1-\theta_w} \hat{\pi}_t^w.$$

Finally, it can be stated that the individual consumption level can be written in loga-

[5] For more details about the evaluation of this condition and for the discussion of the non-positiveness of Υ see Guerron-Quintana (2007).

rithmic terms as [6]

$$\hat{c}_t(i) = \hat{c}_t + \Upsilon \frac{\theta_w}{1-\theta_w} \hat{\pi}_t^w(i), \tag{15}$$

3.2 Entrepreneurs

Entrepreneurs manage the production of the wholesale good and are risk neutral. Following Bernanke et al. (1999) the entrepreneurs have a finite lifetime. In particular, with probability κ each entrepreneur survives to the next period. Each of those who have left are replaced by new entrepreneurs in next period. The entrepreneurs use the following production process to produce the wholesale good Y_t:

$$Y_t = \varepsilon_t K_{t-1}^{\alpha} \left(Z_{T,t} N_t\right)^{1-\alpha}, \tag{16}$$

where capital K_{t-1} is purchased at the end of period $t-1$ for the production of the wholesale goods in period t. The parameter α refers to the capital share used for production. The variable Z_t reflects the exogenous technology common to all entrepreneurs and is modeled as AR(1) process with drift:

$$Z_{T,t} = \exp\left(\hat{\mu} + Z_{T,t-1} + \epsilon_{T,t}\right), \tag{17}$$

where $\epsilon_{T,t}$ is i.i.d. normally distributed with standard deviation σ_T and μ is the technology growth path.

The variable ε_t captures an anticipated shock, equivalent to Christiano et al. (2007)[7], which is modeled in log-linearized terms as:

$$\hat{\varepsilon}_t = \rho_\varepsilon \hat{\varepsilon}_{t-1} + \epsilon_{\varepsilon,t-p} + \epsilon^{\star}_{\varepsilon,t}, \tag{18}$$

where $\epsilon_{\varepsilon,t}$ and $\epsilon^{\star}_{\varepsilon,t}$ are uncorrelated over time and with each other. The intuition of this shock process is that an impulse $t = 1$ suggests an increase in $\hat{\varepsilon}$ in $t = 1 + p$ periods, a modeling of $\epsilon^{\star}_{\varepsilon,t+p} = -\epsilon_{\varepsilon,t}$ implies that the shock in period $t = 1 + p$ is not realized and the boom episode will bust after p periods. Finally I assume that $\epsilon_{\varepsilon,t} \sim i.i.d.\ N\left(0, \sigma_\varepsilon^2\right)$.

The entrepreneurs demand a level of labor, N_t, for the production. The total level of labor is given by the households H_t and entrepreneurial hours worked H_t^e in period t,

[6] Note that, for the moment the analysis ignores any balanced growth path requirements. For the finally used equations see appendix A.

[7] This kind of anticipated shock was introduced by Beaudry and Portier (2006) and their former articles. Because of the similarities of the present research to Christiano et al. (2007), I, however mainly refer to these authors.

and can be written as:

$$N_t = H_t^{1-\Omega} \left(H_t^e\right)^{\Omega} \,, \tag{19}$$

where H^e is assumed to be inelastic and thus equal to one. This assumption is needed to ensure that new entrepreneurs have some funds available when starting out with production(see Gilchrist and Saito, 2006).

Let $P_{w,t}$ denote the nominal price of the wholesale goods and Q_t the price of capital at the stock market relative to the aggregate price P_t. Then, the entrepreneurs' real revenues can be written as the sum of production revenues and the real value of depreciated capital,

$$\frac{P_{w,t}}{P_t} K_{t-1}^{\alpha} \left(Z_{T,t} N_t\right)^{1-\alpha} + Q_t \left(1-\delta\right) K_{t-1},$$

where δ is the physical depreciation rate of capital.

At the end of period t, the entrepreneurs purchase capital K_t from the capital producers at the asset market price Q_t. The new amount of capital for production in $t+1$ is financed partly with net worth of the entrepreneurs and partly with debt borrowed from the households:

$$Q_t K_t = NW_t + \frac{D_t}{P_t} \tag{20}$$

Given the amount of capital available for production in period t, entrepreneurs demand households' and entrepreneurial labor. The first order conditions regarding labor choice are given by:

$$\left(1-\Omega\right)\left(1-\alpha\right) \frac{Y_t}{H_t} = \frac{W_t}{Pw, t} \tag{21}$$

and

$$\Omega \left(1-\alpha\right) \frac{Y_t}{H_t^e} = \frac{W_t^e}{Pw, t} \tag{22}$$

The optimal first-order condition for capital purchase is given, such that the marginal revenues and the marginal costs of capital are equalized:

$$E_t \left[R_{t+1}^s Q_t\right] = E_t \left[\frac{P_{w,t+1}}{P_{t+1}} \alpha \frac{Y_{t+1}}{K_t} + \left(1-\delta\right) Q_{t+1}\right] \tag{23}$$

Bernanke et al. (1999) define the external finance premium F_t as the ratio of costs of external funds to costs of internal funds:

$$F_t = \frac{E_t \left[R_{t+1}^s\right]}{E_t \left[R_t^N \frac{P_t}{P_{t+1}}\right]} \tag{24}$$

In the absence of financial market imperfections, the external finance premium does not exist ($F_t = 1$). The external finance premium is affected moreover, by the balance-sheet conditions of the entrepreneur. It increases if the ratio of capital expenditures to entrepreneurial net worth increases:

$$F_t = F\left(\frac{Q_t K_t}{NW_t}\right) = \left(\frac{Q_t K_t}{NW_t}\right)^{\sigma} \tag{25}$$

Following the approach of Gilchrist and Saito (2006) this parametric function is assumed; it is increasing for $NW_t < Q_t K_t$.

The aggregate net worth of an entrepreneur, NW_t, at the end of period t is defined as:

$$NW_t = \kappa\left(R_t^s Q_{t-1} K_{t-1} - E_{t-1}\left[R_t^s\right]\frac{D_{t-1}}{P_{t-1}}\right) + \frac{W^e}{P_t}, \tag{26}$$

where κ is the probability that an entrepreneur survived from period $t-1$ to t. Moreover, the aggregate net worth is defined as the sum of the equity held by entrepreneurs who have survived and the entrepreneurial real wage. The fraction of entrepreneurs who leave the business in period t consumes the residual equity:

$$C_t^e = (1-\kappa)\left(R_t^s S_{t-1} K_{t-1} - E_{t-1}\left[R_t^s\right]\frac{D_{t-1}}{P_{t-1}}\right), \tag{27}$$

where C_t^e refers to the consumption of the entrepreneur and $1-\kappa$ obviously captures the fraction of entrepreneurs who have left the business.

3.3 Capital Producers

The capital used by the entrepreneurs for the production of the wholesale good is produced with existing capital K_{t-1} and the investments in period t. The production process of new capital is characterized by the function

$$\Phi\left(Z_{I,t}\frac{I_t}{K_{t-1}}\right)K_{t-1},$$

where $\Phi(\cdot)$ is an increasing and concave function that satisfies the following steady-state conditions (see also Jermann, 1998)

$$\Phi(\cdot) = \delta, \quad \Phi'(\cdot) = 1, \text{and} \quad \Phi''(\cdot) = -\frac{1}{\zeta\frac{\bar{i}}{\bar{k}}} \quad \forall \quad \zeta > 0$$

The variable $Z_{I,t}$ refers to a cost push shock in the production process of capital and is given as an autoregressive process in the log-linearized form,

$$\hat{z}_{I,t} = \rho_I \hat{z}_{I,t-1} + \epsilon_{I,t} \tag{28}$$

with ρ_I the AR(1) parameter and $\epsilon_{I,t}$ the exogenous normally i.i.d. distributed shock parameter with standard deviation σ_I.

The aggregate capital accumulation is given by

$$K_t = \left(1 - \delta + \Phi\left(Z_{I,t}\frac{I_t}{K_{t-1}}\right)\right)K_{t-1}\ . \tag{29}$$

Finally, the first-order condition for capital producers is finally given by,

$$Q_t = \frac{1}{\Phi'\left(Z_{I,t}\frac{I_t}{K_{t-1}}\right)}, \tag{30}$$

what implies that investments and the quantity of new capital increases when the market price of capital, Q_t, increases.

3.4 Staggered Prices

The wholesale goods are purchased by an existing continuum of monopolistically competitive firms (retailers), who produce the final good at zero resource costs (see also Gilchrist and Saito, 2006). The final good, Y_t, is produced under the constant-return-to-scale production function:

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\varepsilon_p - 1}{\varepsilon_p}}\right]^{\frac{\varepsilon_p}{\varepsilon_p - 1}},$$

where $Y_t(i)$ is the retail good and let $P_t(i)$ be its nominal price, such that the corresponding price index, P_t is given by:

$$P_t = \left[\int_0^1 P_t(i)^{1-\varepsilon_p}\right]^{\frac{1}{1-\varepsilon_p}}.$$

It is assumed that consumers, capital producers, and the government demand the final good.

The demand curve of the retail good is given by the first-order condition of the monopolistically competitive firm:

$$Y_t(i) = \left[\frac{P_t}{P_t(i)}\right]^{\varepsilon_p} Y_t \tag{31}$$

As postulated by Calvo (1983) I assume that the prices are staggered. This means that a retailer can adjust his prices, $P_t^\star$, with probability $1-\theta_p$, independently from other retailers and independently of the subsequent price setting. Thus, a fraction of $1-\theta_p$ retailers adjust their prices in period t, while the rest of the retailers θ_p cannot adjust their prices and set $P_t(i) = \bar{\pi} P_{t-1}$. These assumption ca be written as aggregate price index in form of:

$$P_t = \left[\theta_p \left(\bar{\pi} P_{t-1}\right)^{1-\varepsilon_p} + \left(1-\theta_p\right)\left(P_t^\star\right)^{1-\varepsilon_p}\right]^{\frac{1}{1-\varepsilon_p}} \tag{32}$$

The real marginal costs for each retailer are given by the price ratio of the wholesale good and the final good, $P_{w,t}/P_t$. Furthermore, each retailer takes the demand curve and the wholesale price as given and set $P_t(i)$. Under these circumstances, the profit maximization of the retailer becomes

$$\max_{P_t(i)} \quad E_t \sum_{j=0}^{\infty} \theta_p^j m_{t+j} \left[\bar{\pi}^j P_t(i)\, Y_{t+j}(i) - MC_{t+j} Y_{t+i}(i)\right] . \tag{33}$$

MC_t denotes the nominal marginal cost of the retailer and m_t is the real stochastic discount factor given as $m_{t+j} = \beta^j \frac{\lambda_{t+j} P_t}{\lambda_t P_{t+j}}$. The first-order condition of this maximization problem implies that retailers set their prices in period t according to:

$$\frac{P_t(i)}{P_t} = \frac{\varepsilon_p}{\varepsilon_p - 1} \frac{E_t\left[\sum_{j=0}^{\infty} \theta_p^j m_{t+j} mc_{t+j} Y_{t+j}(i) \frac{P_{t+j}}{P_t}\right]}{E_t\left[\sum_{j=0}^{\infty} \theta_p^j m_{t+j} \bar{\pi}^j Y_{t+j}(i)\right]}, \tag{34}$$

where the mc_{t+j} refers to real marginal costs.

3.5 Government & Aggregate Resource Constraint

The general resource constraint of the economy is given by

$$Y_t = C_t + C_t^e + I_t + G_t\,. \tag{35}$$

In contrast to Bernanke et al. (1999), this research assumes that resource costs with respect to bankruptcy are negligible. This assumption is comparable to the assumption made by Gilchrist and Saito (2006).

Government expenditures are exogenous and financed by lump-sum taxes and money creation:

$$G_t = \frac{M_t - M_{t-1}}{P_t} + T_t \tag{36}$$

The government expenditures, G_t, are modeled as an exogenous process and can be written as AR(1) process in the log-linearized form as

$$\hat{g}_t = \rho_G \hat{g}_{t-1} + \epsilon_{G,t}, \tag{37}$$

where ρ_G is the autoregressive parameter and the noise $\epsilon_{G,t}$ is normally i.i.d. with standard deviation σ_G.

3.6 Monetary Policy Rules

The policy maker uses interest rate to lead monetary policy. As a benchmark policy rule I assume that the monetary policy has only information on past inflation and past output in the economy and sets the interest rate in log-linearized terms as follows:

$$\hat{r}_t^N = \gamma_R \hat{r}_{t-1}^N + \left(1 - \gamma_R\right)\left[\gamma_\pi \hat{\pi}_{t-1} + \gamma_Y \hat{y}_{t-1}\right]\ . \tag{38}$$

The different γ-parameters refer to different weights within the interest setting rule. The benchmark rule does not recognize any activities of the asset market directly.

4 Simulation

I simulate the model using a standard calibration following the recent literature. The financial frictions are modeled according to Bernanke et al. (1999) and Gilchrist and Saito (2006). As suggested by Gilchrist and Saito (2006) the steady-state leverage ratio ρ, the ratio of the market value of capital stock to the entrepreneurs' net worth, is 80%. Since one period in the model is a quarter, the elasticity of the finance premium or the risk spread is chosen to be 0.05. This implies a steady-state risk spread of 2.98%. The values of the price elasticity and the wage elasticity are set to be 11 and 5 and the probabilities to adjust prices or wages are calibrated to 0.75 and 0.65 respectively. The steady state growth path is chosen modestly with $\mu = .005$, which corresponds to an annual growth rate of 2.02%. Furthermore, with the discount factor $\beta = 0.995$ the steady-state quarterly risk-free rate is 1.26%. The probability κ that an entrepreneur survives the period is implied by the previously presented parameters.[8] The resulting probability $\kappa = .9604$ corresponds to the recent literature (Bernanke et al., 1999). The preference parameters are chosen to receive plausible steady-state values for the Frisch elasticity and the labor supply. The resulting Frisch elasticity of 0.535 is small but in line with recent findings of Justiniano and Primiceri (2006), while the steady state labor supply evaluated at 0.23 is at the lower end of the conventional wisdom. Table 1 sums up the deep parameters of the simulated model.

Parameter	Description	Value
β	discount factor	.995
A	preference parameter	.0075
χ	habit persistence in consumption	.4
ψ	habit persistence in leisure	.8
ν	preference parameter	1
η	power utility parameter	1.5
δ	depreciation rate	.025
α	capital share	.35
Ω	discount factor	.0154
μ	steady state growth rate	.005
$1/\zeta$	elasticity of the price of capital	.20
σ	elasticity of external finance premium	.05
ε_p	price elasticity	11
ε_w	wage elasticity	5
θ_p	Calvo parameter for prices	.75
θ_w	Calvo parameter for wages	.65
ρ	leverage	.8
κ	probability to survive	.9604

Table 1: Calibration of deep model parameters

The standard deviation of all shocks is set to 1%. The autoregressive parameters for shocks to capital adjustment costs and to government spending are chosen to be 0.95, while I follow Christiano et al. (2007) with respect to the technology shock and use $\rho_\varepsilon = 0.83$. Given the provided parameter γ_R in the monetary policy rule is equal to 0.8, figure 4 shows possible parameter combinations for past inflation and past output in order to obtain a stable equilibrium. The choice of $\gamma_\pi = 1.8$ and $\gamma_y = 0.15$ is similar to the rule used by Christiano et al. (2007). This parameter setting rule is used to achieve a benchmark calibration which illustrates the interactions within the economy. In the following, different monetary policy regimes will be discussed in more detail. All, above

[8] For more details about the calculation of the steady state see appendix A.2.

Parameter	Description	Value
ρ_I	AR(1) parameter capital adjustment cost process	.95
ρ_ε	AR(1) parameter technology process	0.83
ρ_G	AR(1) parameter government spending	.95
$\sigma_{T,t}$	standard deviation of anticipated technology shock	.01
$\sigma_{j,t}$	standard deviation of any other shock	.01
γ_R	weight on past nominal interest rate	0.8
γ_π	weight on past inflation	1.8
γ_y	weight on past output gap	.15

Table 2: Calibration of exogenous parameters and monetary policy parameters

mentioned parameters can be found in table 2.

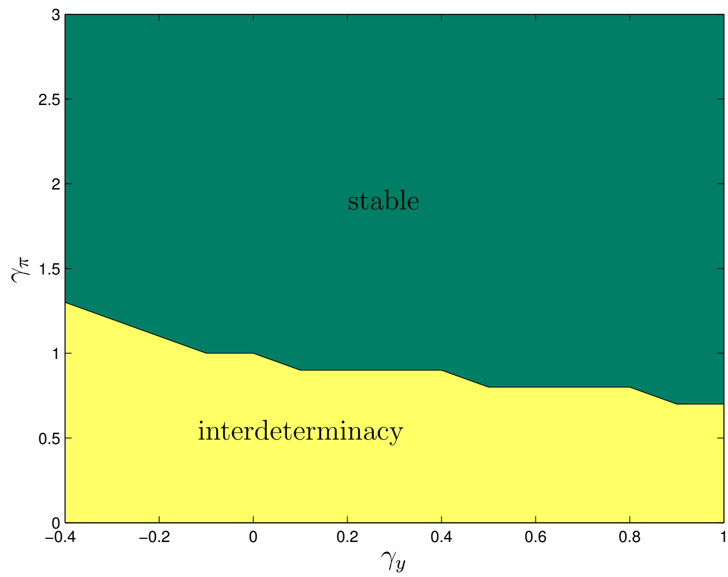

Figure 4: Interdeterminacy region for the simple monetary policy rule

Figure 5 presents the responses of selected variables to a anticipated shock to technology, which finally not occur. Recalling the stylized facts, the observed boom/bust episodes of the last decades had an average duration of six or seven years. Following Christiano et al. (2007) I simulate that the individuals in period t assume a level-shift of technology in sixteen periods (equal to four years).

As observed in the stylized facts, output, investments, hours worked, and real wages increase during the boom episode. At the point, the individuals recognize that the shock

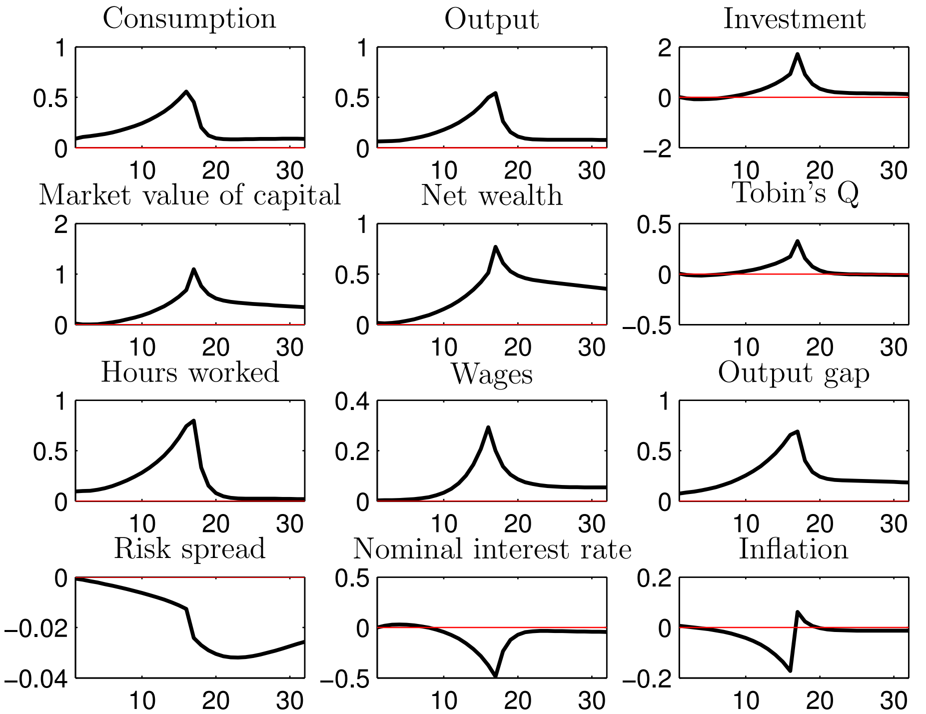

Figure 5: Impulse responses to a news shock which finally not occurs

does not occur, all these variables decrease. Furthermore, the inflation is declining during the boom period, which also in line with the stylized facts.

After the anticipation of the shock the entrepreneurs start to adjust their productivity. This increases the capital stock, investments, and hours worked. However, due to the nominal rigidities and a small Frisch elasticity the households are unwilling to reduce their nominal wages. This limits the increase of additional employment and explains the comparatively higher investments. The increasing net wealth of the entrepreneur reduces the external finance premium and makes credits more attractive for firms. Along with the decreasing costs of debt, the marginal costs reduce and inflation decreases, too. This is followed by increasing real wages. The inflation-targeting central bank recognizes that and starts to reduce the nominal interest rates. Unfortunately, due to a decreasing risk spread this additionally triggers a credit boom, what extends the stock market boom. Finally, it is worth pointing out that in the investigated economy, the magnitude of the boom essentially depends on the monetary policy, the nominal wage rigidities, and the Frisch elasticity of the households.

5 Theory and Data

In this section, the impulse responses of the investigated model are compared to selected variables. As discussed in section 2 I investigate the fluctuations of several business cycle facts around their trend. First, I compare the average fluctuations during the identified boom and bust episodes at the end of the 1980's and 1990's. Afterwards, I investigate the model with the stock market boom and bust at the end of the 1990's in more detail.

Figure 6 illustrates the response to a two percent anticipated technology shock, which finally not occurs and additionally the corresponding business cycle variables. As mentioned above, the model is able to replicate the signs of the variables during the boom as well as the bust episode. Of course, there exists a problem to replicate the correct timing of each variable wit respect to the data. The model also underestimates the impact of the bust on the variables. Additionally, the model cannot explain the strong increase of hours worked and wages compared to consumption and output. However, given the simplicity of the model as well as the standard parameterizations, the model is successful.

As a proper example of an anticipated technology shock, which finally not occurs often

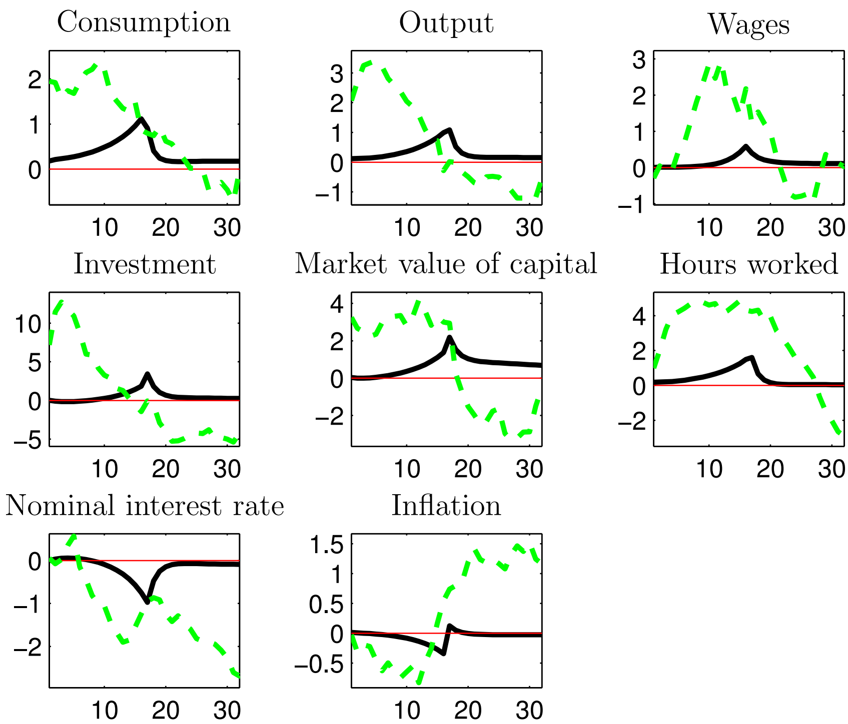

Figure 6: Impulse responses (solid line) and data (dashed line) for stock market booms in the 1980's and late 1990's

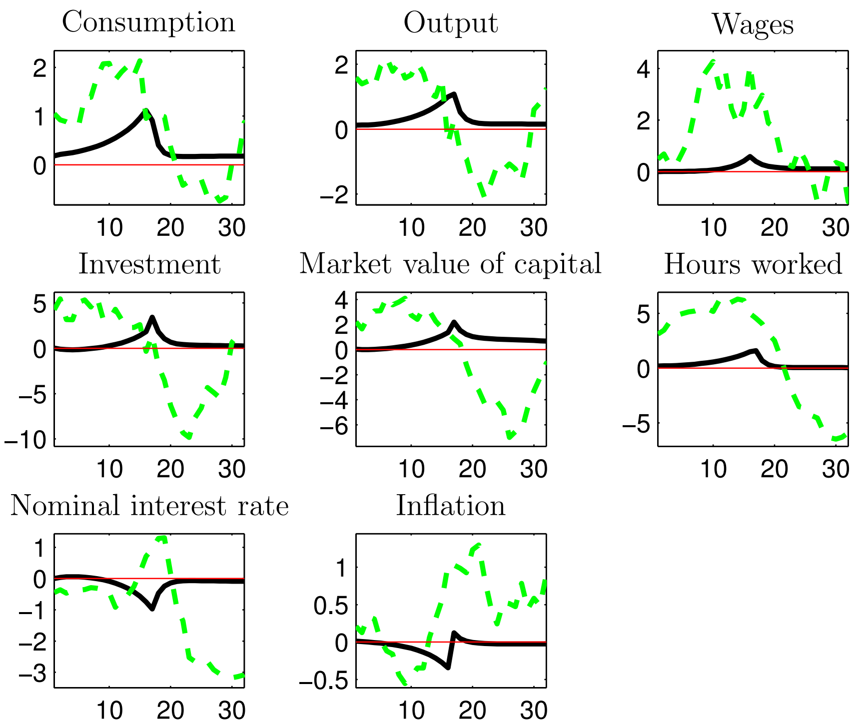

Figure 7: Impulse responses (solid line) and data (dashed line) for the stock market boom in the late 1990's

the ‘new economy boom’ is mentioned. For this reason figure 7 compares just the data of this episode with the model. Considering the nominal interest rates as well as the inflation behavior before the peak of this boom episode, the model is able to replicate the interaction of the monetary policy regime and the real economy in these days.

6 Monetary Policy

This section investigates the stabilization performance of the given simple policy rule. Therefore I investigate its performance regarding the respond coefficients under different policy regimes. I assume that the monetary authority has a standard loss function, equal to the weighted sum of unconditional variances of inflation, output gap, and changes in the nominal interest rate:

$$\mathscr{L} = Var\left(\pi_t\right) + \lambda_y Var\left(\Delta y_t\right) + \lambda_r Var\left(\Delta r_t^n\right) \ . \tag{39}$$

The weight $\lambda_y \geq 0$ measures the policy-maker’s preference to reduce output gap variability and $\lambda_r \geq 0$ the preference to reduce nominal interest rate variability, $\Delta r_t^n = r_t^n - r_{t-1}^n$, relative to inflation variability. The loss function used in this paper corresponds to this used by Küster and Wieland (2005), Coenen (2007), Levin and Williams (2003), or Levin, Wieland, and Williams (1999). Of course, it would be beneficial to use an micro-founded loss function derived from a second-order-approximation of the representative agent’s utility following Rotemberg and Woodford (1997) or based on a linear-quadratic approximation as postulated by Benigno and Woodford (2006). These welfare criterions would suggest weights that are functions of the model parameter. Unfortunately, the model previously presented is only accurate up to first-order. Due to this fact, I use this standard quadratic loss function, not to suggest optimal policy, moreover, to get an idea about the stabilization performance of the optimized monetary policy rule under different regimes.

Therefore, I investigate different sets of weights, which refer to different policy regimes. For $\lambda_y = \lambda_r = 0.1$ the monetary policy corresponds to a "strict" inflation-targeting monetary authority, while $\lambda_y, \lambda_r > 0$ characterizes a more "flexible" inflation-targeting authority (Küster and Wieland, 2005). The analyzed weights are $\lambda_y = \{0, 0.5, 1\}$ and $\lambda_r = \{0.1, 0.5, 1\}$, which are similar to those studied by Levin and Williams (2003) and Küster and Wieland (2005).

I calculate the optimized monetary policies, due to minimizing the loss-function. Dur-

	$\lambda_y = 0$			$\lambda_y = 0.5$			$\lambda_y = 1.0$		
	γ_r	γ_π	γ_y	γ_r	γ_π	γ_y	γ_r	γ_π	γ_y
$\lambda_r = 0.1$	0.7539	3.0450	-0.0665	0.7096	2.4918	-0.0619	0.9000	8.8436	0.1431
$\lambda_r = 0.5$	0.8220	4.4857	-0.0732	0.7797	3.5086	-0.0669	0.7751	3.7497	-0.0393
$\lambda_r = 1.0$	0.8136	4.2486	-0.0724	0.8096	4.3033	-0.0567	0.8421	5.8670	-0.0032

Table 3: Optimized monetary policy rules

ing the minimization it is ensured that the Blanchard-Kahn conditions for a stable unique solution are satisfied. I neglect the anticipated news shock during the minimization. Obviously, the finally obtained rules depend only on the five different shocks to technology, to a labor augmented technology, to adjustment costs, to monetary policy, and to government spending. This implies a degree of uncertainty by the central bank because the different regimes do not take into account the possibility of asset market booms triggered by overoptimistic expectations. This simplification allows to investigate how well the standardized monetary policy rules would work during asset market boom and bust episodes. Table 3 presents the optimized monetary policy rule coefficients under different regimes. Each of the rules is optimal regarding its loss function, which makes it impossible to compare the losses with each other. The results, especially the negative response to past output is a known phenomenon for money in the utility (Woodford, 2003).

Because the differences are small over the different regimes, in the following, I investigate the two most extreme regimes. At first, the strictly inflation-targeting monetary authority, $\lambda_y = 0$ and $\lambda_r = 0.1$ and, secondly, the more flexible inflation-targeting regime with modest changes of the nominal interest rate, $\lambda_r = 1$ and $\lambda_y = 1$.

Figure 8 illustrates the response of the economy to an anticipated technology shock, which finally not occurs, under "strict" inflation-targeting monetary policy (solid line) as well as under the mentioned "flexible" inflation targeting optimized policy rule (dashed line). It is obvious, that the differences between both are small. Both policies reduces the fluctuation during the boom and bust episode accordingly to the benchmark solution previously presented. Under both regimes, it is optimal to continuously increase the nominal interest rates during the boom. Due to the fact that the central bank does not reduce the nominal interest rate with respect to the decreasing inflation, the boom is not further fueled. This "leaning against the wind" policy avoids a credit expansion.

Moreover, it can be figured out that the more flexible monetary policy rule has an addi-

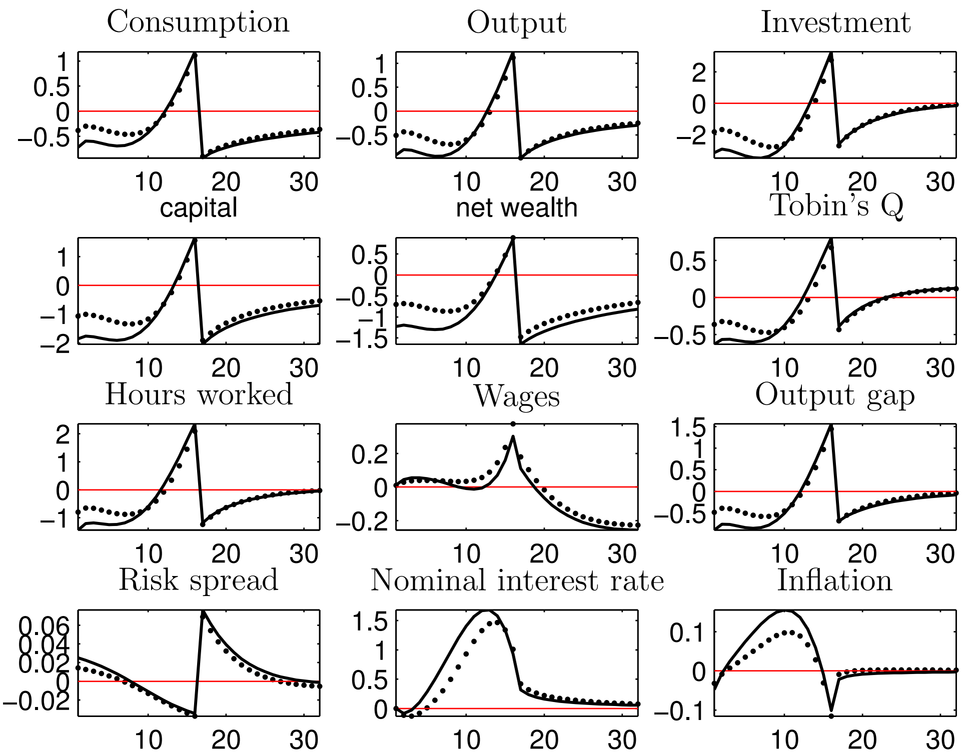

Figure 8: Relative response to an anticipated technology shock which finally not occurs using optimized policy rules. The solid line denotes the responses within a "strict" inflation-targeting regime while the dashed line denotes the responses in a "flexible" inflation targeting regime.

tional advantage because the central bank cares more about the changes of the nominal interest rate, thus the interest rate has a more slightly increase. Driven by this fact, the fluctuations are not as large, when the expectations about the future technology are disappointed.

To conclude the investigation of the different monetary policy regimes, it can be adhered that under any policy regime it is optimal to increase the nominal interest rate during a boom episode. Also for strictly inflation-targeting regimes it is advantageous to incorporate output into the monetary policy rule. However, such a strict policy would raise the nominal interest rate too much, in the hope to avoid an overshooting boom. Within the given model framework a more flexible monetary policy is welfare-increasing because it stabilizes the economy during the boom and during the bust more effectively.

7 Conclusion

In this paper, I have presented a DSGE model that is an extension of the model presented by Christiano et al. (2007). The extended model allows to simulate the joint rise of consumption, investment, output, hours worked, and especially real wages during an asset market boom and the overall fall during the bust. Furthermore, the standardized monetary policy rule yields a declining inflation during such a boom episode. All these are stylized facts of the observed boom and bust episodes in the 1980's and late 1990's.

The main contribution of explaining the simultaneous rise of hours worked and real wages is a necessary point to allow for a more detailed discussion regarding monetary policy during asset market booms. The use of nonseparable preferences between consumption and leisure, which are both habitually formed is necessary in order to obtain this simultaneous increase. Both features result in a small Frisch elasticity with respect to the conventional wisdom. Combined with nominal wage rigidities, the individuals are less willing to reduce their wages as a consequence of a technology shock. Obviously, this is not efficient with respect to potential employment. However, together with the decreasing inflation this allows to recover the observed increase of real wages in the stylized facts.

The investigation of different monetary policy regimes in this paper suggests that for any regime it is necessary to continuously increase the nominal interest rate throughout a stock market boom. This avoids an overshooting of the stock market boom and stabilizes the economy with respect to an unexpected bust of the stock market. Finally, the paper proposes that a "flexible" inflation-targeting monetary policy which is preferable to a "strict" inflation-targeting policy rule.

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A Calculations

The economy described in the paper follows the trend μ_t. Additionally, I add a the variable z_t:

$$s_t = \frac{z_t}{z_{t-1}}, \tag{A.3.-1}$$

what implies that shocks to labor augmented technology processes can be expressed as:

$$s_t = \exp\left(\mu + \epsilon_{\mu,t}\right). \tag{A.3.-2}$$

To write the equilibrium conditions in stationary terms, the set of variables has to be detrended by z_{t-1} as follows:

$$\tilde{c}_t = \frac{C_t}{z_{t-1}}, \qquad \tilde{y}_t = \frac{Y_t}{z_{t-1}}, \qquad \tilde{c}_t^e = \frac{C_t^e}{z_{t-1}}, \qquad \tilde{w}_t = \frac{W_t}{z_{t-1}}, \qquad \tilde{w}_t^e = \frac{W_t^e}{z_{t-1}}$$

$$\widetilde{mrs}_t = \frac{MRS_t}{z_{t-1}} \qquad \tilde{k}_{t-1} = \frac{K_{t-1}}{z_{t-1}}, \qquad \tilde{d}_{t-1} = \frac{D_{t-1}}{z_{t-1}}, \qquad \widetilde{nw}_{t-1} = \frac{NW_{t-1}}{z_{t-1}}, \qquad \tilde{\lambda}_t = \frac{\lambda_t}{z_{t-1}^{-\eta}}$$

A.1 FONCs

Because of the transformation of the equilibrium conditions into stationary equation all necessary conditions will be rewritten in this subsection.

$$H_t = 1 - L_t \tag{A.3.-3}$$

$$\tilde{\lambda}_t = \left(\tilde{c}_t - \chi\frac{\tilde{c}_{t-1}}{s_{t-1}}\right)^{-\eta}\left(A + \left(L_t - \psi L_{t-1}\right)^{\nu}\right)^{1-\eta} \tag{A.3.-4}$$

$$\widetilde{mrs}_t = \frac{\nu\left(\tilde{c}_t - \chi\frac{\tilde{c}_{t-1}}{s_{t-1}}\right)}{A\left(L_t - \psi L_{t-1}\right)^{1-\nu} + L_t - \psi L_{t-1}} \tag{A.3.-5}$$

$$1 = E_t\left[\beta\frac{\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t}s_t^{-\eta}R_t^N\frac{P_t}{P_{t+1}}\right] \tag{A.3.-6}$$

$$\tilde{y}_t = \varepsilon_t\tilde{K}_{t-1}^{\alpha}N_t^{1-\alpha}s_t^{1-\alpha} \tag{A.3.-7}$$

$$N_t = H_t\,(i)^{1-\Omega}\left(H_t^e\right)^{\Omega} \tag{A.3.-8}$$

$$Q_t\tilde{k}_t = \widetilde{nw}_t + \tilde{d}_t \tag{A.3.-9}$$

$$(1-\Omega)(1-\alpha)\frac{\tilde{y}_t}{H_t}mc_t = \tilde{w}_t \tag{A.3.-10}$$

$$\Omega\left(1-\alpha\right)\frac{\tilde{y}_t}{H_t^e}mc_t=\tilde{w}_t^e \tag{A.3.-11}$$

$$E_t\left[R_{t+1}^q Q_t\right]=E_t\left[\frac{P_{w,t+1}}{P_{t+1}}\alpha\frac{\tilde{y}_{t+1}}{\tilde{k}_t}+\left(1-\delta\right)Q_{t+1}\right] \tag{A.3.-12}$$

$$F_t=\frac{E_t\left[R_{t+1}^q\right]}{E_t\left[R_t^N\frac{P_t}{P_{t+1}}\right]} \tag{A.3.-13}$$

$$F_t=\left(\frac{Q_t\tilde{k}_t}{\widetilde{nw}_t}\right)^{\sigma} \tag{A.3.-14}$$

$$\widetilde{nw}_t s_t=\kappa\left(R_t^q Q_{t-1}\tilde{k}_{t-1}-E_{t-1}\left[R_t^q\right]\tilde{d}_{t-1}\right)+\tilde{w}^e \tag{A.3.-15}$$

$$\tilde{c}_t^e=\left(1-\kappa\right)\left(R_t^q Q_{t-1}\tilde{k}_{t-1}-E_{t-1}\left[R_t^q\right]\tilde{d}_{t-1}\right) \tag{A.3.-16}$$

$$\tilde{k}_t s_t=\left(1-\delta+\Phi\left(Z_{I,t}\frac{\tilde{i}_t}{\tilde{k}_{t-1}}\right)\right)\tilde{k}_{t-1} \tag{A.3.-17}$$

$$Q_t=\frac{1}{\Phi'\left(Z_{I,t}\frac{\tilde{i}_t}{\tilde{k}_{t-1}}\right)} \tag{A.3.-18}$$

The necessary first order conditions of the households to set wages:

$$E_t\left[\sum_{j=0}^{\infty}\left(\theta_w\beta\right)^j\left[\bar{\pi}^j\frac{W_t\left(i\right)}{P_{t+j}}-\frac{\varepsilon_w}{\varepsilon_w-1}MRS_{t+j}\left(H_{t+j}\left(i\right),C_{t+j}\left(i\right)\right)\right]\right]=0 \tag{A.3.-19}$$

with the corresponding aggregate wage index:

$$W_t=\left[\theta_w\left(\bar{\pi}W_{t-1}\right)^{1-\varepsilon_w}+\left(1-\theta_w\right)\left(W_t\left(i\right)\right)^{1-\varepsilon_w}\right]^{\frac{1}{1-\varepsilon_w}} \tag{A.3.-20}$$

Similar, the first order condition of the monopolistic firms to set their prices:

$$\frac{P_t\left(i\right)}{P_t}=\frac{\varepsilon_p}{\varepsilon_p-1}\frac{E_t\left[\sum_{j=0}^{\infty}\theta_p^j m_{t+j}mc_{t+j}Y_{t+j}\left(i\right)\frac{P_{t+j}}{P_t}\right]}{E_t\left[\sum_{j=0}^{\infty}\theta_p^j m_{t+j}\bar{\pi}^j Y_{t+j}\left(i\right)\right]}, \tag{A.3.-21}$$

and also the corresponding aggregate price index:

$$P_t=\left[\theta_p\left(\bar{\pi}P_{t-1}\right)^{1-\varepsilon_p}+\left(1-\theta_p\right)\left(P_t\left(i\right)\right)^{1-\varepsilon_p}\right]^{\frac{1}{1-\varepsilon_p}} \tag{A.3.-22}$$

The wage inflation is described by the following equation:

$$\frac{\pi_{w,t}}{\pi_t}=\frac{\tilde{w}_t}{\tilde{w}_{t-1}}s_{t-1} \tag{A.3.-23}$$

Finally, the aggregate resource constraint of the economy:

$$\tilde{y}_t = \tilde{c}_t + \tilde{c}_t^e + \tilde{i}_t + \tilde{g}_t \tag{A.3.-24}$$

The economy is closed by the remaining structural shock equations and the monetary policy rule described in the corresponding section.

A.2 Steady State

To calculate the steady state of the model, lets take the following as given:

The steady state values of technology and cost-function for producing capital are 1 and the growth path is given through $\exp(\mu)$:

$$\bar{z}_T = \bar{z}_I = 1 \quad \text{and} \quad \bar{s} = e^{\mu}; \tag{A.3.-25}$$

The government spending is approximately 20% of the total output of the economy:

$$\frac{\bar{g}}{\bar{y}} = 0.2 \tag{A.3.-26}$$

Further, there exists no inflation, $\bar{\pi} = 1$, and the real marginal costs are:

$$\overline{mc} = \frac{\varepsilon_p - 1}{\varepsilon_p} \tag{A.3.-27}$$

The steady state price of capital is:

$$\bar{q} = 1 \tag{A.3.-28}$$

Given these assumption and the parameter φ for leverage of the entrepreneurs, it holds:

$$\frac{\bar{k}}{\overline{nw}} = 1 + \varphi \tag{A.3.-29}$$

Given these assumption, its easy to solve for:

$$\bar{r}^N = \frac{e^{\mu}}{\beta} \qquad \bar{f} = \left[\frac{\bar{k}}{\overline{nw}}\right]^{\sigma} \qquad \bar{r}^S = \bar{f}\bar{r}^N \tag{A.3.-30}$$

From equation (A.3.-17) and (A.3.-12) we can solve for:

$$\frac{\bar{i}}{\bar{k}} = e^{\mu} - 1 + \delta \qquad \frac{\bar{y}}{\bar{k}} = \frac{\bar{r}^{q} - 1 + \delta}{\alpha \cdot \overline{mc}} \tag{A.3.-31}$$

Given (eq. A.3.-11) and (eq. A.3.-15),it is easy to see that for $\bar{r}^{k}$ it has also to hold that:

$$0 = \kappa \bar{r}^{q} + \frac{\Omega (1-\alpha)}{\alpha} \frac{\bar{k}}{\overline{nw}} \left(\bar{r}^{q} - 1 + \delta\right) \tag{A.3.-32}$$

To capture this condition the parameter κ is set to solve this equation.

Now it is easy to solve for:

$$\frac{\bar{w}^{e}}{\bar{k}} = \Omega (1-\alpha) \frac{\bar{y}}{\bar{k}} \overline{mc} \tag{A.3.-33}$$

$$\frac{\bar{c}^{e}}{\bar{k}} = (1-\kappa) \bar{r}^{q} \left(\frac{\bar{k}}{\overline{nw}}\right)^{-1} \tag{A.3.-34}$$

Following the market clearing condition implies that:

$$\frac{\bar{c}}{\bar{y}} = 1 - \frac{\bar{i}}{\bar{k}} \frac{\bar{k}}{\bar{y}} - \frac{\bar{c}^{e}}{\bar{k}} \frac{\bar{k}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \tag{A.3.-35}$$

Given the information that $\bar{w} = \frac{\varepsilon_{w}}{\varepsilon_{w}-1} \overline{mrs}$ and using equation (A.3.-5) and (A.3.-10)we can find:

$$\left(\frac{\bar{c}}{\bar{y}}\right)^{-1} \cdot \frac{\varepsilon_{w} - 1}{\varepsilon_{w}} \frac{(1-\Omega)(1-\alpha)\left(1-\psi\right)\overline{mc}}{\left(1 - \frac{\chi}{\exp(\mu)}\right)\nu} = \frac{1-\bar{l}}{\bar{l}\,(1-\Gamma)}, \tag{A.3.-36}$$

where

$$\bar{l} = 1 - \bar{h} \qquad \text{and} \qquad \Gamma = A\left(1-\psi\right)^{-\nu} \bar{l}^{-\nu}. \tag{A.3.-37}$$

Given the equations A.3.-36 and A.3.-37 we can now determine the steady state values for h and l.

Under the assumption that the entrepreneur's steady state supply of hours worked is constant and 1 its also holds that,

$$\bar{n} = \bar{h}^{1-\Omega} \cdot 1^{\Omega} \tag{A.3.-38}$$

and

$$\bar{k} = \left(\frac{\bar{y}}{\bar{k}}\right)^{\frac{1}{\alpha-1}} \bar{n} e^{\mu}. \tag{A.3.-39}$$

Given all these results, we can now solve for:

$$\bar{c}, \bar{c}^e, \bar{g}, \bar{i}, \bar{w}^e, \overline{nw}, \bar{\lambda}, \overline{mrs}, \text{ and } \bar{w}$$

A.3 Log-Linearization

The fluctuation of leisure around its steady state are given by:

$$\hat{l}_t = -\frac{\bar{h}}{1-\bar{h}}\hat{h}_t \tag{A.3.-40}$$

Given the first order condition for the wages (A.3.-19) and extend the equation with W_t/W_t and W_{t+j}/W_{t+j}. Afterwards, define real wages, $w_t = W_t/P_t$, relative wages, $W_{R,t} = W_t(i)/W_t$, and finally the nominal wage inflation, $\pi_t^w = s_{t-1}\cdot W_t/(W_{t-1}\bar{\pi})$; the corresponding FONC can rewritten as:

$$E_t\left[\sum_{j=0}^{\infty}(\theta_w\beta)^j\left[W_{R,t}\left(\prod_{s=1}^{j}\frac{1}{\pi_{t+s}^w}\right)\tilde{w}_{t+j}-\frac{\varepsilon_w}{\varepsilon_w-1}\widetilde{MRS}_{t+j}\left(H_{t+j}(i),C_{t+j}(i)\right)\right]\right]=0 \tag{A.3.-41}$$

Doing log-linearize the equation and respect that for steady state holds $\bar{\pi}^w = 1$ and $\bar{w} = \frac{\varepsilon_w}{\varepsilon_w-1}\overline{MRS}$, it is easy to show that the following holds:

$$\frac{1}{1-\beta\theta_w}\hat{w}_{R,t}+\sum_{j=0}^{\infty}(\beta\theta_w)^j\hat{\tilde{w}}_{t+j}-\sum_{j=0}^{\infty}(\beta\theta_w)^j\sum_{s=1}^{j}\hat{\pi}_{t+s}^w=\sum_{j=0}^{\infty}(\beta\theta_w)^j\widehat{\widetilde{mrs}}_t(i) \tag{A.3.-42}$$

The individual marginal substitution rate can written in log-linear terms as:

$$\widehat{\widetilde{mrs}}_t(i)=\left(\frac{1}{1-\frac{\chi}{\mu}}\right)\left(\hat{\tilde{c}}_t(i)-\frac{\chi}{\mu}\left(\hat{\tilde{c}}_{t-1}-\hat{s}_{t-1}\right)\right)-\left[\frac{\Gamma(1-\upsilon)+1}{1+\Gamma}\right]\frac{\bar{h}}{1-\bar{h}}\frac{1}{1-\psi}\left(\hat{h}_t(i)-\psi\hat{h}_{t-1}\right) \tag{A.3.-43}$$

Using know the knowledge about the aggregate labor demand and the evaluated aggregate consumption level, the corresponding individual levels in logarithmic terms are:

$$\hat{h}_{t+j}(i)=\hat{h}_{t+j}-\varepsilon_w\left(\hat{w}_{R,t}-\sum_{s=1}^{j}\hat{\pi}_{t+s}^w\right) \tag{A.3.-44}$$

$$\hat{c}_{t+j}(i)=\hat{c}_{t+j}+\Upsilon\left(\hat{w}_{R,t}-\sum_{s=1}^{j}\hat{\pi}_{t+s}^w\right) \tag{A.3.-45}$$

For simplicity, define:

$$\hat{\Theta}_t = \left(\frac{1}{1-\frac{\chi}{\mu}}\right)\left(\hat{\hat{c}}_t - \frac{\chi}{\mu}\left(\hat{\hat{c}}_{t-1} - \hat{s}_{t-1}\right)\right) - \left[\frac{\Gamma(1-\upsilon)+1}{1+\Gamma}\right]\frac{\bar{h}}{1-\bar{h}}\frac{1}{1-\psi}\left(\hat{h}_t - \psi\hat{h}_{t-1}\right) \quad \text{(A.3.-46)}$$

and

$$\Xi = \frac{\Upsilon}{1-\frac{\chi}{\mu}} + \left[\frac{\Gamma(1-\upsilon)+1}{1+\Gamma}\right]\frac{\bar{h}}{1-\bar{h}}\frac{\varepsilon_w}{1-\psi}, \quad \text{(A.3.-47)}$$

additionally use equations (A.3.-43), (A.3.-44), and (A.3.-45) to rewrite (A.3.-42) as:

$$\frac{1-\Xi}{1-\beta\theta_w}\hat{w}_{R,t} + \sum_{j=0}^{\infty}\left(\beta\theta_w\right)^j\hat{\hat{w}}_{t+j} - (1-\Xi)\sum_{j=0}^{\infty}\left(\beta\theta_w\right)^j\sum_{s=1}^{j}\hat{\pi}^w_{t+s} = \sum_{j=0}^{\infty}\left(\beta\theta_w\right)^j\hat{\Theta}_t \quad \text{(A.3.-48)}$$

After some algebra and re-arranging the equation can also be expressed as:

$$\frac{1-\Xi}{1-\beta\theta_w}\hat{w}_{R,t} = \frac{(1-\Xi)\beta\theta_w}{1-\beta\theta_w}\hat{w}_{R,t+1} + \frac{(1-\Xi)\beta\theta_w}{1-\beta\theta_w}\hat{\pi}^w_{t+1} + \hat{\Theta}_t - \hat{\hat{w}}_t \quad \text{(A.3.-49)}$$

As written at the end of subsection 3.1, it is known that $\hat{w}_{R,t} = \frac{\theta_w}{1-\theta_w}\hat{\pi}^w_t$, which allows to rewrite the equation above in the following familiar way

$$\hat{\pi}^w_t = \beta\hat{\pi}^w_{t+1} + \frac{\left(1-\beta\theta_w\right)(1-\theta_w)}{(1-\Xi)\theta_w}\left(\hat{\Theta}_t - \hat{\hat{w}}_t\right), \quad \text{(A.3.-50)}$$

as shown by Woodford (2003), Ξ depends on the inverse of the Frisch elasticity (FE) of labor supply like $\Xi = -\varepsilon_w/\mathrm{FE}$.

From the complete capital market assumption it is known that the marginal utility across households has to be constant. Taking into account the findings from the previous sections, the log-linear formulation is is given by:

$$\hat{\lambda}_t = \left(\frac{-\eta}{1-\frac{\chi}{\mu}}\right)\left(\hat{\hat{c}}_t - \frac{\chi}{\mu}\left(\hat{\hat{c}}_{t-1} - \hat{s}_{t-1}\right)\right) - \left[\frac{\upsilon\left(1-\eta\right)}{1+\Gamma}\right]\frac{\bar{h}}{1-\bar{h}}\frac{1}{1-\psi}\left(\hat{h}_t - \psi\hat{h}_{t-1}\right). \quad \text{(A.3.-51)}$$

Finally, the euler equation completes the households first order conditions and can be written in log-linear terms as:

$$\hat{\hat{\lambda}}_t + \eta\hat{s}_t = E_t\left[\hat{r}^N_t + \hat{\hat{\lambda}}_{t+1} - \hat{\pi}_{t+1}\right] \quad \text{(A.3.-52)}$$

For the entrepreneurial sector the log-linearized equations are:

Technology:

$$\hat{\hat{y}}_t = \hat{\varepsilon}_t + \alpha \hat{\hat{k}}_{t-1} + (1-\alpha)\,\hat{n}_t + (1-\alpha)\,\hat{s}_t \tag{A.3.-53}$$

with

$$\hat{n}_t = (1-\Omega)\,\hat{h}_t. \tag{A.3.-54}$$

Real marginal cost:

$$\hat{mc}_t = \hat{\hat{w}}_t - \hat{\hat{y}}_t + \hat{h}_t \tag{A.3.-55}$$

Entrepreneurial wage:

$$\hat{w}_t^e = \hat{\hat{y}}_t + \hat{mc}_t \tag{A.3.-56}$$

The net worth of the entrepreneur is given through:

$$\widehat{nw}_t + \hat{s}_t = \kappa \frac{\bar{R}^q}{\bar{s}} \frac{\bar{k}}{\overline{nw}} \left(\hat{r}_t^q - E_{t-1}\left[\hat{r}_t^q\right]\right) + \kappa \frac{\bar{R}^q}{\bar{s}} \left(\widehat{nw}_{t-1} + E_{t-1}\left[\hat{r}_t^q\right]\right) + \frac{\bar{w}^e}{\overline{nw}\,\bar{s}} \hat{w}_t^e \tag{A.3.-57}$$

Following, the corresponding consumption of the entrepreneur is given by:

$$\hat{\hat{c}}_t^e = (1-\kappa)\,\frac{\bar{R}^q}{\bar{c}^e} \bar{k} \left(\hat{r}_t^q - E_{t-1}\left[\hat{r}_t^q\right]\right) + (1-\kappa)\,\frac{\bar{R}^q}{\bar{c}^e} \overline{nw} \left(\widehat{nw}_{t-1} + E_{t-1}\left[\hat{r}_t^q\right]\right) \tag{A.3.-58}$$

The term spread $\hat{f}$ implies the following equation on the capital market side

$$\hat{f}_t = E_t\left[\hat{r}_{t+1}^q\right] + E_t\left[\hat{\pi}_{t+1}\right] - \hat{r}_t^N \tag{A.3.-59}$$

and on firm-level

$$\hat{f}_t = \sigma\left(\hat{\hat{k}}_t + \hat{q}_t - \widehat{nw}_t\right). \tag{A.3.-60}$$

For the expected return on capital the following equation can established

$$E_{t-1}\left[\hat{r}_t^q\right] = \frac{\bar{R}^q - (1-\delta)}{\bar{R}^q} \left(\hat{mc}_t + \hat{\hat{y}}_t - \hat{\hat{k}}_{t-1}\right) + \frac{1-\delta}{\bar{R}^q} \hat{q}_t - \hat{q}_{t-1} \tag{A.3.-61}$$

For the capital producers the necessary log-linearized equations are:

Capital accumulation:

$$\bar{s}\hat{s}_t + \bar{s}\hat{\hat{k}}_t = (1-\delta)\,\hat{\hat{k}}_{t-1} + (\bar{s} - 1 + \delta)\left(\hat{z}_{I,t} + \hat{\hat{i}}_t\right) \tag{A.3.-62}$$

The cost of capital are given through:

$$\hat{q}_t = \frac{1}{\zeta}\hat{\hat{i}}_t - \frac{1}{\zeta}\hat{\hat{k}}_{t-1} + \frac{1}{\zeta}\hat{z}_{I,t} \tag{A.3.-63}$$

Similar to the evaluation of the wage inflation equation above, I use first order condition for the optimal price (A.3.-21) and define relative prices, $P_{R,t} = P_t(i)/P_t$. Additionally, using the nominal price inflation is given by $\pi_t = P_t/(P_{t-1}\bar{\pi})$, the elasticity condition,

$$\tilde{y}_{t+j}(i) = \tilde{y}_{t+j}\left(\frac{P_t(i)}{P_t}\frac{P_t\bar{\pi}^j}{P_{t+j}}\right)^{-\varepsilon_p},$$

and the equation for the pricing kernel

$$\tilde{m}_{t+j} = \beta^j \frac{\tilde{\lambda}_{t+j}P_t}{\tilde{\lambda}_t P_{t+j}}\left(\frac{z_{t+j}}{z_t}\right)^{-\eta}.$$

The transformed FONC for the optimal price is then:

$$P_{R,t}E_t\left[\sum_{j=0}^{\infty}(\theta_p\beta)^j\frac{\tilde{\lambda}_{t+j}}{\tilde{\lambda}_t}\left(\prod_{s=1}^{j}\frac{1}{\pi_{t+s}}\right)\left(\frac{z_{t+j}}{z_t}\right)^{-\eta}\tilde{y}_{t+j}\left(P_{R,t}\frac{P_t\bar{\pi}^j}{P_{t+j}}\right)^{-\varepsilon_p}\right] = \tag{A.3.-64}$$
$$\frac{\varepsilon_p}{\varepsilon_p-1}E_t\left[\sum_{j=0}^{\infty}(\theta_p\beta)^j\frac{\tilde{\lambda}_{t+j}}{\tilde{\lambda}_t}\left(\frac{z_{t+j}}{z_t}\right)^{-\eta}mc_{t+j}\tilde{y}_{t+j}\left(P_{R,t}\frac{P_t\bar{\pi}^j}{P_{t+j}}\right)^{-\varepsilon_p}\right].$$

Doing log-linearize the equation and respect that for steady state holds $\bar{\pi} = 1$ and $\frac{\varepsilon_p-1}{\varepsilon_p} = \overline{mc}$, it is easy to show that the following holds:

$$\frac{1}{1-\beta\theta_p}\hat{p}_{R,t} - \sum_{j=0}^{\infty}(\beta\theta_p)^j\sum_{s=1}^{j}\hat{\pi}_{t+s} = \sum_{j=0}^{\infty}(\beta\theta_p)^j\,\widehat{mc} \tag{A.3.-65}$$

Employing that $\hat{p}_{R,t} = \frac{\theta_p}{\theta_p-1}\hat{\pi}_t$ and some algebra the finally log-linearized inflation equation is given by:

$$\hat{\pi}_t = \beta E_t[\hat{\pi}_{t+1}] + \frac{(1-\beta\theta_p)(1-\theta_p)}{\theta_p}\hat{m}c_t \tag{A.3.-66}$$

With the knowledge about the inflation, its easy to figure out the interaction between price inflation and nominal wage inflation.

$$\hat{\pi}_t^w - \hat{\pi}_t = \hat{\hat{w}}_t - \hat{\hat{w}}_{t-1} + \hat{s}_{t-1} \tag{A.3.-67}$$

The aggregate resource constraint is characterized by:

$$\bar{y}\hat{\hat{y}}_t = \bar{c}\hat{c}_t + \bar{c}^e\hat{c}_t^e + \bar{i}\hat{\hat{i}}_t + \bar{g}\hat{\hat{g}}_t \tag{A.3.-68}$$

The number of exogenous state variables within the model will be extended by the different shock process, which introduces different impulses into the economy.

Labor augmenting technology shock:

$$\hat{s}_t = \epsilon_{T,t} \tag{A.3.-69}$$

Anticipated technology shock:

$$\hat{\varepsilon}_t = \rho_\varepsilon \hat{\varepsilon}_{t-1} + \epsilon^1_{\varepsilon,t-12} + \epsilon^2_{\varepsilon,t} \tag{A.3.-70}$$

Government spending shock:

$$\hat{\hat{g}}_t = \rho_G \hat{\hat{g}}_{t-1} + \epsilon_{G,t} \tag{A.3.-71}$$

Capital adjustment cost shock:

$$\hat{z}_{I,t} = \rho_I \hat{z}_{I,t-1} + \epsilon_{I,t}, \tag{A.3.-72}$$

Finally, the monetary policy, which closes the economy is given by:

$$\hat{r}_t^N = \gamma_R \hat{r}_{t-1}^N + (1-\gamma_R)\left[\gamma_\pi \hat{\pi}_{t-1} + \gamma_Y \hat{\hat{y}}_{t-1} + \gamma_Q \hat{\hat{q}}_{t-1}\right] \tag{A.3.-73}$$

Up to this point the model is closed and can be solved. Additional corresponding interesting variables in levels values are:
Consumption:

$$\hat{c}_t = \hat{\hat{c}}_t + \hat{z}_{t-1} \tag{A.3.-74}$$

Investment:

$$\hat{i}_t = \hat{\hat{i}}_t + \hat{z}_{t-1} \tag{A.3.-75}$$

Capital:

$$\hat{k}_t = \hat{\hat{k}}_t + \hat{z}_t \tag{A.3.-76}$$

Output:

$$\hat{y}_t = \hat{\hat{y}}_t + \hat{z}_{t-1} \tag{A.3.-77}$$

Wages:

$$\hat{w}_t = \hat{\hat{w}}_t + \hat{z}_{t-1} \tag{A.3.-78}$$

B Data

Within this paper I use several macro and financial time series. This appendix describes some modifications and especially the source of the raw data. The finally used frequency of all data is quarterly.

Nominal GDP: This is a measure for the nominal GDP given by the series *GDP, Gross Domestic Product* at the Federal Reserve Board of St. Louis. It is measured in billions of dollars. Source: *http://research.stlouisfed.org/fred2/*.

Private Consumption: Nominal consumption expenditures for non-durables and services is the sum of the respective values of the series *PCND, Personal Consumption Expenditures: Nondurable Goods* and *PCESV, Personal Consumption Expenditures: Services* at the Federal Reserve Board of St. Louis. Both series are measured in billions of dollars. Source: *http://research.stlouisfed.org/fred2/*

Implicit Consumption Deflator This series is *BEA: NIPA table 1.1.5 line 2* divided by *BEA: NIPA table 1.1.6 line 2*.

Private Investment: Total real private investment is the sum of the respective nominal values of the series *BEA NIPA table 1.1.6 line 6 (A006RX1)* and *PCDG, Personal Consumption Expenditures: Durable Goods* at the Federal Reserve Board of St. Louis and finally deflated by the consumption deflator mentioned above (billions of dollars). Source: *http://research.stlouisfed.org/fred2/*

Hours worked: This index series (1992=100) is measured as hours worked in non-farm business sectors by the Bureau of Labor Statistics. The series' identification number is: *PRS85006033*. Source: *http://www.bls.gov/data*.

Wage: The wage rate is the series *COMPNFB, Nonfarm Business Sector: Compensation Per Hour* at the Federal Reserve Board of St. Louis.
Source: *http://research.stlouisfed.org/fred2/*

Civilian Population: This is a quarterly measure for the population given by the respective average of the monthly values of the series *CNP16OV, Civilian Noninstitutional Population* at the Federal Reserve Board of St. Louis. The numbers have been converted from thousands to billions.
Source: *http://research.stlouisfed.org/fred2/*

S&P 500: The quarterly nominal price index of the S&P 500 is calculated by the quarterly average of monthly values of this series. The monthly values are averages of daily closing prices calculated by Robert J. Shiller and provided on his website.
Source: *http://www.econ.yale.edu/ shiller/data.htm*

C Impulse Responses

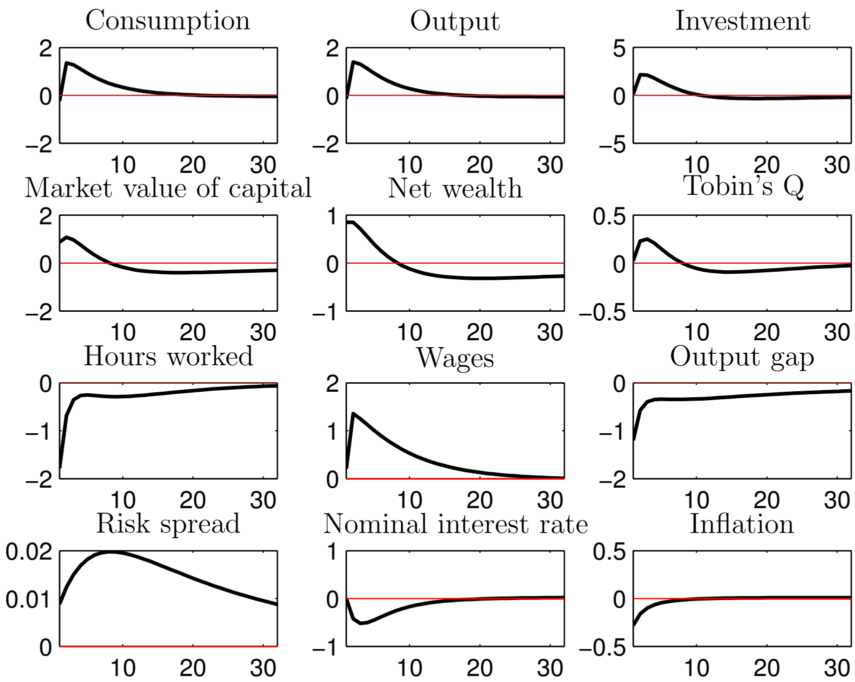

Figure 9: Impulse Responses to productivity shock

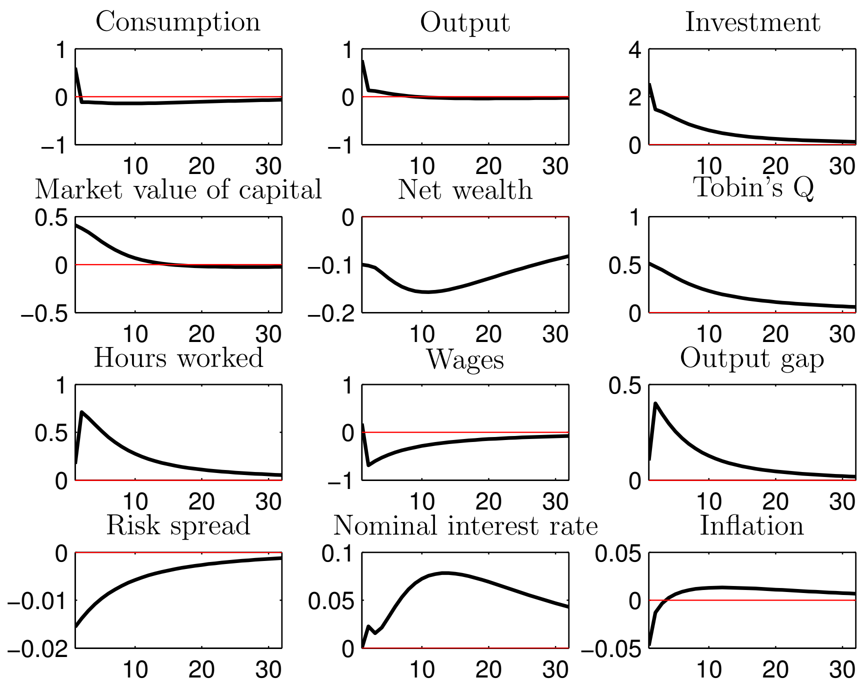

Figure 10: Impulse Responses to a labor augmented productivity shock

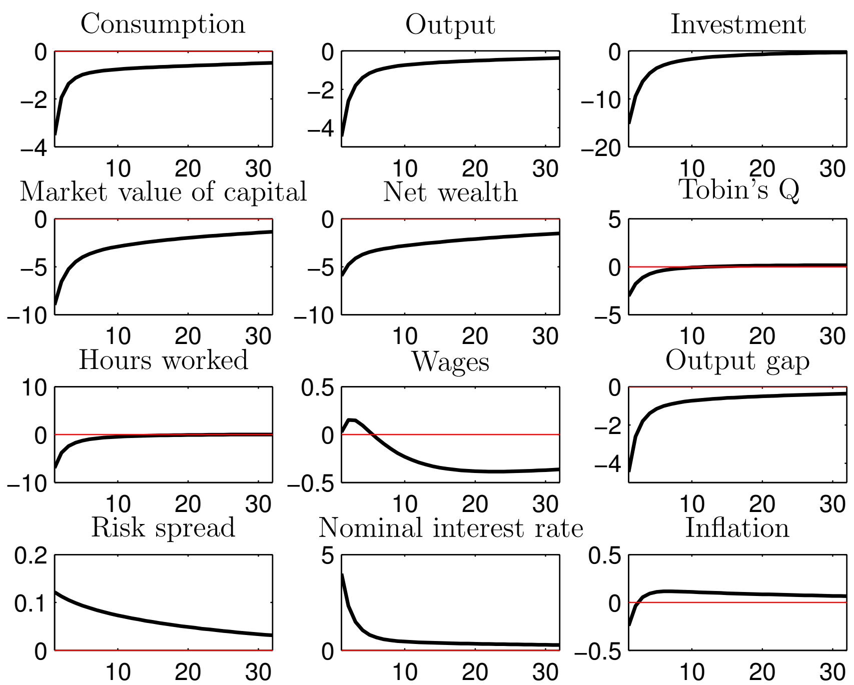

Figure 11: Impulse Responses to a monetary policy shock

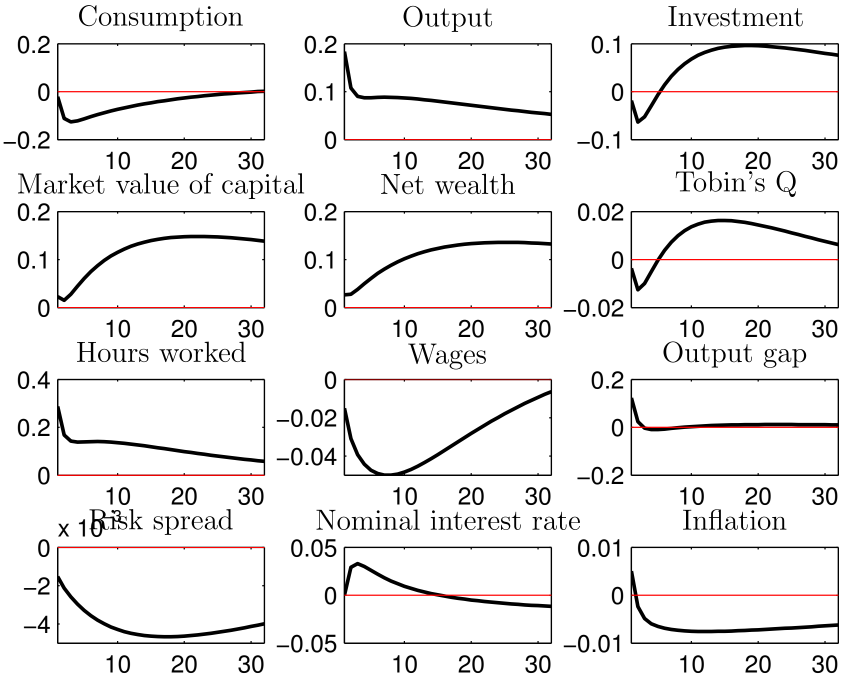

Figure 12: Impulse Responses to a government spending shock

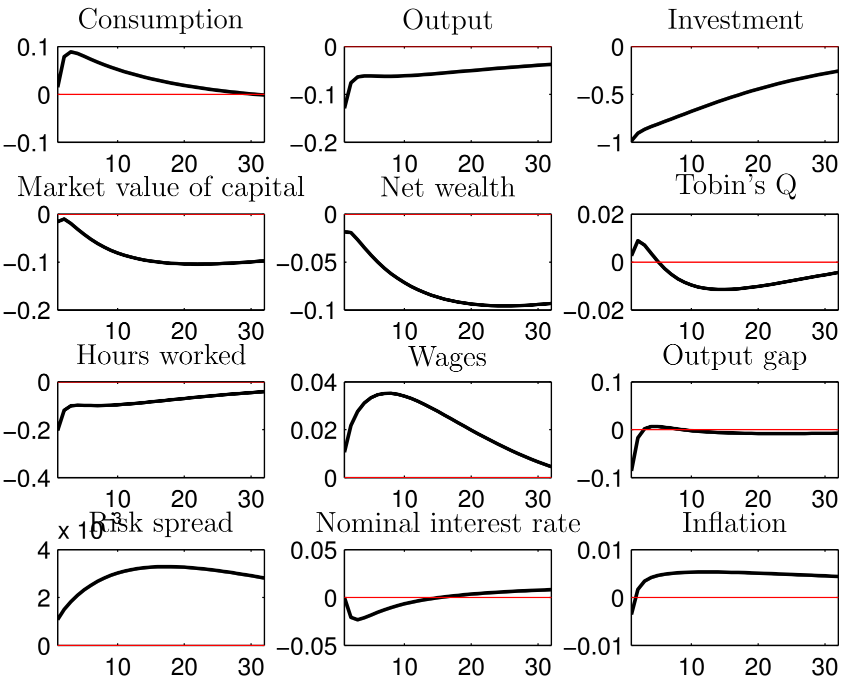

Figure 13: Impulse Responses to a adjustment cost shock