News and Financial Intermediation in Aggregate Fluctuations

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Abstract

We develop a two-sector DSGE model with financial intermediation to investigate the role of news as a driving force of the business cycle. We find that news about future capital quality is a significant source of aggregate fluctuations, accounting for around 37% in output variation in cyclical frequencies. Financial intermediation is essential for the importance and propagation of capital quality shocks. In addition, news shocks in capital quality generate **aggregate** and **sectoral** comovement as in the data and is consistent with procyclical movements in the value of capital. From a historical perspective, news shocks to capital quality are to a large extent responsible for the recession following the 1990s investment boom and the latest recession following the financial crisis, but played a much smaller role during the recession at the beginning of the 1990s. This is in line with the belief that revisions of overoptimistic expectations contributed to the last two recessions while movements in fundamentals played a much bigger role for the recession at the beginning of the 1990s.

Keywords: News, Anticipation effects, Business cycles, DSGE, Bayesian estimation.

JEL Classification: E2, E3.

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1 Introduction

"What shocks are responsible for economic fluctuations? Despite at least two hundred years in which economists have observed fluctuations in economic activity, we still are not sure." (Cochrane (1994), page 1).

This statement was made almost 20 years ago, and yet it still seems almost as valid today as it did then. However, in the intervening years, research into the sources of business cycle fluctuations has made important progress. While total factor productivity (TFP) or monetary shocks had often been potential candidates, recently, Fisher (2006) and Justiniano and Primiceri (2008) suggest investment specific shocks to be the primary driving force of the post-WWII business cycle. The information technology (IT) revolution with the associated boom in investment rates in the late 1990s in the US and other G7 countries have resurrected interest into an old idea, present in the writings of Beveridge (1909), Pigou (1926) and Clark (1935) whereby shifts in expectations about future fundamentals can generate and sustain business cycles. Even though economists had always thought of these effects as potential drivers of the business cycle (see for example Cochrane (1994)), their actual implementation in economic models or the empirical measurement of their effects has proven to be challenging.[1] The recent theoretical advances of Beaudry and Portier (2004), Beaudry and Portier (2007), Jaimovich and Rebelo (2009) and others provided guidance on how to generate empirically recognizable expectations driven business cycles whereby investment, consumption and hours work comove with economic activity. In conjunction with the development of modern estimation techniques, these advances have allowed researchers to evaluate the role of news shocks and anticipation effects on business cycles. Davis (2007) and Schmitt-Grohe and Uribe (2010) are the first to report that in addition to unanticipated shocks as estimated by Justiniano and Primiceri (2008), anticipated shocks are also important sources of aggregate fluctuations. [2]

Despite the fact, as demonstrated by Beaudry and Portier (2004) and Jaimovich and Rebelo (2009), that it is theoretically possible to generate an expansion with an anticipated shock that signals an improvement in TFP, it has proven difficult to empirically estimate this expansionary effect in the data, or when such effect is present, it has at best a very limited contribution to explaining aggregate fluctuations. For example, Barsky and Sims (2011) show that good news about TFP in the future generates a recession today. Similarly, in estimated DSGE models, Schmitt-Grohe and Uribe (2010) find that news about wage mark-up, preference, government spending shocks dominate TFP news which only have a minor impact on fluctuations. Broadly similar conclusions about the limited importance of news components in technology related disturbances are reached by Khan and Tsoukalas (2009) and Fujiwara et al. (2011) in estimated New Keynesian DSGE models. Thus, the quantitative contribution of news shocks is still an open question. And in addition to broad based comovement—in the main macroeconomic aggregates—the issue of sectoral comovement in response to news is at the heart of business cycle analysis. Sectoral comovement is a question that does not attract a lot of interest and has

[1] Barro and King (1984) describe the obstacles to generating empirically recognizable expectations driven cycles in standard macroeconomic models. Leeper et al. (2009) and Uhlig (2009) discuss the difficulties that arise when attempting to identify the news components of structural shocks using a VAR analysis. Schmitt-Grohe and Uribe (2010) come to the conclusion that in general, the conventional VAR methodology may not identify anticipation effects and has several additional disadvantages compared to a model based full information econometric strategy.

[2] Other important contributions to this literature are Khan and Tsoukalas (2009) and Fujiwara et al. (2011).

almost entirely neglected in the news shocks literature.

This paper contributes to the ongoing debate on the importance of news shocks. We investigate the role of news in a model with separate consumption and investment sectors by emphasizing the role of financial intermediation in the propagation of these shocks. There are two important reasons why we consider a more elaborate two sector framework than most existing DSGE studies. First, we would like to study sectoral co-movement. Second, we would like to have a general framework of relative productivity differentials across sectors that give rise to a general measure of investment specific technological change and consequently a more refined concept of investment specific shocks. This generality is lacking in one sector models. The latter is important in order to precisely assess the quantitative contribution of investment specific shocks in aggregate fluctuations. While the earlier literature has focused on studying news about future fundamentals (mainly through TFP) we mainly focus on anticipation effects that can also arise through variations in the return to capital. Based on the finance literature (see for example Merton (1973)), we introduce a shock to the quality of capital which can generate exogenous variation in the value of the capital.[3] We then link the return to capital with information we obtain from corporate bond spreads in order to empirically estimate news about capital quality. Financial intermediation is thus essential in order to be able to identify this anticipation channel we propose.

We estimate the model for the US economy over the period, 1990Q2 to 2011Q1. We include the latest recession in our analysis in order to get a first pass at its possible sources. In the estimation, we include separate corporate bond market spreads for the consumption and the investment sector. These bond market spreads help us to identify news shocks as they are likely to contain information in addition to the what can be extracted from macroeconomic aggregates.[4] This information is especially relevant in a framework like ours that takes anticipation effects into account, as agents have a larger information set compared to a more standard model which only contains unanticipated shocks. For this reason, it has been popular in the literature to include financial information with high predictive power when analysing the impact of anticipation effects. Beaudry and Portier (2006) argue that stock prices contain information about future TFP movements and can therefore be useful to capture news shocks. Schmitt-Grohe and Uribe (2010) experiment with stock prices in their set of observables to investigate the importance of news shocks as drivers of the business cycle and confirm the evidence for their predictive power. Davis (2007) argues that interest rates and information from the yield curve can be useful for identifying anticipated effects. Including bond market spreads in our set of observables confers a main advantage: in contrast to other financial variables, like stock prices for example, bond market spreads are relatively closely related to other macroeconomic aggregates; e.g. they are less volatile, less noisy and have a higher absolute correlation with output. For example, Gilchrist and Zakrajsek (2011) underline the high predictive content of bond market spreads for economic activity.

Our results are as follows. *First*, we find that news shocks to capital quality are a significant source of fluctuations. These shocks account for 37% of output, 40% of consumption, 44% of aggregate investment, 43% of aggregate hours fluctuations at business cycle frequencies. The

[3]This shock enjoys growing popularity. It has for example also been adopted in the frameworks of (Gertler and Karadi (2011)), Brunnermeier and Sannikov (2009), Gertler and Kiyotaki (2010) and Gertler et al. (2011).

[4]In addition to their predictive power, credit spreads may also include risk premia. However, Cochrane and Piazzesi (2005) argue that this possibility is very unlikely.

capital quality shocks in the consumption sector are the primary drivers. These shocks also explain a significant fraction of movements in bond market spreads as well as sectoral investment and hours worked. *Second*, news shocks in capital quality generates **aggregate** and **sectoral** comovement as in the data. In addition they generate procyclical movements in the value of capital consistent with observed movements in the stock market. *Third*, conditional on the model, the data reject news components in conventional drivers of the business cycle such as the TFP processes in the investment and consumption sector. *Fourth*, from a historical perspective, news shocks to capital quality are to a large extent responsible for the recession following the 1990s investment boom and the latest recession, but played a much smaller role during the recession at the beginning of the 1990s. This is in line with the belief that revisions of overoptimistic expectations contributed to the last two recessions while movements in fundamentals played a much bigger role for the recession at the beginning of the 1990s.[5] The finding that news shocks are to a great extent responsible for these two recessions is also consistent with work of Beaudry and Portier (2004). They interpret Pigou's theory of expectations driven business cycles as a theory of recessions. The historical decomposition further indicates an asymmetry in the revision of beliefs: expectations are revised much faster at the peak of the cycle than at the trough, subsequently contributing to a sharp downturn and a slow recovery. This is consistent with the results in Görtz and Tsoukalas (2011a) and Van Nieuwerburgh and Veldkamp (2006).

The remaining parts of the paper are organised as follows. The next section describes the model economy. The estimation methodology and the data are outlined in section 3. This section also describes the information assigned to the parameters prior to the estimation. Section 4 summarises the estimation results. Section 5 assesses the importance of different structural shocks as driving forces for the business cycle using a business cycle variance decomposition, while Section 6 discusses the impact of anticipated and unanticipated shocks from a historical perspective. Section 7 provides a description of the economy's response to anticipated and unanticipated capital quality shocks. Section 8 concludes.

2 The Model

The model economy is based on the framework presented in Görtz and Tsoukalas (2011b) and extends it by modelling financial intermediaries. The model includes seven different types of economic actors: A continuum of households that consume, save and supply labour on a monopolistically competitive labour market. Employment agencies aggregate different types of labour to a homogenous input good for production. A continuum of intermediate goods producers produce investment and consumption goods in two distinct sectors. Intermediate goods producers in both sectors rent labour and capital as production inputs. Their outputs are aggregated by final goods producers in both sectors which produce the final consumption and investment goods, respectively. Based on the mechanisms outlined in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), banks intermediate funds between households and firms. A monetary policy authority fixes the short-run nominal interest rate through open market operations. The government conducts a fiscal policy which is fully Ricardian and finances its budget deficit by issuing short term bonds.

The model includes nominal and real frictions. Both, prices as well as wages are reoptimised at random intervals (as in Calvo (1983) and Erceg et al. (2000)) and investment is

[5] See for example Walsh (1993) and Christiano et al. (2008).

subject to adjustment costs (as in Christiano et al. (2005)). Since capital is immobile across sectors, there are separate investment and capital utilization decisions for the consumption and the investment sector. The setup comprises several orthogonal structural shocks including TFP shocks to production in both sectors, shocks to the quality of capital (including news shocks about capital quality), shocks to bank's equity capital, price and wage mark-up shocks as well as preference and monetary policy shocks.

2.1 Final goods producers

Final goods, C_t and I_t, in the consumption and the investment sector are produced by perfectly competitive firms according to the technology:

$$C_t = \left[\int_0^1 (C_t(i))^{\frac{1}{1+\lambda_{p,t}^C}} di \right]^{1+\lambda_{p,t}^C},$$

$$I_t = \left[\int_0^1 (I_t(i))^{\frac{1}{1+\lambda_{p,t}^I}} di \right]^{1+\lambda_{p,t}^I},$$

where $C_t(i)$ and $I_t(i)$ are intermediate goods produced in the two sectors. Final goods producers re-package intermediate output where it takes one unit of intermediate output to produce one unit of final goods producers output. The elasticity $\lambda_{p,t}^x$ is the time varying price markup over marginal cost for intermediate firms. It is given by the exogenous stochastic process

$$\log(1+\lambda_{p,t}^x) = (1-\rho_{\lambda_p^x})\log(1+\lambda_p^x) + \rho_{\lambda_p^x}\log(1+\lambda_{p,t-1}^x) + \varepsilon_{p,t}^x,$$

where $\rho_{\lambda_p^x} \in (0,1)$ and $\varepsilon_{p,t}^x$ is $i.i.d.\ N(0,\sigma_{\lambda_p^x}^2)$, with $x = C, I$. Shocks to $\lambda_{p,t}^x$ can be interpreted as cost-push shocks to the inflation equation.

Profit maximisation and the zero profit condition imply that the prices of the final goods in the consumption and investment sector, $P_{C,t}$ and $P_{I,t}$, are CES aggregates of the prices of intermediate goods in the respective sector, $P_{C,t}(i)$ and $P_{I,t}(i)$,

$$P_{C,t} = \left[\int_0^1 P_{C,t}(i)^{\frac{1}{\lambda_{p,t}^C}} di \right]^{\lambda_{p,t}^C}, \qquad P_{I,t} = \left[\int_0^1 P_{I,t}(i)^{\frac{1}{\lambda_{p,t}^I}} di \right]^{\lambda_{p,t}^I}.$$

2.2 Intermediate goods producers

2.2.1 Intermediate goods producer's production and cost minimisation

Intermediate goods in the consumption sector are produced by a monopolist according to the production function

$$C_t(i) = max\Big\{A_t(L_{C,t}(i))^{1-a_c}(K_{C,t}(i))^{a_c} - A_t V_t^{\frac{a_c}{1-a_i}} F_C; 0\Big\}.$$

Intermediate goods in the investment sector are produced by a monopolist according to the production function

$$I_t(i) = max\Big\{V_t(L_{I,t}(i))^{1-a_i}(K_{I,t}(i))^{a_i} - V_t^{\frac{1}{1-a_i}} F_I; 0\Big\},$$

where $K_{x,t}(i)$ and $L_{x,t}(i)$ denote the amount of capital and labour rented by firm i in sector $x = C, I$ and $a_c, a_i \in (0,1)$ denote the share of capital in the respective production function. Fixed costs of production, $F_C, F_I > 0$, ensure that profits are zero along a non-stochastic balanced growth path and allow us to dispense with the entry and exit of intermediate good producers (Christiano et al. (2005), Rotemberg and Woodford (1995)).[6] The variable A_t represents the non-stationary level of TFP in the consumption sector and its growth rate, $z_t = ln\left(\frac{A_t}{A_{t-1}}\right)$, follows the process:

$$z_t = (1-\rho_z)g_a + \rho_z z_{t-1} + \varepsilon_t^z, \tag{1}$$

Similarly, V_t is the non-stationary level of TFP in the investment sector and its growth rate, $v_t = ln\left(\frac{V_t}{V_{t-1}}\right)$ follows the process

$$v_t = (1-\rho_v)g_v + \rho_v v_{t-1} + \varepsilon_t^v, \tag{2}$$

Here, ε_t^z and ε_t^v are $i.i.d.$ $N(0,\sigma_z^2)$ and $N(0,\sigma_v^2)$, respectively. The parameters g_a and g_v are the steady state growth rates of the two processes and $\rho_z, \rho_v \in (0,1)$ govern their persistence.

2.2.2 Intermediate goods producer's pricing decisions

A constant fraction $\xi_{p,x}$ of intermediate firms in sector $x = C, I$ cannot choose its price optimally in period t but resets the price — as in Calvo (1983) — according to the indexation rule

$$P_{C,t}(i) = P_{C,t-1}(i)\pi_{C,t-1}^{\iota_{pC}}\pi_C^{1-\iota_{pC}},$$
$$P_{I,t}(i) = P_{I,t-1}(i)\pi_{I,t-1}^{\iota_{pI}}\pi_I^{1-\iota_{pI}}\left[\left(\frac{A_t}{A_{t-1}}\right)^{-1}\left(\frac{V_t}{V_{t-1}}\right)^{\frac{1-a_c}{1-a_i}}\right]^{\iota_{pI}},$$

where $\pi_{C,t} \equiv \frac{P_{C,t}}{P_{C,t-1}}$ and $\pi_{I,t} \equiv \frac{P_{I,t}}{P_{I,t-1}}\left(\frac{A_t}{A_{t-1}}\right)^{-1}\left(\frac{V_t}{V_{t-1}}\right)^{\frac{1-a_c}{1-a_i}}$ is gross inflation in the two sectors and π_C, π_I are their steady state values.

The remaining fraction of firms, $(1-\xi_{p,x})$, in sector $x = C, I$ can adjust the price in period t. Identical to Görtz and Tsoukalas (2011b), consumption and investment sector firms choose their price optimally by maximising the present discounted value of future profits. The resulting aggregate price index in the consumption sector is

$$P_{C,t} = \left[(1-\xi_{p,C})\tilde{P}_{C,t}^{\frac{1}{\lambda_{p,t}^C}} + \xi_{p,C}\left(\left(\frac{\pi_{C,t-1}}{\bar{\pi}_t}\right)^{\iota_{pC}}\pi_C^{1-\iota_{pC}}P_{C,t-1}\right)^{\frac{1}{\lambda_{p,t}^C}}\right]^{\lambda_{p,t}^C}.$$

The aggregate price index in the investment sector is

$$P_{I,t} = \left[(1-\xi_{p,I})\tilde{P}_{I,t}^{\frac{1}{\lambda_{p,t}^I}} + \xi_{p,I}\left(P_{I,t-1}\left(\frac{\pi_{I,t-1}}{\bar{\pi}_t}\right)^{\iota_{pI}}\pi_I^{1-\iota_{pI}}\left[\left(\frac{A_t}{A_{t-1}}\right)^{-1}\left(\frac{V_t}{V_{t-1}}\right)^{\frac{1-a_c}{1-a_i}}\right]^{\iota_{pI}}\right)^{\frac{1}{\lambda_{p,t}^I}}\right]^{\lambda_{p,t}^I}.$$

[6]The fixed costs are assumed to grow at the same rate as output in the consumption and investment sector to ensure that they do not become asymptotically negligible.

2.2.3 Employment agencies

The firms are owned by a continuum of households indexed by $j \in [0,1]$. Each household supplies specialised labour, $L_t(j)$, monopolistically as in Erceg et al. (2000). A large number of competitive "employment agencies" aggregate this specialised labour into a homogenous labour input good which is sold to intermediate firms in a competitive market. Aggregation is done according to the following production function:

$$L_t = \left[\int_0^1 L_t(j)^{\frac{1}{1+\lambda_{w,t}}} dj \right]^{1+\lambda_{w,t}}.$$

The desired markup of wages over the household's marginal rate of substitution, $\lambda_{w,t}$, follows the exogenous stochastic process

$$\log(1+\lambda_{w,t}) = (1-\rho_w)\log(1+\lambda_w) + \rho_w \log(1+\lambda_{w,t-1}) + \varepsilon_{w,t},$$

where $\rho_w \in (0,1)$ and $\varepsilon_{w,t}$ is $i.i.d.\ N(0,\sigma^2_{\lambda_w})$. The expression $\lambda_{w,t}$ is the wage markup shock which can also be interpreted as a labour supply shock since it has the same effect on the household's first-order condition for the choice of hours as the shock to the preference for leisure popularised by Hall (1997).

Profit maximisation by the perfectly competitive employment agencies implies the labour demand function

$$L_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t, \tag{3}$$

where $W_t(j)$ is the wage received from employment agencies by the supplier of labour of type j, while the wage paid by intermediate firms for their homogenous labour input is

$$W_t = \left[\int_0^1 W_t(j)^{\frac{1}{\lambda_{w,t}}} dj \right]^{\lambda_{w,t}}.$$

2.3 Households

2.3.1 Household's utility and budget

Households maximise the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t b_t \left[\ln(C_t - hC_{t-1}) - \varphi \frac{(L_{C,t}(j) + L_{I,t}(j))^{1+\nu}}{1+\nu} \right], \quad \beta \in (0,1), \quad \varphi > 0, \quad \nu > 0, \tag{4}$$

where E_0 is the conditional expectation operator, β is the discount factor and h is the degree of habit formation which will help to introduce inertia in the response of consumption to shocks. The inverse Frisch labour supply elasticity is denoted by ν and φ is a free parameter which allows to calibrate total labour supply in the steady state to be unity. Owing to the non-stationarity of the technological progress, utility is logarithmic to ensure the existence of a balanced growth path. Consumption is not indexed by (j) because the existence of state contingent securities ensures that in equilibrium consumption and asset holdings are the same for all households. The variable b_t is a shock to the discount factor, which affects both the marginal utility of consumption and the marginal disutility of labour. The intertemporal preference shock follows the stochastic process

$$\log b_t = \rho_b \log b_{t-1} + \varepsilon_t^b, \tag{5}$$

where $\rho_b \in (0,1)$ and ε_t^b is $i.i.d\ N(0, \sigma_b^2)$.

The household's flow budget constraint is

$$\begin{aligned}
&\frac{P_{I,t}}{P_{C,t}}(I_{I,t} + I_{C,t}) + C_t + a(u_{C,t})\xi_{C,t}^K \bar{K}_{C,t-1} A_t V_t^{\frac{a_C-1}{1-a_i}} + a(u_{I,t})\xi_{I,t}^K \bar{K}_{I,t-1} A_t V_t^{\frac{a_C-1}{1-a_i}} + \frac{B_t}{P_{C,t}} \\
\leq &\frac{W_t}{P_{C,t}}(L_{C,t} + L_{I,t}) + \frac{R_{C,t}^K}{P_{C,t}} u_{C,t}\xi_{C,t}^K \bar{K}_{C,t-1} + \frac{R_{I,t}^K}{P_{C,t}} u_{I,t}\xi_{I,t}^K \bar{K}_{I,t-1} + R_{t-1}\frac{B_{t-1}}{P_{C,t}} \\
&+ \frac{Q_t}{P_{C,t}} + \frac{\Pi_t}{P_{C,t}} - \frac{T_t}{P_{C,t}},
\end{aligned} \tag{6}$$

where B_t is holdings of government bonds, Q_t is the net cash flow from household's portfolio of state contingent securities, T_t is lump-sum taxes, R_t the nominal interest rate and Π_t is the per-capita profit accruing to households from ownership of the firms.

In the spirit of Gertler and Karadi (2011) we introduce a shock to the quality of available capital in both sectors, $\xi_{C,t}^K$. It evolves according to

$$\log \xi_{x,t}^K = \rho_{\xi^K,x} \log \xi_{x,t}^K + \varepsilon_{x,t}^{\xi^K}, \qquad x = C, I,$$

where $\rho_{\xi^K,x} \in (0,1)$. Referring to the finance literature (see for example Merton (1973)), Gertler and Karadi (2011) use this shock as an exogenous source of variations in the value of capital.[7]

The capital quality shock can serve as a candidate to resemble exogenous variations in the intangible capital stock. The literature typically subdivides the capital stock into physical capital, i.e. machines and buildings, and intangible capital. The intangible capital stock consists of production factors that are not included in the available capital stock but raise a corporation's ability to produce or lower it's costs of production; examples are marketing, strategic planning, the management structure or knowledge created by research and development.

It will be shown below that the market price of capital is determined endogenously in this model. As the capital quality shock is a source for variations in the price of capital, it can potentially trigger asset price variation.

We introduce news shocks about the quality of capital.[8] The innovation of the shock process consists of two components

$$\varepsilon_{x,t}^{\xi^K} = \varepsilon_{x,t}^{\xi^{K,0}} + \varepsilon_{x,t}^{\xi^{K,news}}, \qquad x = C, I, \tag{7}$$

[7] Recently this kind of exogenous variation to the value of capital has enjoyed increasing popularity in macroeconomic models. Other studies that include a shock to the quality of capital are for example Gourio (2009), Brunnermeier and Sannikov (2009), Gertler and Kiyotaki (2010) and Gertler et al. (2011).

[8] News shocks are introduced in a similar way for example in Davis (2007), Schmitt-Grohe and Uribe (2010), Khan and Tsoukalas (2009) and Fujiwara et al. (2011).

where the first component, $\varepsilon^{\xi^{K,0}}_{x,t}$, is unanticipated and the second component, $\varepsilon^{\xi^{K,news}}_{x,t}$, is anticipated. News can be anticipated several quarters ahead so that

$$\varepsilon^{\xi^{K,news}}_{x,t} \equiv \sum_{h=1}^{H} \varepsilon^{\xi^{K,h}}_{x,t-h},$$

where $\varepsilon^{\xi^{K,h}}_{x,t-h}$ is news received by agents at period $t-h$ about the quality of capital which materialises in t. H is the maximum horizon over which agents can anticipate news about the quality of capital. It is assumed that the anticipated and unanticipated components for sector $x = C, I$ and horizon $h = 0, 1, \ldots, H$ are $i.i.d.$ with $N(0, \sigma^2_{\xi^{K,h},x})$ and uncorrelated across sector, horizon and time. The process above also allows for revisions in expectations, so that the framework allows for the possibility of news failing to materialise.[9]

Households own capital and can choose the capital utilisation rate which transforms available capital into effective capital according to

$$K_{x,t} = u_{x,t}\xi^K_{x,t}\bar{K}_{x,t-1}, \qquad x = C, I,$$

where $u_{x,t}$ denotes capital utilisation rate in sector x. Effective capital is rented to the firms at rate R^K_x. The costs of capital utilisation per unit of available capital are denoted by $a(u_{x,t})$. This function has the properties that in the steady state $u = 1$, $a(1) = 0$ and $\chi \equiv \frac{a''(1)}{a'(1)}$, where "$'$"s denote differentiation.[10]
available capital in the consumption and investment sector is accumulated according to

$$\bar{K}_{x,t} = (1-\delta_x)\xi^B_{x,t}\bar{K}_{x,t-1} + \left(1 - S\Big(\frac{I_{x,t}}{I_{x,t-1}}\Big)\right)I_{x,t}, \qquad x = C, I, \tag{8}$$

where $\delta_x \in (0,1)$ is the depreciation rate in sector $x = C, I$. Notice from the two separate capital accumulation functions that captial is immobile across the two sectors. Available capital accumulation is subject to investment adjustment costs in the spirit of Christiano et al. (2005). The function $S(\cdot)$ is restricted to satisfy the following properties: $S(1) = S'(1) = 0$ and $S''(1) = \kappa > 0$, where "$'$"s denote differentiation.[11] These costs imply that any deviation from the balanced growth path of investment is costly.

2.3.2 Household's optimality conditions

Households solve the Lagrangian $\mathcal{L}$ by maximising their utility function (4) with respect to the budget constraint in consumption units (6) and the capital accumulation equations for both

[9] A part of the news literature argues that news about technology diffuses slowly through the economy. This part of the literature focuses mainly on news about productivity, see for example Rotemberg (2003) or Alexopoulos (2011). Schmitt-Grohe and Uribe (2010) show that the adopted formulation of news shocks nests technology diffusion as a special case.

[10] In the log-linear approximation of the model solution the curvature χ is the only parameter that matters for the dynamics.

[11] In the log-linear approximation of the model solution the curvature κ is the only parameter that matters for the dynamics.

sectors (8). The resulting first order conditions are

$$
\begin{aligned}
\frac{\partial \mathcal{L}}{\partial C_t} &:\Lambda_t = \frac{b_t}{C_t - hC_{t-1}} - \beta h \frac{b_{t+1}}{C_{t+1} - hC_t}, \\
\frac{\partial \mathcal{L}}{\partial B_t} &:\Lambda_t = \beta E_t \Lambda_{t+1} R_t \frac{1}{\Pi_{c,t+1}}, \qquad \text{with } \Pi_{c,t+1} = \frac{P_{C,t+1}}{P_{C,t}}, \\
\frac{\partial \mathcal{L}}{\partial I_{C,t}} &:\Lambda_t \frac{P_{I,t}}{P_{C,t}} = \Phi_{C,t}\left[1 - S\Big(\frac{I_{C,t}}{I_{C,t-1}}\Big) - S'\Big(\frac{I_{C,t}}{I_{C,t-1}}\Big)\frac{I_{C,t}}{I_{C,t-1}}\right] \\
&\quad + \beta E_t \Phi_{C,t+1}\left[S'\Big(\frac{I_{C,t+1}}{I_{C,t}}\Big)\Big(\frac{I_{C,t+1}}{I_{C,t}}\Big)^2\right], \\
\frac{\partial \mathcal{L}}{\partial I_{I,t}} &:\Lambda_t \frac{P_{I,t}}{P_{C,t}} = \Phi_{I,t}\left[1 - S\Big(\frac{I_{I,t}}{I_{I,t-1}}\Big) - S'\Big(\frac{I_{I,t}}{I_{I,t-1}}\Big)\frac{I_{I,t}}{I_{I,t-1}}\right] \\
&\quad + \beta E_t \Phi_{I,t+1}\left[S'\Big(\frac{I_{I,t+1}}{I_{I,t}}\Big)\Big(\frac{I_{I,t+1}}{I_{I,t}}\Big)^2\right], \\
\frac{\partial \mathcal{L}}{\partial \bar{K}_{C,t}} &:\Phi_{C,t} = \beta E_t \xi^K_{C,t+1}\left\{\Phi_{C,t+1}(1-\delta_C) + \Lambda_{t+1}\Big(\frac{R^K_{C,t+1}}{P_{C,t+1}} u_{C,t+1} - a(u_{C,t+1}) A_{t+1} V_{t+1}^{\frac{a_c - 1}{1 - a_i}}\Big)\right\}, \\
\frac{\partial \mathcal{L}}{\partial \bar{K}_{I,t}} &:\Phi_{I,t} = \beta E_t \xi^K_{I,t+1}\left\{\Phi_{I,t+1}(1-\delta_I) + \Lambda_{t+1}\Big(\frac{R^K_{I,t+1}}{P_{I,t+1}} u_{I,t+1} - a(u_{I,t+1}) A_{t+1} V_{t+1}^{\frac{a_c - 1}{1 - a_i}}\Big)\right\}, \\
\frac{\partial \mathcal{L}}{\partial u_{C,t}} &:r^K_{C,t} = a'(u_{C,t}), \qquad \text{with} \quad r^K_{C,t} = \frac{R^K_{C,t}}{P_{C,t}} V_t^{\frac{1-a_c}{1-a_i}} A_t^{-1}, \\
\frac{\partial \mathcal{L}}{\partial u_{I,t}} &:r^K_{I,t} = a'(u_{I,t}), \qquad \text{with} \quad r^K_{I,t} = \frac{R^K_{I,t}}{P_{C,t}} V_t^{\frac{1-a_c}{1-a_i}} A_t^{-1}, \\
\frac{\partial \mathcal{L}}{\partial L_{C,t}} &:\Lambda_t \frac{W_t}{P_{C,t}} = b_t \varphi (L_{C,t} + L_{I,t})^{\nu}, \\
\frac{\partial \mathcal{L}}{\partial L_{I,t}} &:\Lambda_t \frac{W_t}{P_{C,t}} = b_t \varphi (L_{C,t} + L_{I,t})^{\nu},
\end{aligned}
$$

where Λ_t is the Lagrange multiplier on equation (6), $\Phi_{I,t}$ and $\Phi_{C,t}$ are the respective Lagrange multipliers on equation (8) and $K_{x,t} = u_{x,t}\xi^K_{x,t}\bar{K}_{x,t-1}$ is the input into $K_{x,t}$ with $x = C, I$.

2.3.3 Household's wage setting

Following Erceg et al. (2000), in each period a fraction ξ_w of the households cannot freely adjust its wage but follows the indexation rule

$$W_{j,t+1} = W_{j,t}\Big(\pi_{c,t} e^{z_t + \frac{a_c}{1-a_i} v_t}\Big)^{\iota_w}\Big(\pi_c e^{g_a + \frac{a_c}{1-a_i} g_v}\Big)^{1-\iota_w}.$$

The wages grow at the economy's consumption sector growth rate. The remaining fraction of households, $(1-\xi_w)$, chooses an optimal wage, $W_t(j)$, by maximising[12]

$$E_t\left\{\sum_{s=0}^{\infty}\xi_w^s\beta^s\left[-b_{t+s}\varphi\frac{L_{t+s}(j)^{1+\nu}}{1+\nu}+\Lambda_{t+s}W_t(j)L_{t+s}(j)\right]\right\},$$

subject to the labour demand function (3). The aggregate wage evolves according to

$$W_t=\left\{(1-\xi_w)(\tilde{W}_t)^{\frac{1}{\lambda_w}}+\xi_w\left[\left(\pi_c e^{g_a+\frac{a_c}{1-a_i}g_v}\right)^{1-\iota_w}\left(\pi_{c,t-1}e^{z_{t-1}+\frac{a_c}{1-a_i}v_{t-1}}\right)^{\iota_w}W_{t-1}\right]^{\frac{1}{\lambda_w}}\right\}^{\lambda_w},$$

where $\tilde{W}_t$ is the optimally chosen wage.

2.4 Banking sector

2.4.1 Financial Intermediaries

A household in this model includes two different types of agents. The first type are workers which provide labour services to intermediate goods producers in the two sectors. The second type of agents are bankers. Banks are financial intermediaries which obtain funds from households and use these as well as their own equity capital to lend funds to non-financial intermediate good producers. The market for banks is segmented; there are two continua of banks which are specialised to either lend to the producers in the consumption sector or the investment sector. Therefore, one can think of households as families of which one family member provides labour to intermediate goods producers, one member is working in a bank specialised for the consumption sector and one in a bank specialised for the investment sector. The implementation of banks and their role as financial intermediaries in this model is based on the framework presented in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) and extends it for the two sector setup.

The balance sheet of a financial intermediary for the consumption or investment sector can be expressed as

$$Q_{x,t}S_{x,t}^p=N_{x,t}+B_{x,t},\qquad x=C,I,$$

where $S_{x,t}^p$ denotes the quantity of financial claims on non-financial firms held by the intermediary and $Q_{x,t}$ denotes the price of a claim in the consumption or investment sector. The variable $N_{x,t}$ represents the bank's wealth at the end of period t and $B_{x,t}$ are the deposits the intermediary for the consumption or investment sector obtains from households.[13] Banks intermediate the demand and supply for equity from households to the producers in the two sectors. Additionally, they engage in maturity transformation by holding long term assets of borrowers which are funded with the bank's own equity capital and lenders short term liabilities. The assets held by the financial intermediary of sector x at time t pay in the next period the stochastic

[12] All households that can reoptimise will choose the same wage. The probability to be able to adjust the wage, $(1-\xi_w)$, can be seen as a reduced-form representation of wage rigidities with a broader microfoundation; for example quadratic adjustment costs (Calvo (1983)), information limitations (Mankiw, N. Gregory and Reis, Ricardo (2002), Sims (2003)) and contract costs (Caplin and Leahy (1997)).

[13] The total quantity of bonds held by households, B_t, is the sum of bonds from the intermediaries of the two sectors as well as the government

return $R^B_{x,t+1}$ from borrowers in this sector. Intermediaries pay at $t+1$ the non-contingent real gross return R_t to households for their deposits made at time t. Then, the intermediary's wealth evolves over time as

$$\begin{aligned} N_{x,t+1} &= R^B_{x,t+1} Q_{x,t} S^p_{x,t} - R_t B_{x,t} \\ &= R^B_{x,t+1} Q_{x,t} S^p_{x,t} - R_t (Q_{x,t} S^p_{x,t} - N_{x,t}) \\ &= (R^B_{x,t+1} - R_t) Q_{x,t} S^p_{x,t} + R_t N_{x,t}. \end{aligned}$$

The premium, $R^B_{x,t+1} - R_t$, as well as the quantity of assets, $Q_{x,t} S^p_{x,t}$, determines the growth in bank's wealth above the riskless return. Therefore, the bank will not fund any assets with a negative discounted premium. It follows that for the bank to operate in period i the following inequality must hold

$$E_t \beta^i \Lambda^B_{t+1+i} (R^B_{x,t+1+i} - R_{t+i}) \geq 0, \qquad i \geq 0,$$

where $\beta^i \Lambda^B_{t+1+i}$ is the bank's stochastic discount factor, with

$$\Lambda^B_{t+1} \equiv \frac{\Lambda_{t+1}}{\Lambda_t},$$

where Λ_t is the Lagrange multiplier on the household's budget equation. Under perfect capital markets, arbitrage guarantees that the risk premium collapses to zero and the relation always holds with equality. However, under imperfect capital markets, credit constraints rooted in the bank's inability to obtain enough funds may lead to positive risk premia. As long as the above inequality holds, banks for the investment and the consumption sector will keep building assets by borrowing additional funds from households. Accordingly, the intermediaries in the two sectors have the objective to maximise expected terminal wealth

$$\begin{aligned} V_{x,t} =& max E_t \sum_{i=0} (1-\theta_B) \theta^i_B \beta^i \Lambda^B_{t+1+i} N_{x,t+1+i} \\ =& max E_t \sum_{i=0} (1-\theta_B) \theta^i_B \beta^i \Lambda^B_{t+1+i} [(R^B_{x,t+1+i} - R_{t+i}) Q_{x,t+i} S^p_{x,t+i} + R_{t+i} N_{x,t+i}], \end{aligned} \tag{9}$$

where $\theta_B \in (0,1)$ is the fraction of bankers at t that survive until period $t+1$.

Following the setup in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) the banks are limited from infinitely borrowing additional funds from households by a moral hazard/costly enforcement problem. On the one hand, the agent who works in the bank can choose at the beginning of each period to divert the fraction λ_B of available funds and transfer it back to the household. On the other hand, depositors can force the bank into bankruptcy and recover a fraction $1-\lambda_B$ of assets.[14] Note that the fraction, λ_B, which intermediaries can divert is the same across sectors to guarantee that the household is indifferent between lending funds to the bank in the consumption and the investment sector.

Given this tradeoff, lenders will only supply funds to the financial intermediary when the bank's maximised expected terminal wealth is larger or equal to the bank's gain from diverting the fraction λ_B of available funds. This incentive constraint can be formalised as

$$V_{x,t} \geq \lambda_B Q_{x,t} S^p_{x,t}, \qquad 0 < \lambda_B < 1. \tag{10}$$

[14] We follow the assumption in Gertler and Kiyotaki (2010) that it is too costly for the depositors to recover the fraction λ_B of funds.

Using equation (9), the expression for $V_{x,t}$ can be written as the following first-order difference equation

$$V_{x,t} = \nu_{x,t} Q_{x,t} S^p_{x,t} + \eta_{x,t} N_{x,t},$$

with

$$\begin{aligned}
\nu_{x,t} &= E_t\{(1-\theta_B)\Lambda^B_{t+1}(R^B_{x,t+1} - R_t) + \theta_B \beta Z^x_{1,t+1} \nu_{x,t+1}\}, \\
\eta_{x,t} &= E_t\{(1-\theta_B)\Lambda^B_{t+1} R_t + \theta_B \beta Z^x_{2,t+1} \eta_{x,t+1}\},
\end{aligned}$$

and

$$Z^x_{1,t+1+i} \equiv \frac{Q_{x,t+1+i} S^p_{x,t+1+i}}{Q_{x,t+i} S^p_{x,t+i}}, \qquad Z^x_{2,t+1+i} \equiv \frac{N_{x,t+1+i}}{N_{x,t+i}}.$$

The variable $\nu_{x,t}$ can be interpreted in the following way: For an intermediary of sector x it is the expected discounted marginal gain of expanding assets $Q_{x,t}S_{x,t}$ by one unit while holding wealth $N_{x,t}$ constant. The interpretation of $\eta_{x,t}$ is analogous: For an intermediary of sector x it is the expected discounted value of having an additional unit of wealth, $N_{x,t}$, holding the quantity of financial claims, $S^p_{x,t}$, constant. The gross growth rate in assets is denoted by $Z^x_{1,t+i}$ and the gross growth rate of net worth is denoted by $Z^x_{2,t+i}$.

Then, using the expression for $V_{x,t}$, we can express the bank's incentive constraint (10) as

$$\nu_{x,t} Q_{x,t} S^p_{x,t} + \eta_{x,t} N_{x,t} \geq \lambda_B Q_{x,t} S^p_{x,t}.$$

As indicated above, under perfect capital markets banks will expand borrowing until the risk premium collapses to zero which implies that in this case $\nu_{x,t}$ equals zero as well. However, due to the moral hazard/costly enforcement problem introduced above capital markets are imperfect in this setup. Imperfect capital markets may limit the possibilities for this kind of arbitrage because the intermediaries are constrained by their equity capital. If the incentive constraint binds it follows that

$$\begin{aligned}
Q_{x,t} S^p_{x,t} &= \frac{\eta_{x,t}}{\lambda_B - \nu_{x,t}} N_{x,t} \\
&= \varrho_{x,t} N_{x,t}. \qquad (11)
\end{aligned}$$

In this case the quantity of assets which the intermediary can acquire depends on the equity capital, $N_{x,t}$, as well as the intermediary's leverage ratio, $\varrho_{x,t}$. This leverage ratio is the ratio of the bank's intermediated assets to equity. The moral hazard/costly enforcement problem constraints the bank's ability to acquire assets because it introduces an endogenous capital constraint. By raising the leverage ratio through an increase in $\nu_{x,t}$, the bank's incentive to divert funds and the bank's opportunity costs from being forced into bankruptcy by the depositors increase. The bank's leverage ratio is limited to the point where its maximised expected terminal wealth equals the gains from diverting the fraction λ_B from available funds. However, the constraint (11) binds only if $0 < \nu_{x,t} < \lambda_B$ (given $N_{x,t} > 0$). As described above, the case $\nu_{x,t} < 0$ implies a negative interest rate premium leading the bank to stop operating. In case interest rate premia are relatively high causing $\nu_{x,t}$ to be larger than λ_B, the value of operating always exceeds the bank's gain from diverting funds.

Using the leverage ratio (11) we can express the evolution of the intermediary's wealth as

$$N_{x,t+1} = [(R^B_{x,t+1} - R_t)\varrho_{x,t} + R_t]N_{x,t}.$$

From this equation it also follows that

$$Z^x_{2,t+1} = \frac{N_{x,t+1}}{N_{x,t}} = (R^B_{x,t+1} - R_t)\varrho_{x,t} + R_t,$$

and

$$Z^x_{1,t+1} = \frac{Q_{x,t+1}S^p_{x,t+1}}{Q_{x,t}S^p_{x,t}} = \frac{\varrho_{x,t+1}N_{x,t+1}}{\varrho_{x,t}N_{x,t}} = \frac{\varrho_{x,t+1}}{\varrho_{x,t}}Z^x_{2,t+1}.$$

Financial intermediaries which are forced into bankruptcy can be replaced by new entering banks. Therefore, total wealth of financial intermediaries is the sum of the net worth of existing, $N^e_{x,t}$, and new banks, $N^n_{x,t}$.

$$N_{x,t} = N^e_{x,t} + N^n_{x,t}.$$

The fraction θ_B of bankers at $t-1$ which survive until t is equal across sectors. Then, the law of motion for existing bankers in sector $x = C, I$ is given by

$$N^e_{x,t} = \theta_B[(R^B_{x,t} - R_{t-1})\varrho_{x,t-1} + R_{t-1}]N_{x,t-1}, \qquad 0 < \theta_B < 1. \tag{12}$$

where a main source of fluctuations is the ex-post excess return on assets, $R^B_{x,t} - R_{t-1}$, which increases in impact on $N^e_{x,t}$ in the leverage ratio.

New entering banks receive startup funds from their respective household which are equal to a small fraction of the value of assets held by the existing bankers in their final operating period. Given that the exit probability is i.i.d., the value of assets held by the existing bankers in their final operating period is given by $(1-\theta_B)Q_{x,t}S^p_{x,t}$. The respective household transfers a fraction, ϖ, of this value to the new intermediaries in the two sectors which leads to the following formulation for new banker's wealth

$$N^n_{x,t} = \varpi Q_{x,t}S^p_{x,t}, \qquad 0 < \varpi < 1. \tag{13}$$

Existing banker's net worth (12) and entering banker's net worth (13) lead to the law of motion for total net worth

$$N_{x,t} = \big(\theta_B[(R^B_{x,t} - R_{t-1})\varrho_{x,t-1} + R_{t-1}]N_{x,t-1} + \varpi Q_{x,t}S^p_{x,t}\big)\varsigma_{x,t},$$

where the variable $\varsigma_{x,t}$ is a shock to the bank's equity capital. This shock evolves according to

$$\log\varsigma_{x,t} = \rho_{\varsigma_x}\log\varsigma_{x,t-1} + \epsilon^{\varsigma}_{x,t}, \qquad x = C, I$$

where $\rho_{\varsigma_x} \in (0,1)$ and $\epsilon^{\varsigma}_{x,t}$ is $i.i.d\ N(0, \sigma^2_{\varsigma_x})$.
The external finance premium for sectors $x = C, I$ can be defined as

$$R^{\Delta}_{x,t} = R^B_{x,t+1} - R_t.$$

Gertler and Karadi (2011) state that the financial structure with a one period bond allows interpreting the external finance premium as a credit spread.

Since R_t, λ_B, ϖ and θ_B are equal across sectors, the institutional setup of the two representative banks in the two sectors is symmetric. Both banks hold bonds from households and buy assets from firms in the respective sector. Their performance differs because the demand for capital differs across sectors resulting in sector specific prices of capital, $Q_{x,t}$, and nominal rental rates for capital, $R^K_{x,t}$. Note that the institutional setup of banks does not depend on firm-specific factors. Gertler and Karadi (2011) show that this implies that a setup with a continuum of banks is equivalent to a formulation with a representative bank. Owing to the symmetry of the banks this also holds for our formulation of financial intermediaries in the two-sector setup.

2.4.2 Capital Acquisition of Intermediate Goods Firms

Non-financial firms in the consumption and the investment sector produce intermediate goods. At the end of period t the intermediate goods producers acquire available capital $\bar{K}_{C,t+1}$ and $\bar{K}_{I,t+1}$ for use in production in period $t+1$. At the end of period $t+1$, intermediate goods producers can sell the capital on the open market again. This acquisition of capital for production is financed by funds obtained from financial intermediaries in the respective sector. To acquire the funds to buy capital, the non-financial firms issue $S_{C,t}$ or $S_{I,t}$ claims equal to the number of units of capital acquired, $\bar{K}_{C,t+1}$ or $\bar{K}_{I,t+1}$. They price each claim at the price of a unit of capital $Q_{C,t}$ or $Q_{I,t}$. Then by arbitrage the following borrow in advance constraint holds

$$Q_{x,t}\bar{K}_{x,t+1} = Q_{x,t}S_{x,t},$$

where the left hand side stands for the value of available capital acquired and the right hand side represents the value of claims against this capital. In contrast to the relationship between households and banks which is characterised by the moral hazard/costly enforcement problem, we assume – in line with Gertler and Karadi (2011) – that there are no frictions in the process of non-financial firms obtaining funding from banks. The banks have perfect information about the firms in the consumption and investment sector and have no problem enforcing payoffs.

2.4.3 Stochastic Return for Banks and Price of Capital

From the household's first order conditions of investment for both sectors $x = C, I$ on can derive the price of capital $Q_{x,t} = \Phi_{x,t}/\Lambda_t$ which is the marginal value of installed capital in consumption units. In the expression above, Λ_t is the Lagrange multiplier on the budget equation and $\Phi_{x,t}$ is the Lagrange multipliers on the accumulation equation for capital in sector

x in the household's maximisation problem.

$$\Lambda_t \frac{P_{I,t}}{P_{C,t}} = \Phi_{x,t}\left[1 - S\Big(\frac{I_{x,t}}{I_{x,t-1}}\Big) - S'\Big(\frac{I_{x,t}}{I_{x,t-1}}\Big)\frac{I_{x,t}}{I_{x,t-1}}\right]$$
$$+ \beta E_t \Phi_{x,t+1}\left[S'\Big(\frac{I_{x,t+1}}{I_{x,t}}\Big)\Big(\frac{I_{x,t+1}}{I_{x,t}}\Big)^2\right]$$
$$\Leftrightarrow \frac{P_{I,t}}{P_{C,t}} = Q_{x,t}\left[1 - S\Big(\frac{I_{x,t}}{I_{x,t-1}}\Big) - S'\Big(\frac{I_{x,t}}{I_{x,t-1}}\Big)\frac{I_{x,t}}{I_{x,t-1}}\right]$$
$$+ \beta E_t Q_{x,t+1}\frac{\Lambda_{t+1}}{\Lambda_t}\left[S'\Big(\frac{I_{x,t+1}}{I_{x,t}}\Big)\Big(\frac{I_{x,t+1}}{I_{x,t}}\Big)^2\right].$$

The assets held by the financial intermediary of sector $x = C, I$ pay in the next period the stochastic return $R^B_{x,t+1}$ from borrowers in the respective sector. It can be derived from the household's first-order condition of available capital that

$$R^B_{x,t+1} = \frac{\frac{R^K_{x,t+1}}{P_{x,t+1}}\xi^K_{x,t+1}u_{x,t+1} + Q_{x,t+1}\xi^K_{x,t+1}(1-\delta_x) - a(u_{x,t+1})\xi^K_{x,t+1}A_{t+1}V_{t+1}^{\frac{a_c-1}{1-a_i}}}{Q_{x,t}}, \quad x = C, I.$$

The capital quality shock, $\xi^K_{x,t+1}$ is a source for fluctuations in the price of capital in both sectors. The formulation we have adopted for the capital quality shock process implies that the current asset price will in general depend on beliefs about the expected future path of $\xi^K_{x,t+j}$.

2.5 Monetary and fiscal policy

The nominal interest rate R_t is set by a monetary policy authority and follows a feedback rule of the form

$$\frac{R_t}{R} = \Big(\frac{R_{t-1}}{R}\Big)^{\rho_R}\Big[\Big(\frac{\pi_t}{\pi}\Big)^{\phi_\pi}\Big(\frac{X_t}{X^*_t}\Big)^{\phi_X}\Big]^{1-\rho_R}\Big[\frac{X_t/X_{t-1}}{X^*_t/X^*_{t-1}}\Big]^{\phi_{d,X}}\eta_{mp,t}, \quad \rho_R, \phi_\pi, \phi_X, \phi_{d,X} \in (0,1),$$

where R is the steady state gross nominal interest rate and (X_t/X^*_t) is the GDP gap.[15] The interest rate responds to deviations of inflation from its target level, to the level and the growth rate of the GDP gap and to a monetary policy shock $\eta_{mp,t}$ (as in Smets and Wouters (2007)). This shock follows the process

$$\log \eta_{mp,t} = \rho_{mp}\log \eta_{mp,t-1} + \varepsilon^{mp}_t,$$

where $\rho_{mp} \in (0,1)$ and ε^{mp}_t is $i.i.d.$ $N(0, \sigma^2_{mp})$. The nominal interest rate is implemented through open market operations of the central bank. The surplus or deficit generated my this monetary policy is eliminated through the lump-sum transfers T_t in the household's budget constraint.[16]

[15]The GDP gap is the difference between actual GDP and its level under flexible wages, flexible prices and no markup shocks as in Woodford and Walsh (2005).

[16]While in the past most central banks have implemented the interest rate through open market operations one can also interpret its implementation through interest payments on bank reserves which has been conducted more recently by a number of central banks including the Federal Reserve Bank.

2.6 Market clearing

Output is defined as

$$Y_t = C_t + \frac{P_{I,t}}{P_{C,t}} I_t + G_t + \tau\psi_{C,t} Q_{C,t} S_{C,t} + \tau\psi_{I,t} Q_{I,t} S_{I,t}.$$

where G_t denotes measurement error. We assume that this measurement error in GDP evolves according to

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

where $\rho_g \in (0,1)$ and ε_t^g is $i.i.d.$ $N(0,\sigma_g^2)$. This measurement error is used to capture unmodelled output movements. The resource constraint in the consumption sector is

$$C_t + (a(u_{C,t})\xi^K_{C,t}\bar{K}_{C,t-1} + a(u_{I,t})\xi^K_{I,t}\bar{K}_{I,t-1})\frac{A_t V_t^{\frac{a_c}{1-a_i}}}{V_t^{\frac{1}{1-a_i}}} = A_t L_{c,t}^{1-a_c} K_{c,t}^{a_c} - A_t V_t^{\frac{a_c}{1-a_i}} F_C.$$

The resource constraint in the investment sector is

$$I_{I,t} + I_{C,t} = V_t L_{I,t}^{1-a_i} K_{I,t}^{a_i} - V_t^{\frac{1}{1-a_i}} F_I.$$

It further holds that

$$L_t = L_{I,t} + L_{C,t}, \qquad I_t = I_{I,t} + I_{C,t} \qquad \text{and} \qquad K_t = K_{I,t} + K_{C,t}.$$

3 Data, Estimation and Parameter Information

The model's parameter values are estimated using Bayesian techniques. In the first part of this section we provide an overview about the time series used to estimate the model. In the second part we review the details of the estimation. Finally, we discuss the assumptions made about the parameters prior to the estimation.

3.1 The Data

The model is estimated using a sample from 1990Q2 to 2011Q1. We use 10 quarterly macroeconomic time series. We use the time series for output, consumption, investment, hours worked, the real wage, the nominal interest rate, consumption and investment sector inflation. These are constructed in line with Justiniano et al. (2010). Output is measured by nominal GDP and consumption is the sum of personal consumption expenditures on services and personal consumption expenditures on non-durable goods. Nominal gross investment is defined as the sum of personal consumption expenditures on durable goods and gross private domestic investment. The series of output, consumption and investment are expressed in real terms by dividing with the consumption deflator. Hours worked is the log of hours of all persons in the non-farm business sector. Output, consumption, investment and hours are expressed in per-capita terms by dividing with civilian non-institutional population. The first three series are expressed in growth rates and hours worked as the deviation from the series' average. The time series for the real wage is defined as compensation per hour divided by the consumption deflator and is expressed in growth rates. Inflation for the consumption sector is measured as the quarterly log difference of the consumption deflator. Investment sector inflation is measured analogously. The nominal interest rate is given by the Federal Funds Rate.

The remaining two time series used for the estimation are less standard. Models that include anticipation effects imply that agent's have a larger information set compared to more standard models that include unanticipated shocks only. For this reason, the literature has used financial aggregates with high predictive power as observables when estimating models that include anticipation effects. Beaudry and Portier (2006) argue that stock prices contain information about agent's expectations and can therefore be useful in order to capture news shocks. Schmitt-Grohe and Uribe (2010) experiment with stock prices in their set of observables to investigate the importance of news shocks as drivers of the business cycle and confirm the evidence for their predictive power. Davis (2007) argues that interest rates and information of the yield curve can be useful for identifying anticipated effects. He shows that this data has a similar information content to the stock price data used by Beaudry and Portier (2006). Since our model explicitly includes financial intermediation, it is rather natural to provide information about the cost of credit by using time series for the external finance premium in the consumption and investment sector. Another advantage of using the external finance premia as observables is that unlike other financial variables, like stock prices for example, these variables are relatively closely related to other macroeconomic aggregates, meaning that they are for example less volatile and have a higher absolute correlation with output.

The series for the external finance premia are constructed by aggregating credit spreads issued by companies operating in the consumption or investment sector. A credit spread is defined as the difference between the bond's yield and the yield of a US Treasury bond with an identical maturity. In line with Gilchrist and Zakrajsek (2011) we only consider bonds with a rating above investment grade and maturity longer than one and shorter than 30 years. We also exclude all credit spreads below 10 and above 5000 basis points to ensure that the time series are not driven by a small number of extreme observations.[17]

The limited availability of credit spread data for the 1980s is a factor that restricts the sample for the estimation.[18] All data except the nominal interest rate and the credit spreads are seasonally adjusted. The data are not demeaned or de-trended but we estimate separate (stochastic) trends in the two production sectors.

3.2 Estimation Methodology

This Bayesian methodology we apply has been extensively used to estimate DSGE models for the US economy.[19] The log-linearised equilibrium of the detrended model can be expressed in state space form:

$$x_t = Ax_{t-1} + B\epsilon_t, \tag{14}$$

[17]To generate the credit spread series for the consumption/investment sector, we aggregate the spreads of 12999/2058 bonds and take the arithmetic average.

[18]The construction of all time series is described in detail in Appendix E.

[19]See for example Smets and Wouters (2007), Lubik and Schorfheide (2004), Levin et al. (2005) and Del Negro et al. (2007). A general review of Bayesian estimation techniques is provided by An and Schorfheide (2007) and Fernández-Villaverde (2010).

where x_t denotes the vector of model variables and ϵ_t is a vector of exogenous disturbances. A and B are matrices which contain reduced form coefficients that are non-linear functions of the model's structural parameters. The vector Y_t contains the observables at time t

$$\mathbf{Y}_t = \left[\Delta \log Y_t, \Delta \log C_t, \Delta \log I_t, \Delta \log W_t, \pi_{C,t}, \pi_{I,t}, \log L_t, R_t, R^{\Delta}_{C,t}, R^{\Delta}_{I,t}\right]. \tag{15}$$

Then $\mathbf{Y}^T = [\mathbf{Y}_1, \ldots, \mathbf{Y}_T]$ is a matrix which contains the observables' time-series and therefore represents the whole dataset used for the estimation.

Let Θ be a vector which contains all structural parameters of the model. The non-sample information is summarised in a prior distribution with density $p(\Theta)$ which captures our beliefs about the distributions of the parameters.[20] The sample information is contained in the likelihood function $p(\mathbf{Y}^T|\Theta, \mathcal{M}_i)$, which is conditional on model i, $\mathcal{M}_i$. The likelihood function allows one to update the prior distribution of the estimated parameters $p(\Theta)$. Using Bayes' theorem the parameter's posterior distribution can be expressed as

$$\begin{aligned} p(\Theta|\mathbf{Y}^T, \mathcal{M}_i) &= \frac{p(\mathbf{Y}^T|\Theta, \mathcal{M}_i)p(\Theta)}{p(\mathbf{Y}^T|\mathcal{M}_i)} \\ &\propto p(\mathbf{Y}^T|\Theta, \mathcal{M}_i)p(\Theta), \end{aligned}$$

where the denominator $p(\mathbf{Y}^T|\mathcal{M}_i) = \int p(\Theta, \mathbf{Y}^T|\mathcal{M}_i)d\Theta$ in the equation above is the marginal data density conditional on model M_i which is a constant from the point of view of the distribution for Θ.[21] The posterior distribution is numerically approximated by exploring the likelihood function using the Metropolis-Hastings algorithm. We run the two Metropolis Hastings chains with a constant of proportionality (scaling factor) calibrated so that it implies acceptation rates of 36.8% and 36.9% over all draws. For each chain we generate 1,500,000 Metropolis-Hastings draws from the posterior distribution. As described in Brooks and Gelman (1998), we compute diagnostics to ensure that the parameter's posterior distributions have converged. After dropping the first 20% of the draws the inference in this paper is based on the remaining draws from the posterior distribution.[22]

3.3 Parameter Information

This section provides an overview about the information assigned to the parameters prior to the estimation. A subset of parameters is fixed during the estimation. These parameters are calibrated either because they determine the model's steady state and have limited impact on its cyclical properties or because there is little chance to identify them from the data used in the estimation. Prior distributions are assigned to the subset of parameters which are not fixed during the estimation. The calibration and choice of prior distributions are discussed in the following sections.

[20] The parameters are assumed to be a priori independent from each other. This implies that the joint prior distribution equals the product of the marginal priors which is a widely used assumption in the DSGE literature.

[21] The marginal data density can be used as a measure of model fit in Bayesian analysis. It accounts for goodness of in-sample fit and a penalty for model complexity.

[22] All estimations are conducted using DYNARE version 4.2.0.

3.3.1 Calibrated Parameters

The assumptions underlying the calibration of the depreciation rate, the discount factor and the share of capital in the production function are rather standard in the DSGE literature. The quarterly depreciation rate is calibrated to be symmetrical across sectors, $\delta_C = \delta_I = 0.025$, implying an annual steady state depreciation rate of 10%. From the steady state relationship $\beta = \pi_C/R$ follows that $\beta = 0.9974$. The shares of capital in the production function, a_C and a_I, are fixed at 0.3 which is in line with values used for this parameter in previous studies (see for example Khan and Tsoukalas (2009)). The steady state values for quarterly inflation in the consumption and investment sector as well as the steady state ratio of nominal investment to consumption are calibrated to be consistent with the average values in the data.

The calibration of the parameters concerned with the setup of the banking sector is in consistent with the procedure applied in Gertler and Karadi (2011). The parameter θ_B does not have an empirical counterpart and is fixed at 0.9.[23] This value implies an average survival time of bankers of about 11 quarters. The parameters ϖ and λ_B are fixed at values which guarantee that the steady state risk premium and the steady state leverage ratio matches their empirical counterparts. The weighted average of the consumption and investment sector credit spread data implies a steady state risk premium of 53 basis points. Over the time frame of our estimation, the data imply an average leverage ratio of 11.5 which is within the range of values found by Gertler and Karadi (2011). The Federal Reserve Bank directly intermediated funds to non-financial firms and consumers only during the recent financial crisis which represents only a small part of our sample. The absence of 'unconventional' monetary policy during most of our sample makes it hard to provide reliable estimates for the parameters concerned with central bank's direct credit intermediation. Therefore, we shut down central bank's credit intermediation channel for the estimation by setting τ, ϑ_C and ϑ_I equal to zero. All parameter values which are fixed during the estimation and the steady state relationships used to derive these are summarised in Table 1.

3.3.2 Prior Distributions

The prior distributions assigned to the subset of parameters which are estimated are shown in Table 2. The chosen distributions are consistent with the specifications in Smets and Wouters (2007), Justiniano et al. (2010) and Khan and Tsoukalas (2011) are based on statistical restrictions and economic reasoning.

The assumptions about the distributions for the parameters of the utility function are rather standard. The parameter governing the habit persistence, h, follows a Beta distribution with mean 0.5 and standard deviation 0.1. The inverse Frisch labour supply elasticity, ν, is assumed to have a Gamma distribution with mean 2.0 and standard deviation 0.75.

The price and wage setting parameters are assumed to have Beta distributions. The mean of the Calvo price and wage probabilities (0.66) implies an average length of price and wage contracts of three quarters and the standard error allows for variation between about six months and one year. Note that these distributions do not imply any price heterogeneity across sectors before the model is taken to the data.

The elasticities of capital utilisation in the consumption and investment sector are assumed

[23] This is close to the values used in the literature, see for example Gertler and Kiyotaki (2010) and Gertler and Karadi (2011).

Table 1: Calibrated Parameters and Steady State Relationships

Parameter	Value	Description
δ_C	0.025	Consumption sector capital depreciation
δ_I	0.025	Investment sector capital depreciation
a_c	0.3	Consumption sector share of capital
a_I	0.3	Investment sector share of capital
β	0.9974	Discount factor
π_C	0.6722	SS consumption sector inflation
π_I	0.0245	SS investment sector inflation
g	0.18	SS government spending / output
$p_i \frac{i}{c}$	0.399	SS investment / consumption
R	1.0154	SS nominal interest rate
θ_B	0.9	Fraction of bankers that survive
ϖ	0.0032	Share of assets transferred to new bankers
λ_B	0.2749	Fraction of funds bankers can divert
$\frac{qs}{n}$	11.5	SS leverage ratio
R^Δ	0.0053	SS risk premium
ϑ_C	0	Central bank's feedback to external spread
ϑ_I	0	Central bank's feedback to external spread
τ	0	Central bank's cost of providing credit

to follow a Gamma distribution and fluctuate around 5.0 with a standard deviation of 1.0. The same distribution is assumed for the parameter governing the investment adjustment costs with mean 4.0 and unity standard deviation. While this choice of parameters concerned with the production function and capital accumulation is fairly standard, it is somewhat harder to motivate the distributions for the deterministic growth rates of the neutral technology shocks in the consumption and investment sector ($g_a \cdot 100$ and $g_v \cdot 100$). These parameters are assumed to be Normal distributed with standard deviation 0.1. The higher mean of the investment sector growth rate (0.5) compared to the one in the consumption sector (0.3) is motivated by the observation that in our data average growth in the investment sector tends to be higher than in the consumption sector.

The assumptions about the parameters of the monetary policy rule are fairly standard. The parameter governing the persistence of the policy rule is assumed to follow a Beta distribution and fluctuates around 0.6 with a standard deviation of 0.2. The long-run reaction coefficient of inflation is Normal distributed with mean 1.7 and standard deviation 0.3. The parameters concerned with the level and growth of the output gap follow the same distribution with mean 0.125 and standard deviation 0.05.

Finally, all standard deviations of the contemporaneous and the news shocks are assumed to be distributed as an inverse Gamma distribution with 2 degrees of freedom to guarantee a positive standard deviation with a rather large domain. The parameters determining the persistence of these shocks are bound between 0 and 1 which is guaranteed by the assumption that they follow Beta distributions.

4 Estimation Results

4.1 Posterior Distributions

Table 2 also reports the posterior mean and the 10% and 90% intervals of the estimated parameters. Overall, the estimates are consistent with the ones found by Smets and Wouters (2007), Khan and Tsoukalas (2009) and Justiniano et al. (2010). We find a considerable degree of habit formation and the estimate for ν implies a Frisch labour supply elasticity of 0.37 which is also close to the values used in the RBC literature.[24]

We find a substantial degree of heterogeneity in price stickiness where prices in the investment sector are significantly stickier than in the consumption sector. The estimates of the Calvo parameters imply an average contract length in the investment sector of about 4.5 years, while on average contracts are renegotiated every 5 quarters in the consumption sector. There is little guidance in the literature about sectoral price stickiness. Using a VAR framework, DiCecio (2009) also finds that prices in the investment sector are significantly stickier than in the consumption sector. However, using much longer time series for his analysis (1959Q2-2001Q4), he finds prices in both sectors to be somewhat more flexible than implied by our estimates. The Calvo parameter for wage stickiness is very close to the estimates in Smets and Wouters (2007), Khan and Tsoukalas (2009) and Justiniano et al. (2010), implying that on average wages are renegotiated every 5 quarters.

As found by Del Negro et al. (2007) and Justiniano et al. (2010), capital utilisation is not very elastic, where the estimate for consumption sector utilisation is somewhat lower that for the investment sector. The estimate for the investment adjustment costs parameter (0.86) is considerably smaller than in Khan and Tsoukalas (2009) (2.08) and Justiniano et al. (2010) (2.85). We further discover heterogeneity in the growth rates of sectoral TFP, where the growth rate in the investment sector is somewhat higher than in the consumption sector.

Also the estimates for the parameters concerned with the monetary policy rule as well as the persistence and standard deviations of the unanticipated structural shocks are in line with the values reported in Smets and Wouters (2007), Khan and Tsoukalas (2009) and Justiniano et al. (2010).

We estimate a model setup with one, four and eight quarter ahead news about the quality of capital in both sectors. As this is the first study to evaluate the impact of anticipation effects about capital quality, estimates for the standard deviations of these anticipated (news) shocks do not exist in the literature. These standard deviations are estimated to be around or above their unanticipated sectoral counterparts.

4.2 Capital Quality as a Channel for News

As a reminder the capital quality shock can be interpreted as resembling exogenous variations in the intangible capital stock. Hall (2001a) and Laitner and Stolyarov (2003) estimate the quantity of intangible capital in the US using the market value of corporations and identify this type of capital to account for about 25% of the total capital stock. They also find that the size of the intangible capital stock has been increasing vigorously since the beginning of the IT boom in the early 1990s. There is broad consensus in the empirical literature that variations in the value of intangible capital give rise to persistent movements in the stock market (see for

[24] See for example Jaimovich and Rebelo (2009).

Table 2: Prior and Posterior Distributions

Parameter	Description	Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std. dev.	Mean	10%	90%
h	Consumption habit	Beta	0.50	0.10	0.7104	0.6564	0.7666
ν	Inverse labour supply elasticity	Gamma	2.00	0.75	2.6960	1.5233	3.8651
ξ_w	Wage Calvo probability	Beta	0.66	0.10	0.7113	0.6252	0.7995
ξ_C	C-sector price Calvo probability	Beta	0.66	0.10	0.8549	0.8151	0.8956
ξ_I	I-sector price Calvo probability	Beta	0.66	0.10	0.9374	0.9175	0.9576
ι_w	Wage indexation	Beta	0.50	0.15	0.2235	0.1173	0.3260
ι_{p_C}	C-sector price indexation	Beta	0.50	0.15	0.2445	0.1045	0.3773
ι_{p_I}	I-sector price indexation	Beta	0.50	0.15	0.2546	0.0952	0.4081
λ_p	Steady state price markup	Normal	0.125	0.05	0.1254	0.0446	0.2028
λ_w	Steady state wage markup	Normal	0.125	0.05	0.1172	0.0425	0.1874
χ_I	I-sector utilisation	Gamma	5.00	1.00	4.9386	3.3135	6.5201
χ_C	C-sector utilisation	Gamma	5.00	1.00	4.6004	2.9701	6.1726
κ	Investment adjustment cost	Gamma	4.00	1.00	0.8572	0.6237	1.0800
$g_a \cdot 100$	C-sector neutral techn. growth	Normal	0.30	0.10	0.4109	0.3056	0.5172
$g_v \cdot 100$	I-sector neutral techn. growth	Normal	0.50	0.10	0.4551	0.3719	0.5361
ϕ_π	Taylor rule inflation	Normal	1.70	0.30	1.5698	1.3310	1.7972
ρ_R	Taylor rule inertia	Beta	0.60	0.20	0.8608	0.8309	0.8912
ϕ_X	Taylor rule output gap	Normal	0.125	0.05	0.0605	0.0331	0.0871
ϕ_{dX}	Taylor rule output gap growth	Normal	0.125	0.05	0.1857	0.1564	0.2143
ρ_z	C-sector neutral technology	Beta	0.40	0.20	0.1807	0.0792	0.2784
ρ_v	I-sector neutral technology	Beta	0.40	0.20	0.0778	0.0102	0.1370
ρ_b	Preference	Beta	0.60	0.20	0.6357	0.5000	0.7722
ρ_g	GDP measurement error	Beta	0.60	0.20	0.9544	0.9190	0.9933
ρ_{mp}	Monetary policy	Beta	0.40	0.20	0.3731	0.2787	0.4698
$\rho_{\lambda_p^C}$	C-sector price markup	Beta	0.60	0.20	0.2353	0.0776	0.3846
$\rho_{\lambda_p^I}$	I-sector price markup	Beta	0.60	0.20	0.3198	0.1250	0.5045
ρ_{λ_w}	Wage markup	Beta	0.60	0.20	0.3352	0.1687	0.5008
ρ_{ς_C}	C-sector equity capital	Beta	0.60	0.20	0.4853	0.1932	0.7681
ρ_{ς_I}	I-sector equity capital	Beta	0.60	0.20	0.4671	0.1726	0.7532
$\rho_{\xi^K,C}$	C-sector capital quality	Beta	0.60	0.20	0.7050	0.5866	0.8280
$\rho_{\xi^K,I}$	I-sector capital quality	Beta	0.60	0.20	0.1890	0.0462	0.3237
σ_z	C-sector neutral technology	Inv Gamma	0.50	2*	0.6575	0.5589	0.7568
σ_v	I-sector neutral technology	Inv Gamma	0.50	2*	1.2614	1.0798	1.4401
σ_b	Preference	Inv Gamma	0.10	2*	2.0187	1.1970	2.8031
σ_g	GDP measurement error	Inv Gamma	0.50	2*	0.4435	0.3838	0.5021
σ_{mp}	Monetary policy	Inv Gamma	0.10	2*	0.1207	0.0988	0.1426
$\sigma_{\lambda_p^C}$	C-sector price markup	Inv Gamma	0.10	2*	0.3062	0.2520	0.3599
$\sigma_{\lambda_p^I}$	I-sector price markup	Inv Gamma	0.10	2*	0.2395	0.1881	0.2899
σ_{λ_w}	Wage markup	Inv Gamma	0.10	2*	0.2810	0.2173	0.3443
σ_{ς_C}	C-sector equity capital	Inv Gamma	0.50	2*	0.3690	0.1201	0.6373
σ_{ς_I}	I-sector equity capital	Inv Gamma	0.50	2*	0.3304	0.1180	0.5413
$\sigma_{\xi^{K,0},C}$	C-sector capital quality	Inv Gamma	0.50	2*	0.1750	0.1127	0.2344
$\sigma_{\xi^{K,1},C}$	C capital quality 1Q ahead news	Inv Gamma	0.50	2*	0.1681	0.1093	0.2257
$\sigma_{\xi^{K,4},C}$	C capital quality 4Q ahead news	Inv Gamma	0.50	2*	0.2261	0.1417	0.3079
$\sigma_{\xi^{K,8},C}$	C capital quality 8Q ahead news	Inv Gamma	0.50	2*	0.4680	0.2992	0.6341
$\sigma_{\xi^{K,0},I}$	I-sector capital quality	Inv Gamma	0.50	2*	0.1866	0.1141	0.2561
$\sigma_{\xi^{K,1},I}$	I capital quality 1Q ahead news	Inv Gamma	0.50	2*	0.1865	0.1146	0.2555
$\sigma_{\xi^{K,4},I}$	I capital quality 4Q ahead news	Inv Gamma	0.50	2*	0.2136	0.1246	0.3020
$\sigma_{\xi^{K,8},I}$	I capital quality 8Q ahead news	Inv Gamma	0.50	2*	0.2433	0.1288	0.3567

*For the inverse Gamma distribution the degrees of freedom are indicated.

example Hall (2001a)) and that intangible capital is important for the understanding of the relationship between the stock market and aggregate fluctuations.[25] Owing to the predictive power of the stock market, large parts of the variations in intangible capital may be anticipated. This makes the capital quality shock especially prone to being a potential channel for anticipation effects.

In this section, we evaluate the fit of our benchmark model with one, four and eight quarter ahead news shocks about consumption and investment sector capital quality against various other model versions. This includes setups with news shocks about consumption and investment sector TFP, which capture channels the literature has previously investigated of as potential candidates through which news may matter. Prominent examples are Beaudry and Portier (2006) and Khan and Tsoukalas (2009) who consider total factor productivity as a channel for anticipation effects, or Davis (2007) who finds news about investment specific technological change to be an important driver of aggregate fluctuations. The two year horizon we specify for the benchmark model has been found in the literature to be a long enough anticipation horizon for agents (see Beaudry and Portier (2004)). We want to keep our setup for anticipation effects parsimonious since each news component is an additional state variable which makes identification difficult. Therefore, we follow Schmitt-Grohe and Uribe (2010) and restrict the benchmark model to one, four and eight quarter ahead news shocks.

As a measure of fit we use the log marginal data density, $\ln(p(\mathbf{Y}^T|\mathcal{M}_i))$, which accounts for goodness of in-sample fit and includes a penalty for model complexity. Table 3 provides an overview about all different model specifications we considered and the associated log marginal data densities. These log marginal data densities imply a large Bayes factor in favor of the estimated benchmark model with one, four and eight quarter ahead news about the quality of capital in both sectors, indicating that its fit is superior to all other model versions including setups with news shocks about TFP. Note that accounting of anticipation effects improves the model's fit regardless of various different specifications for the forecast horizon or whether we introduce news about TFP, capital quality or a combination of both.

5 Variance Decomposition

In order to evaluate the shock's relative contribution to fluctuations in macroeconomic variables, we perform a business cycle horizon variance decomposition. The median as well as the 5th and 95th percentiles of this exercise are summarised in Table 4.[26] From this table it is evident that anticipated shocks play a major role for fluctuations in output. Taken together, the one, four and eight quarter ahead news shocks about consumption sector capital quality explain about 31% of the fluctuations in output which makes them the primary driving force for this variable. Anticipation effects of investment sector capital quality are far less important as they account together only for about 6% of the output fluctuations.

Our finding that anticipated shocks about consumption sector capital quality are the primary driving force of output is in contrast to the results of Justiniano and Primiceri (2008) who identify investment specific shocks as the primary driving force of this variable. However, these studies only investigate the impact of unanticipated shocks and abstract from any kind of news or anticipation effects. Our results are not completely contrary to those of

[25]Examples of this literature are Hall (2001b), McGrattan and Prescott (2000) and Corrado et al. (2009).

[26]The details of the finite horizon variance decomposition are discussed in Appendix E.

Table 3: Model fit for different specifications of news shocks

	Model setup	Log marginal data density
Benchmark:	1, 4 and 8 quarters ahead news about capital quality in both sectors	-749.1
Setup A:	No news shocks	-1019.2
Setup B:	1 and 4 quarters ahead news about capital quality in both sectors	-763.9
Setup C:	1 to 4 quarters ahead news about capital quality in both sectors	-778.5
Setup D:	1 to 8 quarters ahead news about capital quality in both sectors	-769.2
Setup E:	1, 4 and 8 quarters ahead news about capital quality in both sectors and 1, 4 and 8 quarters ahead news about TFP in both sectors	-764.1
Setup F:	1, 4 and 8 quarters ahead news about capital quality in both sectors and 1 and 4 quarters ahead news about TFP in both sectors	-764.9
Setup G:	1, 4 and 8 quarters ahead news about capital quality in both sectors and 1 and 4 quarters ahead news about consumption sector TFP	-767.3
Setup H:	1, 4 and 8 quarters ahead news about TFP in both sectors	-759.2

Justiniano and Primiceri (2008) as we still find that investment (and consumption) sector TFP shocks play a prominent role as drivers of fluctuations in output.

The important role our investigation assigns to anticipation effects for fluctuations in output is in line with the findings of Schmitt-Grohe and Uribe (2010) and Davis (2007). Both studies emphasize the dominant role of anticipation effects as drivers of the business cycle. They find that news explain about 50% of the fluctuations in output. However, they do not include news about capital quality in their studies but evaluate anticipation effects to a variety of more conventional shocks. This includes anticipation effects about TFP and investment specific technology. As shown above that our benchmark model with news about capital quality is superior to model versions that include anticipation effects about such disturbances. Hence, using the model fit criterion, suggests that in this framework news about technology are not important drivers of the business cycle.

Our decomposition exercise further shows that the monetary policy shock and the price and wage markup shocks are of relatively small importance for fluctuations in GDP.

The anticipated shocks about consumption sector capital quality are also of major importance for fluctuations in consumption and aggregate investment. For these two variables as well as output, the importance of the anticipated shocks tends to increase in the forecast horizon. For fluctuations in consumption, the consumption sector TFP shocks and a range of other shocks are of secondary importance, including the preference, monetary policy, price and wage markup shocks. These results are not surprising as most of these shocks directly affect demand or supply of consumption goods. The role of the investment sector TFP shock for fluctuations in consumption is rather limited.

For fluctuations in aggregate investment, consumption and investment sector TFP shocks are almost equally important. Together with the anticipated and unanticipated consumption sector capital quality shocks, they explain almost 70% of the fluctuations in aggregate investment. The picture is similar for the sectoral parts of investment. The anticipated capital quality shocks of the respective sector are the primary driving force. The anticipated shocks of the other sector are of secondary importance together with the two TFP shocks and the unanticipated shocks about capital quality. For both sectoral investment components, anticipated shocks account for about 45% (investment sector) and 59% (consumption sector) of the fluctuations.

Hours worked in the consumption sector is mainly driven by shocks that primarily affect the consumption side of the economy (the consumption sector TFP shock, the price markup shock, the preference shock and the anticipated consumption sector capital quality shocks). Furthermore, the monetary policy shock plays a role. Fluctuations of hours in the investment sector are primarily driven by shocks that affect production in both sectors (both TFP shocks and anticipated and unanticipated consumption sector capital quality shocks). For aggregate hours worked this implies that all of the discussed shocks contribute to fluctuations in this variable were the aggregated effect of the consumption sector news shocks about capital quality clearly dominates.

The wage markup shock is primarily responsible for fluctuations in the real wage rate. Of secondary importance are the consumption sector TFP and price markup shocks as well as the eight quarter ahead news shock about consumption sector capital quality. Variations in the two inflation rates are predominantly driven by the respective price markup shocks which are responsible for more than 40% of the fluctuations. The main impact on the nominal interest rate is reported to be through anticipated consumption sector capital quality shocks, but also the corresponding unanticipated shock and the two TPF shocks play a role.

The main driving forces for the two interest rate spreads are the respective (anticipated and unanticipated) capital quality shocks. The news components of these shocks explain 34% (consumption sector) and 27% (investment sector) of the fluctuations of the spreads. Also the two TFP shocks are of considerable importance for fluctuations in both interest rate spreads.

In summary, the finite horizon variance decomposition reveals a prominent role for the anticipated consumption sector capital quality shocks. They are the main driving forces for fluctuations in several macroeconomic variables including output and consumption as well as aggregate and sectoral investment and hours worked. Their investment sector counterparts play almost no role for fluctuations in aggregate variables, but are of importance for movements in variables associated with the investment sector (in particular the interest rate spread and sectoral investment). We also find considerable importance of the investment and consumption sector TFP shocks and the unanticipated capital quality shocks as drivers for several variables. Changes in prices and wages are primarily driven by their respective markup shocks. The contribution of monetary policy shocks is limited. We find almost no contribution of the shocks to bank's equity capital. This is unsurprising as these shocks capture exogenous changes to bank's leverage ratios. These may be observed during the recent recession, but not necessarily during many other times of the estimated period. The finite horizon variance decomposition however captures the importance of fluctuations over the whole period of interest. This leads to the low importance of shocks to bank's equity capital in this exercise, even though they might have played a considerable role during specific parts of the sample.

Table 4: Business cycle variance decomposition

	z	v	b	η_{em}	λ_p^C	λ_p^I	λ_w	$\xi_C^{K,0}$	$\xi_C^{K,1}$	$\xi_C^{K,4}$	$\xi_C^{K,8}$	$\xi_I^{K,0}$	$\xi_I^{K,1}$	$\xi_I^{K,4}$	$\xi_I^{K,8}$	ς_C	ς_I	g
Output	0.140 [0.113 0.186]	0.106 [0.087 0.139]	0.006 [0.004 0.009]	0.061 [0.044 0.081]	0.068 [0.049 0.084]	0.044 [0.033 0.058]	0.042 [0.030 0.059]	0.094 [0.072 0.126]	0.087 [0.067 0.119]	0.096 [0.074 0.135]	0.127 [0.093 0.189]	0.006 [0.004 0.008]	0.005 [0.003 0.006]	0.014 [0.010 0.019]	0.040 [0.030 0.049]	0.003 [0.002 0.004]	0.001 [0.000 0.001]	0.041 [0.033 0.052]
Consumption	0.145 [0.105 0.206]	0.045 [0.032 0.063]	0.079 [0.062 0.115]	0.052 [0.038 0.067]	0.066 [0.045 0.095]	0.052 [0.035 0.076]	0.052 [0.033 0.079]	0.071 [0.049 0.101]	0.065 [0.047 0.099]	0.089 [0.048 0.124]	0.206 [0.141 0.287]	0.006 [0.004 0.008]	0.007 [0.004 0.010]	0.015 [0.007 0.022]	0.031 [0.021 0.048]	0.002 [0.001 0.003]	0.000 [0.000 0.001]	0.000 [0.000 0.000]
Investment	0.106 [0.084 0.139]	0.100 [0.078 0.133]	0.035 [0.026 0.050]	0.050 [0.035 0.067]	0.044 [0.033 0.055]	0.044 [0.032 0.058]	0.031 [0.022 0.042]	0.105 [0.078 0.134]	0.100 [0.075 0.139]	0.116 [0.086 0.167]	0.167 [0.127 0.244]	0.009 [0.006 0.013]	0.009 [0.006 0.013]	0.019 [0.013 0.028]	0.046 [0.035 0.058]	0.004 [0.002 0.005]	0.001 [0.001 0.001]	0.000 [0.000 0.000]
C-Investment	0.058 [0.045 0.075]	0.062 [0.050 0.082]	0.014 [0.010 0.019]	0.020 [0.015 0.027]	0.037 [0.028 0.047]	0.039 [0.030 0.051]	0.020 [0.015 0.028]	0.091 [0.070 0.119]	0.088 [0.069 0.122]	0.105 [0.078 0.158]	0.176 [0.134 0.245]	0.047 [0.035 0.067]	0.056 [0.039 0.073]	0.073 [0.052 0.107]	0.091 [0.070 0.123]	0.004 [0.003 0.005]	0.002 [0.001 0.003]	0.000 [0.000 0.000]
I-Investment	0.104 [0.084 0.138]	0.084 [0.066 0.121]	0.045 [0.034 0.063]	0.061 [0.046 0.082]	0.029 [0.020 0.037]	0.050 [0.034 0.072]	0.027 [0.018 0.037]	0.045 [0.031 0.062]	0.042 [0.031 0.058]	0.046 [0.035 0.065]	0.070 [0.052 0.092]	0.085 [0.063 0.107]	0.091 [0.061 0.119]	0.099 [0.072 0.135]	0.100 [0.073 0.146]	0.001 [0.001 0.001]	0.004 [0.003 0.006]	0.000 [0.000 0.000]
Hours Worked	0.082 [0.066 0.112]	0.118 [0.095 0.157]	0.007 [0.004 0.010]	0.074 [0.053 0.100]	0.061 [0.045 0.077]	0.039 [0.030 0.053]	0.044 [0.032 0.060]	0.106 [0.079 0.136]	0.103 [0.078 0.140]	0.120 [0.092 0.167]	0.160 [0.120 0.229]	0.005 [0.004 0.007]	0.004 [0.003 0.006]	0.013 [0.010 0.018]	0.045 [0.034 0.057]	0.004 [0.002 0.005]	0.001 [0.001 0.001]	0.000 [0.000 0.000]
C-Hours	0.141 [0.117 0.174]	0.029 [0.019 0.043]	0.136 [0.110 0.186]	0.109 [0.088 0.146]	0.116 [0.085 0.162]	0.072 [0.051 0.100]	0.093 [0.062 0.133]	0.024 [0.017 0.032]	0.028 [0.024 0.033]	0.032 [0.024 0.046]	0.114 [0.091 0.145]	0.019 [0.013 0.028]	0.020 [0.011 0.030]	0.018 [0.012 0.025]	0.027 [0.020 0.036]	0.001 [0.000 0.001]	0.001 [0.000 0.001]	0.000 [0.000 0.000]
I-Hours	0.106 [0.086 0.141]	0.121 [0.096 0.160]	0.035 [0.026 0.050]	0.050 [0.035 0.068]	0.043 [0.032 0.054]	0.041 [0.031 0.055]	0.032 [0.023 0.043]	0.105 [0.078 0.136]	0.100 [0.076 0.140]	0.117 [0.087 0.166]	0.166 [0.126 0.240]	0.006 [0.005 0.008]	0.006 [0.004 0.007]	0.011 [0.008 0.016]	0.039 [0.030 0.050]	0.004 [0.002 0.005]	0.001 [0.001 0.001]	0.000 [0.000 0.000]
Wage	0.145 [0.104 0.213]	0.020 [0.017 0.025]	0.005 [0.003 0.007]	0.027 [0.019 0.037]	0.144 [0.107 0.182]	0.008 [0.005 0.012]	0.228 [0.175 0.290]	0.066 [0.049 0.099]	0.065 [0.049 0.092]	0.082 [0.052 0.114]	0.132 [0.087 0.197]	0.008 [0.005 0.011]	0.009 [0.005 0.015]	0.014 [0.008 0.022]	0.023 [0.015 0.035]	0.001 [0.001 0.002]	0.000 [0.000 0.000]	0.000 [0.000 0.000]
C-Inflation	0.064 [0.050 0.087]	0.020 [0.014 0.027]	0.022 [0.017 0.031]	0.075 [0.059 0.092]	0.404 [0.365 0.442]	0.005 [0.003 0.007]	0.115 [0.091 0.158]	0.006 [0.003 0.012]	0.008 [0.006 0.012]	0.036 [0.027 0.046]	0.117 [0.086 0.173]	0.023 [0.016 0.031]	0.027 [0.018 0.037]	0.032 [0.023 0.045]	0.035 [0.025 0.047]	0.001 [0.000 0.001]	0.001 [0.000 0.001]	0.000 [0.000 0.000]
I-Inflation	0.017 [0.012 0.028]	0.025 [0.018 0.036]	0.009 [0.006 0.014]	0.052 [0.039 0.070]	0.012 [0.008 0.018]	0.478 [0.430 0.527]	0.045 [0.034 0.061]	0.036 [0.027 0.046]	0.038 [0.029 0.053]	0.066 [0.052 0.093]	0.155 [0.122 0.221]	0.013 [0.010 0.020]	0.014 [0.009 0.020]	0.012 [0.007 0.017]	0.011 [0.009 0.016]	0.001 [0.001 0.002]	0.000 [0.000 0.000]	0.000 [0.000 0.000]
Nom. Inter. Rate	0.073 [0.054 0.099]	0.105 [0.079 0.130]	0.020 [0.015 0.027]	0.038 [0.029 0.050]	0.017 [0.012 0.026]	0.050 [0.037 0.067]	0.021 [0.014 0.030]	0.106 [0.080 0.137]	0.105 [0.078 0.150]	0.141 [0.101 0.200]	0.230 [0.172 0.309]	0.015 [0.011 0.021]	0.015 [0.012 0.018]	0.013 [0.008 0.020]	0.036 [0.027 0.046]	0.004 [0.002 0.005]	0.001 [0.001 0.001]	0.000 [0.000 0.000]
C-Spread	0.131 [0.115 0.154]	0.169 [0.152 0.208]	0.012 [0.010 0.015]	0.010 [0.008 0.014]	0.075 [0.060 0.087]	0.085 [0.070 0.102]	0.026 [0.021 0.035]	0.110 [0.094 0.129]	0.093 [0.079 0.109]	0.067 [0.057 0.087]	0.031 [0.021 0.043]	0.033 [0.029 0.041]	0.037 [0.032 0.044]	0.049 [0.038 0.060]	0.053 [0.042 0.063]	0.012 [0.009 0.015]	0.001 [0.001 0.002]	0.000 [0.000 0.000]
I-Spread	0.165 [0.144 0.186]	0.163 [0.148 0.206]	0.040 [0.032 0.049]	0.045 [0.041 0.059]	0.056 [0.044 0.065]	0.034 [0.027 0.042]	0.032 [0.025 0.043]	0.051 [0.040 0.060]	0.046 [0.039 0.054]	0.049 [0.040 0.063]	0.064 [0.052 0.077]	0.089 [0.076 0.109]	0.081 [0.069 0.095]	0.054 [0.043 0.066]	0.016 [0.013 0.020]	0.001 [0.001 0.001]	0.007 [0.005 0.009]	0.000 [0.000 0.000]

z = TFP in consumption sector, v = TFP in investment sector, b = Preference shock, η_{em} = Monetary policy, λ_p^C = Consumption sector price markup, λ_p^I = Investment sector price markup, λ_w = Wage markup, $\xi_C^{K,0}$ = Unanticipated consumption sector capital quality, $\xi_C^{K,x}$ = x quarter ahead anticipated consumption sector capital quality, $\xi_I^{K,0}$ = Unanticipated investment sector capital quality, $\xi_I^{K,x}$ = x quarters ahead anticipated investment sector capital quality, ς_C = Shock to consumption sector bank's equity capital, ς_I = Shock to consumption sector bank's equity capital, g = GDP measurement error. For a detailed description of how the finite horizon decomposition is performed see Appendix E.

6 The Importance of Anticipated Shocks from a Historical Perspective

Given the importance of news shocks as driving forces suggested by the finite horizon decomposition, we disentangle the impact of anticipated and unanticipated shocks on the growth rate of GDP and investment over time by performing a historical decomposition. Figure 1 depicts the results of this exercise. In this figure we show the accumulated effects of all anticipated and unanticipated shocks. Although not reported in the Figure, within the group of anticipated shocks the disturbances to consumption sector capital quality play the major role. The impact of the anticipated investment sector counterparts of GDP and investment growth is extremely limited.[27] This is consistent with the findings of the finite horizon decomposition exercise.

The historical decompositions show that anticipated (news) shocks are the main sources for the recessions following the dot-com boom (2001Q1 - 2001Q4) and the real estate bust (2007Q4 - 2009Q2). Even though news shocks also contribute to the downturn of GDP and investment in the early 1990s (1990Q3 - 1991Q1), their role during this recession is much more limited. This finding is in line with the general assessment of the reasons for these recessions: While movements in fundamentals are mainly found to be responsible for the recession in the early 1990s (see for example Walsh (1993)), it is thought that expectations played a much bigger role in the two recessions in the early 21st century (see for example Christiano et al. (2008)). These recessions were the result of bursting bubbles thought to be developed due to overoptimistic expectations. The historical decompositions are consistent with this. Notice that expectations about future capital quality are revised downwards immediately at the beginning of the two recessions and explain a substantial fraction of the initial downturn. The finding that news shocks are mainly responsible for these two recessions is also consistent with work of Beaudry and Portier (2004) who interpret Pigou's theory that expectations can drive the business cycle as a theory of recessions.

Anticipated shocks do not only have a strong negative impact during the aforementioned recessions, but also slow down the subsequent recoveries. This is especially clear in the aftermath of the recession in the early 2000s. A similar pattern can be observed after the recent recession, but in this case a longer sample size would be desirable to be able to draw a more complete picture.[28] The slow reversion of anticipated shock's impact on GDP and investment growth at the trough of the cycle and the instant revision at the peak is consistent with the literature that finds agent's forecast accuracy to be positively correlated with output.[29] According to this literature, at the peak of the business cycle agents learn faster and can therefore make more accurate forecasts. This leads to an instant and strong revision of expectations when agents realise the beginning of a recession. At the trough of the cycle however, learning is slow and forecasts are relatively inaccurate. This leads to slower revisions of expectations. The observed impact of anticipated shocks during the different phases of the business cycle is also consistent with the findings in Görtz and Tsoukalas (2011a) that agent's expectations contribute to a sharp downturn and a gradual recovery.

These findings underline the importance of anticipated (news) shocks for aggregate fluctuations.

[27] We do not distinguish between the different types of news shocks in the historical decompositions to maintain a clearly arranged layout.

[28] At the time this thesis is written the data required to estimate the model over a longer horizon is not available.

[29] See for example Van Nieuwerburgh and Veldkamp (2006).

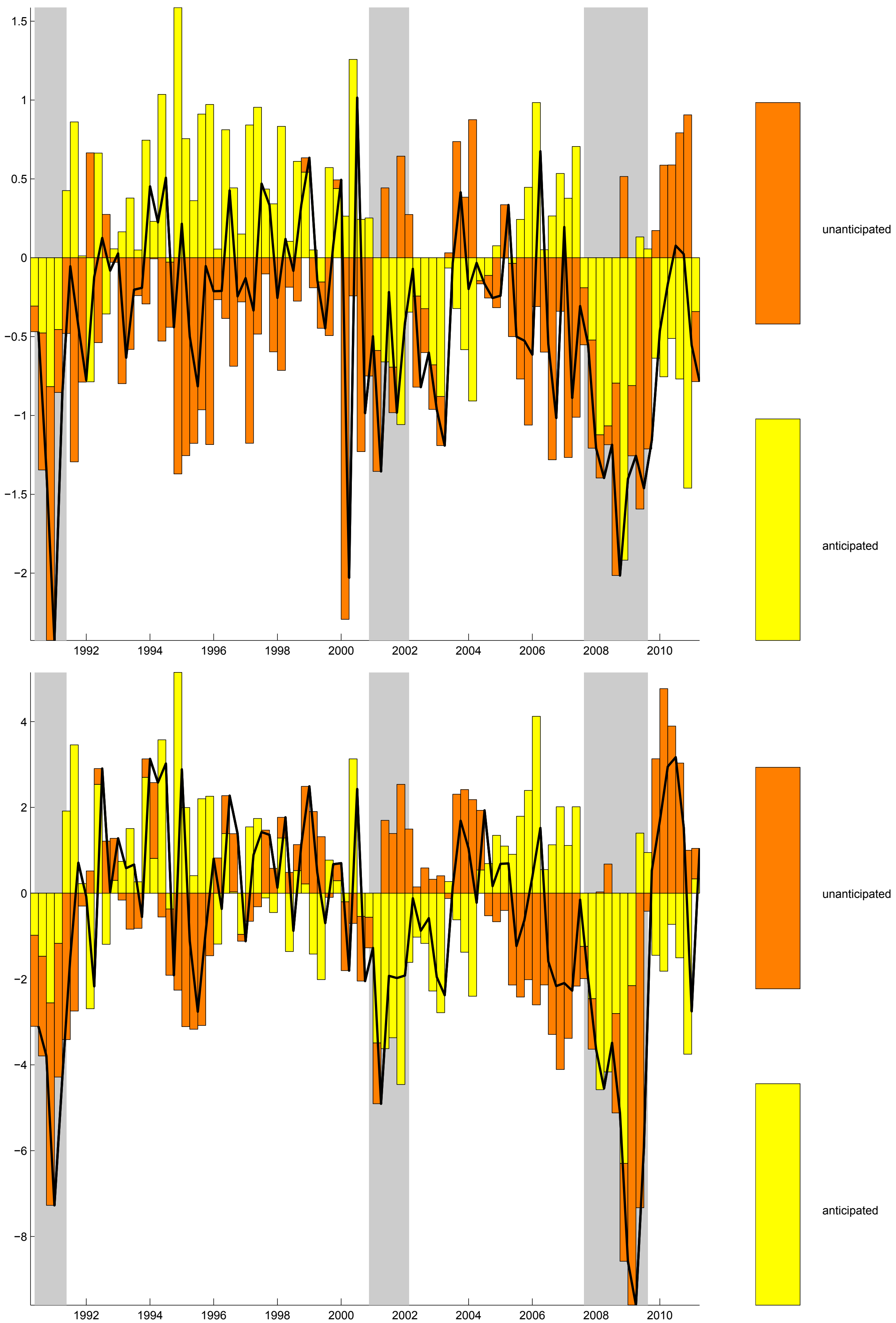

Figure 1: Historical decomposition of the growth rate of GDP (top) and investment (bottom). The grey bars denote recessions as announced by the NBER Business Cycle Dating Committee.

7 The economy's response to capital quality shocks

The finite horizon variance decomposition revealed that unanticipated, and especially anticipated shocks to the quality of consumption sector capital are of particular importance for the dynamics of various macroeconomic aggregates. In this section, we discuss the economy's response to these type of shocks. Gertler and Karadi (2011) argue that these capital quality shocks may be used to capture a scenario similar to the recent sub-prime crisis, albeit in an approximate manner. As will become clear in the discussion of the impulse response functions, an exogenous deterioration of the quality of capital weakens banks' balance sheets and triggers an endogenous second round effect that further amplifies balance sheet deterioration. This causes a rise in credit spreads which finally leads to a downturn of the real economy. This scenario is comparable to the developments during the recent financial crisis. The decline in the value of the US housing stock featured a drop in asset values rather than an initial massive destruction of available capital. The result were significant credit spreads and a reduction of lending which caused the crisis to spread from the banking sector through the whole economy.

Unanticipated Shocks Figure 2 shows the economy's response to a one standard deviation unanticipated shock to consumption sector capital quality (solid line).[30] The initial exogenous decline in capital quality in the consumption sector leads to a decline in bank's asset values and an increase in the leverage ratio. This triggers an endogenous reaction that causes an even more substantial deterioration of asset values in this sector: Owing to the presence of leverage ratio constraints, banks have to sell assets which puts downward pressure on the market price of capital, Q_C. Financial intermediaries aim to strengthen their balance sheets by increasing the rental rate for assets, R_C^B, which is reflected in the sharp increase of the interest rate spread. As a result, consumption sector investment drops which makes the contraction spread to the real economy.

Lower demand for investment goods dampens production in the investment sector and the price per effective unit of capital (Q_I) drops. This drop has a similar effect on this sector's interest rate spread and leverage ratio as just described for the consumption sector. However, the contraction in the investment sector is less strong since the quality of investment sector capital does not decline. The downturn in this sector is triggered purely by the endogenous propagation mechanism.

The lower level of production in the two sectors reduces demand for (sectoral and aggregate) labour and puts downward pressure on the real wage. The contraction in the two sectors results in a sharp decline in total output which is comparable to the contraction of US output during the recent recession. Investment adjustment costs and habit formation lead to hump-shaped responses of output, consumption, investment and hours worked. The economy's recovery takes about 5 to 7 years.

Anticipated Shocks In the following we discuss the economy's responses to four and eight quarter ahead news shocks which have been found to be the most important anticipated shocks to drive fluctuations in output. Figure 2 shows not only the economy's response to an unanticipated shock (solid line) but also the response to a four quarter ahead anticipated shock to

[30] All shocks in this section are set to produce a downturn.

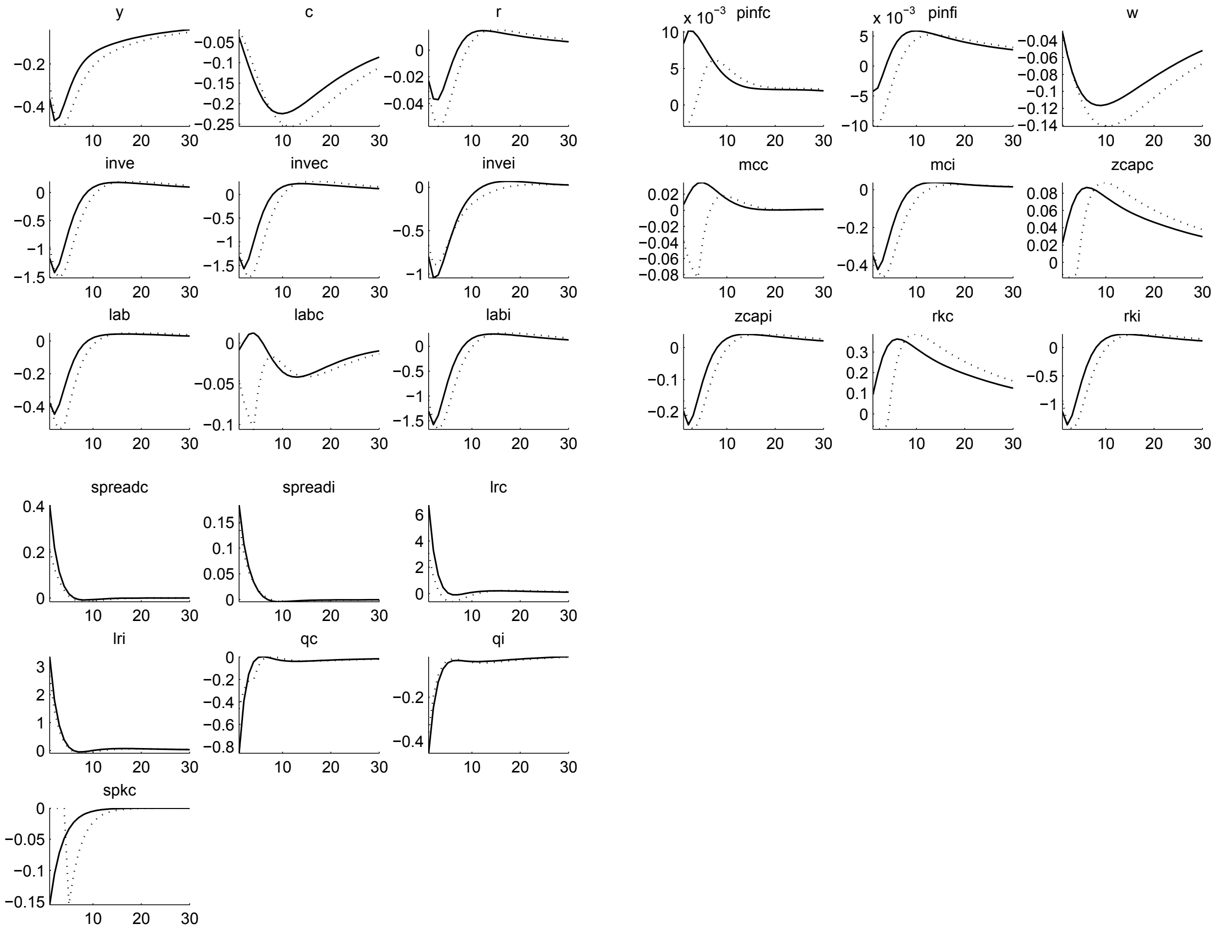

Figure 2: The economies response to an unanticipated (solid line) and four quarter ahead anticipated (dashed line) shock to capital quality in the consumption sector

The size of the anticipated and unanticipated shocks is one standard deviation of the unanticipated shock. Variable key: y = output, c = consumption, r = nominal interest rate, inve = investment, invec = consumption sector investment, invei = investment sector investment, lab = total hours worked, labc = consumption sector hours, labi = investment sector hours, pinfc = consumption sector inflation, pinfi = investment sector inflation, w = real wage rate, mcc = consumption sector marginal cost, mci = investment sector marginal cost, zcapc = consumption sector capital utilisation, zcapi = investment sector captial utilisation, rkc = consumption sector rental rate of capital, rki = investment sector rental rate of capital, spreadc = consumption sector interest rate spread, spreadi = investment sector interest rate spread, lrc = consumption sector leverage ratio, lri = investment sector leverage ratio, qc = consumption sector market price of capital, qi = investment sector market price of capital, spkc = anticipated/unanticipated capital quality shock.

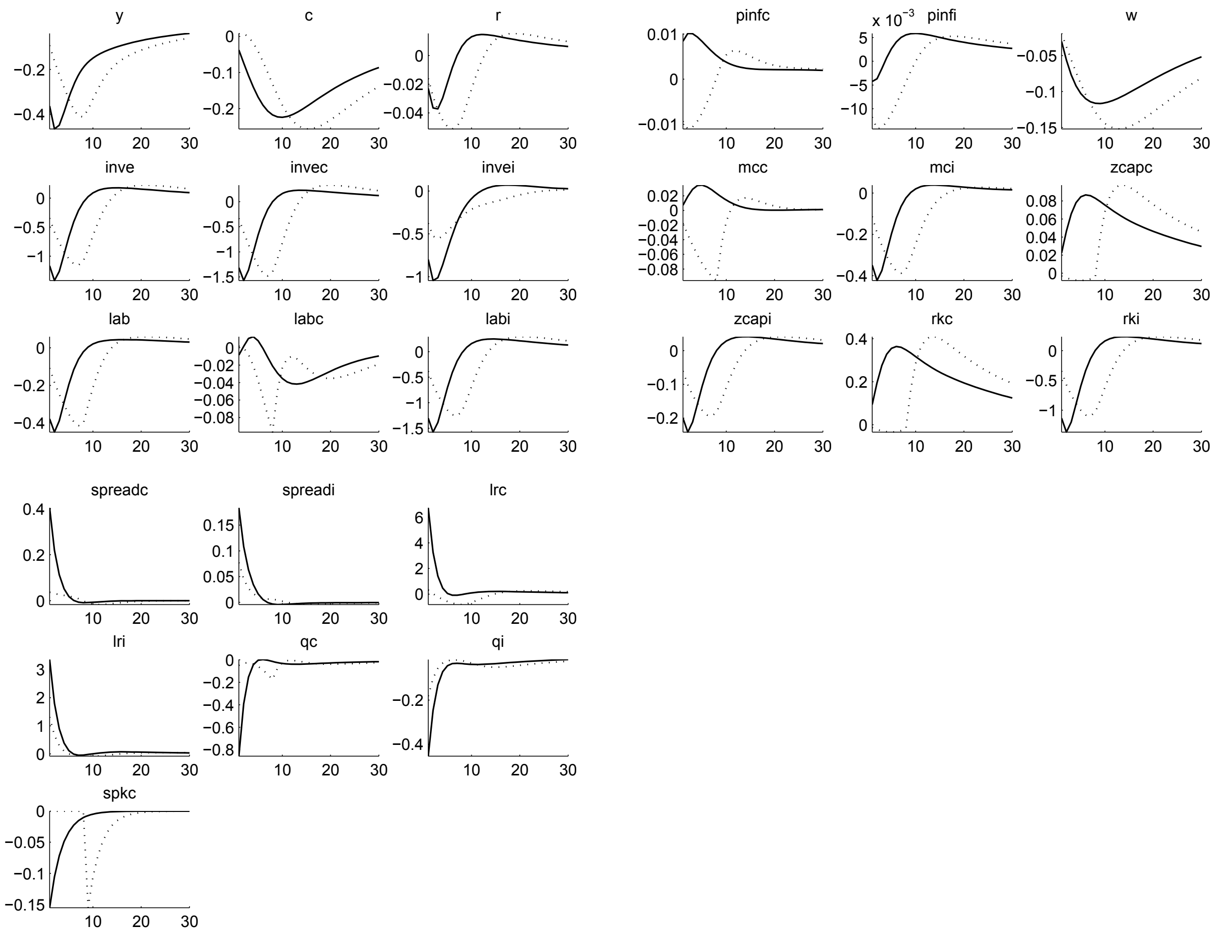

Figure 3: The economies response to an unanticipated (solid line) and eight quarter ahead anticipated (dashed line) shock to capital quality in the consumption sector

The size of the anticipated and unanticipated shocks is one standard deviation of the unanticipated shock. Variable key: y = output, c = consumption, r = nominal interest rate, inve = investment, invec = consumption sector investment, invei = investment sector investment, lab = total hours worked, labc = consumption sector hours, labi = investment sector hours, pinfc = consumption sector inflation, pinfi = investment sector inflation, w = real wage rate, mcc = consumption sector marginal cost, mci = investment sector marginal cost, zcapc = consumption sector capital utilisation, zcapi = investment sector captial utilisation, rkc = consumption sector rental rate of capital, rki = investment sector rental rate of capital, spreadc = consumption sector interest rate spread, spreadi = investment sector interest rate spread, lrc = consumption sector leverage ratio, lri = investment sector leverage ratio, qc = consumption sector market price of capital, qi = investment sector market price of capital, spkc = anticipated/unanticipated capital quality shock.

consumption sector capital quality (dotted line).[31] In anticipation of a decline in the quality of the installed available consumption sector capital in four quarters, agent's demand for this capital decreases today. Lower demand for consumption sector capital leads to a reduction in the production of investment goods which also necessitates a lower capital stock in the investment sector. The reduced demand for investment goods implies a fall in the price per effective unit of capital. This leads to a decline in asset values which puts banks' leverage ratios under pressure and subsequently forces them to increase interest rate spreads. The anticipation of lower capital quality also triggers a negative wealth effect that reduces consumption. The negative effect on consumption and investment leads to a strong initial decline of output before the lower capital quality materialises. When consumption sector capital quality actually decreases, capital utilisation becomes relatively cheaper. Subsequently, firms in the consumption sector increase utilisation to counteract the obsolescence of a part of their capital stock. In comparison to the unanticipated shock, the combination of news and subsequent movements in fundamentals lead to a deeper and longer recession phase, but a slightly less sharp initial downturn. This combination of events may be an explanation the extraordinary contraction of the US economy during the recent recession.

Figure 3 shows the response to an eight quarter ahead anticipated shock to consumption sector capital quality (dotted line). The mechanisms work similarly as in the case of the four quarter ahead news. In anticipation of a decline in asset values in eight quarters, leverage ratios and interest rate spreads increase instantly when the news shock arrives. Output, aggregate and sectoral investment and hours as well as the real wage rate decline instantly in response to the news shock. Consumption contracts only two quarters after the news arrives.

Output, consumption, investment and hours exhibit an instant decline in response to one and four quarter ahead anticipated shocks without any change in fundamentals.[32] This is in line with the comovement of macroeconomic variables described in the literature as a typical response to a news shock (see for example Jaimovich and Rebelo (2009)). While this type of comovement can be observed for all variables in case of one and four quarter ahead news shocks, the eight quarter ahead responses feature an initial very mild increase of consumption before it declines sharply. However, this is not necessarily at odds with the empirical literature since it finds instant comovement of macroeconomic variables in response to news about TFP (see for example Beaudry and Portier (2006)), but has been silent about the economy's response to news about changes in capital quality.

Asset prices are typically observed to be procyclical in the data. The fact that the model can reproduce this procyclicality in response to an anticipated capital quality shock (since Q comoves with Y) is another indication that this shock is an important driver of the business cycle.

8 Conclusions

In this paper we use Bayesian techniques to estimate a two-sector DSGE model for the US economy over a period from 1990Q2 to 2011Q1. The framework explicitly models financial

[31]In order to maintain comparability of the economy's responses, we show impulse responses in which the unanticipated exogenous disturbances change by one standard deviation of the anticipated shock.

[32]The impulse response functions for the one quarter ahead anticipated shock to consumption sector quality are not shown due to space restrictions. They are very similar to the four quarter ahead responses.

intermediation in the spirit of Gertler and Karadi (2011) and includes a shock to the quality of capital among the driving factors. This shock allows for variation in the price of capital and its propagation through financial intermediation makes it especially prone to being a potential channel for anticipation effects. To the best of our knowledge this paper is the first study to investigate the importance of anticipation effects about capital quality. It reveals a significant importance of this type of news for business cycle fluctuations.

We report several important results. *First*, we find that news shocks to capital quality are a significant source of fluctuations. These shocks account for 37% of output, 40% of consumption, 44% of aggregate investment, 43% of aggregate hours fluctuations at business cycle frequencies. The capital quality shocks in the consumption sector are the primary drivers. These shocks also explain a significant fraction of movements in bond market spreads as well as sectoral investment and hours worked. *Second*, news shocks in capital quality generates **aggregate** and **sectoral** comovement as in the data. In addition they generate procyclical movements in the value of capital consistent with observed movements in the stock market. *Third*, conditional on the model, the data rejects news components in conventional drivers of the business cycle such as the TFP processes in the investment and consumption sector. *Fourth*, from a historical perspective, news shocks to capital quality are to a large extent responsible for the recession following the 1990s investment boom and the latest recession, but played a much smaller role during the recession at the beginning of the 1990s. This is in line with the belief that revisions of overoptimistic expectations contributed to the last two recessions while movements in fundamentals played a much bigger role for the recession at the beginning of the 1990s.[33] The finding that news shocks are to a great extent responsible for these two recessions is also consistent with work of Beaudry and Portier (2004). They interpret Pigou's theory of expectations driven business cycles as a theory of recessions. The historical decomposition further indicates an asymmetry in the revision of beliefs: expectations are revised much faster at the peak of the cycle than at the trough, subsequently contributing to a sharp downturn and a slow recovery. This is consistent with the results in Görtz and Tsoukalas (2011a) and Van Nieuwerburgh and Veldkamp (2006).

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[33] See for example Walsh (1993) and Christiano et al. (2008).

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9 Appendix

A Stationary Economy

The model includes two non-stationary technology shocks, A_t and V_t. Therefore, the model variables are normalised as follows[34]

$$k_{x,t} = \frac{K_{x,t}}{V_t^{\frac{1}{1-a_i}}}, \qquad \bar{k}_{x,t} = \frac{\bar{K}_{x,t}}{V_t^{\frac{1}{1-a_i}}}, \qquad k_t = \frac{K_t}{V_t^{\frac{1}{1-a_i}}}, \tag{A.1}$$

$$i_{x,t} = \frac{I_{x,t}}{V_t^{\frac{1}{1-a_i}}}, \qquad i_t = \frac{I_t}{V_t^{\frac{1}{1-a_i}}}, \qquad c_t = \frac{C_t}{A_t V_t^{\frac{a_c}{1-a_i}}}, \tag{A.2}$$

$$r^K_{C,t} = \frac{R^K_{C,t}}{P_{C,t}} A_t^{-1} V_t^{\frac{1-a_c}{1-a_i}}, \qquad r^K_{I,t} = \frac{R^K_{I,t}}{P_{C,t}} A_t^{-1} V_t^{\frac{1-a_c}{1-a_i}}, \qquad w_t = \frac{W_t}{P_{C,t} A_t V_t^{\frac{a_c}{1-a_i}}}. \tag{A.3}$$

From

$$\begin{aligned}
\frac{P_{I,t}}{P_{C,t}} &= \frac{mc_{C,t}}{mc_{I,t}} \frac{1-a_c}{1-a_i} \frac{A_t}{V_t} \left(\frac{K_{I,t}}{L_{I,t}}\right)^{-a_i} \left(\frac{K_{C,t}}{L_{C,t}}\right)^{a_c} \\
&= \frac{mc_{C,t}}{mc_{I,t}} \frac{1-a_c}{1-a_i} A_t V_t^{\frac{a_c-1}{1-a_i}} \left(\frac{k_{I,t}}{L_{I,t}}\right)^{-a_i} \left(\frac{k_{C,t}}{L_{C,t}}\right)^{a_c},
\end{aligned}$$

follows that

$$p_{i,t} = \frac{P_{I,t}}{P_{C,t}} A_t^{-1} V_t^{\frac{1-a_c}{1-a_i}}. \tag{A.4}$$

and the multipliers are normalised as

$$\lambda_t = \Lambda_t A_t V_t^{\frac{a_c}{1-a_i}}, \qquad \phi_t = \Phi_t V_t^{\frac{1}{1-a_i}}. \tag{A.5}$$

Using the growth of investment, it follows from the equations of the price of capital that

$$q_{x,t} = Q_{x,t} A_t^{-1} V_t^{\frac{1-a_c}{1-a_i}}.$$

Using the growth of capital, it follows from the borrow in advance constraint that

$$s_{x,t} = \frac{S_{x,t}}{V_t^{\frac{1}{1-a_i}}}.$$

Then, it follows from entering bankers wealth equation (13) that

$$n^n_{x,t} = N^n_{x,t} A_t^{-1} V_t^{\frac{-a_c}{1-a_i}}.$$

Total wealth, wealth of existing and entering bankers has to grow at the same rate

$$n^e_{x,t} = N^e_{x,t} A_t^{-1} V_t^{\frac{-a_c}{1-a_i}}, \qquad n_{x,t} = N_{x,t} A_t^{-1} V_t^{\frac{-a_c}{1-a_i}}.$$

[34]Lower case variables denote normalised stationary variables.

A.1 Intermediate goods producers

Firm's production function in the consumption sector:

$$c_t = L_{C,t}^{1-a_c} k_{C,t}^{a_c} - F_C. \tag{A.6}$$

Firm's production function in the investment sector:

$$i_t = L_{I,t}^{1-a_i} k_{I,t}^{a_i} - F_I. \tag{A.7}$$

Marginal costs in the consumption sector:

$$mc_{C,t} = (1-a_c)^{a_c-1} a_c^{-a_c} (r_{C,t}^K)^{a_c} w_t^{1-a_c}. \tag{A.8}$$

Marginal costs in the investment sector:

$$mc_{I,t} = (1-a_i)^{a_i-1} a_i^{-a_i} w_t^{1-a_i} (r_{I,t}^K)^{a_i} p_{i,t}^{-1}, \qquad \text{with} \quad p_{i,t} = \frac{P_{I,t}}{P_{C,t}}. \tag{A.9}$$

Capital labour ratios in the two sectors:

$$\frac{k_{C,t}}{L_{C,t}} = \frac{w_t}{r_{C,t}^K} \frac{a_c}{1-a_c}, \qquad \frac{k_{I,t}}{L_{I,t}} = \frac{w_t}{r_{I,t}^K} \frac{a_i}{1-a_i}. \tag{A.10}$$

A.2 Firms' pricing decisions

Price setting equation for firms that change their price in sector $x = C, I$:

$$0 = E_t \left\{ \sum_{s=0}^{\infty} \xi_{p,x}^s \beta^s \lambda_{t+s} \tilde{x}_{t+s} \left[\tilde{p}_{x,t} \tilde{\Pi}_{t,t+s} - (1+\lambda_{p,t+s}^x) mc_{x,t+s} \right] \right\}, \tag{A.11}$$

with

$$\tilde{\Pi}_{t,t+s} = \prod_{k=1}^{s} \left[\left(\frac{\pi_{x,t+k-1}}{\pi_x} \right)^{\iota_{px}} \left(\frac{\pi_{x,t+k}}{\pi_x} \right)^{-1} \right] \quad \text{and} \quad \tilde{x}_{t+s} = \left(\frac{\tilde{P}_{x,t}}{P_{x,t}} \tilde{\Pi}_{t,t+s} \right)^{-\frac{1+\lambda_{p,t+s}^x}{\lambda_{p,t+s}^x}} x_{t+s}$$

$$\text{and} \quad \frac{\tilde{P}_{x,t}}{P_{x,t}} = \tilde{p}_{x,t}.$$

Aggregate price index in the consumption sector:

$$1 = \left[(1-\xi_{x,p}) (\tilde{p}_{x,t})^{\frac{1}{\lambda_{p,t}^x}} + \xi_{x,p} \left[\left(\frac{\pi_{x,t-1}}{\pi_x} \right)^{\iota_{px}} \left(\frac{\pi_{x,t}}{\pi_x} \right)^{-1} \right]^{\frac{1}{\lambda_{p,t}^x}} \right]^{\lambda_{p,t}^x}.$$

It further holds that

$$\frac{\pi_{I,t}}{\pi_{C,t}} = \frac{p_{i,t}}{p_{i,t-1}}. \tag{A.12}$$

A.3 Household's optimality conditions and wage setting

Marginal utility of income:

$$\lambda_t = \frac{b_t}{c_t - hc_{t-1}\Big(\frac{A_{t-1}}{A_t}\Big)\Big(\frac{V_{t-1}}{V_t}\Big)^{\frac{a_c}{1-a_i}}} - \beta h \frac{b_{t+1}}{c_{t+1}\Big(\frac{A_{t+1}}{A_t}\Big)\Big(\frac{V_{t+1}}{V_t}\Big)^{\frac{a_c}{1-a_i}} - hc_t}. \tag{A.13}$$

Euler equation:

$$\lambda_t = \beta E_t \lambda_{t+1}\Big(\frac{A_t}{A_{t+1}}\Big)\Big(\frac{V_t}{V_{t+1}}\Big)^{\frac{a_c}{1-a_i}} R_t \frac{1}{\pi_{c,t+1}}.$$

Optimal capital utilisation in both sectors:

$$r^K_{C,t} = a'(u_{C,t}), \qquad r^K_{I,t} = a'(u_{I,t}).$$

Optimal choice of available capital in sector $x = C, I$:

$$\phi_{Cx,t} = \beta E_t \xi^K_{x,t+1}\left\{\lambda_{t+1}\Big(\frac{V_t}{V_{t+1}}\Big)^{\frac{1}{1-a_i}}(r^K_{x,t+1}u_{x,t+1} - a(u_{x,t+1})) + (1-\delta)E_t\phi_{x,t+1}\Big(\frac{V_t}{V_{t+1}}\Big)^{\frac{1}{1-a_i}}\right\}, \tag{A.14}$$

Optimal choice of investment in sector $x = C, I$:

$$\begin{aligned}
&\lambda_t p_{i,t} \\
&\quad= \phi_{x,t}\left[1 - S\Big(\frac{i_{x,t}}{i_{x,t-1}}\Big(\frac{V_t}{V_{t-1}}\Big)^{\frac{1}{1-a_i}}\Big) - S'\Big(\frac{i_{x,t}}{i_{x,t-1}}\Big(\frac{V_t}{V_{t-1}}\Big)^{\frac{1}{1-a_i}}\Big)\frac{i_{x,t}}{i_{x,t-1}}\Big(\frac{V_t}{V_{t-1}}\Big)^{\frac{1}{1-a_i}}\right] \\
&\qquad + \beta E_t \phi_{x,t+1}\Big(\frac{V_t}{V_{t+1}}\Big)^{\frac{1}{1-a_i}}\left[S'\Big(\frac{i_{x,t+1}}{i_{x,t}}\Big(\frac{V_{t+1}}{V_t}\Big)^{\frac{1}{1-a_i}}\Big)\Big(\frac{i_{x,t+1}}{i_{x,t}}\Big(\frac{V_{t+1}}{V_t}\Big)^{\frac{1}{1-a_i}}\Big)^2\right].
\end{aligned} \tag{A.15}$$

Definition of capital input in both sectors:

$$k_{C,t} = u_{C,t}\xi^K_{C,t}\bar{k}_{C,t-1}\Big(\frac{V_{t-1}}{V_t}\Big)^{\frac{1}{1-a_i}}, \qquad k_{I,t} = u_{I,t}\xi^K_{I,t}\bar{k}_{I,t-1}\Big(\frac{V_{t-1}}{V_t}\Big)^{\frac{1}{1-a_i}}. \tag{A.16}$$

Accumulation of available capital in sector $x = C, I$:

$$\bar{k}_{x,t} = (1-\delta_x)\xi^K_{x,t}\bar{k}_{x,t-1}\Big(\frac{V_{t-1}}{V_t}\Big)^{\frac{1}{1-a_i}} + \bigg(1 - S\Big(\frac{i_{x,t}}{i_{x,t-1}}\Big(\frac{V_t}{V_{t-1}}\Big)^{\frac{1}{1-a_i}}\Big)\bigg)i_{x,t}, \tag{A.17}$$

A.4 Household's wage setting

Household's wage setting:

$$E_t \sum_{s=0}^{\infty} \beta^s \xi_w^s \lambda_{t+s} \tilde{L}_{t+s} \left[\tilde{w}_t \tilde{\Pi}^w_{t,t+s} - (1+\lambda_{w,t+s}) b_{t+s} \varphi \frac{\tilde{L}^{\nu}_{t+s}}{\lambda_{t+s}} \right] = 0, \tag{A.18}$$

with

$$\tilde{\Pi}^w_{t,t+s} = \prod_{k=1}^{s} \left[\left(\frac{\pi_{C,t+k-1} e^{a_{t+k-1} + \frac{a_c}{1-a_i} v_{t+k-1}}}{\pi_c e^{g_a + \frac{a_c}{1-a_i} g_v}} \right)^{\iota_w} \left(\frac{\pi_{C,t+k} e^{a_{t+k} + \frac{a_c}{1-a_i} v_{t+k}}}{\pi_C e^{g_a + \frac{a_c}{1-a_i} g_v}} \right)^{-1} \right]$$

and

$$\tilde{L}_{t+s} = \left(\frac{\tilde{w}_t \tilde{\Pi}^w_{t,t+s}}{w_{t+s}} \right)^{-\frac{1+\lambda_{w,t+s}}{\lambda_{w,t+s}}} L_{t+s}.$$

Wages evolve according to

$$w_t = \left\{ (1-\xi_w) \tilde{w}_t^{\frac{1}{\lambda_{w,t}}} + \xi_w \left[\left(\frac{\pi_{c,t-1} e^{a_{t-1} + \frac{a_c}{1-a_i} v_{t-1}}}{\pi_c e^{g_a + \frac{a_c}{1-a_i} g_v}} \right)^{l_w} \left(\frac{\pi_{c,t} e^{a_t + \frac{a_c}{1-a_i} v_t}}{\pi_c e^{g_a + \frac{a_c}{1-a_i} g_v}} \right)^{-1} w_{t-1} \right]^{\frac{1}{\lambda_{w,t}}} \right\}^{\lambda_{w,t}}.$$

A.5 Financial Intermediation

The stationary stochastic discount factor can be expressed as

$$\lambda^B_{t+1} = \frac{\lambda_{t+1}}{\lambda_t}.$$

Then, one can derive expressions for $\nu_{x,t}$ and $\eta_{x,t}$

$$\nu_{x,t} = E_t \{ (1-\theta_B) \lambda^B_{t+1} \frac{A_t}{A_{t+1}} \left(\frac{V_t}{V_{t+1}} \right)^{\frac{a_c}{1-a_i}} (R^B_{x,t+1} - R_t) + \theta_B \beta z^x_{1,t+1} \nu_{x,t+1} \},$$
$$\eta_{x,t} = E_t \{ (1-\theta_B) \lambda^B_{t+1} \frac{A_t}{A_{t+1}} \left(\frac{V_t}{V_{t+1}} \right)^{\frac{a_c}{1-a_i}} R_t + \theta_B \beta z^x_{2,t+1} \eta_{x,t+1} \},$$

with

$$z^x_{1,t+1+i} \equiv \frac{q_{x,t+1+i} s_{x,t+1+i}}{q_{x,t+i} s_{x,t+i}} \frac{A_{t+1}}{A_t} \left(\frac{V_{t+1}}{V_t} \right)^{\frac{a_c}{1-a_i}}, \qquad z^x_{2,t+1+i} \equiv \frac{n_{x,t+1+i}}{n_{x,t+i}} \frac{A_{t+1}}{A_t} \left(\frac{V_{t+1}}{V_t} \right)^{\frac{a_c}{1-a_i}}.$$

It follows that if the bank's incentive constraint binds it can be expressed as

$$\nu_{x,t} q_{x,t} s_{x,t} + \eta_{x,t} n_{x,t} = \lambda_B q_{x,t} s_{x,t}$$
$$\Leftrightarrow q_{x,t} s_{x,t} = \varrho_{x,t} n_{x,t},$$

with the leverage ratio given as

$$\varrho_{x,t} = \frac{\eta_{x,t}}{\lambda_B - \nu_{x,t}}.$$

It further follows that:

$$z^x_{2,t+1} = \frac{n_{x,t+1}}{n_{x,t}} \frac{A_{t+1}}{A_t} \Big(\frac{V_{t+1}}{V_t}\Big)^{\frac{a_c}{1-a_i}} = (R^B_{x,t+1} - R_t)\varrho_{x,t} + R_t,$$

and

$$z^x_{1,t+1} = \frac{q_{x,t+1}s_{x,t+1}}{q_{x,t}s_{x,t}} \frac{A_{t+1}}{A_t} \Big(\frac{V_{t+1}}{V_t}\Big)^{\frac{a_c}{1-a_i}} = \frac{\varrho_{x,t+1}n_{x,t+1}}{\varrho_{x,t}n_{x,t}} \frac{A_{t+1}}{A_t} \Big(\frac{V_{t+1}}{V_t}\Big)^{\frac{a_c}{1-a_i}} = \frac{\varrho_{x,t+1}}{\varrho_{x,t}} z^x_{2,t+1}.$$

The normalised equation for bank's wealth accumulation is

$$n_{x,t} = \big(\theta_B[(R^B_{x,t} - R_{t-1})\varrho_{x,t-1} + R_{t-1}]\frac{A_{t-1}}{A_t}\Big(\frac{V_{t-1}}{V_t}\Big)^{\frac{a_c}{1-a_i}} n_{x,t-1} + \varpi(1-\psi_{x,t})q_{x,t}s_{x,t}\big)\varsigma_{x,t}.$$

The borrow in advance constraint:

$$\bar{k}_{x,t+1} = s_{x,t}.$$

The leverage equation:

$$q_{x,t}s_{x,t} = \frac{1}{1-\psi_{x,t}}\varrho_{x,t}n_{x,t}.$$

Bank's stochastic return on assets can be described in normalised variables as:

$$R^B_{x,t+1} = \frac{r^K_{x,t+1}u_{x,t+1} + q_{x,t+1}(1-\delta_x) - a(u_{x,t+1})}{q_{x,t}}\xi^K_{x,t+1}\frac{A_{t+1}}{A_t}\Big(\frac{V_{t+1}}{V_t}\Big)^{-\frac{1-a_c}{1-a_i}},$$

knowing from the main model that

$$r^K_{x,t} = \frac{R^K_{x,t}}{P_{x,t}}A_t^{-1}V_t^{\frac{1-a_c}{1-a_i}}.$$

The stationary equation for the price of capital is

$$\begin{aligned} &p_{i,t} \\ =&q_{x,t}\Bigg[1 - S\Big(\frac{i_{x,t}}{i_{x,t-1}}\Big(\frac{V_t}{V_{t-1}}\Big)^{\frac{1}{1-a_i}}\Big) - S'\Big(\frac{i_{x,t}}{i_{x,t-1}}\Big(\frac{V_t}{V_{t-1}}\Big)^{\frac{1}{1-a_i}}\Big)\frac{i_{x,t}}{i_{x,t-1}}\Big(\frac{V_t}{V_{t-1}}\Big)^{\frac{1}{1-a_i}}\Bigg] \\ &+ \beta E_t q_{x,t+1}\frac{\lambda_{t+1}}{\lambda_t}\Big(\frac{V_{t+1}}{V_t}\Big)^{-\frac{1}{1-a_i}}\Bigg[S'\Big(\frac{i_{x,t+1}}{i_{x,t}}\Big(\frac{V_{t+1}}{V_t}\Big)^{\frac{1}{1-a_i}}\Big)\Big(\frac{i_{x,t+1}}{i_{x,t}}\Big(\frac{V_{t+1}}{V_t}\Big)^{\frac{1}{1-a_i}}\Big)^2\Bigg]. \end{aligned}$$

The central bank's feedback rule is

$$\psi_{x,t} = \psi_x + \vartheta_x[(\log R^B_{x,t+1} - \log R_t) - (\log R^B - \log R)].$$

A.6 Monetary policy and market clearing

Monetary policy rule:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{x_t}{x_t^*}\right)^{\phi_X}\right]^{1-\rho_R} \left[\frac{x_t/x_{t-1}}{x_t^*/x_{t-1}^*}\right]^{\phi_{d,X}} \eta_{mp,t},$$

Resource constraint in the consumption sector:

$$c_t + (a(u_{C,t})\bar{k}_{C,t-1} + a(u_{I,t})\bar{k}_{I,t-1})\left(\frac{V_{t-1}}{V_t}\right)^{\frac{1}{1-a_i}} = L_{C,t}^{1-a_c} k_{C,t}^{a_c} - F_C.$$

Resource constraint in the investment sector:

$$i_{I,t} + i_{C,t} = L_{I,t}^{1-a_i} k_{I,t}^{a_i} - F_I.$$

Definition of GDP:

$$y_t = c_t + p_{i,t} i_t + \left(1 - \frac{1}{g_t}\right) y_t + \tau\psi_{C,t} q_{C,t} s_{C,t} + \tau\psi_{I,t} q_{I,t} s_{I,t}.$$

It further holds that

$$L_t = L_{I,t} + L_{C,t}, \qquad i_t = i_{I,t} + i_{C,t} \qquad \text{and} \qquad K_t = K_{I,t} + K_{C,t}.$$

B Steady State

The model economy is in parts identical to the one in Görtz and Tsoukalas (2011b). Therefore, the main part of the derivations of the steady state relationships has already been shown in the appendix to this paper. In this section we discuss the derivation of the remaining steady state values, focussing mostly on the part of the economy concerned with financial intermediation.

Given the steady state values derived in Görtz and Tsoukalas (2011b) (with $\rho = -1$ indicating the absence of intratemporal investment adjustment costs), one can derive the remaining steady state relationships as follows.

The nominal interest rate is given from the Euler equation as

$$R = \frac{1}{\beta} e^{g_a + \frac{a_c}{1-a_i} g_v} \pi_C.$$

The bank's stationary stochastic discount factor can be expressed in the steady state as

$$\lambda^B = 1.$$

The steady state borrow in advance constraint implies that

$$\bar{k}_x = s_x.$$

The steady state price of capital is given by

$$q_{x,t} = p_{i,t}.$$

The steady state leverage equation is set equal to it's average value in the data

$$\frac{q_x s_x}{n_x} = \frac{1}{1-\psi_x}\varrho_x = 11.5.$$

The parameters ϖ and λ_B help aligning the value of the leverage ratio and the interest rate spread with their empirical counterparts. Using the calibrated value for θ_B, the average value for the leverage ratio (11.5) and the weighted quarterly average of the credit spreads ($R_x^B - R = 0.0057$) allows calibrating ϖ using the bank's wealth accumulation equation

$$\varpi = \left[1 - \theta_B[(R_x^B - R)\varrho_x + R]e^{-g_a - \frac{a_c}{1-a_i}g_v}\right]\left((1-\psi_x)\frac{q_x s_x}{n_x}\right)^{-1}.$$

Owing to the non-linearity in the leverage ratio, we solve numerically for the steady state expressions for λ_B, η and ν using

$$\begin{aligned}
\nu_x &= (1-\theta_B)\lambda^B e^{-g_a - \frac{a_c}{1-a_i}g_v}(R_x^B - R) + \theta_B \beta z_1^x \nu_x, \\
\eta_x &= (1-\theta_B)\lambda^B e^{-g_a - \frac{a_c}{1-a_i}g_v} R + \theta_B \beta z_2^x \eta_x,
\end{aligned}$$

with

$$z_2^x = (R_x^B - R)\varrho_x + R, \qquad \text{and} \qquad z_1^x = z_2^x,$$

and the steady state leverage ratio

$$\varrho_x = \frac{\eta_x}{\lambda_B - \nu_x}.$$

C Log-linearised Economy

The log-linear deviations of all variables are defined as

$$\hat{\varsigma}_t \equiv \log \varsigma_t - \log \varsigma,$$

except for

$$\begin{aligned}
\hat{z}_t &\equiv z_t - g_a, \\
\hat{v}_t &\equiv v_t - g_v, \\
\hat{\lambda}_{p,t}^C &\equiv \log(1+\lambda_{p,t}^C) - \log(1+\lambda_p^C), \\
\hat{\lambda}_{p,t}^I &\equiv \log(1+\lambda_{p,t}^I) - \log(1+\lambda_p^I), \\
\hat{\lambda}_{w,t} &\equiv \log(1+\lambda_{w,t}) - \log(1+\lambda_w).
\end{aligned}$$

C.1 Firm's production function and cost minimisation

Production function for the intermediate good producing firm (i) in the consumption sector:

$$\hat{c}_t = \frac{c+F_I}{c}[a_c \hat{k}_{C,t} + (1-a_c)\hat{L}_{C,t}].$$

Production function for the intermediate good producing firm (i) in the investment sector:

$$\hat{i}_t = \frac{i + F_I}{i}[a_i \hat{k}_{I,t} + (1 - a_i)\hat{L}_{I,t}].$$

Capital-to-labour ratios for the two sectors:

$$\hat{r}^K_{C,t} - \hat{w}_t = \hat{L}_{C,t} - \hat{k}_{C,t}, \qquad \hat{r}^K_{I,t} - \hat{w}_t = \hat{L}_{I,t} - \hat{k}_{I,t}. \tag{C.1}$$

Marginal cost in both sectors:

$$\hat{mc}_{C,t} = a_c \hat{r}^K_{C,t} + (1 - a_c)\hat{w}_t, \qquad \hat{mc}_{I,t} = a_i \hat{r}^K_{I,t} + (1 - a_i)\hat{w}_t - \hat{p}_{i,t}. \tag{C.2}$$

C.2 Firm's prices

Price setting equation for firms that change their price in in sector $x = C, I$:

$$0 = E_t \left\{ \sum_{s=0}^{\infty} \xi^s_{p,x} \beta^s \Big[\hat{\tilde{p}}_{x,t} \hat{\tilde{\Pi}}_{t,t+s} - \hat{\lambda}^x_{p,t+s} - \hat{mc}_{x,t+s} \Big] \right\},$$

with

$$\hat{\tilde{\Pi}}_{t,t+s} = \sum_{k=1}^{s} [\iota_{p_x} \hat{\pi}_{t+k-1} - \hat{\pi}_{t+k}].$$

Solving for the summation

$$\begin{aligned}
\frac{1}{1 - \xi_{p,x}\beta} \hat{\tilde{p}}_{x,t} =& E_t \left\{ \sum_{s=0}^{\infty} \xi^s_{p,x} \beta^s \big[- \hat{\Pi}_{t,t+s} + \hat{\lambda}^x_{p,t+s} + \hat{mc}_{x,t+s} \big] \right\} \\
=& - \hat{\Pi}_{t,t} + \hat{\lambda}^x_{p,t} + \hat{mc}_{x,t} - \frac{\xi_{p,x}\beta}{1 - \xi_{p,x}\beta} \hat{\Pi}_{t,t+1} \\
& + \xi_{p,x}\beta E_t \left\{ \sum_{s=1}^{\infty} \xi^{s-1}_{p,x} \beta^{s-1} \big[- \hat{\Pi}_{t+1,t+s} + \hat{\lambda}^x_{p,t+s} + \hat{mc}_{x,t+s} \big] \right\} \\
=& \hat{\lambda}^x_{p,t} + \hat{mc}_{x,t} + \frac{\xi_{p,x}\beta}{1 - \xi_{p,x}\beta} E_t \big[\hat{\tilde{p}}_{x,t+1} - \hat{\Pi}_{t,t+1} \big],
\end{aligned}$$

where we used $\hat{\Pi}_{t,t} = 0$.

Prices evolve as

$$0 = (1 - \xi_{p,x})\hat{\tilde{p}}_{x,t} + \xi_{p,x}(\iota_{p_x}\hat{\pi}_{t-1} - \hat{\pi}),$$

from which we obtain the Phillips curve in sector $x = C, I$:

$$\hat{\pi}_{x,t} = \frac{\beta}{1 + \iota_{p_x}\beta} E_t \hat{\pi}_{x,t+1} + \frac{\iota_{p_x}}{1 + \iota_{p_x}\beta} \hat{\pi}_{x,t-1} + \kappa_x \hat{mc}_{x,t} + \kappa_x \hat{\lambda}^x_{p,t}, \tag{C.3}$$

$$\text{with} \quad \kappa_x = \frac{(1 - \xi_{p,x}\beta)(1 - \xi_{p,x})}{\xi_{p,x}(1 + \iota_{p_x}\beta)}.$$

From equation (A.12) it follows that

$$\hat{\pi}_{I,t} - \hat{\pi}_{C,t} = \hat{p}_{I,t} - \hat{p}_{I,t-1}.$$

C.3 Households

C.3.1 Consumption

Marginal utility:

$$
\begin{aligned}
\hat{\lambda}_t =& \frac{e^G}{e^G - h\beta}\left[\hat{b}_t + \left(\hat{z}_t + \frac{a_c}{1-a_i}\hat{v}_t\right) - \left(\frac{e^G}{e^G - h}\left(\hat{c}_t + \hat{z}_t + \frac{a_c}{1-a_i}\hat{v}_t\right) - \frac{h}{e^G - h}\hat{c}_{t-1}\right)\right] \\
& - \frac{h\beta}{e^G - h\beta}E_t\left[\hat{b}_{t+1} - \left(\frac{e^G}{e^G - h}\left(\hat{c}_{t+1} + \hat{z}_{t+1} + \frac{a_c}{1-a_i}\hat{v}_{t+1}\right) - \frac{h}{e^G - h}\hat{c}_t\right)\right] \\
\Leftrightarrow \hat{\lambda}_t =& \alpha_1 E_t\hat{c}_{t+1} - \alpha_2\hat{c}_t + \alpha_3\hat{c}_{t-1} + \alpha_4\hat{z}_t + \alpha_5\hat{b}_t + \alpha_6\hat{v}_t, \qquad \text{(C.4)}
\end{aligned}
$$

with

$$
\begin{aligned}
&\alpha_1 = \frac{h\beta e^G}{(e^G - h\beta)(e^G - h)}, \quad \alpha_2 = \frac{e^{2G} + h^2\beta}{(e^G - h\beta)(e^G - h)}, \quad \alpha_3 = \frac{he^G}{(e^G - h\beta)(e^G - h)}, \\
&\alpha_4 = \frac{h\beta e^G\rho_z - he^G}{(e^G - h\beta)(e^G - h)}, \quad \alpha_5 = \frac{e^G - h\beta\rho_b}{e^G - h\beta}, \quad \alpha_6 = \frac{(h\beta e^G\rho_v - he^G)\frac{a_c}{1-a_i}}{(e^G - h\beta)(e^G - h)}, \\
&e^G = e^{g_a + \frac{a_c}{1-a_i}g_v}.
\end{aligned}
$$

This assumes the shock processes (1), (2) and (5).

Euler equation:

$$
\hat{\lambda}_t = \hat{R}_t + E_t\left(\hat{\lambda}_{t+1} - \hat{z}_{t+1} - \hat{v}_{t+1}\frac{a_c}{1-a_i} - \hat{\pi}_{C,t+1}\right). \qquad \text{(C.5)}
$$

C.3.2 Investment and Capital

Capital utilisation in both sectors:

$$
\hat{r}^K_{C,t} = \chi\hat{u}_{C,t}, \qquad \hat{r}^K_{I,t} = \chi\hat{u}_{I,t}, \qquad \text{where} \quad \chi^{-1} = \frac{a'(1)}{a''(1)}. \qquad \text{(C.6)}
$$

Choice of investment for the consumption sector:

$$
\begin{aligned}
\hat{\lambda}_t =& - e^{2(\frac{1}{1-a_i}g_v)}\kappa\left(\hat{i}_{C,t} - \hat{i}_{C,t-1} + \frac{1}{1-a_i}\hat{v}_t\right) + \beta e^{2(\frac{1}{1-a_i}g_v)}\kappa E_t\left(\hat{i}_{C,t+1} - \hat{i}_{C,t} + \frac{1}{1-a_i}\hat{v}_{t+1}\right) \\
& + \hat{\phi}_{C,t} - \hat{p}_{i,t}. \qquad \text{(C.7)}
\end{aligned}
$$

Choice of investment for the investment sector:

$$
\begin{aligned}
\hat{\lambda}_t =& - e^{2(\frac{1}{1-a_i}g_v)}\kappa\left(\hat{i}_{I,t} - \hat{i}_{I,t-1} + \frac{1}{1-a_i}\hat{v}_t\right) + \beta e^{2(\frac{1}{1-a_i}g_v)}\kappa E_t\left(\hat{i}_{I,t+1} - \hat{i}_{I,t} + \frac{1}{1-a_i}\hat{v}_{t+1}\right) \\
& + \hat{\phi}_{I,t} - \hat{p}_{i,t}. \qquad \text{(C.8)}
\end{aligned}
$$

Capital input in both sectors:

$$
\hat{k}_{C,t} = \hat{u}_{C,t} + \xi^K_{C,t} + \hat{\bar{k}}_{C,t-1} - \frac{1}{1-a_i}\hat{v}_t, \qquad \hat{k}_{I,t} = \hat{u}_{I,t} + \xi^K_{I,t} + \hat{\bar{k}}_{I,t-1} - \frac{1}{1-a_i}\hat{v}_t. \qquad \text{(C.9)}
$$

Capital accumulation in the consumption and investment sector:

$$\hat{\bar{k}}_{C,t} = (1-\delta_C)e^{-\frac{1}{1-a_i}g_v}\Big(\hat{\bar{k}}_{C,t-1} + \xi^K_{C,t} - \frac{1}{1-a_i}\hat{v}_t\Big) + \Big(1-(1-\delta_C)e^{-\frac{1}{1-a_i}g_v}\Big)\hat{i}_{C,t}, \quad \text{(C.10)}$$

$$\hat{\bar{k}}_{I,t} = (1-\delta_I)e^{-\frac{1}{1-a_i}g_v}\Big(\hat{\bar{k}}_{I,t-1} + \xi^K_{I,t} - \frac{1}{1-a_i}\hat{v}_t\Big) + \Big(1-(1-\delta_I)e^{-\frac{1}{1-a_i}g_v}\Big)\hat{i}_{I,t}. \quad \text{(C.11)}$$

C.3.3 Wages

The wage Phillips curve can be derived to be:[35]

$$\begin{aligned}\hat{w}_t =& \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{\beta}{1+\beta}E_t\hat{w}_{t+1} - \kappa_w\hat{g}_{w,t} + \frac{\iota_w}{1+\beta}\hat{\pi}_{c,t-1} - \frac{1+\beta\iota_w}{1+\beta}\hat{\pi}_{c,t} \\ &+ \frac{\beta}{1+\beta}E_t\hat{\pi}_{c,t+1} + \kappa_w\hat{\lambda}_{w,t} + \frac{\iota_w}{1+\beta}\big(\hat{z}_{t-1} + \frac{a_c}{1-a_i}\hat{v}_{t-1}\big) \\ &- \frac{1+\beta\iota_w-\rho_z\beta}{1+\beta}\hat{z}_t - \frac{1+\beta\iota_w-\rho_v\beta}{1+\beta}\frac{a_c}{1-a_i}\hat{v}_t. \end{aligned} \quad \text{(C.12)}$$

where

$$\kappa_w \equiv \frac{(1-\xi_w\beta)(1-\xi_w)}{\xi_w(1+\beta)\big(1+\nu\big(1+\frac{1}{\lambda_w}\big)\big)},$$

$$\hat{g}_{w,t} \equiv \hat{w}_t - (\nu\hat{L}_t + \hat{b}_t - \hat{\lambda}_t).$$

C.4 Banking sector

The part of the economy concerned with the banking sector is described by the following equations:

The stochastic discount factor:

$$\hat{\lambda}^B_t = \hat{\lambda}_t - \hat{\lambda}_{t-1}. \quad \text{(C.13)}$$

Definition of ν:

$$\begin{aligned}\hat{\nu}_{x,t} =& (1-\theta_B\beta z^x_1)[\hat{\lambda}^B_{t+1} - \hat{z}_{t+1} - \frac{a_c}{1-a_i}\hat{v}_{t+1}] \\ &+ \frac{1-\theta_B\beta z^x_1}{R^B_x - R}[R^B_x\hat{R}^B_{x,t+1} - R\hat{R}_t] + \theta_B\beta z^x_1[\hat{z}^x_{1,t+1} + \hat{\nu}_{x,t+1}], \qquad x = C, I. \end{aligned} \quad \text{(C.14)}$$

Definition of η:

$$\begin{aligned}\hat{\eta}_{x,t} =& (1-\theta_B\beta z^x_2)[\hat{\lambda}^B_{t+1} - \hat{z}_{t+1} - \frac{a_c}{1-a_i}\hat{v}_{t+1} + R_t] \\ &+ \theta_B\beta z^x_2[\hat{z}^x_{2,t+1} + \hat{\eta}_{t+1}], \qquad x = C, I. \end{aligned} \quad \text{(C.15)}$$

Definition of z_1:

$$\hat{z}^x_{1,t} = \hat{\varrho}_{x,t} - \hat{\varrho}_{x,t-1} + \hat{z}^x_{2,t}, \qquad x = C, I. \quad \text{(C.16)}$$

[35] The derivation is equivalent to the one described in the appendix to Görtz and Tsoukalas (2011b).

Definition of z_2:

$$\hat{z}^x_{2,t} = \frac{1}{(R^B_x - R)\varrho_x + R}[R^B_x \varrho_x \hat{R}^B_{x,t} + R(1-\varrho_x)\hat{R}_{t-1} + (R^B_x - R)\varrho_x \hat{\varrho}_{x,t-1}], \qquad x = C, I. \tag{C.17}$$

The leverage ratio:

$$\hat{\varrho}_{x,t} = \hat{\eta}_{x,t} + \frac{\nu}{\lambda_B - \nu}\hat{\nu}_{x,t}, \qquad x = C, I. \tag{C.18}$$

The leverage equation:

$$\hat{q}_{x,t} + \hat{s}_{x,t} = \hat{\varrho}_{x,t} + \hat{n}_{x,t} + \frac{\psi_x}{(1-\psi_x)}\hat{\psi}_{x,t}. \tag{C.19}$$

The bank's wealth accumulation equation

$$\begin{aligned}
\hat{n}_{x,t} =& \varsigma_x \theta_B \varrho_x e^{-g_a - \frac{a_c}{1-a_i}g_v}\Big[R^B_x \hat{R}^B_{x,t} + \Big(\frac{1}{\varrho_x} - 1\Big)R\hat{R}_{t-1} + (R^B_x - R)\hat{\varrho}_{x,t-1}\Big] \\
&+ \varsigma_x \theta_B e^{-g_a - \frac{a_c}{1-a_i}g_v}[(R^B_x - R)\varrho_x + R]\Big[-\hat{z}_t - \frac{a_c}{1-a_i}\hat{v}_t + \hat{n}_{x,t-1}\Big] \\
&+ (1 - \varsigma_x \theta_B e^{-g_a - \frac{a_c}{1-a_i}g_v}[(R^B_x - R)\varrho_x + R])[\hat{q}_t + \hat{s}_t - \frac{\psi}{1-\psi}\hat{\psi}_{x,t}] \\
&+ [\theta_B e^{-g_a - \frac{a_c}{1-a_i}g_v}((R^B_x - R)\varrho_x + R) + (1 - \theta_B((R^B_x - R)\varrho_x + R))]\hat{\varsigma}_{x,t}, \qquad x = C, I.
\end{aligned} \tag{C.20}$$

The borrow in advance constraint:

$$\hat{\bar{k}}_{x,t+1} = \hat{s}_{x,t}, \qquad x = C, I. \tag{C.21}$$

The bank's stochastic return on assets in sector $x = C, I$:

$$\hat{R}^B_{x,t} = \frac{1}{r^K_x + q_x(1-\delta_x)}[r^K_x(\hat{r}^K_{x,t} + \hat{u}_{x,t}) + q_x(1-\delta_x)\hat{q}_{x,t}] - \hat{q}_{x,t-1} + \xi^K_{x,t} + \hat{z}_t - \frac{1-a_c}{1-a_i}\hat{v}_t. \tag{C.22}$$

The price for capital:

$$\begin{aligned}
\hat{q}_{x,t} =& e^{2(\frac{1}{1-a_i}g_v)}\kappa\Big(\hat{i}_{x,t} - \hat{i}_{x,t-1} + \frac{1}{1-a_i}\hat{v}_t\Big) - \beta e^{2(\frac{1}{1-a_i}g_v)}\kappa E_t\Big(\hat{i}_{x,t+1} - \hat{i}_{x,t} + \frac{1}{1-a_i}\hat{v}_{t+1}\Big) \\
&+ \hat{p}_{i,t}, \qquad x = C, I.
\end{aligned} \tag{C.23}$$

The central bank's feedback rule:

$$\hat{\psi}_{x,t} = \vartheta_x(\hat{R}^B_{x,t+1} - \hat{R}_t). \tag{C.24}$$

External finance premium:

$$\hat{R}^\Delta_{x,t} = \hat{R}^B_{x,t+1} - \hat{R}_t, \qquad x = C, I. \tag{C.25}$$

C.5 Monetary policy and market clearing

Monetary policy rule:

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)[\phi_\pi \hat{\pi}_t + \phi_X(\hat{x}_t - \hat{x}_t^*)] + \phi_{dX}[(\hat{x}_t - \hat{x}_{t-1}) - (\hat{x}_t^* - \hat{x}_{t-1}^*)] + \hat{\eta}_{mp,t} \tag{C.26}$$

Resource constraint in the consumption sector:

$$\hat{c}_t + \left(r_C^K \frac{\bar{k}_C}{c} \hat{u}_{C,t} + r_I^K \frac{\bar{k}_I}{c} \hat{u}_{I,t} \right) e^{-\frac{1}{1-a_i} g_v} = \frac{c + F_c}{c} [a_c \hat{k}_{C,t} + (1-a_c) \hat{L}_{C,t}] \tag{C.27}$$

Resource constraint in the investment sector:

$$\hat{i}_t = \frac{i + F_I}{i} [a_i \hat{k}_{I,t} + (1-a_i) \hat{L}_{I,t}] \tag{C.28}$$

Definition of GDP:

$$\begin{aligned} \hat{y}_t = & \frac{c}{c + p_i i} \hat{c}_t + \frac{p_i i}{c + p_i i} (\hat{i}_t + \hat{p}_{i,t}) + \hat{g}_t \\ & + \frac{\tau}{c + p_i i} \big(\psi_C q_C s_C (\hat{\psi}_{C,t} + \hat{q}_{C,t} + \hat{s}_{C,t}) + \psi_I q_I s_I (\hat{\psi}_{I,t} + \hat{q}_{I,t} + \hat{s}_{I,t}) \big). \end{aligned} \tag{C.29}$$

It further holds that

$$\frac{L_C}{L} \hat{L}_{C,t} + \frac{L_I}{L} \hat{L}_{I,t} = \hat{L}_t, \quad \frac{i_C}{i} \hat{i}_{C,t} + \frac{i_I}{i} \hat{i}_{I,t} = \hat{i}_t \quad \text{and} \quad \frac{k_C}{k} \hat{k}_{C,t} + \frac{k_I}{k} \hat{k}_{I,t} = \hat{k}_t. \tag{C.30}$$

C.6 Exogenous processes

The exogenous processes of the 10 shocks can be written in log-linearised form as follows:
Price markup shock in sector $x = C, I$:

$$\hat{\lambda}_{p,t}^x = \rho_{\lambda_p^x} \hat{\lambda}_{p,t-1}^x + \varepsilon_{p,t}^x - \theta_p^x \varepsilon_{p,t-1}^x. \tag{C.31}$$

The TFP growth shock to the consumption sector:

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon_t^z. \tag{C.32}$$

The growth shock to the investment sector:

$$\hat{v}_t = \rho_v \hat{v}_{t-1} + \varepsilon_t^v. \tag{C.33}$$

Wage markup shock:

$$\hat{\lambda}_{w,t} = \rho_w \hat{\lambda}_{w,t-1} + \varepsilon_{w,t} - \theta_w \varepsilon_{w,t-1}. \tag{C.34}$$

Preference shock:

$$\hat{b}_t = \rho_b \hat{b}_{t-1} + \varepsilon_t^b. \tag{C.35}$$

Monetary policy shock:

$$\hat{\eta}_{mp,t} = \rho_{mp}\hat{\eta}_{mp,t-1} + \varepsilon_t^{mp}. \tag{C.36}$$

Government spending shock:

$$\hat{g}_t = \rho_g \hat{g}_{t-1} + \varepsilon_t^g. \tag{C.37}$$

Shock to the bank's equity capital in sector $x = C, I$:

$$\hat{\varsigma}_{x,t} = \rho_{\varsigma_x}\hat{\varsigma}_{x,t-1} + \epsilon_{x,t}^{\varsigma}. \tag{C.38}$$

Shock to the quality of available capital in sector $x = C, I$:

$$\hat{\xi}_{x,t}^K = \rho_{\xi^K,x}\hat{\xi}_{x,t}^K + \varepsilon_{x,t}^{\xi^K} \qquad \text{with} \qquad \varepsilon_{x,t}^{\xi^K} = \varepsilon_{x,t}^{\xi^{K,0}} + \varepsilon_{x,t}^{\xi^{K,news}} \tag{C.39}$$

The whole log-linear economy model of the economy is summarised by equations (C.1) - (C.30) and the shock processes (C.31) - (C.39).

D Measurement equations

For the estimation the model variables are linked with the observables using measurement equations. Let a superscript "o" denote the observables, then – given the shape of the observables and the model variables – the model's measurement equations are

$$
\begin{aligned}
C_t^o &\equiv \log\Big(\frac{C_t}{C_{t-1}}\Big) = \log\Big(\frac{c_t}{c_{t-1}}\Big) + \hat{z}_t + \frac{a_c}{1-a_i}\hat{v}_t + \Big(g_a + \frac{a_c}{1-a_i}g_v\Big),\\
I_t^o &\equiv \log\Big(\frac{I_t}{I_{t-1}}\Big) = \log\Big(\frac{i_t}{i_{t-1}}\Big) + \frac{1}{1-a_i}\hat{v}_t + \Big(g_a + \frac{1}{1-a_i}g_v\Big),\\
\Big(\frac{P_{I,t}}{P_{C,t}}\Big)^o &\equiv \log\Big(\frac{P_{I,t}}{P_{C,t}}/\frac{P_{I,t-1}}{P_{C,t-1}}\Big) = \log\Big(\frac{p_{i,t}}{p_{i,t-1}}\Big) + \hat{z}_t + \frac{a_c-1}{1-a_i}\hat{v}_t + \Big(g_a + \frac{a_c}{1-a_i}g_v\Big),\\
W_t^o &\equiv \log\Big(\frac{W_t}{W_{t-1}}\Big) = \log\Big(\frac{w_t}{w_{t-1}}\Big) + \hat{z}_t + \frac{a_c}{1-a_i}\hat{v}_t + \Big(g_a + \frac{a_c}{1-a_i}g_v\Big),\\
Y_t^o &\equiv \log\Big(\frac{Y_t}{Y_{t-1}}\Big) = \log\Big(\frac{y_t}{y_{t-1}}\Big) + \hat{z}_t + \frac{a_c}{1-a_i}\hat{v}_t + \Big(g_a + \frac{a_c}{1-a_i}g_v\Big),\\
\pi_{C,t}^o &\equiv \pi_{C,t} = \hat{\pi}_{C,t} + 100(\pi_C - 1) \quad \text{and} \quad \hat{\pi}_{C,t} = \log(\pi_{C,t}) - \log(\pi_C),\\
L_t^o &\equiv \log L_t = \hat{L}_t + \log(L),\\
R_t^o &\equiv \log R_t = \log \hat{R}_t + \log\Big(\frac{\pi_C}{\beta}\Big) + \Big(g_a + \frac{a_c}{1-a_i}g_v\Big),\\
R_{C,t}^{\Delta,o} &\equiv \log R_{C,t}^{\Delta} = \log \hat{R}_{C,t+1}^B + \log R_C^B - \log \hat{R}_t,\\
R_{I,t}^{\Delta,o} &\equiv \log R_{I,t}^{\Delta} = \log \hat{R}_{I,t+1}^B + \log R_I^B - \log \hat{R}_t.
\end{aligned}
$$

E Construction of the Observables

Table 5 provides an overview about the raw data used to construct the observables and the steady state relationships. All changes we made to these time series in order to construct the dataset used for the estimation are described in the following.

Total nominal consumption is given by the sum of (nominal) personal consumption expenditures on services and personal consumption expenditures on (nominal) non-durable goods. However, it is not valid to add the chain weighted series to generate total real consumption. The times series for real consumption is constructed as follows. First, the shares of services and non-durable goods in total nominal consumption are calculated. The average per period is taken for each share according to the Tomqvist index. Then, total consumption growth can be calculated as the average share of services times the growth rate of real services plus the average share of non-durables times the growth rate of real non-durable goods. Using this growth rate of real consumption and knowing that nominal consumption equals its real counterpart in the base year (2005), we can construct a series for real consumption. The consumption deflator is calculated as the quotient of nominal over real consumption. Inflation of consumer prices is the growth rate of the consumption deflator. Analogously we construct a time series for the investment deflator using series for (nominal) personal consumption expenditures on durable goods and gross private domestic investment.[36] The relative price of investment is the quotient of the investment deflator and the consumption deflator. The time series for output and real investment are constructed by dividing nominal GDP and nominal investment by the consumption deflator.

The hourly wage is defined as total compensation per hour. Dividing this series by the consumption deflator yields the real wage rate. Hours worked is given by a time series of hours of all persons in the non-farm business sector. The nominal interest rate is constructed using the effective federal funds rate. We use the monthly average per quarter of this series and divide it by four to account for the quarterly frequency of the model.

Following Del Negro et al. (2007) the series of investment, consumption, output and hours worked are expressed in per capita terms by dividing with civilian non-institutional population. All time series used for the estimation are transformed into growth rates. Exceptions are the nominal interest rate rate and inflation in the consumption and investment sector which are used in levels. The time series for hours is in logs and constructed as deviation from the series' average.

Data for credit spreads in the consumption and investment sector are not directly available. Reuters' Datastream provides US credit spreads which we map into the two sectors using SIC industry codes.[37] A credit spread is defined as the difference between the bond's yield and the yield of a US Treasury bond with an identical maturity. In line with Gilchrist and Zakrajsek (2011) we make the following adjustments to the credit spread data: Using ratings from Standard & Poor's and Moody's, we exclude all bonds which are below investment grade as well as the bonds for which ratings are unavailable. We further exclude all spreads with a matu-

[36]The chained dollar series for real consumption expenditures on services, durable and non-durable goods prior to 1995 were constructed by Haver Analytics using chained quantity indexes.

[37]We use the 1987 version of the SIC codes available on the website of the United States Department of Labor. The investment sector is defined to consist of companies in manufacturing and construction industries (SIC codes 15-17 and 20-39). The consumption sector consists of companies in transportation, communications, electric, gas and sanitary services, wholesale and retail trade, services and finance, insurance and real estate (SIC codes 40-89).

rity below one and above 30 years and exclude all credit spreads below 10 and above 5000 basis points to ensure that the time series are not driven by a small number of extreme observations. After these adjustments the dataset (1990Q2-2011Q1) contains 15057 spreads of bonds of which 12999 are classified to be issued by companies in the consumption sector and 2058 issued by companies in the investment sector. This is equivalent to 242595 observations in the consumption and 56516 observations in the investment sector. The average maturity is 18 quarters (consumption sector) and 27 quarters (investment sector) with an average rating around A and A-, respectively. The series for the sectoral credit spreads are constructed by taking the mean over all spreads available in a certain quarter which are classified to be in the consumption and investment sector, respectively. These two series are transformed from basis points into percent and divided by four to guarantee that they are consistent with the quarterly frequency of our model. The correlation between the two series is 0.96.

The steady state leverage ratio of financial intermediaries, used to pin down the parameters ϖ and λ_B, is calculated by taking the inverse of a time series of total equity over total assets of US banks.

Table 5: Time Series used to construct the observables and steady state relationships

Time Series Description	Units	Code	Source
Gross domestic product	CP, SA, billion $	GDP	BEA
Gross Private Domestic Investment	CP, SA, billion $	GPDI	BEA
Real Gross Private Domestic Investment	CVM, SA, billion $	GPDIC1	BEA
Personal Consumption Expenditures: Durable Goods	CP, SA, billion $	PCDG	BEA
Real Personal Consumption Expenditures: Durable Goods	CVM, SA, billion $	PCDGCC96	BEA
Personal Consumption Expenditures: Services	CP, SA, billion $	PCESV	BEA
Real Personal Consumption Expenditures: Services	CVM, SA, billion $	PCESVC96	BEA
Personal Consumption Expenditures: Nondurable Goods	CP, SA, billion $	PCND	BEA
Real Personal Consumption Expenditures: Nondurable Goods	CVM, SA, billion $	PCNDGC96	BEA
Civilian Noninstitutional Population	NSA, 1000s	CNP160V	BLS
Nonfarm Business Sector: Compensation Per Hour	SA, Index 2005=100	COMPNFB	BLS
Nonfarm Business Sector: Hours of All Persons	SA, Index 2005=100	HOANBS	BLS
Effective Federal Funds Rate	NSA, percent	FEDFUNDS	BG
Total Equity / Total Assets	NSA, percent	EQTA	IEC

CP = current prices, CVM = chained volume measures (2005 Dollars), SA = seasonally adjusted, NSA = not seasonally adjusted. BEA = U.S. Department of Commerce: Bureau of Economic Analysis, BLS = U.S. Department of Labor: Bureau of Labor Statistics and BG = Board of Governors of the Federal Reserve System, IEC = Federal Financial Institutions Examination Council.

Appendix C: Finite Horizon Decomposition

This section discusses in detail how the finite horizon decomposition is performed. We randomly draw parameter values from the posterior distributions and generate stationary time series for all variables of interest. Thereby, all but one shock variances are fixed at zero. The time series of variables that exhibit permanent trends are retrended before all variables are detrended with the HP-filter. The first 100 periods of the time series are descarded to avoid any impact of the chosen start values. The remaining part of the variables' time series — that have the same length as the estimation horizon — is used to calculate standard deviations indicating the absolute fluctuations a shock generates for the variables. This procedure is repeated for all shocks so that we have for a certain variable values of absolute contributions for each shock. We then calculate the relative contribution of the shocks to fluctuations in a certain variable by dividing each absolute value by the sum of all shocks' absolute contributions to fluctuations in this variable.

This whole procedure is repeated 500 times, yielding 500 relative contributions of each shock to fluctuations in each variable. The mean and percentiles we calculate from this data for a certain shock and variable combination are shown in Table 4.