News and Financial Intermediation in Aggregate and Sectoral Fluctuations

Görtz, Christoph and Tsoukalas, John

University of Nottingham

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News and Financial Intermediation in Aggregate and Sectoral Fluctuations*

Christoph Görtz† and John D. Tsoukalas‡

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PRELIMINARY

Abstract

We estimate a two-sector DSGE model with financial intermediaries—a-la Gertler and Karadi (2011) and Gertler and Kiyotaki (2010)—and quantify the importance of financial shocks in accounting for aggregate and sectoral fluctuations. Our results indicate a significant role of financial market news as a predictive force behind fluctuations. Specifically, news about the valuation of assets held by financial intermediaries, reflected one to two years in advance in corporate bond markets, affect the supply of credit and are estimated to be a significant source of aggregate fluctuations, accounting for approximately 25% of output, 20% of investment and 25% of hours variation in both cyclical and lower frequencies. Financial intermediation is essential for the importance and propagation of these valuation shocks. Importantly, valuation news shocks generate both *aggregate* and *sectoral* co-movement as in the data.

Keywords: News, Financial intermediation, Business cycles, DSGE, Bayesian estimation.

JEL Classification: E2, E3.

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†University of Nottingham, Sir Clive Granger Building – School of Economics, University Park, Nottingham NG7 2RD. Email: Christoph.Gortz@nottingham.ac.uk.

‡University of Glasgow, Business School/Economics, 312 Adam Smith Building, Glasgow, G12 8RT. Email: john.tsoukalas@glasgow.ac.uk.

1 Introduction

The 2007-2008 financial crisis has highlighted the powerful role and importance of the financial sector. Valuation corrections in an apparently "small" pocket of the housing market, i.e. the market for sub-prime mortgage loans escalated into a deep recession of disproportionate magnitude, dubbed by many observers as the "Great Recession". Disruptions in financial markets at the onset and during the 2007-2008 crisis were first reflected in movements of financial market indicators, e.g. credit spreads on various private sector assets. These movements preceded significant declines in measures of real economic activity during the "Great Recession". Real GDP per capita fell by 4.7%, private per capita domestic investment by 32%, and total non-farm business per capita hours by 9.7%.

In addition to the broad aggregate declines during the recession, there have been severe sectoral downturns, especially in hours worked. Figure 1 shows the behavior of hours worked across two broad sectors of the economy, namely, consumption and investment sectors (to be precisely defined later). There are several interesting observations. First, sectoral hours tend to move together over the cycle. Second, the extent of the recent downturn has been very uneven, with investment sector hours (e.g. in industries such as construction, manufacturing, utilities) experiencing a severe decline, while consumption sector hours (e.g. in industries such as services, retail trade, finance) have been affected relatively less. Moreover, this pattern is not specific to the 2008 recession and can be observed in previous cyclical episodes. Hours worked in investment sector industries are relatively more cyclical compared to hours worked in the consumption sector and they decline significantly more in recessions (see Figure 1 left panel and Table 1) thereby acting as a powerful drag on total hours worked in these periods of depressed activity. In fact, total hours are strongly correlated with investment sector hours and only weakly so with consumption sector hours, suggesting the importance of the former for the behavior of the total. These simple facts serve to demonstrate the importance of looking beyond broad macroeconomic aggregates when studying the business cycle but also beg the question whether and to what extent financial factors, as those experienced during the "Great Recession" can explain (a) patterns of *sectoral comovement* and (b) *sectoral differences* suggested by Figure 1. Our paper sets out to produce answers to these questions by adopting a multi sector approach.

The recent financial crisis and the ensuing recession highlighted the link between financial markets and economic activity. There is a growing literature that establishes the predictive power of financial market indicators for real macroeconomic aggregates (see for example Gilchrist et al. (2009), Gilchrist and Zakrajsek (2011), Mueller (2009), Kurmann and Otrok (2010), Gomes and Schmid (2009) among others). An appealing interpretation is that these indicators may incorporate advance information or *news* about future developments in the economy. Gilchrist et al. (2009) and Gilchrist and Zakrajsek (2011) identify credit market factors from corporate bond spreads that predict future movements in output, employment or industrial production. Philippon (2009) shows corporate bond market spreads to better anticipate—compared to the stock market—future economic activity. Kurmann and Otrok (2010) suggest the slope of the yield curve contains information about future total factor productivity (TFP).[1]

[1]In a similar vain, Beaudry and Portier (2006) suggest that movements in the stock market convey information about the advent and eventual diffusion of new technologies that precede movements in total factor productivity (TFP) and identify these movements as driven by TFP news. They provide evidence of their importance as drivers of business cycles as agents act on revised expectations long before the actual realization of new technologies.

In this paper we quantitatively explore the link between financial markets and the real economy using a model with financial frictions which emphasizes the supply side of credit. A distinctive aspect of our work is the dis-aggregation of production into two sectors, namely consumption and investment sectors. The investment sector produces durable investment goods that are converted into capital and are used as an input by both sectors. The consumption sector produces non-durable consumption and services that provide direct utility for households. Both sectors rely on financing capital acquisitions from intermediaries and adverse developments (real or financial in origin) in the downstream consumption sector spill over to the upstream investment sector through changes in demand for capital goods. This framework allows for a quantitative investigation of real, nominal and financial sources as drivers for aggregate and sectoral US fluctuations. We introduce financial intermediation as in Gertler and Karadi (2011) and Gertler and Kiyotaki (2010). Inspired by the recent financial crisis the financial frictions developed therein emphasize leverage constraints that effectively tie credit flows from the financial sector to the real economy to the equity capital of intermediaries. Recently, DSGE studies have considered financial factors in business cycle models (see Christiano et al. (2010), Nolan and Thoenissen (2009), Christensen and Dib (2008), Jermann and Qudrini (2012) among others). The majority of these studies rely on the framework proposed by Bernanke et al. (1999) in order to introduce financial frictions. However, in that approach, financial intermediation is a veil—what matters is the borrower's balance sheet condition. A very limited number of studies consider financial frictions that constrain the lending behavior of financial intermediaries (see for example, Gerali et al. (2010), Hirakata et al. (2011) and Villa (2010)).

We estimate the model on U.S. real, nominal and financial data over the period, 1990Q2 to 2011Q1. We include the 2008-2009 recession in our analysis in order to get a first look at its drivers, an important consideration given our focus on factors that affect the supply of credit. Besides a host of real and nominal shocks included in the model we also consider two types of financial shocks. *First*, shocks that affect the value of the portfolio of assets held by intermediaries (valuation shocks) and *second*, shocks that capture exogenous movements in the intermediaries' equity capital (equity capital shocks). We assume the former can incorporate information (or signals) about future valuations (valuation news) in addition to standard unanticipated components. In the estimation, we construct and include separate corporate bond spreads that match the definition of sectors we use. The corporate bond spreads help to identify financial *news* shocks as they are likely to contain advance information in addition to what can be extracted from real macroeconomic aggregates. 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.[2] In addition to corporate bond spreads we also include the equity capital of intermediaries as an observable in estimation. Given our focus on the behavior of financial intermediaries and the role of equity capital in determining the demand for assets, we believe it is important to inform the estimation with a variable that determines the degree of leverage of financial intermediaries.[3]

Our results are as follows.

[2]Including corporate bond spreads in our set of observables confers a main advantage: in contrast to other financial variables, like stock prices for example, information from bond market prices is shown to be closely related to various macroeconomic aggregates. For example, Gilchrist et al. (2009), Gilchrist and Zakrajsek (2011) underline the high predictive content of corporate bond market spreads for economic activity.

[3]Despite the intuitive links between financial markets and real aggregates, only a handful of papers include financial market variables when estimating DSGE models with news shocks (Christiano et al. (2010), Davis (2007), Schmitt-Grohe and Uribe (2010)).

- Valuation shocks can explain a sizable fraction of fluctuations at both business cycle and lower frequencies. They can account for approximately 25% of output growth, 20% of aggregate investment growth and 25% of aggregate hours variance. Interestingly, *news* about asset valuations (coined "valuation news") that arrive up to 2 years in advance explain the majority of the variance shares above. Shocks of this type have been examined qualitatively in Gertler and Karadi (2011) and our paper provides, to the best of our knowledge, the first quantitative estimate of their importance. Our estimates moreover indicate that corporate bond market spreads contain substantial information about valuation news shocks. We find the quantitative importance of valuation news—in terms of accounting for the variance shares of real macro variables—doubles when corporate bond spreads are included in the estimation than if they are not. Consequently, the news components of valuation disturbances account for a significant fraction of the variation in corporate bond spreads. Interestingly, comparisons of the estimated valuation news shocks series with a market indicator of default risk provided by Fitch (future probability of default) suggests they can be plausibly interpreted as a stand-in of varying corporate default risk.

- Valuation news shocks can generate **aggregate** and **sectoral** co-movement, a pervasive stylized fact of business cycles and can explain the behavior of total hours worked surprisingly well during recessions. The success in explaining the behavior of total hours during recessions is linked to the fact these shocks almost entirely capture the declines in investment sector hours during these periods, in line with the evidence presented in Figure 1.

- Investment sector TFP shocks (or investment specific shocks popularized by Greenwood et al. (2000) and Fisher (2006)) account for a relatively significant fraction of business cycle variation in output growth, total investment growth and total hours worked consistent with the findings in Fisher (2006). This stands in sharp contrast with their negligible importance reported in several recent estimated one sector DSGE models such as Schmitt-Grohe and Uribe (2010) or Gilchrist et al. (2009). The primary reason for this finding is the tight link imposed in estimation—between investment specific shocks and the relative price of investment. As a result, in those studies, investment specific shocks are identified from the relative price of investment alone. This constraint does not necessarily hold in a two sector model, except under special assumptions.

- From a historical perspective, valuation news shocks can entirely explain the decline in GDP and a large fraction of the investment collapse in the early stages of the 2008 recession. They are also found to be driving, to a significant extent, the declines in GDP and investment in the 2001 recession following the 1990s investment boom. However they are estimated to have played a very limited role during the recession at the beginning of the 1990s consistent with earlier work that found only limited credit supply effects on the severity of the 1990-1991 recession (e.g. Bernanke et al. (1991)).

In addition to providing a quantitative estimate of financial shocks, this paper contributes to the ongoing debate on the importance of news shocks for aggregate fluctuation. Despite the fact, as demonstrated by Beaudry and Portier (2004) and Jaimovich and Rebelo (2009), that it is theoretically possible to generate a broad based expansion with an anticipated shock that signals an improvement in total factor productivity (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 due to wealth effects that depress hours and investment in favor of consumption and leisure. 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 (2011) and Fujiwara et al. (2011) in estimated New Keynesian DSGE models. But at the same time this earlier work points to “other”, but yet to be precisely specified, sources of news as important drivers of aggregate fluctuations. Where exactly these sources of news reside in a macroeconomic model and consequently, the quantitative significance of news shocks is still an open question. Our findings suggest a significant role for news shocks lies within propagation channels that are tightly linked with financial intermediation. And in addition to broad based comovement—in the main macroeconomic aggregates—the issue of sectoral comovement in response to news is a demanding challenge as illustrated by Jaimovich and Rebelo (2009). It should thus come as no surprise that sectoral co-movement has been almost entirely neglected in the news shocks literature. Our paper makes headway in that direction as well.

The rest of the paper is organized as follows. The next section provides some stylized facts on sectoral co-movement in US data. Section 3 describes the model economy. Section 4 describes the estimation methodology and data. Section 5 reports estimation results. Section 6 quantifies the importance of different structural shocks as driving forces for aggregate fluctuations. Section 7 discusses the propagation of valuation shocks while section 8 compares them with financial market measures of lending and default risk. Section 10 discusses the impact of anticipated and unanticipated shocks from a historical perspective. Section 11 concludes.

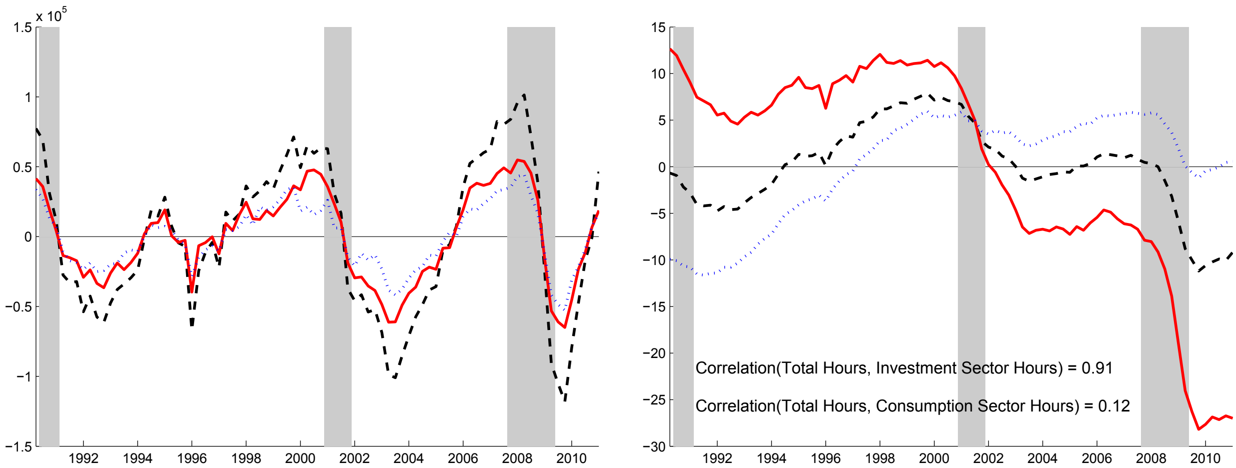

Figure 1: Total hours (black, dashed), consumption sector hours (blue, dotted) and investment sector hours (red, solid) (per capita average weekly hours times employees). Left figure: HP_{1600} detrended series. Right figure: Demeaned time series in levels. See the data Appendix for a description of the sectoral hours series.

Table 1: Peak to trough change of aggregate and sectoral hours in recessions

	Total Hours	Consumption Sector	Investment Sector
1990Q3 – 1991Q1	-0.020	-0.007	-0.029
2001Q1 – 2001Q4	-0.042	-0.020	-0.063
2007Q4 – 2009Q2	-0.097	-0.054	-0.149

Total hours are non-farm business sector in per capita terms. The series for sectoral hours are non-farm average weekly hours times employees in per capita terms. See the data Appendix for a description of the sectoral hours series.

2 Evidence on sectoral co-movement

This section provides a brief description of the relationship between sectoral macroeconomic variables and real GDP. Table 2 reports cross correlations of HP de-trended sectoral hours worked and sectoral investment (only available at an annual frequency) with real GDP. It is immediately apparent that all sectoral variables co-move very strongly with real GDP. The contemporaneous correlation of hours worked in both sectors with GDP is approximately of similar magnitude, about 0.81. Sectoral hours worked appear to lag real GDP by one or two quarters. The sectoral investment series are also very strongly correlated with real GDP. Investment flows produced for the consumption sector are more strongly correlated compared to investment flows produced for use in the investment sector.

Sectoral co-movement of inputs and outputs is a pervasive stylized fact of business cycles as documented in earlier work, yet existing one sector macroeconomic models have been overlooking sectoral fluctuations. A multi sector approach may thus provide better clues on the importance of various and often competing sources of fluctuations. Previous work has considered multi sectoral environments. Important contributions in this area include, but not limited to, Long and Plosser (1983), Huffman and Wynne (1999), Horvath (1998), Horvath (2000), Hornstein and Praschnik (1997). This early work has focused on real business cycle frameworks with real shocks and frictions using a variety of assumptions on input–output linkages. Huffman and Wynne (1999) demonstrated the difficulty of a standard two sector RBC model with free factor mobility to produce sectoral co-movement in response to TFP shocks. More recently, researchers have appealed to the richer structure and implications of multiple sector models to address a variety of questions. Boldrin et al. (2001) use a two sector model with limited factor mobility calibrated to the U.S. economy to account for the risk free rate and equity premium puzzles. Ireland and Schuh (2008), investigate the productivity performance of the U.S. highlighting technological differences across sectors. Guerrieri et al. (2010) provide conditions for an accurate interpretation of investment specific shocks using information from the Input-Output Tables.[4]

[4] Others introduce the multi sector structure to New Keynesian environments (see for example, Edge et al. (2008), DiCecio (2009), Buakez et al. (2009)).

Table 2: Cross-Correlation of aggregate and sectoral variables with real GDP

	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6
Total Hours	-0.174	-0.049	0.129	0.304	0.486	0.685	0.861	0.878	0.816	0.680	0.495	0.308	0.121
Consumption sector hours	-0.275	-0.154	0.004	0.168	0.358	0.579	0.801	0.859	0.840	0.749	0.578	0.412	0.236
Investment sector hours	-0.210	-0.099	0.062	0.225	0.409	0.616	0.819	0.865	0.821	0.708	0.551	0.389	0.219
Total Investment	0.244	0.027	-0.159	-0.346	-0.310	0.144	0.841	0.636	0.048	-0.301	-0.446	-0.367	-0.097
Consumption sector Investment	0.136	-0.015	-0.114	-0.290	-0.257	0.169	0.842	0.684	0.145	-0.177	-0.337	-0.340	-0.170
Investment sector Investment	0.323	0.072	-0.182	-0.343	-0.311	0.084	0.668	0.449	-0.079	-0.389	-0.487	-0.325	0.011

Total hours are non-farm business sector in per capital terms. The series for sectoral hours are non-farm average weekly hours times employees expressed in per capita terms. Statistics for hours are calculated from quarterly per capita HP_{1600} detrended series. Investment series are annual per capita chained investment in private fixed assets. Statistics are calculated from HP_{100} detrended series. Sample for the hours series is 1990Q2-2011Q1. Sample for the investment series is 1990-2010. See the data Appendix for details.

3 The Model

The model is a two sector economy with various real and nominal frictions and financial intermediaries that engage in transforming deposits from households to loans for firms in the two sectors. The sectors in the model produce consumption goods and investment goods. The latter are long-lived and are used as capital inputs in each sectors' production process, while the former are non-storable and enter only into consumers utility functions. To allocate a sector to the consumption or investment category, we used the 2005 Input-Output tables. The Input-Output tables track the flows of goods and services across industries and record the final use of each industry's output into three broad categories: consumption, investment and intermediate uses (as well as net exports and government). First, we determine how much of a 2-digit industry's final output goes to consumption as opposed to investment or intermediate uses. Then we adopt the following criterion: if the majority of an industry's final output is allocated to final consumption demand it is classified as a consumption sector; otherwise, if the majority of an industry's output is allocated to investment or intermediate demand, it is classified as an investment sector. Using this criterion, the mining, construction, manufacturing, transportation and utilities, information and wholesale trade industries are classified as the investment sector, and finance, insurance and real estate (FIRE), retail trade and services industries are classified as the consumption sector.[5]

The model includes eight different types of economic agents: A continuum of households that consume, save in interest bearing deposits and supply labor on a monopolistically competitive labor market. Employment agencies aggregate different types of labor to a homogenous aggregate for intermediate goods production. A continuum of intermediate goods firms produce investment and consumption goods in two distinct sectors using labor and capital services as inputs. They rent labor services from the employment agencies and rent capital services on a perfectly competitive market from capital services producers. Final goods producers aggregate intermediate producers output in each sector. Physical capital producers in each sector use a fraction of investment goods and existing capital to produce new capital goods. Financial intermediaries accept deposits from households and finance capital acquisitions from capital services producers. A monetary policy authority controls the short-run nominal interest rate.

[5]We have checked whether there is any migration of 2-digit industries across sectors for our sample. The only industry which changes classification (from consumption to investment) during the sample is "information" which for the majority of the sample can be classified as investment and we classify it as such.

3.1 Intermediate goods producers

3.1.1 Intermediate goods producer's production and cost minimization

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 labor services 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 TFP processes above and $\rho_z, \rho_v \in (0,1)$ determine the persistence of these processes.

3.1.2 Intermediate goods producer's pricing decisions

A constant fraction $\xi_{p,x}$ of intermediate firms in sector $x = C, I$ cannot choose their price optimally in period t but reset their 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 denote steady state values and where the factor that appears in the investment sector expression corrects for investment specific progress.

[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.

The remaining fraction of firms, $(1-\xi_{p,x})$, in sector $x = C, I$ can adjust the price in period t. Firms in both sectors choose their price optimally by maximizing the present discounted value of future profits. The resulting aggregate price index in the consumption sector is

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

The aggregate price index in the investment sector is

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

3.2 Final goods producers

Final goods, C_t and I_t, in the consumption and investment sector respectively, are produced by perfectly competitive firms combining a continuum—$C_t(i)$ and $I_t(i)$—of intermediate goods, according to the technology:

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

The elasticity $\lambda_{p,t}^x$, $x = C, I$ is the time varying price markup over marginal cost for intermediate firms. It is assumed to follow 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 mark-up (or cost-push) shocks to the inflation equation.

Profit maximization and the zero profit condition for final good firms 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 $P_{I,t}(i)$,

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

3.3 Households

3.3.1 Household's utility and budget constraint

Households consist of two types of members, workers and bankers. At any point in time, there is a fraction $1-f$ that are workers and f that are bankers. The workers supply (specialized) labor and earn wages while the bankers manage a financial intermediary. Both member types return their respective earnings back to the household. This set-up is identical to Gertler and Karadi (2011) except for the fact that workers have monopoly power in setting wages. The household maximize the utility function,

$$E_0 \sum_{t=0}^{\infty} \beta^t b_t \left[\ln(C_t - hC_{t-1}) - \varphi \frac{(L_{C,t}(j) + L_{I,t}(j))^{1+\nu}}{1+\nu}\right], \quad \beta \in (0,1), \quad \varphi > 0, \quad \nu > 0, \tag{3}$$

where E_0 is the conditional expectation operator, β is the discount factor and h is the degree of (external) habit formation. The inverse Frisch labor supply elasticity is denoted by ν while φ is a free parameter which allows to calibrate total labor supply in the steady state to be unity. Due to the non-stationarity of technological (TFP) 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 intertemporal preference shock, which affects both the marginal utility of consumption and the marginal disutility of labor. It is assumed to follow the stochastic process,

$$\log b_t = \rho_b \log b_{t-1} + \varepsilon_t^b, \tag{4}$$

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 (in consumption units) is

$$C_t + \frac{B_t}{P_{C,t}} \leq \frac{W_t(j)}{P_{C,t}}(L_{C,t}(j) + L_{I,t}(j)) + R_{t-1}\frac{B_{t-1}}{P_{C,t}} - \frac{T_t}{P_{C,t}} + \frac{Q_t(j)}{P_{C,t}} + \frac{\Pi_t}{P_{C,t}}, \tag{5}$$

where B_t is holdings of bank deposits (which are risk free and equivalent to 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 paid on deposits and Π_t is the per-capita profit accruing to households from ownership of all firms. Notice above the wage rate, W_t, is identical across sectors due to perfect labor mobility.

3.3.2 Employment agencies

Each household $j \in [0,1]$ supplies specialized labor, $L_t(j)$, monopolistically as in Erceg et al. (2000). A large number of competitive "employment agencies" aggregate this specialized labor into a homogenous labor input which is sold to intermediate goods producers in a competitive market. Aggregation is done according to the following 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 $i.i.d.\ N(0,\sigma_{\lambda_w}^2)$. The expression $\lambda_{w,t}$ is the wage markup shock which can also be interpreted as a labor 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 popularized by Hall (1997).

Profit maximization by the perfectly competitive employment agencies implies the labor demand function

$$L_t(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t, \tag{6}$$

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

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

3.3.3 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.

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

The remaining fraction of households, $(1 - \xi_w)$, chooses an optimal wage, $W_t(j)$, by maximizing[7]

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

subject to the labor demand function (6). 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.

3.4 Capital services producers

There is a perfectly competitive sector with capital services producers that transform physical capital to effective capital. At the end of period t capital services producers in sector $x = C, I$, purchase physical capital $\bar{K}_{C,t}$ or $\bar{K}_{I,t}$ from physical capital goods producers in the respective sector at price $Q_{C,t}$ or $Q_{I,t}$ (described in the next section). At the beginning of the next period, capital services producers set the utilization rate of capital. The utilization rate, $u_{x,t}$, transforms available capital into effective capital according to

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

Capital services producers incur costs when setting utilization, which are denoted by $a(u_{x,t})$ per unit of capital. 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. Capital services producers rent the effective capital in perfectly competitive markets to intermediate goods produces and earn a rental rate equal to $R_{x,t}^K / P_{C,t}$ per unit of capital.

[7] All households that can reoptimize 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 frictions (Mankiw, N. Gregory and Reis, Ricardo (2002), Sims (2003)) and contract costs (Caplin and Leahy (1997)).

In the spirit of Gertler and Karadi (2011) we introduce a shock to the quality of capital, $\xi^K_{x,t}$, in each sector x and assume it evolves according to

$$\log \xi^K_{x,t} = \rho_{\xi^K,x} \log \xi^K_{x,t} + \varepsilon^{\xi^K}_{x,t}, \qquad x = C, I,$$

where $\rho_{\xi^K,x} \in (0,1)$. This disturbance (as shown below) directly affects the value of capital and will be called valuation shock. [8]

We moreover assume the innovation of the shock process consists of two components.[9]

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

where the first component, $\varepsilon^{\xi^{K,0}}_{x,t}$, is unanticipated and the second component, $\varepsilon^{\xi^{K,news}}_{x,t}$, is anticipated or news. 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 a signal (or news) received by agents in period $t-h$ about the quality of capital in period t. H is the maximum horizon over which agents can receive advance information (anticipation horizon). 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. Note the process above also allows for revisions in expectations. In other words, a signal received $t-h$ periods in advance can later be revised by an updated signal received at $t-h+1, ...t-1$. or by the unanticipated component, $\varepsilon^{\xi^{K,0}}_{x,t}$.

Capital services producers in period $t+1$ in sector $x = C, I$ choose the utilization rate of capital to solve,

$$\max_{u_{x,t+1}} \left[\frac{R^K_{x,t+1}}{P_{C,t+1}} u_{x,t+1} \xi^K_{x,t+1} \bar{K}_{x,t} - a(u_{x,t+1}) \xi^K_{x,t+1} \bar{K}_{x,t} A_{t+1} V_{t+1}^{\frac{a_c-1}{1-a_i}} \right]$$

The resulting first order condition for sector $x = C, I$ is

$$r^K_{x,t+1} = a'(u_{x,t+1}), \qquad \text{with} \quad r^K_{x,t+1} = \frac{R^K_{x,t+1}}{P_{C,t+1}} V_{t+1}^{\frac{1-a_c}{1-a_i}} A^{-1}_{t+1}.$$

Capital services producers purchase physical capital at the end of period t at price $Q_{x,t}$ and sell the un-depreciated component at the end of period $t+1$ at price $Q_{x,t+1}$ to the physical capital producers. Hence, total receipts of capital services producers in period $t+1$ are equal to:

$$\frac{R^K_{x,t+1}}{P_{C,t+1}} u_{x,t+1} \xi^K_{x,t+1} \bar{K}_{x,t} - a(u_{x,t+1}) \xi^K_{x,t+1} \bar{K}_{x,t} A_{t+1} V_{t+1}^{\frac{a_c-1}{1-a_i}} + (1-\delta_x) Q_{x,t+1} \bar{K}_{x,t},$$

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

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

which can be expressed as

$$R^B_{x,t+1} Q_{x,t} \bar{K}_{x,t} \tag{8}$$

with

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

where $R^B_{x,t+1}$ is the rate of return on capital for capital services producers. Since the latter finance their purchase of capital at the end of each period with funds from financial intermediaries (to be described below), $R^B_{x,t+1}$ is also the stochastic return for financial intermediaries in sector $x = C, I$. Note that the valuation shock, $\xi^K_{x,t+1}$ is a source of variation in the return to capital. Consequently, the process we have adopted for the valuation shock implies that this return will in general depend on beliefs about the expected future path of $\xi^K_{x,t+j}$.

3.5 Physical capital producers

Capital producers in sector $x = C, I$ use a fraction of investment goods from final goods producers and undepreciated capital stock from capital services producers (as described above) to produce new capital goods, subject to investment adjustment costs as proposed by Christiano et al. (2005). These new capital goods are then sold in perfectly competitive capital goods markets to capital services producers for use in period $t+1$. The technology available for physical capital production is given as:

$$O'_{x,t} = O_{x,t} + \left(1 - S\left(\frac{I_{x,t}}{I_{x,t-1}}\right)\right) I_{x,t}$$

where $O_{x,t}$ denotes the amount of used capital at the end of period t, $O'_{x,t}$ the new capital available for use at the beginning of period $t+1$. The investment adjustment cost function $S(\cdot)$ satisfies the following: $S(1) = S'(1) = 0$ and $S''(1) = \kappa > 0$, where "$'$"s denote differentiation. The investment adjustment cost make the optimization problem of capital producers in sector $x = C, I$ dynamic. Formally,

$$\max_{I_{x,t}, O_{x,t}} E_t \sum_{t=0}^{\infty} \beta^t \Lambda_t \left\{ Q_{x,t} \left[O_{x,t} + \left(1 - S\left(\frac{I_{x,t}}{I_{x,t-1}}\right)\right) I_{x,t} \right] - Q_{x,t} O_{x,t} - \frac{P_{I,t}}{P_{C,t}} I_{x,t} \right\},$$

where $Q_{x,t}$ denotes the price of capital (i.e. the value of installed capital in consumption units). The first order condition for investment goods is

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

From the capital producer's problem it is evident that any value of $O_{x,t}$ is profit maximizing. Let $\delta_x \in (0,1)$ denote the depreciation rate of capital and $\bar{K}_{x,t-1}$ the capital stock available at the beginning of period t in sector $x = C, I$. Then setting $O_{x,t} = (1-\delta)\xi^K_{x,t}\bar{K}_{x,t-1}$ implies the available capital stock in sector x, evolves according to

$$\bar{K}_{x,t} = (1-\delta_x)\xi^K_{x,t}\bar{K}_{x,t-1} + \left(1 - S\left(\frac{I_{x,t}}{I_{x,t-1}}\right)\right) I_{x,t}, \qquad x = C, I, \tag{9}$$

Notice the setup above with separate capital producers for the investment and the consumption sector and the separate capital accumulation equations. The latter imply that installed capital is immobile across the two sectors and only newly produced capital can be re-allocated across sectors.

3.6 Financial sector

3.6.1 Financial Intermediaries

Financial intermediaries (banks) use deposits from households and their own equity capital to lend funds to capital services producers. Moreover, intermediaries face an exogenous $i.i.d.$ probability of exit in each period. Because we work with a two sector model we assume banking is segmented; there are two continua of banks which provide specialized lending either to capital services producers in the consumption or capital services producers in the investment sector. In other words, we assume there are specialized intermediaries for financing each sector. Once it is determined that a household member is a banker the probability that she is specialized to lend in sector $x = C, I$ is equal across sectors and independent across time. The implementation of banks and their role as financial intermediaries in our two sector model is based on the framework developed in Gertler and Karadi (2011) using a standard one sector model, so we only briefly describe it here (Appendix A describes all the equations).[10] The balance sheet of a bank that specializes to lend in sector $x = C, I$ is,

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

where $S_{x,t}$ denotes the quantity of financial claims on capital services producers held by the intermediary and $Q_{x,t}$ denotes the price per unit of such claims. The variable $N_{x,t}$ denotes the bank's equity capital (or wealth) at the end of period t and $B_{x,t}$ are households deposits.

Financial intermediaries are limited from infinitely borrowing funds from households by a moral hazard/costly enforcement problem. Bankers, at the beginning of each period, can choose to divert a fraction λ_B of available funds and transfer it back to the household they belong. Depositors can force the bank into bankruptcy and recover a fraction $1 - \lambda_B$ of assets. Note that the fraction, λ_B, which bankers can divert is the same across sectors to guarantee that the household is indifferent between depositing funds to either type of bank.

Financial intermediaries maximize expected terminal wealth, i.e. the discounted sum of future equity capital of surviving intermediaries. The moral hazard/costly enforcement problem constraints the bank's ability to acquire assets because it introduces an endogenous leverage constraint. 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 and is a function of the marginal gains of expanding assets (holding equity constant), expanding equity (holding assets constant), and the

[10] It is important to highlight that banks in either sector are symmetric. Their performance and hence the evolution of equity capital differs between them because the demand for capital differs across sectors resulting in sector specific prices of capital, $Q_{x,t}$, and rates of return for capital. Moreover the institutional setup of banks does not depend on firm-specific factors. Gertler and Karadi (2011) show this latter fact implies an equivalent formulation with a representative bank.

gain from diverting assets. Formally,

$$Q_{x,t}S_{x,t} = \varrho_{x,t}N_{x,t}, \tag{10}$$

where $S_{x,t}$ denotes the quantity of financial claims held by the intermediary and $Q_{x,t}$ denotes the price of a claim in sector x.

Financial intermediaries which exit the industry can be replaced by new entering banks. Therefore, total wealth of financial intermediaries is the sum of the equity capital 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 the equity capital of existing bankers in sector $x = C, I$ is given by

$$N^e_{x,t} = \theta_B[(R^B_{x,t} - R_{t-1})\varrho_{x,t-1} + R_{t-1}]N_{x,t-1}, \qquad 0 < \theta_B < 1. \tag{11}$$

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

New entering banks receive startup funds from households equal to a small fraction of the value of assets held by the existing banks 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 $(1-\theta_B)Q_{x,t}S_{x,t}$. The household transfers a fraction, ϖ, of this value to the new intermediaries in the two sectors which leads to the following equations for new banker's wealth

$$N^n_{x,t} = \varpi Q_{x,t}S_{x,t}, \qquad 0 < \varpi < 1. \tag{12}$$

Existing banker's equity capital (A.4) and entering banker's equity capital (A.5) lead to the law of motion for total equity capital

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

where $\varsigma_{x,t}$ 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 $i.i.d\ N(0, \sigma^2_{\varsigma_x})$.
It is useful to define the finance (or risk) premium on assets earned by banks in sector $x = C, I$, as

$$R^{\Delta}_{x,t} = R^B_{x,t+1} - R_t. \tag{13}$$

Sources of variation in $R^B_{x,t+1}$. It is instructive to examine the factors that potentially affect the return to capital and consequently the risk premium on assets, using the expression for the return to capital derived in Appendix B (where lower case letters denote stationary variables),

$$R^B_{x,t+1} = \frac{r^K_{x,t+1}u_{x,t+1} + q_{x,t+1}(1-\delta_x) - a(u_{x,t+1})}{q_{x,t}}\xi^K_{x,t+1}e^{z_t}e^{-\frac{1-a_c}{1-a_i}v_t},$$

In addition to variation arising from the value of capital, $q_{x,t+1}$, two exogenous factors directly affect this return, namely, TFP shocks in consumption, z_t, and investment sectors, v_t, as well as the valuation shock, $\xi^K_{x,t+1}$. Of course this return—as the price of capital—will also be in principle affected by all other shocks in the model. For example, a positive TFP shock in the consumption sector would, other things equal, raise the return to capital as the consumption sector demands more capital services and raises the value of capital. On the other hand a positive valuation shock implies the quality of effective capital services rented by capital services producers improves, this also acts as a booster in the return to capital by raising the value of capital.

3.6.2 Financing capital acquisitions by capital services producers

Capital services producers in sector x, acquire physical capital $\bar{K}_{x,t}$ at the end of period t, and sell the capital on the open market again at the end of period $t+1$. This acquisition of capital is financed by financial intermediaries in the respective sector. To acquire the funds to buy capital, capital services producers issue $S_{C,t}$ or $S_{I,t}$ claims equal to the number of units of physical capital acquired, $\bar{K}_{C,t}$ or $\bar{K}_{I,t}$. They price each claim at the price of a unit of capital $Q_{C,t}$ or $Q_{I,t}$. Then by arbitrage the following constraint holds:

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

where the left hand side stands for the value of physical 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 characterized by the moral hazard/costly enforcement problem, we assume—in line with Gertler and Karadi (2011)—there are no frictions in the process of intermediation between non-financial firms and banks. Notice the assumptions above imply financial intermediaries carry all the risk when lending to capital services producers—effectively capital services producers earn zero return. Using the assumptions in Gertler and Karadi (2011) we can interpret these claims as one period state-contingent bonds which allows interpreting the risk premium defined in equation 13 as a corporate bond spread.

3.7 Monetary policy

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

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R}\left[\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi}\left(\frac{\pi_t}{\pi_{t-1}}\right)^{\phi_{\Delta\pi}}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_{\Delta Y}}\right]^{1-\rho_R}\eta_{mp,t}, \quad \rho_R, \phi_\pi, \phi_{\Delta\pi}, \phi_{\Delta Y} \in (0,1),$$

where R is the steady state gross nominal interest rate and (Y_t/Y_{t-1}) is the gross growth in real GDP. The interest rate responds to deviations of inflation from its target level, inflation growth and real GDP growth and is subject to a monetary policy IID shock $\eta_{mp,t}$.

3.8 Market clearing

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

$$\left[I_{I,t}^{-\rho}+I_{C,t}^{-\rho}\right]^{-\frac{1}{\rho}}=V_tL_{I,t}^{1-a_i}K_{I,t}^{a_i}-V_t^{\frac{1}{1-a_i}}F_I.$$

Notice in specifying the resource constraint in the investment sector we, following Huffman and Wynne (1999), allow (but not require) for the realistic possibility that investment goods may be sector specific to some degree, i.e. imperfect substitutes in production. In other words, investment goods produced for the investment sector may not be costlessly converted for use in the consumption sector. There are many examples that can fit this description. The parameter that captures the elasticity of substitution is given by, $-1\leq\rho<-\infty$. For $\rho=-1$, we obtain a standard resource constraint for the investment sector (i.e. perfectly substitutable investment goods), while $\rho<-1$, implies a cost for quickly changing the composition of investment goods across sectors. We estimate this parameter and thus let the data speak on this dimension. Moreover,

$$L_t=L_{I,t}+L_{C,t},\qquad I_t=\left[I_{I,t}^{-\rho}+I_{C,t}^{-\rho}\right]^{-\frac{1}{\rho}}\qquad\text{and}\qquad K_t=K_{I,t}+K_{C,t}.$$

Output (GDP in consumption units) is defined as

$$Y_t=C_t+\frac{P_{I,t}}{P_{C,t}}I_t+e_t.$$

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

$$\log e_t=(1-\rho_e)\log e+\rho_e\log e_{t-1}+\varepsilon_t^e,$$

where $\rho_e\in(0,1)$ and ε_t^e is $i.i.d.$ $N(0,\sigma_e^2)$. This measurement error is used to capture unmodelled output movements (such as government spending/net exports which we abstract from in the model).

4 Data and Methodology

We estimate the model using quarterly US data (1990 Q2 - 2011 Q1) on eleven macroeconomic and financial market variables. Specifically we use data on output, consumption, investment, hours worked, wages, nominal interest rate, consumption sector and investment sector inflation. In addition we include measures of risk premia using non-financial corporate bond spreads and a measure of banks' equity capital. A corporate bond spread is defined as the difference between a corporate bond's yield and the yield of an identical maturity U.S. Treasury bond. Specifically, we compute spreads for corporate bonds issued by companies classified as operating in the consumption and investment sector.[11] All nominal series—except investment, the

[11]This information is provided by Datastream. Another advantage of using bond spreads as observables is that unlike other financial variables, like stock prices for example, these variables are less noisy and have high predictive power for macroeconomic aggregates, such as output and investment as for example shown by Gilchrist and Zakrajsek (2011). 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. 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. To generate the credit spread series for the consumption/investment sector, we aggregate the spreads of 1213/4163 bonds and take the arithmetic average.

nominal interest rate, inflation rates and corporate bond spreads—are expressed in real terms by dividing with the consumption deflator. Moreover, output, consumption, investment and hours worked are expressed in per capita terms by dividing with civilian non-institutional population aged 16 and over. We define nominal consumption as the sum of personal consumption expenditures on nondurable goods and services. As in Justiniano et al. (2010), we define nominal gross investment as the sum of personal consumption expenditures on durable goods and gross private domestic investment. Real consumption is obtained by dividing the nominal series with the consumption deflator while real investment is obtained by dividing the nominal series with the investment deflator. Real wages are defined as compensation per hour in the non-farm business sector divided by the consumption deflator. Hours worked is the log of hours of all persons in the non-farm business sector, divided by the population. Consumption (investment) sector inflation is measured as the quarterly log difference in the consumption (investment) chain weighted deflator. The nominal interest rate series is the effective Federal Funds rate. We measure total equity capital using information from (a) the Federal Reserve Board's H8 release on assets and liabilities of all U.S. commercial Banks and (b) Federal Financial Institutions Examination Council report of conditions and income of all U.S. insured commercial banks. All data except the interest rate and credit spreads are in logs and seasonally adjusted. The limited availability of credit spread data for the 1980s is a factor that restricts the sample for the estimation (see Appendix F for details on data construction). The vector of observables we use in the estimation is given as

$$\mathbf{Y}_t = \left[\Delta \log Y_t, \Delta \log C_t, \Delta \log I_t, \Delta \log W_t, \pi_{C,t}, \pi_{I,t}, \log L_t, R_t, R^{\Delta}_{C,t}, R^{\Delta}_{I,t}, \Delta \log N_t\right]. \quad (14)$$

where Δ denotes the first-difference operator. Finally we demean the data prior to estimation.

We use the Bayesian methodology to estimate model parameters. This methodology is now extensively used in estimating DSGE models (see Schorfheide (2000), Smets and Wouters (2003), Lubik and Schorfheide (2004), Levin et al. (2005), and Del Negro et al. (2007) for early examples). Recent overviews are presented in An and Schorfheide (2007) and Fernández-Villaverde (2009). This methodology combines prior information with the likelihood function of the stationary model to obtain the posterior distribution of model parameters. The key steps in this methodology are as follows. Let Θ denote the vector that contains all the structural parameters of the model. The non-sample information is summarized with a prior distribution with density $p(\Theta)$.[12] The sample information (conditional on version $\mathcal{M}_i$ of the DSGE model) is contained in the likelihood function, $p(\mathbf{Y}_T|\Theta, \mathcal{M}_i)$, where $\mathbf{Y}_T = [Y_1, ..., Y_T]'$ contains the data. The likelihood function allows one to update the prior distribution of Θ, $p(\Theta)$. Then, using Bayes' theorem, we can express the posterior distribution of the parameters as

$$p(\Theta|\mathbf{Y}_T, \mathcal{M}_i) = \frac{p(\mathbf{Y}_T|\Theta, \mathcal{M}_i)p(\Theta)}{p(\mathbf{Y}_T|\mathcal{M}_i)} \quad (15)$$

where the denominator, $p(\mathbf{Y}_T|\mathcal{M}_i) = \int p(\Theta, \mathbf{Y}_T|\mathcal{M}_i)d\Theta$, in (15) is the marginal data density conditional on model $\mathcal{M}_i$. In Bayesian analysis the marginal data density constitutes a measure of model fit with two dimensions: goodness of in-sample fit and a penalty for model complexity. The posterior distribution of parameters is evaluated numerically using the random walk Metropolis-Hastings algorithm. We simulate the posterior using a sample of 500,000 draws

[12]We assume that parameters are *a priori* independent from each other. This is a widely used assumption in the applied DSGE literature and implies the joint prior distribution equals the product of marginal priors.

and use this (after dropping the first 20% of the draws) to (i) report the mean, and the 10 and 90 percentiles of the posterior distribution of the estimated parameters and (ii) evaluate the marginal likelihood of the model.[13] All estimations are done using DYNARE.[14]

4.1 Prior distributions

We use prior distributions that conform to the assumptions used in Smets and Wouters (2007), Justiniano et al. (2010), and Justiniano et al. (2011). The first five columns in Table 1 list the parameters and the assumptions on the prior distributions. A number of parameters are held fixed prior to estimation. We set the quarterly depreciation rate to be equal across sectors, $\delta_C = \delta_I = 0.025$. From the steady state restriction $\beta = \pi_C/R$, we set $\beta = 0.9974$. The shares of capital in the production functions, a_C and a_I, are fixed at 0.36. The steady state values for the ratio of nominal investment to consumption is calibrated to be consistent with the average value in the data. We also calibrate the steady state (deterministic) growth of TFP in the consumption/investment sectors in line with the sample average growth rates of output in the two sectors. This yields $g_a = 0.1\%$ and $g_v = 0.4\%$ per quarter.

There are three parameters specific to financial intermediation. The parameter θ_B, which determines the banker's average life span does not have a direct empirical counterpart and is fixed at 0.96.[15] This value implies an average survival time of bankers of slightly over six years. The parameters ϖ and λ_B are fixed at values which guarantee that the steady state risk premium (the average of spreads across the two sectors) and the steady state leverage ratio matches their empirical counterparts. The average of the consumption sector and investment sector credit spreads are each equal to 50 basis points. The average leverage ratio in the data is computed from the ratio of adjusted assets to equity for all U.S. insured commercial banks. To compute adjusted assets we exclude loans to consumers, real estate and holdings of government bonds from total intermediary assets to arrive at a value which is more in line with the model concept. Over the sample period, data for adjusted assets and equity from all U.S. insured commercial banks imply an average leverage ratio of 5.47. This value is considerably smaller compared to the ratio of total assets to equity, which is equal to 11.52 (see Appendix F for a more detailed description). All parameter values which are fixed during the estimation and the steady state relationships used to derive these are summarized in Table 3. All other parameters are estimated.

The assumptions about the distributions for the parameters of the utility function are standard. The parameter governing the habit persistence, h, follows a Beta distribution with mean 0.5 and standard deviation 0.1. The inverse Frisch labor 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 utilization in the consumption and investment sector are assumed

[13]We also calculate convergence diagnostics in order to check and ensure the stability of the posterior distributions of parameters as described in Brooks and Gelman (1998).

[14]http://www.cepremap.cnrs.fr/dynare/.

[15]This is very similar to the values used by Gertler and Kiyotaki (2010) and Gertler and Karadi (2011).

Table 3: Calibrated Parameters

Parameter	Value	Description
δ_C	0.025	Consumption sector capital depreciation
δ_I	0.025	Investment sector capital depreciation
a_c	0.36	Consumption sector share of capital
a_I	0.36	Investment sector share of capital
β	0.9974	Discount factor
π_C	0.6722	Steady state consumption sector inflation
π_I	0.0245	Steady state investment sector inflation
λ_p	0.1	Steady state price markup
λ_w	0.1	Steady state wage markup
g_a	0.001	Consumption sector average TFP growth
g_v	0.004	Investment sector average TFP growth
$p_i \frac{i}{c}$	0.399	Steady state investment / consumption
θ_B	0.96	Fraction of bankers that survive
ϖ	0.00089	Share of assets transferred to new bankers
λ_B	0.3	Fraction of funds bankers can divert
ϱ	5.47	Steady state leverage ratio
$R^B - R$	0.005	Steady state risk premium

to follow a Gamma distribution with a mean of 5.0 and a standard deviation of 1.0. A Gamma distribution is assumed for the parameter governing the (intertemporal) investment adjustment costs with mean 4.0 and a standard deviation of 1.0. A new parameter we estimate is ρ which determines the degree of intratemporal adjustment investment cost—as opposed to intertemporal. We estimate a transformation of this parameter, given by $\rho^* = 1 + \frac{1}{\rho}$ that lies in the (0,1) interval and has a Beta distribution.

The assumptions regarding the parameters of the monetary policy rule are standard. The parameter governing the persistence of the policy rule is assumed to follow a Beta distribution with a mean of 0.6 and 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 feedback parameter for the growth of GDP follows the same distribution with mean 0.125 and standard deviation 0.05. Finally, the feedback parameter for the change in the inflation rate is assumed to follow a Normal distribution with mean 0.25 and standard deviation 0.10.

Finally, all standard deviations of the contemporaneous and news shocks are assumed to be distributed as an inverse Gamma distribution with a standard deviation of 2.0. Moreover, we specify priors for the news components of valuation shocks such that the sum of the variance of the anticipated components equal the variance of the respective unanticipated component. The parameters determining the persistence of these shocks are bound between 0 and 1, where the growth TFP shocks are assumed to have lower means compared to the stationary shocks.

5 Estimation Results

5.1 Posterior Distributions

Table 4 reports the posterior mean and the 10% and 90% intervals of the estimated parameters. Overall, the estimates are broadly consistent with earlier studies using one sector models, e.g., Smets and Wouters (2007), Khan and Tsoukalas (2011) and Justiniano et al. (2010). We estimate a considerable degree of habit formation (0.68), close (though slightly smaller) to the estimates reported in DiCecio (2009) or Edge et al. (2008), studies using multi-sector models for the U.S. economy. The estimate for ν implies a Frisch labor supply elasticity of approximately 1.0.

The degree of price stickiness is estimated to be similar in the two sectors, though prices in the consumption sector are slightly stickier compared to the investment sector. The estimates of the Calvo parameters imply an average contract length in the investment sector of about 4.3 quarters, while on average contracts are renegotiated every 5.5 quarters in the consumption sector. There is scattered evidence in the DSGE literature about sectoral price stickiness. Using a different estimation methodology and sample, DiCecio (2009) finds that prices in the consumption sector are more flexible than estimated here. The Calvo parameter for wage stickiness is very close to the estimates in Smets and Wouters (2007), Khan and Tsoukalas (2011) and Justiniano et al. (2010), implying that on average wages are renegotiated approximately every 3 quarters. DiCecio (2009) reports a slightly higher estimate for the Calvo wage probability. The estimate for the (intertemporal) investment adjustment costs parameter (2.18) is broadly similar to Khan and Tsoukalas (2011) (2.08) or Justiniano et al. (2010) (2.85) estimated using one sector models. The transformed parameter that captures intratemporal adjustment costs is estimated at 0.358. This maps into a value of -1.55 for ρ, suggesting a mild degree of intratemporal adjustment costs in sectoral investment flows. As far as we know this is the first estimate reported in the literature.

The monetary policy rule parameter estimates as well as the estimates for the persistence parameters and standard deviations of the unanticipated shocks are in line with the values reported in Smets and Wouters (2007), Khan and Tsoukalas (2011) and Justiniano et al. (2010).

Relative to earlier work on estimated DSGE models we estimate two new shocks that are financial in nature. First, a shock to the equity capital of banks specialized in lending to sector $x = C, I$. The posterior estimates for equity shocks suggest a shift from the prior mean. Second, a valuation shock that affects the value (or quality) of assets of banks in sector $x = C, I$. The valuation shock consists of unanticipated and anticipated (news) components. The latter are assumed to arise four and eight quarters ahead in order to help economize on the state space in estimation.[16] As this is the first study to quantify the importance of these shocks, estimates for the volatilities of these news shocks do not exist in the literature. The standard deviations for the valuation news components are estimated to be around or above their unanticipated sectoral counterparts. In general the processes for the valuation shocks in the consumption sector are estimated to be considerably more persistent compared to their counterparts in the investment sector. Similarly, the volatilities of the former are estimated to be larger compared to their counterparts in the investment sector. This suggests that valuation shocks on consumption sector assets may potentially play a larger role in accounting for fluctuations in macroeconomic

[16]Similar specifications about the anticipation horizon of news are considered in Khan and Tsoukalas (2011) and Schmitt-Grohe and Uribe (2010).

aggregates and financial variables a question we now turn to examine.

6 Variance Decompositions

In this section we evaluate the relative contribution and importance of shocks in accounting for fluctuations in the data. We perform several variance decomposition exercises. Table 5 presents our first exercise. Focusing at business cycle frequencies, i.e. 4 to 32 quarter ahead horizons, we can observe that financial shocks (i.e. equity and valuation shocks) account for about 31%, 28%, 28% of the forecast error variance in output growth, investment growth, and hours worked respectively. They also account for a large share of the forecast error variance in the financial variables. Specifically, they account for over 50% of the variance of total equity growth, about 80% of the variance in the consumption sector spread, and about 35% of the variance in the investment sector spread. Within the set of financial shocks, valuation news shocks account for an important share of the forecast error variance: 25%, 20%, 25%, in output growth, investment growth and total hours worked respectively. Within valuation news shocks the most important component is the eight quarter ahead shock in the consumption sector.

TFP shocks are also of considerable importance for fluctuations at business cycle frequencies. TFP shocks in the investment and consumption sectors together account for about 19%, 11%, 36%, 20% of the fluctuations in output growth, consumption growth, investment growth and hours worked respectively. Interestingly, TFP shocks of the investment specific type (i.e. TFP shocks in the investment sector) account for a sizable fraction of fluctuations and thus more important compared to consumption sector TFP. Specifically, they account for about 12%, 35% and around 15-20% of the variance in output growth, investment growth and hours worked respectively. The importance of TFP shocks of the investment specific type is in sharp contrast to findings in earlier studies (e.g. Schmitt-Grohe and Uribe (2010), Christiano et al. (2010)) that find shocks of this type are negligible sources of fluctuations. The reason for these apparently contradicting findings is that these authors, identify the investment specific shock from variation in the relative price of investment alone in one sector estimated DSGE models. This restriction sharply limits the quantitative significance of these shocks. The essence of this argument can be demonstrated using the expression for the relative price of investment from the model:

$$\frac{P_{I,t}}{P_{C,t}} = \frac{\text{mark up}_{I,t}}{\text{mark up}_{C,t}} \frac{1-a_c}{1-a_i} \frac{A_t}{V_t} \left(\frac{K_{I,t}}{L_{I,t}}\right)^{-a_i} \left(\frac{K_{C,t}}{L_{C,t}}\right)^{a_c}$$

where, a_c, a_i are capital shares in consumption, and investment sector respectively. V_t, A_t is TFP in the investment and consumption sector respectively, and $\frac{K_{x,t}}{L_{x,t}}, x = I, C$ the capital-labor ratio in sector x. mark $\text{up}_{x,t}$ is the mark-up or inverse of the real marginal cost in sector x. V_t corresponds to the investment specific shock. Notice how the relative price of investment is driven—at least in the short run—by (a) mark up shocks, (b) TFP in both, the consumption and the investment sector and (c) differences in capital labor ratios across sectors, due to the limited mobility of capital between sectors. The fact that (c) above affects the relative price of investment implies that all shocks can in principle affect this price. In a special case of the model with: (i) perfectly competitive product markets, (ii) identical production functions (factor intensities) in both sectors, (iii) free factor mobility, the expression above becomes,

Table 4: 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	0.6864	0.6184	0.7550
ν	Inverse labour supply elasticity	Gamma	2.00	0.75	1.0112	0.2691	1.7312
ξ_w	Wage Calvo probability	Beta	0.66	0.10	0.6536	0.5853	0.7227
ξ_C	C-sector price Calvo probability	Beta	0.66	0.10	0.8188	0.7537	0.8830
ξ_I	I-sector price Calvo probability	Beta	0.66	0.10	0.7744	0.6663	0.8727
ι_w	Wage indexation	Beta	0.50	0.15	0.2608	0.1400	0.3802
ι_{p_C}	C-sector price indexation	Beta	0.50	0.15	0.2360	0.0992	0.3694
ι_{p_I}	I-sector price indexation	Beta	0.50	0.15	0.2689	0.1026	0.4235
χ_I	I-sector utilization	Gamma	5.00	1.00	5.0041	3.3870	6.6031
χ_C	C-sector utilization	Gamma	5.00	1.00	4.0646	2.4370	5.6471
κ	Investment adjustment cost	Gamma	4.00	1.00	2.1795	1.5915	2.7923
ϕ_π	Taylor rule inflation	Normal	1.70	0.30	2.2351	1.8988	2.5653
ρ_R	Taylor rule inertia	Beta	0.60	0.20	0.9036	0.8815	0.9269
$\phi_{\Delta\pi}$	Taylor rule inflation growth	Normal	0.25	0.10	0.1813	0.0314	0.3195
$\phi_{\Delta Y}$	Taylor rule GDP growth	Normal	0.125	0.05	0.2476	0.1636	0.3294
ρ^*	Intratemporal investment adjustmet cost	Beta	0.50	0.20	0.3578	0.1468	0.5834
	Shocks: **Persistence**						
ρ_z	C-sector TFP	Beta	0.40	0.20	0.1483	0.0148	0.2750
ρ_v	I-sector TFP	Beta	0.40	0.20	0.2585	0.1289	0.3838
ρ_b	Preference	Beta	0.60	0.20	0.8225	0.7588	0.8867
ρ_e	GDP measurement error	Beta	0.60	0.20	0.9741	0.9508	0.9985
$\rho_{\lambda_p^C}$	C-sector price markup	Beta	0.60	0.20	0.2266	0.0670	0.3786
$\rho_{\lambda_p^I}$	I-sector price markup	Beta	0.60	0.20	0.8034	0.6907	0.9269
ρ_{λ_w}	Wage markup	Beta	0.60	0.20	0.3246	0.1583	0.4917
ρ_{ς_C}	C-sector equity capital	Beta	0.60	0.20	0.8047	0.7609	0.8501
ρ_{ς_I}	I-sector equity capital	Beta	0.60	0.20	0.6070	0.4092	0.8002
$\rho_{\xi^K,C}$	C-sector valuation	Beta	0.60	0.20	0.9142	0.8719	0.9570
$\rho_{\xi^K,I}$	I-sector valuation	Beta	0.60	0.20	0.1943	0.0767	0.3050
	Shocks: **Volatilities**						
σ_z	C-sector TFP	Inv Gamma	0.50	2.0	0.2691	0.1628	0.3744
σ_v	I-sector TFP	Inv Gamma	0.50	2.0	1.4572	1.2343	1.6774
σ_b	Preference	Inv Gamma	0.10	2.0	2.0948	1.3957	2.7869
σ_e	GDP measurement error	Inv Gamma	0.50	2.0	0.4310	0.3649	0.4934
σ_{mp}	Monetary policy	Inv Gamma	0.10	2.0	0.1293	0.1114	0.1473
$\sigma_{\lambda_p^C}$	C-sector price markup	Inv Gamma	0.10	2.0	0.2797	0.2298	0.3290
$\sigma_{\lambda_p^I}$	I-sector price markup	Inv Gamma	0.10	2.0	0.2120	0.1547	0.2686
σ_{λ_w}	Wage markup	Inv Gamma	0.10	2.0	0.3268	0.2582	0.3944
σ_{ς_C}	C-sector equity capital	Inv Gamma	0.10	2.0	0.2744	0.2225	0.3245
σ_{ς_I}	I-sector equity capital	Inv Gamma	0.10	2.0	0.1772	0.1105	0.2436
$\sigma_{\xi^K,C}$	C-sector valuation	Inv Gamma	0.10	2.0	0.0558	0.0250	0.0863
$\sigma^2_{\xi^K,4,C}$	C-sector valuation 4Q ahead	Inv Gamma	$0.1/\sqrt{2}$	2.0	0.0521	0.0186	0.0889
$\sigma^2_{\xi^K,8,C}$	C-sector valuation 8Q ahead	Inv Gamma	$0.1/\sqrt{2}$	2.0	0.1709	0.0951	0.2459
$\sigma_{\xi^K,I}$	I-sector valuation	Inv Gamma	0.10	2.0	2.6620	2.1124	3.2142
$\sigma^2_{\xi^K,4,I}$	I-sector valuation 4Q ahead	Inv Gamma	$0.1/\sqrt{2}$	2.0	0.0632	0.0165	0.1229
$\sigma^2_{\xi^K,8,I}$	I-sector valuation 8Q ahead	Inv Gamma	$0.1/\sqrt{2}$	2.0	0.0548	0.0175	0.1004

The parameter that captures the intratemporal adj. cost for investment, is a transformation of the original parameter, ρ, according to, $\rho^* = 1 + \frac{1}{\rho}$.

$$\frac{P_{I,t}}{P_{C,t}} = \frac{A_t}{V_t}$$

In this case the model has a one sector representation (e.g. Greenwood et al. (2000)) and the ratio $(\frac{A_t}{V_t})^{-1}$ defines the investment specific technology shock widely used in one sector models. Thus, under assumptions (i)-(iii), one can identify the investment specific technology shock from the relative price of investment alone. But as demonstrated, this tight restriction, is not necessarily valid in a more elaborate two sector model with an imperfectly competitive investment sector and limited capital mobility across sectors, like ours. In the more general framework we consider, the relative price of investment reflects not only investment specific shocks but also other shocks, such as time varying mark-up shocks. Therefore, investment specific shocks in our model, despite the fact that we also include the relative price of investment in the estimation (through the inclusion of the sectoral inflation rates) are in principle allowed to affect dynamics in a way that is consistent with volatilities and the spectrum of autocorrelations and cross correlations in the entire set of observables, not just the relative price of investment. From a quantitative perspective it is interesting to note our results on the importance of investment sector TFP shocks are more in line with Fisher (2006)), who, using an SVAR methodology, has argued for the significance of investment specific shocks of this type in accounting for fluctuations.

The preference shock accounts for about 45% in the variance of consumption growth. This is line with Justiniano et al. (2010) who also report evidence for the otherwise irrelevant preference shock in accounting for consumption fluctuations. Financial shocks account for a small fraction of the variance in consumption growth, about 7-8%. The price mark-up shock in the investment sector accounts for a sizable fraction in total investment and hours fluctuations, approximately 25% of the forecast error variance in each of these variables. Both price mark up shocks explain to a large extent variation in the sectoral inflation rates, whereas the wage mark-up shock primarily explains a large share of the variance in real wage growth (67%) and to a smaller extent variance in hours worked (13%).

Turning to financial variables, the main driving forces for the consumption sector corporate bond spread are both the valuation and equity capital shocks (for the consumption sector). The eight quarter ahead news component and the equity capital shock, each roughly account for about 35% in its variation. Thus a sizable component of the variance in consumption sector spread can be explained by valuation news. This result suggests there is a significant amount of advance information present in the spread series. By contrast only a small fraction of the variation in the investment sector spread is explained by news shocks. The investment sector TFP shock is the most important shock in explaining the variation in that spread series. Finally, valuation news components account for about 15% in the nominal interest rate. This suggests monetary policy responds to advance signals relating to the quality of banking sector balance sheets, perhaps due to the imminent lending contraction that accompanies a decline in the valuation of assets.

Table 6 presents an unconditional variance decomposition of the data to examine the low frequency impact of shocks. In line with our findings above, this Table also shows the important role of valuation news (four and eight quarter ahead) in accounting for the variance in output (25%), investment (23%) and hours worked (27%). Valuation news together with equity capital shocks account for about 73.5% in the variance of the consumption sector spread and over

40% in the variance of the growth in equity capital. TFP shocks of the investment specific type account for approximately 14%, 37%, 25% in output, investment and hours worked and approximately 31% and 26% in the variance of the investment sector spread and equity capital growth. In the Appendix we compute a variance decomposition implied at the prior means. Table 10 reports the details. Comparing the variance decompositions implied by the posterior estimates with the prior decomposition Table, clearly highlights the shift in the sources of fluctuations implied by our estimates.

The quantitative results on the role of financial shocks have similarities with findings reported in Gilchrist et al. (2009) and Gilchrist and Zakrajsek (2011), obtained using different methodologies. Gilchrist et al. (2009) report that credit market shocks identified through corporate credit spreads in a factor based VAR, explain around 30% of the variation in economic activity (measured from industrial production), quite similar to the share explained by valuation shocks in this paper. Gilchrist and Zakrajsek (2011), decompose the movements in credit spreads to default risk and an excess bond premium and find that the latter can explain around 10% and 25% of output and investment variation respectively, again quite similar to the variance shares in the same variables accounted for by valuation shocks.

We undertake an additional exercise to better appreciate the role of financial and valuation news shocks in explaining the in-sample variation in the data. Figure 2, shows the sample path of output growth, investment growth, total hours worked and credit spreads along with simulation paths generated by the model when either only all financial shocks or all valuation news shocks are turned on. A first visual inspection of Figure 2 illustrates that paths simulated with financial shocks and to a large extent valuation news shocks turned on only, track the patterns of the actual data shown quite closely. A noteworthy finding is that the path generated with valuation news only correctly captures most of the turning points in actual output growth while they also quite successfully account for the 2001 and 2008 recessions. Interestingly, the extent of the decline in output during the 2008 recession can be entirely captured by the path generated by valuation news. They also closely track GDP growth during the 2001 recession, though they do not account very well for the 1990s recession. Further, the valuation news model path tracks quite well the behavior of total hours worked. The simulated path captures the rise after the 1990s recession, and the significant declines in the 2001 and the 2008 recessions. The simulation path with financial shocks (fourth row, left panel) closely tracks the actual path of the consumption sector spread. The path with valuation news only (right panel), correctly predicts the rise of spreads in the 2001 and 2008 recession, but misses the 1990s recession. The path with financial shocks (fifth row), captures to some extent the investment sector spread sample path though not very successfully. The reason for this limited success of financial shocks is that TFP shocks of the investment specific type account for a large share of the variance in this spread.

Figure 3 presents the sample paths of (actual) sectoral hours worked along with the simulation paths from the model with either financial or valuation news shocks turned on only. Note, that sectoral hours worked have not been used as observables in the estimation, hence even a simulation with all shocks active would not be able to perfectly fit the actual sample paths. An interesting observation is the success of the simulation path generated by valuation news in tracking the observed investment sector hours series despite the fact the estimation routine has only used information from total hours. This counterfactual path accounts for the decline in the 1990s as well as the prolonged decline well after the end of that recession. It can also account quite successfully for the decline in the 2001 recession and the continued weakness in the aftermath of the recession—though it predicts a much stronger than actual recovery in the mid part of the 2000s. Finally it accounts for the massive decline in investment sector hours in the 2008 recession. It is also interesting to note that the counterfactual path not only correctly predicts the direction of the change but gets the magnitude of the declines about right both in the 2001 and the 2008 recessions (i.e. the peak to trough declines). The counterfactual paths however do not track well the actual path of consumption sector hours. Essentially these simulation paths miss the robust growth in consumption sector hours for much of the 1990s and until the 2001 recession, though they better capture the movements in this series in the second half of the sample. Additional information about the model's fit on the labor market dimension is provided in Appendix D, Table 9.

In summary, both the the cyclical frequency and unconditional variance decompositions reveal an important role for consumption sector valuation shocks. They are one of the main driving forces for fluctuations in several macroeconomic variables including output growth, investment growth and hours worked. They also explain a large share of the variance in the financial variables of the model. TFP shocks of the investment specific type are also of considerable importance in explaining the variance of real and financial variables. The contribution of monetary policy shocks is limited, below 10% except for consumption growth and the nominal interest rate. Last, we find a very limited contribution of the shocks to bank's equity capital except in accounting for the variance in equity growth and the two credit spread series.

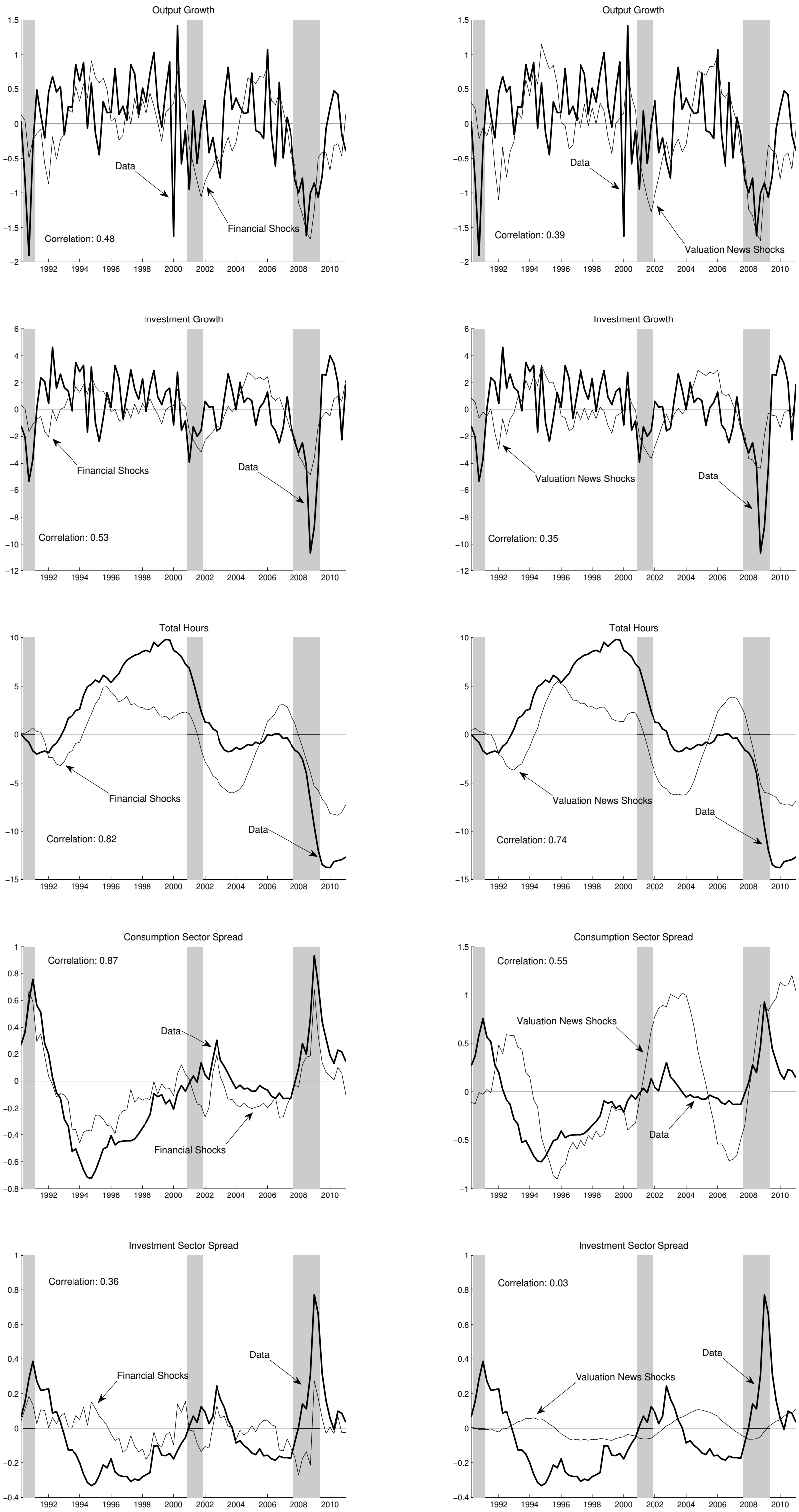

Figure 2: Data (solid line) and counterfactual simulation (thin line) with all financial shocks only (left) or valuation news shocks only (right). From top to bottom row: Output growth, investment growth, total hours, consumption sector credit spread, investment sector credit spread. consumption sector hours, investment sector hours. Dashed lines in the figures for sectoral hours (rows 4 and 5) depicts simulation for sectoral hours with all shocks activated.

Table 5: Variance decomposition at different horizons

									Financial Shocks							
	z	v	b	e	η_{em}	λ_p^C	λ_p^I	λ_w	ς_C	ς_I	$\xi_C^{K,0}$	$\xi_I^{K,0}$	$\xi_C^{K,4}$	$\xi_C^{K,8}$	$\xi_I^{K,4}$	$\xi_I^{K,8}$
Period t=1:																
Output Growth	8.81	0.00	2.64	28.86	11.16	5.28	5.92	6.75	2.75	0.01	2.35	0.15	1.51	23.80	0.00	0.00
Consumption Growth	6.88	0.95	54.61	0.08	17.06	8.74	0.00	7.15	0.05	0.00	0.81	1.14	0.27	2.27	0.00	0.00
Total Investment Growth	1.23	37.75	2.29	0.06	3.50	0.02	22.02	3.76	3.35	0.01	1.69	0.80	1.29	22.22	0.00	0.00
Total Hours	0.24	0.76	4.62	0.14	14.52	1.57	20.36	10.53	3.46	0.01	2.24	12.07	1.80	27.67	0.00	0.00
Real Wage Growth	0.56	0.05	0.33	0.00	0.33	21.90	0.33	75.85	0.01	0.00	0.08	0.02	0.04	0.50	0.00	0.00
C-Sector Inflation	0.22	1.78	2.30	0.01	2.16	87.50	0.40	4.10	0.00	0.00	0.01	0.03	0.04	1.45	0.00	0.00
I-Sector Inflation	0.00	6.56	0.04	0.04	4.39	0.14	51.02	3.38	0.40	0.00	0.65	18.26	0.63	14.48	0.00	0.00
Nom. Interest Rate	0.11	0.43	1.32	0.45	64.93	29.26	0.52	0.78	0.05	0.00	0.07	0.03	0.09	1.96	0.00	0.00
C-Sector Spread	0.88	1.36	0.87	0.02	5.49	4.51	1.35	0.98	64.19	0.00	1.40	0.35	0.97	17.62	0.00	0.00
I-Sector Spread	2.34	3.00	1.81	0.08	26.21	13.77	2.97	2.41	0.71	39.21	0.00	7.29	0.01	0.19	0.01	0.01
Equity Growth	7.28	27.48	2.81	0.08	5.17	3.64	0.00	1.87	8.07	0.04	3.96	7.50	1.88	30.22	0.00	0.00
Period t=4:																
Output Growth	7.02	14.49	1.91	17.54	9.06	3.59	9.64	7.30	2.03	0.01	2.05	0.78	1.41	23.18	0.00	0.00
Consumption Growth	9.17	0.84	48.97	0.08	15.81	8.69	0.02	10.03	0.08	0.00	1.17	1.53	0.39	3.21	0.00	0.00
Total Investment Growth	0.89	43.35	1.78	0.04	2.57	0.04	24.64	3.28	2.11	0.01	1.13	2.24	0.95	16.95	0.00	0.00
Total Hours	0.50	12.57	2.22	0.11	10.90	1.23	28.42	11.87	1.69	0.00	1.55	2.00	1.59	25.36	0.00	0.00
Real Wage Growth	2.49	7.97	0.33	0.00	0.48	18.77	0.86	67.48	0.02	0.00	0.19	0.11	0.08	1.21	0.00	0.00
C-Sector Inflation	0.29	6.42	6.41	0.03	6.60	66.83	1.17	7.54	0.00	0.00	0.01	0.13	0.11	4.47	0.00	0.00
I-Sector Inflation	0.05	17.57	0.25	0.06	7.03	0.18	31.12	2.79	0.34	0.00	0.81	16.93	0.86	22.00	0.00	0.00
Nom. Interest Rate	0.14	2.99	6.88	0.29	40.90	30.39	3.27	4.18	0.07	0.00	0.19	0.29	0.36	10.05	0.00	0.00
C-Sector Spread	0.86	1.17	0.49	0.01	3.14	4.75	4.85	0.50	50.55	0.00	1.65	1.36	1.41	29.26	0.00	0.00
I-Sector Spread	3.05	12.92	1.17	0.05	22.06	19.66	5.47	1.56	0.81	26.16	0.00	6.87	0.01	0.16	0.01	0.02
Equity Growth	7.03	26.16	2.74	0.08	4.98	3.58	0.15	1.84	10.49	0.08	3.86	7.25	1.85	29.90	0.00	0.00
Period t=8:																
Output Growth	6.68	14.90	2.42	16.61	9.26	3.57	9.76	7.18	2.54	0.01	2.05	1.13	1.43	22.45	0.00	0.00
Consumption Growth	8.32	0.98	49.48	0.07	15.07	9.16	0.35	9.00	0.08	0.00	1.16	1.53	0.44	4.35	0.00	0.00
Total Investment Growth	0.90	41.48	1.73	0.04	2.62	0.13	24.82	3.30	2.68	0.01	1.32	2.49	1.09	17.39	0.00	0.00
Total Hours	0.68	18.38	1.25	0.09	8.45	1.08	29.42	12.24	0.89	0.00	1.02	1.13	1.16	24.20	0.00	0.00
Real Wage Growth	2.45	7.64	0.41	0.00	0.45	18.24	0.95	67.82	0.02	0.00	0.21	0.21	0.10	1.49	0.00	0.00
C-Sector Inflation	0.26	8.16	6.97	0.03	7.97	63.10	1.24	6.94	0.02	0.00	0.02	0.16	0.10	5.04	0.00	0.00
I-Sector Inflation	0.06	19.73	0.66	0.06	7.12	0.18	30.97	2.52	0.61	0.00	0.77	15.28	0.81	21.23	0.00	0.00
Nom. Interest Rate	0.12	11.24	11.87	0.20	27.01	20.29	5.28	5.95	0.07	0.00	0.17	0.74	0.42	16.64	0.00	0.00
C-Sector Spread	0.85	3.50	0.50	0.01	2.42	3.71	6.38	0.45	41.20	0.00	1.51	2.46	1.40	35.60	0.00	0.00
I-Sector Spread	3.34	25.67	2.12	0.05	16.87	15.23	6.45	2.29	0.63	19.73	0.02	6.64	0.04	0.87	0.01	0.02
Equity Growth	6.95	25.66	2.69	0.08	4.91	3.53	0.31	1.81	10.75	0.08	3.82	7.26	1.85	30.30	0.00	0.00
Period t=12:																
Output Growth	6.38	14.14	2.36	15.69	9.25	3.45	10.94	7.48	2.53	0.01	2.04	1.11	1.44	23.19	0.00	0.00
Consumption Growth	7.73	1.85	48.27	0.07	14.50	8.91	0.72	8.91	0.08	0.00	1.09	1.55	0.45	5.85	0.00	0.00
Total Investment Growth	0.87	38.14	1.65	0.04	2.55	0.12	26.34	3.36	2.54	0.01	1.33	2.47	1.13	19.45	0.00	0.00
Total Hours	0.71	21.55	1.11	0.08	7.86	1.08	28.39	12.48	0.90	0.00	0.90	1.09	1.02	22.81	0.00	0.00
Real Wage Growth	2.44	7.71	0.46	0.00	0.46	18.18	0.95	67.61	0.03	0.00	0.21	0.25	0.10	1.60	0.00	0.00
C-Sector Inflation	0.26	8.61	6.88	0.03	8.12	62.37	1.25	6.93	0.03	0.00	0.05	0.16	0.12	5.19	0.00	0.00
I-Sector Inflation	0.08	19.12	0.84	0.06	6.88	0.17	30.24	2.44	0.80	0.00	0.88	14.87	0.91	22.68	0.00	0.00
Nom. Interest Rate	0.11	17.16	13.60	0.17	22.56	16.92	5.09	6.09	0.16	0.00	0.16	0.87	0.36	16.75	0.00	0.00
C-Sector Spread	0.86	4.85	0.67	0.01	2.45	3.96	6.23	0.52	39.40	0.00	1.45	2.74	1.35	35.50	0.00	0.00
I-Sector Spread	3.38	30.24	2.35	0.06	15.37	14.18	5.90	2.21	0.60	17.01	0.03	6.77	0.06	1.81	0.01	0.02
Equity Growth	6.95	25.55	2.68	0.08	4.95	3.61	0.32	1.80	10.71	0.08	3.81	7.29	1.85	30.33	0.00	0.00
Period t=20:																
Output Growth	6.27	13.85	2.32	15.36	9.17	3.40	11.36	7.67	2.49	0.01	2.01	1.18	1.43	23.49	0.00	0.00
Consumption Growth	7.42	3.81	46.59	0.07	13.99	8.57	0.83	9.03	0.11	0.00	1.06	1.57	0.44	6.53	0.00	0.00
Total Investment Growth	0.86	36.99	1.64	0.04	2.50	0.13	26.76	3.34	2.48	0.01	1.30	2.70	1.11	20.13	0.00	0.00
Total Hours	0.68	24.04	1.11	0.08	7.38	1.03	26.75	11.94	0.98	0.00	0.97	1.13	1.04	22.88	0.00	0.00
Real Wage Growth	2.43	7.97	0.47	0.00	0.48	18.12	0.99	67.31	0.03	0.00	0.21	0.26	0.10	1.63	0.00	0.00
C-Sector Inflation	0.26	8.76	6.78	0.03	7.98	61.09	1.36	6.86	0.03	0.00	0.09	0.21	0.16	6.39	0.00	0.00
I-Sector Inflation	0.10	18.72	0.88	0.06	6.67	0.22	29.01	2.34	0.79	0.00	0.94	14.32	0.96	24.98	0.00	0.00
Nom. Interest Rate	0.10	23.43	13.62	0.15	19.89	15.01	4.62	5.76	0.24	0.00	0.33	0.81	0.40	15.64	0.00	0.00
C-Sector Spread	0.84	5.28	0.71	0.01	2.46	4.15	6.91	0.53	37.40	0.00	1.47	2.66	1.38	36.19	0.00	0.00
I-Sector Spread	3.47	31.68	2.20	0.06	15.15	14.23	5.51	2.04	0.62	15.54	0.03	7.32	0.06	2.06	0.01	0.02
Equity Growth	6.93	25.46	2.67	0.08	5.00	3.69	0.44	1.79	10.69	0.08	3.79	7.26	1.84	30.28	0.00	0.00
Period t=32:																
Output Growth	6.26	13.91	2.33	15.35	9.15	3.40	11.34	7.67	2.49	0.01	2.01	1.19	1.42	23.46	0.00	0.00
Consumption Growth	7.26	5.22	45.59	0.07	13.68	8.39	0.87	8.89	0.12	0.00	1.09	1.55	0.45	6.84	0.00	0.00
Total Investment Growth	0.86	36.95	1.65	0.04	2.49	0.13	26.74	3.34	2.48	0.01	1.30	2.75	1.11	20.14	0.00	0.00
Total Hours	0.63	24.68	1.05	0.07	6.91	0.96	25.45	11.18	0.93	0.00	1.04	1.49	1.08	24.52	0.00	0.00
Real Wage Growth	2.42	8.24	0.47	0.00	0.48	18.05	1.02	67.04	0.03	0.00	0.21	0.26	0.10	1.68	0.00	0.00
C-Sector Inflation	0.26	8.85	6.71	0.03	7.89	60.40	1.40	6.79	0.03	0.00	0.11	0.26	0.18	7.08	0.00	0.00
I-Sector Inflation	0.10	18.63	0.88	0.06	6.63	0.24	28.95	2.33	0.81	0.00	0.94	14.38	0.96	25.09	0.00	0.00
Nom. Interest Rate	0.09	25.77	12.32	0.14	17.77	13.41	4.57	5.20	0.22	0.00	0.56	0.99	0.55	18.41	0.00	0.00
C-Sector Spread	0.79	5.02	0.66	0.01	2.33	3.94	7.32	0.49	35.08	0.00	1.47	2.90	1.41	38.57	0.00	0.00
I-Sector Spread	3.49	31.31	2.35	0.06	15.10	14.16	5.73	2.06	0.62	15.17	0.03	7.67	0.06	2.13	0.01	0.02
Equity Growth	6.90	25.51	2.67	0.08	4.99	3.69	0.51	1.79	10.66	0.08	3.77	7.23	1.83	30.28	0.00	0.00

z = TFP in consumption sector, v = TFP in investment sector, b = Preference shock, e = GDP measurement error, η_{em} = Monetary policy, λ_p^C = Consumption sector price markup, λ_p^I = Investment sector price markup, λ_w = Wage markup, ς_C = Consumption sector equity capital shocks, ς_I = Investment sector equity capital shock, $\xi_C^{K,0}$ = Unanticipated consumption sector valuation, $\xi_C^{K,x}$ = x quarter ahead anticipated consumption sector valuation, $\xi_I^{K,0}$ = Unanticipated investment sector valuation, $\xi_I^{K,x}$ = x quarters ahead valuation investment sector.

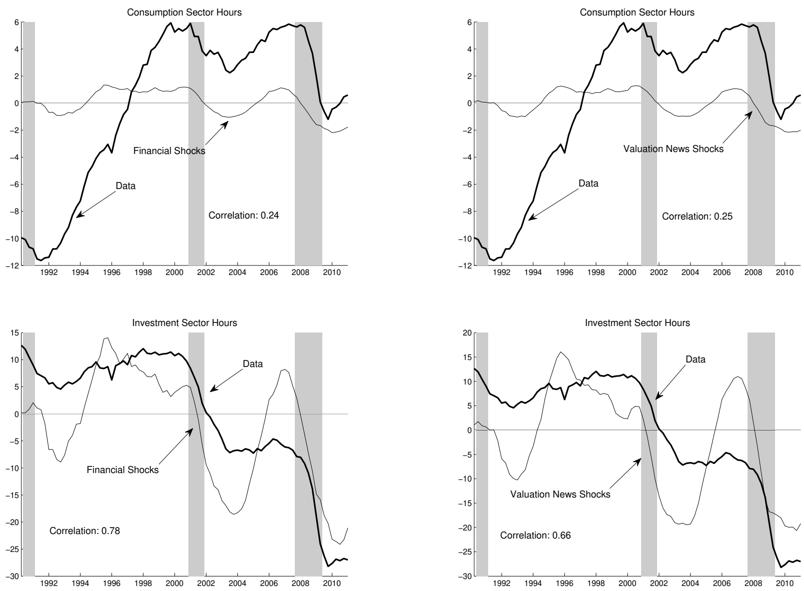

Figure 3: Data (solid line) and counterfactual simulation (thin line) with all financial shocks only (left) or valuation news shocks only (right). Dashed lines in the figures for sectoral hours depicts simulation for sectoral hours with all shocks activated. From top to bottom row: consumption sector hours, investment sector hours.

Table 6: Unconditional Variance Decomposition (Benchmark Model)

									Financial Shocks									
	z	v	b	e	η_{em}	λ_p^C	λ_p^I	λ_w	ς_C	ς_I	$\xi_C^{K,0}$	$\xi_I^{K,0}$	$\xi_C^{K,4}$	$\xi_C^{K,8}$	$\xi_I^{K,4}$	$\xi_I^{K,8}$
Output Growth	6.24	13.97	2.33	15.37	9.14	3.39	11.32	7.66	2.48	0.01	2.01	1.20	1.42	23.45	0.00	0.00
Consumption Growth	7.07	6.05	44.40	0.06	13.33	8.17	0.95	8.67	0.11	0.00	1.12	1.69	0.49	7.91	0.00	0.00
Total Investment Growth	0.86	36.91	1.65	0.04	2.49	0.13	26.71	3.34	2.48	0.01	1.30	2.75	1.12	20.21	0.00	0.00
Total Hours	0.61	24.96	1.03	0.07	6.62	0.92	24.56	10.71	0.89	0.00	1.07	2.09	1.10	25.36	0.00	0.00
Real Wage Growth	2.40	8.44	0.47	0.00	0.48	17.94	1.03	66.66	0.03	0.00	0.23	0.29	0.11	1.90	0.00	0.00
C-Sector Inflation	0.26	8.94	6.68	0.04	7.85	60.09	1.41	6.75	0.03	0.00	0.12	0.33	0.19	7.30	0.00	0.00
I-Sector Inflation	0.10	18.57	0.88	0.07	6.60	0.24	28.90	2.32	0.81	0.00	0.94	14.46	0.97	25.13	0.00	0.00
Nom. Interest Rate	0.10	26.46	11.25	0.14	16.19	12.20	4.51	4.77	0.21	0.00	0.71	1.68	0.65	21.13	0.00	0.00
C-Sector Spread	0.78	4.96	0.65	0.01	2.29	3.88	7.35	0.49	34.54	0.00	1.46	3.21	1.41	38.98	0.00	0.00
I-Sector Spread	3.48	31.14	2.41	0.06	15.02	14.09	5.75	2.07	0.62	15.07	0.03	7.84	0.07	2.32	0.01	0.02
Equity Growth	6.87	25.69	2.66	0.08	4.98	3.68	0.52	1.79	10.61	0.08	3.76	7.21	1.83	30.25	0.00	0.00

z = TFP in consumption sector, v = TFP in investment sector, b = Preference shock, e = GDP measurement error, η_{em} = Monetary policy, λ_p^C = Consumption sector price markup, λ_p^I = Investment sector price markup, λ_w = Wage markup, ς_C = Consumption sector equity capital shocks, ς_I = Investment sector equity capital shock, $\xi_C^{K,0}$ = Unanticipated consumption sector valuation, $\xi_C^{K,x}$ = x quarter ahead anticipated consumption sector valuation, $\xi_I^{K,0}$ = Unanticipated investment sector valuation, $\xi_I^{K,x}$ = x quarters ahead valuation investment sector.

7 The Propagation of Valuation Shocks

The variance decompositions above suggest valuation shocks are significant in accounting for the dynamics of the macroeconomic aggregates and financial variables. In this section, we discuss the model's responses to these type of shocks through a series of impulse response functions (IRFs). We attempt to understand the reasons for their important role in accounting for fluctuations. We examine both news and unanticipated valuation shocks.

Anticipated Shocks. We discuss the model's responses to an eight quarter ahead valuation shock. Figure 4 shows the responses to a signal of a future (two year ahead) decline in the value of assets of banks portfolios in the consumption sector.[17] The value of assets (held in the bank's portfolios) decline on impact upon arrival of bad news. This initial decline in the value of assets leads to de-leveraging by the financial sector: banks use equity capital to cover losses on assets held (to satisfy their balance sheet constraint), while at the same time reducing demand for new assets. The initial depressing effect on the value of assets can be readily illustrated with the equation that defines the value of capital in the consumption sector,

$$Q_{c,t} = \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t} \xi^K_{c,t+1} \left(\frac{R^K_{c,t+1}}{P_{c,t+1}} u_{c,t+1} + Q_{c,t+1}(1-\delta_c) - a(u_{c,t+1}) A_{t+1} V_{t+1}^{\frac{a_c-1}{1-a_i}} \right),$$

Given the forward looking behavior of $Q_{c,t}$ the equation above shows that news about the future path of $\xi^K_{c,t}$, affects the value of capital today. Banks deleverage relatively quickly: while leverage initially rises due to the big impact of the decline in equity capital, it falls below the steady state within four quarters. Recapitalization of banks with equity develops quickly; when the shock actually materializes banks have more equity capital compared with assets so their leverage ratio is smaller than what they begun with. In this sense, banks prepare for the anticipated decline in asset values ahead of time with a significant reduction in asset demand. Credit spreads in the consumption sector rise in anticipation of the deterioration in asset quality, consistent with the countercyclical behavior of risk premia in the data. This type of financial shock spills over to the investment sector through lower demand for capital goods. Lower demand for consumption sector assets by intermediaries leads to a reduction in the demand for capital (by capital services producers from physical producers) which in turn leads to an an overall reduction in the production of investment goods, including investment goods produced for the investment sector. The reduction in the demand for investment goods leads to a decline in their relative price. This can be seen by noting that the growth in the relative price of investment is equal to the sectoral inflation differential (i.e. investment minus consumption sector inflation). The reduction in investment demand leads to a lower volume of financing for investment sector capital goods and consequently lower valuation of these assets. The interesting aspect of the IRFs, especially in relation to hours worked, is the prediction of a relatively strong decline in investment sector in relation to consumption sector hours. In addition, the behavior of total hours mirrors the behavior of investment sector hours. Thus the model is able to successfully replicate the sectoral facts about hours worked discussed in the introduction. Its important to note, that the bulk of the adverse effects felt in the investment sector from the bad valuation

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

news in the consumption sector are due to the real link between the two sectors, i.e. the reduction in demand for capital goods from the consumption sector. Figure 5 attempts to isolate this channel. It shows IRFs from the benchmark model and compares them with IRFs from a model where financial intermediation is turned off in the investment sector only. The IRFs from the two models are qualitatively and quantitatively very similar. The only material difference arises with respect to investment goods produced for the investment sector; in the benchmark model the decline in production is more pronounced and it takes longer for investment in that sector to recover. The anticipation of the decline in the valuation of assets also triggers a negative wealth effect that reduces consumption. The negative effect on consumption and investment leads to a strong initial decline in output before the shock to valuation materializes. One noteworthy aspect of the adjustment to the valuation news disturbance is the fact the contractionary phase is quite long and recovery is slow. In comparison to the unanticipated shock IRFs (shown below), the combination of news and subsequent movements in fundamentals lead to a deeper and longer recession phase. The arrival of bad news itself generate significant declines in the various macroeconomic aggregates. However, the actual realization of the bad news sets off an extended phase of reduced financing, depressed asset values and economic activity. This is quite noticeable from Figure 4. Financial claims, i.e. volume of financing, declines further at the time when the shock materializes and remains depressed for an extended period of time.

The broad macroeconomic aggregates, namely, output, consumption, investment and hours worked exhibit co-movement in response to the valuation news shock. Output, consumption, investment and hours worked fall instantly in response to the signal that valuation of consumption sector assets will deteriorate in the future. Importantly, the IRFs illustrate that this type of news shock can generate the pattern of sectoral co-movement that is a distinctive feature of the business cycle. Both sectoral hours and sectoral investment rates experience a decline in response to the unfavorable valuation news shock.

Unanticipated Shocks. Figure 6 shows the economy's response to a one standard deviation unanticipated valuation shock. The effects are quite similar as those for the news shock. The initial exogenous decline in the valuation of assets in the consumption sector leads to an increase in the leverage ratio. The increase in the leverage ratio reflects the destruction in banks equity capital to cover the asset losses. 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 strengthen their balance sheets by demanding a higher return, R_C^B, which leads in a sharp increase of the credit spread. As a result, consumption sector investment drops substantially which makes the contraction spread to the real economy.

Lower demand for investment goods from the consumption sector 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 credit spread and leverage ratio as just described for the consumption sector above. However, the contraction in the investment sector is less strong since the valuation of investment sector capital does not decline. As explained above, the downturn in this sector is triggered by the endogenous link between the two sectors, through lower demand for capital.

Inspecting the mechanism. The discussion of the impulse response functions illustrates that valuation shocks of the anticipated type generate the broad based aggregate and sectoral co-

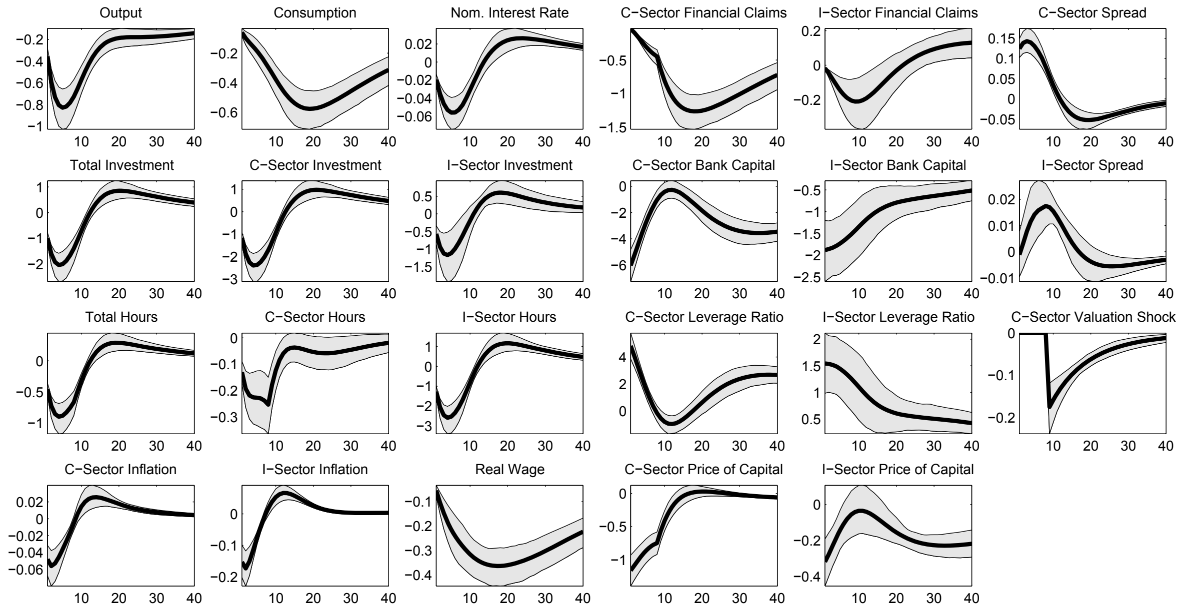

Figure 4: Responses to a negative valuation news shock (anticipated 8 quarters ahead) in the consumption sector.

movement observed in the data. In this section we investigate in more detail the reasons why these shocks turn out to be important. Specifically, we study the IRFs from a model with and a model without frictions in financial intermediation. In both models we use identical parameter values as estimated in Table 4.

Figure 7 shows impulse responses to a valuation news shock for the model with (solid line) and without financial frictions (dotted line). It is evident that the model without financial frictions cannot generate aggregate or sectoral comovement. In that model, output, investment and total hours worked respond positively to this unfavorable shock. Both sectoral investment variables rise in response while investment sector hours rise and consumption sector hours fall in response to the same shock. The reason for the radically different responses is that in the model without financial frictions the valuation shock acts as a negative supply shock, i.e. reducing the productivity of capital services production. Agents attempt to protect from the future deterioration in the productivity of capital services by building more capital now via higher investment. Given the immobility of capital between sectors, this is the only feasible way to change the effective quantity of capital across sectors. Hours can change swiftly across sectors, thus to boost capital production the household reallocates hours from the consumption to the investment sector. Figure 7 shows that financial frictions strongly amplify the economy's response to the valuation news shock, through its impact of the leverage constraint that restricts the amount of credit in the real economy. In the model with frictionless financial intermediation this shock does not have any implications for bank's ability to intermediate funds. Thus investment spending can be swiftly financed in order to cover the expected deterioration in the productivity of capital services. The increase in investment and the negative wealth effect due to bad news about capital productivity crowds out consumption.

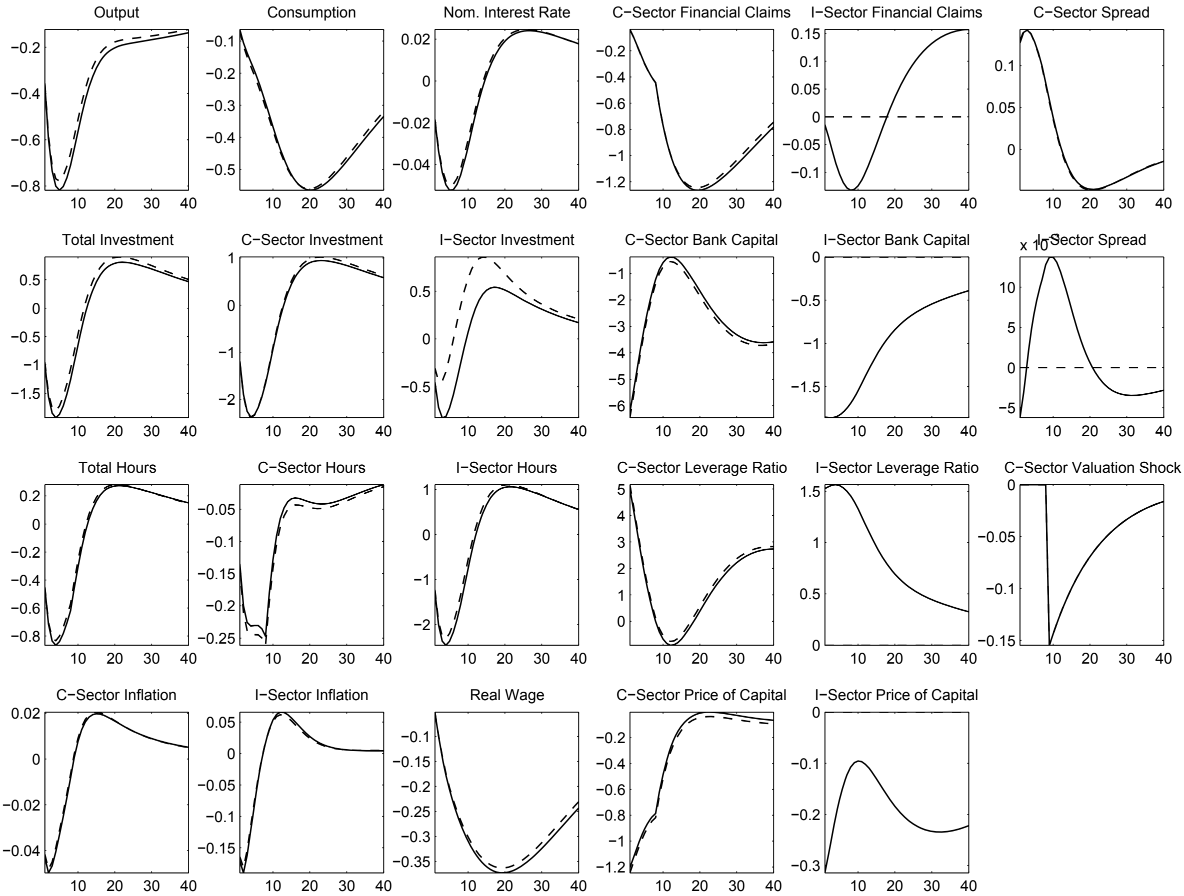

Figure 5: Responses to a negative valuation news shock (anticipated 8 quarters ahead) in the consumption sector. Benchmark model (solid lines) vs. Model without financial intermediation in the investment sector (dotted lines).

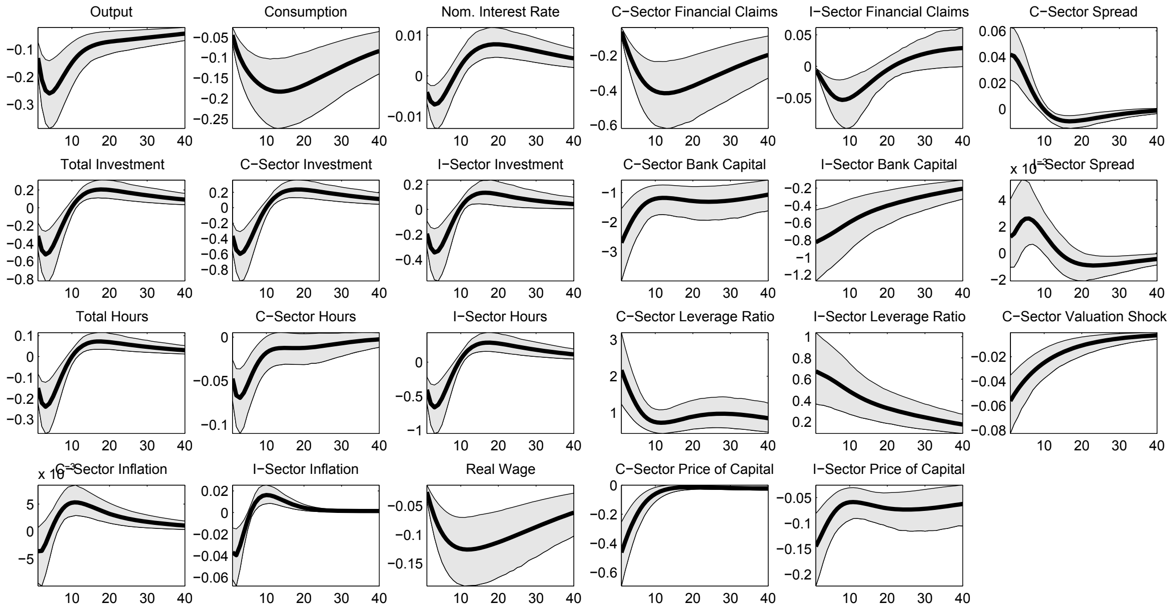

Figure 6: Responses to a negative unanticipated valuation shock in the consumption sector.

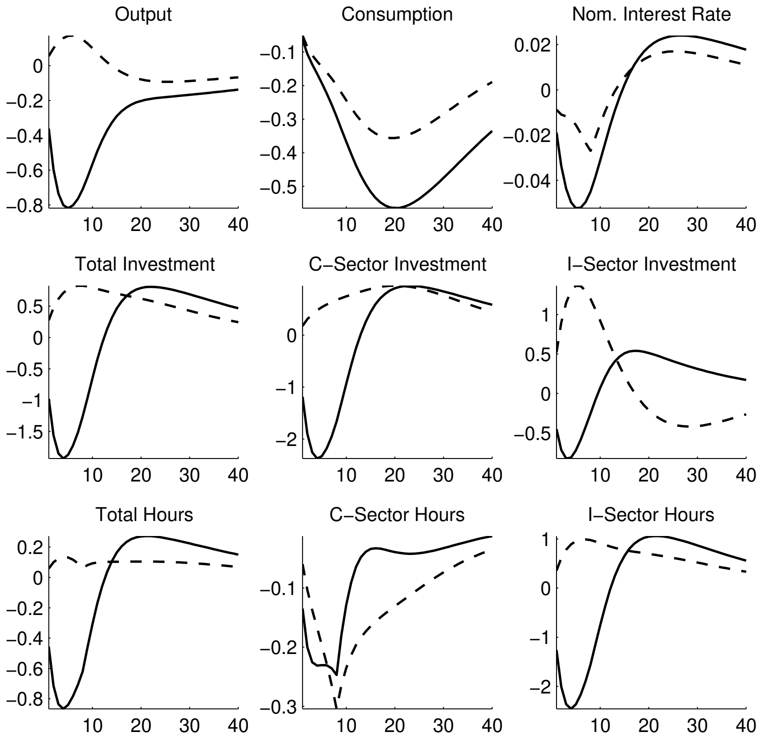

Figure 7: Responses to a negative valuation news shock (anticipated 8 quarters ahead) in the consumption sector. Model with (solid line) and without (dashed line) financial frictions.

8 Interpreting Valuation Shocks

The exercise above indicates that the frictions in financial intermediation is a key mechanism that enables the valuation shock to play an important role in aggregate fluctuations. In this section we undertake comparisons of the estimated valuations shocks from the model with two widely used financial market indicators.

Valuation shocks and lending indicators. We compare the estimated valuations shocks from the model (news and unanticipated) to an observable indicator that captures banking sector lending practices. Specifically, we use the Federal Reserve Board's Loan Officer Opinion Survey (LOOS) that asks senior management from big US banks the following question:

Over the past three months, how have your bank credit standards for approving loan applications for Commercial and Industrial loans or credit lines–excluding those to finance mergers and acquisitions–changed? 1. Tightened considerably, 2. tightened somewhat, 3. remained basically unchanged, 4. eased somewhat, 5. eased considerably

The survey reports the net percent balance of banks reporting that lending standards for commercial and industrial loans have tightened (number of loan officers reporting tightening less the number reporting easing divided by the total number); responses account for around 60% of all US bank loans and around 70% of all US business loans. The lending standards index is a qualitative indicator of credit tightness. In Figure 8, we plot the net balance from the survey against the inverse of unanticipated (left panel) and eight quarter ahead valuation news shock (right panel).[18] The correlation of the lending standards index over the entire sample is 0.41 and 0.38 for the unanticipated and news valuation respectively and is significant at the 1% level. The Figure also shows that the estimated shocks track the lending standards indicator much better in the second half of the sample. A notable feature in Figure 8 is the fact that both lending standards and unfavorable news about valuations rise sharply before and during recessions. In both the early 2001 and the 2007-2008 recessions the estimated series gives advance signals of declines in the valuations of assets held by intermediaries and as explained in Section 7 generate reductions in the supply of credit. Interestingly, Lown and Morgan (2006), using a VAR methodology find that innovations to LOOS lending standards predict contractions in loans and output.[19]

Valuation shocks and default indicators. We compare the estimated eight quarter ahead valuation news shock with an indicator of default risk of the non-financial corporate sector available from Fitch. Figure 9 plots the estimated (inverse) of valuation news shocks series against the Fitch 5-year ahead probability of default available from 2001. In Appendix E, Figure 11, we compare the shock series with the Fitch 1-year ahead probability.[20] The default probability is a forward looking measure of default risk, providing advance information of

[18]To facilitate comparison with each shock series the lending standards index is normalized to have a zero mean and the same standard deviation as each of the shock series.

[19]Bassett et al. (2010) identify loan supply shocks using detailed information on the reasons reported by loan officers for changes in lending standards; they show among the most important ones for changing standards are perceptions of future economic outlook, suggesting that the LOOS reflects to some degree anticipated macroeconomic fundamentals, and risk tolerance.

[20]To facilitate comparison with the shock series the default risk indicator is normalized to have a zero mean and the same standard deviation as the shock series.

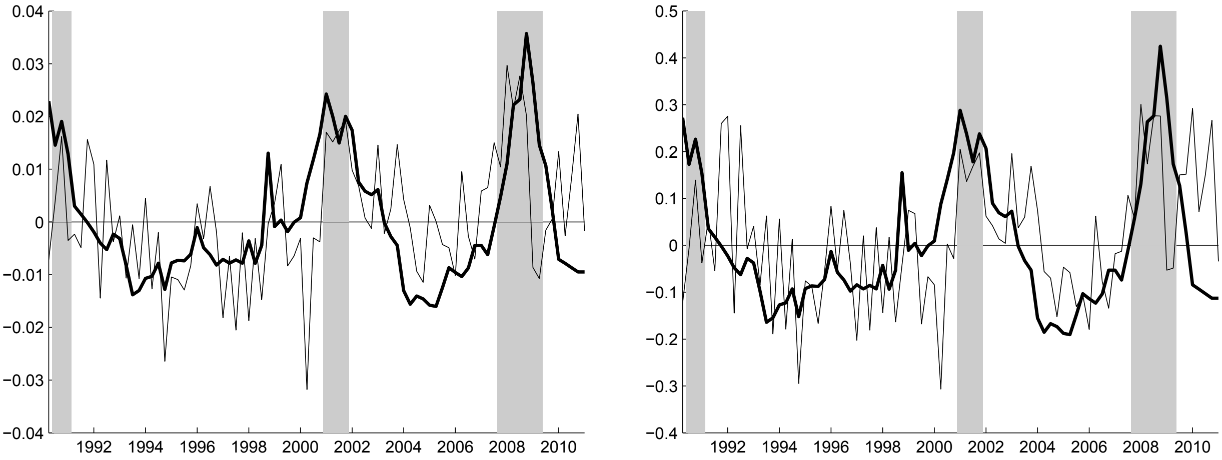

Figure 8: Contemporaneous valuation shock (thin line, left figure), eight quarter ahead valuation shock (thin line, right figure) and Senior Loan Officer Opinion Survey on Bank Lending Practices by the Federal Reserve Board (thick line).

changes in the credit quality of bond issuing firms. The estimated valuation news series is strongly correlated with both the 1 and the 5 year ahead measure, though more so with the latter. Figure 9 indicates the valuation news series captures the rise in the probability of default both in the 2001 and the 2008 recessions. Interestingly, our shock series begins to signal unfavorable news at the same time when the probability of default measure begins to pick up in the mid 2007. The close association between our shock series and the market probability of default measure strongly indicates the close association of the valuation shock with default risk and supports its interpretation as a financial shock.

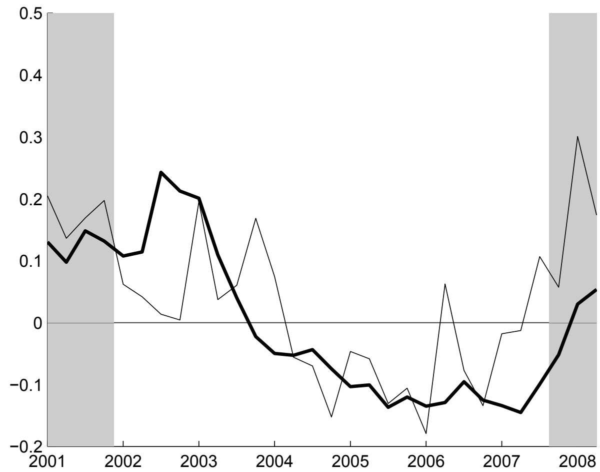

Figure 9: Valuation news (8 quarter ahead) shock (thin line) and Fitch five-year ahead probability of default measure (thick line). A positive value for the valuation shock series indicates unfavorable news.

9 Model Fit Comparisons

This section presents a comparison of different model versions. We aim to assess the fit of the benchmark model in relation to alternatives, without financial intermediation, without news shocks or with news shocks in both TFP and valuation processes. Table 7 reports all the different specifications we have considered. The top panel reports the marginal data densities computed using the modified harmonic mean estimator suggested by Geweke (1999). The benchmark model with four and eight quarters ahead anticipated valuation components dominates—in terms of this metric—specifications that include TFP news only (model B and C) or both TFP and valuation news (model D and E). It dominates model versions with signals that arrive more frequently. It also dominates the model with unanticipated shocks only (model F). Last, we also compare the fit of the benchmark model to a model with financial frictions turned off. This comparison is reported in the bottom panel of the Table. To facilitate the comparison we estimate these versions on a restricted set of data, namely, excluding both corporate bond spreads and equity as the model without financial frictions makes no predictions for financial variables. The benchmark model with valuation shocks (four and eight quarter ahead valuation news and unanticipated) dominates this frictionless model on the restricted set of observables, highlighting the importance of financial frictions in fitting the data. Last, we highlight the fact that the presence of financial variables in the estimation significantly raises the contribution of valuation news shocks in accounting for the variance in the data. When we estimate the model with the restricted set of data (model version G), the unconditional variance shares of valuation news shocks decline significantly compared to the benchmark model with the financial series used in estimation. Specifically, in model version G, valuation news account for 13.40%, 10.60%, 12.60% of the forecast error variance in output growth, investment growth and hours worked respectively. By contrast, in the benchmark model, they account for approximately, 25%, 21.30% and 26.50% of the variance in the same variables, thus approximately doubling in importance.

Table 7: Log marginal data densities for different model setups

	Model Setup	Log Marginal Data Density
	Estimated with full data set	
Benchmark	4 and 8 quarter ahead valuation news shocks in both sectors	-761.15
Model A:	1, 4 and 8 quarter ahead valuation news shocks in both sectors	-763.00
Model B:	4 and 8 quarter ahead TFP news shocks in both sectors	-778.00
Model C:	1, 4 and 8 quarter ahead TFP news shocks in both sectors	-778.00
Model D:	4 and 8 quarter ahead valuation news shocks and TFP news in both sectors	-770.24
Model E:	1, 4 and 8 quarter ahead valuation news shocks and TFP news in both sectors	-772.90
Model F:	Model without any anticipated components	-771.74
	Estimated with restricted data set	
Model G:	Benchmark estimated without spread and equity data as observables	-532.54
Model H:	Model with frictionless financial intermediation estimated without spread and equity data as observables	-533.70

10 A Historical Perspective and the 2008 Recession

Given the quantitative importance of news shocks as driving forces, we attempt to disentangle the impact of anticipated and unanticipated shocks on the in-sample variation of GDP and investment by performing a historical decomposition. Figure 10 depicts the results of this exercise. In this figure we show the combined effects of valuation news vs. all other unanticipated shocks.

The historical decompositions show that news shocks were the main sources for the recessions in 2001 (2001Q1 - 2001Q4) and 2008 (2007Q4 - 2009Q2). Valuation news shocks contribute very little to the downturn of GDP and investment in the early 1990s (1990Q3 - 1991Q1) recession. 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 expectation shifts may have played a much bigger role in the last two recessions (see for example Christiano et al. (2008)). These are thought by many to be the result of bursting bubbles due to a correction of overoptimistic expectations. The historical decompositions are consistent with this view. Notice that expectations about future valuations are revised downwards immediately at the beginning of the two recessions and explain a substantial fraction of both downturns. 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 cycles as a theory of recessions.

Anticipated shocks 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 2001 recession where we have a complete set of observations on the recovery and expansion phase until the 2008 recession. 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. 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.[21]

11 Conclusions

In this paper we used Bayesian techniques to estimate a two-sector DSGE model for the US economy using a sample from 1990Q2 to 2011Q1. The framework explicitly models financial intermediation in the spirit of Gertler and Karadi (2011) and includes two types of financial shocks among other sources considered in the literature on business cycles. These shocks are, first, a shock to the valuation of intermediary assets and second, an equity capital shock. The former 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.

We report several results. *First*, we find valuation shocks can explain a sizable fraction of fluctuations at both business cycle and lower frequencies. They can account for approximately 25% of output growth, 20% of aggregate investment growth and 25% of aggregate hours variance. Interestingly, *news* about asset valuations (coined "valuation news") that arrive up to 2 years in advance explain the majority of the variance shares above. Shocks of this type have been examined qualitatively in Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) and

[21] See for example Van Nieuwerburgh and Veldkamp (2006) and Görtz and Tsoukalas (2011a).

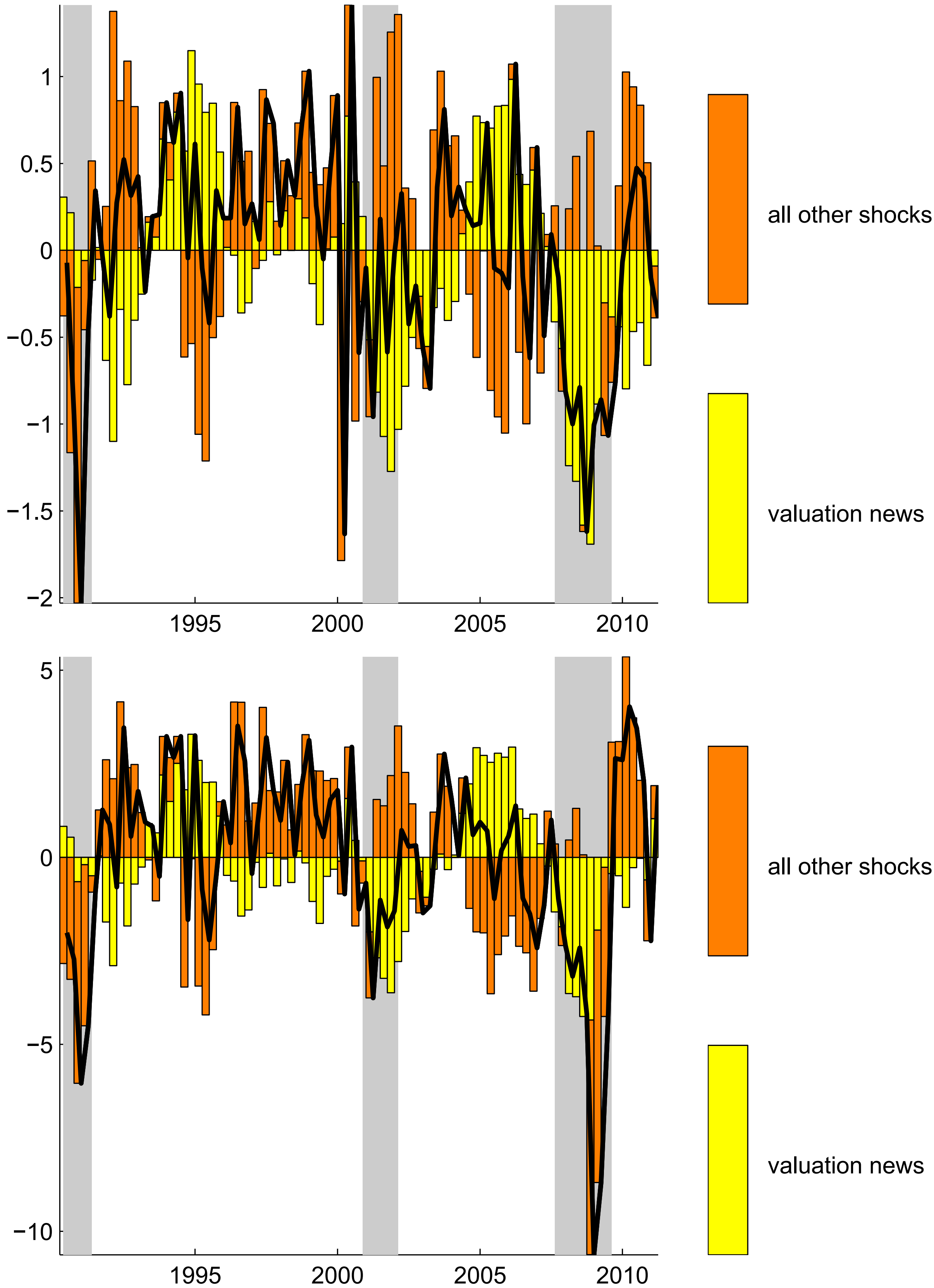

Figure 10: Historical decomposition of the growth rate of GDP (top) and investment (bottom). The grey bars denote recessions as announced by the NBER Business Cycle Dating Committee.

our paper provides, to the best of our knowledge, the first quantitative estimate of their importance. Our estimates moreover indicate that corporate bond market spreads contain substantial information about valuation news shocks. *Second*, valuation news shocks can generate **aggregate** and **sectoral** co-movement, a pervasive stylized fact of business cycles and can explain the behavior of total hours worked surprisingly well during recessions. The success in explaining the behavior of total hours during recessions is linked to the fact these shocks almost entirely capture the declines in investment sector hours during these periods, in line with the evidence presented in the introduction. *Third*, investment sector TFP shocks (or investment specific shocks popularized by Greenwood et al. (2000) and Fisher (2006)) account for a relatively significant fraction of business cycle variation in output growth, total investment growth and total hours worked consistent with the findings in Fisher (2006). This stands in sharp contrast with their negligible importance reported in several recent estimated one sector DSGE models such as Schmitt-Grohe and Uribe (2010) or Gilchrist et al. (2009). The primary reason for this finding is the tight link imposed in estimation—between investment specific shocks and the relative price of investment. As a result, in those studies, investment specific shocks are identified from the relative price of investment alone. This constraint does not necessarily hold in a two sector model, except under special assumptions. *Last*, from a historical perspective, valuation news shocks can entirely explain the decline in GDP and a large fraction of the investment collapse in the early stages of the 2008 recession. They are also found to be driving, to a significant extent, the declines in GDP and investment in the 2001 recession following the 1990s investment boom. However they are estimated to have played a very limited role during the recession at the beginning of the 1990s consistent with earlier work that found only limited credit supply effects on the severity of the 1990-1991 recession (e.g. Bernanke et al. (1991)).

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12 Appendix

A Financial Intermediaries

This part of the appendix describes in detail how the setup of Gertler and Karadi (2011) is adapted for the two sector model. It further outlines in detail how the equations for financial intermediaries in the main part of this paper are derived.

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

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

where $S_{x,t}$ 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.[22] 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 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

$$\begin{aligned} N_{x,t+1} &= R^B_{x,t+1}Q_{x,t}S_{x,t} - R_t\frac{B_{x,t}}{P_{C,t}} \\ &= R^B_{x,t+1}Q_{x,t}S_{x,t} - R_t(Q_{x,t}S_{x,t} - N_{x,t}) \\ &= (R^B_{x,t+1} - R_t)Q_{x,t}S_{x,t} + R_tN_{x,t}. \end{aligned}$$

The premium, $R^B_{x,t+1} - R_t$, as well as the quantity of assets, $Q_{x,t}S_{x,t}$, 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

[22] 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

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 maximize expected terminal wealth

$$\begin{aligned} V_{x,t} =& maxE_t \sum_{i=0} (1-\theta_B)\theta_B^i \beta^i \Lambda_{t+1+i}^B N_{x,t+1+i} \\ =& maxE_t \sum_{i=0} (1-\theta_B)\theta_B^i \beta^i \Lambda_{t+1+i}^B [(R_{x,t+1+i}^B - R_{t+i}) Q_{x,t+i} S_{x,t+i}^p + R_{t+i} N_{x,t+i}], \end{aligned} \tag{A.1}$$

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.[23] 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 maximized 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 formalized as

$$V_{x,t} \geq \lambda_B Q_{x,t} S_{x,t}, \qquad 0 < \lambda_B < 1. \tag{A.2}$$

Using equation (A.1), the expression for $V_{x,t}$ can be written as the following first-order difference equation

$$V_{x,t} = \nu_{x,t} Q_{x,t} S_{x,t} + \eta_{x,t} N_{x,t},$$

with

$$\begin{aligned} \nu_{x,t} &= E_t\{(1-\theta_B)\Lambda_{t+1}^B (R_{x,t+1}^B - R_t) + \theta_B \beta Z_{1,t+1}^x \nu_{x,t+1}\}, \\ \eta_{x,t} &= E_t\{(1-\theta_B)\Lambda_{t+1}^B R_t + \theta_B \beta Z_{2,t+1}^x \eta_{x,t+1}\}, \end{aligned}$$

and

$$Z_{1,t+1+i}^x \equiv \frac{Q_{x,t+1+i} S_{x,t+1+i}}{Q_{x,t+i} S_{x,t+i}}, \qquad Z_{2,t+1+i}^x \equiv \frac{N_{x,t+1+i}}{N_{x,t+i}}.$$

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, $S_{x,t}$, constant. The gross growth rate in assets is denoted by $Z_{1,t+i}^x$ and the gross growth rate of net worth is denoted by $Z_{2,t+i}^x$.

[23] 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.

Then, using the expression for $V_{x,t}$, we can express the bank's incentive constraint (A.2) as

$$\nu_{x,t} Q_{x,t} S_{x,t} + \eta_{x,t} N_{x,t} \geq \lambda_B Q_{x,t} S_{x,t}.$$

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

$$\begin{aligned} Q_{x,t} S_{x,t} &= \frac{\eta_{x,t}}{\lambda_B - \nu_{x,t}} N_{x,t} \\ &= \varrho_{x,t} N_{x,t}. \end{aligned} \tag{A.3}$$

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 maximized expected terminal wealth equals the gains from diverting the fraction λ_B from available funds. However, the constraint (A.3) 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 (A.3) 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

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

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

$$N^e_{x,t} = \theta_B[(R^B_{x,t} - R_{t-1})\varrho_{x,t-1} + R_{t-1}]N_{x,t-1}, \qquad 0 < \theta_B < 1. \tag{A.4}$$

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 $(1-\theta_B)Q_{x,t}S_{x,t}$. 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

$$N^n_{x,t} = \varpi Q_{x,t}S_{x,t}, \qquad 0 < \varpi < 1. \tag{A.5}$$

Existing banker's net worth (A.4) and entering banker's net worth (A.5) lead to the law of motion for total net worth

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

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.

B Stationary Economy

The model includes two non-stationary technology shocks, A_t and V_t. Therefore, the model variables are normalized as follows[24]

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

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

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

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

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

and the multipliers are normalized as

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

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 (A.5) 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

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

[24] Lower case variables denote normalized stationary variables.

B.1 Intermediate goods producers

Firm's production function in the consumption sector:

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

Firm's production function in the investment sector:

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

Marginal costs in the consumption sector:

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

Marginal costs in the investment sector:

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

Capital labour ratios in the two sectors:

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

B.2 Firms' pricing decisions

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

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

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

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

B.3 Household's optimality conditions and wage setting

Marginal utility of income:

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

Euler equation:

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

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 $x = C, I$:

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

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

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

Definition of capital input in both sectors:

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

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

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

B.4 Household's wage setting

Household's wage setting:

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

with

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

and

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

Wages evolve according to

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

B.5 Financial Intermediation

The stationary stochastic discount factor can be expressed as

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

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

$$\begin{aligned}
\nu_{x,t} &= E_t \{ (1-\theta_B) \lambda_{t+1}^B \frac{A_t}{A_{t+1}} \left(\frac{V_t}{V_{t+1}} \right)^{\frac{a_c}{1-a_i}} (R_{x,t+1}^B - R_t) + \theta_B \beta z_{1,t+1}^x \nu_{x,t+1} \}, \\
\eta_{x,t} &= E_t \{ (1-\theta_B) \lambda_{t+1}^B \frac{A_t}{A_{t+1}} \left(\frac{V_t}{V_{t+1}} \right)^{\frac{a_c}{1-a_i}} R_t + \theta_B \beta z_{2,t+1}^x \eta_{x,t+1} \},
\end{aligned}$$

with

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

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

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

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 normalized equation for bank's wealth accumulation is

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

The borrow in advance constraint:

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

The leverage equation:

$$q_{x,t}s_{x,t} = \varrho_{x,t}n_{x,t}.$$

Bank's stochastic return on assets can be described in normalized 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

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

B.6 Monetary policy and market clearing

Monetary policy rule:

$$\frac{R_t}{R} = \Big(\frac{R_{t-1}}{R}\Big)^{\rho_R} \Big[\Big(\frac{\pi_t}{\pi}\Big)^{\phi_\pi} \Big(\frac{\pi_t}{\pi_{t-1}}\Big)^{\phi_{\Delta\pi}} \Big(\frac{y_t}{y_{t-1}}\Big)^{\phi_{\Delta Y}}\Big]^{1-\rho_R} \eta_{mp,t},$$

Resource constraint in the consumption sector:

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

Resource constraint in the investment sector:

$$i_t = L^{1-a_i}_{I,t} k^{a_i}_{I,t} - F_I.$$

Definition of GDP:

$$y_t = c_t + p_{i,t}i_t + \Big(1 - \frac{1}{e_t}\Big)y_t.$$

It further holds that

$$L_t = L_{I,t} + L_{C,t}, \qquad i_t = \Big[i^{-\rho}_{I,t} + i^{-\rho}_{C,t}\Big]^{-\frac{1}{\rho}} \qquad \text{and} \qquad K_t = K_{I,t} + K_{C,t}.$$

C 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

$$\frac{q_x s_x}{n_x} = \varrho_x = 5.47.$$

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 (5.47) and the weighted quarterly average of the credit spreads ($R_x^B - R = 0.005$) allows calibrating ϖ using the bank's wealth accumulation equation

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

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

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

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

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

D Log-linearized Economy

The log-linear deviations of all variables are defined as

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

except for

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

D.1 Firm's production function and cost minimization

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:

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

Marginal cost in both sectors:

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

D.2 Firm's prices

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

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

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

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

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 $x=C,I$:

$$\begin{aligned}&\hat{\pi}_{x,t}=\frac{\beta}{1+\iota_{p_x}\beta}E_t\hat{\pi}_{x,t+1}+\frac{\iota_{p_x}}{1+\iota_{p_x}\beta}\hat{\pi}_{x,t-1}+\kappa_x\hat{mc}_{x,t}+\kappa_x\hat{\lambda}_{p,t}^x,\\ &\text{with}\quad \kappa_x=\frac{(1-\xi_{p,x}\beta)(1-\xi_{p,x})}{\xi_{p,x}(1+\iota_{p_x}\beta)}.\end{aligned}\tag{D.3}$$

From equation (B.12) it follows that

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

D.3 Households

D.3.1 Consumption

Marginal utility:

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

with

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

This assumes the shock processes (1), (2) and (4).

Euler equation:

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

D.3.2 Investment and Capital

Capital utilisation in both sectors:

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

Choice of investment for the consumption sector:

$$\begin{aligned}\hat{\lambda}_t =& -e^{2(\frac{1}{1-a_i}g_\upsilon)}\kappa\left(\hat{i}_{C,t} - \hat{i}_{C,t-1} + \frac{1}{1-a_i}\hat{\upsilon}_t\right) + \beta e^{2(\frac{1}{1-a_i}g_\upsilon)}\kappa E_t\left(\hat{i}_{C,t+1} - \hat{i}_{C,t} + \frac{1}{1-a_i}\hat{\upsilon}_{t+1}\right) \\ & + \hat{\phi}_{C,t} - \hat{p}_{i,t} - (1+\rho)\left[(i_I^{-\rho} + i_C^{-\rho})^{-1}(i_C^{-\rho}\hat{i}_{C,t} + i_I^{-\rho}\hat{i}_{I,t}) - \hat{i}_{C,t}\right]. \qquad \text{(D.7)}\end{aligned}$$

Choice of investment for the investment sector:

$$\begin{aligned}\hat{\lambda}_t =& -e^{2(\frac{1}{1-a_i}g_\upsilon)}\kappa\left(\hat{i}_{I,t} - \hat{i}_{I,t-1} + \frac{1}{1-a_i}\hat{\upsilon}_t\right) + \beta e^{2(\frac{1}{1-a_i}g_\upsilon)}\kappa E_t\left(\hat{i}_{I,t+1} - \hat{i}_{I,t} + \frac{1}{1-a_i}\hat{\upsilon}_{t+1}\right) \\ & + \hat{\phi}_{I,t} - \hat{p}_{i,t} - (1+\rho)\left[(i_I^{-\rho} + i_C^{-\rho})^{-1}(i_C^{-\rho}\hat{i}_{C,t} + i_I^{-\rho}\hat{i}_{I,t}) - \hat{i}_{I,t}\right]. \qquad \text{(D.8)}\end{aligned}$$

Capital input in both sectors:

$$\hat{k}_{C,t} = \hat{u}_{C,t} + \xi^K_{C,t} + \hat{\bar{k}}_{C,t-1} - \frac{1}{1-a_i}\hat{\upsilon}_t, \qquad \hat{k}_{I,t} = \hat{u}_{I,t} + \xi^K_{I,t} + \hat{\bar{k}}_{I,t-1} - \frac{1}{1-a_i}\hat{\upsilon}_t. \tag{D.9}$$

Capital accumulation in the consumption and investment sector:

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

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

D.3.3 Wages

The wage Phillips curve can be derived to be:[25]

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

where

$$\begin{aligned}\kappa_w &\equiv \frac{(1-\xi_w\beta)(1-\xi_w)}{\xi_w(1+\beta)\big(1+\nu\big(1+\frac{1}{\lambda_w}\big)\big)},\\ \hat{g}_{w,t} &\equiv \hat{w}_t - (\nu\hat{L}_t + \hat{b}_t - \hat{\lambda}_t).\end{aligned}$$

D.4 Banking sector

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

The stochastic discount factor:

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

Definition of ν:

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

Definition of η:

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

Definition of z_1:

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

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

Definition of z_2:

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

The leverage ratio:

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

The leverage equation:

$$\hat{q}_{x,t} + \hat{s}_{x,t} = \hat{\varrho}_{x,t} + \hat{n}_{x,t}. \tag{D.19}$$

The bank's wealth accumulation equation

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

The borrow in advance constraint:

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

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

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

External finance premium:

$$\hat{R}^\Delta_{x,t} = \hat{R}^B_{x,t+1} - \hat{R}_t, \qquad x = C, I. \tag{D.23}$$

D.5 Monetary policy and market clearing

Monetary policy rule:

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)\Big[\phi_\pi \hat{\pi}_t + \phi_{\Delta\pi}(\hat{\pi}_t - \hat{\pi}_{t-1}) + \phi_{\Delta Y}(\hat{y}_t - \hat{y}_{t-1})\Big] + \hat{\eta}_{mp,t} \tag{D.24}$$

Resource constraint in the consumption sector:

$$\hat{c}_t + \Big(r^K_C \frac{\bar{k}_C}{c}\hat{u}_{C,t} + r^K_I \frac{\bar{k}_I}{c}\hat{u}_{I,t}\Big) e^{-\frac{1}{1-a_i} g_v} = \frac{c + F_c}{c}[a_c \hat{k}_{C,t} + (1-a_c)\hat{L}_{C,t}] \tag{D.25}$$

Resource constraint in the investment sector:

$$\hat{i}_t = \frac{i + F_I}{i}[a_i \hat{k}_{I,t} + (1 - a_i)\hat{L}_{I,t}] \tag{D.26}$$

Definition of GDP:

$$\hat{y}_t = \frac{c}{c + p_i i}\hat{c}_t + \frac{p_i i}{c + p_i i}(\hat{i}_t + \hat{p}_{i,t}) + \hat{e}_t. \tag{D.27}$$

It further holds that

$$\frac{L_C}{L}\hat{L}_{C,t} + \frac{L_I}{L}\hat{L}_{I,t} = \hat{L}_t, \quad \left[i_C^{-\rho} + i_I^{-\rho}\right]^{-1}\left(i_I^{-\rho}\hat{i}_{I,t} + i_C^{-\rho}\hat{i}_{C,t}\right) = \hat{i}_t \quad \text{and} \quad \frac{k_C}{k}\hat{k}_{C,t} + \frac{k_I}{k}\hat{k}_{I,t} = \hat{k}_t. \tag{D.28}$$

D.6 Exogenous processes

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

$$\hat{\lambda}^x_{p,t} = \rho_{\lambda^x_p}\hat{\lambda}^x_{p,t-1} + \varepsilon^x_{p,t} - \theta^x_p \varepsilon^x_{p,t-1}. \tag{D.29}$$

The TFP growth shock to the consumption sector:

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon^z_t. \tag{D.30}$$

The TFP growth shock to the investment sector:

$$\hat{v}_t = \rho_v \hat{v}_{t-1} + \varepsilon^v_t. \tag{D.31}$$

Wage markup shock:

$$\hat{\lambda}_{w,t} = \rho_w \hat{\lambda}_{w,t-1} + \varepsilon_{w,t} - \theta_w \varepsilon_{w,t-1}. \tag{D.32}$$

Preference shock:

$$\hat{b}_t = \rho_b \hat{b}_{t-1} + \varepsilon^b_t. \tag{D.33}$$

Monetary policy shock:

$$\hat{\eta}_{mp,t} = \varepsilon^{mp}_t. \tag{D.34}$$

GDP measurement error:

$$\hat{e}_t = \rho_e \hat{e}_{t-1} + \varepsilon^e_t. \tag{D.35}$$

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

$$\hat{\varsigma}_{x,t} = \rho_{\varsigma_x}\hat{\varsigma}_{x,t-1} + \epsilon^{\varsigma}_{x,t}. \tag{D.36}$$

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

$$\hat{\xi}^K_{x,t} = \rho_{\xi^K,x}\hat{\xi}^K_{x,t} + \varepsilon^{\xi^K}_{x,t} \qquad \text{with} \qquad \varepsilon^{\xi^K}_{x,t} = \varepsilon^{\xi^{K,0}}_{x,t} + \varepsilon^{\xi^{K,news}}_{x,t} \tag{D.37}$$

The whole log-linear economy model of the economy is summarized by equations (D.1) - (D.28) and the shock processes (D.29) - (D.37).

E Measurement equations

For the estimation the model variables are linked with the observables using measurement equations. Letting a superscript "d" denote the observables, then the model's measurement equations are,

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

F Data Appendix

Table 8 provides an overview of the data used to construct the observables. All the data transformations we have made in order to construct the dataset used for the estimation of the model are described in the following.

Real and nominal variables. Consumption (in current prices) is defined as the sum of personal consumption expenditures on services and personal consumption expenditures on non-durable goods. The times series for real consumption is constructed as follows. First, we compute the shares of services and non-durable goods in total (current price) consumption. Then, total real consumption growth is obtained as the chained weighted (using the nominal shares above) growth rate of real services and 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 ratio 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 (current price) personal consumption expenditures on durable goods and gross private domestic investment and chain weight to arrive at the real aggregate. The relative price of investment is the ratio of the investment deflator and the consumption deflator. Real output is GDP expressed in consumption units by dividing current price GDP with 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 hours of all persons in the non-farm business sector. The nominal interest rate is 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, aged 16 and over. The time series for hours is in logs. Moreover, all series in estimation (including the financial time series described below) are expressed in deviations from their sample average.

Financial variables. Data for credit spreads defined separately for the two sectors in the model are not directly available. However, Reuters' Datastream provides US credit spreads for companies which we map into the two sectors using The North American Industry Classification System (NAICS).[26] A credit spread is defined as the difference between a company's corporate bond yield and the yield of a US Treasury bond with an identical maturity. In constructing credit spreads we only consider non-financial corporations. In line with Gilchrist and Zakrajsek (2011) we make the following adjustments to the credit spread data we construct: 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 maturity 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. The series for the sectoral credit spreads are constructed by taking the mean over all spreads available in a certain quarter. 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. After these adjustments the dataset (1990Q2-2011Q1) contains 5376 spreads of bonds of which 1213 are classified to be issued by companies in the consumption sector and 4163 issued by companies in the investment sector. This is equivalent to 36425 observations in the consumption and 116628 observations in the investment sector over the entire sample. The average maturity is 30 quarters (consumption sector) and 28 quarters (investment sector) with an average rating for both sectoral bond issues between BBB+ and A-. The total number of firms in our sample is equal to 1696, with 516 firms belonging to the consumption sector and 1180 firms belonging to the investment sector. The correlation between the two sectoral spread series is equal to 0.83.

Sectoral Hours. Disaggregated data on hours worked that is fully consistent with the concept of our series for aggregate hours (hours of All Persons, non-farm business sector) are not available. To construct series for sectoral hours worked we use the product of all employees and average weekly hours of production and non-supervisory workers at the 2-digit level. This

[26] We use the 2005 NAICS codes. The investment sector is defined to consist of companies in mining, utilities, transportation and warehousing, information, manufacturing, construction and wholesale trade industries (NAICS codes 21 22 23 31 32 33 42 48 49 51 (except 491)). The consumption sector consists of companies in retail trade, finance, insurance, real estate, rental and leasing, professional and business services, educational services, health care and social assistance,arts, entertainment, recreation, accommodation and food services and other services except government (NAICS codes 6 7 11 44 45 52 53 54 55 56 81).

data is aggregated for the consumption and investment sector by using 2005 NAICS codes. The 2-digit industries are allocated to the consumption and investment sector according to the sectoral definitions derived from the 2005 Input-Output tables outlined in Section 3, and is consistent with the allocation used for the sectoral bond spreads.

Steady state financial parameters. The steady state leverage ratio of financial intermediaries in the model, used to pin down the parameters ϖ and λ_B, is calculated by taking the sample average of the inverse of total equity over "adjusted" assets of all insured US commercial banks available from the Federal Financial Institutions Examination Council. The same body reports a series of equity over total assets. We multiply this ratio with total assets in order to get total equity for the US banking sector that we use in estimation. Total assets includes consumer loans and holdings of government bonds which we want to exclude from total assets to be consistent with the model concept. Thus, to arrive at an estimate for adjusted assets we subtract consumer, real estate loans and holdings of government and government guaranteed bonds (such as government sponsored institutions) from total assets of all insured U.S. commercial banks.

Table 8: 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	NSA	EQTA	IEC
Total Assets	NSA	H.8	FRB
All Employees	SA	B-1	BLS
Average Weekly Hours	SA	B-7	BLS

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, FRB = Federal Reserve Board.

Appendix D: Additional Tables

Table 9: Cross-Correlations of total and sectoral (model and data) hours with real GDP

	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6
Data													
Total Hours	-0.174	-0.049	0.129	0.304	0.486	0.685	0.861	0.878	0.816	0.680	0.495	0.308	0.121
Consumption sector hours	-0.275	-0.154	0.004	0.168	0.358	0.579	0.801	0.859	0.840	0.749	0.578	0.412	0.236
Investment sector hours	-0.210	-0.099	0.062	0.225	0.409	0.616	0.819	0.865	0.821	0.708	0.551	0.389	0.219
Model (all shocks activated)													
Total Hours	-0.174	-0.049	0.129	0.304	0.486	0.685	0.861	0.878	0.816	0.680	0.495	0.308	0.121
Consumption sector hours	-0.072	0.075	0.257	0.419	0.582	0.748	0.901	0.857	0.747	0.603	0.423	0.225	0.046
Investment sector hours	-0.241	-0.150	0.002	0.166	0.342	0.544	0.717	0.784	0.772	0.660	0.495	0.340	0.170

Data and model time series are HP_{1600} detrended.

Table 10: Unconditional Variance Decomposition (at Prior Means)

									Financial Shocks							
	z	v	b	e	η_{em}	λ_p^C	λ_p^I	λ_w	ς_C	ς_I	$\xi_C^{K,0}$	$\xi_I^{K,0}$	$\xi_C^{K,4}$	$\xi_C^{K,8}$	$\xi_I^{K,4}$	$\xi_I^{K,8}$
Output Growth	51.69	2.67	0.03	24.87	0.36	2.50	0.06	16.91	0.00	0.00	0.56	0.00	0.24	0.10	0.00	0.00
Consumption Growth	69.70	1.89	0.18	0.01	0.91	5.31	0.02	20.52	0.00	0.00	0.93	0.01	0.26	0.25	0.00	0.00
Total Investment Growth	37.32	13.10	0.01	0.01	0.56	0.35	2.74	42.92	0.02	0.00	0.70	0.11	1.20	0.90	0.04	0.02
Total Hours	19.89	3.16	0.02	0.00	0.53	1.52	0.53	72.72	0.00	0.00	0.37	0.01	0.65	0.58	0.01	0.01
Real Wage Growth	60.29	4.67	0.00	0.00	0.01	9.27	0.01	25.33	0.00	0.00	0.24	0.00	0.09	0.07	0.00	0.00
C-Sector Inflation	12.85	8.97	0.07	0.03	0.76	38.90	0.12	34.94	0.00	0.00	0.54	0.02	0.84	1.90	0.02	0.03
I-Sector Inflation	7.61	20.69	0.02	0.02	2.52	5.51	35.87	16.58	0.02	0.00	1.51	0.85	3.31	4.76	0.33	0.40
Nom. Interest Rate	8.43	14.54	0.08	0.43	5.26	29.89	0.20	36.21	0.00	0.00	0.76	0.04	1.22	2.85	0.04	0.05
C-Sector Spread	24.83	6.38	0.05	0.52	6.13	38.38	0.64	10.64	2.58	0.00	0.26	0.10	3.04	6.32	0.06	0.06
I-Sector Spread	26.24	4.70	0.07	0.59	6.57	36.98	0.15	16.99	0.00	2.83	0.09	0.12	1.36	2.92	0.17	0.25
Equity Growth	65.87	14.27	0.01	0.02	0.42	3.08	0.01	13.36	0.08	0.01	1.99	0.02	0.59	0.26	0.00	0.00

z = TFP in consumption sector, v = TFP in investment sector, b = Preference shock, e = GDP measurement error, η_{em} = Monetary policy, λ_p^C = Consumption sector price markup, λ_p^I = Investment sector price markup, λ_w = Wage markup, ς_C = Consumption sector equity capital shocks, ς_I = Investment sector equity capital shock, $\xi_C^{K,0}$ = 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.

Table 11: Correlation of GDP with macroeconomic aggregates and credit spreads

	Consumption	Investment	Hours	Consumption Sector Credit Spread	Investment Sector Credit Spread
GDP	0.870	0.927	0.861	-0.484	-0.555

All time series except the spreads are per capita and HP_{1600} filtered.

Appendix E: Additional Figures

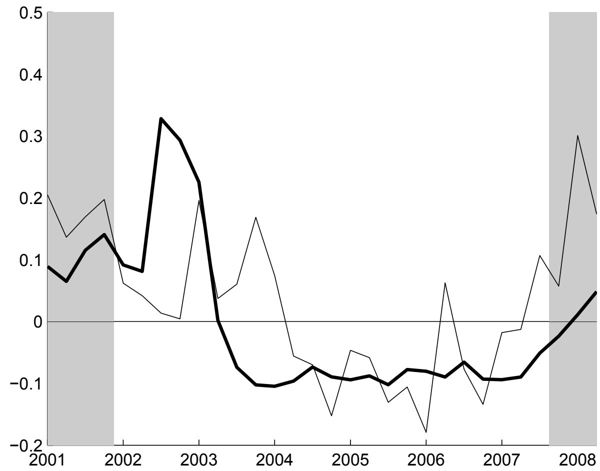

Figure 11: Valuation news (8 quarter ahead) shock (thin line) and Fitch one-year ahead probability of default measure (thick line). A positive value for the valuation shock series indicates unfavorable news.

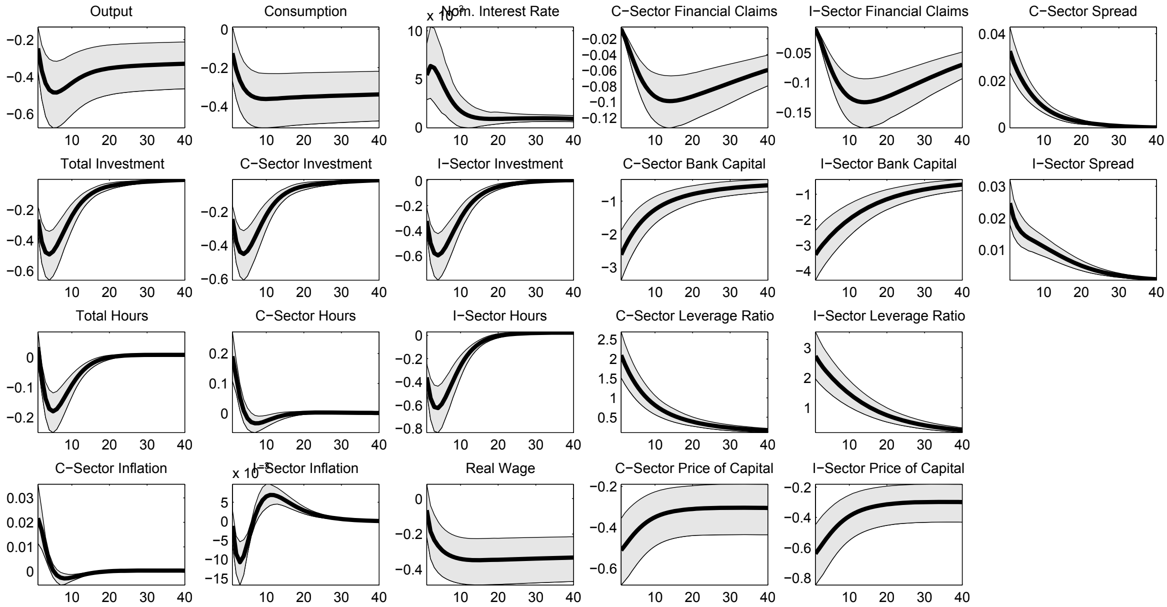

Figure 12: Responses to a negative one standard deviation unanticipated TFP shock in the consumption sector.

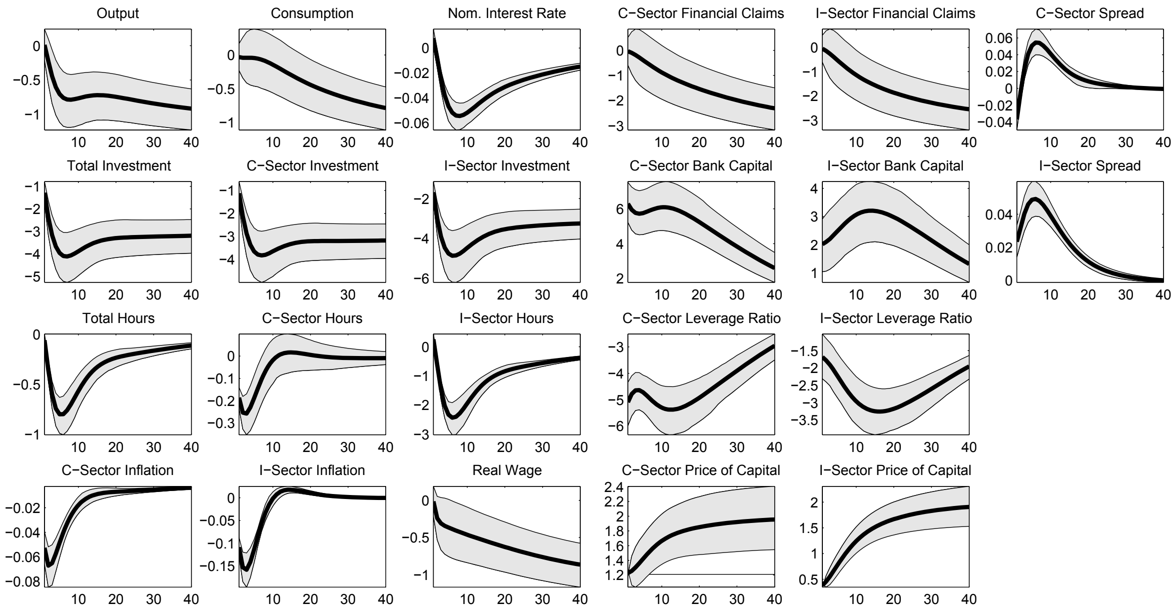

Figure 13: Responses to a negative one standard deviation unanticipated TFP shock in the investment sector.

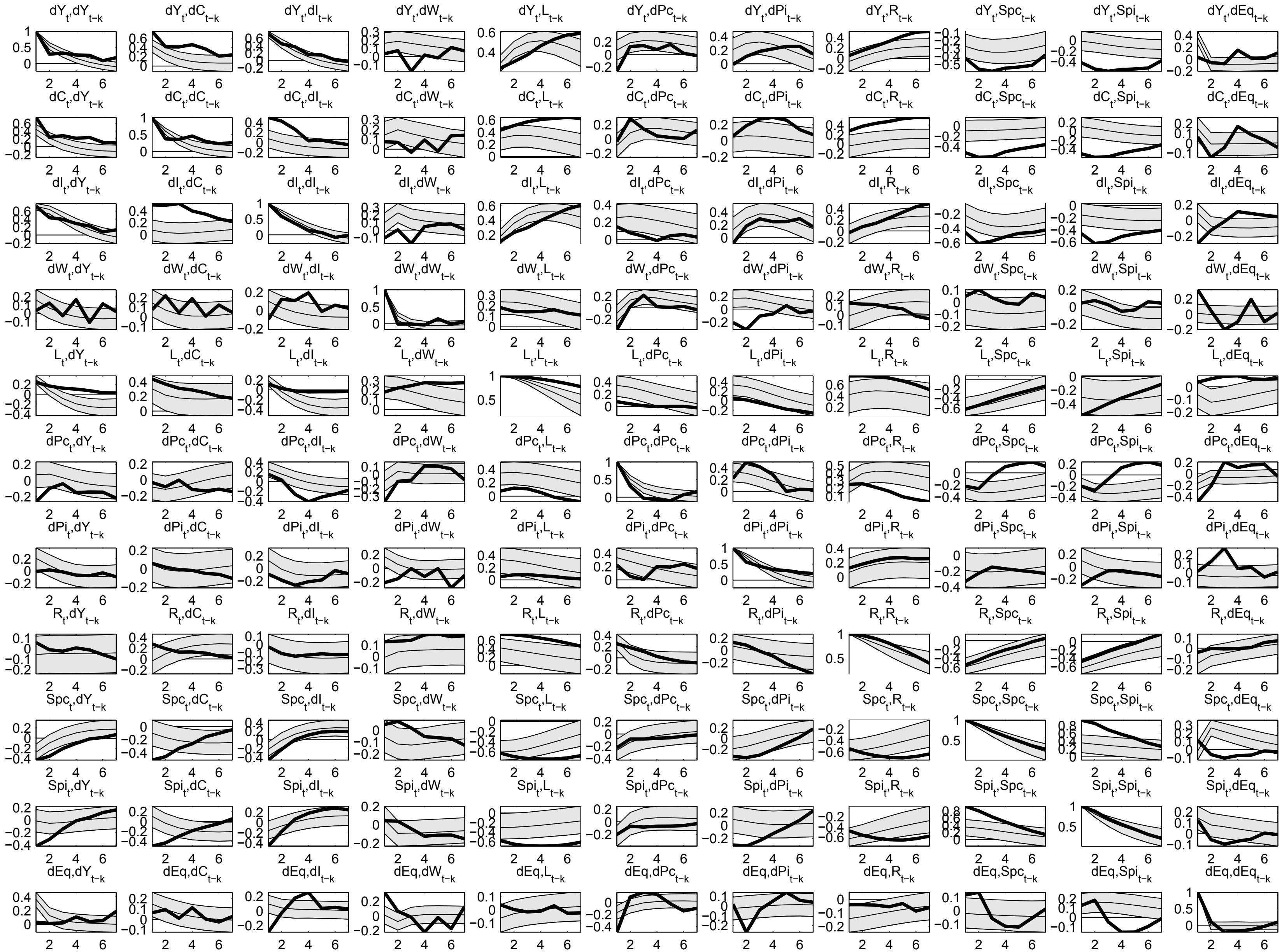

Figure 14: This figure shows the autocorrelation functions observed in the data (thick line) and the estimated model (median—thin line). Dotted lines show the 5 and 95 percentiles.