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News and Financial Intermediation in Aggregate and Sectoral Fluctuations*

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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 news 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 value of assets held by financial intermediaries, reflected one to two years in advance in corporate bond markets, generate countercyclical corporate bond spreads, affect the supply of credit, and are estimated to be a significant source of aggregate fluctuations, accounting for approximately 31% of output, 22% of investment and 31% of hours worked variation in cyclical frequencies. Importantly, asset value news shocks generate both *aggregate* and *sectoral* co-movement with a standard preference specification. Financial intermediation is key for the importance and propagation of asset value news shocks.

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

JEL Classification: E2, E3.

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1 Introduction

The 2007-2009 financial crisis has highlighted the powerful role of the financial sector. Severe disruptions in financial markets first reflected in movements of financial market indicators, e.g., credit spreads on private sector assets were followed by significant declines in measures of real economic activity. During the "Great Recession", real GDP (per capita) fell by 4.7%, private domestic investment (per capita) by 32%, and total non-farm business hours (per capita) by 9.7%. 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 (2012), Mueller (2009), Kurmann and Otrok (2012), Gomes and Schmid (2009), Philippon (2009) among others). An appealing interpretation is that these indicators may incorporate advance information or *news* about future economic developments, real or financial in nature. In this paper we quantitatively explore the interaction between financial markets, news shocks and the real economy using a two sector model.

There are several facts that motivate our approach. A careful look beyond the broad declines reported above, reveals sectoral downturns that vary in severity, 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). While sectoral hours tend to move together over the cycle, 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 significant decline, while consumption sector hours (e.g. in industries such as services, retail trade, finance) have been affected relatively less. Importantly, this pattern is not unique to the last recession—it can also be observed in the two previous episodes. Thus, hours worked in investment sector industries decline significantly more in recessions (see also Table 1) thereby acting as a powerful drag on total hours 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 real side of the model builds on the two sector RBC model of Huffman and Wynne (1999). We add nominal and real frictions that have been found to be important in recent work (see e.g., Christiano et al. (2005), Smets and Wouters (2007)) and introduce financial intermediation constraints as in Gertler and Karadi (2011) and Gertler and Kiyotaki (2010). The financial sector holds corporate sector assets and in exchange provides financing for capital expenditures, while being subject to a limit on how much leverage can be tolerated by depositors. Leverage constraints effectively tie credit flows—from the financial sector to the real economy—to the equity capital of intermediaries and create a feedback loop between equity capital and asset prices. This framework allows for a quantitative investigation of real, nominal and financial sources as drivers for aggregate and sectoral U.S. fluctuations.[1]

We estimate—using Bayesian methods—the model on real, nominal and financial U.S. data over the period, 1990Q2 to 2011Q1. Besides a host of real and nominal shocks previously considered in the literature, we introduce two types of financial shocks. *First*, shocks that affect the value of assets held by intermediaries and *second*, shocks that capture exogenous movements in intermediaries' equity capital (equity capital shocks). We assume the former—in addition to a purely unanticipated component—can encompass news components. These represent information received by agents in advance of the actual realization of the innovation and helps in generating richer forecasts about the future value of assets—relative to a conventional specification with unanticipated shocks. Our motivation stems from recent work by Gilchrist et al. (2009) and Gilchrist and Zakrajsek (2012) who identify credit market factors from corporate bond spreads that predict future movements in output, employment or industrial production and work by Philippon (2009) who shows corporate bond market spreads to better anticipate—compared to the stock market—future economic activity.[2]

We can summarize our results as follows. *First*, asset value *news* shocks explain a sizeable fraction of fluctuations at business cycle frequencies, accounting for 31% of output, 22% of investment and 31% of hours variation. Previous work (see Gertler and Karadi (2011), Gertler and Kiyotaki (2010), Gourio (2012)) has examined qualitatively the properties of purely unanticipated shocks of this type in the context of one sector calibrated models. By considering both unanticipated and news shocks our paper provides, to the best of our knowledge, the first quantitative assessment of the magnitude and the relative importance of these different components.[3] Our estimation method exploits the fact that financial variables (corporate bond spreads

[1]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 Quadrini (2012) among others). The majority of these studies rely on the framework proposed by Bernanke et al. (1999). 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, Dib (2010), Gerali et al. (2010), Hirakata et al. (2011) and Villa (2010)).

[2]We inform the estimation with separate sectoral corporate bond spreads that in principle can 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. In addition to corporate bond spreads we also include the equity capital of intermediaries as an observable in estimation. Given our focus on credit supply factors and the role of equity capital in determining the demand for assets by the financial sector, we believe it is important to inform the estimation with a variable that determines the degree of leverage of financial intermediaries. Recent studies that exploit the link between between financial markets and real economy and include financial market variables when estimating DSGE models with news shocks include Christiano et al. (2010), Davis (2007), Schmitt-Grohe and Uribe (2012)).

[3]Gertler and Karadi (2011) call them capital quality shocks, while Gourio (2012) calls them depreciation shocks.

and equity capital) contain substantial information about asset value news shocks. We find the quantitative importance of news shocks—in terms of accounting for the variance shares of real macro variables reported above—approximately doubles when financial variables are included in the estimation than if they are not. Consequently, the news component of asset value disturbances accounts for a significant fraction of the variation in corporate bond spreads and equity capital. Its interesting to note, the data strongly favors news shocks that only directly affect the value of assets in the consumption sector—investment sector asset value disturbances are largely irrelevant for fluctuations. Instead, the data prefers to use the sectoral links of the model as a natural propagation mechanism of consumption sector shocks across sectors.

Second, this type of financial news shock 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. It is important to note these co-movement properties of news shocks obtain with a standard preference specification. It is useful to describe the intuition behind the transmission mechanism of an asset value news shock. We focus on news received 2 years in advance of a decline in the value of consumption sector assets. This is quantitatively the dominant news component borne out by our estimates. There are *two channels* that propagate this shock in the model: a *financial* channel and a *real sectoral link* channel. The former works through the leverage constraint of intermediaries while the latter works through the demand from the consumption sector for capital goods produced by the investment sector.

The financial channel begins to operate as soon as financial intermediaries receive the news that asset values will decline in the future. Since asset prices are forward looking the value of assets falls immediately, intermediaries cover losses from their buffer of equity capital and respond by reducing leverage and consequently lending to the consumption sector. The spread (difference between the return of corporate bonds and cost of funds for the bank) in that sector rises immediately signalling the imminent deterioration in asset values and the increase in the cost of lending to that sector. The reduction in lending hits production and factor input use in the consumption sector. The two sector structure of the model propagates the shock to the investment sector causing output in the latter to contract as demand for capital goods from the consumption sector declines. The resulting decline in the demand for investment goods causes hours worked to sharply fall in that sector, but also in the aggregate, generating behavior of hours consistent with the observed movements documented above. All macroeconomic quantities decline, both sectoral spreads rise and lending contracts as a result of the gloomy news, generating aggregate and sectoral co-movement—bad news sets off a recession today in both sectors. It is important to note that, as formally demonstrated in section 7, this type of news shock cannot generate co-movement in the core of the two sector model where financial frictions are absent, i.e. the financial channel described above is key for the propagation and co-movement properties of the news shock.[4]

Our paper contributes to the ongoing debate on the importance of news shocks for aggregate fluctuations and highlights a new—financial—channel that can generate quantitatively important real effects of news shocks. Moreover, we also make some headway in addressing sectoral co-movement with news shocks—a demanding challenge as illustrated by Jaimovich and Rebelo (2009). Earlier theoretical work, e.g. Beaudry and Portier (2004) and Jaimovich and Rebelo (2009), has shown it is possible to generate a broad based expansion with an news shock that signals an improvement in total factor productivity (TFP). But subsequent empirical work has produced mixed results. Using a VAR methodology, Beaudry and Portier (2006) report quantitative important effects from TFP news shocks while 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. In an estimated RBC model with real rigidities, Schmitt-Grohe and Uribe (2012) find that news about wage mark-up, preference and government spending predict around half of aggregate fluctuations and dominate TFP news shocks. Broadly similar conclusions are reported by Khan and Tsoukalas (2012) and Fujiwara et al. (2011) in estimated New Keynesian DSGE models, though the share of fluctuations explained by news shocks is noticeably smaller. Recently, Christiano et al. (2010) and Christiano et al. (2012) estimate a DSGE model and identify news shocks arising in the riskiness of the entrepreneurial sector as a major source of fluctuations. Like ours, these authors point to news that propagate and can be identified, having distinct implications about financial prices and quantities, through the financial sector. Our findings similarly suggest a significant role for news shocks lies within propagation channels that are tightly linked with financial intermediation.[5] [6]

The rest of the paper is organized as follows. The next section provides some stylized facts on sectoral co-movement in U.S. data. Section 3 describes the model economy. Section 4 describes the estimation methodology, data and discusses estimation results. Section 5 quantifies the importance of different structural shocks as driving forces behind aggregate fluctuations.

[4] In the restricted model environment the shock acts as an anticipated capital depreciation shock: to avoid a large fall in future consumption agents respond by building up capital immediately, increasing hours worked in the production of investment goods and substitute resources out of consumption, smoothing out the negative wealth shock. Production of investment goods, hours worked and output (as the rise in investment dominates the decline in consumption) rise immediately. Thus, the resulting dynamics fail to resemble the typical business cycle pattern of co-movement.

[5] A related channel is emphasized in Gunn and Johri (2011) who in the context of a calibrated model investigate the role of news in the efficiency and innovation of intermediation in the financial system. This type of news is shown to be able to generate boom-bust cycles in liquidity and economic activity.

[6] Other recent work identifies channels that can give rise to important effects of news, for example, Beaudry and Portier (2007), Christiano et al. (2008), Karnizova (2010), Gunn and Jorhi (2011), Kobayashi and Nutahara (2010), Den Haan and Kaltenbrunner (2009).

Section 6 discusses the propagation of asset value news shocks while Section 7 compares them with financial market indicators. Section 8 concludes.

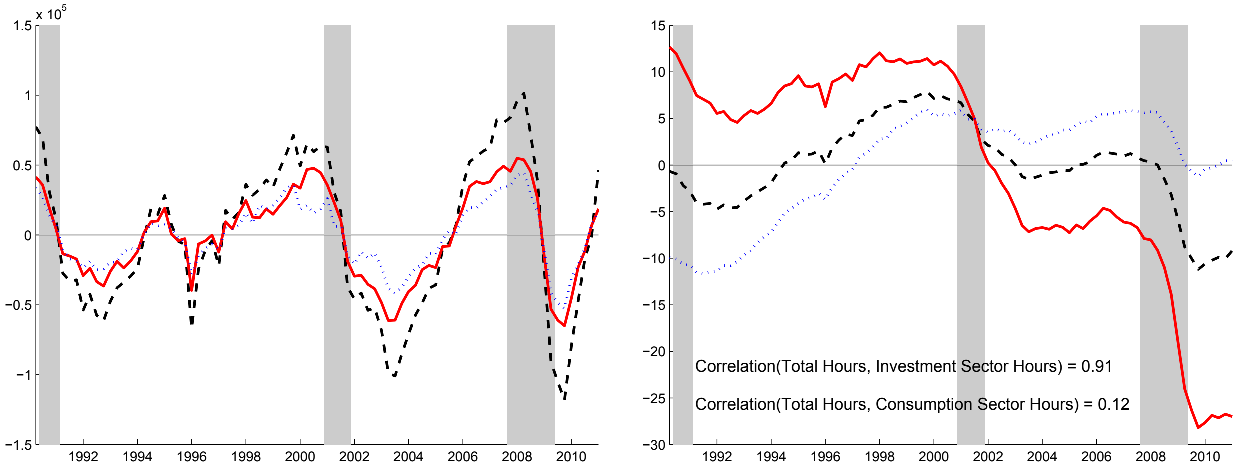

Figure 1: Total hours (black, dashed), consumption sector hours (blue, dotted) and investment sector hours (red, solid) (per capita average weekly hours times employees). Left panel: HP_{1600} detrended series. Right panel: Demeaned series in levels. Dark grey bars show NBER dated recessions. See the Data Appendix B 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 per capita non-farm average weekly hours times employees. See the Data Appendix B for a description of the sectoral hours series.

2 Evidence on sectoral co-movement

Sectoral co-movement of inputs and outputs is a pervasive stylized fact of business cycles. Table 2 presents some basic facts; it reports cross correlations of HP de-trended sectoral hours worked and sectoral investment (only available at an annual frequency) with real GDP. All sectoral variables co-move very strongly with real GDP. Sectoral hours worked appear to lag real GDP by one or two quarters. Investment flows produced for the consumption sector are more strongly correlated compared to investment flows produced for use in the investment sector. Previous work has considered multi sector environments. Important contributions in this area include, but are not limited to, Long and Plosser (1983), Huffman and Wynne (1999), Horvath (1998), Horvath (2000), Hornstein and Praschnik (1997), Dupor (1999), Ramey and Shapiro (1998). This early work has focused on RBC frameworks 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. Foerster et al. (2011) examine quantitatively the relative importance of aggregate and sector specific shocks in U.S. industrial production.[7]

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 capita 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 the HP_{1600} detrended series. Investment series are annual per capita real 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 B for details.

3 The Two Sector Model

The sectors in the model produce consumption 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

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

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, mining, utilities, transportation and warehousing, information, manufacturing, construction and wholesale trade industries are classified as the investment sector and 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 are classified as the consumption sector.[8]

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 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 use a fraction of investment goods and existing capital to produce new sector specific capital goods. Financial intermediaries collect deposits from households and finance the capital acquisitions of capital services producers. A monetary policy authority controls the nominal interest rate.

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,

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

[8]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.

where $K_{x,t}(i)$ and $L_{x,t}(i)$ denote the amount of capital services 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)).[9] The variable A_t denotes 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 their persistence.

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,

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

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. The factor that appears in the investment sector expression adjusts for investment specific progress.

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

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

[9]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 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 $\lambda_{p,t}^{x}$ 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.

Profit maximization and the zero profit condition for final good firms imply that sectoral prices of the final goods, $P_{C,t}$ 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,

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

where B_t is holdings of bank deposits (which are risk free and equivalent to government bonds), Ψ_t is the net cash flow from household's portfolio of state contingent securities, T_t is lump-sum taxes, R_t the (gross) nominal interest rate paid on deposits and Π_t is the net (after a start-up fund given to new bankers' members of household) per-capita profit accruing to households from ownership of all firms (financial and non-financial). 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 (or wage markup), $\lambda_{w,t}$, follows the exogenous stochastic process,

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

where $\rho_w \in (0,1)$ and $\varepsilon_{w,t}$ is $i.i.d.\ N(0, \sigma^2_{\lambda_w})$.

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 the 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,[10]

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

[10] 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)) and contract costs (Caplin and Leahy (1997)).

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 producers (described in the next section) in the respective sector at price $Q_{C,t}$ or $Q_{I,t}$. At the beginning of the next period, capital services producers set the utilization rate of capital. The utilization rate, $u_{x,t}$, transforms physical capital into effective capital according to

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

Capital services producers incur costs when setting utilization, which are denoted by $a_x(u_{x,t})$ per unit of capital. This function has the properties that in the steady state $u = 1$, $a_x(1) = 0$ and $\chi_x \equiv \frac{a''_x(1)}{a'_x(1)}$, where "$'$"s denote differentiation. Capital services producers rent effective capital in perfectly competitive markets to intermediate goods produces and earn a rental rate equal to $R^K_{x,t}/P_{C,t}$ per unit of capital.

In transforming physical into effective capital we allow for a capital quality shock (as in Gertler and Karadi (2011)), $\xi^K_{x,t}$, and assume it evolves according to

$$\log \xi^K_{x,t} = \rho_{\xi^K,x} \log \xi^K_{x,t-1} + \varepsilon^{\xi^K}_{x,t}, \qquad x = C, I,$$

where $\rho_{\xi^K,x} \in (0,1)$. Because this disturbance (as shown below) directly affects the value of capital—equivalently value of assets held by intermediaries since they provide finance for capital acquisitions—we call it an asset value shock.[11]

We introduce a richer information structure with respect to this process. Specifically, we assume the innovation of the shock process consists of two components,

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

[11] Recently this type of exogenous variation to the value of capital has enjoyed increasing popularity in macroeconomic models. Other studies that include this type of shock include for example Gourio (2012), Sannikov and Brunnermeier (2010), Gertler and Kiyotaki (2010) and Gertler et al. (2011).

where the first component, $\varepsilon^{\xi^{K,0}}_{x,t}$, is unanticipated and the second component, $\varepsilon^{\xi^{K,news}}_{x,t}$, is anticipated or news. For example, Alexopoulos (2011) and Ramey (2011) document, using a variety of sources from US data, people receive information (or news) in advance of the actual realization of technology and government spending innovations.[12] 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 advanced information (or news) received by agents in period $t-h$ about the innovation that affects asset values 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, information received $t-h$ periods in advance can later be revised by updated information received at $t-h+1, ...t-1$ or by the unanticipated component, $\varepsilon^{\xi^{K,0}}_{x,t}$. This implies news received at any anticipation horizon may only be partially (or fail to) materialize. To clarify this information structure, suppose we consider a one-quarter ahead news horizon so $H = 1$ and $\varepsilon^{\xi^{K}}_{x,t} = \varepsilon^{\xi^{K,0}}_{x,t} + \varepsilon^{\xi^{K,1}}_{x,t-1}$. Now in period t rational agents can form expectations about one period ahead asset value shock process as follows,

$$\begin{aligned}
\log \xi^K_{x,t} &= \rho_{\xi^K,x} \log \xi^K_{x,t-1} + \varepsilon^{\xi^{K,0}}_{x,t} + \varepsilon^{\xi^{K,1}}_{x,t-1} \\
\log \xi^K_{x,t+1} &= \rho_{\xi^K,x} \log \xi^K_{x,t} + \varepsilon^{\xi^{K,0}}_{x,t+1} + \varepsilon^{\xi^{K,1}}_{x,t} \\
\log \xi^K_{x,t+1} &= \rho_{\xi^K,x} \left(\rho_{\xi^K,x} \log \xi^K_{x,t-1} + \varepsilon^{\xi^{K,0}}_{x,t} + \varepsilon^{\xi^{K,1}}_{x,t-1} \right) + \varepsilon^{\xi^{K,0}}_{x,t+1} + \varepsilon^{\xi^{K,1}}_{x,t} \\
E_t \left[\log \xi^K_{x,t+1} \right] &= \rho^2_{\xi^K,x} \log \xi^K_{x,t-1} + \rho_{\xi^K,x} \varepsilon^{\xi^{K,0}}_{x,t} + \rho_{\xi^K,x} \varepsilon^{\xi^{K,1}}_{x,t-1} + \varepsilon^{\xi^{K,1}}_{x,t}. \qquad (8)
\end{aligned}$$

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

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

Further, they 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

[12] News shocks are introduced in a similar way for example in Davis (2007), Schmitt-Grohe and Uribe (2012), Khan and Tsoukalas (2012) and Fujiwara et al. (2011).

producers. Hence, total receipts of capital services producers in period $t+1$ are equal to,

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

which can be expressed as,

$$R^B_{x,t+1}Q_{x,t}\bar{K}_{x,t} \tag{9}$$

with

$$R^B_{x,t+1} = \frac{\frac{R^K_{x,t+1}}{P_{x,t+1}}\xi^K_{x,t+1}u_{x,t+1} + Q_{x,t+1}\xi^K_{x,t+1}(1-\delta_x) - a_x(u_{x,t+1})\xi^K_{x,t+1}A_{t+1}V_{t+1}^{\frac{a_C-1}{1-a_i}}}{Q_{x,t}}, \quad x = C, I, \tag{10}$$

where $R^B_{x,t+1}$ is the rate of return on capital. 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 earned by financial intermediaries in sector $x = C, I$. Note that the asset value shock process, $\xi^K_{x,t+1}$ directly affects the return to capital suggesting the news component of the process may potentially affect this return.

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. 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 optimization problem of capital producers in sector $x = C, I$ is given as,

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

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,

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

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 (sector specific) capital stock in sector x, evolves according to,

$$\bar{K}_{x,t} = (1-\delta_x)\xi^K_{x,t}\bar{K}_{x,t-1} + \left(1 - S\Big(\frac{I_{x,t}}{I_{x,t-1}}\Big)\right)I_{x,t}, \qquad x = C, I, \tag{11}$$

Sector specific capital implies that installed capital is immobile between sectors. Our assumption of sector specific capital is motivated by evidence in Ramey and Shapiro (2001) who report significant costs of reallocating capital across sectors.[13]

3.6 Financial sector

3.6.1 Financial Intermediaries

Financial intermediaries use deposits from households and their own equity capital and lend funds to capital services producers. 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 to capital services producers in each sector. In other words, we assume there are specialized intermediaries for financing each sector. This set-up can also be interpreted as one intermediary with two independent branches where the probability of lending specialization is equal across sectors and independent across time. The implementation of financial intermediaries in our two sector model is based on the framework developed in Gertler and Karadi (2011) in a standard one sector model, so we only briefly describe it here (Appendix C provides all the equations).[14] The balance sheet of an intermediary that lends in sector $x = C, I$, is,

[13] Two sector models with sector specific capital include, among others, Boldrin et al. (2001), Ireland and Schuh (2008), Huffman and Wynne (1999) and Papanikolaou (2011). Limited factor mobility is shown to be able to correct many counterfactual predictions of one sector models with respect to both aggregate quantities and asset returns. For example, Boldrin et al. (2001) show it can rationalize the equity premium puzzle, co-movement of sectoral inputs over the business cycle, the inverted leading indicator property of interest rates.

[14] 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 allowing the emergence of a representative bank in each sector.

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

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 claim. The variable $N_{x,t}$ denotes 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 of deposit allocation.

Financial intermediaries maximize expected terminal wealth, i.e. the discounted sum of future equity capital. The moral hazard/costly enforcement problem constraints the bank's ability to acquire assets and hence lending 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, $\varrho_{x,t}$. The leverage ratio (bank's intermediated assets to equity) is a function of the marginal gains of expanding assets (holding equity constant), expanding equity (holding assets constant), and the gain from diverting assets. Formally,

$$Q_{x,t}S_{x,t} = \varrho_{x,t}N_{x,t}, \tag{12}$$

Financial intermediaries which exit the industry can be replaced by new ones. Therefore, total wealth of financial intermediaries is the sum of the equity capital of existing, $N^e_{x,t}$, and new ones, $N^n_{x,t}$,

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

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,

$$N^e_{x,t} = \theta_B[(R^B_{x,t} - R_{t-1})\varrho_{x,t-1} + R_{t-1}]N_{x,t-1}, \qquad 0 < \theta_B < 1. \tag{13}$$

where, $R^B_{x,t} - R_{t-1}$ denotes the ex-post excess return on assets and $R^B_{x,t}$ is the return to capital given by equation (10). 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, ϖ, 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 $(1-\theta_B)Q_{x,t}S_{x,t}$. Therefore, new intermediaries begin with,

$$N^n_{x,t} = \varpi Q_{x,t}S_{x,t}, \qquad 0 < \varpi < 1. \tag{14}$$

Combining (13) and (14) leads 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, assumed to evolve as,

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

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,

$$R^{\Delta}_{x,t} = R^B_{x,t+1} - R_t. \tag{15}$$

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 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 denotes 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 (15) as a corporate bond spread.

3.7 Monetary policy

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

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

where R is the steady state (gross) nominal interest rate and (Y_t/Y_{t-1}) is the gross growth rate in real GDP. The interest rate responds to deviations of consumption sector 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,

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

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 converted (without cost) to use in the consumption sector. There are many examples that can fit this description. For example equipment produced for use in the automobile industry cannot be immediately or costlessly converted in equipment for use in services industries.[15] As shown by Huffman and Wynne (1999) this feature helps with sectoral co-movement in a two sector RBC model. 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 its magnitude. Moreover,

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

[15] Huffman and Wynne (1999) motivate this assumption by stating: "...it is trivial to observe that factories cannot immediately be refurbished so as to produce computers instead of pipelines, or trucks instead of cement. It takes time and resources to change the composition of goods produced."

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 $i.i.d.$ $N(0, \sigma_e^2)$. The measurement error is used to capture unmodelled output movements. These can arise from government spending or net exports which we abstract from in the model, motivated by recent evidence that assigns a relatively unimportant role of government spending shocks as a driving force of the business cycle. For example, Justiniano et al. (2010) report that government spending shocks account for about 2% in the variance of many macroeconomic aggregates, such as output, consumption and hours in business cycle frequencies.

4 Data and Methodology

We estimate the model using quarterly U.S. data (1990 Q2 - 2011 Q1) on eleven macroeconomic and financial market variables. Specifically, we use data on output, consumption, investment, wages, consumption and investment sector inflation, hours worked, nominal interest rate. Moreover we include non-financial corporate bond spreads and a measure of intermediaries' equity capital. We construct and use only sector specific spreads for corporate bonds issued by non-financial companies that are actively traded in the secondary market.[16] Appendix B describes the data sources and methods in detail. The vector of observables we use in the estimation is given as,

$$\mathbf{Y}_t = \left[\Delta \log Y_t, \Delta \log C_t, \Delta \log I_t, \Delta \log W_t, \pi_{C,t}, \pi_{I,t}, \log L_t, R_t, R_{C,t}^{\Delta}, R_{I,t}^{\Delta}, \Delta \log N_t\right]. \quad (16)$$

where Δ denotes the first-difference operator and we demean the data prior to estimation. In the vector above, $Y_t, C_t, I_t, W_t, \pi_{C,t}, \pi_{I,t}, L_t, R_t, R_{C,t}^{\Delta}, R_{I,t}^{\Delta}, N_t$, denote, output, consumption, investment, real wage, consumption sector inflation, investment sector inflation, hours worked,

[16] This information is provided by Datastream. In line with Gilchrist and Zakrajsek (2012) 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. The limited availability of credit spread data for the 1980s is a factor that restricts the sample for the estimation.

nominal interest rate, consumption sector bond spread, investment sector bond spread and bank equity respectively.

We use the Bayesian methodology to estimate the model parameters. 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 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. We also perform a test of (local) parameter identifiability as proposed by Iskrev (2010). This test evaluates the Jacobian of the vector containing all parameters (including the parameters describing the exogenous processes) which determine the first two moments of the data. When evaluated at the posterior mean of our parameter estimates this Jacobian matrix has full column rank—equal to the number of parameters to be estimated. This implies that any chosen vector of parameters around our estimates will give rise to an auto-covariance function that is different than that implied by our estimates. The test therefore suggests all parameters are identifiable in a neighbourhood of our estimates.[17]

Prior distributions. A number of parameters is held fixed during estimation. These are shown in Table 3.[18] For the remaining parameters we use prior distributions that conform to the assumptions used in Smets and Wouters (2007), Justiniano et al. (2010), Justiniano et al. (2011), Khan and Tsoukalas (2012). The first five columns in Table 4 list the parameters and the assumptions on the prior distributions.

A new parameter we estimate is ρ which determines the degree of intratemporal investment adjustment cost. This parameter was originally introduced in Huffman and Wynne (1999) and has been shown to be important, in the context of a calibrated two sector RBC model, in gen-

[17]All estimations are done using DYNARE (see Adjemian et al. (2011)), http://www.dynare.org. We calculate convergence diagnostics in order to check and ensure the stability of the posterior distributions of parameters as described in Brooks and Gelman (1998).

[18]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 assumed equal across sectors and 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. The steady state sectoral inflation rates are set to the sample averages and the sectoral steady state mark-ups are assumed to be equal to 10%. 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, very similar to the value used by Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). 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 in the sample. The average leverage ratio in the data is computed from the ratio of assets (excluding loans to consumers, real estate and holdings of government bonds) to equity for all U.S. insured commercial banks and is equal to 5.47. This value is considerably smaller compared to the ratio of total assets to equity, which is equal to 11.52 (see Appendix B for a detailed description).

erating sectoral co-movement in response to sector specific TFP shocks. We estimate a transformation of this parameter, given by $\rho^* = 1 + \frac{1}{\rho}$ that lies in the (0,1) interval and assume has a Beta distribution.

In the benchmark model we consider four and eight quarter ahead asset value news. This choice is guided by the desire to economise on the state space and consequently on parameters to be estimated while being flexible enough such that the news process is able to accommodate revisions in expectations. In section A.1 we show this choice to be supported by the model fit criterion though we also discuss denser information structures. Similar news horizons are considered by Christiano et al. (2010), Schmitt-Grohe and Uribe (2012) and Khan and Tsoukalas (2012). 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. Its important to note we specify priors for the news components of asset value shocks such that the sum of the variance of the news components equal the variance of the respective unanticipated component. This choice is partly guided by the findings of Beaudry and Portier (2006) and Beaudry and Lucke (2010) who estimate that news shocks (TFP) account for around 50% of macroeconomic fluctuations. In fact our choice implies that "a-priori" news shocks are relatively unimportant in explaining the variation in the set of observables. Therefore, shocks of this type are handicapped in relation to more conventional shocks before the model is taken to the data. Table 9 reports a variance decomposition computed at the prior means of parameters which illustrates this fact: the combined contribution of news shocks does not exceed 4% in the variance of any of the main macroeconomic aggregates and where shocks to TFP processes, wage mark-up and sectoral price mark-ups dominate.

Posterior distributions. Table 4 reports the posterior mean and the 10% and 90% intervals of estimated parameters. Overall, the estimates are broadly consistent with earlier studies using one sector models, e.g., Smets and Wouters (2007), Khan and Tsoukalas (2012) and Justiniano et al. (2010) and we do not discuss them in detail. The transformed parameter that captures intratemporal investment adjustment costs is estimated at 0.358. This maps into a value of $\rho = -1.55$, suggesting a mild degree of intratemporal adjustment costs in changing the composition of sectoral investment flows. As far as we are aware this is the first estimate based on a DSGE model reported in the literature.

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 intermediaries. The posterior estimates for the volatility of equity shocks suggest a considerable rightward shift from the prior mean and the estimates for the AR(1) parameters suggest considerable persistence for the consumption sector equity capital shock. Second, a shock that affects the value of assets of intermediaries in sector $x = C, I$. The asset value shock consists of unanticipated and anticipated (news) components. The standard deviations for the news components (consumption sector) are es-

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 (both sectors)
λ_w	0.1	Steady state wage markup
g_a	0.001	Consumption sector sample average TFP growth
g_v	0.004	Investment sector sample average TFP growth
$p_i \frac{i}{c}$	0.399	Steady state investment to consumption ratio
θ_B	0.96	Probability of bankers survival
ϖ	0.00089	Share of assets 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 (per quarter)

timated to be around or above their unanticipated components suggesting the former may be important in accounting for the variation in the data. In general the processes for the asset value shocks in the consumption sector are estimated to be considerably more persistent compared to their counterparts in the investment sector. Similarly, the volatilities in the news components of the former are estimated to be larger compared to their counterparts in the investment sector. We now turn to examine the importance of shocks in accounting for fluctuations.

5 Variance Decompositions

In this section we evaluate the relative contribution and importance of various disturbances in accounting for fluctuations in the data. We discuss results from a decomposition at the frequency domain, focussing on business cycle frequencies. We also report an unconditional decomposition in Appendix A.6 (Table10).

Frequency domain. Table 5 reports a variance decomposition based on the spectral density of the level of the observables at business cycle frequencies focusing on periodic components that encompass cycles between 6 and 32 quarters. Asset value news shocks (consumption sector) account for 30.5%, 22.4%, 31.0% of the variance in output, investment and hours worked respectively, with news arriving two years ahead being the dominant component. Financial shocks (i.e. equity and asset value shocks combined) account for 36.1%, 28.1%, 35.1% of the

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 asset value	Beta	0.60	0.20	0.9142	0.8719	0.9570
$\rho_{\xi^K,I}$	I-sector asset value	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 asset value	Inv Gamma	0.10	2.0	0.0558	0.0250	0.0863
$\sigma_{\xi^{K,4,C}}$	C-sector asset value 4Q ahead	Inv Gamma	$0.1/\sqrt{2}$	2.0	0.0521	0.0186	0.0889
$\sigma_{\xi^{K,8,C}}$	C-sector asset value 8Q ahead	Inv Gamma	$0.1/\sqrt{2}$	2.0	0.1709	0.0951	0.2459
$\sigma_{\xi^K,I}$	I-sector asset value	Inv Gamma	0.10	2.0	2.6620	2.1124	3.2142
$\sigma_{\xi^{K,4,I}}$	I-sector asset value 4Q ahead	Inv Gamma	$0.1/\sqrt{2}$	2.0	0.0632	0.0165	0.1229
$\sigma_{\xi^{K,8,I}}$	I-sector asset value 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, $\rho^* = 1 + \frac{1}{\rho}$.

variance in the same set of variables. In Appendix A.3 we undertake a comparison of sample paths generated by the model (with news shocks only) against the actual sample paths of the observables. This exercise visually illustrates the role of asset value news shocks in explaining the in-sample variation in the data. A noteworthy finding is that the path generated from the news shocks simulation of the model correctly captures most of the turning points in actual output growth and can successfully account for the 2001 and 2008 recessions. It also tracks quite well the behavior of total hours worked.

TFP shocks are also of considerable importance at business cycle frequencies. Sectoral TFP shocks together account for 19.7%, 11.2%, 31.5%, 12.8% of the variance in output, consumption, investment and hours worked respectively. Interestingly, TFP shocks of the investment specific type (i.e. TFP shocks in the investment sector) account for the bulk of the variance shares above (except consumption). Specifically, they account for 14.1%, 30.8% and 12.2% of the variance in output, investment and hours worked respectively. The importance of TFP shocks of the investment specific type stands in contrast to findings in earlier studies (e.g. Schmitt-Grohe and Uribe (2012), Christiano et al. (2010)) that find shocks of this type are negligible sources of fluctuations but more in line with the findings in Justiniano et al. (2010) and Fisher (2006) who report a large share of fluctuations to be accounted for by investment specific shocks. The reason for these apparently contradicting findings is that the former studies, identify investment specific shocks 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 as they have to match point-by-point in the sample the time series properties of the relative price of investment. But in our two sector model this restriction is not necessarily valid and hence other shocks can also affect the relative price of investment, leaving more room for investment specific shocks to affect model dynamics in the short run. To conserve space we present a more detailed explanation for this finding in Appendix A.4.

The preference shock accounts for about 42.5% in the variance of consumption. This is line with Justiniano et al. (2010) who also report evidence for the otherwise irrelevant preference shock in accounting for consumption fluctuations. The price mark-up shock in the investment sector accounts for a sizeable fraction in the variance of investment and hours worked, approximately 34% of the forecast error variance in each of these variables. Both price mark up shocks explain a large fraction of variation in the sectoral inflation rates along with the investment sector TFP which accounts for 22.0% in the variance of that sector's inflation. The wage mark-up shock primarily explains a large share of the variance in real wage (56.5%) and to a much smaller extent variance in hours worked (8.5%).

Turning to financial variables, the main driving forces for the variance in consumption sector corporate bond spread are asset value news and equity capital shocks (consumption sector). The eight quarter ahead news component and the equity capital shock, account for 39.3% and

32.7% in its variance, respectively. Thus a sizeable fraction of the variance in the consumption sector spread can be accounted for by news shocks, suggesting a significant amount of advance information present in the corporate bond spread series. By contrast only a small fraction of the variation in the investment sector spread is accounted for by news shocks. The investment sector TFP, monetary policy, consumption sector mark-up and investment sector equity shocks each approximately account for 20.0% in the variance of that series. Finally, news components account for about 23.0% in the nominal interest rate. This suggests monetary policy may be responding 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.

The importance of news shocks. Why do asset value news shocks become so important in accounting for the variation in the data in the presence of multiple sources of disturbances? This type of news shock is distinct from other, more conventional, shocks included in the estimation that may also affect the value of assets, e.g. TFP shocks. Importantly, relative to these other disturbances, it generates the right type of co-movements between aggregate quantities, prices and intermediaries' equity capital (see section 6 for an exposition of the transmission). More specifically it generates, (a) procyclical movements in quantities, (b) countercyclical movements in credit spreads, (c) inverted lead indicator property (with respect to output) of the short term nominal rate—the fact that in the data the nominal rate is positively correlated with past and negatively correlated with future output growth)—and (d) the lead-lag relationship between equity capital growth on the one hand with output growth and investment growth on the other, namely the fact that equity growth is positively correlated with future output and investment growth. An illustration of the facts above can be confirmed by examining Figure 2. The Figure presents dynamic correlations among several key variables pertaining to facts (a)-(d) above, in the data (solid line), model with all shocks (line with '+'), model with the dominant 2 year ahead news shock only (line with circles). The dynamic correlations generated by the news only driven model (all the other shocks set at zero) are very similar to the correlations generated by the model with all shocks active. At the same time the news driven model also generates correlations broadly similar with the dynamic correlations in the data. These findings combined explain why the news shock becomes important in accounting for fluctuations in aggregate quantities and prices.

Table 5: Variance decomposition at posterior estimates—business cycle frequencies (6-32 quarters)

									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	0.055	0.141	0.013	0.034	0.080	0.015	0.214	0.085	0.018	0.000	0.017	0.021	0.015	0.290	0.000	0.000
	[0.044 0.066]	[0.125 0.162]	[0.010 0.018]	[0.029 0.039]	[0.070 0.089]	[0.011 0.019]	[0.164 0.267]	[0.062 0.108]	[0.015 0.022]	[0.000 0.000]	[0.013 0.023]	[0.017 0.025]	[0.011 0.021]	[0.249 0.329]	[0.000 0.000]	[0.000 0.000]
Consumption	0.106	0.006	0.425	0.001	0.135	0.075	0.020	0.146	0.003	0.000	0.014	0.010	0.006	0.053	0.000	0.000
	[0.088 0.125]	[0.004 0.009]	[0.384 0.456]	[0.000 0.001]	[0.117 0.153]	[0.059 0.092]	[0.013 0.032]	[0.113 0.179]	[0.002 0.003]	[0.000 0.000]	[0.011 0.018]	[0.009 0.012]	[0.004 0.008]	[0.044 0.064]	[0.000 0.000]	[0.000 0.000]
Total Investment	0.007	0.308	0.012	0.000	0.018	0.001	0.344	0.025	0.013	0.000	0.009	0.036	0.010	0.214	0.000	0.000
	[0.005 0.008]	[0.274 0.346]	[0.009 0.016]	[0.000 0.000]	[0.016 0.020]	[0.001 0.002]	[0.281 0.412]	[0.018 0.033]	[0.010 0.016]	[0.000 0.000]	[0.007 0.012]	[0.028 0.045]	[0.007 0.014]	[0.178 0.244]	[0.000 0.000]	[0.000 0.000]
Total Hours	0.006	0.122	0.013	0.001	0.072	0.007	0.344	0.085	0.014	0.000	0.012	0.015	0.015	0.295	0.000	0.000
	[0.005 0.008]	[0.107 0.142]	[0.009 0.019]	[0.001 0.001]	[0.062 0.081]	[0.004 0.009]	[0.280 0.410]	[0.062 0.111]	[0.011 0.017]	[0.000 0.000]	[0.009 0.016]	[0.013 0.017]	[0.011 0.020]	[0.245 0.333]	[0.000 0.000]	[0.000 0.000]
Real Wage	0.068	0.086	0.014	0.000	0.017	0.134	0.054	0.565	0.001	0.000	0.007	0.007	0.003	0.039	0.000	0.000
	[0.056 0.085]	[0.075 0.098]	[0.008 0.021]	[0.000 0.000]	[0.012 0.023]	[0.113 0.166]	[0.039 0.071]	[0.513 0.610]	[0.001 0.002]	[0.000 0.000]	[0.005 0.010]	[0.006 0.008]	[0.003 0.005]	[0.029 0.049]	[0.000 0.000]	[0.000 0.000]
Nom. Interest Rate	0.001	0.094	0.100	0.001	0.234	0.188	0.085	0.051	0.003	0.000	0.004	0.009	0.007	0.223	0.000	0.000
	[0.001 0.002]	[0.085 0.105]	[0.082 0.117]	[0.001 0.002]	[0.206 0.257]	[0.154 0.221]	[0.060 0.117]	[0.037 0.062]	[0.002 0.004]	[0.000 0.000]	[0.003 0.005]	[0.008 0.011]	[0.005 0.010]	[0.190 0.255]	[0.000 0.000]	[0.000 0.000]
C-Sector Inflation	0.004	0.099	0.115	0.000	0.120	0.368	0.038	0.109	0.000	0.000	0.001	0.004	0.003	0.135	0.000	0.000
	[0.004 0.006]	[0.089 0.112]	[0.095 0.137]	[0.000 0.001]	[0.106 0.136]	[0.310 0.421]	[0.025 0.055]	[0.084 0.134]	[0.000 0.001]	[0.000 0.000]	[0.001 0.001]	[0.003 0.005]	[0.002 0.005]	[0.109 0.159]	[0.000 0.000]	[0.000 0.000]
I-Sector Inflation	0.001	0.220	0.005	0.001	0.075	0.001	0.203	0.016	0.009	0.000	0.011	0.115	0.013	0.326	0.000	0.000
	[0.001 0.002]	[0.199 0.246]	[0.004 0.006]	[0.001 0.001]	[0.066 0.084]	[0.001 0.002]	[0.164 0.250]	[0.013 0.019]	[0.007 0.011]	[0.000 0.000]	[0.008 0.014]	[0.101 0.132]	[0.009 0.018]	[0.281 0.371]	[0.000 0.000]	[0.000 0.000]
C-Sector Spread	0.005	0.033	0.008	0.000	0.022	0.042	0.106	0.004	0.327	0.000	0.016	0.025	0.016	0.393	0.000	0.000
	[0.004 0.007]	[0.028 0.038]	[0.006 0.010]	[0.000 0.000]	[0.019 0.026]	[0.033 0.051]	[0.078 0.141]	[0.003 0.006]	[0.293 0.367]	[0.000 0.000]	[0.012 0.020]	[0.021 0.030]	[0.012 0.023]	[0.346 0.434]	[0.000 0.000]	[0.000 0.000]
I-Sector Spread	0.019	0.187	0.033	0.001	0.191	0.179	0.097	0.025	0.009	0.206	0.000	0.026	0.001	0.023	0.000	0.000
	[0.015 0.022]	[0.165 0.215]	[0.026 0.040]	[0.001 0.001]	[0.169 0.213]	[0.147 0.212]	[0.060 0.151]	[0.019 0.030]	[0.007 0.011]	[0.161 0.257]	[0.000 0.000]	[0.020 0.033]	[0.001 0.001]	[0.017 0.031]	[0.000 0.000]	[0.000 0.001]
Equity	0.066	0.211	0.013	0.001	0.090	0.078	0.042	0.008	0.074	0.001	0.027	0.077	0.014	0.294	0.000	0.000
	[0.055 0.077]	[0.189 0.235]	[0.010 0.018]	[0.001 0.001]	[0.080 0.100]	[0.062 0.095]	[0.029 0.059]	[0.005 0.011]	[0.064 0.087]	[0.001 0.001]	[0.021 0.034]	[0.070 0.088]	[0.011 0.020]	[0.252 0.338]	[0.000 0.000]	[0.000 0.000]

Median shares are reported with values in brackets 5 and 95 percentiles. 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, ς_I = Investment sector equity capital, $\xi_C^{K,0}$ = Unanticipated consumption sector asset value, $\xi_C^{K,x}$ = x quarter ahead consumption sector asset value news, $\xi_I^{K,0}$ = Unanticipated investment sector asset value, $\xi_I^{K,x}$ = x quarters ahead investment sector asset value news. Business cycle frequencies considered in the decomposition correspond to periodic components with cycles between 6 and 32 quarters. The decomposition is performed using the spectrum of the DSGE model and an inverse first difference filter to reconstruct the levels for output, consumption, total investment, the real wage and equity. The spectral density is computed from the state space representation of the model with 500 bins for frequencies covering the range of periodicities.

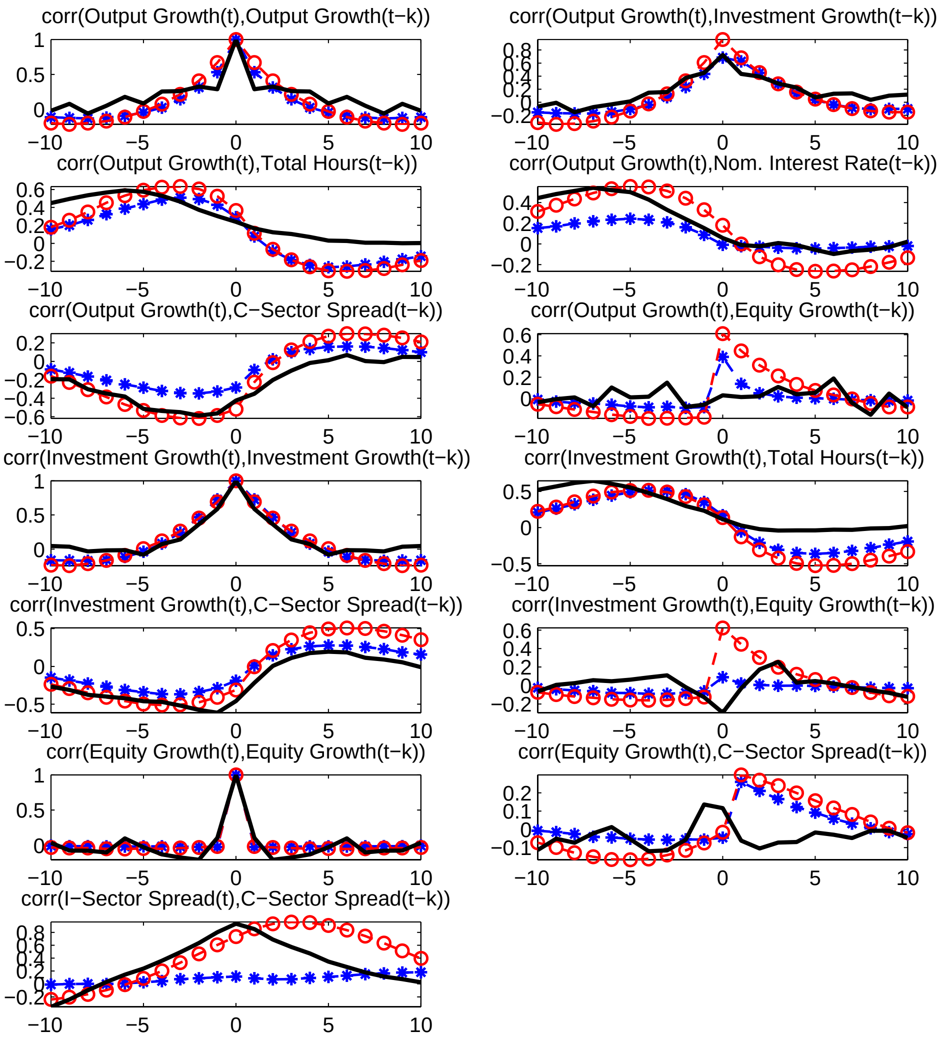

Figure 2: Dynamic correlations among several key variables in the data (solid line), implied by the baseline model with all shocks (blue line with '+') and the model with the eight quarter ahead consumption sector asset value news shock only (red line with circles).

Our quantitative results are similar with findings reported in Gilchrist et al. (2009) and Gilchrist and Zakrajsek (2012), studies that exploit information from corporate bond spreads but 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). Gilchrist and Zakrajsek (2012), decompose the movements in credit spreads to variation in default risk and excess bond premium with the latter shown to be tightly associated with the quality of balance sheets of key financial intermediaries. They find variation in the excess bond premium can explain around 10% and 25% of output and investment variation respectively, quite similar to the variance shares in the same variables accounted for by news shocks. In section 7 we show that our estimated news shocks are strongly correlated with both market measures of default risk and the excess bond premium which explains the similarities in the findings above. Our quantitative results also bear similarities with findings reported in Christiano et al. (2010) who identify news shocks (in riskiness about entrepreneurial activity) in a one sector DSGE model with Bernanke et al. (1999) style financial frictions to be a significant source of U.S. fluctuations.

In summary, the variance decompositions reveal an important role for (consumption sector) asset value news shocks, suggesting they are one of the main driving forces behind fluctuations in the majority of real macro and financial variables. We now turn to describe how these shocks propagate in the model.

6 The Propagation of Asset Value News Shocks

The variance decompositions above suggest news shocks are important in accounting for the dynamics of the data. In this section, we discuss the model's responses to this type of shock through a series of impulse response functions (IRFs) in order to shed light on the reasons for their important role in accounting for fluctuations.

News Shocks. Figure 3 shows the responses to an anticipated (two year ahead) decline in the value of (consumption sector) assets held by the financial sector.[19] The value of assets decline on impact upon arrival of bad news (C-sector price of capital). 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 expression that defines the return to capital in the consumption sector, equation (10) re-arranged to yield,

$$Q_{C,t} = \frac{\frac{R^K_{C,t+1}}{P_{C,t+1}}\xi^K_{C,t+1}u_{C,t+1} + Q_{C,t+1}\xi^K_{C,t+1}(1-\delta_C) - a(u_{C,t+1})\xi^K_{C,t+1}A_{t+1}V_{t+1}^{\frac{a_C-1}{1-a_i}}}{R^B_{C,t+1}}.$$

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 eight quarters as equity capital losses slow down. Notice, when the shock actually materializes banks hold considerably less assets relative to equity capital 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 and lending (C-sector financial claims). Credit spread in the consumption sector rise (C-sector

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

spread) in anticipation of the deterioration in asset values, consistent with its countercyclical behavior in the data. The shock spills over to the investment sector through lower demand for capital goods from this sector. 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 overall reduction in the production of investment goods, including investment goods produced for the investment sector. The reduction in investment demand leads to a lower volume of financing for investment sector capital goods (I-sector financial claims) and consequently lower valuation of these assets (I-sector price of capital). 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 experienced by the investment sector are due to the *real sectoral link* between the two sectors, i.e. the reduction in demand for capital goods from the consumption sector sets off a recession in the investment sector. [20]

The anticipation of the decline in the value of assets also triggers a negative wealth effect that reduces consumption. The negative effect on consumption and investment (as explained above) leads to a strong initial decline in output before the shock materializes. One noteworthy aspect of the adjustment to the value news disturbance is the fact that the contractionary phase is quite long and recovery is slow. The combination of news and subsequent realization lead to a deeper and longer recession phase. The arrival of bad news itself generate significant declines in macroeconomic aggregates. However, the actual realization of the innovation sets off an extended phase of reduced financing, depressed asset values and economic activity. Figure 3 shows that lending declines further at the time when the shock materializes and remains depressed for an extended period of time.

All macroeconomic aggregates exhibit co-movement in response to the news shock: output, consumption, investment and hours worked immediately decline in response to bad news. 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 news shock.

Inspecting the mechanism. The discussion of the IRFs above illustrates that news shocks generate the broad based aggregate and sectoral comovement typically observed during a business cycle. In this section we investigate in more detail the reasons why news shocks turn out

[20] In order to isolate this *real sectoral link* channel we undertake an experiment where we shut off the financial intermediation in the investment sector while keeping it active in the consumption sector. Figure 9 in Appendix A.5 shows the IRFs.

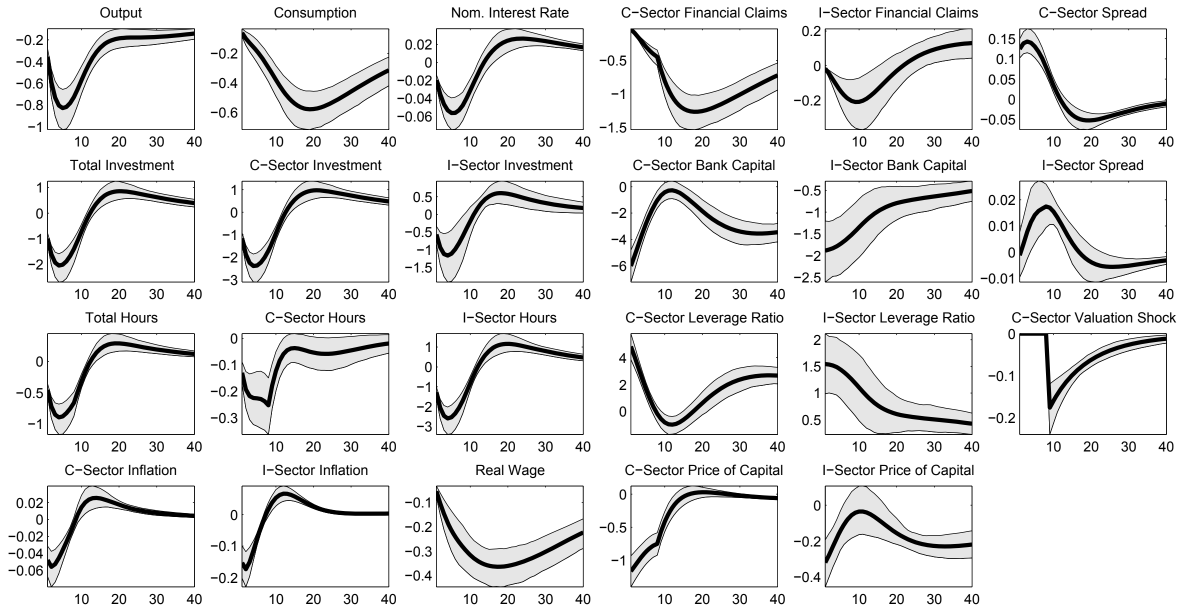

Figure 3: Responses to a one std. deviation negative asset value news shock (anticipated 8 quarters ahead) in the consumption sector.

to be producing dynamics that resemble the business cycle. Specifically, in Figure 4 we compare the IRFs from a model with and a model without a financial intermediation channel. In both sets of IRFs we use identical parameter values as estimated in Table 4 and we show the responses to an eight quarter ahead news shock.

Figure 4 demonstrates that financial intermediation not only strongly amplify the economy's response to the news shock, through its impact on the leverage constraint that restricts the amount of credit flowing to the real economy, but also changes its transmission. The model without the financial channel cannot generate aggregate or sectoral comovement in response to the news shock. The shock generates a decline in the value of capital (not shown) as in the model with the financial channel but contrary to the responses in the latter, output, investment and total hours worked respond positively to this unfavorable shock. Both sectoral investment variables rise, while investment sector hours rise and consumption sector hours fall in response to this shock. The reason for the radically different responses is that in the model without a financial channel this shock acts as an anticipated negative supply shock, i.e. agents anticipate a reduction in the productivity of capital services and depreciation of the capital stock in the consumption sector. This implies that consumption will have to fall in the future. Agents attempt to protect from the future deterioration in consumption sector capital now via higher investment that builds up capital in that sector. Given the sector specific nature of capital (installed capital cannot move between sectors), investment is the only feasible way to change the effective quantity of capital across sectors. Thus investment sector output rises. Since labor moves freely, hours worked can change swiftly across sectors, thus to boost capital production the household reallocates hours worked from the consumption to the investment sector. Effectively, agents substitute resources out of consumption into the investment sector to smooth out the future consumption decline.

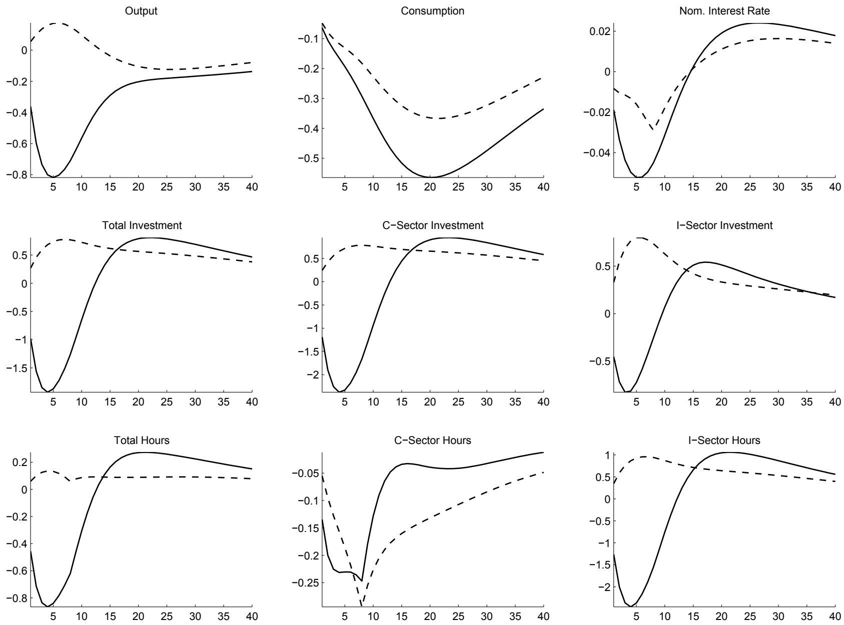

Figure 4: Responses to a negative one std. deviation asset value news shock (anticipated 8 quarters ahead) in the consumption sector. Model with (solid line) and without (dashed line) financial frictions.

7 Relation of asset value news shocks with financial market indicators

The exercise above indicates that the financial intermediation channel is key for the ability of the news shock to play a quantitatively important role in accounting for aggregate fluctuations.

While not directly comparable (the timing is different since it is anticipated), it acts similar to a depreciation shock as in Gourio (2012) in terms of quantities and risk premia, though a standard preference specification like ours implies countercyclical consumption behavior in Gurio. We have introduced this disturbance as in Gertler and Karadi (2011) who dub it broadly as a capital quality shock. As shown above, the shock directly affects the value of capital and consequently value of assets in intermediaries balance sheets. But what factors reflect news about capital quality and consequently news about asset values? Installed capital may rapidly lose value during recessions if, for example, capital is good or firm-specific and existing products get obsolete during these periods—in line with the evidence in Bernard et al. (2010) who show there is substantial cyclical product creation and destruction in the U.S. manufacturing sector. This may be anticipated by investors in corporate bond markets and Philippon (2009) argues the latter are likely to be more informative for the pricing of installed capital, compared to the stock market.[21]

Recently attention has been given to the role financial intermediaries play in the determination of asset prices. Evidence reported in Adrian et al. (2010), emphasize that losses in balance sheets of key financial intermediaries (e.g. securities broker-dealers and shadow banks) affect a wide spectrum of asset returns and cause in effect risk averse behavior: a reduction in lending to the corporate sector and increases in risk premia (excess returns). For example, Adrian et al. (2010) show that negative leverage growth of such intermediaries is associated with higher future excess corporate bond returns and lower output growth. Adrian et al. (2010) suggest these dynamics can be interpreted as the (time-varying) effective risk bearing capacity of the financial sector, in other words its willingness to bear risk as balance sheets contract or expand. It is worth noting the financial channel in the model predicts behavior consistent with these findings above: the leverage constraint in the model implies gloomy asset value news generate losses in equity capital, reducing leverage and lending to the corporate sector and cause corporate bond spreads to rise. It would thus be interesting to compare the estimated asset value news process with a measure that proxies for the effective risk bearing capacity of the financial sector as well as other available financial market indicators as a way of model validation.

News shocks, expected default and the excess bond premium. We compare the estimated news shock (eight quarter ahead) series with three financial market indicators. We consider two indicators of default risk for the U.S. non-financial corporate sector available from Fitch and the GZ—excess bond premium, estimated by Gilchrist and Zakrajsek (2012) from firm-level U.S. corporate bond spreads. Figure 5 plots from left to right the estimated news shock series with, (a) Fitch 5-year ahead probability of default of all firms, (b) Fitch 5-year ahead probability of default of consumption sector firms only and (c) GZ—excess bond premium. The plots begin in 2001 due to data availability of the expected default series.[22] The default probability is a forward looking measure of default risk, providing advance information of changes in the credit quality of bond issuing firms, whereas the estimated GZ—excess bond premium series captures factors emphasized by Adrian et al. (2010) described above, that is, factors that cause variation in intermediaries' balance sheets and risk premia and proxy for variation in the effective risk

[21] The argument is that bond market prices will reflect the existing firm technology rather than growth options or equivalently organizational rents from expanding into new areas which are thought to be better reflected in stock prices.

[22] In these plots, a positive value of the the asset news series indicates bad news. To facilitate comparison the default risk indicator is normalized to have a zero mean and the same standard deviation as the shock series. The same normalization applies to the other indicators. The Fitch measure includes information from 655 non-financial US corporations, 222 of which are in the consumption sector. We have also undertaken comparisons with the 1 year ahead probability of default and found a somewhat weaker correlation suggesting the news shocks we identify reflect more long term risks.

bearing capacity of the financial sector as a whole.[23]

The estimated news shock series though noticeably more volatile is strongly correlated with all three measures. Gloomy news is associated with a rise in expected defaults but also a rise in the excess bond premium suggesting these phenomena may reflect a common factor. Figure 5 indicates the estimated news process captures the rise in the probability of default both in the 2001 and the 2008 recessions. It begins to signal unfavorable news at the same time when both probability of default measures and the excess bond premium begin to pick up in the mid 2007. Note that, prior to the 2008 recession, the probability of default especially for non-financial consumption sector firms (middle panel), picks up more sharply compared to the all-firm inclusive measure, indicating more serious risks in that sector and this is captured successfully by the estimated news process. Our estimated news shock also co-moves quite strongly with the GZ—excess bond premium. This fact should not be surprising since the leverage constraint in the model creates a feedback loop between intermediaries' equity capital and asset prices that resembles the effective risk capacity dynamics described in Gilchrist and Zakrajsek (2012) and Adrian et al. (2010).

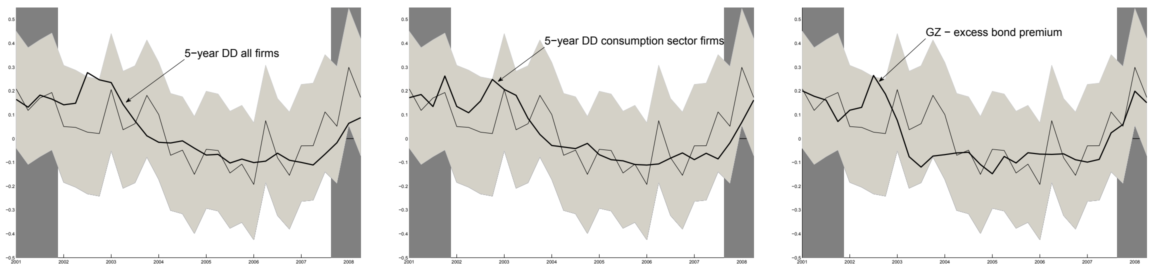

Figure 5: Asset value news (8 quarter ahead) shock (thin line) and financial market indicators (thick line) — Fitch five-year ahead probability of default–all firms (left panel), Fitch five-year ahead probability of default of companies in the consumption sector (middle panel), Gilchrist and Zakrajsek (2012) excess bond premium (right panel). A positive value for the news shock series indicates unfavorable news. Light grey areas indicate two standard deviation bands of the shock series. Dark grey bars show NBER dated recessions.

Asset value news shocks and lending indicators. Given the strong correlation of the news shock series with the excess bond premium and the tight connection of the latter with lending behavior, we compare the estimated news shock to the Federal Reserve Board's Loan Officer Opinion Survey (LOOS), a qualitative indicator that captures banking sector lending practices.[24]

[23]Equivalently it captures variation in the price of default risk, i.e. deviations in the pricing of corporate bonds relative to the default risk of the issuer, or extra compensation (relative to expected default) demanded by investors for holding corporate bonds.

[24]The LOOS 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*

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 6, we plot the net balance from the survey against the (negative) of the 2 year ahed value news shock.[25] The news shock series comoves with the lending standards index over the entire sample. 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 6 is the fact that both lending standards and unfavorable news about asset values rise sharply before and during recessions suggesting a tight connection during those periods.[26]

In addition the LOOS survey includes responses for the specific reasons given for changes in lending standards. These reasons include, ”reduced tolerance for risk”, ”future economic outlook”, ”degree of competition”, ”industry specific problems”, ”reduced liquidity in the secondary market for loans” among others. Its interesting to note that our news shock series is more strongly correlated with the net percent balance of banks reporting ”reduced tolerance for risk” (both relative to the entire net balance and the remaining reasons cited) as a primary reason behind tightening in lending standards. This is consistent with the tight association between the news shock series and the excess bond premium discussed above.

8 Conclusions

In this paper we used Bayesian techniques to estimate a two-sector DSGE model for the U.S. economy using a sample from 1990Q2 to 2011Q1 in order to quantitatively explore the interaction between financial markets, news shocks and the real economy. The model we use borrows elements from earlier RBC multi-sector environments and allows for financial intermediation constraints of the same type as in Gertler and Karadi (2011), Gertler and Kiyotaki (2010). We allow for a variety of disturbances that have been proposed in earlier literature and introduce

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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

[25] A positive value of the shock indicates bad news. To facilitate comparison with the shock series the lending standards index is normalized to have a zero mean and the same standard deviation as the shock series.

[26] Interestingly, Lown and Morgan (2006), using a VAR methodology find that innovations to LOOS lending standards predict contractions in loans and output. Most recently, Gambetti and Musso (2012) using a time-varying VAR methodology, find loan supply shocks to have a sizeable impact on US GDP, explaining approximately 20% of its variance, with their estimated contribution particularly important during recessions. 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.

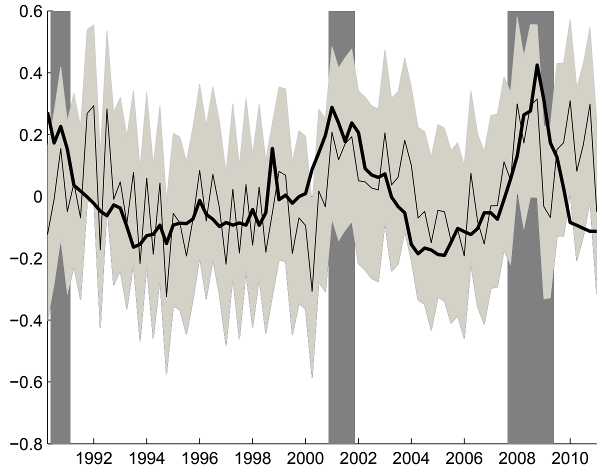

Figure 6: Asset value news (8 quarter ahead) shock (thin line) and Senior Loan Officer Opinion Survey on Bank Lending Practices by the Federal Reserve Board (thick line). Light grey areas indicate two standard deviation confidence bands of the shock series. Dark grey bars show NBER dated recessions.

two types of financial shocks, namely, equity capital and asset value shocks. These latter disturbances incorporate components that provide advance information or news to agents when forming forecasts about the future value of assets. Our paper contributes to the ongoing debate on the importance of news shocks for aggregate fluctuations and highlights a new—financial—channel that can give quantitatively important real effects of news shocks while at the same time makes some headway in addressing sectoral co-movement.

Our results are as follows. *First*, asset value *news* shocks explain a sizeable fraction of fluctuations at business cycle frequencies, accounting for 31% of output, 22% of investment and 31% of hours variation. Previous work (see Gertler and Karadi (2011), Gertler and Kiyotaki (2010), Gourio (2012)) has examined qualitatively the properties of purely unanticipated shocks of this type in the context of one sector calibrated models. By considering both unanticipated and news shocks our paper provides, to the best of our knowledge, the first quantitative assessment of the magnitude and the relative importance of these different components. Our estimation method exploits the fact that financial variables (corporate bond spreads and equity capital) contain substantial information about asset value news shocks. We find the quantitative importance of news shocks—in terms of accounting for the variance shares of real macro variables reported above—approximately doubles when financial variables are included in the estimation than if they are not. Consequently, the news component of asset value disturbances accounts for a significant fraction of the variation in corporate bond spreads and equity capital. Its interesting to note, the data strongly favors news shocks that only directly affect the value of assets in the consumption sector—investment sector asset value disturbances are largely irrelevant for fluctuations. Instead, the data prefers to use the sectoral links of the model as a natural propagation mechanism of consumption sector shocks across sectors.

Second, and more importantly this type of financial news shock 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. Moreover, these co-movement properties of news shocks obtain with a standard preference specification. Instead the financial channel of the model is key for co-movement and propagation. Gloomy news about asset values generate loses in intermediaries' equity capital, reductions in lending to the corporate sector and a feedback loop between equity capital, lending and countercyclical credit spreads, a process that sets off a recession. These dynamics are very similar to those reported in recent work by Gilchrist and Zakrajsek (2012) and Adrian et al. (2010), based on very different methodologies, suggesting that the model estimated here captures to a large extent the key links between financial markets and the real economy present in the data and provides a useful perspective to further study these phenomena.

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9 Appendix (For online publication)

A Additional Results, Tables and Figures

A.1 Robustness

In this section we aim to assess the fit of the benchmark model in relation to plausible alternatives. Specifically we undertake three broad comparisons. We compare the benchmark with, (a) model without financial intermediation, (b) model without news shocks or, (c) model with news in either TFP or asset value disturbances or both. Models with TFP news components have been estimated in Khan and Tsoukalas (2012), Fujiwara et al. (2011) and Schmitt-Grohe and Uribe (2012) among others, using one sector DSGE frameworks, but the results therein have been pointing towards a limited quantitative role of TFP news shocks. At the same time it is entirely possible that our richer two sector model and use of several financial sector variables may yield different conclusions on the role of TFP news shocks. Table 6 reports a comparison of different specifications we have considered based on marginal data densities computed using the modified harmonic mean estimator suggested by Geweke (1999). First, we note the benchmark model with four and eight quarters ahead asset value news dominates—in terms of this metric—specifications that include TFP news only (model B and C) or both TFP and asset value news (model D and E). Further, it dominates model versions with news that arrive more frequently, i.e. 1,4 and 8 quarter ahead news and also dominates the model with unanticipated shocks only (model F). Second, we also compare the fit of the benchmark model to a model with financial frictions turned off. This latter model version is a two-sector New Keynesian model with the same nominal and real frictions and shocks as the benchmark. 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 since the model without financial frictions makes no predictions for financial variables. The benchmark model with financial frictions has a higher marginal data density compared to the model without financial frictions on the restricted set of observables, highlighting the importance of financial frictions in fitting the data. Third, we highlight the fact that the presence of financial variables in the estimation significantly raises the contribution of asset value news shocks in accounting for the dynamics in the data. When we estimate the model with the restricted set of data (model version G), the variance shares accounted for by news shocks decline significantly compared to the benchmark model with the financial series used in estimation. Specifically, in model version G, news shocks account for approximately 15%, 12%, 19% of the forecast error variance (business cycle frequencies) in output, investment and hours worked respectively (see Table 8). These shares are approximately only half of the shares accounted for by news shocks in the benchmark.

We have considered four additional robustness exercises briefly described here.[27] First, we estimate the benchmark model with the addition of a marginal efficiency of investment (MEI) shock, motivated by previous work in one sector estimated DSGE models that finds a significant share of macroeconomic quantities are driven by shocks of this type (see Justiniano et al. (2010), Justiniano et al. (2011), Khan and Tsoukalas (2012)). We find the MEI shock to be irrelevant in accounting for the variation in the data—essentially we obtain a nearly identical variance decomposition to the benchmark model (without an MEI). For space consideration we do not report the results from this exercise but we note the model includes an investment sector TFP shock that can properly capture dynamics induced by an MEI shock. Second, we estimate the benchmark model with the addition of AR(1) measurement errors that we assume are present in the financial observables, namely the corporate bond spreads and the equity capital series, potentially accounting for model misspecification in the financial channel of the model. We assume relatively tight Normal priors such that the measurement error standard deviation mean values correspond to 10% of the corresponding variables' standard deviation and assume Beta distributions with a prior mean of 0.5 for the AR(1) coefficients of measurement errors. While not reported for brevity, we obtain a slightly reduced contribution of asset value news shocks though still broadly similar with the benchmark results. Thirdly, we estimate a model with a correlated news structure, similar to the process for news adopted in Christiano et al. (2010).[28] Correlated news across time has been suggested by Leeper and Walker (2011) as an alternative way to incorporate advance signals about future innovations that may also help resolve co-movement problems. The variance decomposition we obtain from this specification is broadly similar to the benchmark results, that is news shocks continue to be an important source of fluctuations. However, we note that the marginal data density from the correlated news model is significantly smaller compared to the benchmark model by approximately 45 log points. Fourth, in the section below, we perform a final robustness exercise. Specifically, we estimate a model that—in addition to sector specific TFP—includes a common aggregate TFP shock, motivated by, (a) recent work in Foerster et al. (2011) who report common TFP shocks are quantitatively important in the post 1980s period in accounting for the variability in U.S. industrial production and (b) a plausible concern that our asset value news shock may be substituting for an aggregate common TFP that we did not consider during estimation. Similar to the benchmark model (without a common aggregate TFP shock) results, asset value news shocks account for a significant and almost identical fraction of the variance shares in the observables in this alternative model (see Table 7).

[27] The results from these additional exercises are available upon request.

[28] Specifically we assume a process with eight in total news components, each arriving per quarter for a span of 2 years. We assume a correlation between them that is a function of time and impose a common variance on all components.

Table 6: Log marginal data densities for alternative models

	Model Setup	Log Marginal Data Density
	Estimated with full data set (including financial variables)	
Benchmark	4 and 8 quarter ahead asset value news shocks in both sectors	-761.15
Model A:	1, 4 and 8 quarter ahead asset value 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 asset value news shocks and TFP news shocks in both sectors	-770.24
Model E:	1, 4 and 8 quarter ahead asset value news shocks and TFP news shocks in both sectors	-772.90
Model F:	Model without news components	-771.74
	Estimated with restricted data set (excluding financial variables)	
Model G:	Benchmark estimated without spread and equity data as observables	-532.54
Model H:	Model without financial intermediation estimated without spread and equity data as observables	-533.70

A.2 Model with a Common Aggregate TFP Shock

Foerster et al. (2011) highlight the importance of aggregate TFP shocks in explaining the variability in aggregate U.S. industrial production. They quantify the relative importance of aggregate and sectoral TFP shocks bridging the literature of multi-sector models with dynamic factor models and find that in the post 1980 period, aggregate TFP shocks are as important as sectoral TFP shocks in explaining this variability. Aggregate TFP shocks in principle are better candidates for generating co-movement in different sectors, whereas sector specific shocks require sectoral links to propagate in the aggregate. Given the emphasis we place on the co-movement properties of asset value news shocks in this paper and motivated by these recent findings we subject our findings to a further scrutiny test by incorporating a common aggregate TFP shock that affects both sectors symmetrically. This shock is a natural candidate in generating co-movement so its interesting to check whether the importance of news shocks in accounting for the variance in the data survives in this extended model. We introduce a stationary TFP shock to the production function of both sectors as follows,

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

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

where the TFP shock, f_t, follows,

$$f_t = (1-\rho_f)f + \rho_f f_{t-1} + \varepsilon_t^f, \tag{A.1}$$

Here, ε_t^f is $i.i.d.$ $N(0, \sigma_f^2)$, and the parameter $\rho_f \in (0,1)$ determines the persistence of the process.

Table 7 reports the variance decomposition results. Comparing Table 7 with Table 5 indicates the broad similarity in the variance shares accounted for by news shocks. In this extended model news shocks account for 30.4%, 26.4%, 31.6% in the forecast error variance in output, investment and hours worked at business cycle frequencies, respectively. These shares are nearly identical to the shares reported from the benchmark model with sector specific shocks only, with a small increase in the share of variance in investment explained by news in the model with an aggregate TFP shock. The shares explained by these shocks in the financial variables are also broadly similar across the two specifications. Carefully comparing the variance shares, illustrates the reason why the quantitative significance of news shocks remains broadly unchanged: a large fraction of the variance shares accounted for by consumption sector TFP in the benchmark model is now explained by the aggregate TFP shock in the extended model. Both types of shocks generate similar patterns of co-movement: the aggregate TFP by affecting symmetrically both sectors whereas the consumption sector TFP in the baseline model by affecting demand for investment goods from the investment sector in addition to the effects in the consumption sector, i.e. through sectoral linkages. We conjecture the estimation prefers to load on the aggregate TFP shock in comparison to the sectoral TFP, because the former does not need to work as hard as the latter in generating co-movement. However, we note that the fundamental reason for the robustness of news shocks lies in the fact that the benchmark model does already allow for several potential sources of co-movement, i.e., in sectoral TFP shocks (see for example Figures 10 and 11) as well as in other sources such as monetary policy or price mark-up shocks. We thus conclude that the findings on the importance of news shocks are robust to the inclusion of an aggregate TFP disturbance.

Table 7: Variance decomposition at business cycle frequencies — benchmark model with common aggregate TFP shock

										Financial Shocks							
	z	v	f	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	0.022	0.085	0.086	0.016	0.030	0.105	0.035	0.201	0.076	0.015	0.000	0.024	0.000	0.018	0.286	0.000	0.000
Consumption	0.035	0.002	0.104	0.423	0.001	0.142	0.129	0.010	0.098	0.002	0.000	0.014	0.000	0.005	0.035	0.000	0.000
Total Investment	0.004	0.223	0.037	0.014	0.001	0.032	0.001	0.358	0.034	0.014	0.000	0.017	0.000	0.015	0.249	0.000	0.000
Total Hours	0.003	0.083	0.014	0.017	0.001	0.100	0.019	0.329	0.084	0.013	0.000	0.020	0.000	0.018	0.298	0.000	0.000
Real Wage	0.022	0.078	0.046	0.018	0.000	0.032	0.148	0.055	0.530	0.001	0.000	0.008	0.000	0.004	0.058	0.000	0.000
Nom. Interest Rate	0.000	0.057	0.011	0.072	0.002	0.255	0.320	0.064	0.026	0.003	0.000	0.006	0.000	0.007	0.175	0.000	0.000
C-Sector Inflation	0.001	0.057	0.037	0.076	0.000	0.085	0.583	0.015	0.065	0.000	0.000	0.001	0.000	0.002	0.077	0.000	0.000
I-Sector Inflation	0.001	0.186	0.003	0.007	0.001	0.098	0.001	0.283	0.015	0.008	0.000	0.018	0.000	0.017	0.361	0.000	0.000
C-Sector Spread	0.004	0.019	0.013	0.010	0.000	0.019	0.065	0.109	0.011	0.349	0.000	0.023	0.000	0.019	0.358	0.000	0.000
I-Sector Spread	0.012	0.105	0.027	0.026	0.001	0.223	0.300	0.034	0.029	0.007	0.213	0.001	0.000	0.001	0.017	0.001	0.003
Equity	0.033	0.155	0.011	0.009	0.002	0.130	0.171	0.036	0.004	0.076	0.001	0.039	0.000	0.019	0.313	0.000	0.000

Median shares are reported and values in brackets 5 and 95 percentiles. z = TFP in consumption sector, v = TFP in investment sector, f = common aggregate TFP shock (both sectors), 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, $\xi_C^{K,0}$ = Unanticipated consumption sector asset value, $\xi_C^{K,x}$ = x quarter ahead consumption sector asset value news, $\xi_I^{K,0}$ = Unanticipated investment sector asset value, $\xi_I^{K,x}$ = x quarters ahead investment sector asset value news. Business cycle frequencies considered in the decomposition correspond to periodic components with cycles between 6 and 32 quarters. The decomposition is performed using the spectrum of the DSGE model and an inverse first difference filter to reconstruct the levels for output, consumption, total investment, the real wage and equity. The spectral density is computed from the state space representation of the model with 500 bins for frequencies covering the range of periodicities.

A.3 Comparison of Sample Paths: Model vs. Data

We undertake an additional exercise to better appreciate the role of financial and in particular asset value news shocks in explaining the in-sample variation in the data. Figure 7, shows the actual sample path of output growth, investment growth, total hours worked and sectoral credit spreads along with simulation paths generated by the model when either, (a) only all financial shocks or, (b) only all asset value news shocks are turned on (all other shocks are set equal to zero). A first visual inspection of Figure 7 illustrates that both simulation paths track movements of the actual data quite closely. A noteworthy finding is that the path generated with news shocks only correctly captures most of the turning points in actual output growth and also quite successfully account for the 2001 and 2008 recessions (though not very well the 1990s recession). Interestingly, the extent of the decline in output growth during the 2008 recession can be entirely captured by the simulation path generated by news shocks. Importantly, the news shocks simulation 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 news shocks 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 investment specific TFP shocks account for a large share of the variance in this spread.

Figure 8 presents the sample paths of (actual) sectoral hours worked along with the simulation paths described above. 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 news shocks in tracking the observed investment sector hours series despite the fact we have only used information from total hours. This simulation 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 recovery than that experienced in the mid part of the 2000s. Finally, it accounts for the significant decline in investment sector hours in the 2008 recession. The simulation 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 A.6 (Table 11).

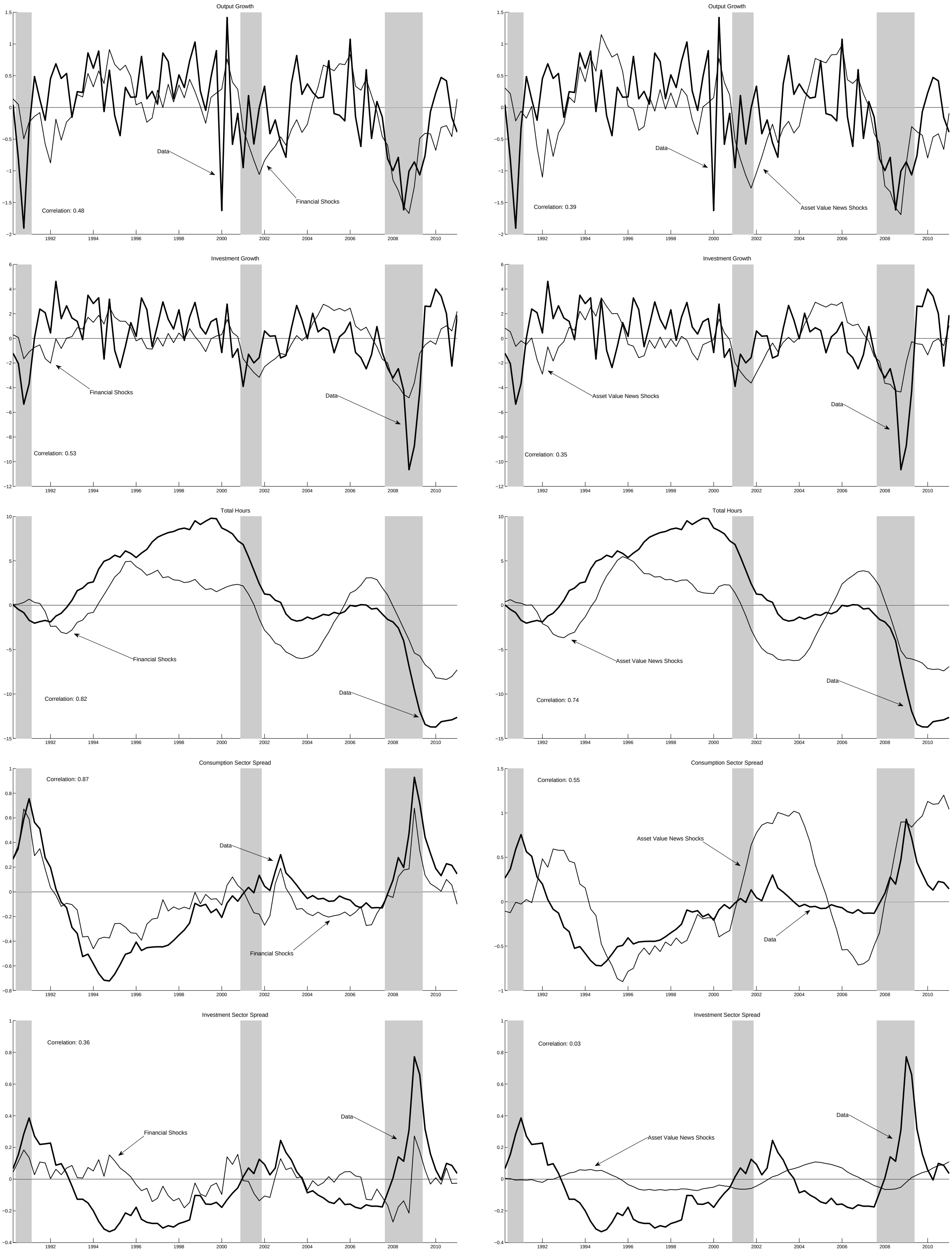

Figure 7: Data (solid line) and counterfactual simulation (thin line) with all financial shocks only (left) or news shocks only (right). From top to bottom row: Output growth, investment growth, total hours, consumption sector credit spread, investment sector credit spread. Dark grey bars show NBER dated recessions.

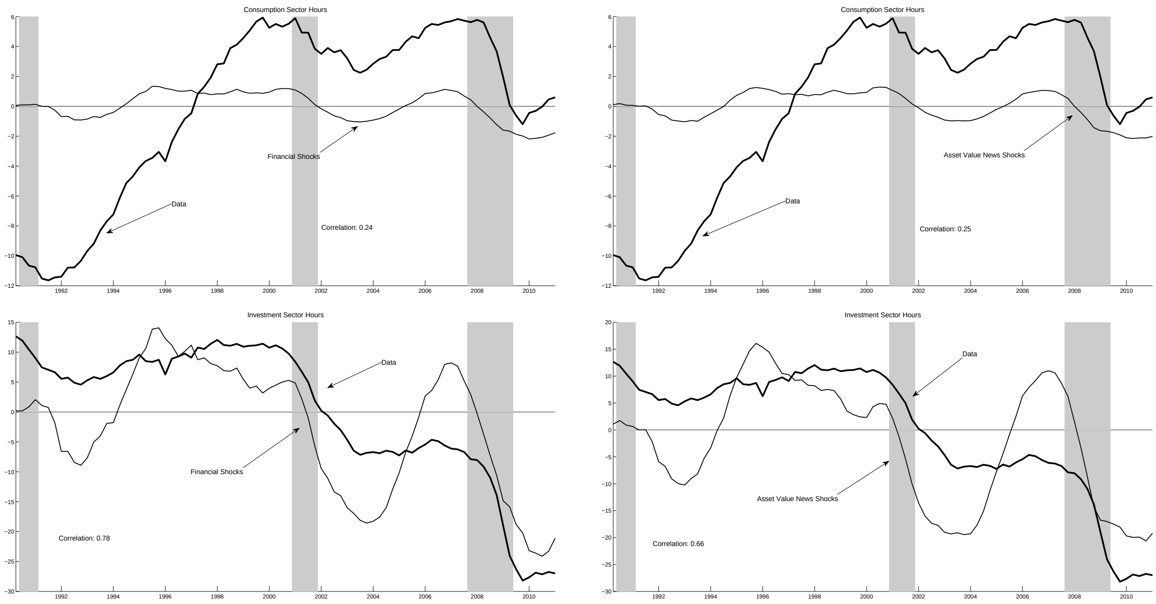

Figure 8: Data (solid line) and counterfactual simulation (thin line) with all financial shocks only (left) or news shocks only (right). From top to bottom row: consumption sector hours, investment sector hours. Dark grey bars show NBER dated recessions

A.4 Investment Sector TFP Shocks and the Relative Price of Investment

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) sector specific TFP and (c) differences in capital labor ratios across 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,

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

In this case the model has a one sector representation (e.g. Greenwood et al. (2000)). Further, one can readily redefine the investment sector TFP process as $V_t = A_t V_t^*$, where in this formulation A_t denotes sector neutral TFP, while V_t^* denotes investment specific TFP. Under this equivalent formulation the expression above becomes, $\frac{P_{I,t}}{P_{C,t}} = (V_t^*)^{-1}$, a commonly used restriction in one sector estimated DSGE 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, variation in the relative price of investment reflects not only investment specific shocks but also (in principle) all other 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 model dynamics—in a way that is consistent with volatilities and the spectrum of autocorrelations and cross correlations in the entire set of observables—-and are not tightly identified through 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 and only a long run restriction linking the relative price with investment specific shocks—thus allowing for the latter to freely affect dynamics in the short run—has found an important role of investment specific shocks in accounting for fluctuations in output and hours worked.

A.5 Additional Impulse Response Functions

Shutting off financial intermediation in the investment sector. Figure 9 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.

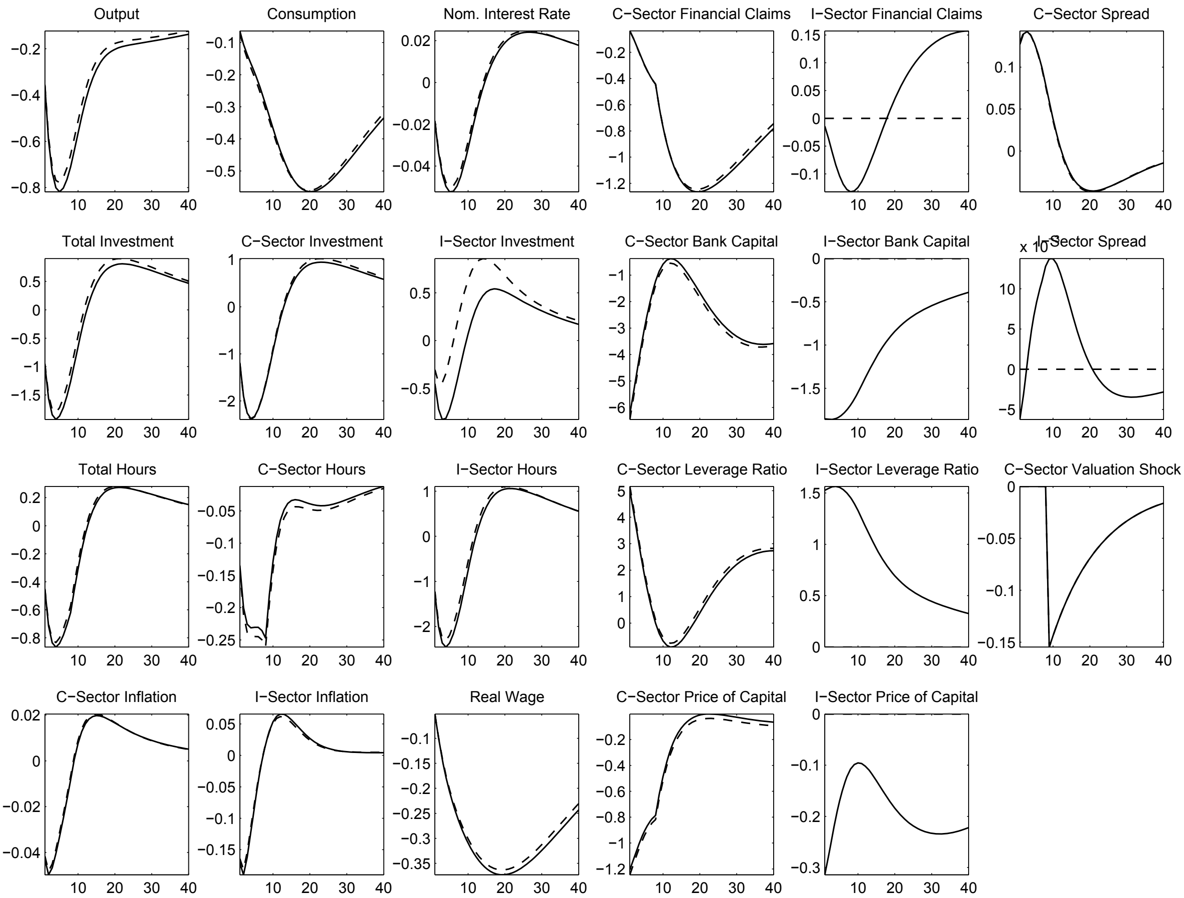

Figure 9: Responses to a negative one std. deviation asset value news shock (anticipated 8 quarters ahead) in the consumption sector. Benchmark model (solid lines) vs. Model without financial intermediation in the investment sector (dotted lines).

Sector specific TFP shocks. The two Figures below show IRFs in response to sector specific TFP shocks.

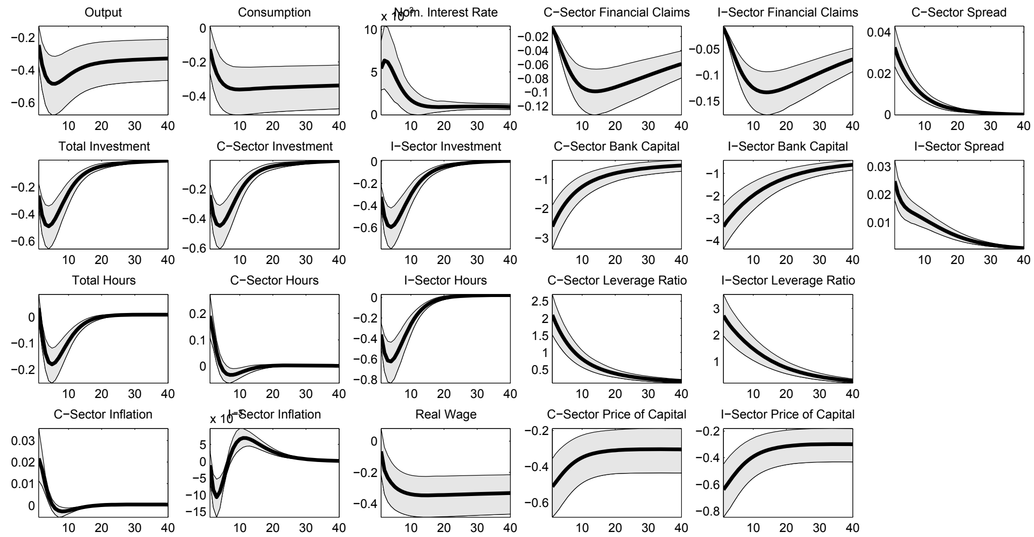

Figure 10: Responses to a negative one standard deviation unanticipated TFP shock in the consumption sector.

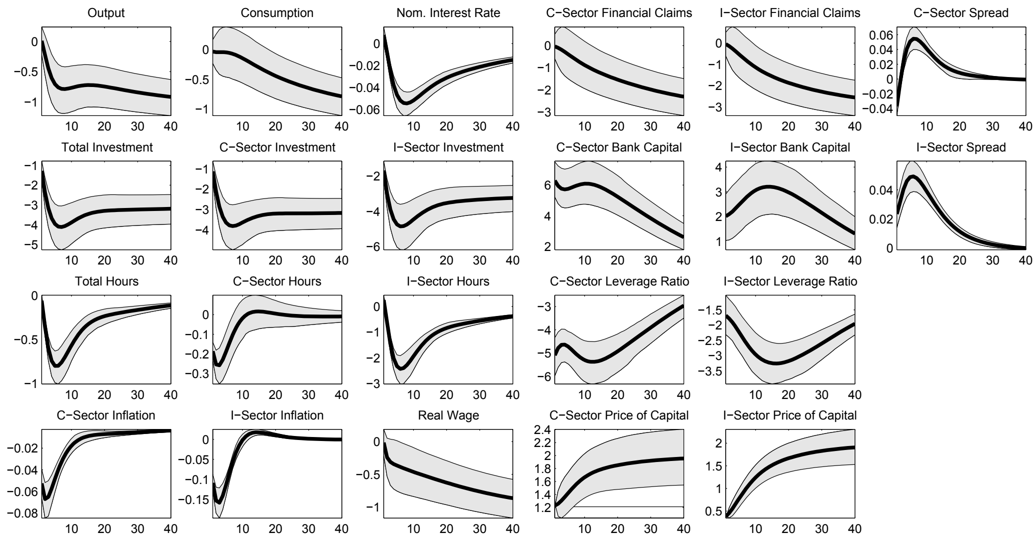

Figure 11: Responses to a negative one standard deviation unanticipated TFP shock in the investment sector.

A.6 Additional Tables

Table 8: Spectral Variance Decomposition at posterior estimates (excluding financial variables)

									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	0.234	0.184	0.005	0.009	0.078	0.003	0.109	0.096	0.000	0.000	0.067	0.066	0.032	0.119	0.000	0.000
Consumption	0.291	0.004	0.440	0.000	0.061	0.012	0.013	0.113	0.000	0.000	0.020	0.032	0.005	0.009	0.000	0.000
Total Investment	0.031	0.413	0.028	0.000	0.027	0.001	0.204	0.023	0.000	0.000	0.038	0.127	0.021	0.088	0.000	0.000
Total Hours	0.043	0.219	0.011	0.000	0.095	0.001	0.243	0.111	0.000	0.000	0.063	0.023	0.038	0.153	0.000	0.000
Real Wage	0.291	0.069	0.019	0.000	0.001	0.117	0.027	0.438	0.000	0.000	0.013	0.013	0.004	0.009	0.000	0.000
Nom. Interest Rate	0.030	0.153	0.205	0.000	0.206	0.113	0.069	0.096	0.000	0.000	0.011	0.035	0.011	0.071	0.000	0.000
C-Sector Inflation	0.054	0.167	0.219	0.000	0.076	0.203	0.046	0.157	0.000	0.000	0.004	0.021	0.007	0.048	0.000	0.000
I-Sector Inflation	0.002	0.259	0.012	0.000	0.059	0.002	0.103	0.014	0.000	0.000	0.037	0.383	0.022	0.108	0.000	0.000
C-Sector Spread	0.042	0.141	0.045	0.000	0.028	0.052	0.106	0.005	0.001	0.000	0.114	0.128	0.064	0.274	0.000	0.000
I-Sector Spread	0.025	0.108	0.059	0.000	0.068	0.059	0.167	0.018	0.000	0.002	0.005	0.466	0.004	0.019	0.000	0.000
Equity	0.207	0.195	0.048	0.000	0.056	0.023	0.017	0.021	0.000	0.000	0.074	0.226	0.028	0.105	0.000	0.000

Median shares are reported. 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, ς_I = Investment sector equity capital, $\xi_C^{K,0}$ = Unanticipated consumption sector asset value, $\xi_C^{K,x}$ = x quarter ahead consumption sector asset value news, $\xi_I^{K,0}$ = Unanticipated investment sector asset value, $\xi_I^{K,x}$ = x quarters ahead investment sector asset value news. Business cycle frequencies considered in the decomposition correspond to periodic components with cycles between 6 and 32 quarters. The decomposition is performed using the spectrum of the DSGE model and an inverse first difference filter to reconstruct the levels for output, consumption, total investment, the real wage and equity. The spectral density is computed from the state space representation of the model with 500 bins for frequencies covering the range of periodicities.

Table 9: Unconditional Variance Decomposition (computed 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, ς_I = Investment sector equity capital, $\xi_C^{K,0}$ = Unanticipated consumption sector asset value, $\xi_C^{K,x}$ = x quarter ahead consumption sector asset value news, $\xi_I^{K,0}$ = Unanticipated investment sector asset value, $\xi_I^{K,x}$ = x quarters ahead investment sector asset value news.

Table 10: Unconditional Variance Decomposition at posterior estimates

									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

Median shares are reported. 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, ς_I = Investment sector equity capital, $\xi_C^{K,0}$ = Unanticipated consumption sector asset value, $\xi_C^{K,x}$ = x quarter ahead consumption sector asset value news, $\xi_I^{K,0}$ = Unanticipated investment sector asset value, $\xi_I^{K,x}$ = x quarters ahead investment sector asset value news.

Table 11: 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
Model (eight quarter ahead asset value news shock activated)													
Total Hours	-0.134	0.031	0.199	0.347	0.477	0.583	0.656	0.682	0.672	0.627	0.547	0.429	0.279
Consumption sector hours	-0.198	-0.033	0.143	0.298	0.442	0.566	0.659	0.693	0.690	0.651	0.575	0.463	0.317
Investment sector hours	-0.119	0.045	0.211	0.357	0.484	0.584	0.653	0.678	0.667	0.620	0.539	0.422	0.269

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

A.7 A Historical Perspective and the 2008 Recession

Given the quantitative importance of news shocks as driving forces behind fluctuations, we attempt to disentangle the impact of news and unanticipated shocks on the in-sample variation of GDP and investment growth by performing a historical decomposition. This exercise can also reveal the importance of shocks during different time periods. Figure 12 depicts the results of this exercise. It shows the decomposition of output and investment growth into news and all other shocks.

The decomposition shows that news shocks account for a large fraction of the recessions in 2001 (2001Q1 - 2001Q4) and 2008 (2007Q4 - 2009Q2). They account for the majority of the drop in GDP growth and a large share of the decline in investment growth during the 2008 recession. The remaining decline in investment growth (orange bars towards the end of the recession) is accounted for by unfavorable investment sector TFP shocks. By contrast, news shocks contribute very little to the downturn of GDP and investment in the early 1990s (1990Q3 - 1991Q1) recession, which according to this exercise is driven by unfavorable investment sector TFP shocks. 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)), the recent literature on news shocks entertains the idea that expectation shifts (e.g. due to correction of overoptimistic beliefs about asset prices) may have played a much bigger role in the last two recessions.

It is apparent from this decomposition that news 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. Unfavorable news continue to arrive well after the official end of the 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 news shock's impact on GDP and investment growth at the trough of the cycle is consistent with a literature that finds agent's forecast accuracy to be positively correlated with output.[29]

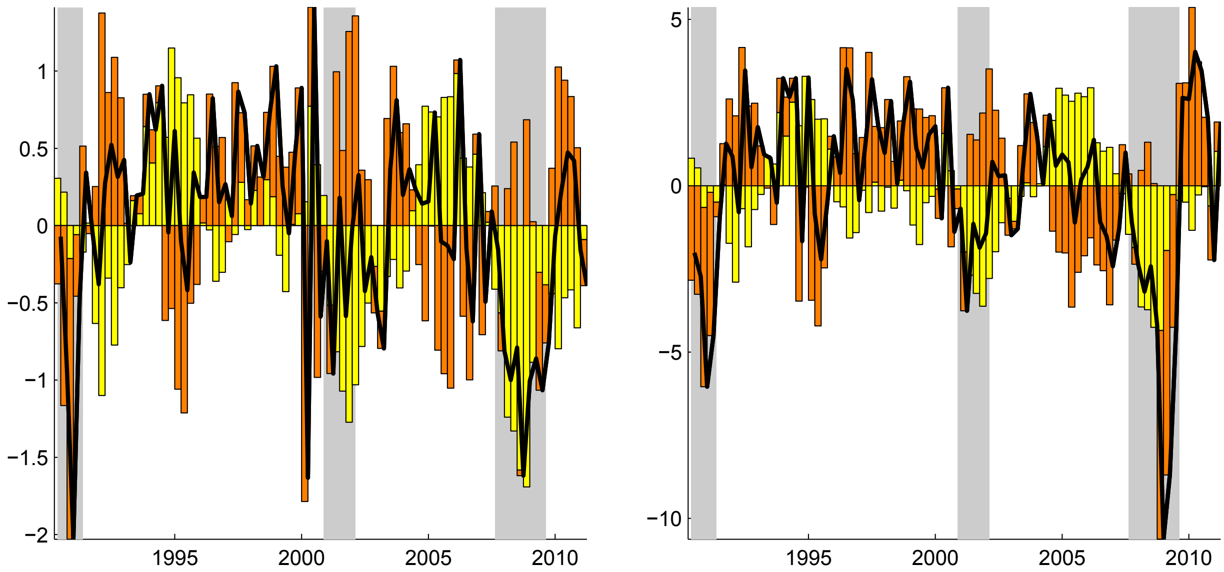

Figure 12: Historical decomposition of the growth rate of GDP (left) and investment (right) into value news shocks (yellow) and all other shocks (orange). The grey bars denote NBER dated recessions.

B Data Sources and Time Series Construction

Table 12 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 detail below.

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 the growth rate of real consumption we construct a series for real consumption using 2005 as the base year. 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,

[29]See for example Görtz and Tsoukalas (2012).

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. All series described above as well as the equity capital series (described below) are expressed in per capita terms using the the series of non-institutional population, ages 16 and over. 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. The time series for hours is in logs. Moreover, all series used in estimation (including the financial time series described below) are expressed in deviations from their sample average.

Financial variables. Data for sectoral credit spreads are not directly available. However, Reuters' Datastream provides U.S. credit spreads for companies which we map into the two sectors using The North American Industry Classification System (NAICS).[30] 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 and only bonds traded in the secondary market. In line with Gilchrist and Zakrajsek (2012) 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 average 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

[30]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).

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 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 U.S. 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 12: 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.

C Model Details and Derivations

We provide the model details and derivations required for replication of the model. We begin with the financial sector followed by the normalization of the model to render it stationary, the description of the steady state and the log-linearized model equations.

C.1 Financial Intermediaries

This section describes in detail how the setup of Gertler and Karadi (2011) is adapted for the two sector model and describes in detail how the equations for financial intermediaries in the main text 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.[31] 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

[31] 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

inequality must hold,

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

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

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

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

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

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.[32] 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,

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

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

[32] 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.

ence equation,

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

with,

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

and,

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

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

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

$$\begin{aligned}
Q_{x,t} S_{x,t} &= \frac{\eta_{x,t}}{\lambda_B - \nu_{x,t}} N_{x,t} \\
&= \varrho_{x,t} N_{x,t}. \qquad \text{(C.3)}
\end{aligned}$$

In this case the quantity of assets which the intermediary can acquire depends on the equity capital, $N_{x,t}$, as well as the intermediary's leverage ratio, $\varrho_{x,t}$. This leverage ratio is the ratio of the bank's intermediated assets to equity. The moral hazard/costly enforcement problem constraints the bank's ability to acquire assets because it introduces an endogenous capital constraint. By raising the leverage ratio through an increase in $\nu_{x,t}$, the bank's incentive to divert funds and the bank's opportunity costs from being forced into bankruptcy by the depositors increase. The bank's leverage ratio is limited to the point where its maximized expected terminal wealth equals the gains from diverting the fraction λ_B from available funds. However, the constraint (C.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 (C.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 ones, $N^n_{x,t}$,

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

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,

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

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 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,

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

Existing banker's net worth (C.4) and entering banker's net worth (C.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.

C.2 Stationary Economy

The model includes two non-stationary technology shocks, A_t and V_t. This section shows how we normalize the model to render it stationary. Lower case variables denote normalized stationary variables.

The model variables can be stationarized as follows:

$$k_{x,t} = \frac{K_{x,t}}{V_t^{\frac{1}{1-a_i}}}, \qquad \bar{k}_{x,t} = \frac{\bar{K}_{x,t}}{V_t^{\frac{1}{1-a_i}}}, \qquad k_t = \frac{K_t}{V_t^{\frac{1}{1-a_i}}}, \tag{C.6}$$

$$i_{x,t} = \frac{I_{x,t}}{V_t^{\frac{1}{1-a_i}}}, \qquad i_t = \frac{I_t}{V_t^{\frac{1}{1-a_i}}}, \qquad c_t = \frac{C_t}{A_t V_t^{\frac{a_c}{1-a_i}}}, \tag{C.7}$$

$$r^K_{C,t} = \frac{R^K_{C,t}}{P_{C,t}} A_t^{-1} V_t^{\frac{1-a_c}{1-a_i}}, \qquad r^K_{I,t} = \frac{R^K_{I,t}}{P_{C,t}} A_t^{-1} V_t^{\frac{1-a_c}{1-a_i}}, \qquad w_t = \frac{W_t}{P_{C,t} A_t V_t^{\frac{a_c}{1-a_i}}}. \tag{C.8}$$

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

$$p_{i,t} = \frac{P_{I,t}}{P_{C,t}} A_t^{-1} V_t^{\frac{1-a_c}{1-a_i}}. \tag{C.9}$$

and the multipliers are normalized as

$$\lambda_t = \Lambda_t A_t V_t^{\frac{a_c}{1-a_i}}, \qquad \phi_{x,t} = \Phi_{x,t} V_t^{\frac{1}{1-a_i}}. \tag{C.10}$$

where $\Phi_{x,t}$ denotes the multiplier on the respective capital accumulation equation. Using the growth of investment, it follows from the equations of the price of capital that

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

with the price of capital in sector x, defined as

$$q_{x,t} = \phi_{x,t}/\lambda_t, \quad x = C, I.$$

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 (C.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

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

C.2.1 Intermediate goods producers

Firm's production function in the consumption sector:

$$c_t = L_{C,t}^{1-a_c} k_{C,t}^{a_c} - F_C. \tag{C.11}$$

Firm's production function in the investment sector:

$$i_t = L_{I,t}^{1-a_i} k_{I,t}^{a_i} - F_I. \tag{C.12}$$

Marginal costs in the consumption sector:

$$mc_{C,t} = (1-a_c)^{a_c-1} a_c^{-a_c} (r^K_{C,t})^{a_c} w_t^{1-a_c}. \tag{C.13}$$

Marginal costs in the investment sector:

$$mc_{I,t} = (1-a_i)^{a_i-1} a_i^{-a_i} w_t^{1-a_i} (r^K_{I,t})^{a_i} p_{i,t}^{-1}, \qquad \text{with} \quad p_{i,t} = \frac{P_{I,t}}{P_{C,t}}. \tag{C.14}$$

Capital labour ratios in the two sectors:

$$\frac{k_{C,t}}{L_{C,t}} = \frac{w_t}{r^K_{C,t}} \frac{a_c}{1-a_c}, \qquad \frac{k_{I,t}}{L_{I,t}} = \frac{w_t}{r^K_{I,t}} \frac{a_i}{1-a_i}. \tag{C.15}$$

C.2.2 Firms' pricing decisions

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

$$0 = E_t \left\{ \sum_{s=0}^{\infty} \xi^s_{p,x} \beta^s \lambda_{t+s} \tilde{x}_{t+s} \left[\tilde{p}_{x,t} \tilde{\Pi}_{t,t+s} - (1+\lambda^x_{p,t+s}) mc_{x,t+s} \right] \right\}, \tag{C.16}$$

with

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

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

Aggregate price index in the consumption sector:

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

It further holds that

$$\frac{\pi_{I,t}}{\pi_{C,t}} = \frac{p_{i,t}}{p_{i,t-1}}. \tag{C.17}$$

C.2.3 Household's optimality conditions and wage setting

Marginal utility of income:

$$\lambda_t = \frac{b_t}{c_t - hc_{t-1}\left(\frac{A_{t-1}}{A_t}\right)\left(\frac{V_{t-1}}{V_t}\right)^{\frac{a_c}{1-a_i}}} - \beta h \frac{b_{t+1}}{c_{t+1}\left(\frac{A_{t+1}}{A_t}\right)\left(\frac{V_{t+1}}{V_t}\right)^{\frac{a_c}{1-a_i}} - hc_t}. \tag{C.18}$$

Euler equation:

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

Labor supply

$$\lambda_t w_t = b_t \varphi (L_{C,t} + L_{I,t})^{\nu},$$

C.2.4 Capital services

Optimal capital utilization in both sectors:

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

Definition of capital services in both sectors:

$$k_{C,t} = u_{C,t}\xi^K_{C,t}\bar{k}_{C,t-1}\left(\frac{V_{t-1}}{V_t}\right)^{\frac{1}{1-a_i}}, \qquad k_{I,t} = u_{I,t}\xi^K_{I,t}\bar{k}_{I,t-1}\left(\frac{V_{t-1}}{V_t}\right)^{\frac{1}{1-a_i}}. \tag{C.19}$$

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

$$\phi_{x,t} = \beta E_t \xi^K_{x,t+1} \left\{ \lambda_{t+1} \left(\frac{V_t}{V_{t+1}} \right)^{\frac{1}{1-a_i}} (r^K_{x,t+1} u_{x,t+1} - a(u_{x,t+1})) + (1-\delta) E_t \phi_{x,t+1} \left(\frac{V_t}{V_{t+1}} \right)^{\frac{1}{1-a_i}} \right\}, \tag{C.20}$$

C.2.5 Physical capital producers

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

$$\begin{aligned} &[i_{I,t}^{-\rho} + i_{C,t}^{-\rho}]^{-\frac{1}{\rho}-1} i_{x,t}^{-\rho-1} \lambda_t p_{i,t} \\ &\quad = \phi_{x,t} \left[1 - S\left(\frac{i_{x,t}}{i_{x,t-1}} \left(\frac{V_t}{V_{t-1}} \right)^{\frac{1}{1-a_i}} \right) - S'\left(\frac{i_{x,t}}{i_{x,t-1}} \left(\frac{V_t}{V_{t-1}} \right)^{\frac{1}{1-a_i}} \right) \frac{i_{x,t}}{i_{x,t-1}} \left(\frac{V_t}{V_{t-1}} \right)^{\frac{1}{1-a_i}} \right] \\ &\qquad + \beta E_t \phi_{x,t+1} \left(\frac{V_t}{V_{t+1}} \right)^{\frac{1}{1-a_i}} \left[S'\left(\frac{i_{x,t+1}}{i_{x,t}} \left(\frac{V_{t+1}}{V_t} \right)^{\frac{1}{1-a_i}} \right) \left(\frac{i_{x,t+1}}{i_{x,t}} \left(\frac{V_{t+1}}{V_t} \right)^{\frac{1}{1-a_i}} \right)^2 \right]. \end{aligned} \tag{C.21}$$

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

$$\bar{k}_{x,t} = (1-\delta_x) \xi^K_{x,t} \bar{k}_{x,t-1} \left(\frac{V_{t-1}}{V_t} \right)^{\frac{1}{1-a_i}} + \left(1 - S\left(\frac{i_{x,t}}{i_{x,t-1}} \left(\frac{V_t}{V_{t-1}} \right)^{\frac{1}{1-a_i}} \right) \right) i_{x,t}, \tag{C.22}$$

C.2.6 Household's wage setting

Household's wage setting:

$$E_t \sum_{s=0}^{\infty} \beta^s \xi_w^s \lambda_{t+s} \tilde{L}_{t+s} \left[\tilde{w}_t \tilde{\Pi}^w_{t,t+s} - (1+\lambda_{w,t+s}) b_{t+s} \varphi \frac{\tilde{L}^{\nu}_{t+s}}{\lambda_{t+s}} \right] = 0, \tag{C.23}$$

with

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

and

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

Wages evolve according to

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

C.2.7 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 $\eta_{x,t}$

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

with

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

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:

$$z_{2,t+1}^x = \frac{n_{x,t+1}}{n_{x,t}} \frac{A_{t+1}}{A_t}\Big(\frac{V_{t+1}}{V_t}\Big)^{\frac{a_c}{1-a_i}} = (R_{x,t+1}^B - R_t)\varrho_{x,t} + R_t,$$

and

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

The normalized equation for bank's wealth accumulation is

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

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:

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

knowing from the main model that

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

C.2.8 Monetary policy and market clearing

Monetary policy rule:

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

Resource constraint in the consumption sector:

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

Resource constraint in the investment sector:

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

Definition of GDP:

$$y_t = c_t + p_{i,t} i_t + \left(1 - \frac{1}{e_t}\right) y_t. \tag{C.24}$$

Moreover

$$L_t = L_{I,t} + L_{C,t}, \qquad i_t = \left[i_{I,t}^{-\rho} + i_{C,t}^{-\rho}\right]^{-\frac{1}{\rho}}.$$

C.3 Steady State

This section describes the model's steady state.

From the optimal choice of available capital (C.20) and the optimal choice of investment (C.21) in both sectors:

$$r_C^K = \left(\frac{e^{\frac{1}{1-a_i}g_v}}{\beta} - (1-\delta_C)\right)(i_I^{-\rho} + i_C^{-\rho})^{-\frac{1}{\rho}-1} i_C^{-\rho-1} p_i, \tag{C.25}$$

$$r_I^K = \left(\frac{e^{\frac{1}{1-a_i}g_v}}{\beta} - (1-\delta_I)\right)(i_I^{-\rho} + i_C^{-\rho})^{-\frac{1}{\rho}-1} i_I^{-\rho-1} p_i. \tag{C.26}$$

From firm's price setting in both sectors (C.16)

$$mc_C = \frac{1}{1+\lambda_p^C}, \qquad mc_I = \frac{1}{1+\lambda_p^I}. \tag{C.27}$$

Using equations (C.27) and imposing knowledge of the steady state expression for r_C^K and r_I^K, one can derive expressions for the steady state wage from the equations for the marginal costs in both sectors ((C.13) and (C.14)):
Consumption sector:

$$w = \left(\frac{1}{1+\lambda_p^C}(1-a_c)^{1-a_c} a_c^{a_c} (r_C^K)^{-a_c}\right)^{\frac{1}{1-a_c}}. \tag{C.28}$$

Investment sector:

$$w = \left(\frac{1}{1+\lambda_p^I}(1-a_i)^{1-a_i} a_i^{a_i} (r_I^K)^{-a_i} p_i\right)^{\frac{1}{1-a_i}}. \tag{C.29}$$

Since labour can move across sectors the steady state wage has to be the same in the consumption and investment sector. The equality is verified by p_i. An expression for p_i can be found by setting (C.28) equal to (C.29):

$$
\begin{aligned}
&\Big(\frac{1}{1+\lambda_p^C}(1-a_c)^{1-a_c}a_c^{a_c}(r_C^K)^{-a_c}\Big)^{\frac{1}{1-a_c}} = \Big(\frac{1}{1+\lambda_p^I}(1-a_i)^{1-a_i}a_i^{a_i}(r_I^K)^{-a_i}p_i\Big)^{\frac{1}{1-a_i}} \\
\Leftrightarrow&\Big(\frac{1}{1+\lambda_p^C}(1-a_c)^{1-a_c}a_c^{a_c}\Big(\frac{e^{\frac{1}{1-a_i}g_v}}{\beta}-(1-\delta_C)\Big)^{-a_c}\big[(i_I^{-\rho}+i_C^{-\rho})^{-\frac{1}{\rho}-1}i_C^{-\rho-1}\big]^{-a_c}p_i^{-a_c}\Big)^{\frac{1}{1-a_c}} \\
&=\Big(\frac{1}{1+\lambda_p^I}(1-a_i)^{1-a_i}a_i^{a_i}\Big(\frac{e^{\frac{1}{1-a_i}g_v}}{\beta}-(1-\delta_I)\Big)^{-a_i}p_i^{-a_i}\big[(i_I^{-\rho}+i_C^{-\rho})^{-\frac{1}{\rho}-1}i_I^{-\rho-1}\big]^{-a_i}p_i\Big)^{\frac{1}{1-a_i}} \\
\Leftrightarrow&p_i = \frac{\frac{1}{1+\lambda_p^C}(1-a_c)^{1-a_c}a_c^{a_c}\Big(\frac{e^{\frac{1}{1-a_i}g_v}}{\beta}-(1-\delta_C)\Big)^{-\alpha_c}\big[(i_I^{-\rho}+i_C^{-\rho})^{-\frac{1}{\rho}-1}i_C^{-\rho-1}\big]^{-a_c}}{\Big[\frac{1}{1+\lambda_p^I}(1-a_i)^{1-a_i}a_i^{a_i}\Big(\frac{e^{\frac{1}{1-a_i}g_v}}{\beta}-(1-\delta_I)\Big)^{-\alpha_i}\big[(i_I^{-\rho}+i_C^{-\rho})^{-\frac{1}{\rho}-1}i_I^{-\rho-1}\big]^{-a_i}\Big]^{\frac{1-a_c}{1-a_i}}}.
\end{aligned}
\tag{C.30}
$$

Knowing w, r_C^K and r_I^K, the expressions given in (C.15) can be used to find the steady state capital-to-labour ratios in the two sectors:

$$\frac{k_C}{L_C} = \frac{w}{r_C^K}\frac{a_c}{1-a_c}, \tag{C.31}$$

$$\frac{k_I}{L_I} = \frac{w}{r_I^K}\frac{a_i}{1-a_c}. \tag{C.32}$$

The zero profit condition for intermediate goods producers in the consumption sector, $c - r_C^K k_C - wL_C = 0$, and (C.11) imply:

$$
\begin{aligned}
&L_C^{1-a_c}k_C^{a_c} - F_C - r_C^K k_C - wL_C = 0 \\
\Leftrightarrow&\frac{F_C}{L_C} = \Big(\frac{k_C}{L_C}\Big)^{a_c} - r_C^K\frac{k_C}{L_C} - w.
\end{aligned}
$$

Analogously the zero profit condition for intermediate goods producers in the investment sector, $i - r_I^K k_I - wL_I = 0$, and (C.12) imply:

$$\frac{F_I}{L_I} = \Big(\frac{k_I}{L_I}\Big)^{a_i} - r_I^K\frac{k_I}{L_I} - w.$$

These expressions pin down the steady state consumption-to-labour and investment-to-labour ratios which follow from the intermediate firms' production functions ((C.11) and (C.12)):

$$\frac{c}{L_C} = \Big(\frac{k_C}{L_C}\Big)^{a_c} - \frac{F_C}{L_C}, \qquad \frac{i}{L_I} = \Big(\frac{k_I}{L_I}\Big)^{a_i} - \frac{F_I}{L_I}.$$

$$1+\lambda_p^C=\frac{c+F_C}{c}\Leftrightarrow\lambda_p^C c=F_C,\qquad\text{and}\qquad 1+\lambda_p^I=\frac{i+F_I}{i}\Leftrightarrow\lambda_p^I i=F_I.$$

This and the steady state consumption-to-labour ratio can be used to derive an expression for steady state consumption:

$$\begin{aligned} c&=\left(\frac{k_C}{L_C}\right)^{a_c}L_C-F_C\\ \Leftrightarrow c&=\left(\frac{k_C}{L_C}\right)^{a_c}L_C-\lambda_p^C c\\ \Leftrightarrow c&=\frac{1}{1+\lambda_p^C}\left(\frac{k_C}{L_C}\right)^{a_c}L_C. \end{aligned}$$

Analogously one can derive an expression for steady state investment:

$$i=\frac{1}{1+\lambda_p^I}\left(\frac{k_I}{L_I}\right)^{a_i}L_I.$$

Combining these two expressions leads to

$$\begin{aligned} p_i\frac{i}{c}&=\frac{\frac{1}{1+\lambda_p^I}\left(\frac{k_I}{L_I}\right)^{a_i}L_I}{\frac{1}{1+\lambda_p^C}\left(\frac{k_C}{L_C}\right)^{a_c}L_C}p_i\\ \Leftrightarrow\frac{L_I}{L_C}&=p_i\frac{i}{c}\frac{\frac{1}{1+\lambda_p^C}\left(\frac{k_C}{L_C}\right)^{a_c}}{\frac{1}{1+\lambda_p^I}\left(\frac{k_I}{L_I}\right)^{a_i}}p_i^{-1}. \end{aligned}$$

Total labour L is set to unity in the steady state. However, since a_i and a_c are not necessarily calibrated to be equal one needs to fix another quantity in addition to $L=1$. We fix the steady state investment-to-consumption ratio, $p_i\frac{i}{c}$, which equals 0.399 in the data. This allows us to derive steady state expressions for labour in the two sectors. Steady state labour in the investment sector is given by

$$L_I=1-L_C, \tag{C.33}$$

and the two equations above imply that steady state labour in the consumption sector can be expressed as

$$L_C = \left(1 + p_i \frac{i}{c} \frac{\frac{1}{1+\lambda_p^C}\left(\frac{k_C}{L_C}\right)^{a_c}}{\frac{1}{1+\lambda_p^I}\left(\frac{k_I}{L_I}\right)^{a_i}} p_i^{-1}\right)^{-1}. \tag{C.34}$$

The steady state values for labour in the two sectors imply:

$$k_C = \frac{k_C}{L_C} L_C, \quad k_I = \frac{k_I}{L_I} L_I, \quad c = \frac{c}{L_C} L_C, \quad i = \frac{i}{L_I} L_I, \quad F_C = \frac{F_C}{L_C} L_C, \quad F_I = \frac{F_I}{L_I} L_I.$$

It follows from (C.19) that

$$k_C = \bar{k}_C e^{-\frac{1}{1-a_i} g_v}, \qquad \text{and} \qquad k_I = \bar{k}_I e^{-\frac{1}{1-a_i} g_v}.$$

The accumulation equation of available capital (C.22) can be used to solve for investment in the two sectors:

$$i_C = k_C \left(1 - e^{-\frac{1}{1-a_i} g_v} (1 - \delta_C)\right), \tag{C.35}$$

$$i_I = k_I \left(1 - e^{-\frac{1}{1-a_i} g_v} (1 - \delta_I)\right). \tag{C.36}$$

From the definition of GDP (C.24):

$$y = c + p_i i + \left(1 - \frac{1}{g}\right) y.$$

From the marginal utility of income (C.18):

$$\lambda = \frac{1}{c - hce^{-g_a - \frac{a_c}{1-a_i} g_v}} - \frac{\beta h}{ce^{g_a + \frac{a_c}{1-a_i} g_v} - hc}.$$

From the household's wage setting (C.23)

$$\sum_{s=0}^{\infty} \beta^s \xi_w^s \lambda L \left[w - (1 + \lambda_w) \varphi \frac{L^\nu}{\lambda}\right] = 0,$$

follows the expression for L:

$$w - (1 - \lambda_w) \varphi \frac{L^\nu}{\lambda} = 0 \quad \Rightarrow \quad L = \left[\frac{w\lambda}{(1 + \lambda_w)\varphi}\right]^{\frac{1}{\nu}}.$$

This expression can be solved for φ to be consistent with $L = 1$:

$$1 = \left[\frac{w\lambda}{(1+\lambda_w)\varphi}\right]^{\frac{1}{\nu}}$$
$$\Leftrightarrow \varphi = \frac{1+\lambda_w}{\lambda w}.$$

It further holds from equation (C.17) that

$$\frac{\pi_I}{\pi_C} = e^{g_a - \frac{1-a_c}{1-a_i} g_v}$$

Due to the nonlinearity introduced by the intratemporal investment adjustment costs one cannot solve analytically for the steady state. A system of 10 equations (C.25, C.26, C.28, C.30, C.31, C.32, C.33, C.34, C.35, C.36) is solved numerically for the 10 steady state variables k_C, k_I, w, i_C, i_I, r_C^K, r_I^K, L_C, L_I and p_i. The steady state values for the remaining variables follow from the expressions above.

Given these steady state variables, the remaining steady state values which are mainly related to financial intermediaries can be derived 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

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

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

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

with

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

and the steady state leverage ratio

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

C.4 Log-linearized Economy

This section collects the log-linearized model equations. The log-linear deviations of all variables are defined as

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

except for

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

C.4.1 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:

$$\hat{r}^K_{C,t} - \hat{w}_t = \hat{L}_{C,t} - \hat{k}_{C,t}, \qquad \hat{r}^K_{I,t} - \hat{w}_t = \hat{L}_{I,t} - \hat{k}_{I,t}. \tag{C.37}$$

Marginal cost in both sectors:

$$\hat{mc}_{C,t} = a_c\hat{r}^K_{C,t} + (1-a_c)\hat{w}_t, \qquad \hat{mc}_{I,t} = a_i\hat{r}^K_{I,t} + (1-a_i)\hat{w}_t - \hat{p}_{i,t}. \tag{C.38}$$

C.4.2 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

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

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

Prices evolve as

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

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

$$\begin{aligned}
&\hat{\pi}_{x,t}=\frac{\beta}{1+\iota_{p_x}\beta}E_t\hat{\pi}_{x,t+1}+\frac{\iota_{p_x}}{1+\iota_{p_x}\beta}\hat{\pi}_{x,t-1}+\kappa_x\hat{mc}_{x,t}+\kappa_x\hat{\lambda}^x_{p,t}, \\
&\text{with}\quad \kappa_x=\frac{(1-\xi_{p,x}\beta)(1-\xi_{p,x})}{\xi_{p,x}(1+\iota_{p_x}\beta)}.
\end{aligned} \tag{C.39}$$

From equation (C.17) it follows that

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

C.4.3 Households

Marginal utility:

$$
\begin{aligned}
\hat{\lambda}_t =& \frac{e^G}{e^G - h\beta}\left[\hat{b}_t + \left(\hat{z}_t + \frac{a_c}{1-a_i}\hat{v}_t\right) - \left(\frac{e^G}{e^G - h}\left(\hat{c}_t + \hat{z}_t + \frac{a_c}{1-a_i}\hat{v}_t\right) - \frac{h}{e^G - h}\hat{c}_{t-1}\right)\right] \\
& - \frac{h\beta}{e^G - h\beta}E_t\left[\hat{b}_{t+1} - \left(\frac{e^G}{e^G - h}\left(\hat{c}_{t+1} + \hat{z}_{t+1} + \frac{a_c}{1-a_i}\hat{v}_{t+1}\right) - \frac{h}{e^G - h}\hat{c}_t\right)\right] \\
\Leftrightarrow \hat{\lambda}_t =& \alpha_1 E_t\hat{c}_{t+1} - \alpha_2\hat{c}_t + \alpha_3\hat{c}_{t-1} + \alpha_4\hat{z}_t + \alpha_5\hat{b}_t + \alpha_6\hat{v}_t, \qquad \text{(C.40)}
\end{aligned}
$$

with

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

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

Euler equation:

$$
\hat{\lambda}_t = \hat{R}_t + E_t\left(\hat{\lambda}_{t+1} - \hat{z}_{t+1} - \hat{v}_{t+1}\frac{a_c}{1-a_i} - \hat{\pi}_{C,t+1}\right). \qquad \text{(C.41)}
$$

C.4.4 Investment and Capital

Capital utilisation in both sectors:

$$
\hat{r}^K_{C,t} = \chi_C\hat{u}_{C,t}, \qquad \hat{r}^K_{I,t} = \chi_I\hat{u}_{I,t}, \qquad \text{where} \quad \chi^{-1} = \frac{a'(1)}{a''(1)}. \qquad \text{(C.42)}
$$

Choice of investment for the consumption sector:

$$
\begin{aligned}
\hat{q}_{C,t} =& e^{2(\frac{1}{1-a_i}g_v)}\kappa\left(\hat{i}_{C,t} - \hat{i}_{C,t-1} + \frac{1}{1-a_i}\hat{v}_t\right) - \beta e^{2(\frac{1}{1-a_i}g_v)}\kappa E_t\left(\hat{i}_{C,t+1} - \hat{i}_{C,t} + \frac{1}{1-a_i}\hat{v}_{t+1}\right) \\
& + \hat{p}_{i,t} + (1+\rho)\left[(i_I^{-\rho} + i_C^{-\rho})^{-1}(i_C^{-\rho}\hat{i}_{C,t} + i_I^{-\rho}\hat{i}_{I,t}) - \hat{i}_{C,t}\right], \qquad \text{(C.43)}
\end{aligned}
$$

with $\hat{q}_{C,t} = \hat{\phi}_{C,t} - \hat{\lambda}_t$.

Choice of investment for the investment sector:

$$\begin{aligned}\hat{q}_{I,t} =& e^{2(\frac{1}{1-a_i}g_v)}\kappa\Big(\hat{\hat{i}}_{I,t} - \hat{\hat{i}}_{I,t-1} + \frac{1}{1-a_i}\hat{v}_t\Big) - \beta e^{2(\frac{1}{1-a_i}g_v)}\kappa E_t\Big(\hat{\hat{i}}_{I,t+1} - \hat{\hat{i}}_{I,t} + \frac{1}{1-a_i}\hat{v}_{t+1}\Big)\\ &+ \hat{p}_{i,t} + (1+\rho)\Big[(i_I^{-\rho} + i_C^{-\rho})^{-1}(i_C^{-\rho}\hat{\hat{i}}_{C,t} + i_I^{-\rho}\hat{\hat{i}}_{I,t}) - \hat{\hat{i}}_{I,t}\Big], \qquad \text{(C.44)}\end{aligned}$$

with $\hat{q}_{I,t} = \hat{\phi}_{I,t} - \hat{\lambda}_t$.

Capital input in both sectors:

$$\hat{k}_{C,t} = \hat{u}_{C,t} + \xi_{C,t}^K + \hat{\bar{k}}_{C,t-1} - \frac{1}{1-a_i}\hat{v}_t, \qquad \hat{k}_{I,t} = \hat{u}_{I,t} + \xi_{I,t}^K + \hat{\bar{k}}_{I,t-1} - \frac{1}{1-a_i}\hat{v}_t. \qquad \text{(C.45)}$$

Capital accumulation in the consumption and investment sector:

$$\hat{\bar{k}}_{C,t} = (1-\delta_C)e^{-\frac{1}{1-a_i}g_v}\Big(\hat{\bar{k}}_{C,t-1} + \xi_{C,t}^K - \frac{1}{1-a_i}\hat{v}_t\Big) + \Big(1 - (1-\delta_C)e^{-\frac{1}{1-a_i}g_v}\Big)\hat{\hat{i}}_{C,t}, \qquad \text{(C.46)}$$

$$\hat{\bar{k}}_{I,t} = (1-\delta_I)e^{-\frac{1}{1-a_i}g_v}\Big(\hat{\bar{k}}_{I,t-1} + \xi_{I,t}^K - \frac{1}{1-a_i}\hat{v}_t\Big) + \Big(1 - (1-\delta_I)e^{-\frac{1}{1-a_i}g_v}\Big)\hat{\hat{i}}_{I,t}. \qquad \text{(C.47)}$$

C.4.5 Wages

The wage setting equation for workers renegotiating their salary:

$$0 = E_t\Big\{\sum_{s=0}^{\infty}\xi_w^s\beta^s\Big[\hat{\tilde{w}}_t + \hat{\tilde{\Pi}}_{t,t+s}^w - \hat{\lambda}_{w,t+s} - \hat{b}_{t+s} - \nu\hat{\tilde{L}}_{t+s} + \hat{\lambda}_{t+s}\Big]\Big\},$$

with

$$\hat{\tilde{\Pi}}_{t,t+s}^w = \sum_{k=1}^{s}\Big[\iota_w\Big(\hat{\pi}_{c,t+k-1} + \hat{z}_{t+k-1} + \frac{a_c}{1-a_i}\hat{v}_{t+k-1}\Big) - \Big(\hat{\pi}_{c,t+k} + \hat{z}_{t+k} + \frac{a_c}{1-a_i}\hat{v}_{t+k}\Big)\Big],$$

and

$$\hat{\tilde{L}}_{t+s} = \hat{L}_{t+s} - \Big(1 + \frac{1}{\lambda_w}\Big)\big(\hat{\tilde{w}}_t + \hat{\tilde{\Pi}}_{t,t+s}^w - \hat{w}_{t+s}\big).$$

Then using the labor demand function,

$$\begin{aligned}
0 =& E_t\Big\{ \sum_{s=0}^{\infty} \xi_w^s \beta^s \Big[\hat{\tilde{w}}_t + \hat{\tilde{\Pi}}^w_{t,t+s} - \hat{\lambda}_{w,t+s} - \hat{b}_{t+s} \\
& - \nu\Big(\hat{L}_{t+s} - \Big(1 + \frac{1}{\lambda_w}\Big)\big(\hat{\tilde{w}}_t + \hat{\tilde{\Pi}}^w_{t,t+s} - \hat{w}_{t+s})\Big) + \hat{\lambda}_{t+s}\Big]\Big\} \\
\Leftrightarrow 0 =& E_t\Big\{ \sum_{s=0}^{\infty} \xi_w^s \beta^s \Big[\hat{\tilde{w}}_t \Big(1 + \nu\Big(1 + \frac{1}{\lambda_w}\Big)\Big) + \hat{\tilde{\Pi}}^w_{t,t+s} - \hat{\lambda}_{w,t+s} - \hat{b}_{t+s} \\
& - \nu\Big(\hat{L}_{t+s} - \Big(1 + \frac{1}{\lambda_w}\Big)\big(\hat{\tilde{\Pi}}^w_{t,t+s} - \hat{w}_{t+s})\Big) + \hat{\lambda}_{t+s}\Big]\Big\}.
\end{aligned}$$

Solving for the summation

$$\begin{aligned}
\frac{\nu_w}{1 - \xi_w \beta}\hat{\tilde{w}}_t =& E_t\Big\{ \sum_{s=0}^{\infty} \xi_w^s \beta^s \Big[- \Big(1 + \nu\big(1 + \frac{1}{\lambda_w}\big)\Big)\hat{\tilde{\Pi}}^w_{t,t+s} + \hat{\psi}_{t+s}\Big]\Big\} \\
=& - \nu_w \hat{\tilde{\Pi}}^w_{t,t} + \hat{\psi}_t + E_t\Big\{ \sum_{s=0}^{\infty} \xi_w^s \beta^s \Big[- \nu_w \hat{\tilde{\Pi}}^w_{t,t+s} + \hat{\psi}_{t+s}\Big]\Big\} \\
=& \hat{\psi}_t - \frac{\xi_w \beta}{1 - \xi_w \beta}\nu_w \hat{\Pi}^w_{t,t+1} + \xi_w \beta E_t\Big\{ \sum_{s=0}^{\infty} \xi_w^s \beta^s [-\nu_w \hat{\Pi}^w_{t+1,t+1+s} + \hat{\psi}_{t+1+s}]\Big\} \\
=& \hat{\psi}_t + \frac{\xi_w \beta}{1 - \xi_w \beta}\nu_w E_t\big[\hat{\tilde{w}}_{t+1} - \hat{\tilde{\Pi}}^w_{t,t+1}\big]. \qquad \text{(C.48)}
\end{aligned}$$

where

$$\begin{aligned}
\hat{\psi}_t &\equiv \hat{\lambda}_{w,t} + \hat{b}_t + \nu \hat{L}_t + \nu\Big(1 + \frac{1}{\lambda_w}\Big)\hat{w}_t - \hat{\lambda}_t, \qquad \text{(C.49)} \\
\nu_w &\equiv 1 + \nu\Big(1 + \frac{1}{\lambda_w}\Big),
\end{aligned}$$

and recall that $\hat{\tilde{\Pi}}^w_{t,t} = 0$.

Wages evolve as

$$\begin{aligned}
\hat{w}_t =& (1 - \xi_w)\hat{\tilde{w}}_t + \xi_w\Bigg(\hat{w}_{t-1} + \iota_w \hat{\pi}_{c,t-1} + \iota_w\Big(\hat{z}_{t-1} + \frac{a_c}{1 - a_i}\hat{v}_{t-1}\Big) - \hat{\pi}_{c,t} - \hat{z}_t - \frac{a_c}{1 - a_i}\hat{v}_t\Bigg) \\
\Leftrightarrow \hat{w}_t =& (1 - \xi_w)\hat{\tilde{w}}_t + \xi_w(\hat{w}_{t-1} + \hat{\tilde{\Pi}}^w_{t,t-1}). \qquad \text{(C.50)}
\end{aligned}$$

Equation (C.50) can be solved for $\hat{\tilde{w}}_t$. This expression, as well as the formulation for $\hat{\psi}_t$ given in (C.49) can be plugged into equation (C.48). After reformulation this yields the wage Phillips curve The wage Phillips curve can be derived to be:

$$
\begin{aligned}
\hat{w}_t =& \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{\beta}{1+\beta}E_t\hat{w}_{t+1} - \kappa_w\hat{g}_{w,t} + \frac{\iota_w}{1+\beta}\hat{\pi}_{c,t-1} - \frac{1+\beta\iota_w}{1+\beta}\hat{\pi}_{c,t} \\
& + \frac{\beta}{1+\beta}E_t\hat{\pi}_{c,t+1} + \kappa_w\hat{\lambda}_{w,t} + \frac{\iota_w}{1+\beta}\big(\hat{z}_{t-1} + \frac{a_c}{1-a_i}\hat{v}_{t-1}\big) \\
& - \frac{1+\beta\iota_w-\rho_z\beta}{1+\beta}\hat{z}_t - \frac{1+\beta\iota_w-\rho_v\beta}{1+\beta}\frac{a_c}{1-a_i}\hat{v}_t.
\end{aligned} \tag{C.51}
$$

where

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

C.4.6 Financial sector

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

The stochastic discount factor:

$$\hat{\lambda}_t^B = \hat{\lambda}_t - \hat{\lambda}_{t-1}. \tag{C.52}$$

Definition of ν:

$$
\begin{aligned}
\hat{\nu}_{x,t} =& (1-\theta_B\beta z_1^x)[\hat{\lambda}_{t+1}^B - \hat{z}_{t+1} - \frac{a_c}{1-a_i}\hat{v}_{t+1}] \\
& + \frac{1-\theta_B\beta z_1^x}{R_x^B - R}[R_x^B\hat{R}_{x,t+1}^B - R\hat{R}_t] + \theta_B\beta z_1^x[\hat{z}_{1,t+1}^x + \hat{\nu}_{x,t+1}], \qquad x = C, I.
\end{aligned} \tag{C.53}
$$

Definition of η:

$$
\begin{aligned}
\hat{\eta}_{x,t} =& (1-\theta_B\beta z_2^x)[\hat{\lambda}_{t+1}^B - \hat{z}_{t+1} - \frac{a_c}{1-a_i}\hat{v}_{t+1} + \hat{R}_t] \\
& + \theta_B\beta z_2^x[\hat{z}_{2,t+1}^x + \hat{\eta}_{t+1}], \qquad x = C, I.
\end{aligned} \tag{C.54}
$$

Definition of z_1:

$$\hat{z}_{1,t}^x = \hat{\varrho}_{x,t} - \hat{\varrho}_{x,t-1} + \hat{z}_{2,t}^x, \qquad x = C, I. \tag{C.55}$$

Definition of z_2:

$$\hat{z}^x_{2,t} = \frac{1}{(R^B_x - R)\varrho_x + R}[R^B_x \varrho_x \hat{R}^B_{x,t} + R(1-\varrho_x)\hat{R}_{t-1} + (R^B_x - R)\varrho_x \hat{\varrho}_{x,t-1}], \qquad x = C, I. \tag{C.56}$$

The leverage ratio:

$$\hat{\varrho}_{x,t} = \hat{\eta}_{x,t} + \frac{\nu}{\lambda_B - \nu}\hat{\nu}_{x,t}, \qquad x = C, I. \tag{C.57}$$

The leverage equation:

$$\hat{q}_{x,t} + \hat{s}_{x,t} = \hat{\varrho}_{x,t} + \hat{n}_{x,t}. \tag{C.58}$$

The bank's wealth accumulation equation

$$\begin{aligned}
\hat{n}_{x,t} =& \varsigma_x \theta_B \varrho_x e^{-g_a - \frac{a_c}{1-a_i}g_v}\Big[R^B_x \hat{R}^B_{x,t} + \Big(\frac{1}{\varrho_x} - 1\Big)R\hat{R}_{t-1} + (R^B_x - R)\hat{\varrho}_{x,t-1}\Big] \\
&+ \varsigma_x \theta_B e^{-g_a - \frac{a_c}{1-a_i}g_v}[(R^B_x - R)\varrho_x + R]\Big[-\hat{z}_t - \frac{a_c}{1-a_i}\hat{v}_t + \hat{n}_{x,t-1}\Big] \\
&+ (1 - \varsigma_x \theta_B e^{-g_a - \frac{a_c}{1-a_i}g_v}[(R^B_x - R)\varrho_x + R])[\hat{q}_t + \hat{s}_t] \\
&+ [\theta_B e^{-g_a - \frac{a_c}{1-a_i}g_v}((R^B_x - R)\varrho_x + R) + (1 - \theta_B((R^B_x - R)\varrho_x + R))]\hat{\varsigma}_{x,t}, \qquad x = C, I.
\end{aligned} \tag{C.59}$$

The borrow in advance constraint:

$$\hat{\bar{k}}_{x,t+1} = \hat{s}_{x,t}, \qquad x = C, I. \tag{C.60}$$

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

$$\hat{R}^B_{x,t} = \frac{1}{r^K_x + q_x(1-\delta_x)}[r^K_x(\hat{r}^K_{x,t} + \hat{u}_{x,t}) + q_x(1-\delta_x)\hat{q}_{x,t}] - \hat{q}_{x,t-1} + \xi^K_{x,t} + \hat{z}_t - \frac{1-a_c}{1-a_i}\hat{v}_t. \tag{C.61}$$

External finance premium:

$$\hat{R}^{\Delta}_{x,t} = \hat{R}^B_{x,t+1} - \hat{R}_t, \qquad x = C, I. \tag{C.62}$$

C.4.7 Monetary policy and market clearing

Monetary policy rule:

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)\Big[\phi_\pi \hat{\pi_{c,t}} + \phi_{\Delta\pi}(\hat{\pi_{c,t}} - \hat{\pi_{c,t-1}}) + \phi_{\Delta Y}(\hat{y}_t - \hat{y}_{t-1})\Big] + \hat{\eta}_{mp,t} \quad \text{(C.63)}$$

Resource constraint in the consumption sector:

$$\hat{c}_t + \left(r_C^K \frac{\bar{k}_C}{c}\hat{u}_{C,t} + r_I^K \frac{\bar{k}_I}{c}\hat{u}_{I,t}\right)e^{-\frac{1}{1-a_i}g_v} = \frac{c+F_c}{c}[a_c\hat{k}_{C,t} + (1-a_c)\hat{L}_{C,t}] \quad \text{(C.64)}$$

Resource constraint in the investment sector:

$$\hat{i}_t = \frac{i+F_I}{i}[a_i\hat{k}_{I,t} + (1-a_i)\hat{L}_{I,t}] \quad \text{(C.65)}$$

Definition of GDP:

$$\hat{y}_t = \frac{c}{c+p_i i}\hat{c}_t + \frac{p_i i}{c+p_i i}(\hat{i}_t + \hat{p}_{i,t}) + \hat{e}_t. \quad \text{(C.66)}$$

Market clearing:

$$\frac{L_C}{L}\hat{L}_{C,t} + \frac{L_I}{L}\hat{L}_{I,t} = \hat{L}_t, \quad \left[i_C^{-\rho} + i_I^{-\rho}\right]^{-1}\left(i_I^{-\rho}\hat{i}_{I,t} + i_C^{-\rho}\hat{i}_{C,t}\right) = \hat{i}_t. \quad \text{(C.67)}$$

C.4.8 Exogenous processes

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

$$\hat{\lambda}^x_{p,t} = \rho_{\lambda^x_p}\hat{\lambda}^x_{p,t-1} + \varepsilon^x_{p,t}. \quad \text{(C.68)}$$

The TFP growth shock to the consumption sector:

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon^z_t. \quad \text{(C.69)}$$

The TFP growth shock to the investment sector:

$$\hat{v}_t = \rho_v \hat{v}_{t-1} + \varepsilon^v_t. \quad \text{(C.70)}$$

Wage markup shock:

$$\hat{\lambda}_{w,t} = \rho_w \hat{\lambda}_{w,t-1} + \varepsilon_{w,t}. \quad \text{(C.71)}$$

Preference shock:

$$\hat{b}_t = \rho_b \hat{b}_{t-1} + \varepsilon_t^b. \tag{C.72}$$

Monetary policy shock:

$$\hat{\eta}_{mp,t} = \varepsilon_t^{mp}. \tag{C.73}$$

GDP measurement error:

$$\hat{e}_t = \rho_e \hat{e}_{t-1} + \varepsilon_t^e. \tag{C.74}$$

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

$$\hat{\varsigma}_{x,t} = \rho_{\varsigma_x} \hat{\varsigma}_{x,t-1} + \epsilon_{x,t}^{\varsigma}. \tag{C.75}$$

asset value shock in sector $x = C, I$:

$$\hat{\xi}_{x,t}^K = \rho_{\xi^K,x} \hat{\xi}_{x,t-1}^K + \varepsilon_{x,t}^{\xi^K} \qquad \text{with} \qquad \varepsilon_{x,t}^{\xi^K} = \varepsilon_{x,t}^{\xi^{K,0}} + \varepsilon_{x,t}^{\xi^{K,news}} \tag{C.76}$$

The entire log-linear model is summarized by equations (C.37) - (C.47) and (C.51) - (C.67) as well as the shock processes (C.68) - (C.76).

C.5 Measurement equations

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

$$\Delta C_t^d \equiv \log\left(\frac{C_t}{C_{t-1}}\right) = \log\left(\frac{c_t}{c_{t-1}}\right) + \hat{z}_t + \frac{a_c}{1-a_i}\hat{v}_t,$$

Real investment growth,

$$\Delta I_t^d \equiv \log\left(\frac{I_t}{I_{t-1}}\right) = \log\left(\frac{i_t}{i_{t-1}}\right) + \frac{1}{1-a_i}\hat{v}_t,$$

Relative price of investment,

$$\left(\frac{P_{I,t}}{P_{C,t}}\right)^d \equiv \log\left(\frac{P_{I,t}}{P_{C,t}} / \frac{P_{I,t-1}}{P_{C,t-1}}\right) = \log\left(\frac{p_{i,t}}{p_{i,t-1}}\right) + \hat{z}_t + \frac{a_c-1}{1-a_i}\hat{v}_t,$$

Real wage growth,

$$\Delta W_t^d \equiv \log\left(\frac{W_t}{W_{t-1}}\right) = \log\left(\frac{w_t}{w_{t-1}}\right) + \hat{z}_t + \frac{a_c}{1-a_i}\hat{v}_t,$$

Real output growth,

$$\Delta Y_t^d \equiv \log\left(\frac{Y_t}{Y_{t-1}}\right) = \log\left(\frac{y_t}{y_{t-1}}\right) + \hat{z}_t + \frac{a_c}{1-a_i}\hat{v}_t,$$

Consumption sector inflation,

$$\pi_{C,t}^d \equiv \pi_{C,t} = \hat{\pi}_{C,t} \quad \text{and} \quad \hat{\pi}_{C,t} = \log(\pi_{C,t}) - \log(\pi_C),$$

Investment sector inflation,

$$\pi_{I,t}^d \equiv \pi_{I,t} = \hat{\pi}_{I,t} \quad \text{and} \quad \hat{\pi}_{I,t} = \log(\pi_{I,t}) - \log(\pi_I),$$

Total hours worked,

$$L_t^d \equiv \log L_t = \hat{L}_t,$$

Nominal interest rate (federal funds rate),

$$R_t^d \equiv \log R_t = \log \hat{R}_t,$$

Consumption sector corporate spread,

$$R_{C,t}^{\Delta,d} \equiv \log R_{C,t}^{\Delta} = \log \hat{R}_{C,t+1}^B - \log \hat{R}_t,$$

Investment sector corporate spread,

$$R_{I,t}^{\Delta,d} \equiv \log R_{I,t}^{\Delta} = \log \hat{R}_{I,t+1}^B - \log \hat{R}_t,$$

Real total equity capital growth,

$$\begin{aligned}\Delta N_t^d \equiv& \log\left(\frac{N_t}{N_{t-1}}\right)\\ =& e^{g_a + \frac{a_c}{1-a_i} g_v}\left(\frac{n_C}{n_C+n_I}(\hat{n}_{C,t} - \hat{n}_{C,t-1}) + \frac{n_I}{n_C+n_I}(\hat{n}_{I,t} - \hat{n}_{I,t-1}) + \hat{z}_t + \frac{a_c}{1-a_i}\hat{v}_t\right).\end{aligned}$$