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News Shocks and Business Cycles: Bridging the Gap  
from Different Methodologies

**Christoph Görtz**  
University of Birmingham

**John D. Tsoukalas**  
University of Glasgow

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# News Shocks and Business Cycles: Bridging the Gap from Different Methodologies\*

Christoph Görtz<sup>†</sup> and John D. Tsoukalas<sup>‡</sup>

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## Abstract

An important disconnect in the news driven view of the business cycle formalized by Beaudry and Portier (2004), is the lack of agreement between different—VAR and DSGE—methodologies over the empirical plausibility of this view. We argue that this disconnect can be largely resolved once we augment a standard DSGE model with a financial channel that provides amplification to news shocks. Both methodologies suggest news shocks to the future growth prospects of the economy to be significant drivers of U.S. business cycles in the post-Greenspan era (1990-2011), explaining as much as 50% of the forecast error variance in hours worked in cyclical frequencies.

*Keywords:* News shocks, Business cycles, DSGE, VAR, Bayesian estimation.

*JEL Classification:* E2, E3.

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<sup>†</sup>University of Birmingham, Department of Economics, J.G. Smith Building, Edgbaston, Birmingham, B15 2TT. Email: c.g.gortz@bham.ac.uk.

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

# 1 Introduction

Motivated by the U.S. investment boom–bust episode of the 1990s, news shocks about future total factor productivity (TFP) have been proposed as a potentially important source of fluctuations (Beaudry and Portier (2004), Jaimovich and Rebelo (2009)). However, conflicting estimates in the literature, question the empirical plausibility of the “news” view of fluctuations. In the context of Vector autoregressive (VAR) methodologies, Beaudry and Portier (2006) and Beaudry and Lucke (2010) find that TFP news shocks are important drivers of business cycles, while Barsky and Sims (2011) and Forni et al. (2012) find they are not. The estimated DSGE methodology (Fujiwara et al. (2011), Khan and Tsoukalas (2012), Schmitt-Grohe and Uribe (2012)), find them to be negligible sources of fluctuations. In this paper we show that in the post–Greenspan era (1990-2011), different empirical methodologies, namely DSGE and VAR, yield a unified answer that provides strong support for the “news” view. The essential element is a strong link between financial markets and real activity that results in amplification of news shocks.

We revisit the VAR evidence. Figure 1 shows impulse responses of key macro aggregates to a favorable (permanent) TFP news shock obtained from a five variable VAR based on the Barsky and Sims (2011) methodology. We document two new facts. *First*, the corporate bond spread declines significantly on impact and anticipates future movements in TFP. *Second*, and quite importantly, in the sample we examine, good news about future TFP generate a boom.<sup>1</sup>

RBC type (as proposed in Jaimovich and Rebelo (2009)) and New Keynesian (NK) models (see Christiano et al. (2008), Khan and Tsoukalas (2012)) can in principle gener-

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<sup>1</sup>This finding stands in contrast to results reported in Barsky and Sims (2011) who find that good news about TFP, over the sample 1960-2007, generate recessions. In on-going work (Korobilis and Tsoukalas (2013)), we find evidence suggesting that TFP news shock may have been more relevant for business cycles in the last two and a half decades. Specifically, we detect a structural break in the impulse responses of a TFP news shock that occurs in the mid-1980s. We find TFP news to be contractionary in a pre-1982 sample (1960-1981), but expansionary in a post-1982 (1982-2012) sample, thus helping to explain those differences. The sample used in Barsky and Sims (2011) contains both sub-samples and we conjecture that the early sample has more influence on the impulse responses.

ate a boom following good news about TFP. However, in those models, absent financial frictions, there is no role for risk premiums as reflected in corporate bond spreads. This does not square with the VAR evidence presented above. It follows that the lack of variation in this financial indicator predicted by standard models, (a) eliminates transmission channels that link financial markets with real activity and (b) ignores potentially useful information that can help in the identification of TFP news shocks. A growing literature argues that corporate bond markets provide informative signals about future fundamentals (Gilchrist et al. (2009), Gilchrist and Zakrajsek (2012), Philippon (2009)). This paper proposes a model that links (a) and (b).

We augment a two sector NK model with a financial channel featuring leverage constraints as in Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) (henceforth GK).<sup>2</sup> The model features a final goods (consumption) and a capital goods (investment) sector with (different) sector specific technologies. The final goods sector buys goods from the capital goods sector, acting as a demand source for the latter. The model permits examining sectoral co-movement, a salient feature of the business cycle, but also a more demanding challenge for macroeconomic models (see Christiano and Fitzgerald (1998), Jaimovich and Rebelo (2009)) to pass, thus serving as a stricter test for the credibility of the “news” view.<sup>3</sup> Empirically, the model is motivated by the positive correlation between the relative price of investment and various measures of activity reported in Table 1, which strongly suggests the presence of at least two shocks affecting the relative price.<sup>4</sup> At a minimum, in our two sector framework, the relative price of investment can be affected by both sector specific technologies.

We estimate the model (using Bayesian techniques) in a post–Greenspan U.S. sample (1990-2011), allowing for many sources of uncertainty (including financial shocks) considered in the literature, using real, nominal and financial data (corporate bond spreads and

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<sup>2</sup>Recent evidence (see Adrian et al. (2010), Gilchrist and Zakrajsek (2012)) highlighting the important role of intermediaries—especially in the post 1990s—in affecting the flow of credit and determination of asset prices motivates the GK framework in our analysis.

<sup>3</sup>See Huffman and Wynne (1999) for evidence on sectoral co-movement.

<sup>4</sup>In one sector models, the correlation is predicted to be strongly negative since *only* investment specific technology affects the relative price of investment (see Fisher (2006) for an illustration).

bank equity). Our findings suggest news about the future growth prospects of the economy can explain a large fraction of business cycles. They account for approximately 37%, 31%, 50%, 30% of the variance in output, investment, hours worked and consumption respectively, in business cycle frequencies. They also account for significant shares of the variance in nominal and financial variables. The majority of the shares reported above are accounted for by a *consumption specific* TFP news shock, which acts as a *demand shock* in the model. Following the anticipation of a future permanent increase in its own TFP, the final goods (consumption) sector demands capital goods from the investment sector, and the latter responds by hiring more hours worked to satisfy demand, bidding up the price of investment goods and the price of capital. Financing the demand for capital is facilitated by intermediaries which face a leverage constraint tied to their equity. A higher price of capital boosts equity capital, relaxes the constraint and stimulates more lending, in turn providing a source of financial amplification. The financial channel we evaluate is consistent with the motivating facts discussed above. In the model, the corporate bond spread declines, and activity rises following an anticipated change in the future productivity of capital. When the model is taken to the data, the transmission favored is one in which investment demand drives the cycle, consistent with the “news” view of fluctuations (Beaudry and Portier (2004)).

We then investigate whether the proposed financial channel can bring in line DSGE and VAR methodologies over the empirical importance of news shocks. To accomplish this, we undertake three comparisons. *First*, a comparison of the DSGE based and VAR based impulse response functions to a TFP news shock. Both methodologies predict a statistically significant expansion of hours, consumption, output and investment and a decline in the corporate bond spread to an expected future TFP improvement. *Second*, a comparison of the shares in forecast error variance of key macro aggregates accounted for by the TFP news shock. We find those shares to be quite similar across the two methodologies. *Third*, we investigate whether the empirical VAR responses following the news shock, can be replicated by responses of VARs estimated on artificial model samples

(assuming the DSGE model to be the data generating process), and we find this to be the case for the majority of the empirical VAR responses examined. These findings suggest both methodologies produce a consistent assessment of TFP news shocks that supports them as a significant driver of fluctuations in the post–Greenspan era.

Our paper contributes to the ongoing debate on the importance of news shocks for aggregate fluctuations and highlights a new—financial—channel that can (i) generate significant real effects of news shocks and (ii) provide reconciliation between DSGE and VAR methodologies. A related financial channel is emphasized in Gunn and Johri (2013) who 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 the boom-bust cycle in liquidity and economic activity observed during the Great Recession. Recent work in Christiano et al. (2012), point to news shocks in the riskiness of the corporate sector that propagate and can be identified, as in our model, having distinct implications about financial prices and quantities, through the financial sector. Other recent empirical work, that supports the “news” view includes, among others, Alexopoulos (2011) and Leduc and Sill (2013), while different propagation channels of news shocks are explored in Beaudry and Portier (2007), Karnizova (2010), Gunn and Johri (2011), Walentin (2012), Theodoridis and Zanetti (2013).

The rest of the paper is organized as follows. Section 2 describes the model economy. Section 3 describes the estimation methodology, data, and discusses estimation results. Section 4 quantifies the importance of news shocks as driving forces behind fluctuations while Section 5 discusses the propagation of TFP news shocks. Section 6 discusses the relation with VAR–based findings. Section 7 concludes.

## 2 The Two Sector Model

The sectors in the model produce consumption and investment goods. The latter are used as capital inputs in each sectors’ production process, while the former enter only into

households utility functions. The model is sufficiently symmetric and nests a one sector NK model once we assume (a), that capital is immediately mobile across sectors (b), the investment sector is perfectly competitive and (c), adopt an appropriate re-normalization of TFP.<sup>5</sup>

Households consume, save in interest bearing deposits and supply labor on a monopolistically competitive labor market. A continuum of sector specific intermediate goods firms produce distinct investment and consumption goods using labor and capital services. They are subject to sector specific Calvo contracts when setting prices. Capital producers use investment goods and existing capital to produce new capital goods. Financial intermediaries collect deposits from households and finance capital acquisitions. A monetary policy authority controls the nominal interest rate.

## 2.1 Intermediate and final goods production

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

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

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

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

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 capital shares in production.<sup>6</sup> The variable  $A_t$  denotes the (non-stationary) level of TFP in the consumption sector and its

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<sup>5</sup>Recent work by Basu et al. (2010) measuring sector specific technical change with a growth accounting methodology and annual industry data, find significant evidence against summarizing technology with a single aggregate index, consistent with our analysis.

<sup>6</sup>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)). 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.

growth rate,  $z_t = \ln\left(\frac{A_t}{A_{t-1}}\right)$ , follows the process,

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

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,

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

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.

**News shocks.** We introduce a richer information structure with respect to the sectoral TFP processes. Specifically, we assume the respective innovation in the processes, (1) and (2), above consist of two components,

$$\varepsilon_t^z = \varepsilon_{t,0}^z + \varepsilon_{t,news}^z, \quad \varepsilon_t^v = \varepsilon_{t,0}^v + \varepsilon_{t,news}^v,$$

where the first component,  $\varepsilon_{t,0}^x$ , is unanticipated and the second component,  $\varepsilon_{t,news}^x$ ,  $x = z, v$  is anticipated or news. For example, Alexopoulos (2011) documents, people receive information (or news) in advance of the actual realization of technology innovations.<sup>7</sup> News can be anticipated several quarters ahead so that,

$$\varepsilon_{t,news}^x \equiv \sum_{h=1}^H \varepsilon_{t-h,h}^x, \quad x = z, v$$

where  $\varepsilon_{t-h,h}^x$ ,  $x = z, v$  is advanced information (or news) received by agents in period  $t - h$  (equivalently  $h$  periods ahead) about the innovation that affects sectoral TFP 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  $h = 0, 1, \dots, H$  are *i.i.d.* with  $N(0, \sigma_{z,t-h}^2)$ ,  $N(0, \sigma_{v,t-h}^2)$  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  $t-h+1, \dots, t-1$ , or by the unanticipated component,  $\varepsilon_{t,0}^v, \varepsilon_{t,0}^z$  at time  $t$ . This implies news received at any anticipation horizon may

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<sup>7</sup>News shocks are introduced in a similar way as for example in Davis (2007), Schmitt-Grohe and Uribe (2012), Khan and Tsoukalas (2012) and Fujiwara et al. (2011).



only be partially (or fail to) materialize.

The intermediate goods producers also make a pricing decision under Calvo (1983) contracts which, for space considerations, is described in Appendix C.

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,

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

The elasticities  $\lambda_{p,t}^C$  and  $\lambda_{p,t}^I$  are the time varying price markup over marginal cost. They are assumed to follow an AR(1) process,  $\log(1 + \lambda_{p,t}^x) = (1 - \rho_{\lambda_p^x}) \log(1 + \lambda_p^x) + \rho_{\lambda_p^x} \log(1 + \lambda_{p,t-1}^x) + \varepsilon_{p,t}^x$ , with persistence  $\rho_{\lambda_p^x} \in (0, 1)$  and  $\varepsilon_{p,t}^x$  (i.e. mark-up shock) which is *i.i.d.*  $N(0, \sigma_{\lambda_p^x}^2)$  (for  $x = C, I$ ). As is standard in NK models, prices of final goods are CES aggregates of intermediate good prices. Details about these prices and the processes for the mark-up shocks are given in Appendix C.

## 2.2 Households

Households consist of two member types, workers (relative size  $1-f$ ) and bankers (relative size  $f$ ). Workers supply (specialized) labor, indexed by  $j$ , and earn wages while 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 maximizes,

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

where  $E_0$  is the conditional expectation operator,  $\beta$  is the discount factor and  $h$  is the degree of (external) habit formation. The inverse Frisch labor supply elasticity is denoted by  $\nu$ , while  $\varphi$  is a free parameter which allows to calibrate total labor supply in the steady

state.<sup>8</sup> The variable  $b_t$  is a intertemporal preference shock. It is assumed to follow the stochastic process,  $\log b_t = \rho_b \log b_{t-1} + \varepsilon_t^b$ , where  $\rho_b \in (0, 1)$  and  $\varepsilon_t^b$  is *i.i.d*  $N(0, \sigma_b^2)$ . The household's flow budget constraint (in consumption units) is,

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

where  $B_t$  is holdings of risk free bank deposits,  $\Psi_t$  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  $\Pi_t$  is the net profit accruing to households from ownership of all firms. Notice above, the wage rate,  $W_t$ , is identical across sectors due to perfect labor mobility.

**Wage setting.** Each household  $j \in [0, 1]$  supplies specialized labor,  $L_x t(j)$ ,  $x = C, I$ , 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. The wage decision details are described in Appendix C.

## 2.3 Capital goods production

**Capital services producers.** These agents purchase—using funds from intermediaries—physical capital from physical capital producers (described below), transform it to capital services (by choosing the utilization rate), which they rent—in perfectly competitive markets—to intermediate goods producers earning a rental rate equal to  $R_{x,t}^K/P_{C,t}$  per unit of capital. They sell the un-depreciated portion of capital at the end of period  $t + 1$  at price  $Q_{x,t+1}$  to physical capital producers.<sup>9</sup> The utilization rate,  $u_{x,t}$ , transforms physical

<sup>8</sup>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.

<sup>9</sup>The price of capital, equivalent to Tobin's marginal  $Q$ ,  $Q_{x,t} = \frac{\Phi_{x,t}}{\Lambda_t}$ , where  $\Lambda_t$ ,  $\Phi_{x,t}$ , are the lagrange multipliers on the households' budget constraint, and capital accumulation constraint respectively.

capital into capital services according to

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

and incurs a cost 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  $\chi_x \equiv \frac{a_x''(1)}{a_x'(1)}$ , denotes the cost elasticity.

In the transformation above, we allow for a capital quality shock (as in Gertler and Karadi (2011)),  $\xi_{x,t}^K$ , and assume it evolves according to  $\log \xi_{x,t}^K = \rho_{\xi^K, x} \log \xi_{x,t-1}^K + \varepsilon_{x,t}^{\xi^K}$  where  $\rho_{\xi^K, x} \in (0, 1)$  and  $\varepsilon_{x,t}^{\xi^K}$  is *i.i.d*  $N(0, \sigma_{\xi^K}^2)$ , with  $x = C, I$ . This disturbance shifts the demand for capital and directly affects its value—equivalently the value of assets held by intermediaries since they provide finance for capital acquisitions. For this reason we interpret it as a financial shock.<sup>10</sup>

These producers solve,

$$\max_{u_{x,t+1}} \left[ \frac{R_{x,t+1}^K}{P_{C,t+1}} u_{x,t+1} \xi_{x,t+1}^K \bar{K}_{x,t} - a_x(u_{x,t+1}) \xi_{x,t+1}^K \bar{K}_{x,t} A_{t+1} V_{t+1}^{\frac{a_c-1}{1-a_i}} \right] \quad x = C, I$$

Total receipts of capital services producers in period  $t + 1$  are equal to,

$$R_{x,t+1}^B Q_{x,t} \bar{K}_{x,t},$$

with

$$R_{x,t+1}^B = \frac{\frac{R_{x,t+1}^K}{P_{x,t+1}} \xi_{x,t+1}^K u_{x,t+1} + Q_{x,t+1} \xi_{x,t+1}^K (1 - \delta_x) - a_x(u_{x,t+1}) \xi_{x,t+1}^K A_{t+1} V_{t+1}^{\frac{a_c-1}{1-a_i}}}{Q_{x,t}} \quad (3)$$

where  $R_{x,t+1}^B$  is the real rate of return on capital and  $\delta_x$  is the sectoral depreciation rate. Since these agents finance their purchase of capital at the end of each period with funds from financial intermediaries (to be described below),  $R_{x,t+1}^B$  is the stochastic return earned by financial intermediaries.

**Physical capital production.** Capital producers in sector  $x = C, I$ , use a fraction of investment goods from final goods producers and undepreciated capital from capital services producers to produce new capital goods, subject to investment adjustment costs

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<sup>10</sup>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).

as proposed by Christiano et al. (2005). Solving their optimization problem yields a standard capital accumulation equation,<sup>11</sup>

$$\bar{K}_{x,t} = (1 - \delta_x)\xi_{x,t}^K \bar{K}_{x,t-1} + \left(1 - S\left(\frac{I_{x,t}}{I_{x,t-1}}\right)\right)I_{x,t}, \quad x = C, I. \quad (4)$$

## 2.4 Financial sector

Financial intermediaries use deposits from households and their own equity capital to finance the acquisitions of capital by capital services producers. The implementation of financial intermediaries is based on Gertler and Karadi (2011), so we only briefly describe it here (Appendix C provides all the equations), focusing on the essential mechanics.<sup>12</sup> These can be described with three key equations. The balance sheet identity, the demand for assets that links equity capital with the value of assets (physical capital), and finally, the evolution of equity capital.

The **balance sheet** (in nominal terms) of a branch that lends in sector  $x = C, I$ , is,

$$Q_{x,t}P_{C,t}S_{x,t} = N_{x,t}P_{C,t} + B_{x,t},$$

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  $t$ ,  $B_{x,t}$  are households deposits and  $P_{C,t}$  is the consumption sector price level.

Financial intermediaries are limited from infinitely borrowing household funds by a moral hazard/costly enforcement problem, where bankers can steal funds and transfer

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<sup>11</sup>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. 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.

<sup>12</sup>We interpret the financial sector as a single intermediary with two independent branches, each specializing in providing financing to one sector only, where the probability of lending specialization is equal across sectors and independent across time.

them to households (see Appendix C for detailed exposition). Intermediaries maximize expected terminal wealth, i.e. the discounted sum of future equity capital. The moral hazard problem introduces an endogenous **leverage constraint**, limiting the bank's ability to acquire assets. This is formalized in the equation that determines the demand for assets,

$$Q_{x,t}S_{x,t} = \varrho_{x,t}N_{x,t}. \quad (5)$$

In the equation above, the value of assets which the intermediary can acquire depends on equity capital,  $N_{x,t}$ , scaled by the leverage ratio,  $\varrho_{x,t}$ .<sup>13</sup> With  $\varrho_{x,t} > 1$ , the leverage constraint magnifies changes in equity capital on the demand for assets. Higher demand for capital goods for example, which raises the price of capital, increases equity capital (through the balance sheet identity) which in turn brings about further changes in the demand for assets by intermediaries pushing the price of capital further. This amplification turns out to be the key reason for the important role of news shocks we recover from the estimated model.

Finally, the evolution of equity capital is described by the following **law of motion for equity capital**,

$$N_{x,t+1} = (\theta_B[(R_{x,t+1}^B\pi_{C,t} - R_t)\varrho_{x,t} + R_t]\frac{N_{x,t}}{\pi_{C,t+1}} + \varpi Q_{x,t+1}S_{x,t+1}).$$

where,  $\theta_B$  is the exit rate of bankers,  $\varpi$  denotes the fraction of assets given to new bankers and  $\pi_{C,t}$  is consumption goods inflation. It is useful to define the expected (nominal) excess return (or risk premium) on assets earned by banks as

$$R_{x,t}^S = R_{x,t+1}^B\pi_{C,t+1} - R_t, \quad x = C, I. \quad (6)$$

The presence of the financial intermediation constraint in equation (5), implies a non-negative excess return (equivalently wedge between the expected return on capital and the risk free interest rate), which varies over time with the equity capital of intermediaries.

**Financing capital acquisitions by capital services producers.** Capital services

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<sup>13</sup>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.

producers issue  $S_{x,t}$  claims equal to units of physical capital acquired,  $\bar{K}_{x,t}$ , priced at  $Q_{x,t}$ . 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.<sup>14</sup> 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 (6) as a corporate bond spread.

## 2.5 Monetary policy and market clearing

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

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

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 goods (gross) inflation from its target level, and real GDP growth and is subject to a monetary policy IID shock  $\eta_{mp,t}$ . GDP (in consumption units) is defined as,

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

where  $G_t$  denotes government spending (in consumption units) which we assume to evolve exogenously according to  $G_t = \left(1 - \frac{1}{g_t}\right)Y_t$ , with,  $\log g_t = (1 - \rho_g)\log g + \rho_g\log g_{t-1} + \varepsilon_t^g$  where  $\rho_g \in (0, 1)$  and  $\varepsilon_t^g$  is *i.i.d.*  $N(0, \sigma_g^2)$ . The sectoral resource constraints are stated in Appendix C.

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<sup>14</sup>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 assume all the risk when lending to capital services producers.

### 3 Data and Methodology

We estimate the model using quarterly U.S. data (1990 Q2 - 2011 Q1) on eleven real, nominal and financial market variables. Our financial observables consist of sectoral (non-financial) corporate bond spreads and a publicly available measure of intermediaries' equity capital reported by the Federal Financial Institutions Examination Council. We use sector specific spreads for investment grade corporate bonds issued by non-financial companies that are actively traded in the secondary market. We focus on investment grade issues (source: Datastream) motivated by the evidence in Gilchrist and Zakrajsek (2012). Companies who are investment grade issuers are also less likely to be facing constraints in the intermediation process, consistent with the assumptions of the model. The average rating range/duration in our sample is A- to BBB+/7.5 years, A- to BBB+/7 years, in the consumption, investment sector respectively. Our bond spread indicators appear to be quite informative, especially compared to other popular indicators—such as Baa spread, S&P 500 return—for future company fundamentals, as captured by the (I/B/E/S) long term earnings forecast.<sup>15</sup> Specifically, the correlation of (i) our average spread indicator, (ii) Baa spread, (iii) S&P 500 real return with the (I/B/E/S) earnings forecast is,  $-0.60^*$ ,  $-0.27^*$ ,  $-0.04$ , respectively, where  $*$  indicates significance at the 5% level. These correlations suggest, our spread indicators may have the ability to strongly anticipate future changes in corporate fundamentals.

The vector of observables we use in the estimation is given as,

$$\mathbf{Y}_t = [\Delta \log Y_t, \Delta \log C_t, \Delta \log I_t, \Delta \log W_t, \pi_{C,t}, \pi_{I,t}, \log L_t, R_t, R_{C,t}^S, R_{I,t}^S, \Delta \log N_t],$$

where  $\Delta$  denotes the first-difference operator and we demean the data prior to estimation. In the vector above,  $Y_t, C_t, I_t, W_t, \pi_{C,t}, \pi_{I,t}, L_t, R_t, R_{C,t}^S, R_{I,t}^S, N_t$ , denote, output (GDP), consumption, investment, real wage, consumption sector inflation, investment sector inflation, hours worked, nominal interest rate, consumption sector bond spread, investment sector bond spread and bank equity respectively. Appendix B describes the

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<sup>15</sup>The latter was shown in Cummins et al. (2006) to capture future corporate fundamentals that drive U.S. corporate investment.

data sources and methods in detail.

**Prior and posterior distributions.** A number of fairly standard parameters are calibrated and are summarized in Table 2 (described in detail in Appendix A.1). For the parameters we estimate we use prior distributions that conform to the assumptions in Justiniano et al. (2010) and Khan and Tsoukalas (2012). We consider four and eight quarter ahead sector specific TFP news. This choice is guided by the desire to economize 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. Similar news horizons are considered by Christiano et al. (2012), Schmitt-Grohe and Uribe (2012) and Khan and Tsoukalas (2012). The prior means assumed for the TFP news components are in line with the studies mentioned above and imply that the sum of the variance of news components is at most one half of the variance of the corresponding unanticipated component. We undertake robustness checks on the weight of the priors in section 4. We use the Bayesian methodology to estimate the parameters. Table 3 reports information on prior, the posterior mean and the 10% to 90% probability interval 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. One finding we draw attention to, is the degree of price stickiness estimated for the investment sector. The Calvo probability is estimated at 0.70. This implies that one of the restrictions, namely a perfectly competitive investment sector, required to write the two sector model as a particular one sector model (as in Justiniano et al. (2010), Khan and Tsoukalas (2012)) is not satisfied.

**Identification.** We use two tests to check for identification of the model parameters, proposed by, (i) Iskrev (2010) and (ii) Koop et al. (2012), the latter being a more powerful test in cases of weak identification. Both tests indicate that the parameters are well identified (see Appendix A.3 for the details).



## 4 Variance Decompositions

In this section we document the relative contribution of the model's disturbances in accounting for fluctuations. We discuss results from a decomposition at the frequency domain, focussing on business cycle frequencies.<sup>16</sup> Table 4 reports our findings.

**News shocks.** TFP news shocks account for approximately 37%, 30%, 31%, 50% of the variance in output, consumption, investment and hours worked respectively, with the majority of these shares accounted for by *consumption specific* TFP news (see next section for a description of the propagation). Moreover, they account for a significant fraction in the variance of both corporate bond spread series, exceeding 40%, suggesting a significant amount of variation in the latter may reflect future fundamentals. They also account for over 50% in the variance of the nominal interest rate, and between, approximately, 34% to 41% of the variance in the sectoral inflation rates. Investment specific TFP news components account for significantly smaller variance shares in all observables, namely, less than 10% (except the variance share in the real wage, approximately 17%). The finding that investment specific news shocks are of lesser quantitative importance effectively rests on the property that these shocks signal future changes in the supply not demand for capital goods. An expected improvement in the productivity of the capital goods sector, makes installed capital less valuable and generates a decline of capital prices on impact, severing the financial amplification channel which rests on procyclical capital prices. Econometrically, these shocks fail to replicate data moments, among these, the pro-cyclicality of the relative price of investment and the counter-cyclicality of corporate bond spreads.

**The importance of consumption specific TFP news shocks.** Why do consumption specific TFP news shocks become so important in accounting for the variance in the data, in the presence of multiple sources of disturbances? Relative to other disturbances, they generate the right type of co-movements between aggregate quantities and prices

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<sup>16</sup>For space considerations we summarize results that are of most interest to our discussion and report a detailed decomposition on all shocks in Table 7 in Appendix A.2.

(see Section 5 for an exposition of the transmission). More specifically, (a) procyclical movements in quantities, (b) countercyclical movements in corporate bond spreads and a set of cross correlations of the latter with real macro aggregates in line with those in the data. 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) and (b) above, in the data (solid line), model with all shocks active (line with '+'), model with the dominant TFP news shock only active (and all other shocks set to zero—line with circles). The dynamic correlations implied by the model simulated with consumption specific TFP news shocks only are very similar to the correlations generated by the model with all shocks active. Moreover, in some dimensions the correlations implied by the former (e.g. see subplots (1,3)—output growth with hours, (2,2)—output growth with C sector spread, (3,1)—investment growth with C sector spread, (3,2)—sectoral bond spreads, (3,3)—hours worked) are extremely well aligned to the empirical ones, highlighting their importance for the ability of the model to match them so closely.

**News shocks with the financial channel turned off.** The findings on the overall importance of TFP news shocks stand in contrast to earlier DSGE (Fujiwara et al. (2011), Khan and Tsoukalas (2012), Schmitt-Grohe and Uribe (2012)) work, despite many model similarities. However, the frameworks considered therein do not allow for the link between the financial sector and real activity. We now illustrate the impact of the financial channel on the empirical relevance of TFP news shocks. Table 5 reports the variance shares accounted for by TFP news shocks from two model specifications, namely, the baseline against a simple model estimated with the financial channel stripped off. This exercise helps to quantify the size of the amplification generated by the financial channel. Overall, the quantitative importance of TFP news shocks in the simpler model declines significantly. For example, the contribution of consumption specific TFP news shocks in the variance of output declines from approximately 31% in the baseline, to less than 7% in the estimated model without the financial channel, whereas the total contribution of TFP news shocks in the variance of output (hours) declines from 37% (50%) to ap-

proximately 15% (17%). In the simple model therefore, the empirical role of TFP news shocks is broadly in line (though somewhat higher) with earlier findings reported in estimated one sector models, such as Khan and Tsoukalas (2012), Fujiwara et al. (2011), Schmitt-Grohe and Uribe (2012).<sup>17</sup> This is not surprising since our estimated two sector model nests these simpler one sector frameworks. We finally note, that the baseline model dominates, in terms of fit, the model without the financial sector when both are estimated on the same dataset (excluding the financial variables). The difference in the marginal data densities is equal to 12.13 log points in favor of the baseline.

Overall the model suggests, TFP (consumption and investment specific) shocks, unanticipated and news, account for the majority of the forecast error variance in the data (see the next to last column in Table 4), thus becoming the dominant source of fluctuations. Investment specific TFP shocks, in contrast to estimated one sector models (e.g. Khan and Tsoukalas (2012), Schmitt-Grohe and Uribe (2012), Christiano et al. (2012)), are sizable drivers of fluctuations, broadly consistent with earlier findings in Greenwood et al. (2000), Fisher (2006) and Justiniano et al. (2010). The key reason, is that, in our framework, these shocks are not identified from the relative price of investment alone.<sup>18</sup> It is also interesting to report that (ad-hoc) wage mark-up or price mark up shocks play a very limited role. Finally, the contribution of capital quality shocks, which we interpret as financial shocks, is fairly limited, accounting for less than 10% in the majority of macroeconomic real and nominal series (except consumption), but nevertheless account for shares close to 20% in two out of the three financial observables, consistent with the interpretation we adopt for these shocks.<sup>19</sup>

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<sup>17</sup>Khan and Tsoukalas (2012) and Schmitt-Grohe and Uribe (2012) find that wage mark-up and preference news shocks explain a large share of the variance in the data, especially for hours worked. However, that these ad-hoc disturbances are found to explain large fractions of the variance in hours worked is not satisfactory from a structural perspective, because it likely indicates mis-specification.

<sup>18</sup>The relative price of investment in the model is given as,  $P_{I,t}/P_{C,t} = \text{wedge}_t A_t/V_t$ , where the  $\text{wedge}_t$ , is a function of price mark-ups and capital labor ratios. The presence of the wedge implies, all shocks affect this price (Appendix A.6 provides a detailed exposition.) We note, the transmission following an unanticipated investment specific shock is qualitatively very similar to that generated from a one sector model as in Justiniano et al. (2010) so we do not discuss it in detail.

<sup>19</sup>A positive shock of this type has the property that it raises the price of capital and thus causes a revaluation of assets in the banks' portfolios, leading to gains in bank equity and expansion in lending consistent with this interpretation.

**Robustness.** We undertake several robustness exercises to assess the sensitivity of our results, along four dimensions. First, we allow for a common aggregate TFP shock, as a source of broad based co-movement, that affects symmetrically both sectors. Second, we vary the assumptions on prior distributions of shocks in the model, and prior weights assigned on news shocks. Third, we exclude the most recent “Great Recession” period, namely, observations from 2008Q1 to 2011Q1, from the estimation sample, to guard against the possibility that the empirical role of news shocks may be driven by this recent volatile period, as well as potential misspecification of the monetary policy rule when the policy rate approaches the zero lower bound. Fourth, we add news components in the non-structural disturbances of the model as in Khan and Tsoukalas (2012) and Schmitt-Grohe and Uribe (2012). These robustness checks are reported in Appendix A.4. Briefly, we find, in line with our baseline results, consumption specific TFP news shocks continue to be significant drivers of business cycles along all perturbations described above.

## 5 Propagation and amplification of consumption specific TFP news

In this section, we discuss the model’s impulse responses to a consumption specific TFP news shock to better understand the propagation. Figure 3 shows impulse responses (IRFs) to an anticipated (two year ahead) positive, consumption specific TFP shock. The broad aggregates, namely, consumption, investment, and hours worked rise along with output in anticipation of the future improvement in TFP. The sectoral aggregates move together with aggregate activity. Thus the shock generates both *aggregate* and *sectoral* co-movement in response to the news shock.<sup>20</sup>

The two sector structure of the model propagates the shock to the investment sector.

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<sup>20</sup>We have checked that sectoral investment and hours worked exhibit co-movement in the data. We do not discuss this evidence in detail given that we have not attempted to match data moments from sectoral hours and investment in the estimation.

The anticipation that future productivity of capital will be permanently higher in the consumption sector creates demand for capital goods produced by the investment sector. The strong demand causes the relative price of investment to rise, consistent with the procyclicality of the relative price of investment in our sample (see Table 1). Capital prices rise as well. The price of (consumption sector) capital increases in anticipation of the expected future improvement in TFP and future productivity of capital. The price of investment sector capital increases as well: more inputs, including capital specific to this sector, will be employed in order to satisfy higher demand for investment goods from the consumption sector. Thus, both hours worked and investment goods allocated to the investment sector rise. The key mechanisms that generate co-movement in the broad and sectoral aggregates are the presence of countercyclical price and wage mark-ups which shift outward labor demand and labor supply in response of the news shock. One sector NK models featuring countercyclical mark-ups can generate co-movement in response to TFP news shocks (see e.g. Christiano et al. (2008)), but in those estimated models (Khan and Tsoukalas (2012), Schmitt-Grohe and Uribe (2012)), TFP news shocks are found to be very minor sources of business cycles, suggesting mark-ups alone cannot provide enough amplification.<sup>21</sup>

Importantly, higher capital prices boost bank equity as the value of capital held by intermediaries rises, causing them to expand financing. Sectoral bond spreads decline in anticipation of the future improvement in TFP, consistent with the time path of capital prices. Thus, corporate bond spreads signal the future improvement in TFP.<sup>22</sup> It is also interesting to note that both sectoral inflation rates and the nominal interest rate rise in response to this type of TFP news shock. Overall, the TFP news shock has dynamics that

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<sup>21</sup>In the model, the real wage and equilibrium hours both rise on impact, implying an increase in labor demand. Given the preference specification we utilize, which is of the King et al. (1988) type, the positive TFP news shock implies a negative wealth effect on labor supply. However, this negative wealth effect is dominated by a strong expansion of labor demand and a rightward shift in labor supply and equilibrium hours rise. We discuss nominal rigidities in more detail in Appendix A.5.

<sup>22</sup>The sectoral bond spread in the model corresponds to the expected excess return to capital (wedge between expected return to capital and risk free rate). The expected return to capital (between time  $t, t + 1$ ) declines (as capital prices are expected to fall) and the risk free rate rises to produce the decline in the corporate bond spreads shown in the Figure.

resemble a demand shock, with activity and inflation moving in the same direction and the reaction of the nominal interest rate following the surge in consumption goods inflation is consistent with a conventional view of monetary policy (see e.g. Bernanke and Gertler (2000)), according to which it acts as a stabilizing force that dampens expectation driven cycles.

**Financial intermediation and amplification.** To illustrate the impact of the financial intermediation channel, we compare the IRFs from the baseline model with the same set of IRFs from the estimated model without financial intermediation, shown in Figure 4. We show the responses to a positive (eight quarter ahead) consumption specific TFP news shock (the size of the shock is normalized to be equal across the two models).<sup>23</sup>

The Figure demonstrates that financial intermediation generates a significant amplification in real activity, by causing the capital prices to rise more strongly in the baseline model. With an active leverage constraint, equation (5), gains in intermediaries' equity caused by higher capital prices, create a very strong demand for capital, bidding up capital prices further in comparison to the model version without a financial channel. This strong rise in capital prices, in turn stimulates investment demand, hours worked and overall activity.

## 6 Reconciling DSGE and VAR findings

This section provides a comparison of our DSGE-based with a VAR-based identification of a *consumption specific* TFP news shock. To identify the latter we use the Barsky and Sims (2011) methodology and estimate a six variable VAR featuring a (utilization-adjusted) consumption specific TFP measure, consumption-sector corporate bond spread, consumption, output, hours and inflation in that order.<sup>24</sup> In a VAR with the TFP mea-

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<sup>23</sup>We do not show the estimated parameter values from this model specification for space considerations, but are available on request. We note the amplification we discuss also obtains when both models are simulated at the baseline model's parameter values.

<sup>24</sup>This methodology is appealing because identification rests on very minimal assumptions. The results are qualitatively similar to a smaller or larger VAR specifications (e.g. 4-7 variables, including for example the Michigan confidence indicator measure or using a weighted (taking into account both sectoral) spread

sure first in the ordering, the reduced form innovation serves as the surprise TFP shock, while the TFP news shock is identified as the shock orthogonal to the surprise component that best explains future movements in TFP over a finite horizon. We recover the TFP news shock by maximizing the share of the variance in TFP over horizons from 1 to 10 years. Our choice is guided by the model results, since it implies only surprise TFP innovations can account for the variance in TFP over the first year while TFP news shocks can affect the variance of (consumption) TFP only after the 1st year. Figure 5 presents the results from the VAR specification described above, with the point estimate and  $\pm$  one standard deviation bootstrapped (shaded areas) bands as described in Kilian (1998). Note, first, consistent with the model, TFP begins to rise significantly above zero with a delay of about 10 quarters. Moreover, the VAR identified TFP news shock, in line with the model, creates a boom today: output, consumption, and hours increase significantly on impact.<sup>25</sup> In addition, the corporate bond spread declines significantly echoing the finding documented in Figure 1, namely that corporate bond markets anticipate future TFP.<sup>26</sup> Investment also rises significantly in response to good news about future TFP (see Figure 6, based on an alternative VAR specification). Inflation rises with a delay. To facilitate illustration, in Figure 7 we plot the DSGE model responses

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series. The consumption specific TFP measure is derived from the growth accounting methodology of Basu et al. (2006), and corrects for unobserved capacity utilization (described in Fernald (2012)). However, it does not contain all the corrections as in Basu et al. (2006), namely imperfect competition or reallocation effects.

<sup>25</sup>We note, the empirical VAR responses in the Figure stand in contrast to Barsky and Sims (2011) who use an aggregate TFP measure, or Nam and Wang (2012) who use sectoral TFP series like us and a much longer sample. In Barsky and Sims (2011) (Nam and Wang (2012)), hours and output decline in anticipation of a favorable aggregate (consumption specific) TFP news shock. In on-going work (Korobilis and Tsoukalas (2013)), with time-varying parameter VARs, we document a significant and qualitatively important difference in the IRFs of output and hours across time, detecting a break that occurs in the mid-1980s. Specifically, we find that while in a pre-1982 (1960-1982) sample, output and hours decline significantly (on impact) in response to a favorable consumption specific (or aggregate) TFP news shock, in a post-1982 (1982-2011) sample, the same variables increase significantly on impact in response to the same two shocks. These findings seem to be related to the shares of variance of TFP accounted for by the news shocks at different horizons. In the early sample, the bulk of the variance share of TFP accounted by the news shock obtains in very short horizons, where TFP rises immediately and strongly, while the opposite is true in the late samples, where TFP exhibits a significantly delayed response.

<sup>26</sup>We note, that the impulse responses following the *consumption specific* TFP news shock are very similar—both quantitatively and qualitatively—with the corresponding responses reported in Figure 1. This is due to the fact that the two TFP series, namely, aggregate and consumption specific TFP, track each other very closely, with a correlation of 0.98.

to a 2 year ahead consumption specific TFP news shock along with the responses from the estimated VAR (as shown in Figure 5) and simulated responses obtained from VARs estimated on artificial samples generated from the model (to be discussed below). The empirical VAR responses are qualitatively consistent with the model's responses. There are some differences in terms of magnitudes, most notably in the output and inflation response on impact, especially in the first periods. Note however each methodology uses different moments from the data to estimate the TFP news component. Nevertheless, the consistency of VAR and DSGE responses we believe lends credibility to the financial channel we propose.<sup>27</sup>

How does the quantitative role for TFP news compares across the two methodologies? Figure 8 provides an answer, focusing on the empirical importance of TFP news for output and hours. It plots the variance shares accounted for by TFP news shocks, predicted by (i) the VAR, (ii) baseline DSGE model and (iii) DSGE model estimated without the financial channel (as discussed in section 4). The variance shares predicted by the VAR and baseline DSGE model are very similar (especially in shorter horizons). For example, at the 12 quarter horizon, the baseline DGSE predicts 30% (41%) of the forecast error variance of output (hours worked) attributed to TFP news shocks, very similar to the variance shares in the same variables obtained from the VAR, equal to 31% (49%). By contrast, the differences between the VAR and the model without the financial channel are substantial, in fact the variance shares in the latter are several orders of magnitude smaller compared to the VAR. Table 6 provides more information on the remaining variables. In business cycle frequencies (6-32 quarters), the VAR based TFP news shock (top panel) accounts for between 21%–38% in the variance of consumption, 28%–41% in the variance of the corporate bond spread, 15%–45% in the variance of investment and 21% in the variance of inflation. The middle panel reports the variance shares from the (identical) simulated VAR specifications estimated on the artificial model samples. This panel reports the median and (20%, 80%) confidence bands. Interestingly, the shares

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<sup>27</sup>Note, that the VAR, in line with the convention in this literature, also utilizes an observable indicator of TFP to identify the news shock.



reported for the empirical VAR are, for the vast majority of horizons and variables, within the confidence bands generated by the VARs estimated on artificial data.

We next investigate whether the empirical VAR responses could have been generated by the model, assuming the latter as the data generating process. To accomplish this, we generated 1,000 artificial model samples by drawing parameter values from the posterior distributions and simulated the model. We then compare the empirical VAR IRFs with those generated by identical VAR specifications (along with confidence bands) estimated on the artificial model samples.<sup>28</sup> Figure 7 shows this comparison for the consumption specific TFP news shock. Figure 9 shows the comparison for the aggregate TFP measure, where in this figure, the empirical VAR responses are identical to those in Figure 1.<sup>29</sup> We observe that for both measures of TFP and in the majority of periods we plot, the empirical VAR responses are within the confidence bands generated by the simulated VAR responses taking the model as the data generating process. These findings overall suggest both DGSE and VAR methodologies provide a consistent empirical assessment of TFP news shocks.<sup>30</sup>

## 7 Conclusions

The empirical evaluation of the “news” driven view of business cycles has been challenging on both modelling and econometric front (see Beaudry and Portier (2013)). Considerable

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<sup>28</sup>We have simulated the model over 1084 periods. We construct the level of the resulting time series and discard all but the last 84 periods to minimize the impact of initial values. Note that the issue of non-invertibility does not seem to be particularly acute since the simulated VARs seem to pick the model responses, quite accurately, except for TFP.

<sup>29</sup>To generate an aggregate TFP measure from the model we take the weighted average of the consumption specific and investment specific measures using as weights their output shares, consistent with the methodology in Fernald (2012). We then use this aggregate measure in the VARs estimated on the artificial samples to identify the aggregate TFP news shock.

<sup>30</sup>We undertake a final robustness check. Because a significant amount of information for the identification of TFP news shocks is contained in the corporate bond spread series we find it informative to investigate an alternative interpretation. Gilchrist and Zakrajsek (2012) argue that innovations in corporate bond spreads are, to a certain extent, driven by the excess bond premium (EBP), an indicator of disruptions in the supply of credit that may be orthogonal to corporate fundamentals. We investigate whether the EBP Granger causes the TFP news shocks. The results from this exercise are clear cut. We cannot reject the hypothesis that the EBP does not Granger cause either of the TFP news shocks at conventional significance levels. The Granger causality tests are carried out with 12 lags.

disagreement exists between VAR based and DSGE based methodologies on the empirical relevance of this view. DSGE models, despite incorporating model frictions that in theory allow TFP news shocks to matter, estimate them to be unimportant as sources of business cycles. VARs often reach diametrically opposite conclusions on their empirical importance. In this paper we propose and empirically evaluate a financial channel that links in a parsimonious way leveraged lenders, capital prices and real activity in a DSGE model. When we discipline this channel with information from corporate bond markets, we find that TFP news shocks are important drivers of the U.S. business cycles in the post-Greenspan era. Importantly, we show that the financial channel can bring close in line the empirical estimates of TFP news shocks from DSGE and VAR methodologies and thus resolves an important empirical disconnect in the literature.

## References

- Adjemian, S., Bastani, H., Juillard, M., Mihoubi, F., Perendia, G., Ratto, M., and Villemot, S. (2011). Dynare: Reference manual, version 4. *Dynare Working Papers*, 1.
- Adrian, T., Moench, E., and Shin, H. S. (2010). Financial intermediation asset prices and macroeconomic fundamentals. *Federal Reserve Bank of New York Staff Report*, (422).
- Alexopoulos, M. (2011). Read all about it! What happens following a technology shock? *American Economic Review*, (101):1144–79.
- Barsky, R. B. and Sims, E. R. (2011). News shocks and business cycles. *Journal of Monetary Economics*, 58(3):273–289.
- Basu, S., Fernald, J., J., F., and M., K. (2010). Sector specific technical change. *Mimeo*.
- Basu, S., Fernald, J., and Kimpball, M. (2006). Are technology improvements contractionary? *American Economic Review*, 96(5):1418–1448.
- Beaudry, P. and Lucke, B. (2010). Letting different views about business cycles compete. In *NBER Macroeconomics Annual 2009, Volume 24*, NBER Chapters, pages 413–455. National Bureau of Economic Research, Inc.
- Beaudry, P. and Portier, F. (2004). An exploration into Pigou’s theory of cycles. *Journal of Monetary Economics*, 51(6):1183–1216.
- Beaudry, P. and Portier, F. (2006). News, stock prices and economic fluctuations. *The American Economic Review*, 96(4):1293–1307.

- Beaudry, P. and Portier, F. (2007). When can changes in expectations cause business cycle fluctuations in neo-classical settings? *Journal of Economic Theory*, 135:458–477.
- Beaudry, P. and Portier, F. (2013). News driven business cycles: Insights and challenges. NBER Working Papers 19411, National Bureau of Economic Research, Inc.
- Bernanke, B. and Gertler, M. (2000). Monetary policy and asset price volatility. Working Papers 7559, NBER.
- Boldrin, M., Christiano, L. J., and Fisher, J. D. M. (2001). Habit persistence, asset returns, and the business cycle. *American Economic Review*, 91(1):149–166.
- Brooks, S. P. and Gelman, A. (1998). General methods for monitoring convergence of iterative simulations. *Journal of Computational and Graphical Statistics*, 7(4):434–455.
- Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*, 12(3):383–398.
- Caplin, A. and Leahy, J. (1997). Aggregation and optimization with state-dependent pricing. *Econometrica*, 65(3):601–626.
- Christiano, L., Motto, R., and Rostagno, M. (2008). Monetary policy and stock market boom-bust cycles. Working Paper Series 955, European Central Bank.
- Christiano, L., Motto, R., and Rostagno, M. (2012). Risk shocks. Working paper series, Northwestern University.
- Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1):1–45.
- Christiano, L. J. and Fitzgerald, T. J. (1998). The business cycle: it’s still a puzzle. *Federal Reserve Bank of Chicago Economic Perspectives*, (Q IV):56–83.
- Cummins, J., Hassett, K., and Oliner, S. (2006). Investment behavior, observable expectations, and internal funds. *American Economic Review*, (96):796–810.
- Davis, J. (2007). News and the term structure in general equilibrium. *Manuscript, Northwestern University*.
- DiCecio, R. (2009). Sticky wages and sectoral labor comovement. *Journal of Economic Dynamics and Control*, 33(3):538 – 553.
- Erceg, C. J., Henderson, D. W., and Levin, A. T. (2000). Optimal monetary policy with staggered wage and price contracts. *Journal of Monetary Economics*, 46(2):281–313.
- Fernald, J. (2012). A quarterly, utilization–adjusted series on total factor productivity. *Working Paper*, (2012-19).
- Fisher, J. D. M. (2006). The dynamic effects of neutral and investment-specific technology shocks. *Journal of Political Economy*, 114(3):413–451.

- Forni, M., Gambetti, L., and Sala, L. (2012). No news in business cycles. *mimeo*.
- Fujiwara, I., Hirose, Y., and Shintani, M. (2011). Can news be a major source of aggregate fluctuations? A Bayesian DSGE approach. *Journal of Money, Credit and Banking*, 43(1):1–29.
- Gertler, M. and Karadi, P. (2011). A model of unconventional monetary policy. *Journal of Monetary Economics*, 58(1):17 – 34.
- Gertler, M., Kiyotaki, N., and Queralto, A. (2011). Financial crises, bank risk exposure and government financial policy. *Princeton University Mimeo*.
- Gertler, M. L. and Kiyotaki, N. (2010). Financial intermediation and credit policy in business cycle analysis. In Friedman, B. M. and Woodford, M., editors, *Handbook of Monetary Economics*, volume 3, chapter 11, pages 547–599. Elsevier, 1 edition.
- Gilchrist, S., Yankov, V., and Zakrajsek, E. (2009). Credit market shocks and economic fluctuations: Evidence from corporate bond and stock markets. *Journal of Monetary Economics*, 56:471–493.
- Gilchrist, S. and Zakrajsek, E. (2012). Credit spreads and business cycle fluctuations. *American Economic Review*, 102(4):1692–1720.
- Gourio, F. (2012). Disaster risk and business cycles. *American Economic Review*, forthcoming.
- Greenwood, J., Hercowitz, Z., and Krusell, P. (2000). The role of investment specific technological change in the business cycle. *European Economic Review*, 44:91–115.
- Gunn, C. and Johri, A. (2011). News and knowledge capital. *Review of Economic Dynamics*, 14(1):92–101.
- Gunn, C. and Johri, A. (2013). An expectations-driven interpretation of the “great recession”. *Journal of Monetary Economics*, 60:391–407.
- Huffman, G. W. and Wynne, M. A. (1999). The role of intratemporal adjustment costs in a multisector economy. *Journal of Monetary Economics*, 43(2):317–350.
- Ireland, P. N. and Schuh, S. (2008). Productivity and us macroeconomic performance: Interpreting the past and predicting the future with a two-sector real business cycle model. *Review of Economic Dynamics*, 11(3):473 – 492.
- Iskrev, N. (2010). Local identification in DSGE models. *Journal of Monetary Economics*, 57(2):189 – 202.
- Jaimovich, N. and Rebelo, S. (2009). Can news about the future drive the business cycle? *American Economic Review*, 99(4):1097–1118.
- Justiniano, A., Primiceri, G. E., and Tambalotti, A. (2010). Investment shocks and business cycles. *Journal of Monetary Economics*, 57(2):132–145.

- Justiniano, A., Primiceri, G. E., and Tambalotti, A. (2011). Investment shocks and the relative price of investment. *Review of Economic Dynamics*, 14(1):101 – 121.
- Karnizova, L. (2010). The spirit of capitalism and expectation-driven business cycles. *Journal of Monetary Economics*, 57(6):739 – 752.
- Khan, H. and Tsoukalas, J. (2012). The quantitative importance of news shocks in estimated DSGE models. *Journal of Money Credit and Banking*, forthcoming.
- Kilian, L. (1998). Small sample confidence intervals for impulse response functions. *Review of Economics and Statistics*, 80(2):218–230.
- King, R. G., Plosser, C., and Rebelo, S. T. (1988). Production, growth, and business cycles: I the basic neoclassical model. *Journal of Monetary Economics*, 21:195–232.
- Koop, G., Pesaran, H., and Smith, R. (2012). On identification of bayesian dsge models. *mimeo*.
- Korobilis, D. and Tsoukalas, J. (2013). The time varying nature of news shocks. *mimeo*.
- Leduc, S. and Sill, K. (2013). Expectations and economic fluctuations: An analysis using survey data. *Review of Economics and Statistics*, forthcoming.
- Mankiw, N. Gregory and Reis, Ricardo (2002). Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve. *The Quarterly Journal of Economics*, 117(4):1295–1328.
- Nam, D. and Wang, J. (2012). Are predictable improvements in tfp contractionary or expansionary: Implications from sectoral tfp? *Dallas Fed Working paper no. 114*.
- Papanikolaou, D. (2011). Investment shocks and asset prices. *Journal of Political Economy*, 119(4):639 – 685.
- Philippon, T. (2009). The bond market’s q. *Quarterly Journal of Economics*, 124:1011–1056.
- Ramey, V. and Shapiro, M. D. (2001). Displaced capital: A study of aerospace plant closings. *Journal of Political Economy*, 109:959–992.
- Sannikov, Y. and Brunnermeier, M. K. (2010). A macroeconomic model with a financial sector. Technical report.
- Schmitt-Grohe, S. and Uribe, M. (2012). What’s news in business cycles? *Econometrica*, forthcoming.
- Smets, F. and Wouters, R. (2007). Shocks and frictions in US business cycles: A Bayesian DSGE approach. *American Economic Review*, 97(3):586–606.
- Theodoridis, K. and Zanetti, F. (2013). News and labor market dynamics in the data and in matching models. *Mimeo, University of Oxford*.
- Walentin, K. (2012). Expectation driven business cycles with limited enforcement. *Riksbank Working Paper No. 229*.

Table 1: Correlations: Relative price of investment and economic activity

	Hours	GDP	Investment
Relative Price Investment	0.40*	0.35*	0.26*

Sample is 1990Q2 to 2011Q1. \* denotes significance at the 5% level. All variables are filtered using the HP filter with a smoothing parameter of 1600. The Relative Price of Investment is the chain weighted investment (gross private domestic investment and consumer durables) deflator divided by the chain weighted consumption (non durables and services) deflator. Hours is for all persons in the non farm business sector. Investment is chain weighted gross private domestic investment and consumer durables. All variables are described in Appendix B.

Table 2: Calibrated Parameters

Parameter	Value	Description
$\delta_C$	0.025	Consumption sector capital depreciation
$\delta_I$	0.025	Investment sector capital depreciation
$a_c$	0.3	Consumption sector share of capital
$a_I$	0.3	Investment sector share of capital
$\beta$	0.9974	Discount factor
$\pi_C$	1.006722	Steady state consumption sector quarterly gross inflation (percent)
$\pi_I$	1.000245	Steady state investment sector quarterly gross inflation (percent)
$\lambda_p$	0.15	Steady state price markup
$\lambda_w$	0.15	Steady state wage markup
$g_a$	0.141	Steady state C-sector TFP growth (percent quarterly)
$g_v$	0.434	Steady state I-sector TFP growth (percent quarterly)
$p_i^i$	0.399	Steady state investment / consumption
$\frac{G}{Y}$	0.19	Steady state government spending / output
$\theta_B$	0.96	Fraction of bankers that survive
$\varpi$	0.0021	Share of assets transferred to new bankers
$\lambda_B$	0.69	Fraction of funds bankers can divert
$\varrho$	5.47	Steady state leverage ratio
$R^B - R$	0.5	Steady state risk premium (percent quarterly)

Notes.  $\beta, \pi_C, \pi_I, g_a, g_v, p_i^i, \varrho, R^B - R$  are based on sample averages.  $\varpi$  and  $\lambda_B$  are set to be consistent with the average values of the leverage ratio,  $\varrho$ , and  $R^B - R$ . For further details see the description in Appendix A.1.

Table 3: 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	0.6275	0.5599	0.6949
$\nu$	Inverse labour supply elasticity	Gamma	2.00	0.75	0.8718	0.2447	1.4893
$\xi_w$	Wage Calvo probability	Beta	0.66	0.10	0.6599	0.6196	0.7003
$\xi_C$	C-sector price Calvo probability	Beta	0.66	0.10	0.7785	0.7465	0.8132
$\xi_I$	I-sector price Calvo probability	Beta	0.66	0.10	0.7058	0.6334	0.7773
$\iota_w$	Wage indexation	Beta	0.50	0.15	0.1306	0.0581	0.2034
$\iota_{PC}$	C-sector price indexation	Beta	0.50	0.15	0.0726	0.0281	0.1139
$\iota_{PI}$	I-sector price indexation	Beta	0.50	0.15	0.3033	0.1348	0.4702
$\chi_I$	I-sector utilization	Gamma	5.00	1.00	4.9975	3.3997	6.6080
$\chi_C$	C-sector utilization	Gamma	5.00	1.00	4.6983	3.0598	6.3562
$\kappa$	Investment adj. cost	Gamma	4.00	1.00	2.2881	1.7747	2.7620
$\phi_\pi$	Taylor rule inflation	Normal	1.70	0.30	1.5864	1.3976	1.7665
$\rho_R$	Taylor rule inertia	Beta	0.60	0.20	0.8434	0.8191	0.8681
$\phi_{dX}$	Taylor rule output growth	Normal	0.25	0.10	0.6822	0.5706	0.7921
<b>Shocks: Persistence</b>							
$\rho_z$	C-sector TFP	Beta	0.40	0.20	0.7498	0.6973	0.801
$\rho_v$	I-sector TFP	Beta	0.40	0.20	0.1415	0.0455	0.2328
$\rho_b$	Preference	Beta	0.60	0.20	0.9136	0.8762	0.9542
$\rho_e$	GDP measurement error	Beta	0.60	0.20	0.9826	0.9664	0.9993
$\rho_{\lambda_p^C}$	C-sector price markup	Beta	0.60	0.20	0.0539	0.0145	0.0919
$\rho_{\lambda_p^I}$	I-sector price markup	Beta	0.60	0.20	0.8871	0.8442	0.9337
$\rho_{\lambda_w}$	Wage markup	Beta	0.60	0.20	0.0523	0.0087	0.0945
$\rho_{\xi^{\kappa,C}}$	C-sector capital quality	Beta	0.60	0.20	0.8437	0.8133	0.8765
$\rho_{\xi^{\kappa,I}}$	I-sector capital quality	Beta	0.60	0.20	0.0862	0.0215	0.1471
<b>Shocks: Volatilities</b>							
$\sigma_z$	C-sector TFP	Inv Gamma	0.50	2	0.1721	0.1288	0.2147
$\sigma_z^4$	C-sector TFP. 4Q ahead news	Inv Gamma	$0.5/\sqrt{2}$	2	0.1174	0.0839	0.1521
$\sigma_z^8$	C-sector TFP. 8Q ahead news	Inv Gamma	$0.5/\sqrt{2}$	2	0.2014	0.1544	0.2470
$\sigma_v$	I-sector TFP	Inv Gamma	0.50	2	1.8718	1.5932	2.1517
$\sigma_v^4$	I-sector TFP. 4Q ahead news	Inv Gamma	$0.5/\sqrt{2}$	2	0.2959	0.1090	0.4712
$\sigma_v^8$	I-sector TFP. 8Q ahead news	Inv Gamma	$0.5/\sqrt{2}$	2	0.7001	0.5282	0.8661
$\sigma_b$	Preference	Inv Gamma	0.10	2	1.4524	1.1644	1.7339
$\sigma_e$	GDP measurement error	Inv Gamma	0.50	2	0.5102	0.4357	0.5794
$\sigma_{mp}$	Monetary policy	Inv Gamma	0.10	2	0.1204	0.1023	0.1386
$\sigma_{\lambda_p^C}$	C-sector price markup	Inv Gamma	0.10	2	0.6045	0.5184	0.6839
$\sigma_{\lambda_p^I}$	I-sector price markup	Inv Gamma	0.10	2	0.2282	0.1647	0.2863
$\sigma_{\lambda_w}$	Wage markup	Inv Gamma	0.10	2	0.3689	0.3100	0.4274
$\sigma_{\xi^{\kappa,C}}$	C-sector capital quality	Inv Gamma	0.50	2	0.3118	0.2237	0.3948
$\sigma_{\xi^{\kappa,I}}$	I-sector capital quality	Inv Gamma	0.50	2	2.4029	2.0458	2.7600

Notes. 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 discard the first 100,000 of the draws.

Table 4: Variance decomposition at posterior estimates—business cycle frequencies (6-32 quarters)

	TFP shocks:				financial shocks: all other shocks		all TFP shocks	all TFP news shocks
	$z$	$z^4$	$z^8$	$v$	$v^4$	$v^8$	sum of cols. 1-6	sum of cols. 2,3,5,6
Output	0.195	0.093	0.213	0.187	0.006	0.054	0.748	0.366
Consumption	0.241	0.106	0.185	0.023	0.001	0.011	0.568	0.303
Investment	0.040	0.043	0.165	0.384	0.009	0.090	0.730	0.306
Total Hours	0.063	0.091	0.341	0.163	0.006	0.057	0.720	0.494
Real Wage	0.206	0.083	0.131	0.038	0.015	0.150	0.623	0.379
Nom. Interest Rate	0.036	0.070	0.466	0.122	0.003	0.024	0.719	0.562
C-Sector Inflation	0.006	0.017	0.231	0.103	0.007	0.079	0.443	0.334
I-Sector Inflation	0.028	0.044	0.315	0.226	0.003	0.047	0.663	0.410
C-Sector Spread	0.077	0.078	0.313	0.080	0.001	0.009	0.556	0.400
I-Sector Spread	0.093	0.083	0.329	0.140	0.001	0.029	0.675	0.442
Equity	0.190	0.088	0.324	0.056	0.002	0.008	0.668	0.422
Rel. Price of Investment	0.086	0.021	0.021	0.583	0.009	0.066	0.787	0.117

$z = \text{TFP}$  in consumption sector,  $z^x = x$  quarters ahead consumption sector TFP news shock,  $v = \text{TFP}$  in investment sector,  $v^x = x$  quarters ahead investment sector TFP news shock,  $\xi_C$  and  $\xi_I = \text{capital quality shocks}$  in the consumption and investment sector. 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, equity and the relative price of investment. The spectral density is computed from the state space representation of the model with 500 bins for frequencies covering the range of periodicities. We report median shares.



Table 5: Variance Decompositions—TFP News shocks: Importance of financial intermediation channel

	Baseline Model			Simple Model estimated without financial intermediation		
	C-Sector TFP News	All TFP News	All TFP Shocks	C-Sector TFP News	All TFP News	All TFP Shocks
Output	0.306	0.366	0.748	0.066	0.146	0.472
Consumption	0.291	0.303	0.568	0.103	0.300	0.739
Investment	0.208	0.306	0.730	0.045	0.133	0.649
Total Hours	0.432	0.494	0.720	0.050	0.170	0.455
Real Wage	0.215	0.379	0.623	0.062	0.209	0.487
Nom. Interest Rate	0.536	0.562	0.719	0.041	0.209	0.626
C-Sector Inflation	0.249	0.334	0.443	0.072	0.197	0.633
I-Sector Inflation	0.359	0.410	0.663	0.014	0.023	0.395
C-Sector Spread	0.390	0.400	0.556	n.a.	n.a.	n.a.
I-Sector Spread	0.412	0.442	0.675	n.a.	n.a.	n.a.
Equity	0.412	0.422	0.668	n.a.	n.a.	n.a.
Rel. Price of Investment	0.042	0.117	0.787	0.028	0.112	0.926

Notes. The simple model strips off the financial channel but is otherwise identical to the baseline. The Table reports only the variance shares accounted for by all TFP shocks, unanticipated and news, thus they sum to less than 1. 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, equity and the relative price of investment. The spectral density is computed from the state space representation of the model with 500 bins for frequencies covering the range of periodicities.

Table 6: Variance decompositions: TFP news—VARs and DSGE

	6	12	Horizon 20	24	32
Empirical VAR (point estimate)					
Consumption	0.38	0.32	0.25	0.23	0.21
Output	0.36	0.31	0.25	0.23	0.21
Hours	0.61	0.49	0.33	0.29	0.25
Investment*	0.45	0.30	0.21	0.19	0.15
Bond Spread	0.41	0.31	0.30	0.29	0.28
Inflation	0.21	0.21	0.21	0.21	0.21
VAR on simulated model data (medians with [20%,80%] bands)					
Consumption	0.36	0.51	0.57	0.58	0.57
	[0.11, 0.59]	[0.22, 0.74]	[0.29, 0.78]	[0.30, 0.78]	[0.31, 0.79]
Output	0.51	0.53	0.54	0.54	0.54
	[0.20, 0.72]	[0.23, 0.76]	[0.25, 0.74]	[0.26, 0.75]	[0.27, 0.74]
Hours	0.45	0.41	0.40	0.41	0.41
	[0.17, 0.69]	[0.18, 0.64]	[0.21, 0.62]	[0.22, 0.62]	[0.23, 0.61]
Investment*	0.39	0.37	0.38	0.38	0.39
	[0.10, 0.69]	[0.14, 0.67]	[0.16, 0.65]	[0.18, 0.63]	[0.19, 0.63]
Bond Spread	0.25	0.27	0.29	0.29	0.30
	[0.12, 0.44]	[0.13, 0.44]	[0.14, 0.44]	[0.15, 0.44]	[0.16, 0.45]
Inflation	0.11	0.12	0.14	0.14	0.14
	[0.05, 0.21]	[0.06, 0.23]	[0.07, 0.24]	[0.07, 0.24]	[0.07, 0.25]
DSGE (medians) (sum of 4 and 8 quarter ahead c-specific TFP news)					
Consumption	0.13	0.07	0.20	0.29	0.37
Output	0.27	0.30	0.30	0.31	0.31
Hours	0.38	0.41	0.45	0.43	0.41
Investment	0.23	0.21	0.23	0.21	0.18
Bond Spread	0.07	0.25	0.40	0.41	0.43
Inflation	0.04	0.18	0.25	0.26	0.26

Sample is 1990Q2 to 2011Q1. The decomposition in the top panel is obtained from a six variable VAR featuring consumption specific TFP, corporate bond spread, consumption, output, hours and inflation estimated with two lags, suggested by AIC and SC lag length criteria. \* News share for investment is obtained from a six variable VAR as above but where investment replaces output. The decomposition in the middle panel is from identical VAR specifications (as in the top panel) run on 1,000 artificial samples from the model.

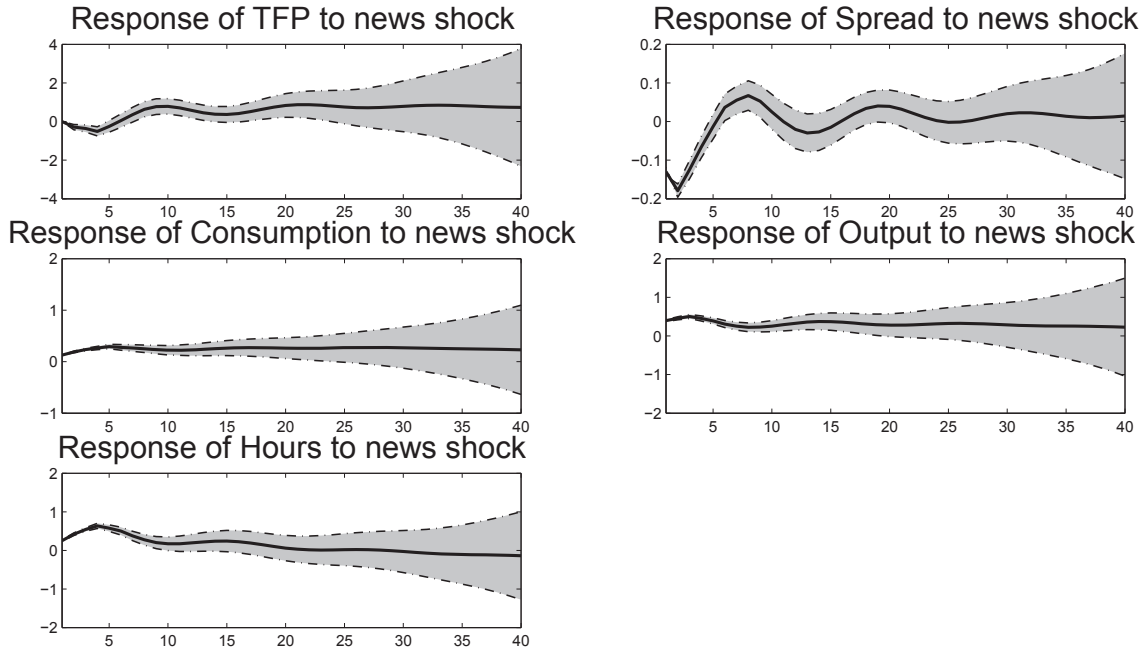


Figure 1: Sample is 1990Q2-2011Q1. The solid line is the estimated impulse response to an aggregate TFP news shock. The VAR includes, in this order, utilization-adjusted TFP, (investment grade) corporate bond spread, consumption, output and hours worked with 4 lags as suggested by the AIC criterion. The TFP data is from Fernald (2012). The rest of the data are described in detail in the Appendix. The identification of the news shock (based on the method of Barsky and Sims (2011) with the truncation horizon set to  $H=40$ ) and impulse responses presented in Figure 1 are very robust to changing the order of the variables or choosing different subsets of variables (including for example the Michigan consumer confidence indicator, inflation or S&P 500 index). The shaded gray areas are the  $\pm$  one standard deviation confidence band from 2000 bias-corrected bootstrap replications of the reduced form VAR. The horizontal axes refer to forecast horizons (quarters) and the units of the vertical axes are percentage deviations

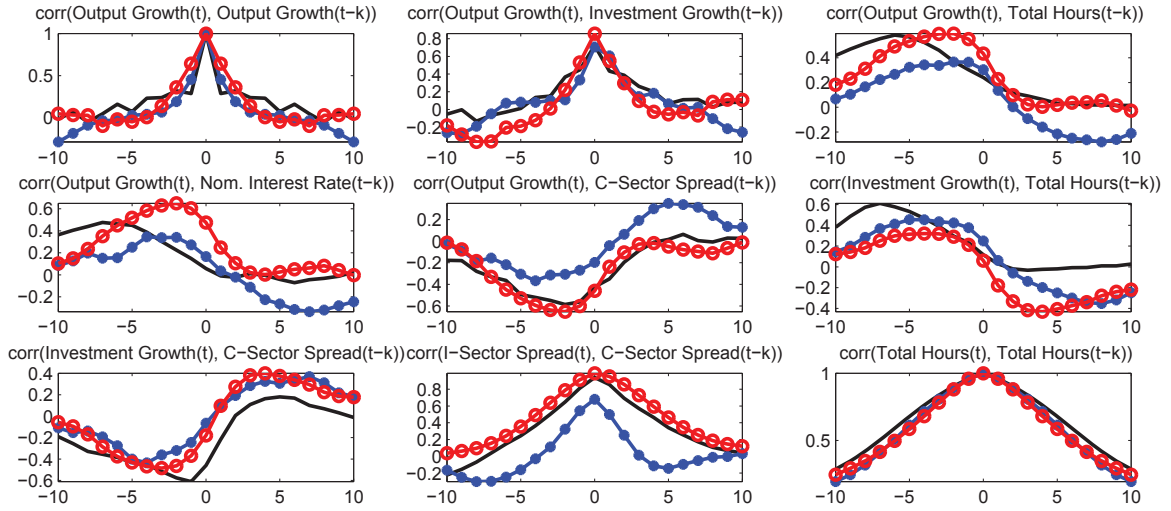


Figure 2: Dynamic correlations between key variables in the data (solid black line), implied by the baseline model with all shocks (blue line with stars) and the model with the eight quarter ahead consumption specific TFP news shock only (red line with circles).

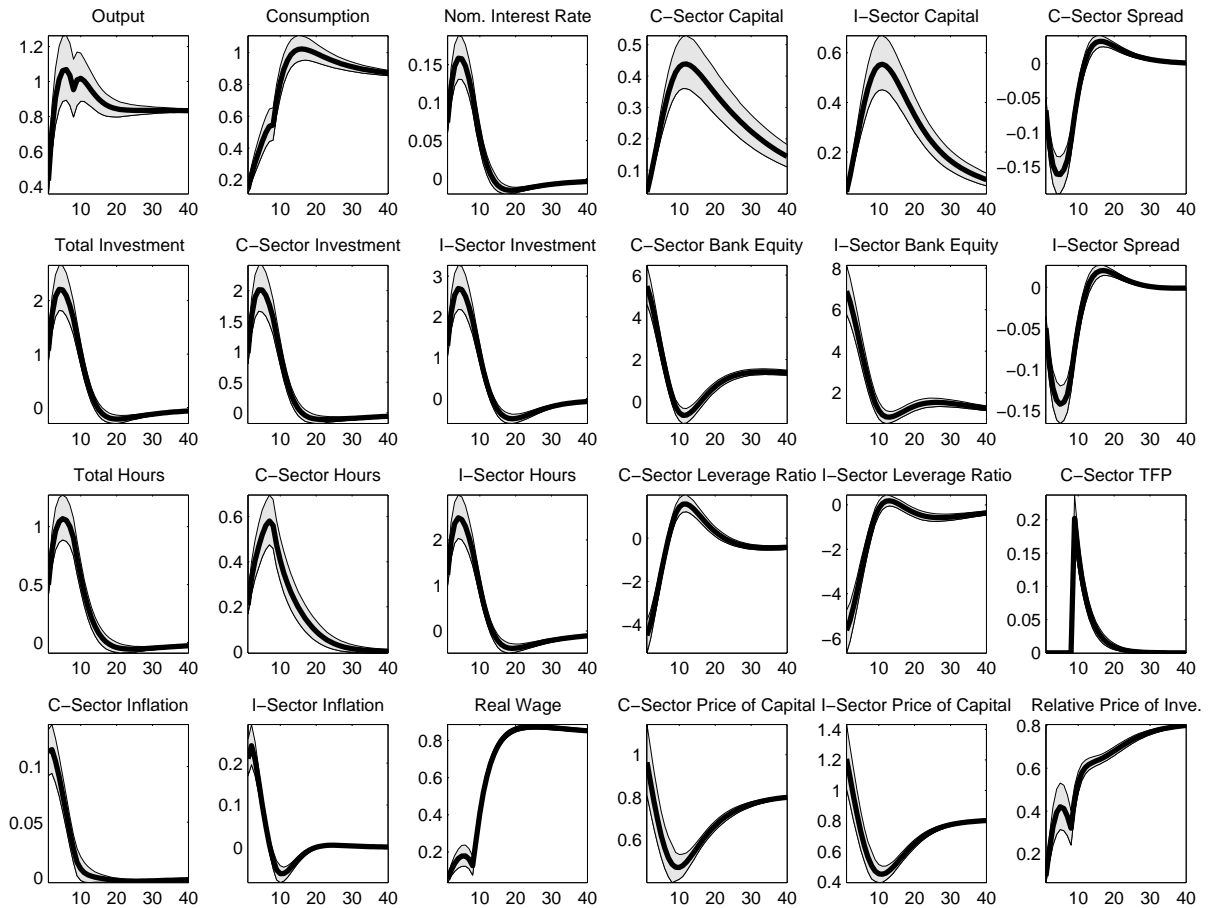


Figure 3: IRFs to a one std. deviation TFP news shock (anticipated 8 quarters ahead) in the consumption sector. Median responses with 90% confidence bands in shaded areas. The horizontal axes refer to quarters and the units of the vertical axes are percentage deviations

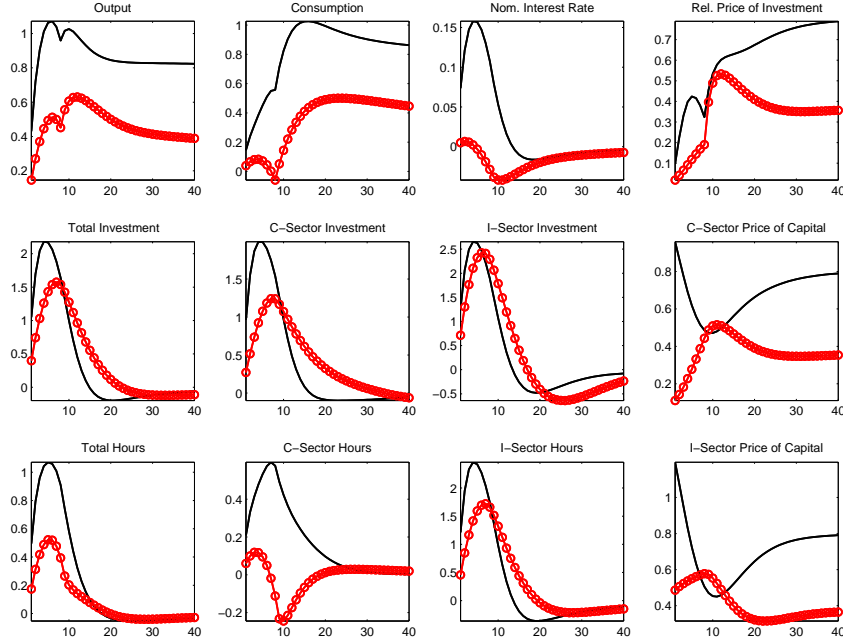


Figure 4: Responses to a one std. deviation TFP news shock (anticipated 8 quarters ahead) in the consumption sector. Baseline model with financial intermediation (black solid line), and estimated model without financial intermediation (red line with circles). The horizontal axes refer to quarters and the units of the vertical axes are percentage deviations

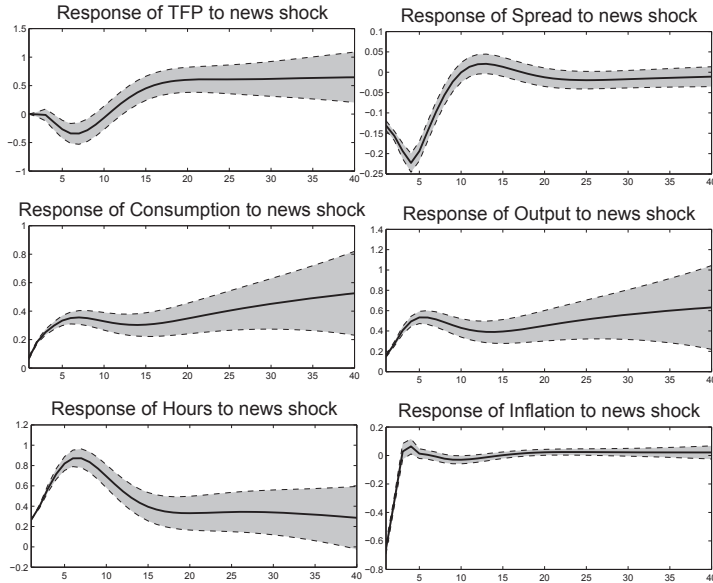


Figure 5: Sample is 1990Q2-2011Q1. The solid line is the estimated impulse response to a consumption specific TFP news shock from a six variable VAR featuring consumption specific TFP, (investment grade) corporate bond spread, consumption, output, hours and inflation with 2 lags as suggested by the AIC criterion. The identification of the news shock is based on the method of Barsky and Sims (2011) with the truncation horizon set to  $H=40$ . The shaded gray areas are the  $\pm$  one standard deviation confidence band from 2000 bias-corrected bootstrap replications of the reduced form VAR. The horizontal axes refer to forecast horizons (quarters) and the units of the vertical axes are percentage deviations

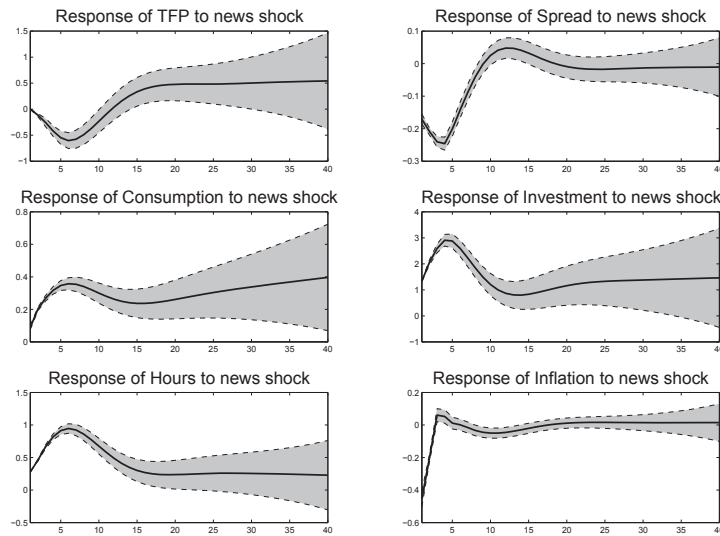


Figure 6: Sample is 1990Q2-2011Q1. The solid line is the estimated impulse response to a consumption specific TFP news shock from a six variable VAR featuring consumption specific TFP, (investment grade) corporate bond spread, consumption, investment, hours and inflation with 2 lags as suggested by the AIC criterion. The identification of the news shock is based on the method of Barsky and Sims (2011) with the truncation horizon set to  $H=40$ . The shaded gray areas are the  $\pm$  one standard deviation confidence band from 2000 bias-corrected bootstrap replications of the reduced form VAR. The horizontal axes refer to forecast horizons (quarters) and the units of the vertical axes are percentage deviations

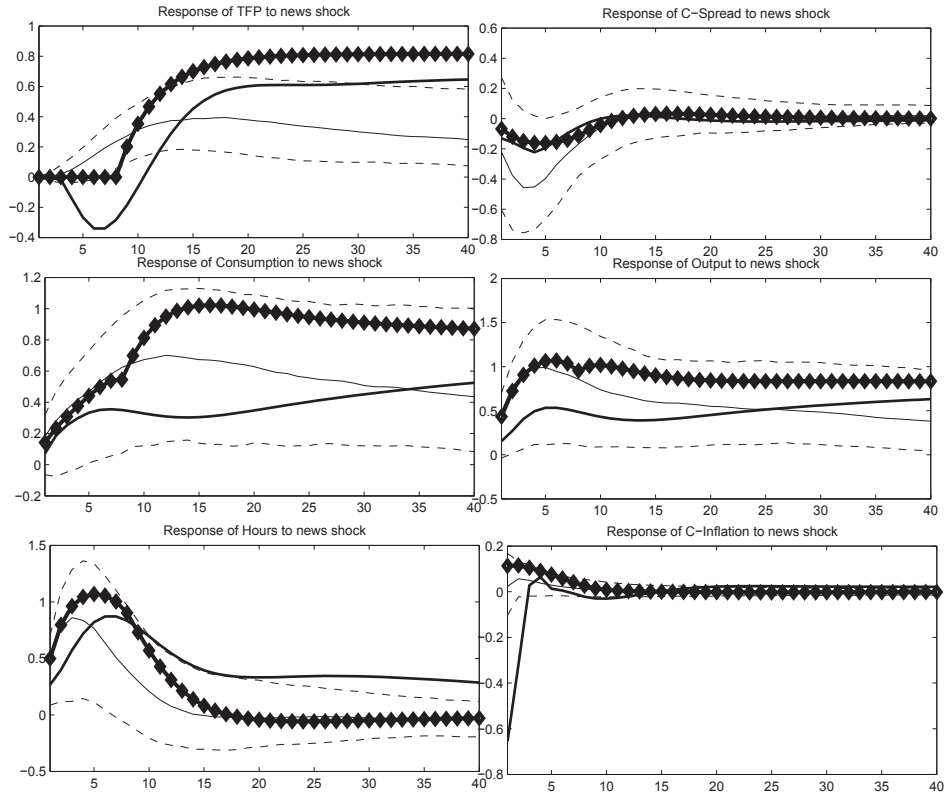


Figure 7: Sample is 1990Q2-2011Q1. The line with diamonds is the impulse response to a 2 year ahead consumption specific TFP news shock from the DSGE model. The thick solid line is the impulse response to a consumption specific TFP news shock from a six variable VAR featuring TFP, (investment grade) corporate bond spread, consumption, output, hours and inflation. The thin solid line (dotted lines) is the median (20%, 80% confidence bands) impulse response to a consumption specific TFP news shock estimated from a VAR (identical to the empirical VAR, 6 variables, 2 lags and 84 observations) on 1,000 samples, generated from the model. The horizontal axes refer to forecast horizons (quarters) and the units of the vertical axes are percentage deviations.

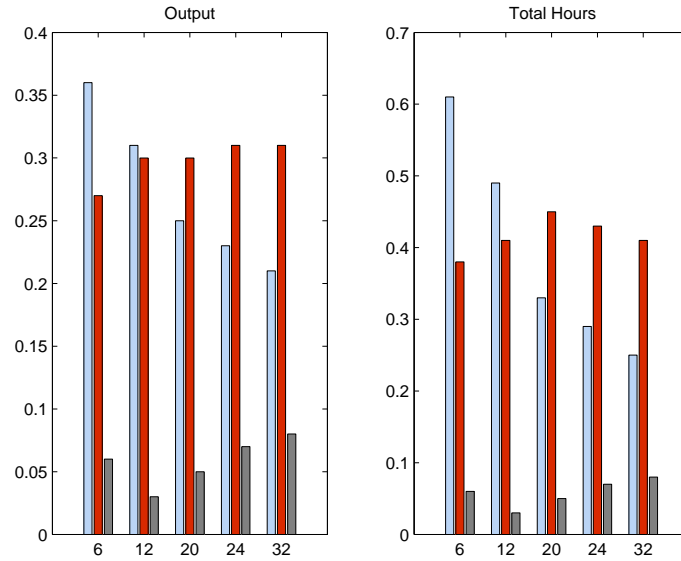


Figure 8: Sample is 1990Q2-2011Q1. Share of variance in output and total hours accounted for by consumption specific TFP news shocks in the VAR (light blue), the baseline DSGE model with the financial channel (red) and the baseline model without the financial channel (grey). The horizontal axis indicates the decomposition horizon in quarters. Median shares are reported for the DSGE models, point estimate for the VAR.

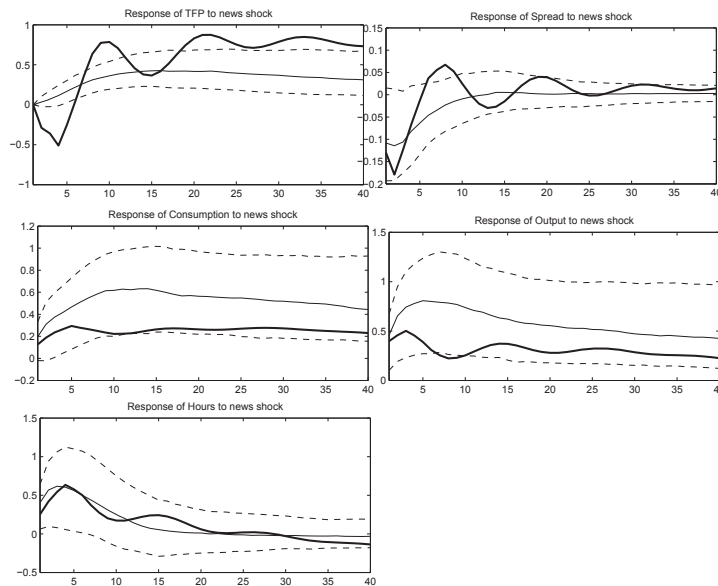


Figure 9: Sample is 1990Q2-2011Q1. The thick solid line is the impulse response to an aggregate TFP news shock from a five variable VAR featuring TFP, (investment grade) corporate bond spread, consumption, output, hours (identical to Figure 1). The thin solid line (dotted lines) is the median (20%, 80% confidence bands) impulse response to an aggregate TFP news shock estimated from a VAR (identical to the empirical VAR, 5 variables, 4 lags and 84 observations) on 1,000 samples, generated from the model. The horizontal axes refer to forecast horizons (quarters) and the units of the vertical axes are percentage deviations.



## 8 Appendix with supplementary material (Not for publication)

### A Supporting details and results

#### A.1 Calibration and estimation

**Calibration.** Table 2 describes the calibrated parameters referred to in section 3. 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 0.3. The steady state values for the ratios of nominal investment to consumption and government spending to output are calibrated to be consistent with the average values 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 15%. 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  $g_a = 0.141\%$  and  $g_v = 0.434\%$  per quarter. There are three parameters specific to financial intermediation. The parameter  $\theta_B$ , 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  $\varpi$  and  $\lambda_B$  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.

#### A.2 Full variance decomposition

**Variance decomposition.** Table 7 below reports the full decomposition results referred to in section 4.

Table 7: Variance decomposition at posterior estimates—business cycle frequencies (6-32 quarters)

	All TFP	$z$	$z^4$	$z^8$	$v$	$v^4$	$v^8$	$b$	$\eta_{tm}$	$\lambda_C^p$	$\lambda_y^p$	$\lambda_w$	$g$	$\xi_C$	$\xi_I$
	Sum of cols. 1 to 6														
Output	0.748	0.195 [0.177 0.221]	0.063 [0.084 0.104]	0.213 [0.193 0.231]	0.187 [0.169 0.207]	0.006 [0.004 0.008]	0.054 [0.049 0.060]	0.009 [0.008 0.011]	0.047 [0.043 0.052]	0.005 [0.004 0.005]	0.089 [0.073 0.110]	0.010 [0.008 0.011]	0.018 [0.015 0.020]	0.067 [0.057 0.079]	0.006 [0.005 0.006]
Consumption	0.508	0.241 [0.220 0.266]	0.106 [0.094 0.117]	0.185 [0.170 0.202]	0.023 [0.020 0.027]	0.001 [0.000 0.001]	0.011 [0.010 0.013]	0.113 [0.102 0.126]	0.020 [0.018 0.023]	0.032 [0.029 0.036]	0.037 [0.028 0.048]	0.020 [0.018 0.022]	0.003 [0.003 0.004]	0.196 [0.180 0.217]	0.007 [0.006 0.008]
Investment	0.730	0.040 [0.035 0.047]	0.043 [0.038 0.048]	0.165 [0.150 0.182]	0.384 [0.356 0.415]	0.009 [0.006 0.012]	0.090 [0.082 0.100]	0.004 [0.003 0.004]	0.017 [0.016 0.019]	0.003 [0.002 0.003]	0.188 [0.154 0.225]	0.002 [0.002 0.003]	0.003 [0.002 0.003]	0.041 [0.036 0.048]	0.011 [0.009 0.012]
Total Hours	0.720	0.063 [0.055 0.074]	0.091 [0.080 0.101]	0.341 [0.316 0.366]	0.163 [0.145 0.183]	0.006 [0.004 0.008]	0.057 [0.052 0.064]	0.009 [0.008 0.012]	0.040 [0.036 0.044]	0.001 [0.001 0.001]	0.159 [0.132 0.190]	0.012 [0.010 0.013]	0.007 [0.006 0.007]	0.048 [0.041 0.056]	0.003 [0.003 0.004]
Real Wage	0.623	0.206 [0.188 0.228]	0.083 [0.074 0.092]	0.131 [0.119 0.145]	0.038 [0.034 0.043]	0.015 [0.011 0.021]	0.150 [0.134 0.164]	0.007 [0.005 0.009]	0.007 [0.006 0.008]	0.129 [0.119 0.137]	0.018 [0.014 0.023]	0.135 [0.126 0.145]	0.001 [0.001 0.001]	0.075 [0.064 0.085]	0.003 [0.003 0.004]
Nominal Interest Rate	0.719	0.036 [0.030 0.043]	0.070 [0.061 0.079]	0.466 [0.441 0.491]	0.122 [0.111 0.135]	0.003 [0.002 0.004]	0.024 [0.020 0.028]	0.055 [0.048 0.061]	0.020 [0.017 0.022]	0.058 [0.052 0.066]	0.089 [0.072 0.111]	0.004 [0.003 0.004]	0.004 [0.003 0.004]	0.046 [0.040 0.053]	0.005 [0.004 0.005]
C-Sector Inflation	0.443	0.006 [0.004 0.008]	0.017 [0.013 0.022]	0.231 [0.205 0.257]	0.103 [0.092 0.115]	0.007 [0.005 0.009]	0.079 [0.067 0.090]	0.122 [0.110 0.134]	0.057 [0.052 0.064]	0.278 [0.254 0.302]	0.041 [0.032 0.052]	0.037 [0.032 0.041]	0.007 [0.006 0.009]	0.013 [0.011 0.016]	0.001 [0.001 0.001]
I-Sector Inflation	0.663	0.028 [0.023 0.034]	0.044 [0.038 0.051]	0.315 [0.289 0.341]	0.226 [0.208 0.246]	0.003 [0.002 0.004]	0.047 [0.043 0.054]	0.021 [0.019 0.024]	0.052 [0.047 0.057]	0.003 [0.003 0.004]	0.155 [0.125 0.187]	0.017 [0.015 0.019]	0.008 [0.007 0.009]	0.026 [0.022 0.031]	0.053 [0.048 0.057]
C-Sector Spread	0.556	0.077 [0.067 0.088]	0.078 [0.069 0.087]	0.313 [0.289 0.333]	0.080 [0.072 0.088]	0.001 [0.001 0.001]	0.009 [0.007 0.011]	0.013 [0.012 0.015]	0.017 [0.015 0.019]	0.138 [0.128 0.148]	0.048 [0.038 0.060]	0.006 [0.005 0.006]	0.003 [0.003 0.003]	0.196 [0.174 0.220]	0.022 [0.020 0.024]
I-Sector Spread	0.675	0.093 [0.083 0.107]	0.083 [0.074 0.092]	0.329 [0.305 0.352]	0.140 [0.126 0.155]	0.001 [0.001 0.002]	0.029 [0.024 0.034]	0.038 [0.033 0.043]	0.026 [0.023 0.028]	0.170 [0.157 0.182]	0.074 [0.059 0.094]	0.008 [0.007 0.009]	0.005 [0.004 0.005]	0.002 [0.001 0.003]	0.002 [0.001 0.002]
Equity	0.668	0.190 [0.172 0.211]	0.088 [0.078 0.099]	0.324 [0.301 0.346]	0.056 [0.051 0.063]	0.002 [0.001 0.003]	0.008 [0.007 0.009]	0.003 [0.003 0.004]	0.078 [0.071 0.086]	0.027 [0.024 0.029]	0.019 [0.015 0.024]	0.005 [0.004 0.005]	0.012 [0.011 0.014]	0.150 [0.134 0.169]	0.037 [0.033 0.040]
Rel. Price of Investment	0.787	0.086 [0.077 0.098]	0.021 [0.019 0.024]	0.021 [0.018 0.024]	0.583 [0.560 0.603]	0.009 [0.007 0.013]	0.066 [0.060 0.073]	0.002 [0.001 0.002]	0.009 [0.008 0.010]	0.036 [0.034 0.039]	0.113 [0.092 0.136]	0.001 [0.001 0.001]	0.002 [0.001 0.002]	0.014 [0.011 0.016]	0.037 [0.033 0.041]

Median shares reported with values in brackets denoting 5 and 95 percentiles.  $z$  = TFP in consumption sector,  $z^x$  =  $x$  quarters ahead consumption sector TFP news shock,  $v$  = TFP in investment sector,  $v^x$  =  $x$  quarters ahead investment sector TFP news shock,  $b$  = Preference shock,  $g$  = Government spending shock,  $\eta_{tm}$  = Monetary policy,  $\lambda_C^p$  = Consumption sector price markup,  $\lambda_y^p$  = Investment sector price markup,  $\lambda_w$  = Wage markup,  $\xi_I$  = investment sector capital quality,  $\xi_C$  = consumption sector capital quality. 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 Identification tests

We perform two tests referred to in section 3. First, a test of (local) parameter identifiability as proposed by Iskrev (2010) the results of which suggest all parameters we estimate are identifiable in a neighborhood of our estimates. 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. 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). Nevertheless because this test is a yes/no proposition it cannot precisely scrutinize for weak identifiability. For this reason we adopt an indicator of Bayesian learning proposed by Koop et al. (2012), namely the “Bayesian learning rate indicator”, which given the focus on asymptotics gives an indication of the informativeness of the data. This indicator examines the rate at which the posterior precision of parameters gets updated with the sample size. For identified parameters the posterior precision increases at rate  $T$  (with  $T$  denoting the sample size). The indicator suggests no evidence of weak identification: we measure this by taking the product of posterior variances with  $T$  and examine if it converges to a constant for all parameters, which we find that it does, suggesting the posterior precision of parameters is updated at the same rate as  $T$ . To implement this test we generate a large sample of simulated data from the model equal to 30,000 observations. We then estimate the model on samples of increasing size which we set to  $T = 50, 100, 1,000, 10,000, 20,000, 25,000, 30,000$ , and compute the posterior variance of parameters for these consecutive samples. Finally, we check the rate at which these variances are declining in comparison to the sample size. In the interest of space we do not report the results, but are available upon request.

### A.4 Robustness checks

As explained in the main text, section 4, we undertake several robustness checks to assess the sensitivity of our results, focusing on the importance of TFP news shocks. To this end, we have estimated five different specifications. Our first specification removes observations from the most recent “Great recession” period (2008Q1 to 2011Q1) addressing a potential concern that the volatility and disruption in financial markets following the Lehman collapse may be, at least partly, driving the important role of TFP news shocks in fluctuations, as well as potential misspecification of the monetary policy rule when the policy rate approaches the zero lower bound. The second specification introduces smaller prior means for the standard deviations for all TFP news shocks, assuming that the sum of the variances of all TFP news components is only one third of the variance of the respective unanticipated TFP component vs. one half assumed in the baseline. The third specification, assumes Gamma distributions for all shocks in the model, allowing for a non-zero probability mass at zero for the standard deviations of news shocks. The fourth specification, introduces a common stationary aggregate TFP process with unanticipated and news components. The last specification, adds news components in all exogenous

processes of the model (except monetary policy shock) including a common aggregate TFP component, as in Khan and Tsoukalas (2012) and Schmitt-Grohe and Uribe (2012). The common TFP process is assumed to follow,

$$f_t = (1 - \rho_f)f + \rho_f f_{t-1} + \varepsilon_t^f, \quad \text{with} \quad \varepsilon_t^f = \varepsilon_{t,0}^f + \varepsilon_{t-4,4}^f + \varepsilon_{t-8,8}^f.$$

Here, each component is assumed,  $N(0, \sigma_{f,t-h}^2)$ ,  $h = 0, 4, 8$ , uncorrelated across horizon and time, and the parameter  $\rho_f \in (0, 1)$  determines the persistence of the process. This aggregate TFP shock is a natural candidate in generating broad based and sectoral co-movement so it is interesting to check whether the importance of consumption sector TFP news shocks in accounting for the variance in the data is robust in this specification.

With the common aggregate TFP process the sectoral production functions become,

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

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

In the estimated specification with the aggregate TFP shock, we indeed find that an aggregate TFP news shock induces qualitatively similar dynamics—and thus co-movement—to a consumption sector TFP news shock with the notable exception of hours worked. While hours worked rise on impact, they nevertheless decline significantly at the time when the positive aggregate TFP shock materializes.<sup>31</sup> This is grossly at odds with the empirical autocorrelations of hours worked in the data, which are strongly autocorrelated even at very long lags (extending even at 10 lags, see Figure 2). A positive common TFP news shock at the four quarter horizon would instead generate counterfactual negative autocorrelations of hours worked at lags and leads beyond 1 and 2. Moreover, the variance shares explained by the aggregate TFP news components are very small and never exceed five percent in any observable. Including news components in non-structural disturbances is motivated by evidence in Khan and Tsoukalas (2012) and Schmitt-Grohe and Uribe (2012), who report, in estimated one sector models, news components in non-structural disturbances, most notably, wage mark-ups, preference, marginal efficiency of investment to dominate TFP news shocks, which are found to be very minor as sources of business cycles. Therefore, it is also interesting scrutinizing whether our baseline result is robust in this specification. Table 8 suggests our finding about the importance of TFP news shocks is robust across all of these different experiments.

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<sup>31</sup>The IRFs are not shown but are available upon request.

Table 8: Spectral Variance Decompositions: Robustness

	Baseline Model			Baseline estimated with data prior to financial crisis			Model with smaller prior weights on news components		
	C-Sector TFP News	All TFP News	All TFP Shocks	C-Sector TFP News	All TFP News	All TFP Shocks	C-Sector TFP News	All TFP News	All TFP Shocks
Output	0.306	0.366	0.748	0.293	0.378	0.708	0.285	0.351	0.745
Consumption	0.291	0.303	0.568	0.276	0.309	0.537	0.268	0.282	0.563
Investment	0.208	0.306	0.730	0.194	0.337	0.727	0.196	0.304	0.734
Total Hours	0.432	0.494	0.720	0.406	0.501	0.697	0.410	0.482	0.717
Real Wage	0.215	0.379	0.623	0.230	0.434	0.653	0.179	0.371	0.618
Nom. Interest Rate	0.536	0.562	0.719	0.503	0.549	0.698	0.527	0.552	0.720
C-Sector Inflation	0.249	0.334	0.443	0.264	0.399	0.508	0.245	0.338	0.452
I-Sector Inflation	0.359	0.410	0.663	0.326	0.403	0.642	0.344	0.401	0.662
C-Sector Spread	0.390	0.400	0.556	0.362	0.382	0.526	0.372	0.381	0.548
I-Sector Spread	0.412	0.442	0.675	0.407	0.457	0.684	0.394	0.430	0.677
Equity	0.412	0.422	0.668	0.379	0.393	0.627	0.392	0.400	0.658
Rel. Price of Investment	0.042	0.117	0.787	0.051	0.142	0.765	0.041	0.110	0.762

	Model with Gamma distribution for all shock priors			Model with common aggregate TFP shock			Model with additional news components		
	C-Sector TFP News	All TFP News	All TFP Shocks	C-Sector TFP News	All TFP News	All TFP Shocks	C-Sector TFP News	All TFP News	All TFP Shocks
Output	0.220	0.304	0.729	0.319	0.409	0.730	0.267	0.286	0.490
Consumption	0.253	0.269	0.642	0.309	0.376	0.620	0.246	0.250	0.323
Investment	0.150	0.270	0.642	0.224	0.308	0.661	0.174	0.204	0.505
Total Hours	0.306	0.390	0.622	0.408	0.476	0.669	0.319	0.335	0.467
Real Wage	0.159	0.352	0.650	0.177	0.356	0.574	0.081	0.104	0.179
Nom. Interest Rate	0.401	0.447	0.608	0.545	0.563	0.690	0.453	0.459	0.544
C-Sector Inflation	0.124	0.258	0.358	0.175	0.267	0.423	0.090	0.093	0.146
I-Sector Inflation	0.204	0.264	0.513	0.346	0.412	0.674	0.278	0.293	0.479
C-Sector Spread	0.405	0.424	0.612	0.403	0.441	0.573	0.327	0.338	0.391
I-Sector Spread	0.281	0.313	0.531	0.389	0.452	0.643	0.307	0.312	0.431
Equity	0.260	0.272	0.584	0.413	0.438	0.655	0.272	0.276	0.430
Rel. Price of Investment	0.019	0.117	0.738	0.062	0.108	0.693	0.092	0.111	0.521

Notes. The Table reports only the variance shares accounted for by all TFP shocks, unanticipated and news, thus they sum to less than 1. All specifications are estimated with the financial observables included. 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, equity and the relative price of investment. The spectral density is computed from the state space representation of the model with 500 bins for frequencies covering the range of periodicities.

## A.5 Nominal rigidities

**Co-movement and nominal rigidities.** These frictions are important for the co-movement properties of the consumption specific TFP news shock. Nominal (price and wage) rigidities give rise to endogenous countercyclical price and wage mark ups. A positive, consumption specific TFP news shock is associated with a fall in both sectoral price mark ups (i.e. the wedge between the marginal product of labor and the real wage), since firms cannot fully adjust prices to higher demand, shifting sectoral labor demand to the right. At the same time, the same shock is associated with a fall in the wage mark up (i.e. the wedge between the marginal rate of substitution and the real wage) causing a rightward shift of the labor supply. Both of these forces, act to counteract and dominate the negative wealth effect on labor supply due to the expected improvement in productivity and equilibrium hours rise. The properties of the model where nominal rigidities are minimized, are shown in Figure 10.<sup>32</sup> The specification where nominal (price and wage) rigidities are (nearly) eliminated has a noticeable effect on the propagation of the news shock. First, co-movement does not obtain: Consumption now declines, caused by a decline in hours worked employed in that sector, suggesting that the behavior of mark-ups is important for sectoral hours comovement, consistent with the analysis in DiCecio (2009). Second, the impact of countercyclical price mark-ups, compared to countercyclical wage mark-ups, is far more important for co-movement (see IRFs in circled lines). We can observe that the elimination of wage rigidities does not change the response of consumption and hours worked in the consumption sector qualitatively—they both continue to increase, though less strongly, compared to the baseline. This demonstrates that, countercyclical price mark-ups alone, with the shift in labor demand they generate, work to counteract the negative wealth effect on labor supply.<sup>33</sup>

## A.6 Investment Specific Shocks and the relative price of investment

We derive the expression for the relative price of investment (RPI) and use it to show that in our two sector model, RPI cannot alone identify investment specific shocks, an assumption built in the majority of one sector models.

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<sup>32</sup>The Figure plots a set of IRFs where both price and wage rigidities are nearly eliminated and a set of IRFs where only wage rigidities are nearly eliminated. The first set is generated from the baseline model where we have set the steady state mark-ups, namely,  $\lambda_p = \lambda_w = 0.01$ , indexation parameters,  $\iota_{p_C} = \iota_{p_I} = \iota_w = 0.01$ , and Calvo probabilities for prices and wages,  $\xi_C = \xi_I = \xi_w = 0.01$ . The second set is generated from the baseline model where we have set the steady state wage mark-up, namely,  $\lambda_w = 0.01$ , indexation parameter,  $\iota_w = 0.01$ , and calvo probability for wages,  $\xi_w = 0.01$ .

<sup>33</sup>We have also examined the sensitivity to variations in real rigidity parameters. Specifically, investment adjustment cost (IAC), habit persistence, utilization elasticity parameters, with all other parameters set to their estimated values. An interesting finding, is that, qualitatively, these parameters do not matter for the co-movement properties of consumption sector TFP news, though of course matter quantitatively. Under all parametrizations we examine, the consumption sector TFP news shock is expansionary. We do not show the IRFs for all different perturbations here in the interest of space, but they are available upon request.

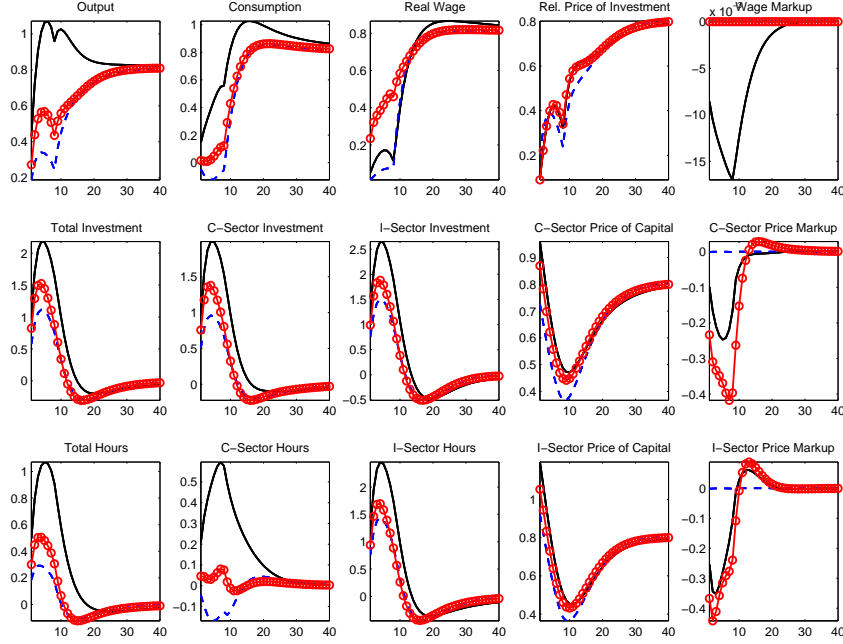


Figure 10: Responses to a one std. deviation TFP news shock (anticipated 8 quarters ahead) in the consumption sector. Baseline model (black solid line) vs. model without wage and price rigidities (blue dashed line) vs. model without wage rigidities (red line with circles) The horizontal axes refer to quarters and the units of the vertical axes are percentage deviations.

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

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  $x$ .  $\text{mark up}_{x,t}$  is the price 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 can be driven—at least in the short run—by, (a) mark up shocks, via their impact on the sectoral price-cost mark ups, (b) sector specific TFP and, (c) differences in capital labor ratios across sectors (due to the sector specific nature of capital in the model). 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 our model with: (i) perfectly competitive product markets, (ii) identical production functions (factor intensities) in both sectors and (iii) full factor mobility, the expression above simplifies to,  $\frac{P_{I,t}}{P_{C,t}} = \frac{A_t}{V_t}$ .<sup>34</sup> In this case the model admits 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

<sup>34</sup>A slightly different and simpler formulation of a two sector model, where investment producers buy final goods and convert them to investment would effectively deliver this restriction (see Justiniano et al. (2011)). This is the approach followed by most one sector New Keynesian models.

$V_t^*$  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 slow 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) other shocks. This is illustrated in Table 7 where investment sector TFP shocks explain around 60% of the variation in the relative price. The remaining 40% is accounted for by, mainly, consumption sector TFP and price mark up shocks.

The variance shares accounted for by investment sector TFP shocks we estimate are smaller compared to, for example, Justiniano et al. (2010). Note however, that in the latter study—in addition to a different sample period—the concept of investment shocks is broader, in that they can include both investment sector TFP as well as, for example, financial shocks affecting the transformation of investment to capital. An advantage of our two sector model is that we can explore a finer decomposition between investment specific shocks and financial type shocks. In the estimation, we allow for capital quality shocks, which directly affect the sectoral capital accumulation equation (see equation (4)).<sup>35</sup> A positive shock of this type has the property that it raises the price of capital and thus causes a revaluation of assets in the banks’ portfolios, leading to gains in bank equity and expansion in lending allowing an interpretation as a financial shock. Table 7 suggests the role of the capital quality shocks is fairly limited, accounting for less than 10% in the majority of macroeconomic real and nominal series (except consumption), but nevertheless account for shares close to 20% in two out of the three financial observables, consistent with the interpretation we adopt for these shocks.

## B Data Sources and Time Series Construction

Table 9 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. Unless otherwise noted, the same variables are used for estimating the various VAR specifications. The data series for aggregate and consumption specific TFP used to estimate the VARs are taken from John Fernald’s website ([http://www.frbsf.org/economic-research/economists/jferald/quarterly\\_tfp.xls](http://www.frbsf.org/economic-research/economists/jferald/quarterly_tfp.xls)), and are described in Fernald (2012).

**Sectoral definition.** To allocate a sector to the consumption or investment category, we used the 2005 Input-Output tables. The Input-Output tables track the flows of goods and services across industries and record the final use of each industry’s output into three broad categories: consumption, investment and intermediate uses (as well as net exports and government). First, we determine how much of a 2-digit industry’s final output goes to consumption as opposed to investment or intermediate uses. Then we adopt the following criterion: if the majority of an industry’s final output is allocated

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<sup>35</sup>These shocks have been recently considered by Gertler and Karadi (2011), Gertler and Kiyotaki (2010) and Gourio (2012) in calibrated one sector models.



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.<sup>36</sup>

**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, 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 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).<sup>37</sup> A credit spread is defined as the difference between a company's corporate bond yield and

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<sup>36</sup>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.

<sup>37</sup>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).

Table 9: 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 Exp.: Durable Goods	CP, SA, billion \$	PCDG	BEA
Real Personal Consumption Exp.: 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 Exp.: Nondurable Goods	CP, SA, billion \$	PCND	BEA
Real Personal Consumption Exp.: 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.

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 duration 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 company level 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 5381 bonds of which 1213 are classified to be issued by companies in the consumption sector and 4168 issued by companies in the investment sector. This is equivalent to 35413 observations in the consumption and 115286 observations in the investment sector over the entire sample. The average duration is 30 quarters (consumption sector) and 28 quarters (investment sector) with an average rating for both sectoral bond issues between BBB+ and A-. The total number of firms in our sample is equal to 1696, where 516 firms belong to the consumption sector and 1180 firms belong to the investment sector. The correlation between the two sectoral spread series is equal to 0.83.

**Steady state financial parameters.** The steady state leverage ratio of financial

intermediaries in the model – which helps to pin down the parameters  $\varpi$  and  $\lambda_B$  – 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.

## C Model Details and Derivations

We provide the model details and derivations required for solution and estimation of the model. We begin with the pricing and wage decisions of firms and households, 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 Intermediate and Final Goods Producers

**Intermediate producers pricing decision.** A constant fraction  $\xi_{p,x}$  of intermediate firms in sector  $x = C, I$  cannot choose their price optimally in period  $t$  but reset their price — as in Calvo (1983) — according to the indexation rule,

$$P_{C,t}(i) = P_{C,t-1}(i) \pi_{C,t-1}^{\iota_{pC}} \pi_C^{1-\iota_{pC}},$$

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

where  $\pi_{C,t} \equiv \frac{P_{C,t}}{P_{C,t-1}}$  and  $\pi_{I,t} \equiv \frac{P_{I,t}}{P_{I,t-1}} \left( \frac{A_t}{A_{t-1}} \right)^{-1} \left( \frac{V_t}{V_{t-1}} \right)^{\frac{1-a_c}{1-a_i}}$  is gross inflation in the two sectors and  $\pi_C, \pi_I$  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,

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

The aggregate price index in the investment sector is,

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

**Final goods producers.** 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  $P_{I,t}(i)$ ,

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

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  $x = C, I$ .

### C.1.1 Household's wage setting

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 mark-up),  $\lambda_{w,t}$ , follows the exogenous stochastic process,

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

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

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

$$L_t(j) = \left( \frac{W_t(j)}{W_t} \right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t, \quad (\text{C.1})$$

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,

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

Following Erceg et al. (2000), in each period, a fraction  $\xi_w$  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,<sup>38</sup>

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

subject to the labor demand function (C.1). 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.

## C.2 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,

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

From the capital producer's problem it is evident that any value of  $O_{x,t}$  is profit maximizing. Let  $\delta_x \in (0, 1)$  denote the depreciation rate of capital and  $\bar{K}_{x,t-1}$  the cap-

<sup>38</sup>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)).

ital stock available at the beginning of period  $t$  in sector  $x = C, I$ . Then setting  $O_{x,t} = (1 - \delta)\xi_{x,t}^K \bar{K}_{x,t-1}$  implies the available (sector specific) capital stock in sector  $x$ , evolves according to,

$$\bar{K}_{x,t} = (1 - \delta_x)\xi_{x,t}^K \bar{K}_{x,t-1} + \left(1 - S\left(\frac{I_{x,t}}{I_{x,t-1}}\right)\right)I_{x,t}, \quad x = C, I, \quad (\text{C.2})$$

as described in the main text.

### C.3 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 for the consumption or investment sector branch can be expressed as,

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

where  $S_{x,t}$  denotes the quantity of financial claims held by the intermediary branch and  $Q_{x,t}$  denotes the sector specific price of a claim. The variable  $N_{x,t}$  represents the bank's wealth (or equity) at the end of period  $t$  and  $B_{x,t}$  are the deposits the intermediary branch obtains from households. The sector specific assets held by the financial intermediary pay the stochastic return  $R_{x,t+1}^B$  in the next period. 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 branch equity evolves over time as,

$$\begin{aligned} N_{x,t+1}P_{C,t+1} &= R_{x,t+1}^B \pi_{C,t+1} P_{C,t} Q_{x,t} S_{x,t} - R_t B_{x,t} \\ N_{x,t+1} \frac{P_{C,t+1}}{P_{C,t}} &= R_{x,t+1}^B \pi_{C,t+1} Q_{x,t} S_{x,t} - R_t (Q_{x,t} S_{x,t} - N_{x,t}) \\ N_{x,t+1} &= [(R_{x,t+1}^B \pi_{C,t+1} - R_t) Q_{x,t} S_{x,t} + R_t N_{x,t}] \frac{1}{\pi_{C,t+1}}. \end{aligned}$$

The premium,  $R_{x,t+1}^B \pi_{C,t+1} - R_t$ , as well as the quantity of assets,  $Q_{x,t} S_{x,t}$ , determines the growth in bank's equity above the riskless return. The bank will not fund any assets with a negative discounted premium. It follows that for the bank to operate in period  $i$  the following inequality must hold,

$$E_t \beta^i \Lambda_{t+1+i}^B (R_{x,t+1+i}^B \pi_{C,t+1+i} - R_{t+i}) \geq 0, \quad i \geq 0,$$

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

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

where  $\Lambda_t$  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 will keep building assets by borrowing additional funds from households. Accordingly, the intermediary branch objective is to maximize expected terminal wealth,

$$\begin{aligned}
V_{x,t} &= \max E_t \sum_{i=0} (1 - \theta_B) \theta_B^i \beta^i \Lambda_{t+1+i}^B N_{x,t+1+i} \\
&= \max E_t \sum_{i=0} (1 - \theta_B) \theta_B^i \beta^i \Lambda_{t+1+i}^B \left[ (R_{x,t+1+i}^B \pi_{C,t+1+i} - R_{t+i}) \frac{Q_{x,t+i} S_{x,t+i}}{\pi_{C,t+1+i}} + \frac{R_{t+i} N_{x,t+i}}{\pi_{C,t+1+i}} \right],
\end{aligned} \tag{C.3}$$

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  $\lambda_B$  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. Note that the fraction,  $\lambda_B$ , which intermediaries can divert is the same across sectors to guarantee that the household is indifferent between lending funds between different branches.

Given this tradeoff, depositors will only lend funds to the intermediary when the latter's maximized expected terminal wealth is larger or equal to the gain from diverting the fraction  $\lambda_B$  of available funds. This incentive constraint can be formalized as,

$$V_{x,t} \geq \lambda_B Q_{x,t} S_{x,t}, \quad 0 < \lambda_B < 1. \tag{C.4}$$

Using equation (C.3), the expression for  $V_{x,t}$  can be written as the following first-order difference equation,

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

with,

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

and,

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

The variable  $\nu_{x,t}$  can be interpreted as 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: it is the expected discounted value of having an additional unit of wealth,  $N_{x,t}$ , holding the quantity of financial claims,  $S_{x,t}$ , constant. The gross growth rate in assets is denoted by  $Z_{1,t+1}^x$  and the gross growth rate of net worth is denoted by

$Z_{2,t+i}^x$ .

Then, using the expression for  $V_{x,t}$ , we can express the intermediary's incentive constraint (C.4) 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. Imperfect capital markets however, limit the possibilities for this kind of arbitrage because the intermediaries are constrained by their equity capital. If the incentive constraint binds it follows that,

$$\begin{aligned} Q_{x,t}S_{x,t} &= \frac{\eta_{x,t}}{\lambda_B - \nu_{x,t}} N_{x,t} \\ &= \varrho_{x,t} N_{x,t}. \end{aligned} \tag{C.5}$$

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,  $\varrho_{x,t}$ , limiting the bank's ability to acquire assets. This leverage ratio is the ratio of the bank's intermediated assets to equity. The bank's leverage ratio is limited to the point where its maximized expected terminal wealth equals the gains from diverting the fraction  $\lambda_B$  from available funds. However, the constraint (C.5) binds only if  $0 < \nu_{x,t} < \lambda_B$  (given  $N_{x,t} > 0$ ). This inequality is always satisfied with our estimates.

Using the leverage ratio (C.5) we can express the evolution of the intermediary's wealth as,

$$N_{x,t+1} = [(R_{x,t+1}^B \pi_{C,t+1} - R_t) \varrho_{x,t} + R_t] \frac{N_{x,t}}{\pi_{C,t+1}}.$$

From this equation it also follows that,

$$Z_{2,t+1}^x = \frac{N_{x,t+1}}{N_{x,t}} = [(R_{x,t+1}^B \pi_{C,t+1} - R_t) \varrho_{x,t} + R_t] \frac{1}{\pi_{C,t+1}},$$

and,

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

Financial intermediaries which are forced into bankruptcy are replaced by new entrants. Therefore, total wealth of financial intermediaries is the sum of the net worth of existing,  $N_{x,t}^e$ , and new ones,  $N_{x,t}^n$ ,

$$N_{x,t} = N_{x,t}^e + N_{x,t}^n.$$

The fraction  $\theta_B$  of bankers at  $t - 1$  which survive until  $t$  is equal across branches. Then,



the law of motion for existing bankers is given by,

$$N_{x,t}^e = \theta_B [(R_{x,t}^B \pi_{C,t} - R_{t-1}) \varrho_{x,t-1} + R_{t-1}] \frac{N_{x,t-1}}{\pi_{C,t}}, \quad 0 < \theta_B < 1. \quad (\text{C.6})$$

where a main source of variation is the ex-post excess return on assets,  $R_{x,t}^B \pi_{C,t} - R_{t-1}$ .

New banks receive startup funds from their respective household, 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 transfer to new intermediaries is a fraction,  $\varpi$ , of this value, leading to the following formulation for new banker's wealth,

$$N_{x,t}^n = \varpi Q_{x,t} S_{x,t}, \quad 0 < \varpi < 1. \quad (\text{C.7})$$

Existing banker's net worth (C.6) and entering banker's net worth (C.7) lead to the law of motion for total net worth,

$$N_{x,t} = (\theta_B [(R_{x,t}^B \pi_{C,t} - R_{t-1}) \varrho_{x,t-1} + R_{t-1}] \frac{N_{x,t-1}}{\pi_{C,t}} + \varpi Q_{x,t} S_{x,t}).$$

The excess return,  $x = C, I$  can be defined as,

$$R_{x,t}^S = R_{x,t+1}^B \pi_{C,t+1} - R_t.$$

Since  $R_t$ ,  $\lambda_B$ ,  $\varpi$  and  $\theta_B$  are equal across sectors, the institutional setup of the two representative banks in the two sectors is symmetric. Both branches hold deposits from households and buy assets from firms in the sector they provide specialized lending. 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,  $R_{x,t}^K$ . Note that the institutional setup of banks does not depend on firm-specific factors. Gertler and Karadi (2011) show that this implies 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.4 Resource Constraints

The resource constraint in the consumption sector is,

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

The resource constraint in the investment sector is,

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

Hours worked are aggregated as,

$$L_t = L_{I,t} + L_{C,t}.$$

## C.5 Stationary Economy

The model includes two non-stationary TFP 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:

$$k_{x,t} = \frac{K_{x,t}}{V_t^{\frac{1}{1-a_i}}}, \quad \bar{k}_{x,t} = \frac{\bar{K}_{x,t}}{V_t^{\frac{1}{1-a_i}}}, \quad k_t = \frac{K_t}{V_t^{\frac{1}{1-a_i}}}, \quad (C.8)$$

$$i_{x,t} = \frac{I_{x,t}}{V_t^{\frac{1}{1-a_i}}}, \quad i_t = \frac{I_t}{V_t^{\frac{1}{1-a_i}}}, \quad c_t = \frac{C_t}{A_t V_t^{\frac{a_c}{1-a_i}}}, \quad (C.9)$$

$$r_{C,t}^K = \frac{R_{C,t}^K}{P_{C,t}} A_t^{-1} V_t^{\frac{1-a_c}{1-a_i}}, \quad r_{I,t}^K = \frac{R_{I,t}^K}{P_{C,t}} A_t^{-1} V_t^{\frac{1-a_c}{1-a_i}}, \quad w_t = \frac{W_t}{P_{C,t} A_t V_t^{\frac{a_c}{1-a_i}}}. \quad (C.10)$$

From

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

follows that,

$$p_{i,t} = \frac{P_{I,t}}{P_{C,t}} A_t^{-1} V_t^{\frac{1-a_c}{1-a_i}}. \quad (C.11)$$

and the multipliers are normalized as,

$$\lambda_t = \Lambda_t A_t V_t^{\frac{a_c}{1-a_i}}, \quad \phi_{x,t} = \Phi_{x,t} V_t^{\frac{1}{1-a_i}}. \quad (C.12)$$

where  $\Phi_{x,t}$  denotes the multiplier on the respective capital accumulation equation. Using the growth of investment, it follows that the prices of capital can be normalized as,

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

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,

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

Then, it follows from entering bankers wealth equation (C.7) that,

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

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

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

### C.5.1 Intermediate goods producers

Firm's production function in the consumption sector:

$$c_t = L_{C,t}^{1-a_c} k_{C,t}^{a_c} - F_C. \quad (\text{C.13})$$

Firm's production function in the investment sector:

$$i_t = L_{I,t}^{1-a_i} k_{I,t}^{a_i} - F_I. \quad (\text{C.14})$$

Marginal costs in the consumption sector:

$$mc_{C,t} = (1 - a_c)^{a_c-1} a_c^{-a_c} (r_{C,t}^K)^{a_c} w_t^{1-a_c}. \quad (\text{C.15})$$

Marginal costs in the investment sector:

$$mc_{I,t} = (1 - a_i)^{a_i-1} a_i^{-a_i} w_t^{1-a_i} (r_{I,t}^K)^{a_i} p_{i,t}^{-1}, \quad \text{with } p_{i,t} = \frac{P_{I,t}}{P_{C,t}}. \quad (\text{C.16})$$

Capital labour ratios in the two sectors:

$$\frac{k_{C,t}}{L_{C,t}} = \frac{w_t}{r_{C,t}^K} \frac{a_c}{1 - a_c}, \quad \frac{k_{I,t}}{L_{I,t}} = \frac{w_t}{r_{I,t}^K} \frac{a_i}{1 - a_i}. \quad (\text{C.17})$$

### C.5.2 Firms' pricing decisions

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

$$0 = E_t \left\{ \sum_{s=0}^{\infty} \xi_{p,x}^s \beta^s \lambda_{t+s} \tilde{x}_{t+s} \left[ \tilde{p}_{x,t} \tilde{\Pi}_{t,t+s} - (1 + \lambda_{p,t+s}^x) mc_{x,t+s} \right] \right\}, \quad (\text{C.18})$$

with

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

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

Aggregate price index in the consumption sector:

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

It further holds that

$$\frac{\pi_{I,t}}{\pi_{C,t}} = \frac{p_{i,t}}{p_{i,t-1}}. \quad (\text{C.19})$$

### C.5.3 Household's optimality conditions and wage setting

Marginal utility of income:

$$\lambda_t = \frac{b_t}{c_t - hc_{t-1} \left( \frac{A_{t-1}}{A_t} \right) \left( \frac{V_{t-1}}{V_t} \right)^{\frac{a_c}{1-a_i}}} - \beta h \frac{b_{t+1}}{c_{t+1} \left( \frac{A_{t+1}}{A_t} \right) \left( \frac{V_{t+1}}{V_t} \right)^{\frac{a_c}{1-a_i}} - hc_t}. \quad (\text{C.20})$$

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.5.4 Capital services

Optimal capital utilization:

$$r_{C,t}^K = a'_C(u_{C,t}), \quad r_{I,t}^K = a'_I(u_{I,t}).$$

Definition of capital services:

$$k_{C,t} = u_{C,t} \xi_{C,t}^K \bar{k}_{C,t-1} \left( \frac{V_{t-1}}{V_t} \right)^{\frac{1}{1-a_i}}, \quad k_{I,t} = u_{I,t} \xi_{I,t}^K \bar{k}_{I,t-1} \left( \frac{V_{t-1}}{V_t} \right)^{\frac{1}{1-a_i}}. \quad (\text{C.21})$$

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

$$\phi_{x,t} = \beta E_t \xi_{x,t+1}^K \left\{ \lambda_{t+1} \left( \frac{V_t}{V_{t+1}} \right)^{\frac{1}{1-a_i}} (r_{x,t+1}^K u_{x,t+1} - a(u_{x,t+1})) + (1 - \delta) E_t \phi_{x,t+1} \left( \frac{V_t}{V_{t+1}} \right)^{\frac{1}{1-a_i}} \right\}, \quad (\text{C.22})$$

### C.5.5 Physical capital producers

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

$$\begin{aligned} \lambda_t p_{i,t} = & \phi_{x,t} \left[ 1 - S \left( \frac{i_{x,t}}{i_{x,t-1}} \left( \frac{V_t}{V_{t-1}} \right)^{\frac{1}{1-a_i}} \right) - S' \left( \frac{i_{x,t}}{i_{x,t-1}} \left( \frac{V_t}{V_{t-1}} \right)^{\frac{1}{1-a_i}} \right) \frac{i_{x,t}}{i_{x,t-1}} \left( \frac{V_t}{V_{t-1}} \right)^{\frac{1}{1-a_i}} \right] \\ & + \beta E_t \phi_{x,t+1} \left( \frac{V_t}{V_{t+1}} \right)^{\frac{1}{1-a_i}} \left[ S' \left( \frac{i_{x,t+1}}{i_{x,t}} \left( \frac{V_{t+1}}{V_t} \right)^{\frac{1}{1-a_i}} \right) \left( \frac{i_{x,t+1}}{i_{x,t}} \left( \frac{V_{t+1}}{V_t} \right)^{\frac{1}{1-a_i}} \right)^2 \right]. \end{aligned} \quad (\text{C.23})$$

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

$$\bar{k}_{x,t} = (1 - \delta_x) \xi_{x,t}^K \bar{k}_{x,t-1} \left( \frac{V_{t-1}}{V_t} \right)^{\frac{1}{1-a_i}} + \left( 1 - S \left( \frac{i_{x,t}}{i_{x,t-1}} \left( \frac{V_t}{V_{t-1}} \right)^{\frac{1}{1-a_i}} \right) \right) i_{x,t}, \quad (\text{C.24})$$

### C.5.6 Household's wage setting

Household's wage setting:

$$E_t \sum_{s=0}^{\infty} \beta^s \xi_w^s \lambda_{t+s} \tilde{L}_{t+s} \left[ \tilde{w}_t \tilde{\Pi}_{t,t+s}^w - (1 + \lambda_{w,t+s}) b_{t+s} \varphi \frac{\tilde{L}_{t+s}^\nu}{\lambda_{t+s}} \right] = 0, \quad (\text{C.25})$$

with

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

and

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

Wages evolve according to

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

### C.5.7 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  $\eta_{x,t}$ ,

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

with

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

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

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

with the leverage ratio given as,

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

It further follows that:

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

and

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

The normalized equation for bank's wealth accumulation is,

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

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:

$$R_{x,t+1}^B = \frac{r_{x,t+1}^K u_{x,t+1} + q_{x,t+1} (1 - \delta_x) - a(u_{x,t+1})}{q_{x,t}} \xi_{x,t+1}^K \frac{A_{t+1}}{A_t} \left(\frac{V_{t+1}}{V_t}\right)^{-\frac{1-a_c}{1-a_i}},$$

knowing from the main model that

$$r_{x,t}^K = \frac{R_{x,t}^K}{P_{x,t}} A_t^{-1} V_t^{\frac{1-a_c}{1-a_i}}.$$

### C.5.8 Monetary policy and market clearing

Monetary policy rule:

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

Resource constraint in the consumption sector:

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

Resource constraint in the investment sector:

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

Definition of GDP:

$$y_t = c_t + p_{i,t} i_t + \left( 1 - \frac{1}{e_t} \right) y_t. \quad (\text{C.26})$$

Moreover

$$L_t = L_{I,t} + L_{C,t}, \quad i_t = i_{C,t} + i_{I,t}.$$

## C.6 Steady State

This section describes the model's steady state.

From the optimal choice of available capital (C.22) and the optimal choice of investment (C.23) in both sectors:

$$r_C^K = \left( \frac{e^{\frac{1}{1-a_i} g_v}}{\beta} - (1 - \delta_C) \right) p_i, \quad (\text{C.27})$$

$$r_I^K = \left( \frac{e^{\frac{1}{1-a_i} g_v}}{\beta} - (1 - \delta_I) \right) p_i. \quad (\text{C.28})$$

From firm's price setting in both sectors (C.18),

$$mc_C = \frac{1}{1 + \lambda_p^C}, \quad mc_I = \frac{1}{1 + \lambda_p^I}. \quad (\text{C.29})$$

Using equations (C.29) 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 that define

marginal costs in the two sectors ((C.15) and (C.16)).

Consumption sector:

$$w = \left( \frac{1}{1 + \lambda_p^C} (1 - a_c)^{1-a_c} a_c^{a_c} (r_C^K)^{-a_c} \right)^{\frac{1}{1-a_c}}. \quad (\text{C.30})$$

Investment sector:

$$w = \left( \frac{1}{1 + \lambda_p^I} (1 - a_i)^{1-a_i} a_i^{a_i} (r_I^K)^{-a_i} p_i \right)^{\frac{1}{1-a_i}}. \quad (\text{C.31})$$

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.30) equal to (C.31):

$$\begin{aligned} \left( \frac{1}{1 + \lambda_p^C} (1 - a_c)^{1-a_c} a_c^{a_c} (r_C^K)^{-a_c} \right)^{\frac{1}{1-a_c}} &= \left( \frac{1}{1 + \lambda_p^I} (1 - a_i)^{1-a_i} a_i^{a_i} (r_I^K)^{-a_i} p_i \right)^{\frac{1}{1-a_i}} \\ \Leftrightarrow \left( \frac{1}{1 + \lambda_p^C} (1 - a_c)^{1-a_c} a_c^{a_c} \left( \frac{e^{\frac{1}{1-a_i} g_v}}{\beta} - (1 - \delta_C) \right)^{-a_c} p_i^{-a_c} \right)^{\frac{1}{1-a_c}} \\ &= \left( \frac{1}{1 + \lambda_p^I} (1 - a_i)^{1-a_i} a_i^{a_i} \left( \frac{e^{\frac{1}{1-a_i} g_v}}{\beta} - (1 - \delta_I) \right)^{-a_i} p_i^{-a_i} p_i \right)^{\frac{1}{1-a_i}} \\ \Leftrightarrow p_i &= \frac{\frac{1}{1 + \lambda_p^C} (1 - a_c)^{1-a_c} a_c^{a_c} \left( \frac{e^{\frac{1}{1-a_i} g_v}}{\beta} - (1 - \delta_C) \right)^{-a_c}}{\left[ \frac{1}{1 + \lambda_p^I} (1 - a_i)^{1-a_i} a_i^{a_i} \left( \frac{e^{\frac{1}{1-a_i} g_v}}{\beta} - (1 - \delta_I) \right)^{-a_i} \right]^{\frac{1-a_c}{1-a_i}}}. \end{aligned} \quad (\text{C.32})$$

Knowing  $w$ ,  $r_C^K$  and  $r_I^K$ , the expressions given in (C.17) can be used to find the steady state capital-to-labour ratios in the two sectors:

$$\frac{k_C}{L_C} = \frac{w}{r_C^K} \frac{a_c}{1 - a_c}, \quad (\text{C.33})$$

$$\frac{k_I}{L_I} = \frac{w}{r_I^K} \frac{a_i}{1 - a_c}. \quad (\text{C.34})$$

The zero profit condition for intermediate goods producers in the consumption sector,  $c - r_C^K k_C - w L_C = 0$ , and (C.13) imply:

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

Analogously the zero profit condition for intermediate goods producers in the investment



sector,  $i - r_I^K k_I - wL_I = 0$ , and (C.14) imply:

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

These expressions pin down the steady state consumption-to-labour and investment-to-labour ratios which follow from the intermediate firms' production functions ((C.13) and (C.14)):

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

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

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,

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

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

$$L_I = 1 - L_C, \tag{C.35}$$

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

$$L_C = \left( 1 + p_i \frac{i}{c} \frac{\frac{1}{1+\lambda_p^C} \left(\frac{k_C}{L_C}\right)^{a_c}}{\frac{1}{1+\lambda_p^I} \left(\frac{k_I}{L_I}\right)^{a_i}} p_i^{-1} \right)^{-1}. \quad (\text{C.36})$$

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.21) that,

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

The accumulation equation of available capital (C.24) can be used to solve for investment in the two sectors:

$$i_C = k_C (e^{\frac{1}{1-a_i} g_v} - (1 - \delta_C)), \quad (\text{C.37})$$

$$i_I = k_I (e^{\frac{1}{1-a_i} g_v} - (1 - \delta_I)). \quad (\text{C.38})$$

From the definition of GDP (C.26):

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

From the marginal utility of income (C.20):

$$\lambda = \frac{1}{c - h c e^{-g a - \frac{a_c}{1-a_i} g_v}} - \frac{\beta h}{c e^{g a + \frac{a_c}{1-a_i} g_v} - h c}.$$

From the household's wage setting (C.25)

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

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  $\varphi$  to be consistent with  $L = 1$ :

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

$$\Leftrightarrow \varphi = \frac{\lambda w}{1 + \lambda_w}.$$

It further holds from equation (C.19) that,

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

A system of 10 equations (C.27, C.28, C.30, C.32, C.33, C.34, C.35, C.36, C.37, C.38) can be solved 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 its average value in the data over the sample period.

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

The parameters  $\varpi$  and  $\lambda_B$  help to align the value of the leverage ratio and the corporate bond spread with their empirical counterparts. Using the calibrated value for  $\theta_B$ , the average value for the leverage ratio (5.47) and the weighted quarterly average of the corporate spreads ( $R_x^B - R = 0.5\%$ ) allows calibrating  $\varpi$  using the bank's wealth accumulation equation,

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

Given the non-linearity in the leverage ratio, we solve numerically for the steady state expressions for  $\eta$  and  $\nu$  using,

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

with

$$z_2^x = [(R_x^B \pi_C - R)\varrho_x + R] \frac{1}{\pi_C}, \quad \text{and} \quad z_1^x = z_2^x,$$

and the steady state leverage ratio,

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

## C.7 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

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

### C.7.1 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:

$$\hat{r}_{C,t}^K - \hat{w}_t = \hat{L}_{C,t} - \hat{k}_{C,t}, \quad \hat{r}_{I,t}^K - \hat{w}_t = \hat{L}_{I,t} - \hat{k}_{I,t}. \quad (\text{C.39})$$

Marginal cost in both sectors:

$$\hat{m}c_{C,t} = a_c \hat{r}_{C,t}^K + (1 - a_c) \hat{w}_t, \quad \hat{m}c_{I,t} = a_i \hat{r}_{I,t}^K + (1 - a_i) \hat{w}_t - \hat{p}_{i,t}. \quad (\text{C.40})$$

### C.7.2 Firm's prices

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

$$0 = E_t \left\{ \sum_{s=0}^{\infty} \xi_{p,x}^s \beta^s \left[ \hat{p}_{x,t} \hat{\Pi}_{t,t+s} - \hat{\lambda}_{p,t+s}^x - \hat{m}c_{x,t+s} \right] \right\},$$

with

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

Solving for the summation

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

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

Prices evolve as

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

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

$$\begin{aligned} \hat{\pi}_{x,t} &= \frac{\beta}{1 + \iota_{p_x} \beta} E_t \hat{\pi}_{x,t+1} + \frac{\iota_{p_x}}{1 + \iota_{p_x} \beta} \hat{\pi}_{x,t-1} + \kappa_x \hat{m}c_{x,t} + \kappa_x \hat{\lambda}_{p,t}^x, \quad (\text{C.41}) \\ \text{with } \kappa_x &= \frac{(1 - \xi_{p,x} \beta)(1 - \xi_{p,x})}{\xi_{p,x}(1 + \iota_{p_x} \beta)}. \end{aligned}$$

From equation (C.19) it follows that

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

### C.7.3 Households

Marginal utility:

$$\begin{aligned} \hat{\lambda}_t &= \frac{e^G}{e^G - h\beta} \left[ \hat{b}_t + \left( \hat{z}_t + \frac{a_c}{1 - a_i} \hat{v}_t \right) - \left( \frac{e^G}{e^G - h} \left( \hat{c}_t + \hat{z}_t + \frac{a_c}{1 - a_i} \hat{v}_t \right) - \frac{h}{e^G - h} \hat{c}_{t-1} \right) \right] \\ &\quad - \frac{h\beta}{e^G - h\beta} E_t \left[ \hat{b}_{t+1} - \left( \frac{e^G}{e^G - h} \left( \hat{c}_{t+1} + \hat{z}_{t+1} + \frac{a_c}{1 - a_i} \hat{v}_{t+1} \right) - \frac{h}{e^G - h} \hat{c}_t \right) \right] \\ \Leftrightarrow \hat{\lambda}_t &= \alpha_1 E_t \hat{c}_{t+1} - \alpha_2 \hat{c}_t + \alpha_3 \hat{c}_{t-1} + \alpha_4 \hat{z}_t + \alpha_5 \hat{b}_t + \alpha_6 \hat{v}_t, \end{aligned} \quad (\text{C.42})$$

with

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

This assumes the shock processes for  $\hat{z}_t$  and  $\hat{b}_t$ .

Euler equation:

$$\hat{\lambda}_t = \hat{R}_t + E_t \left( \hat{\lambda}_{t+1} - \hat{z}_{t+1} - \hat{v}_{t+1} \frac{a_c}{1 - a_i} - \hat{\pi}_{C,t+1} \right). \quad (\text{C.43})$$

### C.7.4 Investment and Capital

Capital utilization in both sectors:

$$\hat{r}_{C,t}^K = \chi_C \hat{u}_{C,t}, \quad \hat{r}_{I,t}^K = \chi_I \hat{u}_{I,t}, \quad \text{where } \chi_x = \frac{a_x''(1)}{a_x'(1)}. \quad (\text{C.44})$$

Choice of investment for the consumption sector:

$$\begin{aligned} \hat{q}_{C,t} &= e^{2(\frac{1}{1-a_i} g_v)} \kappa \left( \hat{i}_{C,t} - \hat{i}_{C,t-1} + \frac{1}{1 - a_i} \hat{v}_t \right) - \beta e^{2(\frac{1}{1-a_i} g_v)} \kappa E_t \left( \hat{i}_{C,t+1} - \hat{i}_{C,t} + \frac{1}{1 - a_i} \hat{v}_{t+1} \right) \\ &\quad + \hat{p}_{i,t}, \end{aligned} \quad (\text{C.45})$$

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

Choice of investment for the investment sector:

$$\begin{aligned} \hat{q}_{I,t} &= e^{2(\frac{1}{1-a_i} g_v)} \kappa \left( \hat{i}_{I,t} - \hat{i}_{I,t-1} + \frac{1}{1 - a_i} \hat{v}_t \right) - \beta e^{2(\frac{1}{1-a_i} g_v)} \kappa E_t \left( \hat{i}_{I,t+1} - \hat{i}_{I,t} + \frac{1}{1 - a_i} \hat{v}_{t+1} \right) \\ &\quad + \hat{p}_{i,t}, \end{aligned} \quad (\text{C.46})$$

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

Capital services input in both sectors:

$$\hat{k}_{C,t} = \hat{u}_{C,t} + \xi_{C,t}^K + \hat{k}_{C,t-1} - \frac{1}{1-a_i} \hat{v}_t, \quad \hat{k}_{I,t} = \hat{u}_{I,t} + \xi_{I,t}^K + \hat{k}_{I,t-1} - \frac{1}{1-a_i} \hat{v}_t. \quad (\text{C.47})$$

Capital accumulation in the consumption and investment sector:

$$\hat{k}_{C,t} = (1 - \delta_C) e^{-\frac{1}{1-a_i} g_v} \left( \hat{k}_{C,t-1} + \xi_{C,t}^K - \frac{1}{1-a_i} \hat{v}_t \right) + \left( 1 - (1 - \delta_C) e^{-\frac{1}{1-a_i} g_v} \right) \hat{i}_{C,t}, \quad (\text{C.48})$$

$$\hat{k}_{I,t} = (1 - \delta_I) e^{-\frac{1}{1-a_i} g_v} \left( \hat{k}_{I,t-1} + \xi_{I,t}^K - \frac{1}{1-a_i} \hat{v}_t \right) + \left( 1 - (1 - \delta_I) e^{-\frac{1}{1-a_i} g_v} \right) \hat{i}_{I,t}. \quad (\text{C.49})$$

### C.7.5 Wages

The wage setting equation for workers renegotiating their salary:

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

with

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

and

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

Then using the labor demand function,

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

Solving for the summation,

$$\begin{aligned}
\frac{\nu_w}{1 - \xi_w \beta} \hat{w}_t &= E_t \left\{ \sum_{s=0}^{\infty} \xi_w^s \beta^s \left[ - \left( 1 + \nu \left( 1 + \frac{1}{\lambda_w} \right) \right) \hat{\Pi}_{t,t+s}^w + \hat{\psi}_{t+s} \right] \right\} \\
&= - \nu_w \hat{\Pi}_{t,t}^w + \hat{\psi}_t + E_t \left\{ \sum_{s=0}^{\infty} \xi_w^s \beta^s \left[ - \nu_w \hat{\Pi}_{t,t+s}^w + \hat{\psi}_{t+s} \right] \right\} \\
&= \hat{\psi}_t - \frac{\xi_w \beta}{1 - \xi_w \beta} \nu_w \hat{\Pi}_{t,t+1}^w + \xi_w \beta E_t \left\{ \sum_{s=0}^{\infty} \xi_w^s \beta^s \left[ - \nu_w \hat{\Pi}_{t+1,t+1+s}^w + \hat{\psi}_{t+1+s} \right] \right\} \\
&= \hat{\psi}_t + \frac{\xi_w \beta}{1 - \xi_w \beta} \nu_w E_t \left[ \hat{w}_{t+1} - \hat{\Pi}_{t,t+1}^w \right]. \tag{C.50}
\end{aligned}$$

where

$$\begin{aligned}
\hat{\psi}_t &\equiv \hat{\lambda}_{w,t} + \hat{b}_t + \nu \hat{L}_t + \nu \left( 1 + \frac{1}{\lambda_w} \right) \hat{w}_t - \hat{\lambda}_t, \tag{C.51} \\
\nu_w &\equiv 1 + \nu \left( 1 + \frac{1}{\lambda_w} \right),
\end{aligned}$$

and recall that  $\hat{\Pi}_{t,t}^w = 0$ .

Wages evolve as,

$$\begin{aligned}
\hat{w}_t &= (1 - \xi_w) \hat{w}_t + \xi_w \left( \hat{w}_{t-1} + \iota_w \hat{\pi}_{c,t-1} + \iota_w \left( \hat{z}_{t-1} + \frac{a_c}{1 - a_i} \hat{v}_{t-1} \right) - \hat{\pi}_{c,t} - \hat{z}_t - \frac{a_c}{1 - a_i} \hat{v}_t \right) \\
\Leftrightarrow \hat{w}_t &= (1 - \xi_w) \hat{w}_t + \xi_w (\hat{w}_{t-1} + \hat{\Pi}_{t,t-1}^w). \tag{C.52}
\end{aligned}$$

Equation (C.52) can be solved for  $\hat{w}_t$ . This expression, as well as the formulation for  $\hat{\psi}_t$  given in (C.51) can be plugged into equation (C.50). After rearranging this yields the wage Phillips curve,

$$\begin{aligned}
\hat{w}_t &= \frac{1}{1 + \beta} \hat{w}_{t-1} + \frac{\beta}{1 + \beta} E_t \hat{w}_{t+1} - \kappa_w \hat{g}_{w,t} + \frac{\iota_w}{1 + \beta} \hat{\pi}_{c,t-1} - \frac{1 + \beta \iota_w}{1 + \beta} \hat{\pi}_{c,t} \\
&\quad + \frac{\beta}{1 + \beta} E_t \hat{\pi}_{c,t+1} + \kappa_w \hat{\lambda}_{w,t} + \frac{\iota_w}{1 + \beta} \left( \hat{z}_{t-1} + \frac{a_c}{1 - a_i} \hat{v}_{t-1} \right) \\
&\quad - \frac{1 + \beta \iota_w - \rho_z \beta}{1 + \beta} \hat{z}_t - \frac{1 + \beta \iota_w - \rho_v \beta}{1 + \beta} \frac{a_c}{1 - a_i} \hat{v}_t. \tag{C.53}
\end{aligned}$$

where

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



### C.7.6 Financial sector

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

The stochastic discount factor:

$$\hat{\lambda}_t^B = \hat{\lambda}_t - \hat{\lambda}_{t-1}. \quad (\text{C.54})$$

Definition of  $\nu$  for  $x = C, I$ :

$$\begin{aligned} \hat{\nu}_{x,t} = & (1 - \theta_B \beta z_1^x) [\hat{\lambda}_{t+1}^B - \hat{z}_{t+1} - \frac{a_c}{1 - a_i} \hat{\nu}_{t+1}] \\ & + \frac{1 - \theta_B \beta z_1^x}{R_x^B \pi_C - R} [R_x^B \pi_C \hat{R}_{x,t+1}^B + R_x^B \pi_C \hat{\pi}_{C,t+1} - R \hat{R}_t] + \theta_B \beta z_1^x [\hat{z}_{1,t+1}^x + \hat{\nu}_{x,t+1}]. \end{aligned} \quad (\text{C.55})$$

Definition of  $\eta$ :

$$\begin{aligned} \hat{\eta}_{x,t} = & (1 - \theta_B \beta z_2^x) [\hat{\lambda}_{t+1}^B - \hat{z}_{t+1} - \frac{a_c}{1 - a_i} \hat{\nu}_{t+1} + \hat{R}_t] \\ & + \theta_B \beta z_2^x [\hat{z}_{2,t+1}^x + \hat{\eta}_{t+1}], \quad x = C, I. \end{aligned} \quad (\text{C.56})$$

Definition of  $z_1$ :

$$\hat{z}_{1,t}^x = \hat{\varrho}_{x,t} - \hat{\varrho}_{x,t-1} + \hat{z}_{2,t}^x, \quad x = C, I. \quad (\text{C.57})$$

Definition of  $z_2$  for  $x = C, I$ :

$$\hat{z}_{2,t}^x = \frac{\pi_C}{(R_x^B - R) \varrho_x + R} [R_x^B \varrho_x [\hat{R}_{x,t}^B + \hat{\pi}_{C,t}] + \frac{R}{\pi_C} (1 - \varrho_x) \hat{R}_{t-1} + (R_x^B \pi_C - R) \frac{\varrho_x}{\pi_C} \hat{\varrho}_{x,t-1}] - \hat{\pi}_{C,t}. \quad (\text{C.58})$$

The leverage ratio:

$$\hat{\varrho}_{x,t} = \hat{\eta}_{x,t} + \frac{\nu}{\lambda_B - \nu} \hat{\nu}_{x,t}, \quad x = C, I. \quad (\text{C.59})$$

The leverage equation:

$$\hat{q}_{x,t} + \hat{s}_{x,t} = \hat{\varrho}_{x,t} + \hat{n}_{x,t}. \quad (\text{C.60})$$

The bank's wealth accumulation equation

$$\begin{aligned} \hat{n}_{x,t} = & \theta_B \frac{\varrho_x}{\pi_C} e^{-g_a - \frac{a_c}{1 - a_i} g_v} \left[ R_x^B \pi_C [\hat{R}_{x,t}^B + \hat{\pi}_{C,t}] + \left( \frac{1}{\varrho_x} - 1 \right) R \hat{R}_{t-1} + (R_x^B \pi_C - R) \hat{\varrho}_{x,t-1} \right] \\ & + \frac{\theta_B}{\pi_C} e^{-g_a - \frac{a_c}{1 - a_i} g_v} [(R_x^B \pi_C - R) \varrho_x + R] \left[ -\hat{z}_t - \frac{a_c}{1 - a_i} \hat{\nu}_t + \hat{n}_{x,t-1} - \hat{\pi}_{C,t} \right] \\ & + \left( 1 - \frac{\theta_B}{\pi_C} e^{-g_a - \frac{a_c}{1 - a_i} g_v} [(R_x^B \pi_C - R) \varrho_x + R] \right) [\hat{q}_{x,t} + \hat{s}_{x,t}], \quad x = C, I. \end{aligned} \quad (\text{C.61})$$

The borrow in advance constraint:

$$\hat{k}_{x,t+1} = \hat{s}_{x,t}, \quad x = C, I. \quad (\text{C.62})$$

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

$$\hat{R}_{x,t}^B = \frac{1}{r_x^K + q_x(1 - \delta_x)} [r_x^K (\hat{r}_{x,t}^K + \hat{u}_{x,t}) + q_x(1 - \delta_x) \hat{q}_{x,t}] - \hat{q}_{x,t-1} + \xi_{x,t}^K + \hat{z}_t - \frac{1 - a_c}{1 - a_i} \hat{v}_t. \quad (\text{C.63})$$

Excess (nominal) return:

$$\hat{R}_{x,t}^S = \frac{R_x^B \pi_C}{R_x^B \pi_C - R} (\hat{R}_{x,t+1}^B + \hat{\pi}_{C,t+1}) - \frac{R}{R_x^B \pi_C - R} \hat{R}_t, \quad x = C, I. \quad (\text{C.64})$$

### C.7.7 Monetary policy and market clearing

Monetary policy rule:

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1 - \rho_R) \left[ \phi_\pi \hat{\pi}_{c,t} + \phi_{\Delta Y} (\hat{y}_t - \hat{y}_{t-1}) \right] + \hat{\eta}_{mp,t} \quad (\text{C.65})$$

Resource constraint in the consumption sector:

$$\hat{c}_t + \left( r_C^K \frac{\bar{k}_C}{c} \hat{u}_{C,t} + r_I^K \frac{\bar{k}_I}{c} \hat{u}_{I,t} \right) e^{-\frac{1}{1-a_i} g_v} = \frac{c + F_c}{c} [a_c \hat{k}_{C,t} + (1 - a_c) \hat{L}_{C,t}] \quad (\text{C.66})$$

Resource constraint in the investment sector:

$$\hat{i}_t = \frac{i + F_I}{i} [a_i \hat{k}_{I,t} + (1 - a_i) \hat{L}_{I,t}] \quad (\text{C.67})$$

Definition of GDP:

$$\hat{y}_t = \frac{c}{c + p_i i} \hat{c}_t + \frac{p_i i}{c + p_i i} (\hat{i}_t + \hat{p}_{i,t}) + \hat{e}_t. \quad (\text{C.68})$$

Market clearing:

$$\frac{L_C}{L} \hat{L}_{C,t} + \frac{L_I}{L} \hat{L}_{I,t} = \hat{L}_t, \quad \frac{i_C}{i} \hat{i}_{i,t} + \frac{i_I}{i} \hat{i}_{i,t} = \hat{i}_t. \quad (\text{C.69})$$

### C.7.8 Exogenous processes

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

$$\hat{\lambda}_{p,t}^x = \rho_{\lambda_p^x} \hat{\lambda}_{p,t-1}^x + \varepsilon_{p,t}^x. \quad (\text{C.70})$$

The TFP growth (consumption sector):

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon_t^z. \quad (\text{C.71})$$

The TFP growth (investment sector):

$$\hat{v}_t = \rho_v \hat{v}_{t-1} + \varepsilon_t^v. \quad (\text{C.72})$$

Wage markup:

$$\hat{\lambda}_{w,t} = \rho_w \hat{\lambda}_{w,t-1} + \varepsilon_{w,t}. \quad (\text{C.73})$$

Preference:

$$\hat{b}_t = \rho_b \hat{b}_{t-1} + \varepsilon_t^b. \quad (\text{C.74})$$

Monetary policy:

$$\hat{\eta}_{mp,t} = \varepsilon_t^{mp}. \quad (\text{C.75})$$

GDP measurement error:

$$\hat{e}_t = \rho_e \hat{e}_{t-1} + \varepsilon_t^e. \quad (\text{C.76})$$

Capital quality in sector  $x = C, I$ :

$$\hat{\xi}_{x,t}^K = \rho_{\xi^K, x} \hat{\xi}_{x,t-1}^K + \varepsilon_{x,t}^{\xi^K}. \quad (\text{C.77})$$

The entire log-linear model is summarized by equations (C.39) - (C.49) and (C.53) - (C.69) as well as the shock processes (C.70) - (C.77).

## C.8 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 as follows:

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,

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

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,

$$R_{C,t}^{\Delta,d} \equiv \log R_{C,t}^{\Delta} = \frac{R_x^B \pi_C}{R_x^B \pi_C - R} (\log \hat{R}_{C,t+1}^B + \log \hat{\pi}_{C,t+1}) - \frac{R}{R_x^B \pi_C - R} \log \hat{R}_t,$$

Investment sector corporate spread,

$$R_{I,t}^{\Delta,d} \equiv \log R_{I,t}^{\Delta} = \frac{R_x^B \pi_C}{R_x^B \pi_C - R} (\log \hat{R}_{I,t+1}^B + \log \hat{\pi}_{C,t+1}) - \frac{R}{R_x^B \pi_C - R} \log \hat{R}_t,$$

Real total equity capital growth,

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