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Financial intermediation, consumption dynamics, and business cycles

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ABSTRACT

The recent financial crisis highlighted the need to deepen our understanding of the impact of the financial intermediation sector on the real economy. We examine the quantitative implications of financial intermediation and firm's financing frictions in explaining the observed cyclical properties of both real and financial variables. We find that a modified version of the financial intermediation framework of Gertler and Karadi (2011) augmented with financing frictions in production does a good job in matching the unconditional moments of financial fluctuations without compromising key real co-movements. Our results are relevant for macro-prudential policy analysis as they underscore the importance of carefully identifying the sources of aggregate fluctuations in models in which financial intermediaries and financial frictions play a non-trivial role.

1. Introduction

The Great Recession (2007–2009) made it painfully clear that financial markets have important real effects. In particular, the financial intermediation sector has been identified as a crucial component to understand the recent financial crisis (Woodford, 2010). Furthermore, financial intermediaries and markets constitute an important source of corporate funding in the U.S. A recent study by Ajello (2016) points out that a substantial 35% of corporate sector investment is funded through financial markets. Furthermore, about one third (1/3) of total financial dependence is associated with firms operating expenditures (i.e., working capital needs).

In this study we pose two questions. First, what are the cyclical properties of aggregate variables in the financial sector? And second, to what extent does financial intermediation and financial frictions impinge on real outcomes? To answer the first question we document five empirical linkages of macro and financial variables in the U.S during the period 1984–2010. We examine the second question through the lens of a dynamic stochastic general equilibrium (DSGE) framework that incorporates a financial intermediation sector and firm's financial frictions. The financial intermediation sector draws on the framework proposed by Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). In this framework, disruptions in financial markets can cause large swings in economic activity, and financial frictions can have large effects on how shocks affect the economy. In particular, an external finance premium arises from movements in asset prices that affect the balance sheet of the intermediation sector. Intermediaries are assumed to be constrained in their lending activities, which limits their ability to attract funding from savers. This leads to a premium of external financing over internal financing. As a result, shocks that affect the size of the balance sheet of the intermediation sector impinge on the external finance (risk) premium, which in turn affects the ability of firms to borrow and produce, effectively propagating credit disturbances into the real economy.

The contribution of this study is twofold. First, I document jointly five empirical regularities of macro and financial co-movements. Second, I explain the evidence by developing a basic extension of the financial intermediation framework of Gertler and Karadi (2011). Namely, I assume (1) financing frictions in production and (2) only two sources of fluctuations, productivity and monetary policy shocks. I find that, unlike the baseline financial frictions model, the extended model fits the co-movements of financial variables without compromising the dynamic properties of aggregate consumption.

On the empirical side, this study documents five linkages of financial and real variables that are still little understood, namely, (i) counter-cyclical risk premium, (ii) pro-cyclical debt, (iii) pro-cyclical net worth, (iv) counter-cyclical financial intermediation leverage, and (v) the negative co-movement between labor and average productivity. Facts (i)–(iv) apply to aggregate variables in the U.S. financial sector and have been independently confirmed by Mimir (2015).

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Furthermore, fact (v) is consistent with the findings of Barnichon (2010), Gali and van Rens (2015), and Fernald and Wang (2015). We add to this literature through a joint study of all five empirical regularities.

On the theory side, we examine the quantitative implications of different specifications of the financial intermediation framework of Gertler and Karadi (2011) (henceforth GK). We find that (1) the baseline GK model has key counter-factual implications for the dynamics of consumption and (2) a modified version of the baseline that assumes financing frictions in production has a better quantitative fit in terms of the co-movements of both real and financial variables. Crucially, in the baseline model shocks that affect the level of investment imply counter-factual consumption co-movements.[1] Thus, we simplify the model and eliminate exogenous disturbances to investment. Further, we augment the model assuming a basic financing friction where firms rely on outside finance in order to fund their operating (working capital) expenses. Our theoretical results are twofold. First, they underscore the need to carefully identify sources of fluctuations in models in which financial intermediaries play a non-trivial role. Second, they suggest an important effect of firm's financing frictions on the dynamic properties of both real and financial variables.

1.1. Literature review

This study is related to a strand of the literature that examines the behavior of financial conditions and real outcomes. Bernanke et al. (1999) propose a financial accelerator mechanism in which the cost of external funds (i.e., the external finance premium) is negatively associated with the net worth position of entrepreneurs. Along these lines, Christensen and Dib (2008) estimate the Bernanke et al. (1999) model and find evidence for a financial accelerator mechanism at work in the U.S. economy. Christiano et al. (2014) implement a version of Bernanke et al. (1999) with the addition of a risk shock, defined as time varying volatility of an idiosyncratic productivity shock. Their estimation results ascribe a large fraction the variation in real variables to the risk shock. Merola (2015) estimates a medium-scale DSGE model with financial accelerator and shows that the model does well in explaining the Great Recession. This literature provides consistent evidence on the importance of the financial accelerator for explaining aggregate fluctuations. More closely related with this study, Gertler and Karadi (2011) and Gertler and Kiyotaki (2010), apply the financial accelerator mechanism to develop a financial intermediation framework where fluctuations in financial intermediaries' balance sheets influence the risk premium, investment, and real economic outcomes.

Our study is also closely related to Mimir (2015) who independently confirms the stylized facts of financial variables documented here. In a similar vein, Mimir (2015) uses the GK financial intermediation framework to account for the cyclical properties of financial and real variables. Consistent with this paper, our study finds that the GK framework is relevant to account the fluctuations of financial variables. Importantly, our study adds to the literature by examining the implications of different specifications of the GK framework on the cyclical properties of consumption, as well as the co-movement between labor and average labor productivity.

Last, this study documents a negative co-movement between labor and average labor productivity in the U.S. during 1984–2010, which is consistent with the findings of Barnichon (2010), Gali and van Rens (2015), and Fernald and Wang (2015) who document that strength of the co-movement between average labor productivity and labor has steadily diminished since the post-war period. These studies attribute the observed phenomenon to non-technology shocks, declining power of labor unions, and reduced variation in factor utilization, respectively. I add to this literature by providing an alternative explanation where financial conditions may play an important role in explaining the declining co-movement between labor and average productivity.

The rest of the paper proceeds as follows. Section 2 presents the empirical findings. Section 3 describes the model. Section 4 discusses the model solution and calibration. Section 5 analyzes the model's quantitative properties and dynamic behavior. Section 6 concludes.

2. Empirical regularities

This section documents five features of macro and financial data that received little attention prior to the Great Recession. First, I examine the dynamic behavior of average labor productivity. Second, I document the cyclical properties of four financial variables, namely the corporate bond premium (credit spread), total financial assets, total financial liabilities, and aggregate financial net worth in the U.S. financial sector.

I use NIPA quarterly data from Federal Reserve Bank of St Louis, labor data from the Bureau of Labor Statistics, and aggregate financial data from the Federal Reserve Board Flow-of-Funds Accounts. The data is quarterly, seasonally adjusted, and the period is 1984–2010. Full details on the data are provided in Appendix B.

First, I document the negative co-movement between hours worked and average labor productivity. Fig. 1 shows the co-movement of labor and labor productivity in the US during 1984–2010. The correlation during this period is negative and significant with a coefficient of correlation of −0.56.

Early studies (Christiano and Eichenbaum, 1992; Gali, 1999) argue that demand shocks, not technology shocks, are important to explain the cyclical behavior of labor and average productivity. Recent studies that examine this relationship document that these two variables historically have been mildly positively correlated, but more recently, they are counter-cyclical (Barnichon, 2010; Gali and van Rens, 2015; Fernald and Wang, 2015). This latter empirical observation is known as the labor productivity puzzle, and it is in stark contrast to the positive co-movement between labor and productivity implied by the standard DSGE model in which during expansions both output and labor increase with labor increasing less than output.[2]

Next I document the co-movement of financial variables with output. The premium or credit spread is measured as the difference between Moody's corporate (baa) bond rate and the 10-year Treasury bill rate, which is a widely accepted measure of default risk (Gilchrist and Zakrajsek, 2012). Debt is measured as real, per capita, credit market instrument liabilities of non-financial business. Financial net worth is the difference between total assets and total liabilities of an aggregate of financial institutions (e.g., commercial banks, asset backed securities (ABS) issuers, finance companies, and funding corpora-

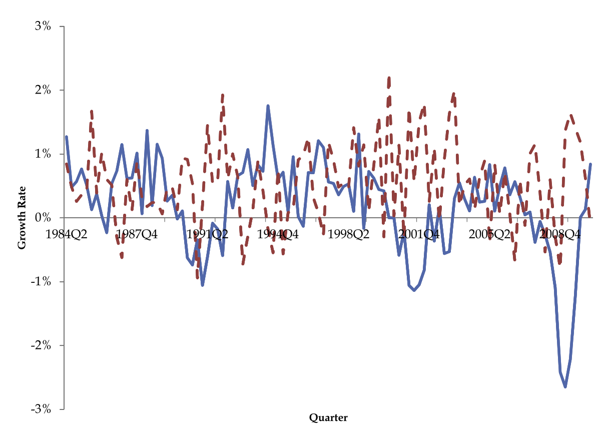

Fig. 1. Hours and labor productivity.

[1] This result is consistent with other studies that document a co-movement problem between consumption and investment in response to investment shocks (Furlanetto and Seneca, 2014; Kamber et al., 2015).

tions).[3] Finally, leverage is calculated as the ratio between debt and financial net worth.

Fig. 2 shows the dynamic behavior of the corporate bond premium (credit spread). The correlation between corporate bond credit spread and output growth is negative and significant with a coefficient of correlation of −0.47. This observation confirms the widely accepted, yet not fully understood, view that expected returns on risky assets vary counter-cyclically over time.

Fig. 3 shows the pro-cyclicality between debt and output. The correlation between these two variables is positive and significant with a coefficient of correlation of 0.42. Fig. 4 shows the co-movement between financial net worth and output growth, which is positive and significant with a coefficient of correlation of 0.42. These two latter findings are consistent with the notion that during good times, there is higher expected profitability for investment opportunities, asset prices increase, which drives up intermediaries net worth and leads to a higher supply of credit. Finally, Fig. 5 shows the co-movement between the change in the leverage ratio and output growth, which is negative and significant with a coefficient of correlation of −0.35. All correlations are significant at the 1% level.

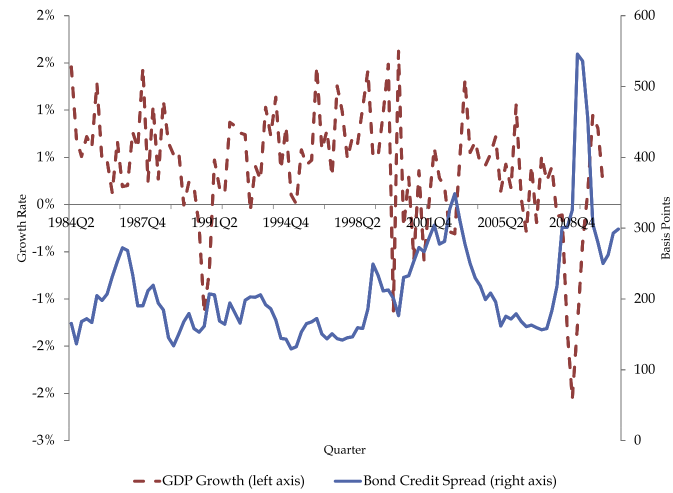

Fig. 2. Corporate bond premium and output.

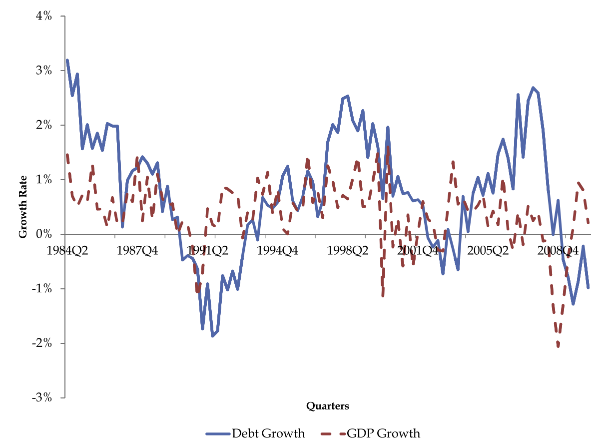

Fig. 3. Debt and output.

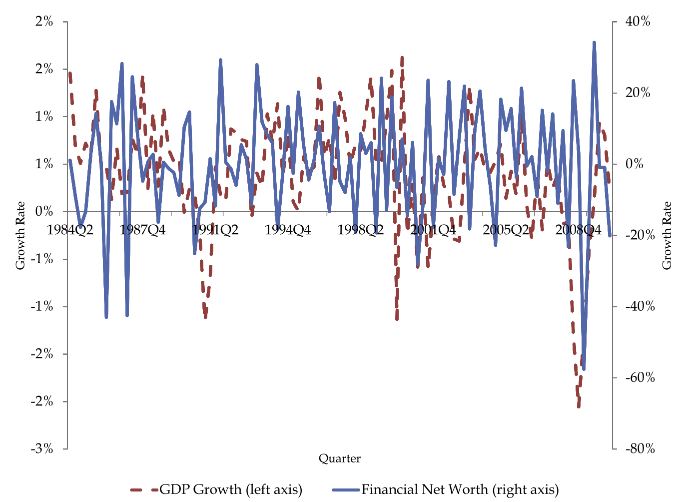

Fig. 4. Financial net worth and output.

3. Model

This section develops a basic extension of the financial intermediation framework posited by Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). The model economy is composed by three types of agents. Namely, entrepreneurs who borrow to fund their projects, households who save, and financial intermediaries that channel funds from households to entrepreneurs. The financial friction in the GK framework is based on a moral hazard problem in financial intermediation, banks may default on their obligations and walk away with a share of intermediated assets. Due to the limited ability to attract funding, banks effectively earn rents on their capital, charging more to borrowers than they pay to savers. In addition, I augment the standard model by assuming that firms also borrow to fund their operating expenses (working capital needs). As in Neumeyer and Perri (2005), firms finance their working capital (WK) bills ahead of the realization of revenues. As a result, the WK friction effectively establishes a link between financial conditions and the firm's demand for labor.

3.1. Financial intermediaries

A continuum of mass one intermediaries raise deposits from households by issuing one-period non-contingent debt D_t that pays a gross interest rate R_t at the end of the period t. Financial intermediaries channel deposits to fund investment in the productive side of the economy by issuing one-period financial claims S_t priced at Q_t. Borrowing firms pay back a gross loan interest rate of R_{kt+1} to intermediaries at the end of the period. The balance sheet of financial intermediary 'j' implies $Q_t S_{jt} - D_{jt} = N_{jt}$, or:

Assets	**Liabilities**
$Q_t S_{jt}$	D_{jt}
	Net Worth
	N_{jt}

The participation constraint for the intermediary is given by:

$$E_t[m_{t+1}(R_{kt+1} - R_{t+1})] \geq 0, \quad \forall \;\; t \geq 0,$$

where m_{t+1} is the stochastic discount factor, and $(R_{kt+1} - R_{t+1})$ is the risk premium (credit spread). The law of motion of intermediary 'j' net worth is given by:

$$N_{jt+1} = R_{kt+1} Q_t S_{jt} - R_{t+1} D_{jt+1}. \tag{1}$$

Each period a fraction θ of intermediaries survives and a fraction $1 - \theta$ exits the market. Intermediary 'j' problem consists in maximizing its expected future wealth:

[2] The prediction of a positive co-movement between average productivity and labor is also consistent with the labor hoarding hypothesis.

[3] Adrian and Shin (2010) provide evidence that market-based financial institutions of this type have become, along with commercial banks, the most dominant sources of financing over the last three decades.

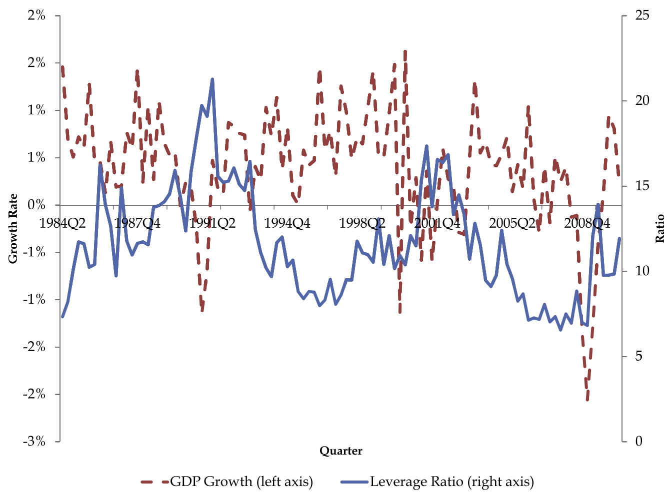

Fig. 5. Financial leverage and output.

$$V_{jt} = \max E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i m_{t+1+i} N_{jt+1+i} = \max E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i m_{t+1+i}[(R_{kt+1+i} - R_{t+1+i})Q_{t+i}S_{jt+i} + R_{t+1+i}N_{jt+i}]. \quad (2)$$

As in Gertler and Karadi (2011), the solution for the 'j-th' intermediary's problem is of the form:

$$V_{jt} = \upsilon_t Q_t S_{jt} + \eta_t N_{jt}, \quad (3)$$

with

$$\upsilon_t = E_t\left[(1-\theta)m_{t+1}(R_{kt+1} - R_{t+1}) + \theta m_{t+1}\frac{Q_{t+1}S_{jt+1}}{Q_t S_{jt}}\upsilon_{t+1}\right],$$
$$\eta_t = E_t\left[(1-\theta) + \theta m_{t+1}\frac{N_{jt+1}}{N_{jt}}\eta_{t+1}\right], \quad (4)$$

where υ_t is the marginal gain of an additional unit of intermediated assets $Q_t S_{jt}$ and η_t is the marginal gain of an additional unit of net worth N_{jt}.

In addition, there is an agency problem where the banker can divert a fraction λ of equity to his/her household. Hence, the incentive constraint of the intermediary is:

$$\eta_t N_{jt} + \upsilon_t Q_t S_{jt} \geq \lambda Q_t S_{jt}, \quad (5)$$

when the incentive constraint binds equity capital is determined by:

$$Q_t S_{jt} = \frac{\eta_t}{\lambda - \upsilon_t} N_{jt} = \phi_t N_{jt}, \quad (6)$$

where ϕ_t represents the (intermediary) leverage ratio. The constraint binds when $\lambda > \upsilon_t > 0$; an increase in υ_t tightens the constraint.

We can use this result and substitute it on the law of motion of net worth to obtain:

$$N_{jt+1} = [(R_{kt+1} - R_{t+1})\phi_t + R_{t+1}]\cdot N_{jt}. \quad (7)$$

It is straightforward to show that the components of the leverage ratio ϕ_t do not depend on intermediary specific factors. Thus we can aggregate wealth over all intermediaries to obtain:

$$Q_t S_t = \phi_t N_t. \quad (8)$$

The relationship above indicates that movements in intermediaries net worth and the leverage ratio are negatively associated with each other and positively associated with aggregate asset demand.

In order to derive the equation for the evolution of aggregate net worth, note that N_t is the net worth of both existing intermediaries N_{et}, and new entrants N_{nt}, so that $N_t = N_{et} + N_{nt}$. Recalling that a fraction θ of intermediaries survives each period, then N_{et} is determined as follows:

$$N_{et} = \theta[(R_{kt} - R_t)\phi_{t-1} + R_t]\cdot N_{t-1}. \quad (9)$$

To calculate N_{nt} for entering bankers we assume that households give a fraction of 'seed' funds to start up the business of new bankers. This 'seed' funding is set as a fraction $\nu/(1-\theta)$ of last period exiting bankers assets $(1-\theta)Q_t S_{t-1}$, thus:

$$N_{nt} = \nu Q_t S_{t-1}. \quad (10)$$

We can now substitute the equations above to derive the expression for the law of motion of aggregate net worth as:

$$N_t = \theta[(R_{kt} - R_t)\phi_{t-1} + R_t]\cdot N_{t-1} + \nu Q_t S_{t-1}. \quad (11)$$

The parameter ν is used to pin down the steady state leverage ratio QS/N.

3.2. Intermediate goods firms

A continuous of competitive firms of mass 1 produces intermediate goods using technology $Y_t = e^{z_t}(U_t\xi_t K_t)^\alpha L_t^{1-\alpha}$ by choosing capital K_t, labor L_t and the utilization rate of capital U_t. The shocks z_t and ξ_t represent exogenous variation to total factor productivity and the quality of capital (Merton, 1973), respectively. The shocks are modeled as AR(1) processes, namely $z_t = \rho_z z_{t-1} + \epsilon_t^z$ and $\xi_t = \rho_\xi \xi_{t-1} + \epsilon_t^\xi$; where $\{\epsilon_t^z, \epsilon_t^\xi\}$ are orthogonal innovations distributed $N \sim (0, \sigma_i^2)$ with $i = \{z, \xi\}$.

Firms issue S_t equity claims equal to the number of units of their capital K_{t+1}. Firms price each claim of capital at price Q_t. Therefore, by arbitrage:

$$Q_t S_t = Q_t K_{t+1}. \quad (12)$$

At the end of each period the firm sells its depreciated capital to capital producer firms at a unit price.

Further, the firm is subject to a working capital friction as in Neumeyer and Perri (2005), which works as follows. At the beginning of each period, the firm finances a fraction χ of its wage bill by borrowing from an outside credit union at the going loan rate $R_t^K = R_{kt}$.[4] Firms use the working capital loan to make payments to workers at the beginning of the period but before the realization of revenues. The loan is repaid at the end of the period upon realization of revenues.

The firm's problem is formulated as the maximization of expected profits subject to production technology:

$$\max_{L_{t+1},U_{t+1},K_{t+1}} E_t\{m_{t+1}[P_{m,t+1}F(\Lambda_t, K_{t+1}, L_{t+1}, U_{t+1}) + (Q_{t+1} - \delta(U_{t+1}))\xi_{t+1}K_{t+1} - W_{t+1}L_{t+1} - R_{kt+1}Q_t K_{t+1} - (R_{t+1}^K - 1)\chi W_{t+1}L_{t+1}]\} \quad (13)$$

where $\Lambda_t = \{z_t, \xi_t\}$ is the exogenous state vector of innovations and P_{mt} is the price of intermediate output.

The optimality condition for the firm's demand for labor is:

$$P_{m,t+1}F_{L_{t+1}}(\Lambda_t, K_{t+1}, L_{t+1}, U_{t+1}) = W_{t+1}(1 + \chi(R_{t+1}^K - 1)), \quad (14)$$

where W_{t+1} is the nominal wage, R_{t+1}^K is the working capital loan interest rate, and χ captures the strength of the working capital friction. Eq. (14) shows that, *ceteris paribus*, factors that increase the loan rate R_t^K lead to higher wage bill costs, which reduces the firm's demand for labor.

The other optimality conditions associated with the firm's problem are derived in Appendix A.

[4] More generally, the working capital loan need not be at the same rate as the return on capital. However, to keep the model as close as possible to the baseline, I assume that the rate at which firms obtain their working capital loan is the same as R_{kt}. As the working capital loan is not internalized by financial intermediaries, this additional feature turns the model into partial equilibrium.

3.3. Capital producers

Capital producers buy used capital from intermediate good firms at the end of period t. The cost to capital producers of buying depreciated capital is normalized to Q=1. Capital producers build new capital and refurbish old capital to sell it to intermediate goods firms at price Q_t per unit at the beginning of next period. Households own the capital producers and receive any profits from their operation.

Let $I_{nt} \equiv I_t - \delta(U_t)\xi_t K_t$ denote net capital investment, I_t gross capital investment, and ξ_t is a shock to the quality of capital.[5]

Capital producers maximize net investment flow I_{nt} subject to adjustment costs of investment. The maximization problem of the capital producer is given by:

$$\max_{I_{nt}} E_t \sum_{t=0}^{\infty} m_t \left\{ (Q_t - 1)I_{nt} - S\left(\frac{I_{nt} + Iss}{I_{nt-1} + Iss}\right)(I_{nt} + Iss) \right\}. \quad (15)$$

As in Christiano et al. (2005), the adjustment cost function $S(\cdot)$ has the following properties: $S(1) = 0$, $S'(1) = 0$, and $S''(1) > 0$.[6] Similarly, the standard restrictions on the utilization cost function apply: (i) $\overline{U} = 1$ in steady state; (ii) $\delta(1) = \overline{\delta}$ captures full depreciation in steady state; and (iii) $\delta''(1)/\delta'(1) = \psi$, where ψ represents the elasticity of marginal depreciation with respect to utilization.

The optimal solution to the capital producer problem yields the price of capital or Tobin's-Q relation:

$$Q_t = 1 + S_t(\cdot) + \frac{I_{nt} + Iss}{I_{nt-1} + Iss} S'(\cdot) - E_t\left[m_{t+1} \left(\frac{I_{nt} + Iss}{I_{nt-1} + Iss} \right)^2 S'(\cdot) \right]. \quad (16)$$

3.4. Final goods firms

Nominal rigidities are introduced in the model in the form of sticky prices following Bernanke et al. (1999). Final good producers are represented by monopolistically competitive firms within a continuum of agents a of mass 1. They buy intermediate goods from entrepreneurs and differentiate these goods at no cost into $Y_t(a)$ to finally sell them at a price $P_t(a)$. Final output Y_t is produced with CES technology:

$$Y_t = \left(\int_0^1 Y_t(a) da \right)^{\epsilon/(\epsilon-1)}, \quad \epsilon > 1,$$

and the associated price index is given by $P_t = \left(\int_0^1 P_t(a)^{1-\epsilon} da \right)^{1/(1-\epsilon)}$. Hence, each final good producer faces the demand curve $Y_t(a) = (P_t(a)/P_t)^{-\epsilon} Y_t$. Prices are sticky in the style of Calvo and are changed every period with probability $1 - \gamma$ so the optimal $P_t(a)$ solves:

$$\sum_{j=0}^{\infty} \gamma^j E_t \left[m_{t+j} \left(\frac{P_t^*(a)}{P_{t+j}} - \frac{X}{X_{t+j}} \right) Y_{t+j}^*(a) \right] = 0, \quad (17)$$

where X_t is the markup, which in steady state equals $X = \epsilon/(\epsilon - 1)$. This condition states that P_t^* equates expected discounted marginal revenue to expected discounted marginal cost. Final producers profits $\Pi_t = (1 - 1/X_t)Y_t$ are finally rebated to the household. As a fraction γ of prices remains unchanged, the aggregate price level evolution is:

$$P_t = [\gamma P_{t-1}^{1-\epsilon} + (1 - \gamma)(P_t^*)^{1-\epsilon}]^{1/(1-\epsilon)}. \quad (18)$$

Combining (17) and (18) plus linearizing yields the forward-looking Phillips curve, which establishes that inflation depends positively on expected inflation and negatively on the markup X_t of final over intermediate goods.

3.5. Households

A continuum of households maximizes expected future utility $\sum_{t=0}^{\infty} \beta^t E_t U(C_t, L_t)$ where C_t is consumption, L_t is labor supply, and β is the discount factor. Households are the owners and shareholders of firms in the economy and also own claims to deposits D_t in financial intermediaries. The household problem is given by:

$$\max_{C_t, L_t} \sum_{t=0}^{\infty} \beta^t \left[\ln(C_t - hC_{t-1}) - \frac{\iota}{1 + \vartheta} L_t^{1+\vartheta} \right] \quad (19)$$

$$\text{s. t.} C_t = W_t L_t + \Pi_t + R_t D_t - D_{t+1}, \quad (20)$$

where h denotes the habit parameter in consumption, $\vartheta$is the inverse Frisch elasticity of labor supply, and ι is the relative utility weight of labor, with $\{\iota, \vartheta\} > 0$.

Eq. (20) represents the households budget constraint where W_t and R_t are the wage and gross interest rate respectively, D_t are one-period deposits at financial intermediaries, and Π_t denotes the net profits received from owning financial and non-financial firms in the economy (net of costs and transfers).

The optimality conditions of the household are given by:

$$W_t \cdot U_{C_t}(C_t, L_t) + U_{L_t}(C_t, L_t) = 0, \quad (21)$$

and

$$E_t[m_{t+1} R_{t+1}] = 1, \quad (22)$$

where m_{t+1} denotes the household's stochastic discount factor which is given by:

$$m_{t+1} \equiv \beta \frac{U_{C_{t+1}}(C_{t+1}, L_{t+1})}{U_{C_t}(C_t, L_t)}. \quad (23)$$

3.6. Monetary policy

The monetary authority uses a conventional Taylor-type interest rate rule of the form:

$$R_t = (R_{t-1})^{r_R} \{ (\pi_{t-1}/\pi)^{r_\pi} (Y_{t-1}/\overline{Y})^{r_Y} \overline{R} \}^{1-r_R} \cdot \epsilon_t^r, \quad (24)$$

where $\overline{Y}$ and $\overline{R}$ are steady-state output and gross real interest rate respectively, r_π and r_y are the monetary rule parameters, and r_R is the interest rate persistence parameter. The monetary policy rule above responds automatically to past inflation and past output. The term ${\epsilon_t}^r$ is a white noise innovation to monetary policy distributed $N(0, \sigma_r^2)$.

4. Calibration

This section discusses the calibration and the implied steady state. The model is then solved with standard perturbation methods applied to the first order approximation of the model around its non-stochastic steady state.

Our calibration strategy is disciplined by the data, whereas for model parameters without an observable data counterpart we draw on the values suggested by Gertler and Karadi (2011).[7] I calibrate the baseline model parameters to US data during 1984–2010. A period in

[5] The shock ξ_t acts as an 'investment' shock in the sense of the investment efficiency shock posited by Justiniano et al. (2010), namely it serves as a source of exogenous variation in the price of capital. Strictly speaking the efficiency of investment shock of Justiniano et al. (2010) affects directly investment (a flow variable) while the shock ξ_t here affects capital (a stock variable); nevertheless both shocks entail a first order effect in the dynamics of the price of capital.

[6] In the (quadratic) adjustment cost function, I_{ss} is the steady state level of net investment I_{nt}, and ψ_k is an adjustment costs constant (not shown).

[7] Notice that in Gertler and Karadi (2011) several key parameters are calibrated to be suggestive for their specific 'crisis scenario'. Instead, the calibration in this study is disciplined by key model analogs in the data. As a result, the model's calibrated parameters differ somewhat from Gertler and Karadi (2011). Despite this difference, the qualitative implications of the baseline model are similar to those of Gertler and Karadi (2011).

the model is equivalent to one quarter. Table C1 in Appendix C provides a summary of the calibrated structural parameters. First, I draw a set of parameter values from Gertler and Karadi (2011). Namely, the habit parameter is h=0.815, the rate of depreciation is $\delta = 0.025$, the capital share is $\alpha = 0.33$, the elasticity of substitution of final goods is $\epsilon = 4.167$, the price stickiness parameter is $\gamma = 0.779$, and the inverse Frisch elasticity of labor supply is $\vartheta = 0.276$. Given this latter parameter, I set the relative utility weight of labor $\iota = 5.8$ to obtain a steady state share of hours worked of 0.3. The discount factor in the model is $\beta = 0.994$, which corresponds to an annual (nominal) interest rate of 4.9%; and the elasticity of marginal depreciation with respect to capital utilization is $\psi = 0.4454$, which corresponds to an annual (nominal) return on assets of 7.1%. The capital adjustment cost parameter in the investment function is set to $\psi_k = 1.21$ to match the relative volatility between net worth and income at 14.77.

Next, I calibrate the financial intermediary parameters as follows. The fraction of diverted capital $\lambda = 0.326$, the 'seed' transfer parameter to entering bankers $\nu = 0.001$, and the survival probability of bankers $\theta = 0.924$. These parameters are set to match two key steady state targets in the data, namely: (i) an average leverage ratio of 11.6 over the sample and (ii) average quarterly external finance premium of 1.0051 over the sample.[8,9] Last, in the versions of the model with firm's financing (working capital) friction, we switch the working capital strength coefficient from $\chi = 0$ to $\chi = 1$ following Neumeyer and Perri (2005).

The technology auto-regressive process persistence parameter is set to $\rho_z = 0.95$, consistent with the estimate of Jermann and Quadrini (2012). The persistence parameter of the capital quality shock process is set $\rho_\xi = 0.66$ as in Gertler and Karadi (2011). Further, to guide the calibration of variances of shocks I draw on (Jermann and Quadrini, 2012) and set the variance of the capital quality shock to be twice the variance of productivity $\sigma_\xi = 2\sigma_z$.[10] Next, we set the standard deviation of the productivity process to $\sigma_z = 0.0011$ to match output volatility of $\sigma_y = 1.06$ as in the data. Similarly, we set the volatility of the monetary shock to $\sigma_r = 0.0002$ to account for an effect of monetary policy of about 2% output volatility. Finally, the coefficients of the monetary policy rule are set to the values estimated by Jermann and Quadrini (2012) for US during 1984–2010. The values are summarized in Table C2 in Appendix C.

4.1. Steady state

Table 1 shows the key non-stochastic steady state ratios implied by the calibrated model *vis-a-vis* the data. The consumption-to-GDP ratio is 0.70 close to the data, the debt-to-GDP ratio is 3.00 somewhat higher than the data with a value of 2.54, the leverage ratio is 11.6 consistent with the sample average in the data, the annualized external finance premium is 2.06% consistent with the sample average of corporate bond credit spread in the data, and the annualized nominal interest rate is 4.9% close to the data.

Table 1
Steady state of the benchmark model *vis-a-vis* data (1984–2010).

Description		Model	Data
Consumption-to_GDP ratio	C/Y	0.699	0.680
Debt-to-GDP ratio	B/Y	3.004	2.535
Leverage ratio	QS/N	11.608	11.582
External finance premium	efp	1.005	1.005
Nominal interest rate (% p.a.)	R^{nom}	4.920	4.868

5. Quantitative analysis

This section examines the quantitative fit of several model specifications *vis-a-vis* the data. First, the models are compared in terms of unconditional macro and financial moments at business cycle frequencies. Next, we discuss the key transmission mechanisms of the extended model. Last, we discuss the impulse responses of the baseline GK model, and the extended model with firm's financing (working capital) friction conditional on different types of shocks.

5.1. Results

Tables 2A and 2B summarize relative volatilities and cross correlations of several model specifications *vis-a-vis* the data. Namely, the baseline model a la (Gertler and Karadi, 2011) (BS1); the baseline model with working capital ($\chi = 1$) friction (BS1a); the baseline model without capital quality shocks (BS2); the BS2 model without habit in consumption (BS3); and last, the benchmark (BM) model, namely the BS3 specification with working capital ($\chi = 1$). The statistics are calculated based on the cyclical component of the HP-filtered data at quarterly frequency with smoothing parameter 1600.

The unconditional matching moments exercise underscores several key results. First, both the baseline (BS) specifications and the benchmark (BM) model are broadly consistent with the documented co-movements of financial variables with output. Namely, (i) pro-cyclical debt; (ii) counter-cyclical credit spread; (iii) counter-cyclical leverage; and (iv) pro-cyclical net worth. Second, relative to the baseline specifications, the BM model has a closer fit with the cyclical properties of *both* macro and financial variables. Third, and crucially, the baseline specifications (BS1 and BS1a) with capital quality shocks, have two striking counter-factual predictions for the dynamics of consumption. Namely, counter-cyclical consumption and a negative co-movement between consumption and investment. In contrast, specifications BS2, BS3 and BM without the capital quality shock, imply positive consumption co-movements consistent with the data. Fourth, the BM specification with working capital implies strong pro-cyclical consumption at 0.72 closer to the data at 0.87, and a strong co-movement between investment and consumption with correlation 0.61 closer to the data at 0.69. Fifth, despite the fact that all specifications underestimate consumption volatility relative to income volatility, the firm's financing (working capital) friction increases the variability of consumption. For instance, the BS1a specification predicts 25% higher relative consumption volatility *vis-a-vis* specification BS1.

Last, I examine the implications for key labor productivity co-movements. Table 2B shows that the baseline (BS1) model predicts (i) negative co-movement between labor and labor productivity with a correlation of −0.40 closer to the data at −0.56 and (ii) a very strong positive co-movement between labor productivity and the real wage at 0.91 (counter-factual). Next, the addition of the firm's financing friction in model BS1a shows a mixed result, namely (i) it cancels out the negative co-movement between labor and productivity at 0.00 (counter-factual), while (ii) it breaks the tight link between labor productivity and the real wage (factual). Eliminating the capital quality shock in models BS2 and BS3 essentially result in a strong co-movement between labor and productivity (counter-factual). Finally, the benchmark (BM) model has a somewhat better fit than the BS2 and BS3 specifications as it predicts (i) low but positive co-movement between labor and productivity with a correlation of 0.34, while (ii) it weakens the tight link between productivity and the real wage with a correlation of 0.58 closer to the data at 0.52.

Overall, the unconditional matching moments exercise highlights

[8] The parameters $\{\lambda, \nu, \theta\}$ need to be calibrated simultaneously for two targets in order to have enough range of values as required by the steady state ratios in the data. The calibrated values are somewhat smaller than those in Gertler and Karadi (2011) who assume a leverage ratio of 4.

[9] The model-analog of the measured 'credit spread' is the 'external finance premium'. In this study, both terms are used interchangeably.

[10] The implications of the capital quality shock are robust to different values of its variance.

Table 2A
US moments of macro and financial variables (1984–2010).

Series	σ_i/σ_y						$\rho_{i,y}$					
	Data	BS1	BS1a	BS2	BS3	BM	Data	BS1	BS1a	BS2	BS3	BM
Cons.	0.83	0.16	0.20	0.16	0.24	0.26	0.87	−0.47	−0.35	0.35	0.47	0.72
Invt.	5.34	4.65	4.65	4.22	4.07	3.80	0.90	0.99	0.99	0.99	0.98	0.99
Hours	1.61	1.07	0.93	0.68	0.69	0.67	0.85	0.98	0.93	0.93	0.93	0.86
Spread	0.12	0.43	0.38	0.30	0.30	0.22	−0.47	−0.88	−0.93	−0.58	−0.55	−0.52
Debt	2.44	1.01	1.12	0.47	0.48	0.37	0.42	0.74	0.68	0.65	0.63	0.67
NW	14.75	14.77	12.82	9.85	9.68	6.97	0.42	0.88	0.92	0.52	0.50	0.45
Lev.	14.73	13.72	11.77	9.36	9.18	6.65	−0.35	−0.88	−0.92	−0.51	−0.48	−0.43

Table 2B
Key co-movements of labor market variables (1984–2010).

Moment	Data	BS1	BS1a	BS2	BS3	BM
$\rho_{CONS,INVT}$	0.69	−0.56	−0.47	0.23	0.30	0.61
$\rho_{LPROD,WAGE}$	0.52	0.91	0.42	0.77	0.75	0.58
$\rho_{LPROD,HOURS}$	−0.56	−0.40	0.00	0.56	0.57	0.34

two key results. First, the capital quality shock has counter-factual predictions for consumption co-movements. Second, the firm's financing friction (i) improves consumption dynamics, (ii) breaks the tight link between productivity and the real wage, and (iii) reduces the strength of the co-movement between productivity and labor.

5.2. Model analysis

This section analyzes the dynamic behavior implied by the benchmark model by examining the two key transmission mechanisms that drive the dynamics of real and financial variables.

- Endogenous leverage:

A key equilibrium condition of the financial intermediary is the relation that determines the leverage ratio:

$$\phi_t = \frac{Q_t K_{t+1}}{N_t}.$$

The equation indicates that leverage co-moves positively with total assets and negatively with net worth.

Next, is the endogenous balance sheet relationship between net worth, credit spreads, and leverage given by the law of motion of net worth:

$$N_t = \theta[(R_{kt} - R_t)\phi_{t-1} + R_t]N_{t-1} + \nu Q_t S_{t-1}.$$

This difference equation indicates that net worth is positively associated with the interaction of the credit spread and leverage.

Last, is the expected return on capital, which is determined by the profitability of current capital and the capital gain or loss associated with the change in asset prices:

$$E_t R_{kt+1} \equiv E_t \frac{P_{mt+1} F_K(\Lambda_{t+1}, U_{t+1}, K_{t+1}, L_{t+1}) + \xi_{t+1}[Q_{t+1} - \delta(U_{t+1})]}{Q_t}$$

In particular, in expansions investment is profitable, asset prices increase and the return on capital is higher. Similarly, positive shocks to the quality of capital increase the return on capital.

The transmission mechanism of the intermediation channel works as follows. Asset demand and asset prices increase during expansions, which improves intermediaries balance sheets. The increase in intermediaries net worth, which is associated with a fall in the leverage ratio, is followed by an increase in credit supply and a drop in credit spread. As a result, cheaper credit drives the increase in aggregate debt, which leads to more investment, output and consumption.

- Working capital friction:

The intermediate goods firm finances its wage bill in advance of production borrowing from a credit union at the going loan rate R_t^K. At the end of the period, and upon realization of profits the firm repays its loan. As a result, fluctuations in financial conditions captured by the dynamic behavior of the loan rate R_t^K bear directly upon the firm's demand for labor. *Ceteris paribus*, a higher loan rate reduces labor demand. This relationship is captured by the optimality condition:

$$P_{mt} \cdot F_L(\Lambda_t, U_t, K_t, L_t) = W_t(1 + (\chi R_t^K - 1)),$$

where $\chi \in (0,1)$ denotes the extent to which the firm relies on outside finance.

The working capital friction works as follows. During a contraction the cost of borrowing and the risk premium increase. The concomitant drop in investment and employment lead output and consumption to fall. On the financial side, the reduction in borrowing by firms results in a reduction in intermediation profits, which reduces net worth and increases leverage. As a result, the working capital friction impinges on the response of both real and financial variables.

5.3. Impulse response functions

Figs. 6–8 summarize the dynamic responses of both the BS1 (dashed line) and BM (solid line) specifications conditional on a negative one standard deviation shock to: capital quality, productivity (TFP), and monetary policy (MP), respectively.

- Negative capital quality shock:

A one standard deviation drop in the quality of capital is associated with a large drop in investment and asset prices, and an increase in the risk premium which lead to a decline in output and labor, and a persistent drop in consumption. The policy rule leads to a persistent decline of nominal interest rates for about 10 quarters. The responses of the BS1 specification are broadly in line with Gertler and Karadi (2011). Furthermore, as the firm increases the capital utilization margin in response to this (demand) shock, average labor productivity increases on impact and then persistently falls as the economy recovers. Last, the responses of the model with WK financing friction are similar to the BS1 specification except in two key aspects. The main effect of WK is on labor productivity which declines sharply on impact due to the large increase in the risk premium. Similarly, due to higher borrowing costs the response of labor demand and investment is less volatile which tends to have a minor dampening effect on other macro and financial variables relative to the BS1 specification.

What about the business cycle implications for consumption? Notice that the *conditional* dynamics appear consistent with pro-cyclical consumption (on impact). However, as shown in Table 2A,

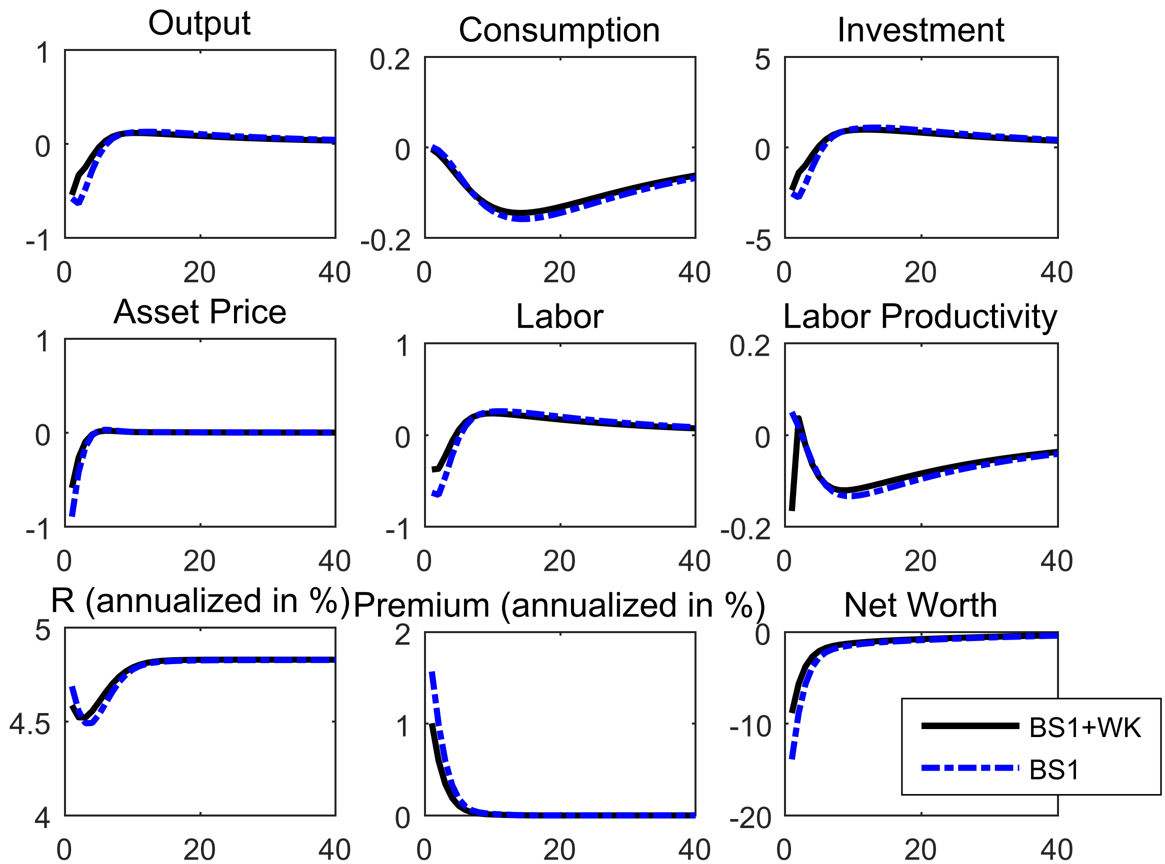

Fig. 6. Dynamic responses to a capital quality shock.

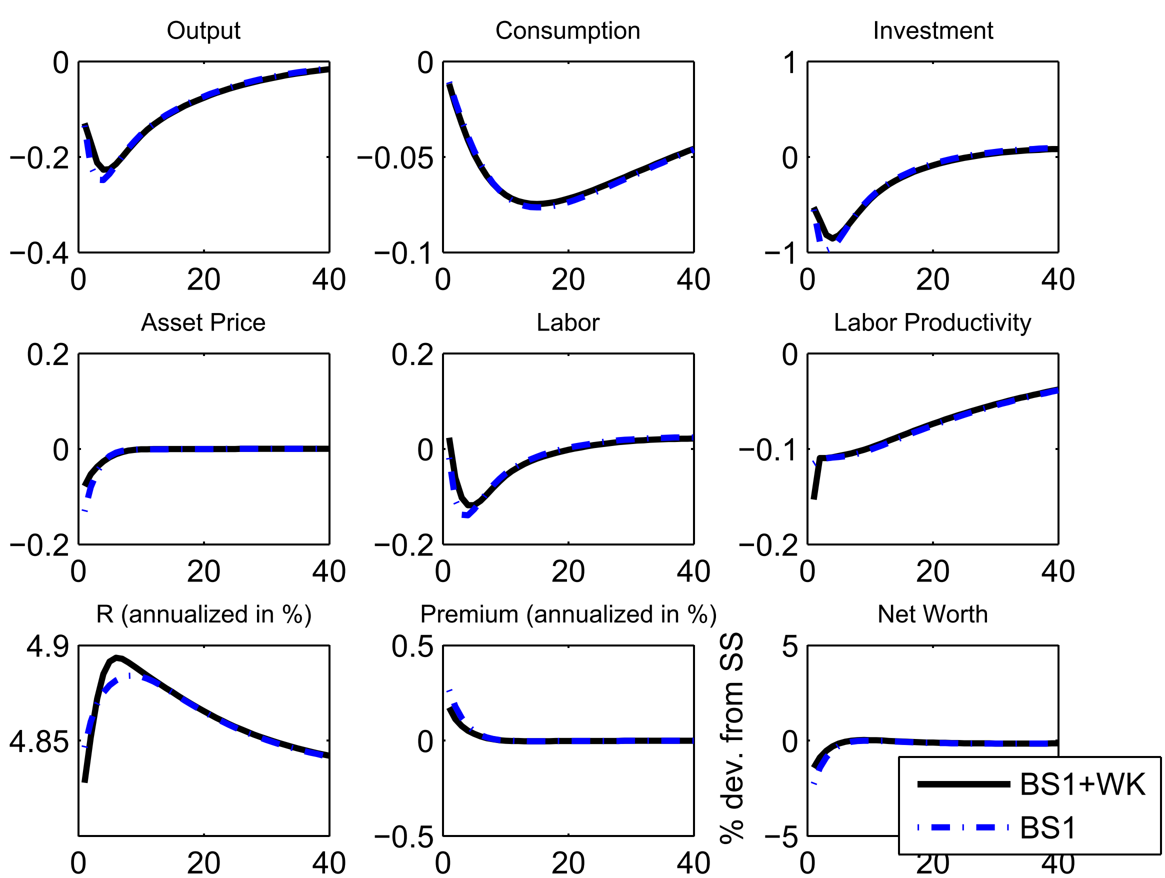

Fig. 7. Dynamic responses to a TFP shock.

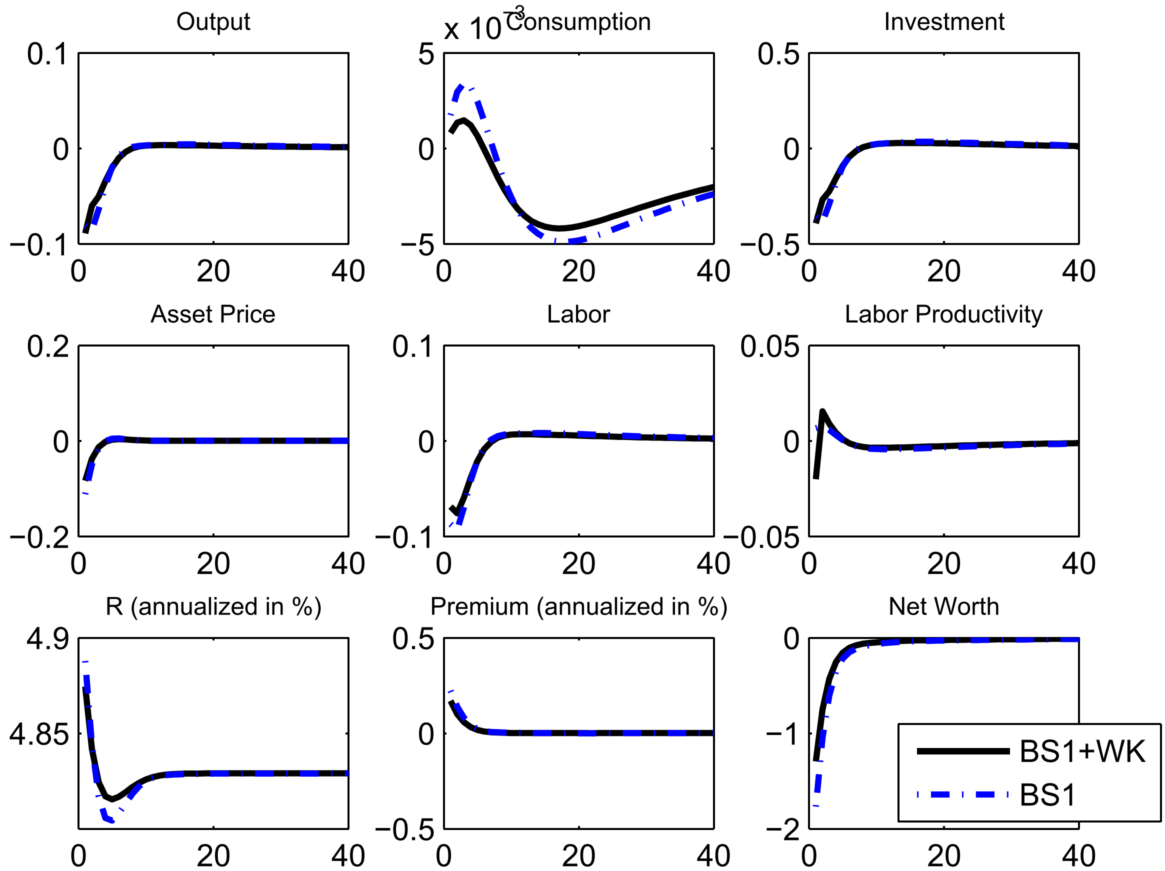

Fig. 8. Dynamic responses to a MP shock.

the *unconditional* moments indicate it otherwise. To better understand the dynamics of consumption under this shock notice that the aggregate resource constraint is

$$1 = \frac{C_t}{Y_t} + \frac{I_t}{Y_t} + \frac{S(I_t)}{Y_t},$$

where Y_t is GDP, C_t is aggregate consumption, I_t is aggregate investment, and $S(I_t)$ captures convex investment adjustment costs.

From the IRFs we can see that the implied elasticity of investment to a capital quality shock is much larger than that of output and consumption. Further, due to consumption smoothing and consumption habit, the response of consumption is much more persistent than that of investment. Therefore, for the constraint above to hold at every period it must be the case that the investment-to-GDP ratio has to overshoot in the recovery phase of the cycle (as observed in the IRF). As a result, the capital quality shock is associated with an unconditional negative co-movement between consumption and investment.

- Negative productivity shock:

A negative one standard deviation drop in TFP causes a fall in output, investment, labor and consumption. As in the standard DSGE model, labor productivity decreases (albeit persistently) during the recession. On the financial side, the drop in investment causes asset prices to drop, pushing down intermediaries net worth. The external finance premium increases consistent with the worsening of financial conditions. In contrast to the capital quality shock, financial variables do not react so sharply and the policy rule briefly reduces nominal interest rates for only one quarter. The results of the BS1 specification are consistent with those of Gertler and Karadi (2011). Last, the main effect of adding the WK friction is a sharper decline of labor productivity on impact, while there is a minor dampening effect on other macro and financial variables.

- Monetary policy shock:

Fig. 8 shows the response conditional on a monetary tightening (demand) shock. The IRFs show that most macro and financial variables move in a similar direction as with a negative TFP shock albeit with a lower magnitude. An important exception is the response of labor productivity, which in the BS1 specification increases and becomes counter-cyclical on impact. This stark response is due to the nature of the MP shock, which essentially operates as an aggregate demand shock. As the policy interest rate increases, net worth of financial intermediaries falls since their profitability depends on the spread gained by supplying credit. The reduction in credit leads to a higher risk premium which reduces investment, output and consumption. The concomitant effect on financial variables is to further depress asset prices and net worth. As a result, firms hire less than they would otherwise (for a given level of TFP) and labor productivity increases on impact. On the other hand, and similar to the previous shocks, the effect of the WK friction leads to a minor dampening in the response of macro and financial variables. In contrast to the BS1 specification, WK leads to a temporary drop in labor productivity on impact due to the increase in the risk premium.

5.4. *Sensitivity to financing friction*

A key assumption in the benchmark (BM) model is the firm's financing (working capital, WK) friction. To what extent is the firm's financing friction important for understanding the cyclical properties of consumption and labor productivity? To answer this question I isolate and quantify the effect of the firm's financing friction in terms of the unconditional moments.[11]

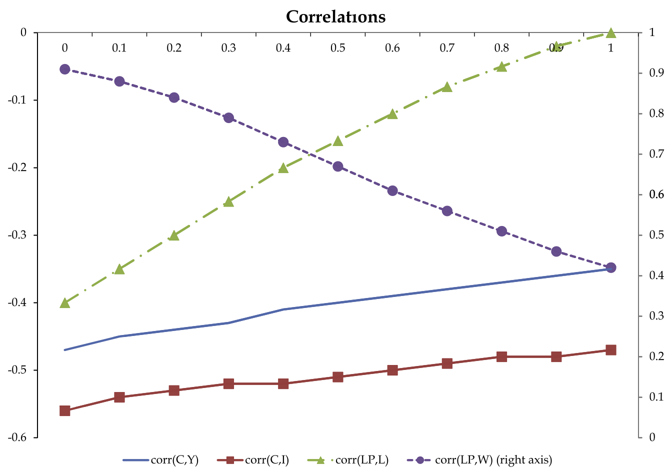

Fig. 9. Sensitivity of real co-movements to firm's financing friction (*BS*1).

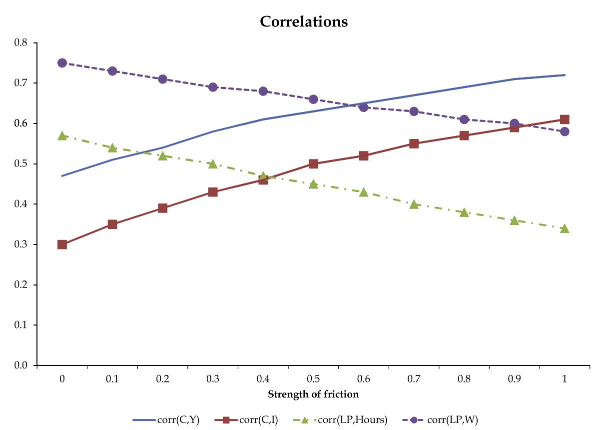

Fig. 10. Sensitivity of real co-movements to firm's financing friction (*BM*).

First, consider the constrained firm's optimality condition for labor demand:

$$\omega_t = \frac{F_L(\cdot)}{1 + (\chi R_t^K - 1)},$$

where ω_t is the real wage, $F_L(\cdot)$ is the marginal product of labor, and $\chi \in (0, 1)$ is the strength of the WK friction.

From the expression above it is straightforward to note that the WK friction introduces a wedge between the marginal product of labor (MPL) and the real wage. In particular, the wedge is largest when $\chi = 1$, and this wedge is determined by fluctuations in $R_t{}^K$. In the same vein, Fig. 9 shows in the *BS*1*a* specification (with capital quality shocks) that as the strength of the friction increases, the tight link between the real wage and the labor productivity is sharply diminished. For a similar reason, the (negative) link between labor productivity and labor is weakened (in absolute terms). Furthermore, as constrained firms adjust labor demand in response to financial fluctuations ($R_t{}^K$), the concomitant effect on investment and output makes the co-movements between investment-and-consumption, and output-and-consumption less counter-cyclical.

Next, Fig. 10 shows the effect of the WK friction in the *BM* model, in which there are no capital quality shocks. Several points are noteworthy. First is the sign change to positive consumption co-movements (consistent with the data), as well as a positive productivity-hours co-movement (counter-factual). The former moments suggest that as firm's financing frictions become stronger, so does the impact of constrained investment on output and consumption. Whereas the latter moment is more in line with the prediction of the standard RBC model driven by productivity shocks.[12]

Finally, as in the previous model specification, an increase in the strength of the WK friction is associated with a decline in the co-movement between labor productivity and the real wage. Altogether, our results are suggestive of important real effects of firm's financing frictions that help rationalize observed consumption and labor productivity dynamics.

6. Conclusion

The recent financial crisis made it acutely necessary to deepen our understanding of the important role of financial intermediation on aggregate fluctuations. This study makes two contributions to the literature. First, I jointly document five facts of macro and financial variables, namely, (i) counter-cyclical credit spread; (ii) pro-cyclical debt; (iii) pro-cyclical net worth, (iv) counter-cyclical leverage; and (v) negative co-movement between labor and average productivity. Findings (i)–(iv) are relatively new and not well understood properties of the aggregate balance sheet of the financial sector. On the real side, I confirm the finding that labor productivity has become counter-cyclical since 1984. Second, I attempt to explain these facts by developing a basic extension of the financial intermediation framework of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). Namely, I assume (i) financing frictions in production and (ii) only two sources of fluctuations, productivity and monetary shocks. The extended model has a superior fit in terms of the cyclical properties of both macro and financial variables. Importantly, the extended model fits the cyclical properties of financial variables without compromising crucial cyclical properties of consumption.

Our results highlight (1) important real effects of firm's financing constraints and (2) the need to discipline the identification of alternative sources of shocks in models that incorporate financial intermediation and financial frictions. Our findings are relevant for the analysis of macro-prudential policy in the light that financial shocks have been found to have important real effects (Gilchrist and Zakrajsek, 2012; Mallick and Sousa, 2013; Christiano et al., 2014; Kamber et al., 2015) and that there are benefits of responding to financial imbalances (Baillu et al., 2015).

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Appendix A. Optimality conditions

- Household

[11] Additional results on the effect of working capital on financial variables is available from the author upon request.

[12] Recall that in the baseline *BS*1 model the firm can optimally adjust the capital utilization margin in response to capital quality (i.e., depreciation) shocks which contributes to its predicted negative co-movement between productivity and hours conditional on this shock.

The household's problem is:

$$\max_{C_t,L_t} E_t \sum_{t=0}^{\infty} \beta^t \left[\ln(C_{t+1} - hC_t) - \frac{\iota}{1+\vartheta} L_t^{1+\vartheta} \right] \text{s. t.} C_t = W_t L_t + \Pi_t + R_t D_t - D_{t+1}.$$

The optimality conditions of the household are given by:

$$W_t \cdot U_{C_t}(C_t, C_{t-1}, L_t) + U_{L_t}(C_t, C_{t-1}, L_t) = 0$$

and

$$E_t[m_{t+1} R_{t+1}] = 1$$

where m_{t+1} denotes the household's stochastic discount factor which is given by

$$m_{t+1} \equiv \beta \frac{U_C(C_{t+1}, L_{t+1})}{U_C(C_t, L_t)}.$$

- Capital producers

The maximization problem of the capital producer is:

$$\max_{I_{nt}} E_t \sum_{t=0}^{\infty} m_t \left\{ (Q_t - 1) I_{nt} - S\left(\frac{I_{nt} + Iss}{I_{nt-1} + Iss} \right) (I_{nt} + Iss) \right\}.$$

The optimality condition yields Tobin's Q relationship:

$$Q_t = 1 + S_t(\cdot) + \frac{I_{nt} + Iss}{I_{nt-1} + Iss} S_t{}'(\cdot) - E_t \left[m_{t+1} \left(\frac{I_{nt} + Iss}{I_{nt-1} + Iss} \right)^2 S_{t+1}{}'(\cdot) \right].$$

- Final goods producers

Producers' k problem consists in choosing the optimal price P_{jt}^* that maximizes its revenues:

$$\max_{P_{kt}^*} \sum_{j=0}^{\infty} \gamma^j E_t \left[m_{t+j} \left(\frac{P_{jt}^*}{P_{t+j}} - \frac{X}{X_{t+j}} \right) Y_{t+j}^* \right].$$

The evolution of the price level in the economy:

$$P_t = [\gamma P_{t-1}^{\epsilon} + (1-\gamma)(P_t^*)^{1-\epsilon}]^{1/(1-\epsilon)}.$$

In symmetric equilibrium all firms that reset their price choose the same price $P_{kt}^* = P_t^*$. The equilibrium condition yields:

$$\sum_{j=0}^{\infty} \gamma^j E_t \left[m_{t+j} \left(\frac{P_t^*}{P_{t+j}} - \frac{X}{X_{t+j}} \right) Y_{t+j}^* \right] = 0.$$

- Intermediate goods producers

The firm's objective is a standard profit maximization problem:

$$\max_{L,U',K'} E_t \{ m_{t+1} [P_{m,t+1} F(\Lambda_{t+1}, K_{t+1}, L_{t+1}, U_{t+1}) \quad + (Q_{t+1} - \delta(U_{t+1}))\xi_{t+1} K_{t+1} - W_{t+1} L_{t+1} - R_{t+1}^K Q_t K_{t+1} \quad - (R_{t+1}^K - 1)\chi W_{t+1} L_{t+1}] \}$$

The optimality condition for capital yields the following relationship for rate of return on capital for intermediate goods:

$$E_t R_{t+1}^K \equiv E_t \frac{P_{mt+1} F_K(\Lambda_{t+1}, U_{t+1}, K_{t+1}, L_{t+1}) + [Q_{t+1} - \delta(U_{t+1})]\xi_{t+1}}{Q_t}$$

where $\Lambda_t = \{z_t, \xi_t\}$ is the state vector of innovations, $F_K(\cdot)$ is the marginal product of capital, U_t is the utilization rate of capital, and λ_t is the Lagrange multiplier associated with the firm's budget constraint.

The optimality condition for the firm's demand for labor is:

$$P_{m,t+1} F_{L_{t+1}}(\Lambda_{t+1} K_{t+1}, L_{t+1}, U_{t+1}) = W_{t+1}(1 + \chi(R_{t+1}^K - 1)),$$

where W_t is the nominal wage.

Table C1
Parameters of benchmark model.

Description	Parameter	Value
Preferences		
Discount rate[a]	β	0.994
Relative utility weight of labor[a]	ι	5.800
Inverse Frisch-elasticity of labor supply	ϑ	0.276
Financial intermediaries		
Fraction of capital that can be diverted[a]	λ	0.326
Transfer to entering bankers[a]	ν	0.001
Survival of bankers[a]	θ	0.924
Intermediate goods firms		
Effective capital share	α	0.330
SS Depreciation rate	δ	0.025
Elasticity of marginal depreciation w.r.t. Utilization[a]	φ	0.445
Capital producing firms		
Capital adjustment cost function parameter[a]	φ_K	1.210
Sticky prices		
Elasticity of substitution	ε	4.167
Probability of fixed price	γ	0.779
Working capital friction		
Fraction of wage financing bill	χ	1.000

[a] Simulated, Gertler and Karadi (2011), Neumeyer and Perri (2005), and Justiniano et al. (2010).

Table C2
Monetary policy and NKPC parameters.

Description	Parameter	Value
Monetary policy		
Inflation gap coefficient	r_π	1.410
Output gap coefficient	r_Y	0.121
Autocorrelations		
Interest rate persistence	r_R	0.745
Shocks: Standard deviations		
Monetary policy[a]	σ_r	0.0002

[a] Simulated, Jermann and Quadrini (2012).

Appendix B. Data

The time series data is collected for period 1984:Q1–2010:Q2 at quarterly frequency and seasonally adjusted. Real series are obtained using the implicit GDP deflator (2005=100). The following macroeconomic and interest rate data is collected from the Federal Reserve Bank of St Louis and the Bureau of Labor Statistics:

- Real gross domestic product per capita=$\frac{RealGDP}{CNP16OV}$.
- Real private consumption expenditures per capita=$\frac{RealCons}{CNP16OV}$.
- Real gross private domestic investment per capita=$\frac{RealInv}{CNP16OV}$.
- Hours=total private average weekly hours, from the Current Employment Statistics, National Survey.
- Wages=real hourly compensation in the business sector.
- Productivity=real output per capita per hour, from BLS labor productivity and cost program LPC.
- CNP16OV=civilian non-institutional population with ages 16 and over.
- Corporate bond premium=$BAArate - 10yTBill$ at quarterly frequency.
- $BAArate$=BAA corporate bond rate.
- $10yTBill$=10-year maturity treasury bond.

The following financial variables are from the Flow of Funds Account data at the Federal Reserve Board (Z1 tables):

- Real debt per capita=$RealDebtpc$=$\frac{CMIL\,/\,GDPDeflator}{CNP16OV}$.
- Real net worth per capita=$RealNWpc$=$\frac{NW\,/\,GDPDeflator}{CNP16OV}$.
- $CMIL$=credit market instruments liabilities from non-financial business (Table F.101, Line 28).
- NW=financial net worth=financial total assets−total liabilities. These measures are constructed from the following aggregate of credit, financial and depository institutions, tables: L.109 Private Depository Institutions, L.110 US-Chartered Depository Institutions, Excluding Credit Unions, L.113 Credit Unions, L.114 Property-Casualty Insurance Companies, L.115 Life Insurance Companies, L.125 Issuers of Asset-Backed Securities, L.126 Finance Companies, L.127 Real Estate Investment Trusts (REITs), L.128 Security Brokers and Dealers, L.129 Holding Companies, L.130 Funding Corporations.
- Leverage ratio=$\frac{RDebtpc}{RNWpc}$ total liabilities over total financial net worth.

Appendix C. Tables

See Tables C1 and C2.

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