Corporate Debt Maturity and Business Cycle Fluctuations*

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Abstract

Long-term debt is the main source of firm-financing in the U.S. In a macroeconomic model with defaultable debt, longer debt maturity can amplify or dampen the response of the economy to shocks depending on firms' costs of issuing equity. Our framework nests two benchmarks: When firms equity issuance is costless, longer maturity amplifies the investment response through a debt overhang channel. When firms cannot issue any equity, longer maturity dampens the response of investment as a debt dilution channel allows firms to leverage up more, and as a balance sheet channel mitigates the decline in net worth. Using firm-level balance sheet data, we estimate equity issuance costs to be significant. In an estimated medium scale DSGE model with realistic equity adjustment costs and debt maturity, credit supply shocks are the main drivers of business cycle fluctuations.

JEL classification: E32, F30, H22
Keywords: Long-term debt; Financial frictions; Debt overhang; Macroeconomic activity.

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1 Introduction

The share of long-term debt in total non-financial corporate debt is around seventy percent and has been rising since the 1980s (figure 1). In this paper we study the role of firms' debt maturity in determining the sensitivity of the economy to shocks.

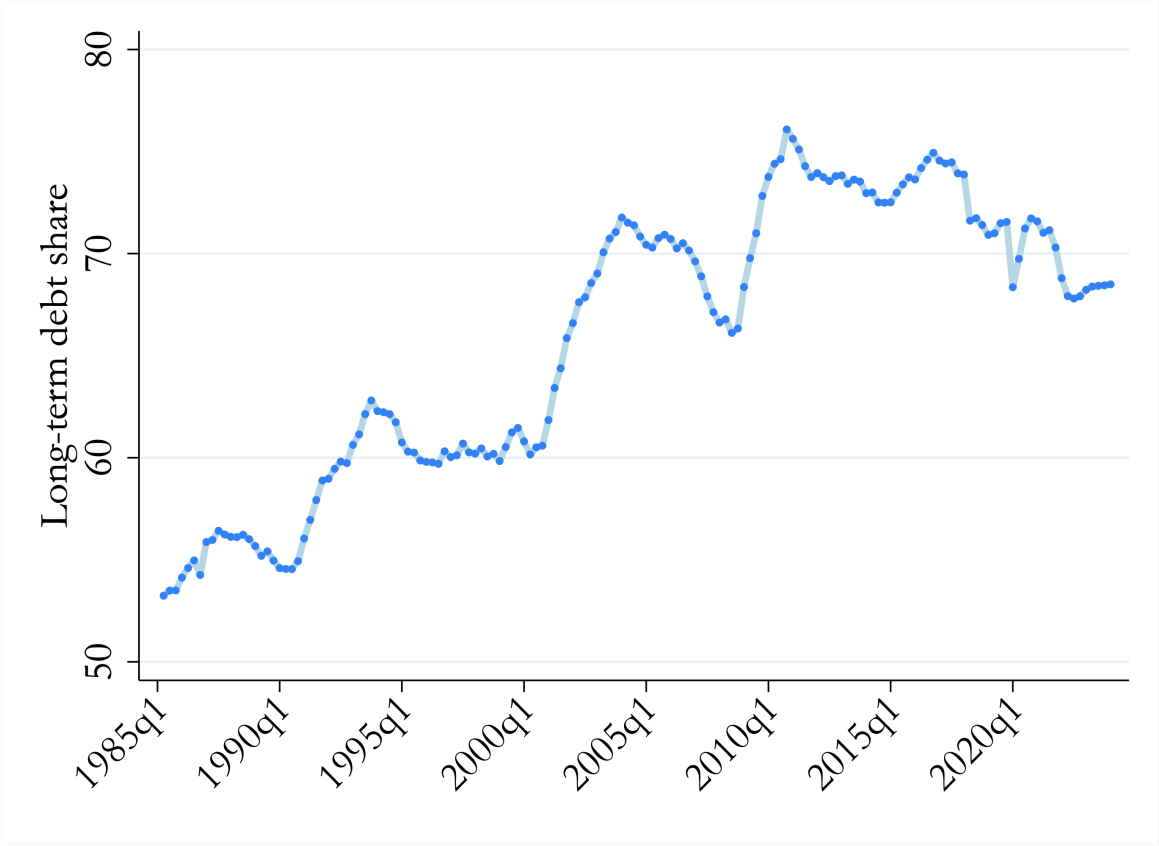


Figure 1: Long-term debt share

Note.- Figure shows the share of debt maturing in more than one year as a percentage of total debt for non-financial corporate businesses. Source: US Financial Accounts.

Traditional macroeconomic models of firm financing, such as Bernanke, Gertler, and Gilchrist (1999) and Kiyotaki and Moore (1997) focus on how financial frictions can amplify the effects of monetary policy and other shocks: shocks that cause investment and the price of capital to decline, lead the balance sheets of borrowers to deteriorate, financial constraints to tighten, and investment to fall further through a *financial accelerator channel*. However, these models typically focus on short-term debt and do not allow firms to issue new equity.

In a more recent contribution, Gomes, Jermann, and Schmid (2016) incorporate nominal

long-term defaultable debt in a macroeconomic model and show how a debt overhang channel works to amplify aggregate fluctuations: The presence of outstanding debt creates a commitment problem for the firm, which results in an additional incentive to increase leverage in order to dilute the value of debt. This leads to persistently elevated default rates, and a stronger contraction in investment in response to standard macroeconomic shocks. However, the model assumes that firms can always issue equity without any cost, and thus it completely abstracts from the financial accelerator channel.

Our paper bridges the gap between these two strands of literature by developing a model in which firms use both long-term defaultable debt and costly equity issuance to finance investment. We use this model to make three contributions. First, we show that equity adjustment costs are key in determining the role of long-term debt in transmitting shocks: when it is costly to adjust equity long term debt dampens the effect of shocks on investment and output, whereas the opposite is true when there are no equity adjustment costs. Second, using cross-sectional data for US firms, we estimate equity adjustment costs to be substantial. Third, we estimate a DSGE model with financial frictions and show that including both realistic equity adjustment costs and the observed maturity of corporate debt implies that a credit supply shock is the main driver of business cycle fluctuations.

We illustrate the first finding by considering the two extreme environments that have been studied in the literature, one in which firms cannot issue equity and one where equity issuance is costless. In each of these environments we assume that prices are flexible and consider a deflationary shock which unexpectedly raises the real value of debt. In line with Gomes et al. (2016), we find that when equity issuance is costless this shock has no effect in an economy with short term debt, while it causes a decline in investment and output when firms have long term debt. With short term debt firms simply issue more equity to offset the rise in the value of debt, and the allocation is unaffected by the shock. In the presence of long-term debt, an increase in the real burden of debt increases firms' incentive to dilute preexisting creditors by increasing leverage. This debt overhang channel results in a higher default rate and lower investment. However, when equity adjustment costs are large (or infinity, as in Bernanke et al. (1999)), we find that the presence of long-term debt *dampens* the effects of the same shock. When equity issuance is very costly, the response of investment is determined by the evolution of firms' net worth as well as by the elasticity of leverage to changes in net worth. In this

case, long-term debt can be dampening for two reasons. First, following the shock, a decline in firms' net worth leads to an increase in leverage, which lowers the price of long-term debt. This price decrease results in a smaller decline in net worth because it lowers the value of firms' outstanding debt obligations. We call this effect the *balance sheet channel* of long term debt. Second, the elasticity of leverage to changes in net worth is higher in the presence of long-term debt. This effect results from the additional perceived benefit of debt which consists of diluting preexisting creditors. Due to this *debt dilution channel*, leverage is higher in the economy with long-term debt, which dampens the contraction in investment when firms are unable to issue equity. Interestingly, the same debt overhang mechanism that is responsible for the drop in investment when there are no costs of adjusting equity, dampens the decline in investment when equity issuance is costly.

Next, we employ the model to derive an optimality condition for equity injections, which we use to estimate the costs of adjusting equity, labeled ψ in our framework, using balance sheet data on firms' dividend payouts and returns on equity from Compustat. The estimated value for ψ is fairly large, implying that the model behaves very similarly to a model with infinite adjustment costs.

Given the estimated value for equity adjustment costs, we go on to estimate a medium scale DSGE model with financial frictions similar to Christiano, Motto, and Rostagno (2014), but with two key new ingredients: i) firms use long term debt for external finance and ii) can adjust equity at a cost. We show that these two ingredients are key for the inference regarding which shocks drive business cycle fluctuations. In particular we find that a shock to the supply of credit is the main driver of business cycle fluctuations when long term debt and costly equity finance are accounted for. This result is due to the fact that the credit supply shock is the only shock in our model that induces the right comovement between macroeconomic and financial variables. A tightening of credit supply induces a recession with credit aggregates and non financial equity declining and credit spreads increasing. Conversely, both the marginal efficiency of investment shock of Justiniano, Primiceri, and Tambalotti (2010) and the risk shock of Christiano et al. (2014), two prominent shocks in the literature, cause equity to rise in response to a recessionary shock. Accounting for long term debt of non financial firms is key in order for the risk shock to be driven out by the credit supply shock. As discussed in Christiano et al. (2014), with short term debt an increase in idiosyncratic investment risk causes equity prices to decline as

asset valuations drop in response to lower investment. This is indeed the main reason why this shock is found to be the main driver of cyclical fluctuations in that framework, once financial variables are used in estimation. With long term debt however, the risk shock causes the value of non financial firms debt to decline as well, causing equity to drop less or actually increase, as is the case in our estimated model. Accounting for substantial costs of adjusting equity in turn is key in order for the credit supply shock to generate a recession. If costs of adjusting equity are zero, firms simply increase equity in response to higher interest rates on debt and end up investing more with less credit.

A final contribution of the paper is methodological. The solution of models with long term defaultable debt is complicated by the necessity of computing the derivative of the entrepreneurial leverage policy function, which cannot be obtained with standard perturbation methods. We overcome this challenge by developing a novel algorithm which is based on a global solution of the entrepreneur's problem around the steady state, and which allows us to approximate this function in a piecewise linear form, making estimation feasible.

Related Literature By studying how the interaction of long-term corporate debt and financial frictions shapes the response to macroeconomic shocks in a medium-scale DSGE model, our work contributes to three strands of literature.

First, we contribute to the literature on the effects of defaultable long-term corporate debt. Gomes et al. (2016) show that unanticipated changes in inflation can have persistent effects on aggregate investment by affecting the real burden of long-term nominal debt. Relatedly, Jungherr and Schott (2022) show that risky long-term debt at the firm-level can lead to an amplified investment response to technology shocks and thereby rationalize the slow adjustment of aggregate leverage during recessions. Both of these papers highlight the distortionary effect of the debt overhang channel on firms' investment decisions but abstract from equity issuance costs. Our paper instead focuses on the interplay between long-term debt and firms' net worth when equity is costly to adjust.

Second, a large literature has studied the implications of corporate debt for macroeconomic fluctuations. These models typically focus on one-period debt and thus abstract from any frictions related to debt with long maturity (e.g. Bernanke et al. (1999), Kiyotaki and Moore (1997), Christiano et al. (2014), Arellano, Bai, and Kehoe (2019), Ottonello and Winberry

(2020)). Furthermore, firms typically cannot raise equity in these models.[1] Papers in this literature include a financial accelerator mechanism which links firm investment to changes in net worth, but abstract from the interaction between the value of long-term debt and firms' balance sheets.[2]

A third strand of literature is related to papers investigating the drivers of business cycle fluctuations in macroeconomic models of the US. Smets and Wouters (2007) were among the first to perform this type of analysis, and found that, in a medium scale DSGE model, demand shocks (like a risk premium shock or a government spending shock) accounted for most of output fluctuations in the short run, whereas supply shocks played an important role for output variations in the medium to long run. Justiniano et al. (2010), show that, once consumption and investment are properly meausured, shocks to the marginal efficiency of investment emerge as the driving force of the business cycle. Christiano et al. (2014) revisit this result by introducing financial frictions and by showing that, once financial variables are included in the estimation, a shock affecting the volatility of idiosyncratic firm uncertainty (risk shock), explains most of the variation in output. We contribute to this literature by showing that the implications of the risk shock crucially depend on corporate debt maturity, and by studying the important role played by a credit supply shock in accounting for business cycle fluctuations.

2 Model

There is a continuum of households, each consisting of a continuum of members. At each point in time a proportion e of household members are entrepreneurs, a proportion b are bankers, and the remaining proportion $1-e-b$ are workers. We describe the optimization problems of these three types of agents in turn.

[1] Notable exceptions include Jermann and Quadrini (2012), Gertler, Kiyotaki, and Queralto (2012), and Gertler, Kiyotaki, and Prestipino (2020), which feature short-term debt and (costly) equity adjustments. Ferrante (2019) features long-term debt but assumes infinitely costly equity issuance.

[2] A related literature focuses on firm heterogeneity. Jungherr, Meier, Reinelt, and Schott (2022) show that the investment of firms with a larger amount of maturing debt is more responsive to monetary policy, and rationalize this finding with a heterogeneous firm model with defaultable long-term debt and costly equity adjustments. In addition, Brunnermeier, Correia, Luck, Verner, and Zimmermann (2023) show that firms with a larger share of long-term debt were more resilient during the German hyper-inflation period of 1919-1923.

2.1 Workers

Workers choose household consumption, C_t, the amounts of savings in banks deposits, D_t and government bonds, B_t, to maximize

$$\sum_{t=0}^{\infty} \beta^t \left[\xi_t^c \log\left(C_t - bC_{t-1}\right) - \frac{\bar{\varphi}}{1+\varphi} \int h_{it}^{1+\varphi} di \right]$$

where ξ_t^c represents a preference shock. Workers' budget constraint is

$$C_t + D_t + B_t = \int w_{it} h_{it} di + D_{t-1} \frac{\tilde{R}_{t-1}^d}{\pi_t} + B_{t-1} \frac{R_{t-1}^g}{\pi_t} + T_t, \tag{1}$$

where $\tilde{R}_{t-1}^d$ and R_{t-1}^g are the nominal rates of return on deposits and government bonds between time $t-1$ and time t, π_t is the rate of inflation, and T_t collects all transfers to the household from firms, entrepreneurs, bankers and the government.

Households optimal holdings of deposits and government bonds satisfy:

$$1 = E_t \Lambda_{t+1} \frac{\tilde{R}_t^d}{\pi_{t+1}} = E_t \Lambda_{t+1} \frac{R_t^g}{\pi_{t+1}} \tag{2}$$

where $\Lambda_{t+1} = \beta \frac{U_c(t+1)}{U_c(t)}$ is the household stochastic discount factor with the marginal utility of consumption given by

$$U_c\left(t\right) = \frac{\xi_t^c}{C_t - bC_{t-1}} - \beta b E_t \frac{\xi_{t+1}^c}{C_{t+1} - bC_t}.$$

2.2 Entrepreneurs

Entrepreneurs are the agents holding productive capital in the economy. To simplify the analysis we assume that entrepreneurs rent their capital to firms at a market rental rate r_t^k. An entrepreneur's return on capital investment is given by

$$\xi_t R_t^k = \xi_t \frac{r_t^k + (1-\delta) Q_t^k}{Q_{t-1}^k},$$

where ξ_t is an idiosyncratic shock to capital returns, Q_t^k is the price of capital, and δ is the depreciation rate of capital. We assume that $\log(\xi_t)$ is distributed as a Normal with mean 0 and standard deviation σ_{t-1}^l, and we allow for "risk shocks" causing exogenous fluctuations in σ_t^l as in Christiano et al. (2014).

Entrepreneurs finance capital purchases with own equity, x_t, and by issuing long-term nom-

inal debt l_t to bankers. Their flow budget constraint at time t is:

$$Q_t^k k_t = x_t + Q_t^l l_t$$

where Q_t^l is the price of debt.[3]

Each unit of debt issued at $t-1$ pays back a coupon c_l at time t, while the remaining portion $1-\lambda_l$ remains outstanding. An entrepreneur that enters time t with capital k_{t-1} and debt l_{t-1}, has net worth n_t given by

$$n_t = \xi_t R_t^k Q_{t-1}^k k_{t-1} - \frac{\left(c_l + (1-\lambda_l) Q_t^l\right)}{\pi_t} l_{t-1}. \tag{3}$$

We assume that it is costly for entrepreneurs to adjust the amount of equity that they invest in the firm. In particular, if an entrepreneur pays a proportion $1-\omega_t$ of net worth back to the family as dividend, the amount of equity that he keeps within the firm is smaller than the remaining proportion, $x_t = f(\omega_t) n_t < \omega_t n_t$. We assume a simple quadratic formulation for equity injection costs:

$$f(\omega_t) = (1-\overline{\psi})\omega_t - \frac{\psi}{2}(\omega_t - \overline{\omega})^2,$$

with $\overline{\psi} \geq 0$, $\psi \geq 0$, and $1-\overline{\omega}$ a fixed target dividend payout rate.

This formulation of equity injection costs is a simple way to capture agency problems that limit entrepreneurs ability to substitute debt finance with equity finance.[4] The parameter $\bar{\psi}$ represents a small linear equity issuance cost which guarantees that, around the steady state of the model, entrepreneurs have an incentive to use debt to finance capital purchases.[5] With no equity issuance costs, i.e. $\bar{\psi} = 0$ and $\psi = 0$, entrepreneurs are able to efficiently substitute debt finance with equity finance in response to changing financial conditions. This is the assumption, for instance, of Gomes et al. (2016). At the other extreme, when it is infinitely costly to adjust equity issuance, i.e. $\psi = \infty$, entrepreneurs always retain a fixed share of net worth, $\overline{\omega}$, as equity in the firm, and their only active margin of financial adjustment is through debt. This is the assumption in most papers with financial frictions following Bernanke et al. (1999). Here we

[3]For ease of notation, we are omitting the dependence of the price of debt on the entrepreneur's financial decisions. We will be explicit about it when describing the entrepreneur's optimality conditions.

[4]See Jermann and Quadrini (2012) for a similar approach at modelling costly dividend payouts. We assume that costs are proportional to net worth in order to obtain aggregation of the entrepreneurs' policy functions.

[5]This cost plays a role similar to a tax advantage subsidy for debt, used, for example, in Gomes et al. (2016).

allow for ψ to take on any positive value and estimate it in section 4.2.2.

Let $V_t(k_{t-1}, l_{t-1}, \xi_t)$ be the optimal value of a firm that enters time t with capital k_{t-1}, debt l_{t-1} and idiosyncratic shock ξ_t. This value is the optimized present discounted value of dividend payouts. It is given by:

$$V_t\left(k_{t-1}, l_{t-1}, \xi_t\right) = \max_{k_t, l_t, \omega_t, n_t} \left\{\left(1-\omega_t\right) n_t + E_t \Lambda_{t,t+1} \max\left\{0, V_{t+1}\left(k_t, l_t, \xi_{t+1}\right)\right\}\right\} \tag{4}$$

subject to (3) and a flow budget constraint

$$Q_t^k k_t = f(\omega_t) n_t + Q_t^l l_t. \tag{5}$$

Let $\eta_t = \frac{l_t}{k_t}$ denote the entrepreneur's leverage ratio, defined as the ratio of debt per unit of capital, and guess that

$$V_t(k_{t-1}, l_{t-1}, \xi_t) = \nu_t(\eta_{t-1}, \xi_t) k_{t-1}. \tag{6}$$

Using (3), (5) and (6) to substitute for n_t, k_t and V_t in (4), we get

$$v_t\left(\eta_{t-1}, \xi_t\right) = \max_{\eta_t, \omega_t} \mu_t\left(\eta_t; \eta_{t-1}, \xi_t\right) \left\{\left(1-\omega_t\right) + \frac{f\left(\omega_t\right)}{\left(Q_t^k - Q_t^l \eta_t\right)} E_t \Lambda_{t,t+1} \max\left\{0, v_{t+1}\left(\eta_t, \xi_{t+1}\right)\right\}\right\} \tag{7}$$

where $\mu_t\left(\eta_t; \eta_{t-1}, \xi_t\right)$ is the amount of entrepreneur's net worth per unit of capital, given by

$$\mu_t\left(\eta_t; \eta_{t-1}, \xi_t\right) = \frac{n_t}{k_{t-1}} = \xi_t R_t^k Q_{t-1}^k - \frac{\left(c_l + \left(1-\lambda_l\right) Q_t^l\right)}{\pi_t} \eta_{t-1}. \tag{8}$$

Notice that μ_t depends on η_t because the price of the entrepreneur's debt, Q_t^l, will vary depending on the individual entrepreneur's choice of leverage, η_t.

As the value to the entrepreneur is increasing in the idiosyncratic shock to the returns on capital, ξ_{t+1}, there is a threshold value for this shock, $\overline{\xi}_{t+1}$, such that the firm defaults when $\xi_{t+1} < \overline{\xi}_{t+1}$. The threshold value satisfies

$$v_{t+1}\left(\eta_t, \overline{\xi}_{t+1}\right) = 0, \tag{9}$$

and it is the value that sets the entrepreneur's equity to zero:

$$\bar{\xi}_{t+1} R_{t+1}^k Q_t^k = \frac{\left(c_l + \left(1-\lambda_l\right) Q_{t+1}^l\right)}{\pi_{t+1}} \eta_t. \tag{10}$$

Equity injections The optimality condition for equity injections is given by the derivative of (7) with respect to ω_t:

$$\begin{aligned} 1 &= f'(\omega_t) \frac{E_t \Lambda_{t,t+1} \max\{0, v_{t+1}(\eta_t, \xi_{t+1})\}}{\left(Q_t^k - Q_t^l \eta_t\right)} \\ &= f'(\omega_t) \frac{E_t \Lambda_{t,t+1} \int_{\bar{\xi}_{t+1}}^{\infty} v_{t+1}(\eta_t, \xi_{t+1}) \, dF_t(\xi_{t+1})}{\left(Q_t^k - Q_t^l \eta_t\right)} \end{aligned} \tag{11}$$

where F_t is the distribution of idiosyncratic shocks at $t+1$, and the second equality follows from (9). The optimality condition for equity injections requires that the marginal cost of equity injections, which is unity, equals the marginal benefits, given by the marginal increase in entrepreneur's equity, $f'(\omega_t)$, times the expected discounted return on equity injections, which we denote by γ_t:

$$\gamma_t = \frac{E_t \Lambda_{t,t+1} \int_{\bar{\xi}_{t+1}}^{\infty} v_{t+1}(\eta_t, \xi_{t+1}) \, dF_t(\xi_{t+1})}{\left(Q_t^k - Q_t^l \eta_t\right)} \tag{12}$$

To characterize γ_t it is useful to introduce the entrepreneur's Tobin's Q on net worth, that is the ratio between the value to the entrepreneur of a unit of net worth and the book value of a unit of net worth, $\varphi_t = \frac{\nu_t}{\mu_t}$. Using (7) and (10) we can write φ_t as:

$$\varphi_t = (1 - \omega_t) + f(\omega_t) \frac{Q_t^k}{\left(Q_t^k - Q_t^l \eta_t^l\right)} E_t \Lambda_{t,t+1} \varphi_{t+1} \int_{\bar{\xi}_{t+1}}^{\infty} \left(\xi_{t+1} - \bar{\xi}_{t+1}\right) R_{t+1}^k dF_t(\xi_{t+1}) \tag{13}$$

Using $\nu_{t+1} = \varphi_{t+1} \mu_{t+1}$ together with the definition of μ_{t+1} from (8) to substitute for ν_{t+1} in (12), we can express the expected discounted returns on equity investment as:

$$\gamma_t = \frac{Q_t^k}{\left(Q_t^k - Q_t^l \eta_t\right)} E_t \Lambda_{t,t+1} \varphi_{t+1} \int_{\bar{\xi}_{t+1}}^{\infty} \left(\xi_{t+1} - \bar{\xi}_{t+1}\right) R_{t+1}^k dF_t(\xi_{t+1}), \tag{14}$$

that says that one unit of equity gets leveraged into $\frac{Q_t^k}{\left(Q_t^k - Q_t^l \eta_t\right)}$ units of capital, which repay a return, $\xi_{t+1} R_{t+1}^k$, net of the debt repayment, $\bar{\xi}_{t+1} R_{t+1}^k$, whenever the idiosyncratic shock is larger than the threshold.

The optimality condition for equity injection then becomes

$$1 = f'(\omega_t) \frac{Q_t^k}{\left(Q_t^k - Q_t^l \eta_t\right)} E_t \Lambda_{t,t+1} \varphi_{t+1} \int_{\bar{\xi}_{t+1}}^{\infty} \left(\xi_{t+1} - \bar{\xi}_{t+1}\right) R_{t+1}^k dF_t(\xi_{t+1}). \tag{15}$$

Leverage The optimality condition for leverage is given by:

$$\frac{\partial \mu_t}{\partial \eta_t}\varphi_t + \frac{f\left(\omega_t\right)\mu_t}{\left(Q_t^k - Q_t^l \eta_t\right)}\left[\left(Q_t^l + \frac{dQ_t^l}{d\eta_t}\eta_t\right)\gamma_t - E\Lambda_{t,t+1}\int_{\bar{\xi}_{t+1}}^{\infty}\frac{\partial v_{t+1}}{\partial \eta_t}dF_t\left(\xi_{t+1}\right)\right] = 0, \tag{16}$$

where

$$\frac{\partial \mu_t}{\partial \eta_t} = -\frac{\left(1-\lambda_l\right)\eta_{t-1}}{\pi_t}\frac{dQ_t^l}{d\eta_t}. \tag{17}$$

The first term in (16), $\frac{\partial \mu_t}{\partial \eta_t}\varphi_t$, captures the *debt dilution incentive*, that is the benefit of increasing leverage through the associated decline in the price of outstanding debt, $\frac{dQ_t^l}{d\eta_t} < 0$. When entrepreneurs have long-term debt, i.e. $\lambda_l < 1$, they have an additional incentive to increase leverage in order to lower the price of debt of preexisting creditors, and hence increasing the net worth of the entrepreneur.

The second term, $\frac{f(\omega_t)\mu_t}{\left(Q_t^k - Q_t^l \eta_t^l\right)}\left(Q_t^l + \frac{dQ_t^l}{d\eta_t}\eta_t^l\right)\gamma_t$, is the marginal benefit of increasing leverage associated with higher returns on capital.

The last term, $-\frac{f(\omega_t)\mu_t}{\left(Q_t^k - Q_t^l \eta_t^l\right)}E\Lambda_{t,t+1}\int_{\bar{\xi}_{t+1}}^{\infty}\frac{\partial v_{t+1}}{\partial \eta_t}dF_t\left(\xi_{t+1}\right)$, captures the marginal cost of leverage. Using the envelope condition we get:

$$\frac{dv_t}{d\eta_{t-1}} = -\frac{\left(c_l + \left(1-\lambda_l\right)Q_t^l\right)}{\pi_t}\varphi_t. \tag{18}$$

So the marginal cost of leverage is given by the cost of repaying the loans in case of non default:

$$E_t\Lambda_{t,t+1}\int_{\bar{\xi}_{t+1}}^{\infty}\frac{\partial v_{t+1}}{\partial \eta_t}dF_t\left(\xi_{t+1}\right) = E_t\Lambda_{t,t+1}\frac{\left(c_l + \left(1-\lambda_l\right)Q_{t+1}^l\right)}{\pi_{t+1}}\varphi_{t+1}\left(1 - F_t\left(\bar{\xi}_{t+1}\right)\right).$$

Using (17) and (18) in (16) we can rewrite the optimality condition for entrepreneur's leverage as:

$$\begin{aligned}&\frac{\left(1-\lambda_l\right)\eta_{t-1}}{\pi_t}\frac{dQ_t^l}{d\eta_t}\varphi_t + \frac{f(\omega_t)\mu_t}{\left(Q_t^k - Q_t^l \eta_t^l\right)}\left(Q_t^l + \frac{dQ_t^l}{d\eta_t}\eta_t^l\right)\frac{Q_t^k}{\left(Q_t^k - Q_t^l \eta_t^l\right)}E_t\Lambda_{t,t+1}\varphi_{t+1}\int_{\bar{\xi}_{t+1}}^{\infty}\left(\xi_{t+1} - \bar{\xi}_{t+1}\right)R_{t+1}^k dF_t\left(\xi_{t+1}\right)\\ &=\\ &\frac{f(\omega_t)\mu_t}{\left(Q_t^k - Q_t^l \eta_t^l\right)}E_t\Lambda_{t,t+1}\varphi_{t+1}\frac{\left(c_l + (1-\lambda_l)Q_{t+1}^l\right)}{\pi_{t+1}}\left(1 - F_t\left(\bar{\xi}_{t+1}\right)\right)\end{aligned} \tag{19}$$

Equations (10), (15) and (19), together with the definition of μ_t and φ_t in (8) and (13), are the optimality conditions for the entrepreneurs problem. We now turn to describing aggregation of the entrepreneurs' policy fucntions.

2.3 Aggregation of entrepreneurs choices

At the beginning of each period, all entrepreneurs return their net worth to the family. Defaulting entrepreneurs exit and become workers and are replaced by an equal number of new entrepreneurs.

New entrants receive a transfer proportional to aggregate net worth X_t, according to $T_t^e = \tau_e X_{t-1}$. New entrepreneurs use these resources to purchase capital

$$Q_t^k k_t^e = T_t^e + Q_t^l l_t^e$$

To preserve aggregation, we make two assumptions. First we assume that new entrants debt, l_t^e, is adjusted so that new entrants' leverage is the same as existing entrepreneurs, that is

$$l_t^e = \eta_t k_t^e$$

Second, we assume that non defaulting entrepreneurs are all given the same amount of capital, $\tilde{\xi}_t K_{t-1} = \frac{1}{1-F_{t-1}\left(\bar{\xi}_t\right)} \int_{\bar{\xi}_t} \xi_t dF_{t-1}\left(\xi_t\right) K_{t-1}$ from the family before making their choices at time t. This ensures that the μ_t in (19) is constant across non defaulting entrepreneurs and hence the leverage choice is constant across all entrepreneurs active at time t.

Aggregate equity of entrepreneurs at time t is then given by:

$$X_t = f\left(\omega_t\right)\left[\left(\tilde{\xi}_t - \bar{\xi}_t\right) R_t^k Q_{t-1}^k\right] K_{t-1}\left(1 - F\left(\bar{\xi}_t^l\right)\right) + T_t^e + \xi_t^N$$

which sums the equity of entrepreneurs that do not default at time t and the transfer to new entrepreneurs. The term ξ_t^N captures a net worth shock which exogenously affects aggregate entrepreneurial net worth, as in, for example, Christiano et al. (2014).

Aggregate capital demand is then given by

$$K_t = \frac{X_t}{\left(Q_t^k - \eta_t Q_t^l\right)},$$

with equations (15) and (19) that determine equity injections, ω_t, and leverage η_t.

2.4 Financial Intermediaries

Financial intermediaries raise deposits from households and invest these funds in corporate loans, according to

$$Q_t^l L_t = \kappa_t D_t, \tag{20}$$

where L_t and D_t represent aggregate loans and deposits respectively, and κ_t is a credit supply shock that affects banks technology for transforming deposits into loans.

The expected return on loans, $R_{t+1}^{l,b}$, which takes into account the possibility of default, is given by

$$R_{t+1}^{l,b} = [1 - F_t\left(\bar{\xi}_{t+1}\right)]R_{t+1}^l + \gamma_l \frac{Q_t^k R_{t+1}^k}{\eta_t Q_t^l} \int_0^{\bar{\xi}_{t+1}} \xi_{t+1} dF_t\left(\xi_{t+1}\right). \tag{21}$$

where the first term in (21) captures the real return on loans to non-defaulting firms

$$R_{t+1}^l = \frac{1}{\pi_t} \frac{\left(c_l + (1-\lambda_l) Q_{t+1}^l\right)}{Q_t^l} \tag{22}$$

whereas the second term represents the recovery value on defaulted loans, which is equal to a fraction γ_l of the capital of defaulting firms. Because each bank lends to a continuum of entrepreneurs, $R_{t+1}^{l,b}$ also represents the realized return on each bank's loan portfolio.

Financial intermediaries are owned by households, and their objective is to maximize profits:

$$\max_{D_t} D_t E_t \Lambda_{t,t+1} \left(\kappa_t R_{t+1}^{l,b} - R_t^d\right)$$

where $R_t^d = \frac{\tilde{R}_t^d}{\pi_t}$ is the real return on deposits.

Optimality implies

$$E_t \Lambda_{t,t+1} \kappa_t R_{t+1}^{l,b} = E_t \Lambda_{t,t+1} R_{t+1}^d = 1 \tag{23}$$

where the second equality comes from households first order conditions. Multiplying (23) by Q_t^l we obtain an expression for entrepreneurs' loans price:

$$Q_t^l = E_t \Lambda_{t+1} \kappa_t \left\{ [1 - F_t\left(\bar{\xi}_{t+1}\right)] \frac{\left(c_l + (1-\lambda_l) Q_{t+1}^l\right)}{\pi_{t+1}} + \gamma_l \frac{Q_t^k R_{t+1}^k}{\eta_t} \int_0^{\bar{\xi}_{t+1}} \xi_{t+1} dF_t\left(\xi_{t+1}\right) \right\} \tag{24}$$

Equations (23) and (24) show that the credit supply shock κ_t introduces an exogenous wedge between the expected return on loans and the risk free rate. A lower κ_t increases the lender's required rate of return on corporate loans, reducing the supply of credit and putting downward

pressure on Q_t^l. As a result, up to first order, we can decompose the spread on loans $E_t(R_{t+1}^l - R_{t+1}^d)$ as

$$E_t(R_{t+1}^l - R_{t+1}^d) = \overbrace{E_t(R_{t+1}^l - R_{t+1}^{l,b})}^{DefaultPremium} + \overbrace{E_t(R_{t+1}^{l,b} - R_{t+1}^d)}^{LiquidityPremium} \tag{25}$$

where the first component captures the expected default risk, which moves with aggregate shocks and is particularly sensitive to the risk shock σ_t^l, whereas the second component moves inversely with κ_t.[6]

Finally, using equation (24) we can compute the derivative of the loan price with respect to entrepreneurial leverage as

$$\begin{aligned}\frac{\partial Q_t^l}{\partial \eta_t} &= -E_t\Lambda_{t+1}\kappa_t\left\{\frac{\partial \bar{\xi}_{t+1}}{\partial \eta_t} f_t\left(\bar{\xi}_{t+1}\right)\left[Q_t^l R_{t+1}^l - \gamma_l \frac{Q_t^k R_{t+1}^k}{\eta_t}\bar{\xi}_{t+1}\right] + \gamma_l \frac{Q_t^k R_{t+1}^k}{(\eta_t)^2}\int_0^{\bar{\xi}_{t+1}} \xi_{t+1} dF_t\left(\xi_{t+1}\right)\right\} \\ &+E_t\Lambda_{t+1}\kappa_t[1 - F_t\left(\bar{\xi}_{t+1}\right)]\left(1-\lambda_l\right)\frac{\partial Q_{t+1}^l}{\partial \eta_{t+1}}\eta_{\eta,t+1}\left(\eta_t\right)\end{aligned} \tag{26}$$

The top term in (26) includes the impact of entrepreneurs' leverage on next period default threshold and on the expected recovery rate in case of default. Because higher η_t^l results in a higher expected probability of default and in a lower recovery rate, this term is negative. The bottom term in (26) captures the effect of current leverage choice on future leverage, as measured by the derivative of the entrepreneur's leverage policy function $\eta_{\eta,t+1}\left(\eta_t\right) = \frac{\partial \eta_{t+1}}{\partial \eta_t}$.[7] As noted by Gomes et al. (2016), long-term debt introduces an incentive for entrepreneurs to dilute the value of preexisting debt by increasing leverage, and rational lenders take this effect into account. The computation of this derivative complicates the numerical solution of the model, because it cannot be computed with standard perturbation methods. As discussed below, to overcome this problem we develop an algorithm which uses global solution techniques to capture the local dynamics of this derivatives around the steady state of the model.

[6] A possible way to endogenize the liquidity premium would be to introduce an agency problem in the financial sector, see, for example Gertler and Karadi (2011) or Ferrante (2019).

[7] We are abusing notation here since the policy function is the individual entrepreneur's policy function for leverage as a function of individual entrepreneur's leverage. See Appendix for details.

2.5 Final good producers

The final good Y_t is a CES composite of different intermediate varieties, given by

$$Y_t = \left[\int Y_t(i)^{\frac{\varepsilon_t - 1}{\varepsilon_t}} \right]^{\frac{\varepsilon_t}{\varepsilon_t - 1}} \tag{27}$$

Where ε_t captures a markup shock. As a result, the demand for each variety will be given by

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon_t} Y_t \tag{28}$$

where the aggregate price level for the home good is given by

$$P_t = \left[\int (P_t(i))^{1-\varepsilon_t} di \right]^{\frac{1}{1-\varepsilon_t}} \tag{29}$$

2.6 Intermediate goods Producers

Intermediate goods producers hire labor, paying a real wage w_t, and rent capital, at rate r_t^k, to be used in a standard Cobb-Douglas technology

$$Y_t = A_t (u_t K_{t-1})^{\chi} H_t^{(1-\chi)} \tag{30}$$

where H_t and K_{t-1} are aggregate labor and capital. In addition, firms can adjust utilization u_t by paying a cost $a(u_t)K_{t-1} = \bar{\gamma}_u (e^{\gamma_u (u_t - 1)} - 1) K_{t-1}$, where, in steady state, $a(1) = 0$ and $\bar{\gamma}_u$ is calibrated to obtain $a'(1) = r_{ss}^k$.

Intermediate goods are sold to monopolistically competitive retailers at real price p_t^m. Then we can write the first order conditions for labor, capital and utilization as

$$w_t = p_t^m (1 - \chi) \frac{Y_t}{H_t} \tag{31}$$

$$r_t^k = p_t^m \chi \frac{Y_t}{K_{t-1}} \tag{32}$$

$$\frac{r_t^k}{u_t} = a'(u_t) \tag{33}$$

2.7 Retailers

Retailers with monopoly power purchase intermediate goods at price p_t^m and set prices for final good varieties facing Rotemberg adjustment costs for deviating from a target inflation rate $\tilde{\pi}_t$, according to $0.5\kappa(\frac{\pi_t}{\tilde{\pi}_t}-1)^2 Y_t$. In particular, $\tilde{\pi}_t = \bar{\pi}_t^{\iota_p}\pi_{t-1}^{(1-\iota_p)}$ where $\bar{\pi}_t$ represents a time-varying inflation target set by the central bank, and ι_p captures the degree of inflation indexation.

As a result, inflation follows a standard Phillips Curve

$$\left(\frac{\pi_t}{\tilde{\pi}_t}-1\right)\frac{\pi_t}{\tilde{\pi}_t} = \left[P_t^m \frac{\varepsilon_t}{(\varepsilon_t-1)}-1\right]\gamma_p + \beta E_t \Lambda_{t,t+1}\left(\frac{\pi_{t+1}}{\tilde{\pi}_{t+1}}-1\right)\frac{\pi_{t+1}}{\tilde{\pi}_{t+1}}\frac{Y_{t+1}}{Y_t} \tag{34}$$

where $\gamma_p = (\varepsilon_t - 1)/\kappa$ represents the slope of the Phillips curve.

2.8 Labor Agencies and Labor Unions

Labor agencies aggregate individual labor supply into a composite labor input that is sold to firms using a constant elasticity of substitution technology:

$$H_t^{\frac{\varepsilon_t^w-1}{\varepsilon_t^w}} = \int h_{it}^{\frac{\varepsilon_t^w-1}{\varepsilon_t^w}} di$$

where ε_t^w captures a wage markup shock. Optimal demand of labor h_{it} is given by:

$$h_{it} = \left(\frac{w_{it}}{w_t}\right)^{-\varepsilon_t^w} H_t \tag{35}$$

where w_t is the real wage paid by firms to purchase the labor composite H_t.

Labor unions set wages while facing Rotemberg adjustment costs $0.5\kappa^w(\frac{\pi_t^w}{\tilde{\pi}_t^w}-1)^2 H_t$, where $\pi_t^w = \frac{w_t}{w_{t-1}}\pi_t$ and $\tilde{\pi}_t^w = \bar{\pi}_t^{\iota_w}\pi_{t-1}^{(1-\iota_w)}$. The parameter ι_w captures the degree of wage indexation to inflation.

Labor unions' optimization delivers the following wage Phillips curve

$$\frac{\pi_t^w}{\tilde{\pi}_t^w}\left(\frac{\pi_t^w}{\tilde{\pi}_t^w}-1\right) = \left(H_t^{\varphi} - (\varepsilon_t^w - 1)W_t\frac{U_{ct}}{\bar{\varphi}\varepsilon_t^w}\right)\gamma_w + \beta\frac{\pi_{t+1}^w}{\tilde{\pi}_{t+1}^w}\left(\frac{\pi_{t+1}^w}{\tilde{\pi}_{t+1}^w}-1\right)\frac{H_{t+1}}{H_t} \tag{36}$$

where $\gamma_w = \bar{\varphi}\varepsilon_t^w/\kappa^w$ captures the slope of the wage Phillips curve.

2.9 Capital goods production

Capital producers sell capital at price Q_t^k and face convex adjustment costs. They solve:

$$\max E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \left[Q_{t+i} I_{t+i} - \mu_t^k I_{t+i} \left(1 - \frac{\gamma_k}{2} (\frac{I_{t+i}}{I_{t+i-1}} - 1)^2 \right) \right]$$

where μ_t^k captures a shock to the marginal efficiency of investment (MEI). Optimality implies the following relation between the price of capital and investment:

$$Q_t^k = \mu_t^k \left(1 + \frac{\gamma_k}{2} (\frac{I_t}{I_{t-1}} - 1)^2 + \gamma_k \frac{I_t}{I_{t-1}} (\frac{I_t}{I_{t-1}} - 1) \right) - \beta E_t \Lambda_{t+1} \mu_{t+1}^k \gamma_k \left(\frac{I_{t+1}}{I_t} \right)^2 (\frac{I_{t+1}}{I_t} - 1) \quad (37)$$

2.10 Monetary policy, Market Clearing and Shocks

Monetary policy sets the interest rate on government bonds according to an inertial Taylor rule that responds to inflation (in deviation from a target) and output growth

$$\log \left(R_{i,t}^g \right) = (1 - \rho_r) R_{SS} + \rho_r \log \left(R_{i,t-1}^g \right) + (1 - \rho_r) \left(\kappa_\pi \log(\frac{\pi_t}{\bar{\pi}_t}) + \kappa_y log(\frac{Y_t}{Y_{t-1}}) \right) + \varepsilon_t^m. \quad (38)$$

where ρ_r is a smoothing parameter and ε_t^m is a monetary policy shock.

Market clearing in the goods and investment market requires

$$Y_t - \nu(1 - \gamma_l) K_{t-1} \int_0^{\bar{\xi}_t^l} \xi_t^l dF_t(\xi_t^l) - \left(\overline{\psi} \omega_t + \frac{\psi}{2} (\omega_t - \overline{\omega})^2 \right) N_t = C_t + I_t + G_t \quad (39)$$

$$K_t = (1 - \delta) K_{t-1} + I_{it} \quad (40)$$

where the term $(1 - \gamma_l) \int_0^{\bar{\xi}_t^l} \xi_t^l dF_t(\xi_t^l)$ represents default costs. The parameter ν governs what share of default costs translate into a loss of real resources. Government consumption G_t is subject to exogenous govermnent spending shocks.

The model features 11 shocks: i) a monetary policy shock ϵ_t^m; ii) a risk shock σ_t^l; iii) a net worth shock ξ_t^N; iv) a shock to the marginal efficiency of investment μ_t; v) a price markup shock ε_t; vi) a wage markup shock ε_t^w; vii) a tfp shock A_t; viii) a government spending shock G_t; ix) a shock to the inflation target $\bar{\pi}_t$; x) a credit supply shock κ_t; xi) a preference shock ξ_t^c.

As is standard in the literature, we assume that each shock ε_t (expressed in deviation from

steady state) has an AR1 representation

$$\varepsilon_t = \rho_\varepsilon \varepsilon_{t-1} + \zeta_t^\varepsilon \tag{41}$$

where $\zeta_t^\varepsilon \sim N(0, \sigma^\varepsilon)$ is an iid innovation and the parameter ρ_ε captures the shock persistence. In addition, following Christiano et al. (2014), we introduce a news component for the risk shock, by assuming that

$$\zeta_t^\sigma = \zeta_{0,t}^\sigma + \zeta_{1,t-1}^\sigma + \dots \zeta_{8,t-8}^\sigma \tag{42}$$

where $\zeta_{0,t}^\sigma \sim N(0, \sigma^\sigma)$ represents the shock innovation realized at time t, whereas $\zeta_{1,t-1}^\sigma \dots \zeta_{8,t-8}^\sigma \sim N(0, \sigma_n^\sigma)$ are news shocks known to the agents up to two years in advance. News shocks have a correlation structure described by the parameter $\rho_{\sigma,n}$. Finally, we assume that the monetary policy shock and the net worth shock have an autocorrelation parameter equal to zero, that is $\rho_N = \rho_m = 0$.

3 The role of equity adjustment costs

We start by illustrating the role of equity adjustment costs in transmitting a negative shock to inflation in a version of our economy without nominal rigidities ($\kappa = \kappa_w = 0$) and without real costs of default, i.e. $\nu = 0$. All the other parameters are calibrated or estimated as described in section 4. This experiment is similar to the one presented in Gomes et al. (2016), and it is useful to highlight the role of long term debt in the transmission of a shock which affects the real value of corporate debt.[8]

We consider the case of no equity adjustment costs and infinite equity adjustment costs, and compare the responses with long-term debt and one period short-term debt.[9]

[8] As shown in figures A1 and A2 in the appendix, very similar results are obtained if we consider a one time shock to the value of the outstanding debt, as captured by R_t^l, in our baseline model with nominal rigidities and $\nu = 0$.

[9] In the appendix, we show that when ψ is exactly equal to zero, the first order conditions of the entrepreneur's problem do not select an optimum, but a saddle point. Therefore, we can think of the case with no equity adjustment cost that we study below as a calibration in which adjustment costs are arbitrarily small. In addition, it can be shown that as ψ goes to zero, the derivative of the leverage policy function, η_η, goes to zero as well.

Model with no equity adjustment costs: When it is costless to adjust equity injections at the margin, i.e. $\psi = 0$, the optimality conditions for the entrepreneur's problem can be summarized by the following three equations:

$$K_t = \frac{\omega_t N_t}{Q_t^k - Q_t^l \eta_t}, \tag{43}$$

$$1 = \frac{Q_t^k}{\left(Q_t^k - Q_t^l \eta_t\right)} E_t \Lambda_{t,t+1} \int_{\bar{\xi}_{t+1}}^{\infty} \left(\xi_{t+1} - \bar{\xi}_{t+1}\right) R_{t+1}^k dF_t\left(\xi_{t+1}\right), \tag{44}$$

$$\left(1 - F_t\left(\bar{\xi}_{t+1}^l\right)\right) E_t \Lambda_{t,t+1} \frac{R_{t+1}^l}{\pi_{t+1}} = \left(1 + \epsilon_{\eta_t}\right) - \epsilon_{\eta_t} \frac{\left(1 - \lambda_l\right) \eta_{t-1}}{\eta_t} \frac{1}{\pi_t} \frac{k_{t-1}}{k_t}, \tag{45}$$

where $\epsilon_{\eta_t} = \frac{dQ_t^l}{d\eta_t} \frac{\eta_t}{Q_t^l} < 0$ is the elasticity of the price of debt.

Equation (43) is the entrepreneur's budget constraint. Equation (44) is the optimality condition for leverage, equation (15), where we used the fact that $f'(\omega_t) = 1 = \varphi_t$ when $\psi = 0$. Equation (45) is the optimality condition for leverage, equation (19), after dividing through by Q_t^l and using (44).

With no equity adjustment costs, the value of entrepreneurial net worth, N_t, does not matter for capital demand as entrepreneurs can always adjust equity injections ω_t, to satisfy any given level of capital demand. The level of capital demand is determined by equation (44), which requires that the rate of return on capital leaves the entrepreneurs indifferent between paying out dividends and injecting equity. This rate of return will depend on the leverage choice of entrepreneurs, which affects both the total amount of capital per unit of equity, $\frac{Q_t^k}{Q_t^k - Q_t^l \eta_t}$, and the expected default threshold $\bar{\xi}_{t+1}$.

Figure 2 shows the response of the economy to an exogenous decrease in inflation with no persistence.[10] The blue solid line is the economy where debt has a maturity of seven years, that is $\lambda_l = \frac{1}{28}$, while the dotted red line is an economy with short-term debt, $\lambda_l = 1$. The decline in inflation causes the real value of entrepreneurs debt to increase and hence their net worth to decline. In the economy with short-term debt, entrepreneurs react to this decline in net worth by reducing dividends payouts, hence increasing equity injections, and keeping the allocation unaffected. This is because with short-term debt, the optimal choice of leverage is

[10] This is the same experiment as in Proposition 1 of Gomes et al. (2016). In our flexible price economy we implement this shock by removing the monetary policy rule and replacing it with $\pi_t = exp(\epsilon_t^{\pi})$ where ϵ_t^{π} is an i.i.d. random variable.

not affected by the decline in inflation, as can be seen by substituting $\lambda = 1$ in equation (45). In contrast, with long-term debt, the increase in the real value of debt raises the entrepreneurs benefits from leverage, as shown by the last term in equation (45). This is because the larger value of debt makes it more profitable for the entrepreneur to dilute the preexisting creditors position by increasing leverage and hence decreasing the price of debt. The increase in leverage causes expected defaults to increase and the required expected return on capital implied by optimal equity injections in equation 44 to rise. As a result, in the economy with long-term debt, investment declines in response to a temporary decline in inflation. This mechanism captures the *debt overhang channel* described, for example, in Gomes et al. (2016).

Model with infinite adjustment costs: Turning to the case of infinite equity adjustment costs, i.e. $\psi = \infty$, the optimality conditions are given by:

$$K_t = \omega \frac{K_{t-1}\left(\xi_t R_t^k Q_{t-1}^k - \frac{\left(c_l + (1-\lambda_l) Q_t^l\right)}{\pi_t}\eta_{t-1}\right)}{\left(Q_t^k - Q_t^l \eta_t\right)} \tag{46}$$

$$\omega_t = \bar{\omega} \tag{47}$$

$$\left(1 - F_t\left(\bar{\xi}_{t+1}^l\right)\right) E_t \Lambda_{t,t+1} \varphi_{t+1} \frac{R_{t+1}^l}{\pi_{t+1}} = \gamma_t \left(1 + \epsilon_{\eta_t}\right) - \epsilon_{\eta_t} \frac{\left(1 - \lambda_l\right) \eta_{t-1}}{\eta_t} \frac{\varphi_t}{\pi_t} \frac{k_{t-1}}{k_t} \tag{48}$$

In this case, as entrepreneurs cannot adjust equity injections, the response of net worth is key in determining the overall response of the economy. When net worth declines, entrepreneurs want to increase their leverage, but their ability to do so is limited by the effect of higher leverage on expected default. Two features will determine the overall response of investment to a given shock: the magnitude of the decline in net worth and the degree to which entrepreneurs increase leverage in response to this decline.

Figure 3 shows the response of the economy to the same decrease in inflation as in Figure 2 but in the case of infinite adjustment costs of equity. The decline in net worth caused by the increase in the real value of debt leads to a decline in investment in both the economy with long-term debt, blue solid line, and in the economy with short-term debt, red dotted line.[11] The investment drop however is dampened in the economy with long-term debt. This is due to

[11]The economy with infinite equity adjustment costs and short-term debt is very similar to the framework considered in Bernanke et al. (1999) and Christiano et al. (2014).

two reasons. First, through a *balance sheet channel*, as entrepreneurs increase leverage the price of debt Q_t^l goes down, dampening the drop in net worth, which declines about fifty percent less than in the model with short term debt. Second, the elasticity of leverage to a given drop in net worth is higher with long-term debt because of the extra benefit of borrowing that comes from diluting pre-existing creditors, the last term in equation (48). Due to this *debt dilution channel*, leverage is higher in the economy with long-term debt, even with a smaller drop in equity, dampening the contraction in investment and output (not shown). Interestingly, the same channel that is responsible for the drop in investment when there are no costs of adjusting equity, causes a smaller economic contraction when it is impossible to adjust equity. To highlight this result, the black dashed line in figure 3 reports the model response when we shut down the debt dilution channel, by assuming that the last term in equation (48) is equal to zero. In this case, the impulse response is very close to the one from the model with short term debt, suggesting that, in this experiment, the debt overhang effect is responsible for most of the dampening of the effect of a deflationary shock.[12]

4 Quantitative Exercises

4.1 Model Solution

As discussed above, defaultable long-term debt complicates the solution of the model by requiring the computation of the derivative of entrepreneurs' individual leverage policy function, $\eta_{\eta,t}(\eta_{t-1})$. To overcome this issue, we use an algorithm combining global methods for the solution of the model's steady state with perturbation methods to obtain impulse response functions.[13] In the first step of the algorithm, we use global methods to compute the policy function η_η as a function of η_{t-1} and of a set of aggregate prices Γ_t in steady state, that is $\eta_{\eta,ss} = g(\eta_{ss}, \Gamma_{ss})$. This result is achieved by an iterative procedure which solves for the model's steady state and for $\eta_{\eta,ss}$ simultaneously. In the second step of the algorithm, we approximate $g(\eta_{t-1}, \Gamma_t)$ with a piecewise linear function $\hat{g}(\eta_{t-1}, \Gamma_t)$ in the neighborhood of the steady state.

[12] In this exercise the movement in Q_t^l is fairly small resulting in a small balance sheet effect. As we discuss below, this channel can be much stronger when an exogenous shock, like a monetary policy shock or a credit supply shock, directly lowers the price of oustsanding debt.

[13] A similar algorithm was also used in Ferrante (2019).

This function can then be used as an additional equation of the model. As a result, standard perturbation techniques can be used to simulate the model dynamics. In addition, once we fix ψ and the parameters determining the steady state values of entrepreneurial variables (like leverage, defaults and spreads), this procedure allows us to use standard Bayesian techniques to estimate the model, as we discuss below.

4.2 Model Parameters

We divide the model parameters in three groups. The first group of parameters is calibrated to target steady state moments. The parameter ψ is estimated using firm-level balance sheet data. Finally, the remaining parameters are estimated using Bayesian methods. This approach guarantees that the steady state value of the derivative of the entrepreneur's policy function, $\eta_\eta(\eta_{ss})$, which is computed using global methods, is not affected by the values of the third group of parameters, making estimation feasible.

4.2.1 Calibrated Parameters

Table 1 reports the calibrated parameters in our baseline model. Most parameters are calibrated to standard values from the literature. For household preferences, we assume log utility and a discount factor equal to .995, implying a steady state real interest rate of 2 percent. The inverse Frisch elasticity is set to unity. The capital share in production and the capital depreciation rate are set to 0.4 and 0.025 respectively. The elasticity of substitution across final goods varieties and final labor varieties are calibrated to 6. We set government spending G to 20 percent of output in steady state.

The parameters pertaining to the entrepreneurs are specific to our model. We set λ_l to obtain a loan duration of 7 years, a value in line with the mean bond duration reported by Gilchrist and Zakrajšek (2012). The parameters T^e, σ_l, γ_l and $\bar{\psi}$ are jointly selected to target i) a corporate leverage of 0.6, ii) an annual default rate in steady state of about 3 percent, iii) a spread on corporate bonds, $(R^l_{t+1} - R_{t+1})$ of 100 basis points annualized and iv) a steady state dividend payout ratio $\omega_{ss} = \bar{\omega} = 0.15$. The target for leverage implies a ratio $\frac{K}{N} = 2.5$ in line with the evidence in Kalemli-Ozcan, Sorensen, and Yesiltas (2012). The default rate is close to the value used in Bernanke et al. (1999). The spread is calibrated to the average value of the

difference between Moody's BAA corporate yield and the AAA corporate yield between 1986 and 2019. This spread captures an average measure of default premium, which is the main credit friction in our model's steady state. We set $\bar{\omega} = .015$ as in Christiano et al. (2014), which implies a steady state dividend/output ratio of around 6 percent, similar to the data for the last twenty years. We assume that 100 percent of default costs entail a resource loss ($\nu = 1$), as in Christiano et al. (2014) and Gomes et al. (2016). The parameter governing the equity adjustment costs, ψ, is a novel parameter which plays an important role in our model, because it determines how long-term debt affects the response of the economy to shocks. We describe the empirical procedure we employ to discipline this parameter in the next section.[14]

4.2.2 Estimation of the equity adjustment cost parameter

The parameter ψ controls the quadratic adjustment costs of equity issuance. It is critical in determining the effect of long-term debt in transmitting shocks to the economy. We use our model-implied restriction on this parameter to directly estimate its value. To a first order, the value of ψ will only affect the optimality condition for entrepreneurs' equity injections. In the model, returns on equity injections are defined as

$$R^x_{t+1} = \frac{\int_{\bar{\xi}_{t+1}}^{\infty} v_{t+1}\left(\eta_t, \xi_{t+1}\right) dF_t\left(\xi_{t+1}\right)}{Q^k_t - Q^l_t \eta_t}.$$

The associated optimality condition, given by (15) and reported here for convenience, shows how ψ relates to the expected return to equity injections:

$$E_t \Lambda_{t,t+1} R^x_{t+1} = \frac{1}{f'\left(\omega_t\right)} = \frac{1}{1 - \bar{\psi} - \psi(\omega_t - \bar{\omega})} \tag{49}$$

We then linearize (49) to obtain:

$$E_t r^x_{t+1} - r_{t+1} = \frac{\psi}{1 - \bar{\psi}} d\omega_t \tag{50}$$

where r^x_{t+1} and r_{t+1} are percent deviation of R^x_{t+1} and the real risk free rate from steady state.[15]

We use firm-level balance sheet data from Compustat to estimate this relationship in the

[14] Furthermore, in order to account for the downward trend in inflation in the early part of the sample, we follow Christiano et al. (2014) and calibrate the parameters governing the inflation target shock to $\rho_{\bar{pi}} = 0.975$ and $\sigma_{\bar{pi}} = 0.0001$.

[15] The parameter $\bar{\psi}$ is a very small number and does not affect the regression in a meaningful way.

data. Our sample consists of 19,341 US non-financial firms between 1985q1 and 2023q1.[16] We define the return on equity as firm i's time $t+1$ cum-dividend market value of equity over its time t cum-dividend book value of equity, $R^x_{i,t+1} = \frac{V_{i,t+1}}{X_{i,t}}$. The market value of equity, $V_{i,t+1}$, is measured as the end-of-quarter market value of equity (using Compustat items `cshoq` and `prccq`). The book value of equity, $X_{i,t}$, is given by `ceqq`. Net dividend payouts are given by dividends (`dvy`), minus net repurchases (`sstkyq` - `prstkcyq`). This lets us define ω_{it} as one minus the fraction of net payouts to shareholders over the cum-dividend book value of equity.

We run the following regression using Compustat data:

$$\frac{R^x_{i,t+1}}{1+r_{t+1}} = \psi\omega_{i,t} + \delta_i + \delta_t + \nu_{it}, \tag{51}$$

where r_{t+1} is the quarterly realized real rate and δ_i and δ_t are firm- and time fixed effects.

This approach produces a value of $\psi = 10.86$ with a standard error of 0.13. The result is robust to the inclusion of the fixed effects. Appendix C presents additional details on the robustness of our results. As we will discuss more in detail in the following sections, this value for ψ is high enough to imply that long term debt dampens the effect of most financial shocks.

4.2.3 Estimated Parameters

The remaining parameters are estimated by using quarterly observations on ten variables between 1985Q4 and 2019Q4. We use seven standard macroeconomic variables: GDP, investment, consumption, hours worked, inflation, real wages and the federal funds rate. In addition, we use three financial variables. The spread between BAA-rated corporate bonds and the ten-year US government bond rate, which we measure in the model with the spread on long term corporate loans, $E_t \sum_{i=1}^{28}(R^l_{t+i} - R^d_{t+i})$. Total credit to nonfinancial firms from the flow of funds, measured with $Q^l_t L_t$ in the model. Finally, equity valuations from the Jones Wilshire 5000 index, which we measure with X_t in our model. We take log differences for GDP, investment, consumption, credit, equity and real wages, and we remove the sample mean from all observable variables. [17]

[16] Details about the data can be found in Appendix C.

[17] Real consumption is the sum of nondurable goods and services. Real investment is obtained as the sum of gross private domestic investment plus durable goods purchases. Aggregate hours are an index of nonfarm business hours for all persons. These variables are converted into real, per-capita, terms by dividing them by the population over 16 and by the GDP implicit price deflator. Inflation is measured as the change in the GDP price deflator. Real wages are hourly compensation of all nonfarm employees divided by the GDP deflator. For the federal funds rate, we use the shadow rate from Wu and Xia (2016). Credit is measured as total liabilities

Table 2 reports the priors and posteriors for the estimated parameters. The priors are calibrated as in Christiano et al. (2014). The posterior standard deviations are typically quite smaller than the standard deviation of the prior distributions, suggesting that the data are fairly informative about the estimated parameters. The top panel of table 2 reports the values for the economic parameters, which are within the range of estimates in the literature. The second panel reports the posterior modes for the shock autocorrelation parameters. Most of the shocks are quite persistent, with the exception of the wage markup shock. The standard deviation of the macroeconomic shocks are reported in the bottom panel of table 2. One thing to notice is that our estimation implies that the standard deviation of the anticipated component of the risk shock $\sigma_{\sigma,n}$ is quite larger than the one on the unanticipated component σ_{σ}. As a result, most of the fluctuations in σ_t are due to anticipated shocks.

4.3 Credit Supply Shocks and Business Cycle Fluctuation

The main takeaway from our estimation exercise is that, through the lens of our model with long term debt and costly equity issuance, the credit supply shock is the main driver of business cycle fluctuations. The top panel of table 3 reports the unconditional variance decomposition of key macroeconomic and financial variables for our baseline calibration with long term debt and costly equity issuance. The credit supply shock is the main driver of output fluctuations, by accounting for about 50 percent of the business cycle variance of GDP growth and investment growth. The credit supply shock also explains a good portion of the fluctuations in financial variables, accounting for 47 percent of the variance of the Federal Funds Rate, 21 percent of the variance of credit growth and 15 percent of the variance of equity fluctuations.[18]

Figure 4 complements the results in table 3 by conducting an in sample exercise that compares the behavior of real and financial variables from the data (solid line) with the model-implied simulations obtained by feeding only the estimated credit supply shocks (starred line). The top left panel shows that the credit supply shock does well at reproducing the time series

for nonfarm, nonfinancial corporate business from the Financial Accounts of the US, converted in real per-capita terms as above. Equity is measured as the Dow Joes Wilshire 5000 index, as in Christiano et al. (2014), converted in real per-capita terms as above.

[18]The credit supply shock accounts for a small share of the unconditional variance of spreads, while the bulk of this variable is explained by the risk shock. This result is mostly due to the fact that the additional news component of the risk shock allows this shock to affect more directly the very forward looking spread variable in our model, that is $E_t \sum_{i=1}^{28}(R^l_{t+i} - R^d_{t+i})$.

for output growth over our estimation sample. In particular, the very large contraction in output during the great financial crisis is associated with a large negative credit supply shock. The credit supply shock does also a good job at tracking the behavior of hours and of the policy rate. The remaining panels in figure 4 show that the credit supply shock also produces financial time series in line with the data, especially for credit growth and spread.

Furthermore, figure 5 shows that the credit supply shock generates a path for the dividends to GDP ratio, a series which is not used in the estimation, which is also fairly close to the data.[19] In particular, our model captures the procyclical nature of dividend payouts. This evidence suggests that our estimate for ψ, obtained with cross-sectional data, results in reasonable time series behavior for aggregate non-financial dividends in the model.

Why credit supply shock? The key reason why the credit supply shock is identified as the driving force of the business cycle in our model is that it delivers impulse responses with the right co-movement among real and financial variables. Figure 6 illustrates this result by reporting the impulse responses to a credit supply shock, solid line, in our estimated model. For comparison, we also include two other shocks which have been studied in the literature as important drivers of economic activity: a risk shock, the dashed line, and a shock to the marginal efficiency of investment, the dotted line. A credit supply shock reduces lenders' appetite for corporate loans, increasing credit spreads by about 40 basis points. Given the significant equity issuance costs ($\psi = 10.9$), entrepreneurs are unable to make up for the decline in loans with external equity. As a result, firms cut investment, putting downward pressure on asset prices and causing equity to decline. This mechanism ignites a standard financial accelerator channel, as in Bernanke et al. (1999), which results in a large contraction in investment, output and consumption. Hence, in our model, a credit supply shock is able to deliver the right co-movement between real and financial variables.

Turning to the risk shock and the shock to the marginal efficiency of investment, the key observation is that they both induce a countercyclical response of firms equity. The shock to the marginal efficiency of investment is an exogenous contraction in the supply schedule of investment goods that causes investment and output to decline and the price of capital to increase. As a result firms asset values rise and so does firms equity. The countercyclical

[19] Dividends are measured as in Jermann and Quadrini (2012).

response of firms equity after a contractionary shock to marginal efficiency of investment was already pointed out by Christiano et al. (2014), who argue that this is the reason why the risk shock drives out the MEI shock, as in their framework with short term debt the risk shock induces a procyclical response of equity, as we also show below. However, in our estimated model with long term debt, the equity response to a risk shock is countercyclical. The reason is that the risk shock causes a large increase in firms debt dilution incentives, that is the first term in equation (16), as the increase in risk makes the price of firms liabilities, Q_t^l, more sensitive to firms leverage. The increased incentives to dilute the value of legacy debt results in a larger drop in firms price of debt, Q_t^l, and dampens the decline in leverage, investment and asset prices, Q_t^k, in response to a risk shock. As a result of the larger drop in firms price of debt, Q_t^l, and more modest decline in asset prices, Q_t^k, firms equity drops less, or actually increases as in our estimated model. Figure 7 illustrates this point by showing the responses of debt dilution incentives, together with the prices of assets and liabilities, after a credit supply shock (solid line) and a risk shock (dashed line). The large increase in debt dilution incentives following the risk shock causes a larger drop in the value of liabilities and a smaller drop in the price of capital compared to the responses to a credit supply shock. As a result, equity increases after a risk shock.[20]

To highlight the importance of including equity prices among the variables observed in estimation, the third panel of table 3 shows that if we remove equity as an observable, the main driver of the business cycle is the shock to the marginal efficiency of investment as in Justiniano et al. (2010).

The role of long term debt Table 3 suggests that model assumptions on corporate debt maturity have important implications for the inference of which shocks drive the business cycle. Assuming that corporate debt is mostly long term, in line with the evidence in figure 1, shifts the balance from the risk shock towards the credit supply shocks. The second panel of table 3 reports the variance decomposition obtained when we re-estimate our model assuming short term debt, that is by setting $\lambda_l = 1$. In this case, the risk shock becomes the main driver of fluctuations in output and investment. This result is in line with Christiano et al. (2014) who

[20]Figure A3 in the appendix shows the impulse response to a net worth shock in our model. As suggested by Christiano et al. (2014), this shock generates a countercyclical response of credit.

find that, in a model with short term defaultable debt, fluctuations in σ_t^l are the most important shock for the business cycle.[21]

The reason why the risk shock becomes the main driver of the business cycle in a model with short term debt is that, when debt is short term, an increase in risk induces the right comovement between macro and financial variables. This point is illustrated in figure 8 that shows the impulse response to a risk shock in our baseline (solid line) and in the estimated model with short term debt (dotted line). A higher value of σ_t^l increases the future dispersion of the idiosyncratic entrepreneurial shocks, implying persistently higher defaults and causing credit spreads to rise and credit to decline. When debt is short term, the firm has no debt dilution incentives, as shown in the bottom panel. As a result, an increase in risk causes a smaller drop in the price of debt and a larger drop in leverage, investment, and asset prices, than in the case with long term debt. As asset prices Q_t^k decline, while the price of outstanding debt remains stable, firms equity declines. Hence, in a model with short term debt, a risk shock induces a pro-cyclical response of equity prices, in line with the data.

The role of equity adjustment costs The last panel in table 3 shows that if we re-estimate our model with $\psi = 0$, we obtain a much smaller role for the credit supply shock and the risk shock is again the main driver of fluctuations in output and investment. Figure 9 shows the impulse response to a credit shock (solid line) and a risk shock (dashed line) in the estimated model with $\psi = 0$. Notice that in this case an exogenous increase in the interest rate that firms pay on their liabilities actually results in an increase in output. When firms can adjust equity freely, they respond to a credit supply shock by substituting debt issuance with equity issuance. As a result, a negative credit supply shock with $\psi = 0$ reduces leverage and default rates, weakening the debt overhang effect. As a result, investment and output increase, while credit spreads tighten. This output boom, however, is associated with a reduction in credit. This counterfactual countercyclical behavior of credit in response to credit supply shocks is the reason why the estimation favors the risk shock in this case. However the marginal data density

[21] When setting $\lambda_l = 1$, our model is very similar to the one used in Christiano et al. (2014). However, there are some differences in the modeling assumptions and in the estimation strategy. In particular: i) Christiano et al. (2014) use the contractual framework of Bernanke et al. (1999) which assumes that entrepreneurs bear all the risk from aggregate shocks, whereas we let lenders face credit risk; ii) we use a longer estimation sample and a slightly different set of shocks; iii) in the estimation, Christiano et al. (2014) match the BAA spread, a measure based on long term securities, with the realized one period spread in their model; iv) in our baseline calibration $\psi = 10.86$, whereas Christiano et al. (2014) and Bernanke et al. (1999) assume $\psi = \infty$.

of the model with $\psi = 0$ is 4643, more than 300 points below the marginal data density in our baseline model of 4985.

Overall, the results in table 3 suggest that to capture the importance of credit supply shocks in an estimated DSGE model with financial frictions, three elements are necessary: i) using financial variables as observables, ii) the presence of long term debt, and iii) having large enough equity adjustment costs.

4.4 Debt Maturity and Macroeconomic Shocks

In section 3, we have shown that when $\psi = \infty$ long term debt weakens the effect of a stylized shock to inflation in a simplified version of our model. We now study how debt maturity affects the transmission of standard shocks used in the DSGE literature. Figure 10 reports the impulse responses to five different shocks in the baseline estimated model (blue line) and in a model with the same parameters but with a maturity of corporate debt of only one period (red dashed line).

The first row of figure 10 shows that, compared with a model with short term debt, long term debt dampens the effect of a credit supply shock on output by about 30 percent. In line with the discussion from section 3, this result is mainly due to the larger drop of Q_t^l, which results in a drop in net worth more then 50 percent smaller than in the model with short term debt, and to the higher elasticity of leverage.

The second row, shows that the interaction of the balance sheet channel and debt dilution channel results in a much larger dampening of the effects of a risk shock. As discussed in the previous section, the mitigation of the effects of the risk shock on net worth is key for the estimation results in our baseline model.

The third row of figure 10 reports the impulse responses to a contractionary monetary policy shock. Apart from the behavior of interest rates, the effects of this shock are similar to the ones of a credit supply shock. Also in this case, long term debt dampens the effect of output by about 30 percent, as a lower Q_t^l damplens the drop in equity. This result, suggests that debt maturity might be an important element for the transmission of monetary policy.

The fourth row, reports the impulse responses to a shock to the marginal efficiency of investment. Unlike the other shocks, in this case we have that long term debt actually amplifies

the effect on output. This result is due to the behavior of the price of debt, which, due to the decline in the real rate, increases. Hence, the path of equity is lower, causing also lower investment and output.

Finally, the last row shos the impulse response to a TFP shock. In this case debt maturity does not affect the behavior of output in a meaningful way, since equity and the price of debt move very little.

Hence, figure (10) suggests that, in a model with realistic equity adjustment costs, long term debt generates an important attenuation in the transmission of financial shocks which affect investment demand, like a credit supply shock, a risk shock or a monetary policy shock. In figure (A4), we repeat the exercise in figure (10) but assuming that $\psi = \infty$. Two findings are worth highlighting. First the impulse response with long term debt are fairly similar to the ones in our baseline, suggesting that a value of $\psi = 10.86$ results in substantial equity adjustment costs for firms. Second, when $\psi = \infty$, the gap between the response to financial shocks of the economy with long term debt and the one with short term debt becomes even larger, suggesting that the balance sheet channel and the debt dilution channel strengthen as ψ increases.

5 Conclusion

In the U.S. most corporate debt is long-term. In addition, debt typically represents the main source of finance for firms. This paper studies the macroeconomic implications of these stylized facts in a medium scale New-Keynesian model.

Our main contribution is to show that the interaction between debt maturity and equity adjustment costs is key to determine the dynamic response of the economy to macroeconomic shocks. When firms cannot adjust equity, longer debt maturity generates some insurance against negative shocks. This result is due to two forces: First, the price of outstanding long-term debt typically declines with contractionary financial shocks, dampening the deterioration of firms' net worth; second, a debt dilution incentive causes firms' leverage to increase more, supporting aggregate investment. After estimating equity adjustment costs consistent with empirical data on firms' net dividend payouts, we show that these channels can affect the inference on the macroeconomic shocks driving the business cycle. In particular, our framework highlights the importance of a credit supply shock as a key driver of business cycle fluctuations.

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Table 1: Calibrated Parameters

Parameter	Value	Description	Target/Source
Households			
β	.995	Discount factor	2% Real rate
σ	1	IES	Standard
φ	1	Inverse Frisch El.	Standard
Intermediate production			
χ	.4	Capital share	Standard
ε_p	6	Elasticity of substitution goods	Standard
ε_w	6	Elasticity of substitution labor	Standard
Investment production			
δ_k	.025	Capital depreciation rate	Standard
Government			
G/Y	0.2	Gov. expenditure over GDP	Standard
Entrepreneurs			
λ_l	.0357	Debt duration	7yrs loan maturity
τ^e	.01	Transfer to new ent.	$\eta^l = .6$
σ_l	.26	Variance idiosync. risk	3% Default rate
γ_l	.79	Loans recovery rate	$R^l - R = 100bp$
$1 - \bar{\omega}$	.015	Dividend Payout	CMR
$\bar{\psi}$	0.0045	Linear cost on equity	$\omega_{ss} = \bar{\omega}$
ψ	10.86	Quadratic cost on equity	Compustat reg.

Table 2: Estimated Parameters in Baseline Model

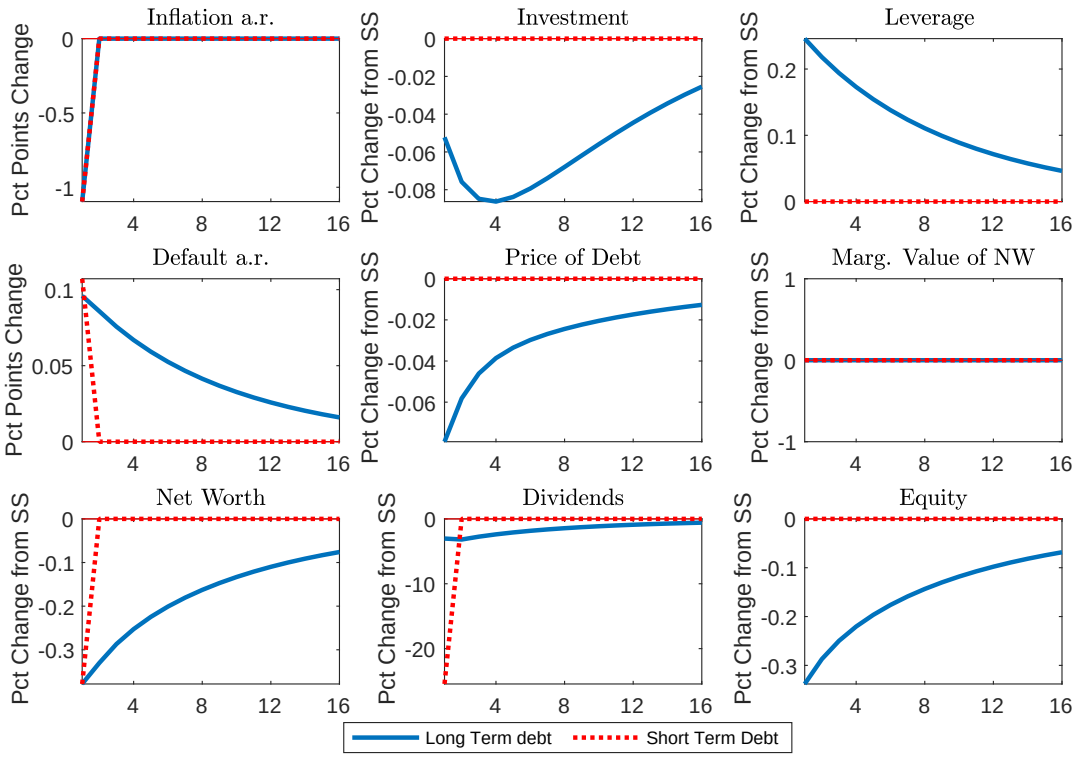
		Prior Distribtuion			Posterior Distribtuion	
Parameter	Description	Prior Dist.	Mean	S.D.	Mode	S.D.
Economic Parameters:						
s_p	Slope price Phillips curve	BETA	.05	.01	.415	.0067
s_w	Slope wage Phillips curve	BETA	.05	.01	.0181	.0037
ι_p	Price indexing	BETA	.5	.15	.90	.04
ι_w	Wage indexing	BETA	.5	.15	.44	.15
κ_π	Policy weight on inflation	NORMAL	1.5	.25	2.53	.14
κ_y	Policy weight on growth	NORMAL	.25	.1	.64	.07
ρ_i	Policy inertia	BETA	.75	.1	.85	.01
b	Habit	BETA	.5	.1	.83	.02
γ_I	Curvature investment costs	NORMAL	5	3	1.20	.15
γ_u	Curvature utilization costs	NORMAL	2	1	4.7	.7
Autocorrelation Parameters:						
ρ_κ	Autocorrelation credit supply	BETA	.5	.2	.84	.012
ρ_σ	Autocorrelation risk	BETA	.5	.2	.98	.008
$\rho_{\sigma,n}$	Autocorrelation risk news	BETA	.5	.2	.58	.008
ρ_I	Autocorrelation M.E.I.	BETA	.5	.2	.99	.002
ρ_ε	Autocorrelation price markup	BETA	.5	.2	.79	.037
ρ_z	Autocorrelation TFP	BETA	.5	.2	.97	.018
ρ_g	Autocorrelation government	BETA	.5	.2	.94	.015
ρ_c	Autocorrelation consumption	BETA	.5	.2	.80	.04
ρ_{ε_w}	Autocorrelation wage markup	BETA	.5	.2	.11	.065
Standard Deviation Parameters:						
σ_κ	S.D. credit supply	IG2	.002	.0048	.007	.001
σ_σ	S.D. risk	IG2	.002	.0033	.0001	.003
$\sigma_{\sigma,n}$	S.D. risk news	IG2	.002	.016	.028	.003
σ_I	S.D. M.E.I.	IG2	.002	.0033	.021	.001
σ_ε	S.D. price markup	IG2	.002	.0033	.001	.0001
σ_z	S.D. TFP	IG2	.002	.0033	.0046	.0003
σ_g	S.D. government	IG2	.002	.0033	.017	.001
σ_c	S.D. consumption	IG2	.002	.0033	.026	.0032
σ_{ε_w}	S.D. wage markup	IG2	.001	.0033	.009	.0001
σ_N	S.D. equity shock	IG2	.002	.0033	.028	.0017
σ_R	S.D. monetary policy	IG2	.583	.825	.46	.0355

Table 3: Variance Decomposition

Baseline Model								
	Credit Supply	Risk	M.E.I.	NW	Markup	Gov	M.P.	TFP
GDP	44	4	6	5	19	8	4	4
Investment	52	4	15	5	14	0	3	2
Consumption	6	4	23	1	2	1	0	4
Spread	6	63	27	3	0	0	0	0
Equity	15	4	13	64	1	0	2	0
Credit	21	10	34	31	1	0	1	0
Inflation	37	7	10	1	21	1	5	5
FFR	47	11	29	2	1	1	2	1
Hours	26	9	37	1	16	2	2	2
Wages	1	1	3	0	10	0	0	3
Model with Short Term Debt								
	Credit Supply	Risk	M.E.I.	NW	Markup	Gov	M.P.	TFP
GDP	5	24	4	9	24	10	5	8
Investment	11	35	13	12	17	0	4	4
Consumption	6	4	15	1	3	1	0	7
Spread	99	1	0	0	0	0	0	0
Equity	5	11	29	48	3	0	5	0
Credit	2	18	9	66	2	0	1	1
Inflation	7	22	18	2	18	1	5	8
FFR	14	28	33	3	2	1	4	2
Hours	10	17	20	2	26	2	2	4
Wages	1	2	2	0	11	0	0	4
Model with Long Term Debt and No Equity Observable								
	Credit Supply	Risk	M.E.I.	NW	Markup	Gov	M.P.	TFP
GDP	8	1	25	2	19	18	5	6
Investment	28	2	38	3	16	0	5	3
Consumption	10	0	0	0	2	2	1	6
Spread	47	22	0	12	0	2	0	2
Equity	13	1	0	70	2	1	8	0
Credit	16	4	4	45	7	2	5	1
Inflation	19	1	4	1	33	2	8	6
FFR	42	2	7	2	4	4	8	2
Hours	22	2	9	1	26	5	3	4
Wages	1	0	0	0	10	0	0	3
Model with Long Term Debt and $\psi = 0$								
	Credit Supply	Risk	M.E.I.	NW	Markup	Gov	M.P.	TFP
GDP	9	54	5	3	17	2	6	3
Investment	9	53	9	4	17	0	6	1
Consumption	4	15	24	1	22	1	1	8
Spread	9	21	25	2	39	0	1	3
Equity	11	4	11	50	17	0	4	2
Credit	12	11	44	13	16	1	1	1
Inflation	7	28	26	1	28	0	3	4
FFR	6	32	24	2	30	0	2	2
Hours	2	15	14	1	60	1	2	4
Wages	2	13	7	0	19	0	1	3

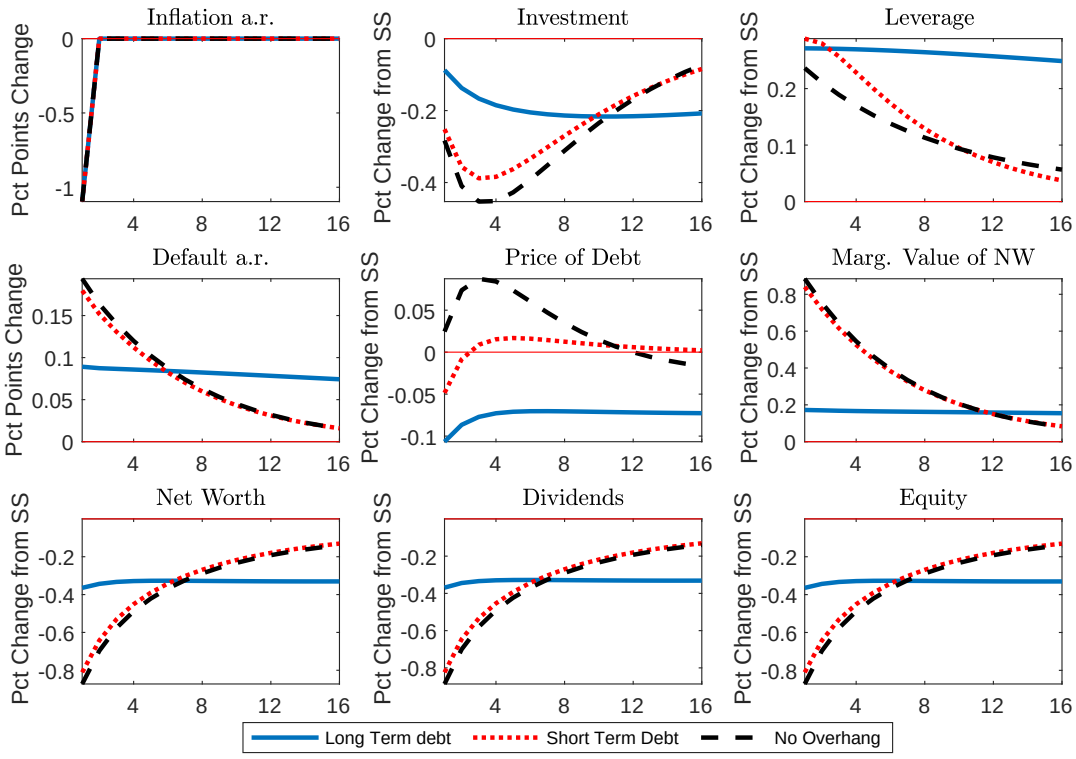
Notes: This table reports the variance decomposition of the observables used in the estimation. The decomposition is computed at the posterior mode for the estimated parameters. The column labeled "Risk" combines the contribution of the unanticipated and of the anticipated risk shock.

Figure 2: Inflation shock in model with flexible prices: no equity adjustment costs



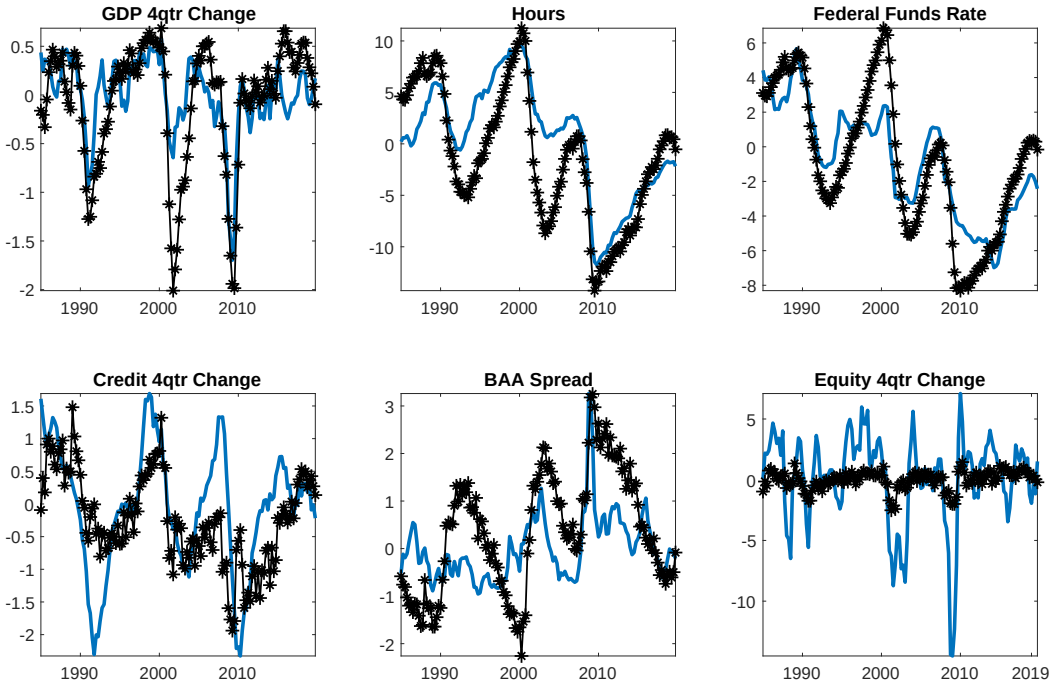
Notes: This figure shows the impulse response to a one time shock to inflation in a simple version of the main model with flexible prices and no real default costs.

Figure 3: Inflation shock in model with flexible prices: infinite equity adjustment costs



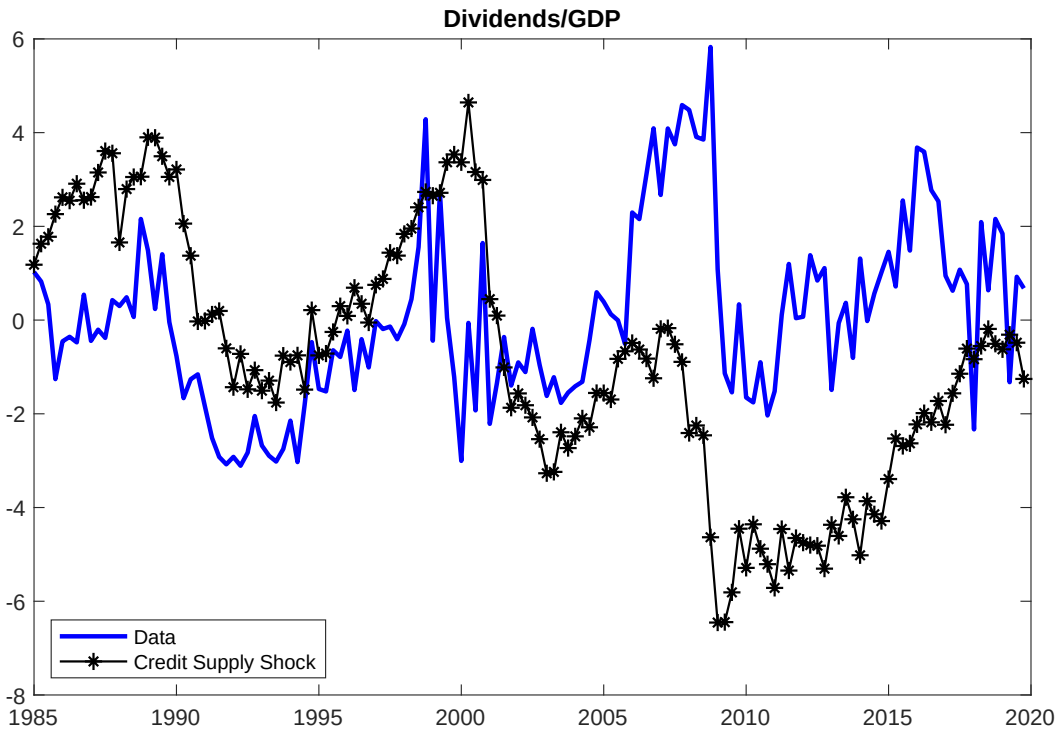
Notes: This figure shows the impulse response to a one time shock to inflation in a simple version of the main model with flexible prices and no real default costs.

Figure 4: The role of the credit supply shock



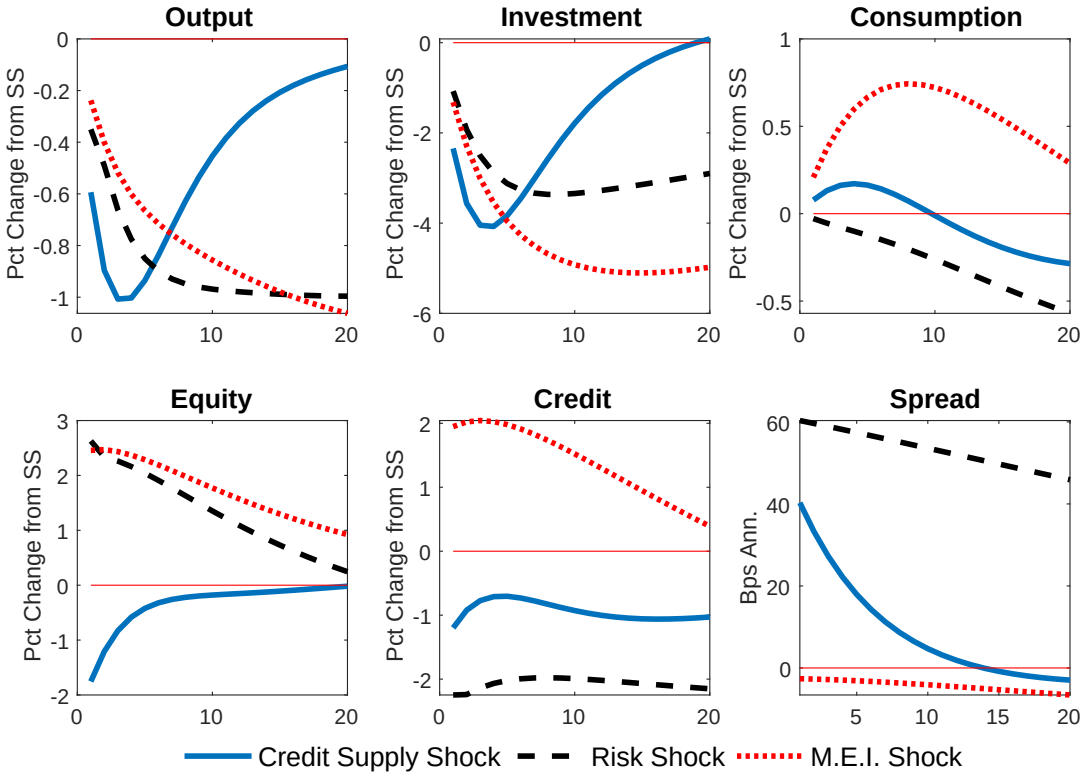
Notes: This figure compares the behavior of selected variables in the data (blue line) with the model-implied behavior attributed to the filtered credit supply shocks (black line). Variables are reported in deviation from their mean.

Figure 5: The role of the credit supply shock: Dividends/GDP



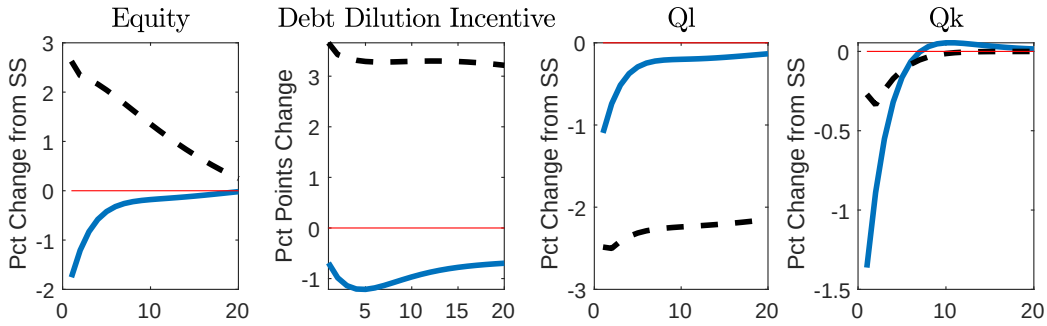
Notes: This figure compares the behavior of Dividends/GDP in the data (blue line) with the model-implied behavior attributed to the filtered credit supply shocks (black line). Variables are reported in deviation from their mean.

Figure 6: Credit supply shock, risk shock and MEI shock



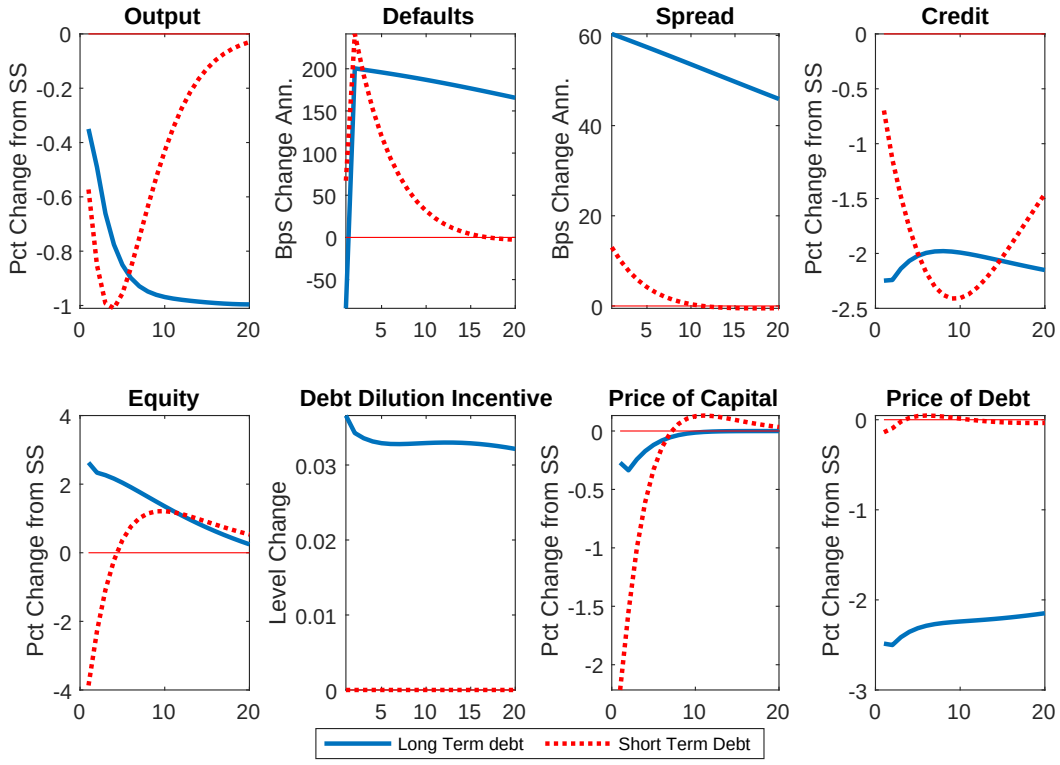
Notes: This figure shows the impulse response to a credit supply shock (solid line), a risk shock (dashed) and a shock to marginal efficiency of investment (dotted) in our baseline model.

Figure 7: Equity response to credit shock and risk shock in baseline model



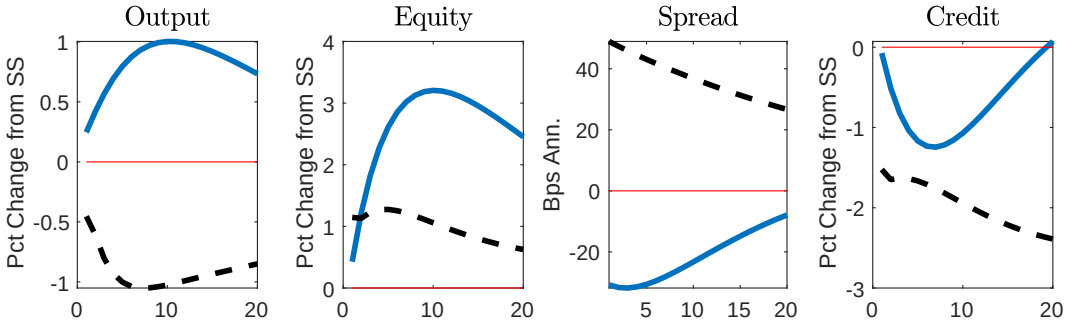
Notes: the figure reports the impulse response to a credit supply shock (blue line) and to a risk shock (dashed line) in our baseline model.

Figure 8: Risk shock in baseline model and in model with short term debt



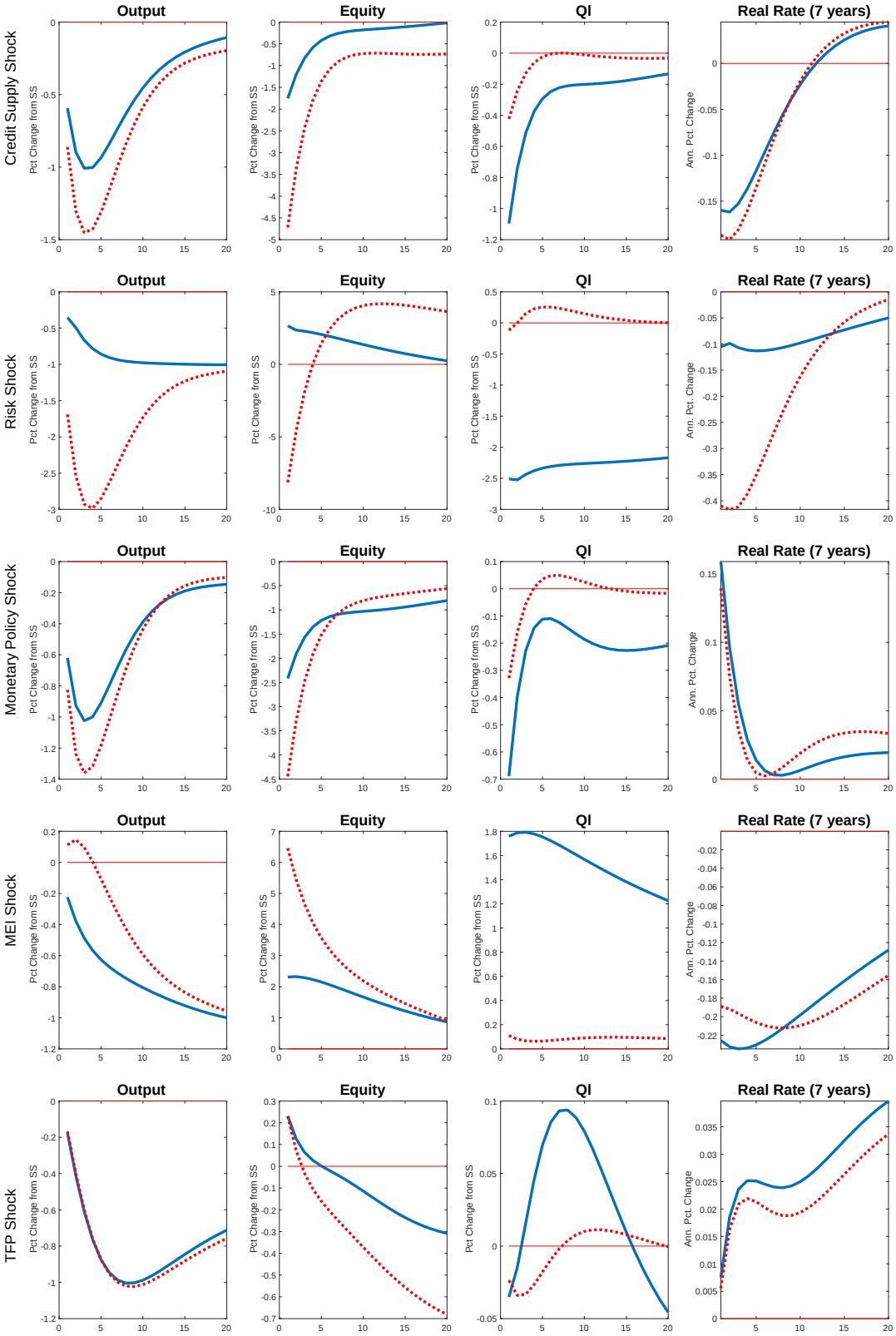
Notes: this figure reports the impuls responses to a risk shock in our estimated baseline model with long term debt (blue line) and in the estimated model with short term debt (red dashed line). Shocks are normalized to deliver a 1 percent decline in output.

Figure 9: Credit shock and risk shock in model with no equity adjustment costs



Notes: the figure reports the impulse response to a credit supply shock (blue line) and to a risk shock (dashed line) in a model with no equity adjustment costs ($\psi = 0$).

Figure 10: Macroeconomic Shocks in Baseline model vs Short-term debt Model



Notes: This figure compares the impulse responses in our estimated baseline model (blue line) and in a model with all the same parameters but with short term debt (red dashed line). All shocks are re-scaled to obtain a one percent drop in output in our baseline.

Appendix

A Properties of the model with $\psi = 0$

TBA

B Algorithm to compute η_η

TBA

C Details on estimation of ψ

This appendix provides more detail on the data treatment, estimation, and robustness of the results presented in Section 4.2.2.

We perform the following cleaning steps on our quarterly Compustat sample. We remove firms in the finance, government, and utility sectors. We remove non-US firms. Observations with negative total assets are dropped. We transform cumulative variables `sstky|`, `dvy`, and `prstkcy` into quarterly variables.

Our dependent variable is $R^x_{i,t+1} = \frac{V_{i,t+1}}{X_{i,t}}$, where $V_{i,t+1}$ is the $t+1$ cum-dividend market value of equity. It is constructed using Compustat variables `cshoq`×`prccq` + `netpayouts`, where `netpayouts` = `dvyq` - (`sstkyq` - `prstkcyq`). We remove negative observations of $V_{i,t+1}$. The denominator $X_{i,t}$ is the cum-dividend book value of equity, defined as `ceqq` + `netpayouts`. Again, we remove negative observations.

Our key independent variable is $\omega_{it} = 1 - \frac{\texttt{netpayouts}}{X_{i,t}}$, i.e., one minus the fraction of net payouts to shareholders over the cum-dividend book value of equity. We remove observations of ω_{it} that include negative values of $X_{i,t}$.

Finally, we trim the independent variable at the 5th and 95th percentile. The dependent variable is truncated at zero from below, we therefore only trim it at the 95th percentile.[22]

[22] Winsorizing instead of trimming the data leads to similar results.

The regression we run is

$$\frac{R^x_{i,t+1}}{1+r_{t+1}} = \psi\omega_{i,t} + \delta_i + \delta_t + \nu_{it}, \tag{52}$$

where r_{t+1} is the quarterly realized real rate and δ_i and δ_t are firm- and time fixed effects.

Our results are shown in Table 4. The first column shows the regression coefficient of the model estimated in (52). Columns (2) and (3) show the effect of removing the firm or time fixed effects.

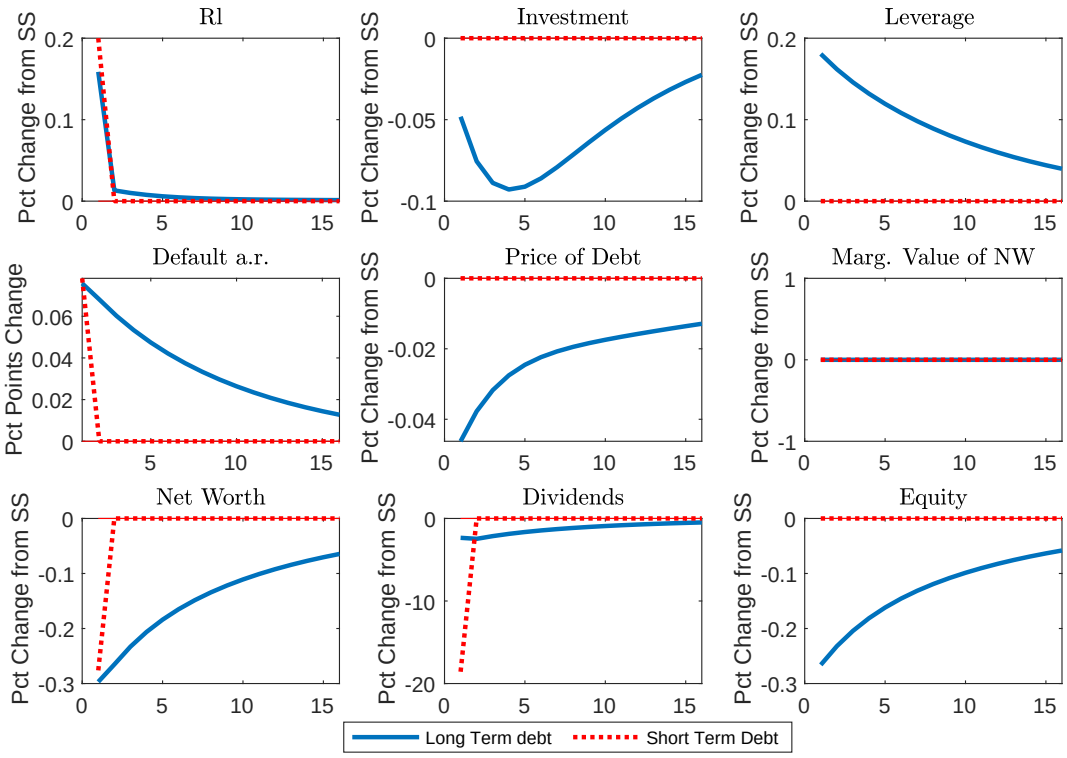
Table 4: Estimating the equity adjustment cost parameter

	(1)	(2)	(3)	(4)	(5)	(6)
ω	10.86	15.45	11.77	10.78	15.31	11.69
	(0.13)	(0.15)	(0.13)	(0.13)	(0.15)	(0.13)
Firm fixed effects	yes	no	yes	yes	no	yes
Time fixed effects	yes	yes	no	yes	yes	no
Additional cleaning	no	no	no	yes	yes	yes
N	512,318	512,848	512,318	494,201	494,651	494,201

Robustness As a robustness exercise, we perform additional cleaning steps. We only keep firms with at least five quarters of information in the sample. Further, we remove firm-quarters that violate the accounting identity by more than 10 per cent of the book value of assets (as in **?**). Lastly, we drop firms involved in major mergers (Compustat footnote `saleq_fn1` code "AB"). As indicated in columns (4)–(6) of Table 4, these additional cleaning steps hardly affect our results.

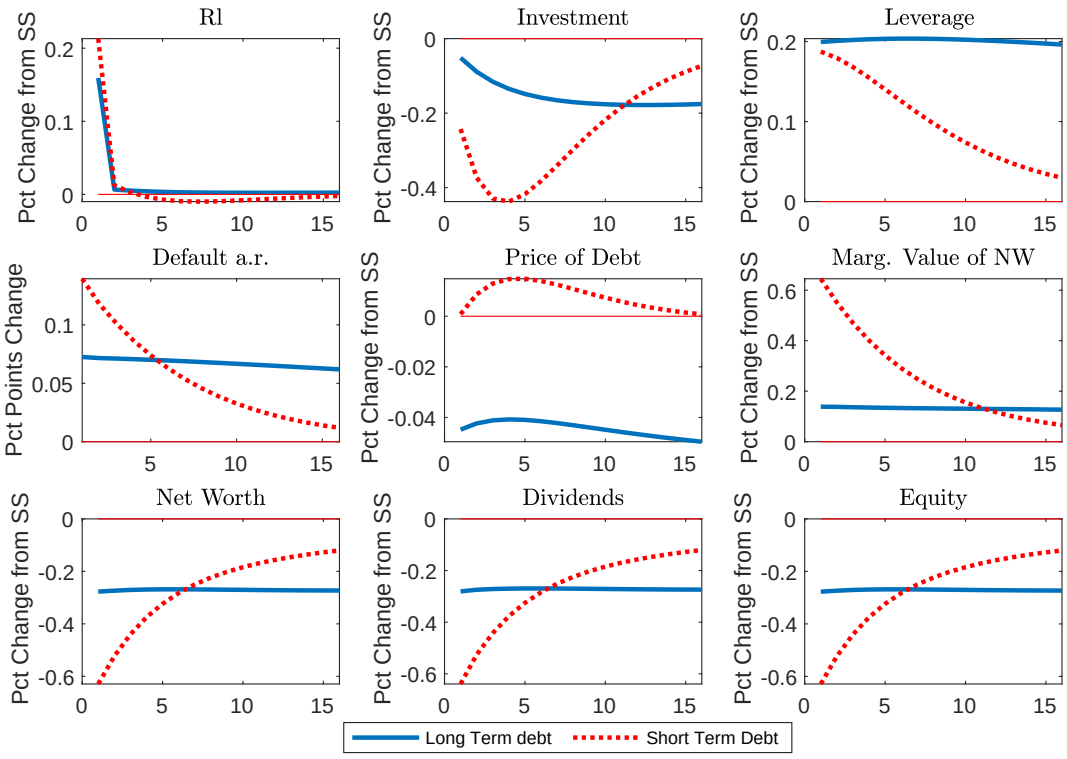
D Additional model experiments

Figure A1: Debt shock in model with flexible prices: no equity adjustment costs



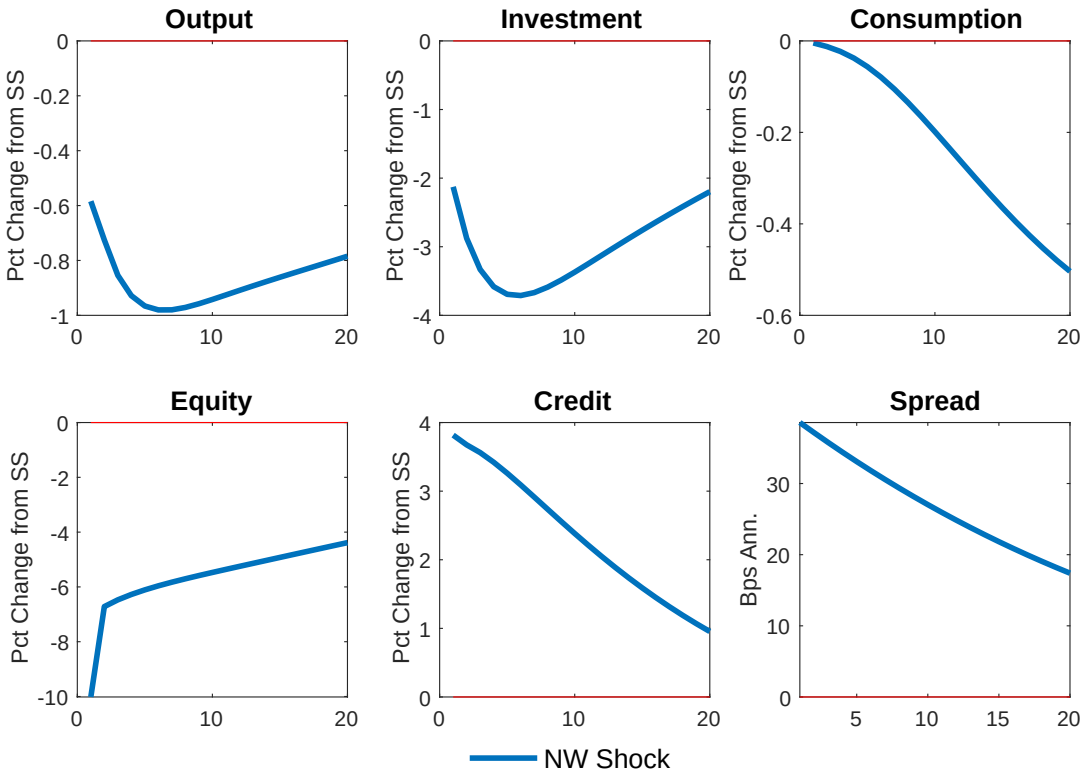
Notes: This figure shows the impulse response to a one time shock to the value of outstanding debt in a simple version of the main model with flexible prices and no real default costs.

Figure A2: Debt shock in model with flexible prices: infinite equity adjustment costs



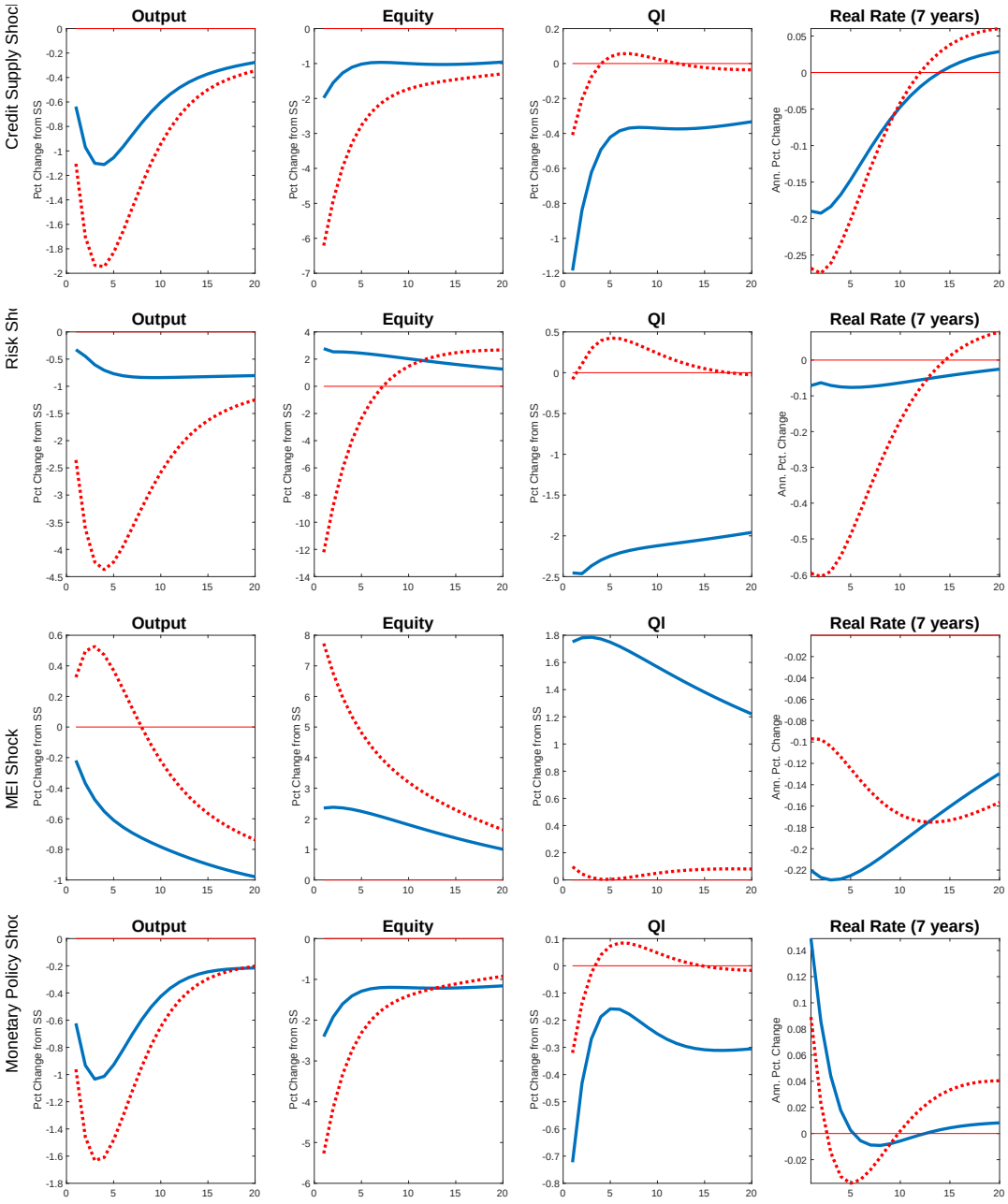
Notes: This figure shows the impulse response to a one time shock to the value of outstanding debt in a simple version of the main model with flexible prices and no real default costs.

Figure A3: Net worth shock in baseline model



Notes: This figure shows the impulse response to a shock to the entrepreneurial net worth in our baseline model.

Figure A4: Long term debt vs short term debt in baseline model with $\psi = \infty$



Notes: This figure compares the impulse responses in our baseline model (blue line) and in a model with short term debt (red dashed line) to the same shocks used in figure 10, but assuming that $\psi = \infty$.