Firm Debt Deflation, Household Precautionary Savings, and the Amplification of Aggregate Shocks[*]

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Abstract

Deleveraging shocks that increase household precautionary savings, and financial and uncertainty shocks to firms, interact and amplify each other, even when these same shocks separately have moderate effects on output and employment. This result is obtained in a model in which heterogeneous households face financial frictions and unemployment risk and in which heterogeneous firms borrow funds using nominally fixed long-term debt and face costly bankruptcy. This novel amplification mechanism is based on a dynamic feedback between the precautionary behavior of households and the bankruptcy and entry decisions of firms. Our results support the view that firm financial frictions are important to understand the effect of household deleveraging on unemployment, consistent with recent empirical studies examining the 2007-2009 Great Recession.

1 Introduction

A growing body of work argues that shocks to household aggregate demand and shocks to firms' access to credit were both important to explain the decline in output and employment during the 2007-2009 Great Recession. On the household side, Mian and Sufi (2014) show that real estate price declines in the U.S. forced consumers to delever and reduce their spending, and that this demand shock was a key factor in increasing unemployment during the 2007-2009 recession.[1] On the firm side, several studies suggest that adverse shocks to the supply of credit significantly restricted firms' ability to hire and invest during this period.[2] Combining both insights, Giroud and Mueller (2017) show that the vast majority of the employment losses caused by the impact of demand shocks occurred in firms with weak balance sheets. This joint importance of firm and household shocks is also emphasized by Gilchrist, Siemer, and Zakrajsek (2018) and Gertler and Gilchrist (2018).

This evidence suggests that it is important to understand the *interaction* between firm credit shocks and household deleveraging shocks. However, despite an extensive literature introducing financial factors into theories of aggregate fluctuations, little is known about how shocks to households and firms interact with each other when they occur simultaneously. Do they have largely independent effects on aggregate fluctuations? Or are there important interactions and feedback effects between these shocks? And if so, do they dampen or amplify each other? This paper addresses these questions by developing a rich general equilibrium framework with heterogeneity, financial frictions, and idiosyncratic shocks both on the household and on the firm side of the economy.

On the household side, we follow Bayer et. al. (2018) and consider heterogeneous households who face incomplete markets, unemployment risk, and hold both liquid and illiquid assets. On the firm side, we consider heterogeneous firms who face financial frictions and borrow using nominally rigid long-term debt, as in Gomes, Jermann, and Schmid (2016). Firms and workers meet in a frictional labor market, which generates endogenous unemployment. We calibrate the model to match several moments of the US economy. We then analyze the transition dynamics of key aggregate variables following unexpected aggregate shocks.

Our simulations show that the feedback effects between households' and firms' decisions, and their aggregate implications, are particularly rich in this environment. An increase in bankruptcies, after

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[1]Additional work stressing the role of the household aggregate demand channel is Hall (2011), Mian, Rao, and Sufi (2013), and Midrigan and Philippon (2016).

[2]See Chodorow-Reich (2014), Mondragon (2014), and Siemer (2016), among others.

a negative financial or uncertainty shock on the firms' side, increases uncertainty and unemployment risk for the households. Importantly, there is a significant increase in uncertainty also for currently employed workers, when the firm that employs them has a higher default risk. This higher uncertainty increases households' demand for liquid assets for precautionary reasons, reduces their consumption, and generates deflationary pressures. Expected deflation increases the real cost of long-term debt and reduces the value of existing firms, increasing default rates. Expected debt deflation also erodes the value of new firms, reducing job creation and making the rise in unemployment more persistent. Expecting higher labor market uncertainty for a longer period, households further increase precautionary saving, worsening deflationary pressures. We quantify the importance of this amplification by comparing the benchmark economy with an economy in which this household precautionary saving feedback channel is eliminated (inflation is kept constant at the steady state level). A shock to the firm side of the economy that increases unemployment from 4.9% to 7.4% in the counterfactual exercise with constant inflation generates, instead, an increase of unemployment to close to 10% in the benchmark model with endogenous deflation caused by households' precautionary savings.

This feedback effect that amplifies firm-level shocks also operates when shocks—such as a deleveraging shock—are originated on the household side. Therefore, our environment is potentially able to significantly amplify and propagate these shocks, and their effects on aggregate output and employment, when they occur simultaneously.

Taken together, the results in this paper highlight the importance of the interaction between the behavior of heterogeneous households and firms for the amplification of the real effects of financial and uncertainty shocks. These theoretical results are useful to better understand the dynamics of the recent Great Recession. In particular, they support the view that firm leverage and firm level shocks are important to understand the effect of household deleveraging on unemployment, consistent with the empirical evidence of Giroud and Mueller (2017) and others.

Related Literature.

Our work is motivated by the empirical studies that analyze the role of financial frictions in explaining the surge in unemployment during the recent Great Recession. A strand of this work has documented that firm-level employment growth was significantly lower in credit constrained firms (Campello, Graham and Harvey (2010), Chodorow-Reich (2014), and Khan and Thomas (2013)), suggesting that firm financing frictions played an important role in unemployment dynamics during this period. Another

strand has focused on the household sector and shown that geographical areas in the US in which household deleveraging was stronger had larger employment drops, more severe economic downturns and slower recoveries (Mian, Rao, and Sufi (2013), Mian and Sufi (2014)). Bridging both pieces of evidence, Giroud and Mueller (2017) show that the impact of demand shocks on employment occurred almost exclusively through highly leveraged firms. Our paper provides a quantitative theoretical mechanism consistent with all of the evidence above, and in particular with Giroud and Mueller's (2017).

This paper is related to several strands of theoretical literature. A large body of work has explored the role of firm financing frictions for aggregate dynamics, starting with Bernanke Gertler and Gilchrist (1999) and Kiyotaki and Moore (1997), mostly focusing on how credit constraints affect the accumulation and allocation of capital, and more recent work has focused on the consequences of firm financing frictions for unemployment (Wesmair and Weil (2004), Monacelli, Quadrini and Trigari (2011), Jermann and Quadrini (2012), Khan and Thomas (2013), Chugh (2013), and Petrosky-Nadeau (2014)). Jermann and Quadrini (2012), similar to us, focus on the effect of financial shocks on firm employment in an environment with borrowing constrained firms, but ignore household sector financial frictions, which is a central ingredient in our mechanism.

Our paper is also related to the literature that, starting with Bewley (1977), studies the macroeconomic implications of incomplete markets for households that face idiosyncratic income risk. In particular, several papers develop models showing how demand shocks caused by households' deleveraging, or by precautionary saving in response to unemployment risk, reduce output in the presence of nominal rigidities in prices or wages (Eggertsson and Krugman (2012), Ravn and Sterk (2013), Challe, Matheron, Ragot, Rubio-Ramirez (2014), and Bayer, Lütticke, Pham-Daoz and Tjadenz (2018)). The demand structure of our paper is similar to these studies. However, we differ in the modelling of the firm sector, and in our emphasis on firm financial frictions as the main channel that interacts with demand shocks to cause large recessions. The paper is also related to Guerrieri and Lorenzoni (2012), who also consider a shock that causes households' deleveraging in a model with heterogeneous entrepreneurial households who face uninsurable idiosyncratic shocks and borrowing constraints.

There has been little work that studies economies in which both households and firms are subject to financial frictions (some exceptions are Gerali, Neri, Sessa, and Signoretti (2010) or Christiano, Eichenbaum and Trabandt (2014)), and to the best of our knowledge, this is the first paper to focus on how they interact with each other.

Finally, in emphasizing the importance of nominally fixed debt, our paper and the modelling of the firms side of our economy is closely related to Gomes, Jermann, and Schmid (2016), who develop a business cycle model in which unanticipated shocks to inflation change the real burden of corporate debt and distort corporate investment and production decisions, and to Eggertsson and Krugman (2012), who consider nominal household debt rigidities as the main friction behind the role of aggregate demand disturbances.

The remainder of the paper is organized as follows. Section 2 introduces the model, and Section 3 describes the calibration and the steady state equilibrium of the economy. The main quantitative results are in Sections 4 and 5, and in Section 6 we analyze the role of nominal wage rigidity. Section 7 concludes.

2   The Model

We introduce an infinite horizon, discrete-time closed economy populated by a measure 1 of households, who provide their labor to firms. Firms are owned by mutual funds, and shares in these funds, which are in fixed aggregate fixed supply, are a store of value and give the right to receive dividend payments from the mutual funds. Firms produce a perishable consumption good with a production function that features idiosyncratic productivity shocks. In Section 3.2, we solve for the equilibrium in the steady state, and in Section 4, we analyze the transitional dynamics following one-time unexpected aggregate shocks.

2.1   Firms

A mutual fund creates a firm when a vacancy is matched with an unemployed worker, a process that is described in detail in Section 2.2. In this section, we describe operating firms' production opportunities, financing options, and their exit decision.

Production Opportunities

Each firm i produces consumption goods using as factors of production one unit of labor and a fixed amount k of capital. Production is subject to idiosyncratic productivity shocks that are i.i.d. across firms and over time. More specifically, firm i produces each period an amount of consumption goods equal to z, which is constant across time and firms, plus a risky idiosyncratic amount $\varepsilon_{i,t}$ that is i.i.d. across firms and time, and follows a with mean zero, density function $\phi(\varepsilon)$, and support $[\underline{\varepsilon}, \overline{\varepsilon}]$. The firm

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sells each consumption good at price P_t. The per-period nominal operating profits of a firm are defined as

$$\pi_{i,t}^n(\varepsilon_{i,t}) \equiv P_t\left(z + \varepsilon_{i,t}\right) - w_t^n, \tag{1}$$

where w_t^n is the wage paid to the worker. This wage is determined according to an expected revenue sharing rule given by

$$w_t^n = \varphi P_t z, \tag{2}$$

where φ satisfies $0 < \varphi < 1$. Implicit in this rule are the assumptions that the idiosyncratic shock is not contractible, so the wage w_t^n cannot be made contingent on ε_t, and that the wage is common across firms.[3] For ease of notation, from now on we drop the reference to each individual firm i. Moreover we divide by the price level P_t to obtain real profits $\pi_{i,t}(\varepsilon_{i,t})$:

$$\pi_{i,t}(\varepsilon_{i,t}) \equiv (z + \varepsilon_{i,t}) - w, \tag{3}$$

where real wage is $w = \varphi z$,

Firms' capital depreciates at a rate δ every period, so that investment every period of a firm in operation is δk.

Sources of Finance

The sources of finance and the financing frictions of firms are modelled following Gomes, Jermann, and Schmid (2016) to be able to replicate some key realistic features. First, firms use long-term defaultable nominal debt, so reductions in the price level increase its real value. Nominal debt rigidity is crucial to understand firm dynamics during financial crises, when lower than anticipated inflation increases the real value of debt burdens, and this feature cannot be evaluated adequately with the standard assumption of one-period debt. Second, firms with a high real debt burden face costs of financial distress in the form of ex post costly bankruptcy and ex ante indirect costs. Third, firms fund themselves by choosing the appropriate mix of debt and equity, both of which are priced fairly by taking into account default and inflation. The choice between debt and equity is driven by the standard trade off theory, in which firms trade off the tax benefits of debt and the worsening effect of debt on

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[3]A more sophisticated wage setting based on a bargaining process between worker and firm over the surplus generated by the match is not likely to substantially change the results. On the one hand, it would imply falling wages for firms that make losses and face an increase in their bankruptcy probability, thus helping them to avoid financial distress. On the other hand, the fall in wages following negative aggregate shocks would put additional downward pressure on prices and worsen the financial condition of firms, thus increasing the probability of bankruptcy, as we show later.

costly financial distress.

We assume–as in Gomes, Jermann, and Schmid (2016)–that in every period a fraction λ of the stock of outstanding defaultable nominal debt B_t^n is paid back, while the remaining $(1 - \lambda)$ remains outstanding. The firm is also required to pay a periodic nominal coupon c per unit of outstanding debt, which is tax deductible. Let Q_t denote the market price of one unit of debt in terms of the consumption good. The proceeds from new debt issues in real terms, or, if negative, the payments for debt reductions, are:

$$Q_t \Delta B_{t+1} = Q_t \left[\frac{B_{t+1}^n}{P_t} - (1 - \lambda) \frac{B_t^n}{P_t} \frac{P_{t-1}}{P_{t-1}} \right] = Q_t \left[B_{t+1} - (1 - \lambda) \frac{B_t}{\mu_t} \right].$$

Where $\mu_t = \frac{P_t}{P_{t-1}}$ is the inflation rate between time t-1 and time t. For the remainder of the paper we will use real values.

Equity Value

Dividends paid to shareholders (the mutual funds) are

$$d_t = (1 - \tau) \pi_t - ((1 - \tau) c + \lambda) B_t + Q_t \Delta B_{t+1} - (1 - \tau) \delta k - \Omega (B_{t+1}), \tag{4}$$

where τ is the corporate tax rate and $\Omega (B_{t+1})$ are costs of financial distress suffered in period t as a function of the debt B_{t+1} carried over to period $t + 1$. These costs are explained in detail below. Expression (4) captures the assumption that operating profits net of capital depreciation and interest rate payments are subject to corporate taxation. Total tax payments are $\tau (\pi_t - cB_t - \delta k)$.

At the beginning of the period, the shock ε_t is realized, and the firm decides whether or not to default. If it does not default, then it produces, pays the wage and suffers the depreciation of capital, and decides dividends payments and debt issuances. The value of the firm to its shareholders, denoted $J(B_t, \varepsilon_t, \mu_t)$, is equal to

$$J(B_t, \varepsilon_t) = \max_{\sigma_t} \left[0, (1 - \tau) \pi_t - ((1 - \tau) c + \lambda) \frac{B_t}{\mu_t} + \tau \delta k + V (B_t) \right], \tag{5}$$

where the continuation value $V (B_t, \mu_t)$ is defined as follows:

$$V (B_t) = \max_{B_{t+1}} \left\{ Q_t \Delta B_{t+1} - \delta k - \Omega (B_{t+1}) + \frac{1}{R_{t+1}} \int_{-\infty}^{\infty} J(B_{t+1}, \varepsilon_{t+1}) d\Phi (\varepsilon_{t+1}) \right\}, \tag{6}$$

and $\sigma_t = \{0, 1\}$ is a choice variable that takes value 1 if the firm decides to default and 0 otherwise.

The rate at which firms discount future nominal dividends is $R_{t+1} = 1 + r_{t+1}$, which is the equilibrium rate of return on shares.

The value function $J(B_t, \varepsilon_t)$ is bounded at zero due to limited liability, which means that we can define a threshold ε_t^* for the idiosyncratic shock below which the firm chooses to default.[4,5] This threshold is given by

$$0 = (1 - \tau)\pi_t(\varepsilon^*) - ((1 - \tau)c + \lambda)\frac{B_t}{\mu_t} + \tau\delta k_t + V(B_t). \tag{7}$$

We can substitute (5) and (7) into (6) to get

$$V(B_t) = \max_{B_{t+1}} \left\{ Q_t \Delta B_{t+1} - \delta k - \Omega(B_{t+1}) \right.$$
$$\left. + \frac{1}{R_{t+1}} \int_{\varepsilon_{t+1}^*}^{\infty} \left[(1 - \tau)\pi_{t+1} - ((1 - \tau)c + \lambda)\frac{B_{t+1}}{\mu_{t+1}} + \tau\delta k + V(B_{t+1}) \right] d\Phi(\varepsilon_{t+1}) \right\}. \tag{8}$$

Financial Distress and Default

In default, the firm is liquidated before period t production occurs. Bondholders receive the recovery value of the capital $(1 - \xi)k$, where $0 \leq \xi \leq 1$. The implicit assumption is that bondholders do not have the necessary knowledge to continue running the firm, and ξ can be interpreted as a fire sale cost of liquidating the capital of the firm.

Given these assumptions, the price of debt can be obtained as

$$Q_t B_{t+1} = \frac{1}{R_{t+1}} \left[1 - \Phi(\varepsilon_{t+1}^*) \right] \left[c + \lambda + (1 - \lambda)Q_{t+1} \right] \frac{B_{t+1}}{\mu_{t+1}} + \frac{1}{R_{t+1}} \Phi(\varepsilon_{t+1}^*) \left[(1 - \xi)k \right].$$

The anticipation of the possibility of bankruptcy creates costs to the shareholders of the firm given by

$$\Omega(B_{t+1}) = \eta \Phi(\varepsilon_{t+1}^* | B_{t+1}) \varphi(B_{t+1}),$$

where φ is a convex function of B_{t+1}. These costs of financial distress are modelled in the spirit of Miao and Wang (2010) and Quadrini and Sun (2015), and capture several indirect ex ante costs of

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[4]Note that the threshold ε^* is a function of the state variable B_t.

[5]We assume that the shareholders are not allowed to exit voluntarily and keep the capital k. If the value of debt to repay $Q_t B_t$ is lower than the value of capital, the shareholders would be willing to voluntarily exit when

$$0 < (1 - \tau)\pi_t - ((1 - \tau)c + \lambda)\frac{B_t}{\mu_t} + \tau\delta k + V(B_t) < k - Q_t B_t.$$

However, it is likely that the above condition is never satisfied in this model.

high indebtedness. Miao and Wang (2010) introduce exogenous agency costs of debt with a similar functional form. Quadrini and Sun (2015) introduce a cost of financial distress as a convex function of the amount of borrowing over the level determined by a collateral constraint. The costs arise from the need to raise costly funds to satisfy the collateral constraint. Gomes, Jermann, and Schmid (2016) derive ex ante costs of debt endogenously. A debt overhang effect distorts the optimal investment policy and generates underinvestment. Introducing ex ante costs of financial distress is supported by their well-documented importance.[6] Deriving these costs endogenously in our setting, however, would require introducing several additional elements (such as an endogenous investment level, risk premia, or customer relationships) that would reduce the tractability of our model and not deliver any additional insight.

2.2 Firm creation

The probability at the beginning of period t that a firm exits is denoted by $\sigma_t(B_t)$:

$$\sigma_t(B_t) = \Phi\left(\varepsilon_t^* | B_t\right) \tag{9}$$

There is a large number of managers available to run firms, a number in excess of the number of unemployed consumers $N_{u,t}$, and a continuum of mass 1 of identical mutual funds, which create vacancies. A new firm created in period t has initial long-term debt $B_t = k$. Therefore its expected value before the shock ε_t is realized is $\int_{-\infty}^{\infty} J(B_t) d\Phi\left(\varepsilon_t\right)$.

The cost of creating M_t firms in period t, in terms of units of the consumption good, is $\xi_t = \xi(N_{u,t}, M_t)$. The function $\xi(N_{u,t}, M_t)$ captures all of the costs of firm creation, and includes the costs of searching for employees and managers and matching them together, and the convex adjustment costs of capital formation. We derive the specific functional form of $\xi(N_{u,t}, M_t)$ in Section 3.1. Free entry requires that the number of new firms M_t satisfies:

$$\int_{-\infty}^{\infty} J(B_t, \varepsilon_t) d\Phi\left(\varepsilon_t\right) = \frac{\partial \xi(N_{u,t}, M_t)}{\partial M_t}. \tag{10}$$

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[6]There are many studies documenting that there are quantitatively important indirect effects that hurt operating activities and firm value in the neighborhood of financial distress. Opler and Titman (1994) find that highly leveraged firms experience significantly higher losses in market share compared to their less leveraged industry peers in industry downturns. Later empirical studies have also found substantial ex ante costs of financial distress related not just to product markets, but also to capital markets, debt overhang costs (such as underinvestment and asset substitution), or risk premia, for example (Bris, Welch, and Zhu (2006), Carlson and Lazrak (2006), Almeida and Philippon (2007), Berk, Stanton, and Zechner (2010), and Van Binsbergen, Graham, and Yang (2010). Furthermore, debt overhang effects have been argued to account for most of the effects of financial crises (Reinhart and Rogoff (2011) and Mian and Sufi (2014)). Nini, Smith and Sufi (2012) study violations of financial debt covenants, a very common form of financial distress, and show that they are associated with a loss of net worth of around 13% of total assets.

The right hand side of (10) captures the cost of creating one additional firm while the left hand side is the value of a new firm. The equilibrium in the firm creation market is ensured by the fact that $\frac{\partial \xi^2(N_{u,t}, M_t)}{\partial M_t^2} > 0$. The resulting firm dynamics are:

$$N_{e,t} = N_{e,t-1} - \int_{-\infty}^{\infty} \sigma_t(B_t) f_t(B_t) dB_t + M_t, \tag{11}$$

where $N_{e,t}$ is the number of employed workers and also the number of firms, while the integral captures the exits of firms at the beginning of this period.

2.3 Mutual Funds

Mutual funds finance firm creation in exchange for share ownership in the firms. In addition, they provide long-term debt finance to firms owned by other mutual funds, in exchange for interest payments. They pay a dividend DIV_t to the holders of mutual fund shares every period, which is given by:

$$DIV_t = payout_t + interest_t - lending_t - \left[\xi(N_{u,t}, M_t) - \phi K_t^S \right]. \tag{12}$$

We define as $f_t(B_t)$ the density of already existing firms with debt level B_t:

$$payout_t \equiv \int_0^{\infty} \left[1 - \sigma_t(B_t) \right] \left[\int_{\varepsilon_t^*}^{\infty} d_t(B_t, \varepsilon_t) d\Phi\left(\varepsilon_t\right) \right] f_t(B_t) dB_t,$$

$$lending_t \equiv \int_0^{\infty} \left\{ \left[1 - \sigma_t(B_t) \right] Q_t \left[B_{t+1} - (1 - \lambda) \frac{B_t}{\mu_t} \right] \right\} f_t(B_t) dB_t + M_t k,$$

$$interest_t \equiv \int_0^{\infty} \left\{ \left[1 - \sigma_t(B_t) \right] (c + \lambda) \frac{B_t}{\mu_t} + \sigma_t(B_t) \left(1 - \xi \right) k \right\} f_t(B_t) dB_t,$$

where $payout_t$ are dividend payments by continuing firms, $lending_t$ is net lending to existing firms plus lending to new firms $M_t k$, and $interest_t$ is repayments to bondholders. The last two terms represent the cost of financing the creation of new firms net of the sale of capital that could not be liquidated in the past. We define K_t^S as the stock of capital liquidated by the exiting firms, and assume that while its resale price is still identical to the price of the consumption good, the mutual funds can only sell a fraction ϕ of it each quarter. Therefore, K_t^S evolves according to the law of motion:

$$K_{t+1}^S = (1 - \phi) K_t^S + (1 - \xi) k \left[\int_0^{\overline{B}} \sigma_t(B_t) f_t(B_t) dB_t \right]. \tag{13}$$

The mutual fund dividend DIV_t, which is paid to the households that own mutual fund shares, perfectly diversifies away firm idiosyncratic risk.

2.4 Households

Households are risk averse and face uninsurable unemployment risk. We assume that households can save by accumulating a riskless bond, and shares in mutual funds. Holdings of both assets have to be non-negative. Moreover, as in Bayer *et al.*(2015) and Kaplan and Violante (2014), we assume that shares are traded infrequently. In particular, we follow Bayer *et al.*(2015) and assume that trading mutual fund shares is subject to a friction: only a randomly selected fraction of households v is allowed to participate in the market for mutual fund shares every period. At the beginning of period t households hold an amount of one period riskless bonds equal to m_t and an amount of shares equal to a_t, for which they receive a return r_t. They also receive, when employed, an income w_t from providing their labor.

Employed households

An employed household which participates to the mutual funds shares market chooses shares holdings a_{t+1}, bond holdings m_{t+1} and real consumption c_t. The budget constraint of the worker is:

$$c_t + a_{t+1} + Q_t^b m_{t+1} = (1 + r_t)a_t + m_t + w_t. \tag{14}$$

Where Q_t^b is the price of one units of bonds, a_t are the value of mutual share holdings at the start of the period, and m_t are the bonds purchased in period $t-1$ and maturing in period t. Workers face financing constraints that mean that they are unable to have negative holdings of both assets.

$$a_{t+1} \geq 0; m_{t+1} \geq 0$$

For an employed household who does not participate in the mutual funds shares market, the budget constraint simplifies to:

$$c_t + Q_t^b m_{t+1} = r_t a_t + m_t/\mu_t + w_t, \tag{15}$$

which takes into account that the household owns an amount of shares $a_\mathbf{t}$ but cannot adjust that amount upward or downward.

We define as $W_t^a(a_t, m_t, B_t)$ the value function of a worker who can participate to the mutual funds shares market and as $W_t^n(a_t, m_t, B_t)$ the value function of a worker who cannot participate:

$$W_t^a(a_t, m_t, B_t) = \max_{c_t, m_{t+1}, a_{t+1}} \left\{ u(c_t) + \beta E_{\varepsilon_t} \left[\begin{array}{c} \sigma_{t+1}(B_{t+1}) U_{t+1}(a_{t+1}, m_{t+1}) \\ + \left(1 - \sigma_{t+1}(n_{t+1}^F)\right) W_{t+1}(a_{t+1}, m_{t+1}, n_{t+1}^F) \end{array} \right] \right\} \tag{16}$$

$$W_t^n(a_t, m_t, B_t) = \max_{c_t, m_{t+1}} \left\{ u(c_t) + \beta E_{\varepsilon_t} \left[\begin{array}{c} \sigma_{t+1}(n_{t+1}^F)U_{t+1}(a_t, m_{t+1}) \\ + \left(1 - \sigma_{t+1}(n_{t+1}^F)\right) W_{t+1}(a_t, m_{t+1}, n_{t+1}^F) \end{array} \right] \right\}, \quad (17)$$

where β is the discount rate. Workers may lose their job with probability $\sigma_{t+1}(B_{t+1})$ the following period and become unemployed. Workers only terminate a match with a firm when the firm exits, because it is never optimal for them to leave a firm voluntarily. A worker that loses his job this period does not enter the pool of unemployed until next period. $U_{t+1}(a_{t+1}, m_{t+1})$ is the value associated with being an unemployed household with asset holdings a_{t+1}, m_{t+1} and $W_{t+1}(a_{t+1}, m_{t+1}, B_{t+1})$ is the value associated with being a worker who is employed in a firm with long-term bond holdings B_{t+1}. Both value functions are measured at the beginning of period $t + 1$, before knowing whether or not they can participate in the shares market. Therefore $W_{t+1}(a_{t+1}, m_{t+1}, n_{t+1}^F)$ is equal to:

$$W_{t+1}(a_{t+1}, m_{t+1}, n_{t+1}^F) = \upsilon W_{t+1}^a(a_{t+1}, m_{t+1}, n_{t+1}^F) + (1 - \upsilon) W_{t+1}^a(a_{t+1}, m_{t+1}, n_{t+1}^F)$$

The solution to the problem faced by an employed worker are policy rules $a_{w,t+1}(a_t, m_t, B_t)$, $c_{w,t}(a_t, m_t, B_t)$ and $m_{w,t+1}(a_t, m_t, B_t)$.

Unemployed households

A consumer who is unemployed during period t and participates in the mutual funds shares market solves the following problem:

$$U_t^a(a_t, m_t) = \max_{c_t, m_{t+1}, a_{t+1}} \left\{ u(c_t) + \beta[(1 - \lambda_{w,t+1})U_{t+1}(a_{t+1}, m_{t+1}) + \lambda_{w,t+1}W_{t+1}(a_{t+1}, m_{t+1}, B_{t+1})] \right\}$$
$$(18)$$

subject to:

$$c_t + Q_t^b m_{t+1} + a_{t+1} = (1 + r_t)a_t + m_t/\mu_t, \quad (19)$$

The probability that a worker finds a job and exits unemployment the following period is $\lambda_{w,t+1}$, and should he find a job, the firm with which he is matched will have just entered the market, with long-term debt B_t equal to the cost of financing initial capital k.

Conversely, an unemployed consumer who cannot participate to the mutual funds shares market solves the following problem:

$$U_t^a(a_t, m_t) = \max_{c_t, m_{t+1}} \left\{ u(c_t) + \beta[(1 - \lambda_{w,t+1})U_{t+1}(a_t, m_{t+1}) + \lambda_{w,t+1}W_{t+1}(a_t, m_{t+1}, B_{t+1})] \right\} \quad (20)$$

subject to:

$$c_t + Q_t^b m_{t+1} = r_t a_t + m_t, \qquad (21)$$

And $U_{t+1}(a_{t+1}, m_{t+1})$ is equal to:

$$U_{t+1}(a_{t+1}, m_{t+1}) = \upsilon U_{t+1}^a(a_{t+1}, m_{t+1}) + (1 - \upsilon) U_{t+1}^a(a_{t+1}, m_{t+1})$$

Households' optimization delivers the following policy functions. For workers participating to the mutual funds shares market: $a_W^{a\prime}(a_W, m_W, B)$, $m_W^{a\prime}(a_W, m_W, B)$, $c_W^a(a_W, m_W, B)$; for workers not participating: $a_W^{n\prime}(a_W, m_W, B)$, $m_W^{n\prime}(a_W, m_W, B)$, $c_W^n(a_W, m_W, B)$. For unemployed participating: $a_U^{a\prime}(a_U, m_U)$, $m_U^{a\prime}(a_U, m_U)$, $c_U^a(a_U, m_U)$; for unemployed not participating: $a_U^{n\prime}(a_U, m_U)$, $m_U^{n\prime}(a_U, m_U)$, $c_U^n(a_U, m_U)$.

2.5 Market Clearing Conditions

Total output is given by output per firm z multiplied by the number of active firms $N_{e,t}$, minus expenditures to create new firms $\xi_t(M_t, N_{u,t})$ plus the output that results from the conversion back into consumption goods of the capital of exiting firms.

Inflation μ is determined by a New Keynesian Phillips curve. Specifically, we use the log-linearized specification from Gali & Gertler (1999, JME)

$$\hat{\mu}_t = \gamma_{BW} \hat{\mu}_{t-1} + \gamma_{FW} \hat{\mu}_{t+1} + \kappa_{PC} \hat{y}_t,$$

where $\hat{\mu} = \log \mu - \log \bar{\mu}$ and $\hat{y} = \log C - \log \bar{C}$ represent log-deviations of inflation and consumption from steady state.

We assume that a monetary authority sets the return on bonds $r_Q = \frac{1}{Q} - 1$ following a monetary policy rule of the form

$$r_Q = \bar{r}_Q + \phi_i \left(r_Q^{old} - \bar{r}_Q \right) + (1 - \phi_i) \left[\phi_\pi \hat{\mu} + \phi_y \hat{y} \right],$$

where ϕ_i regulates the amount of interest rate smoothing, ϕ_π determines the response to inflation, and ϕ_y the response to the output gap. The monetary authority is assumed to supply all bonds demanded by households given the interest rate r_Q, by setting M^s to satisfy

$$\int_0^\infty \int_0^\infty \int_0^\infty \left[\upsilon m_{W,t}^a(a_t, m_t, B_t) + (1 - \upsilon) m_{W,t}^n(a_t, m_t, B_t) \right] f_{W,t}(a_t, m_t, B_t) da_t dm_t dB_t + \qquad (22)$$

$$\int_0^\infty \int_0^\infty \left[\upsilon m_{U,t}^a(a_t, m_t) + (1 - \upsilon) m_{W,t}^n(a_t, m_t) \right] f_{U,t}(a_t, m_t) da_t dm_t = M^s$$

12

where the left hand side of expression (22) captures the aggregate demand for money by employed households and unemployed households.

The equilibrium condition for mutual fund shares is:

$$\int_0^\infty \int_0^\infty \int_0^\infty \left[v a_{W,t}^a(a_t, m_t, B_t) + (1-v) a_{W,t}^n(a_t, m_t, B_t) \right] f_{W,t}(a_t, m_t, B_t) da_t dm_t dB_t +$$

$$\int_0^\infty \int_0^\infty \int_0^\infty \left[v a_{U,t}^a(a_t, m_t) + (1-v) a_{W,t}^n(a_t, m_t) \right] f_{U,t}(a_t, m_t) da_t dm_t dB_t = Q_t^s S \qquad (23)$$

where Q_t^s is the price of one share and the left hand side is the nominal demand for shares. The return on shares R_{t+1} can be expressed as:

$$R_{t+1} = 1 + r_{t+1} = \frac{Q_{t+1}^s + \frac{DIV_{t+1}}{S}}{Q_t^s}. \qquad (24)$$

The numbers of employed and unemployed workers add up to the total population:

$$N = N_{e,t} + N_{u,t}.$$

The goods market equilibrium condition is

$$\int_0^\infty \int_0^\infty \int_0^\infty \left[v C_{W,t}^a(a_t, m_t, B_t) + (1-v) C_{W,t}^n(a_t, m_t, B_t) \right] f_{W,t}(a_t, m_t, B_t) da_t dm_t dB_t + \qquad (25)$$

$$\int_0^\infty \int_0^\infty \left[v C_{U,t}^a(a_t, m_t) + (1-v) C_{W,t}^n(a_t, m_t) \right] f_{U,t}(a_t, m_t) da_t dm_t = P_t \left[z N_{e,t} - \xi(N_{u,t}, M_t) + \phi K_t^S \right],$$

where $f_{W,t}(a_t, m_t, B_t)$ is the function that describes the joint distribution at the beginning of period t of asset holdings of the workers and net asset holdings of the firms for which they work, $f_{U,t}(a_t, m_t)$ is the distribution function of unemployed workers' asset holdings, and $C_{W,t}^a, C_{W,t}^n, C_{U,t}^a$ and $C_{U,t}^n$ are nominal consumption expenditures. Hence the terms in the left-hand-side capture workers' aggregate nominal consumption expenditures (employed and unemployed, respectively). Condition (25) is redundant as, by Walras law, the market for goods should clear once we clear the market for shares and the bond market.

3   Calibration and Steady State

We solve the model numerically and calibrate the economy at the quarterly frequency. We set some parameter values directly based on existing microeconomic and macroeconomic evidence, and calibrate the remaining parameters so that key aggregate variables from the simulated steady state of the model are broadly in line with empirical evidence. We first describe the calibration in detail and then discuss

some properties of the steady state. The Computational Appendix contains an explanation of the computation algorithm used.

3.1 Calibration

Households' subjective discount factor (β) is set to target an annualized steady state real return on shares of 7%. We assume the utility function of households is isoelastic of the form

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma}, \tag{26}$$

As in Kaplan and Violante (2014), we set the risk aversion parameter $\gamma = 4$, which also determines the degree of household precautionary behavior. The relative illiquidity of stocks is driven by the probability households face of being able to trade shares in a particular quarter. Following Bayer et al (2018) and Luetticke (2018), we set this probability to $\upsilon = 6.5\%$.

The calibration of the firm side of the model follows closely the calibration of Gomes, Jermann, and Schmid (2016). We set the labor share of expected revenues to $\varphi = 0.7$, which is a standard value in the literature, and set the firms' productivity to $z = 0.1545$. This implies an implicit rate of return on capital of approximately 4.5%. We assume that the idiosyncratic profit shocks are bounded in $z \in [-1, 1]$ and their probability density function is given by a quadratic polynomial of the form:

$$\phi(z) = \eta_1 + \eta_2 z + \eta_3 z^2, \tag{27}$$

Furthermore, we assume that this distribution is symmetric and has mean zero, which pins down the value of the parameters η_2 and η_3. Parameter η_1 is inversely related to the variance of the idiosyncratic shocks. We set this parameter to $\eta_1 = 0.77$ to match the variance of establishment-level TFP shocks in non-recession years reported by Bloom et al (2018). We normalize the amount of capital k to 1, and set the depreciation rate $\delta = 0.025$. The corporate tax rate is set to $\tau = 0.40$ and the quarterly coupon rate is set at $c = \mu/\beta - 1$. The corporate debt amortization rate is $\lambda = 0.05$, with average expected debt life of $1/\lambda = 20$ quarters or 5 years. The function $\Omega(B_{t+1})$ is assumed to take the form

$$\Omega(B_{t+1}) = \eta \Phi\left(\varepsilon_{t+1}^*|B_{t+1}\right) B_{t+1}^2,$$

where $\Phi\left(\varepsilon_{t+1}^*|B_{t+1}\right)$ is the probability of default next period conditional on the choice B_{t+1}. Parameter η is calibrated together with the loss given default for bondholders ξ to match the steady-state leverage ratio of 42% and a steady-state default rate of 0.26% reported in Gomes. et. al. (2016).

The aggregate matching function for the labor market is as in den Haan, Ramey, and Watson (2000). It is assumed to be constant returns to scale of the form

$$M(N_{u,t}, N_{v,t}) = \frac{N_{u,t} N_{v,t}}{\left(N_{u,t}^L + N_{v,t}^L\right)^{\frac{1}{L}}},\tag{28}$$

which ensures that the number of matches never exceeds $\min(N_{u,t}, N_{v,t})$. The two parameters that affect the labor market, which are the vacancy costs ($\xi = 0.044$) and the matching efficiency ($L = 0.27$), are set jointly to match a target the level of the unemployment rate and the vacancy-unemployment ratio in steady-state. Hall and Milgrom (2008) and Pissarides (2009) report average vacancy-unemployment ratios (N_v/N_u) of 0.5 and 0.72 respectively.

Steady state inflation and nominal riskless returns are set to $\mu = 2\%$ and $r_Q = 4\%$ (in annualized terms). The parameters of the Phillips curve are set to: $\kappa_{PC} = 0.02$, $\gamma_{BW} = 0.339$ and $\gamma_{FW} = 0.539$, which correspond to the restricted estimates of Gali and Gertler for the sample 1980-1997. The parameters of the Taylor-type monetary policy rule are set to ϕ_i=0.8 (interest rate smoothing), ϕ_π =1.5 (response to inflation), and $\phi_y = 0$ (response to output gap). The central bank supplies all bonds demanded by households at this price so this market clears in every period.

3.2 Steady State

We simulate the steady state of an economy with $200,000$ households and a number of mutual fund shares M equal to $200,000$.

We now briefly describe the policy functions of firms and households. Firms' choice variables are their debt level B_{t+1} and their voluntary exit decision. It is optimal for firms to delay dividend payments until they exit, as discussed in Section 2. Figure 1 displays optimal firm debt choices and other relevant firm-level variables. Firm value, in the top left panel, is a negative function of the amount of debt brought over by the firm. The optimal debt choice is displayed in the middle top panel. Firms have an optimal capital structure at the intersection of the solid and dashed lines. When they are below their optimal debt level, they jump to it almost immediately. When they are above their optimal debt level, however, they adjust their debt holdings only slowly. This effect is reminiscent of a similar mechanism in Gomes, Jermann, and Schmid (2016) that generates persistence in leverage. Because debt is priced on the margin, a firm that has a large amount of debt and wants to delever finds it optimal to delever slowly. Delevering immediately means that the firm would have to retire outstanding debt at a relatively high price. This price effect is clear in the top right panel. The price of debt is a negative and highly
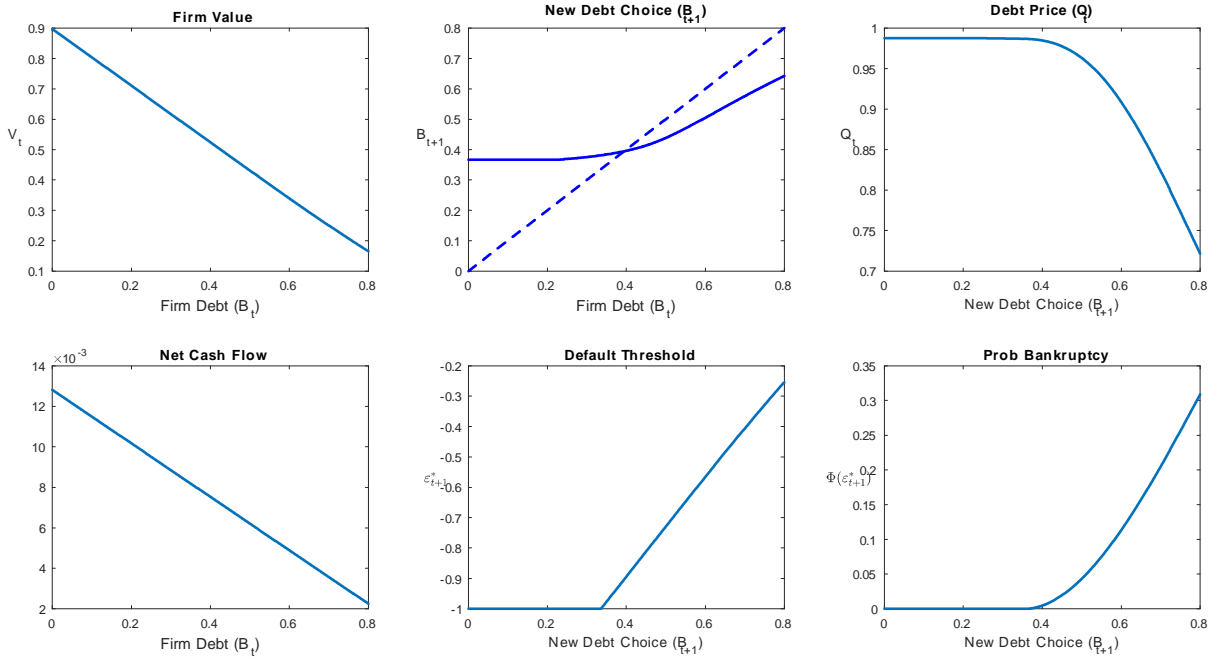
Figure 1: Firm Variables in the Steady State Equilbrium

nonlinear function of the amount of debt issued in period t (B_{t+1}). The reason why the price of debt is so sensitive to the amount of debt issued is clear from the bottom right panel, in which we depict the probability of facing bankruptcy in period $t+1$ as a function of the debt choices made in period t. For low debt level choices, firms will never find it optimal to default ex post the following period. But that choice is not optimal in the presence of a tax advantage of debt, and the optimal debt level obtains when the likelihood of default next period is strictly positive.

One of the main contributions of this paper is to model an endogenous response of households to the balance sheet strength of the firm they provide their labor to. Figure 2 displays the saving and portfolio allocation policies of employed households as a function of the amount of debt in the firm they work for. Given that firms are homogeneous ex-ante, all employed households face the same employer indebtedness. The more indebted the firm, the lower is the propensity of its worker to consume out of income, and the stronger is the incentive of its worker to invest in more liquid (safer) saving instruments (in our case, bonds).
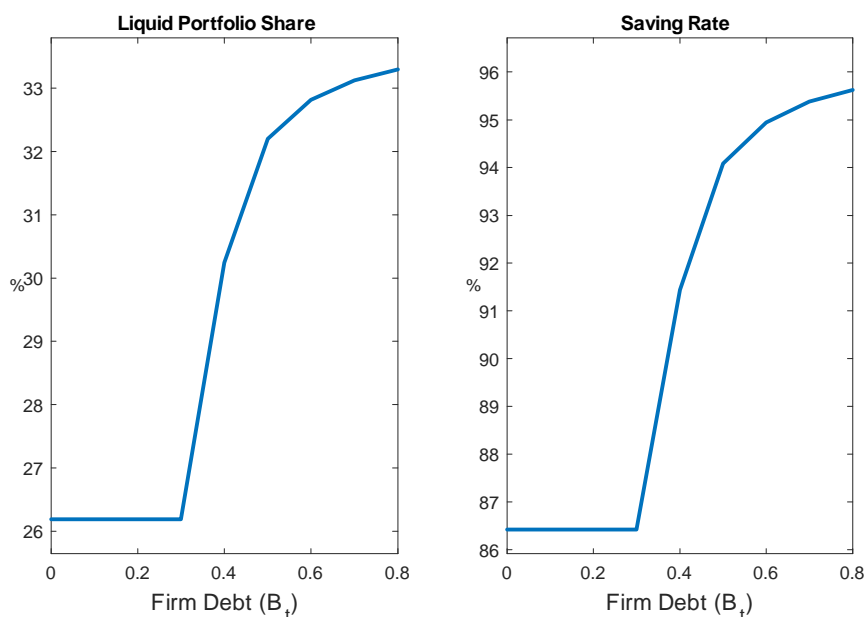
Figure 2: Household's Saving and Porfolio Choice Policies in the Steady State Equilbrium as a Function of its Employer's Financial Strength

4 Transition Dynamics Following Shocks to Households and to Firms

This section analyzes the dynamics of the economy following unexpected temporary aggregate financial shocks. We assume that the economy is in its steady state in period $t = 0$, and that in period $t = 1$ agents are hit with an unexpected aggregate shock (or a combination of shocks). We study the dynamics of the economy during T periods, and choose a value of T sufficiently large so that the economy reverts to the original steady state before $t = T$. We describe our solution method in detail in the Computational Appendix.

The purpose of this exercise is to study the dynamic interaction between shocks to households, which affect the aggregate demand for goods, and credit shocks to firms. We will show that when both households and firms are subject to unexpected negative financial shocks, the reduction in firm creation, output and employment is much larger and more persistent than when the shocks hit only households or only firms. We demonstrate that the interaction between these two shocks is driven by dynamic feedback effects between the precautionary behavior of households and firms.
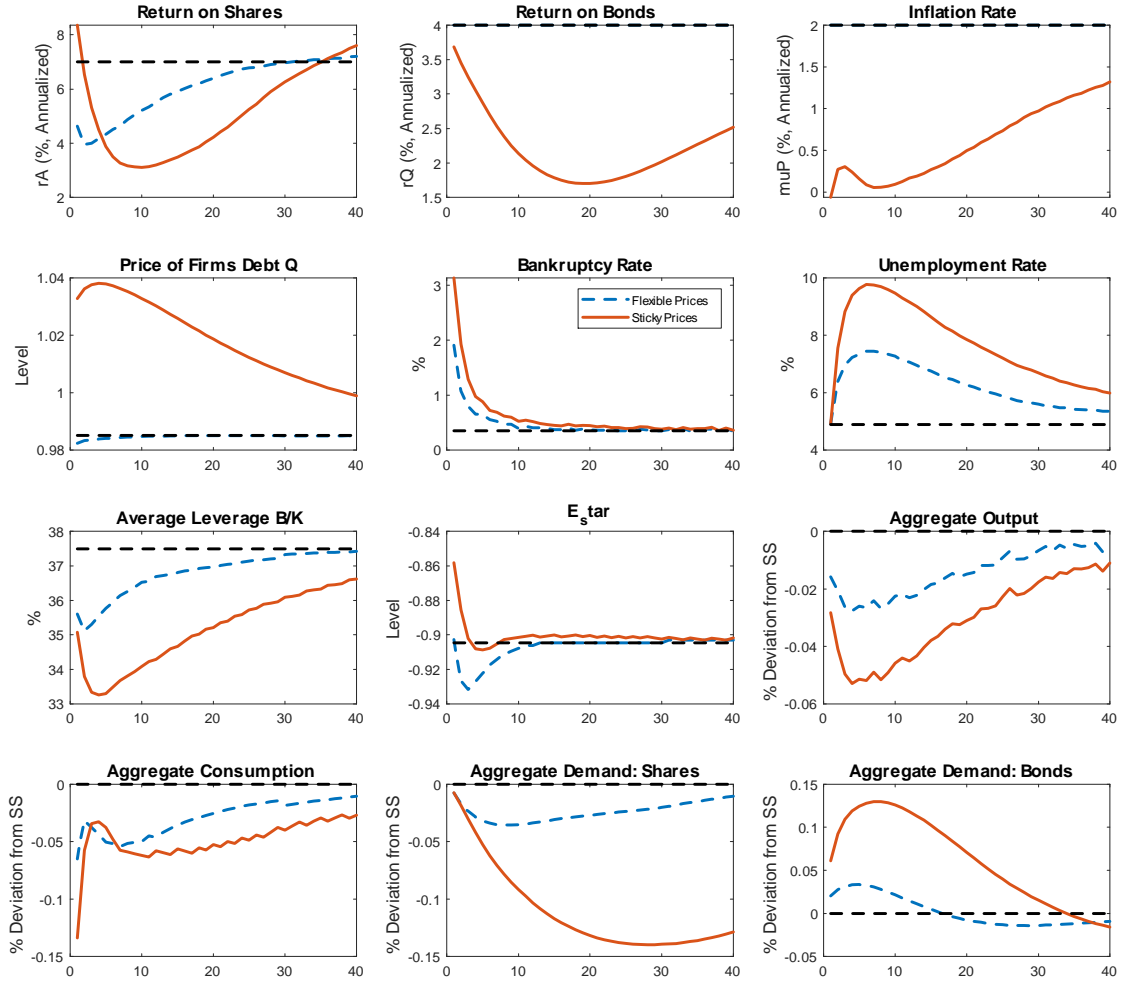
Figure 3: Transition Dynamics - Uncertainty Shock to Firms in Isolation

4.1 Simulation results with only individual shocks

We first consider separately the occurrence of a shock to households and of a shock to firms. In both cases, we contrast the responses in a version of the economy with flexible prices and a version of the economy with sticky prices. The flexible price scenario is implemented by setting $\kappa_{PC} = 0$ in the Phillips Curve equation, so that variations in consumption do not affect inflation. The sticky price scenario is the one with kappa is as in the baseline calibration. The flexible price scenario essentially shuts down the feedback effect from household consumption through inflation and into corporate debt revaluation and default. This exercise is designed to quantify how much amplification we get from the feedback from household decisions through inflation.

We start with the shock to firms. The shock takes the form of a disturbance to the volatility of their idiosyncratic risk, similar in spirit to the 'risk shock' in Christiano, Motto, and Rostagno (2014). In particular, we shock parameter η_1 by reducing it to increase variance. The results of simulating this shock are in Figure 3. This figure plots the evolution of of key aggregate variables; return on shares, inflation, return on liquid bonds, debt, exit threshold, unemployment rate, probability of bankruptcy, and price of debt in levels, and consumption, output, bond holdings, and share holdings in percent deviation from steady state. The uncertainty shock has the immediate effect of increasing the risk of bankruptcy for firms, which shoots up, on impact, nearly 3 percentage points on a quarterly basis in the version of the model with benchmark stickiness of prices (solid red line). There is a large drop in consumption and in inflation in the version with sticky prices, but inflation remains constant in the version with flexible prices (blue dashed line). While the likelihood of default also rises in the absence of any changes to the inflation rate, it remains much lower when inflation is higher; this is due to the effect of a lower inflation hurting firms by increasing the real value of their debt (relative to a scenario with a higher inflation rate). The unemployment rate when the drop in household spending is allowed to affect inflation reaches a much higher peak (close to 10%) than in the scenario in which aggregate demand fluctuations have no effects on the inflation rate (unemployment barely goes above 7%).

We turn now to the deflationary shock exercise. This is a shock that exogenously lowers the inflation rate and persists because of the backward looking component of the Phillips Curve. As before, we contrast the responses in a version of the economy with flexible prices (dashed blue line) and a version of the economy with sticky prices (solid red line). In both cases, the effect of a decrease in inflation in firms' real value of debt results in a moderate increase in the bankruptcy rate. The eventual drop in consumption and its effect on inflation means that, in the version of the model with a feedback from aggregate household spending and inflation, the inflation drop is more persistent and so are the effects on bankruptcy and on unemployment and output.

4.2 Simulation Results with Simultaneous Shocks to Firms and Households

In this section, we discuss the main insight of our paper, which is that when the two shocks occur simultaneously, their effects interact with and amplify each other to generate a very large and persistent negative impact on firm creation, output and employment. Figure 5 replicates the simulations in Figures 3 and 4 for the case of sticky prices and adds the simulation results when both shocks are present. At its peak, unemployment has increased 0.6 percentage points in the simulation with only a demand
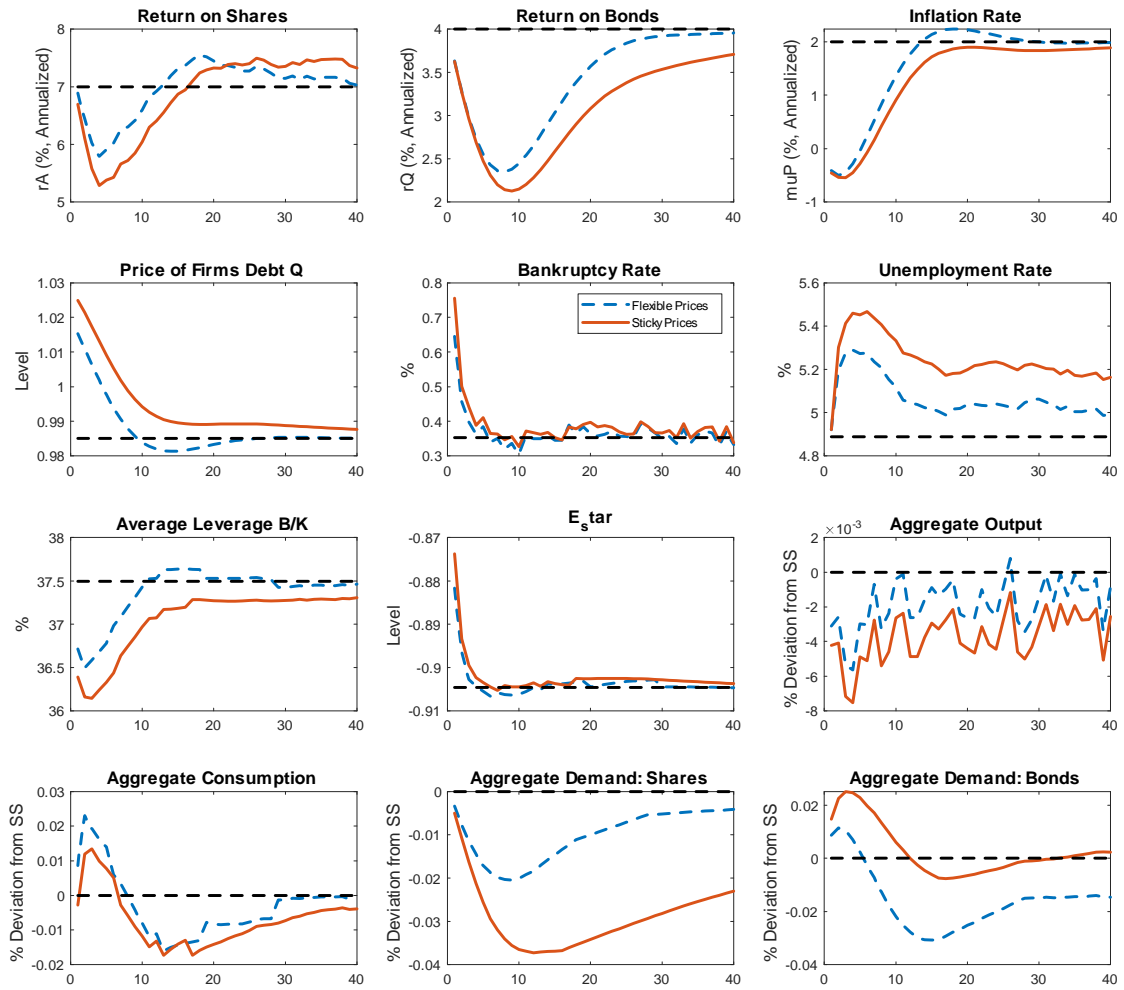
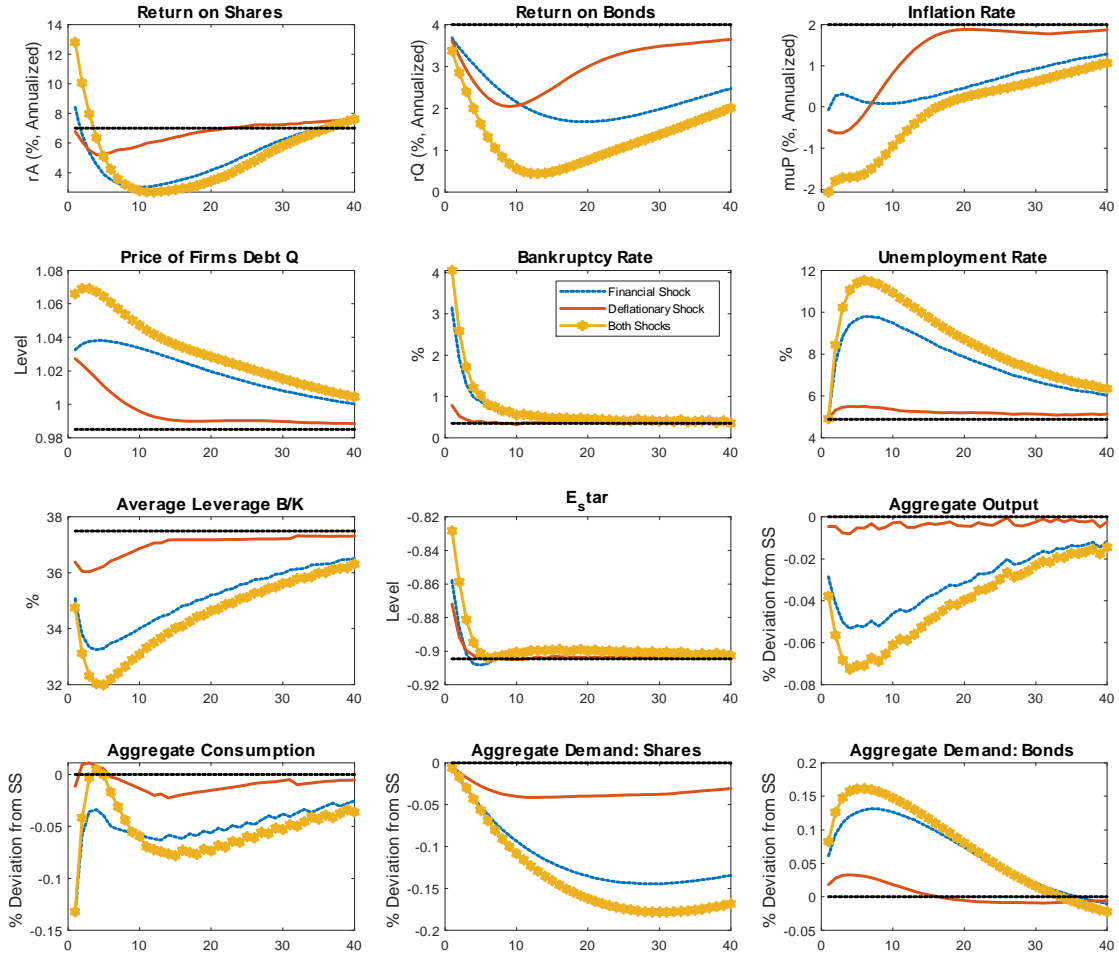Figure 4: Transition Dynamics - Deflation Shock in Isolation

Figure 5: Transition Dynamics - Uncertainty Shock to Firms and Deflation Shock in Isolation and Combined

shock, by 4.9 percentage points in the economy with only the firms' credit shock, and by 6.7 percentage points in the economy with both shocks present. The two shocks interact in such a way that not only substantially increases the peak unemployment rate, but also makes it very persistent.

This amplification and persistence result is caused by the dynamic interaction between the precautionary behavior of heterogeneous firms and heterogeneous households. First, the early voluntary liquidations of firms generate an initial sharp increase in firm destruction and a surge in unemployment. Bankruptcy rates are very high, nearly 4 percentage points higher than in the steady state in the first period following the shocks. By contrast, there is a one percentage point lower default rate in the economy with no aggregate demand shock. These voluntary exits are caused by future expected

financial problems, not just current ones. These firms expect the demand shock to generate a lower inflation rate for a long time in the future, reducing nominal revenues, at the same time as the credit shock increases the volatility of their profits, worsening their liquidity position. These firms are able to continue operating, but because they face lower expected nominal revenues and a lower likelihood of being able to repay their debt in the near future, prefer to liquidate the firm rather than to risk suffering bankruptcy costs in the future. Such fragility also reduces the value of new firms and dampens firm creation. This early surge in voluntary exits and reduction in firm creation explain why the initial sharp increase in unemployment is much larger than after the individual shocks.

Second, households' precautionary response to the increased unemployment risk generates large propagation effects and helps explains the persistence of low firm creation, low output, and high unemployment. Households' attempt to mitigate the negative effects on their labor income by increasing their saving and by shifting away from shares and into the more liquid bonds. Both reactions push inflation further down through the Phillips Curve and generate an increase in firm financial fragility, defaults, and firings.

5 Conclusion

Financial crises typically feature a tightening of credit constraints for both households and firms. Motivated by this observation, this paper introduces a model with financial and labor market frictions and shows that financing constraints of households and firms interact with each other to significantly amplify the effect of financial factors on aggregate output and employment.

We have intentionally left out some important features to be able to introduce a tractable theoretical framework. Our analysis abstracts from the role of countercyclical movements in risk premia, which could have an important impact on firm creation and liquidation in times of credit market distress, and would be likely to further amplify the effects of financial shocks in our model. Our assumption of constant returns to scale at the firm level also limits our ability to study firm behavior more comprehensively, and we ignore nominal rigidities in household debt, even though this could be even more relevant than firm debt nominal rigidities given the long maturity of some types of household debt contracts such as mortgages.

Further research could also focus on the monetary policy implications of nominal debt rigidities in the context of our framework.

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6 Computational Appendix

6.1 Steady State

This appendix describes the numerical methods used to solve the steady state equilibrium of the model described in Section 2.

1. - Households' Problem

The individual decision problem of households is solved using policy function iteration based on a discrete state space Euler equation approach. The state variables for the employed household problem are the household wealth a_t and the firm net wealth n_t^F, and the savings policy function $a_{w,t+1}(a_t, n_t^F)$ is approximated by a function which is piece-wise linear in each of the two arguments. We use 60 gridpoints for a_t and 400 for n_t^F. The density of the a_t grid increases for lower values of a_t, to better capture the nonlinearities in the consumption and savings functions for households with low wealth. The state variable for the unemployed household problem is household wealth a_t, and the savings policy function $a_{u,t+1}(a_t)$ is approximated by a function which is also piece-wise linear in a_t and is discretized in the same way as the grid for working households.

2. - Firms' Problem

The individual decision problem of firms is solved using value function iteration. The state variable for a firm is its current net holdings of financial assets, n_t^F, and its choice variable is its voluntary exit decision $I_{vol,t} \in \{0,1\}$. Dividends are optimally set at $d_t = 0$ while the firm is operating, and are only paid when the firm exits, and in that case equal the liquidation value of the firm, net of bankruptcy costs, if applicable. We discretize the value function $J(n_t^F)$ using 400 gridpoints, which are spaced more closely for low values of n_t^F in which firm value becomes concave due to the possibility of forced or voluntary exit. We start from a probability of firm exit equal to the exogenous exit probability, $\sigma_t(n_t^F) = \eta$, for all n_t^F above or equal to $n_t^{F,bankr}$, and equal to $\alpha_t + \eta(1-\alpha_t)$ for all values below, which are the cases in which the firm is forced to exit if it faces a collateral constraint check. We guess an initial $J(n_t^F)$ and assume there are no voluntary exits and recalculate $J(n_t^F)$. Using the new guess of $J(n_t^F)$, we check if there are any gridpoints in which the condition for a voluntary exit (**??**) is met, and update $\sigma(n_t^F)$ from below by making the first gridpoint a voluntary exit ($I_{vol,t} = 1$ and $\sigma = 1$). We recalculate $J(n_t^F)$ using the new guess for $\sigma(n_t^F)$ and again update $\sigma(n_t^F)$ from below, adding another voluntary exit gridpoint if it satisfies the voluntary exit condition. We repeat this process until convergence of $\sigma(n_t^F)$ and $J(n_t^F)$.

3. - Labor Market and Goods Market Equilibrium

We solve for the equilibrium of the model by simulating an economy with $N = 60,000$ households, an endogenous number ($\leq N$) of firms, and $M = 45,000$ mutual fund shares. We make a guess for the initial distributions of household savings and employment status, and for the initial distribution of firm financial assets and long-term debt, and start our simulation by calculating job creation and job destruction. Taking our guess of unemployment as given, we calculate the vacancies that result from the optimal firms creation condition (10), and obtain a number of matches. These matches constitute new firms, which are created with no financial wealth ($a_{F,t} = 0$) and an amount of debt $D = P_t k$. Unemployed workers are assigned randomly to the newly created firms.

To calculate job destruction, we first identify all firms with net asset holdings below $n_t^{F,vol}$, which will be the ones exiting for voluntary reasons. Next, we apply random checks on collateral constraint (**??**) to all firms with probability α_t, and those that are subject to the check and fail because their net asset holdings are in the range $n_t^{F,vol} < n_t < n_t^{F,bankr}$ are forced to repay their long-term debt and liquidate. Finally, we apply the exogenous exit shock to the remaining surviving firms. These exits happen at the beginning of a period, and the workers that are fired start to search for a job the following period. The new unemployment rate is the result of taking into account these job creation and job destruction flows.

The goods market clears at the price P at which the aggregate demand for consumption goods equals the aggregate supply (condition (**??**)). Aggregate supply of consumption goods arises from

the output of firms and the capital of exiting firms that is transformed back to consumption goods, net of bankruptcy costs, and consumption of goods includes household consumption, expenditures on investment, including adjustment costs of investment, and vacancy posting costs.

Mutual funds' net revenues are calculated using expression (12), and this net cash flow constitutes the dividend mutual funds pay out to households, which determine the equilibrium interest rate given by (24).

4. - Convergence

We recalculate household and firm optimal policy functions after each simulation, updating the aggregate variables and the individual policy and value functions very slowly. 3,000 iterations are sufficient for wealth distributions, aggregate variables, and individual policy and value functions to converge.

6.2 Transitional Dynamics

This appendix describes the numerical methods used to solve for the transitional dynamics exercises introduced in Sections 4 and **??**. We consider a transition period to last from time $t = 1$ to time $t = T$. The economy is in the steady state in period $t = 0$ and in period $t = 1$ households and firms learn about an unexpected sequence of aggregate shocks $\{\Psi\}_0^J$ between $t = 1$ and $t = J < T$. We choose a value of $T = 150$, which is sufficiently large so that the economy returns to the steady state before that time.

We compute the transition dynamics with the following iterative procedure:

1 - Optimization

We calculate the optimal decisions of households and firms conditional on $\{\Psi\}_0^J$ and on an initial guess of the path of aggregate variables $\{r_t, P_t, w_t, \lambda_{w,t}\}_{t=1}^T$. The optimization is done as in the steady state described above, only starting at time $t = T$ and moving backwards to time $t = 1$.

2 - Simulation

We simulate the economy for $t = 1, ...T$ and we update our guess of the aggregate variables $\{r_t, P_t, w_t, \lambda_{w,t}\}_{t=1}^T$ slowly, using an updating parameter of 20%.

3 - Convergence

We iterate between steps 1 and 2 until the sequence of policy functions and aggregate variables converges. 1,000 iterations are sufficient for wealth distributions, aggregate variables, and individual policy and value functions to converge.