



# **The Interaction between Household and Firm Dynamics and the Amplification of Financial Shocks**

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**July 2015**

*Barcelona GSE Working Paper Series*

*Working Paper n° 866*

# The Interaction between Household and Firm Dynamics and the Amplification of Financial Shocks\*

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(This Version: July 2015)

## Abstract

Empirical studies examining the 2007-2009 Great Recession suggest that financial shocks to households and firms are both important to explain output and employment fluctuations. Motivated by this evidence, we develop a model with financial and labor market frictions in which heterogeneous households face unemployment risk, and heterogeneous firms face costly bankruptcy and finance themselves partly with nominally fixed long-term debt. We show that shocks that cause household deleveraging and credit shocks to firms interact to greatly amplify the effects of financial shocks on output and employment, even when these same shocks separately have moderate effects.

Keywords: Financial Shocks, Amplification, Precautionary Savings, Unemployment Risk, Borrowing Constraints, Firm Bankruptcy Risk

JEL Classification: E21, E24, G33

\* A previous version of this paper circulated with the title "Aggregate Implications of Financial and Labor Market Frictions". We thank Chris Carroll, Wouter den Haan, Joao Gomes (discussant), Bob Hall, Juan Jimeno (discussant), Nobu Kiyotaki (discussant), Alberto Martin, Vincenzo Quadrini, Victor Rios-Rull, and Julio Rotemberg for very valuable comments. We also thank participants in the CREI-CEPR "Asset Prices and the Business Cycle" Workshop (Barcelona, December 2011), the CREI faculty seminar, the LSE-FMG 25<sup>th</sup> Anniversary Conference (London, January 2012), the 2012 Royal Economic Society conference, the 2012 NBER Summer Institute meeting on "Capital Markets and the Economy", the 2012 NBER Summer Institute meeting on "Aggregate Implications of Micro Consumption Behavior", the LSE/BOE conference on "Unemployment, Productivity and Potential Output: the Aftermath of the Crisis", the Boston Fed, the University of Glasgow, the MNB 11th Macroeconomic Policy Research Workshop, the Bank of Finland/CEPR conference on "Search Frictions and Aggregate Dynamics", the AEA 2014 Meetings (Philadelphia), the SED 2014 Meetings (Toronto), and the ESSIM 2015 Meeting in Tarragona for helpful comments. Ander Perez acknowledges financial support from the Ministry of Economics of Spain grant ECO2012-32434, and from the Bank of Spain Programme of Excellence in Monetary, Financial and Banking Economics. Andrea Caggese acknowledges financial support from the Ministry of Economics of Spain. All errors are of course our own responsibility. Corresponding author: andrea.caggese@upf.edu.

# 1 Introduction

Economists have long argued that financial factors matter for business cycle fluctuations, and several authors have recently developed business cycle models in which firm financial constraints are important to explain the depth of the 2007-2009 downturn.<sup>1</sup> However, there is growing empirical evidence that both the deleveraging caused by financial shocks to households and shocks to the availability of credit to firms are important to explain the decline in employment during the 2007-2009 Great Recession.<sup>2</sup> What is the quantitative importance of each of these channels in determining the depth of a downturn caused by financial shocks? Are the interactions between these channels a source of amplification and propagation of aggregate shocks? This paper addresses these questions by developing a model with financial and labor market frictions, and shows that when financial shocks to households and firms occur simultaneously they can interact to generate large drops in output and employment, even when these same shocks separately have moderate effects.

We develop a model with heterogeneous firms that produce a consumption good using capital and one unit of labor. Firms finance capital expenditures using long-term debt collateralized by capital. They face idiosyncratic shocks to production costs that generate fluctuations in profits, and suffer costly bankruptcy when the sum of their liquid asset holdings and the collateral value of their capital is insufficient to guarantee their liabilities. This bankruptcy is inefficient given that operating firms have a positive net present value. The demand side of the economy consists of heterogeneous risk-averse consumers that face idiosyncratic unemployment risk, which is endogenous in our model. We assume that households are unable to borrow so they can only insure partially against this risk by accumulating financial assets. The labor market is modeled as in the Diamond-Mortensen-Pissarides framework and features search and matching frictions. In our economy, prices and wages are fully flexible and the only nominal rigidity, which plays a key role for our results, is that long-term debt is fixed in nominal terms.

We solve for the steady state of the model using a calibration designed to match several

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<sup>1</sup>See, among others, Gilchrist and Zakrajsek (2012), Jermann and Quadrini (2012), Khan and Thomas (2013) and Gilchrist, Sim and Zakrajsek (2014).

<sup>2</sup>Chodorow-Reich (2014) shows that exogenous shocks to the availability of credit to firms negatively affected employment during the financial crisis. Mian and Sufi (2014) provide empirical evidence that house price declines in the US forced households to deleverage and to reduce their consumption, and that this demand shock was a key factor in increasing unemployment during the 2007-2009 recession. Giroud and Mueller (2015) show that the impact of demand shocks on employment was significantly stronger for firms with weak balance sheets.

moments of the US economy, and analyze the transition dynamics of key aggregate variables following unexpected aggregate financial shocks. In the steady state, prices are constant and very few firms go bankrupt, as this requires a long sequence of negative idiosyncratic shocks. Instead, after a negative aggregate shock that causes a declining path of the price level, firm nominal profits and the collateral value of capital fall, and the real burden of debt and the likelihood of default increase. As a result, a larger fraction of firms might go bankrupt or decide to liquidate for precautionary reasons in order to avoid future bankruptcy costs.

In order to disentangle the importance of the different shocks and their interactions, we compare three simulations, the first with only shocks to firms, the second with only shocks to households, and the third with shocks to both firms and households. In each case we measure both amplification (the peak unemployment generated by the shock) and persistence (the average output gap in the 30 periods following the beginning of the sequence of shocks). In the first exercise, we simulate the transition dynamics following an unexpected temporary increase in firms' financial constraints, captured by an increase in the interest rate spread on borrowing comparable to the one experienced by firms in the U.S. during the 2007-2009 recession, and which lasts for 8 quarters. This shock increases bankruptcies and reduces job creation. The increase in unemployment, however, is relatively small, from a steady state value of 5.9% to a peak of 7.4% after 8 quarters. Households' desire to smooth consumption sustains demand, increases the price level, and thus increases nominal revenues and the collateral value of capital and reduces the real value of long-term debt. The average output gap over the 30 quarters following the impact of the shock is 1.3%.

In the second exercise, we simulate the transition dynamics following a sequence of unexpected wealth shocks to households that last 8 quarters and progressively reduce their net worth. The shock is calibrated using data from the 2009 Survey of Consumer Finances (SCF), and causes a drop in aggregate demand quantitatively comparable to the one observed in the US during the 2007-2009 recession. This shock reduces output and employment moderately in the short term, and causes an important increase in the medium term. As a result, the average output gap over the 30 quarters following the impact of the shock is only 0.3%. Two opposite forces are at play. On the one hand, this shock reduces aggregate demand, nominal profits, and the collateral value of capital, making it more difficult for firms to repay their long-term

debt and causing an increase in defaults and unemployment. On the other hand, this effect is compensated by a positive effect on job creation, both because of a lower opportunity cost of capital, and because there is an anticipated upward trend in the price level following the initial decrease, which means that new firms expect that it will be easier to repay their long-term debt.

In the third exercise, we simulate the transition dynamics following simultaneous shocks to households and firms. In this simulation unemployment reaches a peak of 10.8%, so that the presence of both shocks generates an increase in unemployment of 4.9% at its peak, compared to the increase of only 1.5% and 1.9% obtained with only the credit shock to firms and households, respectively. Moreover, in this exercise unemployment and the output gap are also very persistent. The average output gap over the 30 quarters following the impact of the combined shocks is 3.5%, and means that while the demand shock in isolation barely affects the average output gap, the same shock in the presence a simultaneous financial shock to firms increases the average output gap by 2.2 percentage points. This is consistent with the amplification and persistence results being generated by a positive interaction between the two shocks rather than by the potential nonlinearity of the individual shocks.

The mechanism behind this result is a feedback between the precautionary behavior of households and firms. The demand shock reduces prices and increases the real value of firms' long-term debt during a time when this debt becomes much more difficult to roll over because of the credit shock, increasing bankruptcies and reducing job creation. The drop in the interest rate and in output makes it more difficult for the household sector to save and accumulate financial assets to their desired level following the wealth shock. So the adjustment process becomes slower and the decline in consumption and prices lasts longer. As a consequence, many firms, expecting low nominal profits for a longer period, display a precautionary behavior and choose to liquidate to avoid suffering bankruptcy costs in the future. The same problem also reduces the expected value of new firms and further dampens the creation of new vacancies.

To provide further evidence on the importance of the interaction between the precautionary behavior of households and firms, we repeat our simulation exercise after removing two key features of our model: the possibility of voluntary exit for firms to avoid future expected bankruptcy costs, and the demand feedback arising from labor income effects for households due to a higher unemployment. Both features are shown to be crucial to generate large interaction

effects.

Finally, we repeat the simulations assuming that wages are nominally rigid in the transition. The presence of wage rigidity does not alter the qualitative results but slightly dampens them quantitatively. Nominal wage rigidity has the expected effect of reducing nominal profits and job creation. However, by increasing the real value of wages it contributes to sustain aggregate consumption. This prevents a large fall in the price level, reducing both bankruptcies and voluntary liquidations of firms. Under our calibration this positive effect on employment is marginally larger than the negative effect on job creation.

### **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 (2015) 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 (2015).

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) focus like us on the effect of financial shocks on firm employment in an environment with borrowing constrained firms but no labor market frictions. Monacelli, Quadrini and Trigari (2011) instead consider the relation

between financial shocks and wage bargaining in the presence of labor market frictions, but like Jermann and Quadrini (2012) ignore household sector financial frictions, which is a central ingredient in our mechanism.

Starting with Bewley (1977), a large literature has studied the macroeconomic implications of incomplete markets for households that face idiosyncratic income risk. Our model is most closely related to Krusell, Mukoyama and Sahin (2010), who introduce an economy featuring heterogeneous households that face incomplete markets and endogenous unemployment risk, just like in our model, but in which firm financing is frictionless. In most of these models, negative aggregate demand shocks can be expansionary by encouraging capital accumulation. A related literature develops models showing how demand shocks caused by households' deleveraging or by precautionary saving in response to unemployment risk instead 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 (2014)). The demand structure of our paper is similar to these, while 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 is related to Gomes, Jermann, and Schmid (2014), 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 Section 4, and in Section 5 we analyze the role of nominal wage rigidity. Section 6 concludes.

## 2 The Model

We introduce an infinite horizon, discrete-time closed economy populated by a measure  $N$  of households, who provide their labor to firms. Firms are owned by industrial conglomerates, and shares in these conglomerates, which are in aggregate fixed supply  $M$ , act as the numeraire and means of payment in the economy, give the right to receive dividend payments from the conglomerates, and are the only store of value. Firms produce a perishable consumption good with a production function that features idiosyncratic productivity shocks. In Sections 2 and 3 we solve for the equilibrium in the steady state, and in Sections 4 and 5 we analyze the transitional dynamics following a one-time unexpected aggregate shock.

### 2.1 Firms

An industrial conglomerate 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.

#### 2.1.1 Production Opportunities

Each firm  $i$  produces consumption goods using as factors of production one unit of labor and a fixed amount of capital  $k$ . 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 satisfies  $E(\varepsilon_{i,t}) = 0$ . For simplicity, we assume that  $\varepsilon_{i,t}$  takes value  $\theta$  with probability 50% and  $-\theta$  with probability 50%, and that  $0 < \theta \leq z$ . The firm sells each consumption good at price  $P_t$  in terms of the numeraire (conglomerate shares). The per-period operating profits of a firm are defined as

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



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

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

where  $\varphi$  satisfies  $0 < \varphi < 1$ . Implicit in this rule are the assumptions that the idiosyncratic shock is not contractible, so the wage  $w_t$  cannot be made contingent on  $\varepsilon_t$ , and that the wage is common across firms.<sup>3</sup> For ease of notation, from now on we drop the reference to each individual firm  $i$ .

### 2.1.2 Sources of Finance, and Financing Constraints

The sources of finance and the financing frictions of firms are modelled to be able to replicate some key realistic features. First, firms use long-term debt that is determined in nominal terms, 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, financing frictions limit both the equity and debt financing of firms. Third, the collateral value of capital matters for firms' borrowing capacity. Finally, firms with very low financial wealth might suffer inefficient liquidation, for example after a negative temporary productivity shock that leads to financial losses, or because a drop in the collateral value of capital forces them to default on their debt obligations. In order to introduce all these features in the model, while at the same time keeping it tractable, we make a series of ad hoc assumptions about the nature of financial imperfections affecting firms.

When an industrial conglomerate creates a firm it assigns it to a manager, who runs the firm in return for a negligible wage with the objective of maximizing the net present value of dividends  $d_t$  paid back to the conglomerate, who is the sole shareholder. Managers are introduced to generate an agency problem between them and the shareholder of the firm they run and justify the financing constraints faced by the firm. They are otherwise irrelevant for the equilibrium.

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<sup>3</sup>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.

A newly created firm needs to install a fixed amount of capital. This capital is purchased from the firm's conglomerate, which produces it by investing  $k$  units of the consumption good and by incurring adjustment costs. Capital  $k$  does not depreciate and can be transformed back into consumption goods and sold when the firm is liquidated, possibly at a cost in some types of liquidation, as will be described below. Firms are created with zero financial wealth, captured by initial asset holdings  $a_t^F = 0$ .

Newly created firms need to finance their initial capital investment and vacancy posting costs. We assume that before starting their activity they only have access to collateralized long-term debt and equity financing. Once they start operating, firms also have access to a line of credit that allows them to borrow for one period, but lose access to additional long-term debt or equity financing. As a result, a firm already in operation can only access short-term debt or past retained profits to finance temporary negative profits. Long-term debt  $D_t$  is fixed in nominal terms, has a stochastic roll-over probability as long as the firm is operation, and is repaid only when the firm ceases to exist. It gives the holder the right to receive an interest of  $r_t$  every period. Given that debt of an operating firm is constant through time, we drop the time subscript and denote its amount by  $D$ .<sup>4</sup> Equity gives the holder the right to receive dividends  $d_t$  every period plus the residual liquidation value of the firm when it ceases to operate.

We introduce financing frictions with the following assumptions. First, after a firm is created it becomes an independent unit and cannot receive additional equity from its own conglomerate, other conglomerates, or workers. This translates into the constraint that dividends cannot be negative:

$$d_t \geq 0. \tag{3}$$

We interpret the restrictions on equity issuance to arise from shareholder-manager agency conflicts.<sup>5</sup>

Second, long-term debt features a covenant that requires the financial assets of the firm, given by liquid asset holdings  $a_t^F$  plus the collateral value  $P_t k$  of capital, to be larger than the

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<sup>4</sup>In order to keep the problem tractable we assume that both types of debt are risk free and, for this reason, are remunerated at the risk free market interest rate  $r_t$ . If the firm goes bankrupt and is not able to repay the debt in full, we assume that the conglomerate who owns the firm makes up for the difference. This could be implemented through a credit default swap issued by the conglomerate to the short-term and long-term debtholders.

<sup>5</sup>For example, there could be a problem of moral hazard, as in Holmstrom and Tirole (1997), that limits the pledgeability of future profits because of the need to endow the manager with a stake in future output to ensure adequate incentive provision.

nominal value of long-term debt  $D$ :

$$a_t^F + P_t k \geq D. \quad (4)$$

When  $a_t^F < 0$  the firm has borrowed using its credit line, and condition (4) can be interpreted as the requirement that total long-term debt  $D$  plus short-term debt ( $-a_t^F$ ) be less than the collateral value of capital. This covenant is checked with probability  $\alpha_t$  every period, and if it is not satisfied the firm is forced to liquidate by the debtholders. We interpret constraint (4) as a shortcut for a moral hazard problem between debtholders and equityholders.<sup>6</sup> If the constraint is satisfied, the debt is rolled over. The advantage of this stochastic debt maturity assumption is that we are able to introduce in the model long-term debt with an expected duration of  $\frac{1}{\alpha_t}$  periods in a very tractable way, since we do not have to keep track of the distribution of debt maturity across firms. Firms can transfer financial wealth to the next period by accumulating conglomerate shares, which yield a return  $r_t$  in equilibrium.

We assume that firms dislike equity dilution and have a preference for financing their initial expenditures with long-term debt. Given constraint (4), the maximum amount of initial expenditures a firm created in a generic period  $s$  can finance with long-term debt is  $D = P_s k$ . The remaining expenditures (capital adjustment and vacancy posting costs) are financed with equity from the conglomerate.

Our assumptions about long-term debt enable us to capture the firm's idiosyncratic state with only one variable, its net financial assets,  $n_t^F$ , which we define as

$$n_t^F = a_t^F - D,$$

and is equal to the difference between financial assets and long-term debt. We denote the minimum level of net financial wealth which allows the firm to avoid bankruptcy if the covenant (4) is checked by  $n_t^{F, \text{bankr}}$ .

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<sup>6</sup>For example, as in Jensen and Meckling (1976), debtholders try to prevent risk-shifting by shareholders when leverage is high. One could then interpret condition (4) as a covenant arising from such an agency problem, and whose violation triggers the obligation to repay the debt immediately.

### 2.1.3 Firm Exit

If a firm exits, it fires its worker, liquidates its capital and pays a final dividend  $d_t^{exit}$  to the conglomerate. Firm exit occurs for three possible reasons, which occur sequentially in the following order. Firms first have the option to liquidate voluntarily at the beginning of the period, a decision which is captured by the indicator function  $I_{vol,t}$ . If the firm chooses to exit ( $I_{vol,t} = 1$ ) it is able to distribute all its assets net of liabilities as exit dividend to the conglomerate and  $d_t^{exit} = n_t^F + P_t k$ .

If the firm decides not to exit voluntarily, it is then exposed to the possibility of a debt covenant examination by its debtholders, which occurs with probability  $\alpha_t$ . The incidence of bankruptcy is captured by indicator function  $I_{bankr,t}$ , which is equal to one if the covenant is examined and the collateral requirement (4) does not hold, so that the firm is forced to repay its debt immediately and liquidate, and equal to zero otherwise. In case of bankruptcy the firm is only able to distribute a fraction  $\chi < 1$  of the value of capital  $P_t k$  to the conglomerate, where  $0 \leq \chi \leq 1$ , so the total exit dividend is  $d_t^{exit} = n_t^F + \chi P_t k$ .<sup>7</sup>

Finally, when a firm has not been forced to liquidate or done so voluntarily, it is still subject to an exogenous probability  $\eta$  of exit, which can be interpreted as a shock that makes the firm's technology obsolete. In this case the firm is able to distribute all of its assets as an exit dividend to the conglomerate, so  $d_t^{exit} = n_t^F + P_t k$ .

The probability at the beginning of period  $t$  that a firm exits for any of the three motives is denoted by  $\sigma_t(n_t^F)$  and is determined as

$$\sigma_t(n_t^F) = I_{vol,t} + (1 - I_{vol,t}) \varphi_t(n_t^F), \quad (5)$$

where  $\varphi_t(n_t^F)$  is the probability that the firm exits conditional on having decided not to exit voluntarily, and is given by

$$\varphi_t(n_t^F) = \alpha_t I_{bankr,t} + (1 - \alpha_t I_{bankr,t}) \eta. \quad (6)$$

If a firm finds it optimal to exit, then  $I_{vol,t} = 1$  and  $\sigma_t = 1$ . If it does not find it optimal to liquidate, but will be forced to repay its debt if it is subject to a collateral constraint check ( $I_{bankr,t} = 1$ ), then  $\sigma_t = \varphi_t = \alpha_t + \eta(1 - \alpha_t)$ . In any other event, it is only subject to the

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<sup>7</sup>The bankruptcy cost  $(1 - \chi)P_t k$  is a deadweight loss.

exogenous exit probability and  $\sigma_t = \varphi_t = \eta$ .

### 2.1.4 Firm Optimization

The timing of events within a period is as follows. A firm starts period  $t$  with a net financial position of  $n_t^F$ , and first undergoes the possibility of deciding or being forced to exit. If the firm continues in operation, it next has the option to pay dividends  $d_t$ . The idiosyncratic productivity shock  $\varepsilon_t$  is generated at the end of the period along with profits  $\pi_t(\varepsilon_t)$ . Also at the end of the period, the return  $r_t n_t^F$  on net financial assets is received, composed of a return  $r_t a_t^F$  on asset holdings minus the interest payment on debt  $r_t D$ , so that the dynamics of a firm's holdings of net financial assets are given by:<sup>8</sup>

$$n_{t+1}^F(\varepsilon_t) = n_t^F(1 + r_t) + \pi_t(\varepsilon_t) - d_t. \quad (7)$$

The value function of a firm with net asset holdings  $n_t^F$  in period  $t$ , which we denote by  $J_t(n_t^F)$ , is derived conditional on not exiting for voluntary reasons in period  $t$ , but before suffering the possibility of a collateral constraint examination, and is given by

$$J_t(n_t^F) = \max_{d_t} \varphi_t(n_t^F) d_t^{exit}(n_t^F) + (1 - \varphi_t(n_t^F)) d_t + \frac{(1 - \varphi_t(n_t^F))}{1 + r_{t+1}} E_{\varepsilon_t} [\bar{J}_{t+1}(n_{t+1}^F)], \quad (8)$$

where  $\bar{J}_{t+1}(n_{t+1}^F)$  is the value function at the beginning of period  $t+1$  before the voluntary exit decision  $I_{vol,t+1}$  is made. The firm maximizes (8) subject to financial constraints (3) and (4), and budget constraint (7). Firm valuation is done using the common discount rate  $r_t$ .<sup>9</sup> Because of the possibility of inefficient liquidation, shareholder value maximization requires that the manager of the firm retains all earnings while the firm is active and has low asset holdings, a situation in which there is a non-negligible probability of facing a forced or voluntary exit. For high values of asset holdings, the likelihood of facing a non-exogenous exit becomes very small and the firm will be close to indifferent between keeping its asset holdings or distributing them as dividends, but will nonetheless prefer to retain them until it exits. As a result, for firms in operation  $d_t = 0$ .

The voluntary exit decision is taken by the firm in order to maximize the beginning of period

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<sup>8</sup> As discussed above, firm debt is remunerated at the risk free rate  $r_t$  (see footnote 4).

<sup>9</sup> Even though the households are heterogeneous and have different marginal rates of substitution, they own the firms through the conglomerates, which diversify away the firm risk. The relevant discount rate for firm valuation is thus the risk free rate  $r_t$ , due to the absence of aggregate risk.

value  $\bar{J}_t(n_t^F)$  :

$$\bar{J}_t(n_t^F) = \max_{I_{vol,t} \in \{0,1\}} [I_{vol,t} d_t^{exit}(n_t^F) + (1 - I_{vol,t}) J_t(n_t^F)] \quad (9)$$

Shareholder value maximization requires that the firm chooses to liquidate voluntarily ( $I_{vol,t} = 1$ ) when

$$J_t(n_t^F) < d_t^{exit}, \quad (10)$$

which might happen when net financial wealth  $n_t^F$  is so low that the likelihood of costly bankruptcy due to a violation of collateral constraint covenant (4) in the short term is high. We denote the level of net financial wealth below which the firm decides to exit voluntarily by  $n_t^{F,vol}$ .

## 2.2 Vacancies and Matching

There is a large number of unemployed 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 industrial conglomerates. Vacancies and unemployed workers are randomly matched each period and an aggregate constant returns-to-scale matching function specifies that  $M(N_{u,t}, N_{v,t})$  matches will be created when there are  $N_{u,t}$  unemployed workers and  $N_{v,t}$  vacancies. A conglomerate that wishes to form a match with a worker posts a vacancy which costs  $P_t \xi$ . The probability that this vacancy is filled in the current period is  $\lambda_{f,t} = M(N_{u,t}, N_{v,t})/N_{v,t}$  and the probability that an unemployed worker finds a job is  $\lambda_{w,t} = M(N_{u,t}, N_{v,t})/N_{u,t}$ . When a worker is matched, he starts working immediately in the current period.

Each conglomerate faces convex costs of adjusting total installed capital  $K_t^I$  under its management given by the function  $\Omega(I_t, K_t^I)$ , with  $\Omega_I > 0$ ,  $\Omega_{II} > 0$  and  $\Omega_{IK} < 0$ , where  $I_t$  and  $K_t^I$  are equal to

$$\begin{aligned} I_t &= M(N_{u,t}, N_{v,t})k, \text{ and} \\ K_t^I &= (N - N_{u,t})k, \end{aligned}$$

given that conglomerates are homogeneous and there is a measure 1 of them.

The optimal number of vacancies solves:

$$\left[ J_t(n^F = -P_t k) - P_t k \frac{\partial \Omega(I_t, K_t^I)}{\partial I_t} \right] \frac{\partial M(N_{u,t}, N_{v,t})}{\partial N_{v,t}} = P_t \xi, \quad (11)$$

which states that optimality requires that the marginal benefit of posting a vacancy (left-hand side) is equal to the cost of posting a vacancy (right-hand side). The marginal benefit of posting a vacancy is equal to the marginal probability of filling the vacancy, given by  $\frac{\partial M(N_{u,t}, N_{v,t})}{\partial N_{v,t}}$ , times the net marginal benefit of a new firm, which is equal to the value of a newly created firm  $J_t(n^F = -P_t k)$  minus the marginal adjustment costs of capital  $P_t k \frac{\partial \Omega(I_t, K_t^I)}{\partial I_t}$ . A newly created firm has net financial assets  $n_t^F = -P_t k$  because firms are created with no financial assets  $a_t^F = 0$  and long-term debt equal to  $P_t k$ .<sup>10</sup>

The resulting unemployment dynamics are:

$$u_{t+1} = (1 - \lambda_{w,t})u_t + (1 - u_t) \int_{-\infty}^{\infty} \sigma_t(n_t^F) f_t(n_t^F) dn_t^F. \quad (12)$$

The first term in the right hand side of equation (12) captures existing unemployed workers who are not matched to a firm this period, while the second term captures the destruction of jobs at the beginning of this period. A worker that loses his job this period does not enter the pool of unemployed until next period.

### 2.3 Industrial Conglomerates

There is a continuum of mass 1 of identical industrial conglomerates, who perform several functions. They finance firm creation, which requires providing resources to cover vacancy posting, investment and capital adjustment costs. They provide long-term debt finance to firms, in exchange for interest payments and the redemption of the debt when the firm exits. They provide equity finance to the firms they create, in exchange for the right to receive dividends from them. They liquidate firms that exit. Finally, they also provide short-term (one period) debt financing to firms. They pay a dividend  $DIV_t$  to the holders of conglomerate shares every

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<sup>10</sup>Capital adjustment costs and vacancy posting costs are paid for by the firm, but are financed with equity provided by the conglomerate that posts the vacancy. For this reason they enter into the optimal vacancy posting condition. If the vacancy is not filled, the cost of posting it is suffered by the conglomerate.

period given by

$$\begin{aligned}
DIV_t = & N(1 - u_t) \int_{-\infty}^{n_t^{F,vol}} \left[ d_t^{exit}(n_t^F) f_t(n_t^F) + \int_0^\infty Dg_t(n_t^F, D) dD \right] dn_t^F \\
& + (\alpha_t + \eta(1 - \alpha_t)) N(1 - u_t) \int_{n_t^{F,vol}}^{n_t^{F,forced}} \left[ d_t^{exit}(n_t^F) f_t(n_t^F) + \int_0^\infty Dg_t(n_t^F, D) dD \right] dn_t^F \\
& + \eta N(1 - u_t) \int_{n_t^{F,forced}}^\infty \left[ d_t^{exit}(n_t^F) f_t(n_t^F) + \int_0^\infty Dg_t(n_t^F, D) dD \right] dn_t^F \\
& + N(1 - u_t) \int_0^\infty \int_{-\infty}^\infty r_t Dg_t(n_t^F, D) dD dn_t^F + N(1 - u_t) \int_{-\infty}^0 r_t (-a_t^F) h_t(a_t^F) da_t^F - P_t \xi N_{v,t} \\
& - P_t k M(N_{u,t}, N_{v,t}) - P_t \Omega(I_t, K_t^I) + \phi P_t K_t^S - (1 - \phi) P_t N(1 - u_t) k \int_{-\infty}^\infty \sigma_t(n_t^F) f_t(n_t^F) dn_t^F,
\end{aligned} \tag{13}$$

where  $f_t(n_t^F)$  and  $h_t(a_t^F)$  are the probability distribution functions of firm net assets and gross assets, respectively, at time  $t$ , and  $g_t(n_t^F, D)$  is the joint probability distribution function of firm net assets and firm long-term debt at time  $t$ . 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 conglomerates can only sell a fraction  $\phi$  of it each quarter. Therefore  $K_t^S$  evolves according to the law of motion:

$$K_{t+1}^S = (1 - \phi) K_t^S + (1 - \phi) N(1 - u_t) k \int_{-\infty}^\infty \sigma_t(n_t^F) f_t(n_t^F) dn_t^F. \tag{14}$$

The first three terms in the right hand side of (13) capture dividend payments and long-term debt repayments received from exiting firms during period  $t$ . The fourth and fifth terms refer to the interest received on all outstanding long-term and short-term debt, respectively, in period  $t$ . The next three terms capture the financing flows from conglomerates to firms. The vacancy creation costs  $P_t \xi N_{v,t}$  and the capital adjustment costs  $P_t \Omega(I_t, K_t^I)$  require equity injections from the conglomerates, while total investment  $P_t k M(N_{u,t}, N_{v,t})$  requires the purchase of long-term debt issued by the firms. The final two terms capture resaleability constraints of liquidated capital. The sale of capital that could not be liquidated in the past produces  $\phi P_t K_t^S$  in revenues, and the final term captures the lower revenues from capital that cannot be sold of firms that exit during the current period. <sup>11</sup>

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<sup>11</sup>Formula (13) takes into account two features of optimal firm choices in equilibrium. First, it does not include dividends issued by active firms as it takes into account that it is optimal for firms not to distribute any dividends until they exit, as explained above. Second, it assumes that  $n_t^{F,forced} \geq n_t^{F,vol}$ , even though it could be the case that  $n_t^{F,forced} < n_t^{F,vol}$ . In the equilibrium under our calibration it is always the case that  $n_t^{F,forced} \geq n_t^{F,vol}$ .



The conglomerate dividend perfectly diversifies away firm idiosyncratic risk. Due to the lack of aggregate uncertainty, absence of arbitrage requires that the risk free interest rate  $r_t$  be equal to the dividend yield of shares, given by

$$r_t = \frac{DIV_t}{M}. \quad (15)$$

## 2.4 Households

Households are risk averse, face uninsurable unemployment risk, and can save by accumulating shares in conglomerates.<sup>12</sup> They receive a return  $r_t$  from their stock  $a_t$  of financial assets, and, when employed, an income  $w_t$  from providing their labor.

An employed household chooses asset holdings  $a_{t+1}$  and consumption  $c_t$  in order to solve the following maximization problem:

$$W_t(a_t, n_t^F) = \max_{c_t, a_{t+1}} \left\{ u(c_t) + \beta E_{\varepsilon_t} \left[ \sigma_{t+1}(n_{t+1}^F) U_{t+1}(a_{t+1}) + (1 - \sigma_{t+1}(n_{t+1}^F)) W_{t+1}(a_{t+1}, n_{t+1}^F) \right] \right\} \quad (16)$$

where  $\beta$  is the discount rate,  $a_t$  are the asset holdings of the worker at the start of the period and  $W_t(a_t, n_t^F)$  is the value associated to being a worker with asset holdings  $a_t$  who is employed in a firm with net asset holdings  $n_t^F$ . Workers may lose their job with probability  $\sigma_{t+1}(n_{t+1}^F)$  the following period and become unemployed, which is associated with a value  $U_{t+1}(a_{t+1})$ . Workers only terminate a match with a firm when the firm exits, because it is never optimal for them to leave a firm voluntarily. The budget constraint of the worker is:

$$P_t c_t + a_{t+1} = a_t(1 + r_t) + w_t. \quad (17)$$

Workers face financing constraints that mean that they are unable to borrow and might be required to hold positive amounts of financial assets, which implies that:

$$a_{t+1} \geq \underline{a} \geq 0. \quad (18)$$

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

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<sup>12</sup>The assumption that households can only save by holding shares in the conglomerates allows us to keep the model simple and tractable, but a model with other means of saving (money, bonds, etc...) would deliver similar implications.

A consumer who is unemployed during period  $t$  solves the following problem:

$$U_t(a_t) = \max_{c_t, a_{t+1}} \{u(c_t) + \beta[(1 - \lambda_{w,t+1})U_{t+1}(a_{t+1}) + \lambda_{w,t+1}W_{t+1}(a_{t+1}, -P_{t+1}k)]\} \quad (19)$$

subject to:

$$P_t c_t + a_{t+1} = a_t(1 + r_t), \quad (20)$$

and the same borrowing constraint (18) as an employed worker. 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 an asset level  $a_{t+1}^F = 0$ , long-term debt  $D = -P_{t+1}k$ , and net financial assets  $n_{t+1}^F = -P_{t+1}k$ , so the value associated to being a worker of a newly created firm next period is  $W_{t+1}(a_{t+1}, -P_{t+1}k)$ . The solution to the problem faced by an unemployed worker are decision rules  $a_{u,t+1}(a_t)$  and  $c_{u,t}(a_t)$ .

## 2.5 Market Clearing Conditions

The goods market equilibrium condition is

$$\begin{aligned} & \int_{\underline{a}}^{\infty} \int_{n_t^{F,vol}}^{\infty} c_{w,t}(a_t, n_t^F) f_{e,t}(a_t, n_t^F) da_t dn_t^F + \int_{\underline{a}}^{\infty} c_{u,t}(a_t) f_{u,t}(a_t) da_t \\ &= P_t \left[ zN_t(1 - u_t) - (I_t + \Omega(I_t, K_t^I)) - \xi N_{v,t} + \phi \chi k N(1 - u_t) \int_{-\infty}^{n_t^{F,vol}} f_t(n_t^F) dn_t^F \right. \\ & \left. + \phi k N(1 - u_t) \int_{n_t^{F,vol}}^{n_t^{F,bankr}} [\alpha_t + \eta(1 - \alpha_t)] f_t(n_t^F) dn_t^F + \phi k N(1 - u_t) \int_{n_t^{F,bankr}}^{\infty} \eta f_t(n_t^F) dn_t^F + \phi K_t^S \right], \end{aligned} \quad (21)$$

where  $f_{e,t}(a_t, n_t^F)$  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, and  $f_{u,t}(a_t)$  is the distribution function of unemployed workers' asset holdings. The terms in the left-hand-side capture workers' aggregate consumption (employed and unemployed, respectively). Total output is given by output per firm  $z$  multiplied by the number of active firms  $N_t(1 - u_t)$ , minus expenditures on investment, including adjustment costs of investment, and vacancy posting, and plus the output that results from the conversion back into consumption goods of the capital of exiting firms, net of costs in cases of bankruptcy.

The equilibrium condition for the conglomerate shares is

$$M = \int_{\underline{a}}^{\infty} \int_{n_t^F, vol}^{\infty} a_t(a_t, n_t^F) f_{e,t}(a_t, n_t^F) da_t dn_t^F + \int_{\underline{a}}^{\infty} a_t(a_t) f_{u,t}(a_t) da_t + \int_0^{\infty} a_t^F(n_t^F) h_t(a_t^F) da_t^F, \quad (22)$$

where the left hand side of expression (22) refers to the constant aggregate supply of conglomerate shares, and the right hand side captures the aggregate demand for shares by employed households, unemployed households, and firms, respectively.

## 2.6 Definition of the Competitive Equilibrium

We express the laws of motion for the distributions  $f_t(n_t^F)$ ,  $h_t(a_t^F)$ ,  $g_t(n_t^F, D)$ ,  $f_{e,t}(a_t, n_t^F)$  and  $f_{u,t}(a_t)$ , respectively, as:

$$\begin{aligned} f_{t+1}(n_{t+1}^F) &= \Gamma_t(f_t(n_t^F)), \\ h_{t+1}(a_{t+1}^F) &= \Theta_t(h_t(a_t^F)), \\ g_{t+1}(n_{t+1}^F, D) &= \Xi_t(g_t(n_t^F, D)), \\ f_{e,t+1}(a_{t+1}, n_{t+1}^F) &= \Psi_t(f_{e,t}(a_t, n_t^F)), \\ f_{u,t+1}(a_{t+1}) &= \Phi_t(f_{u,t}(a_t)). \end{aligned}$$

We can now define the competitive equilibrium.

**Definition 1** *An equilibrium is a sequence of interest rates  $\{r_t\}$  and prices  $\{P_t\}$ , a sequence of unemployment rates  $\{u_t\}$  and vacancies  $\{N_{v,t}\}$ , a sequence of household consumption policies for employed and unemployed households  $\{c_{w,t}(a_t, n_t^F), c_{u,t}(a_t)\}$ , a sequence of firm exit policies  $\{\sigma_t(n_t^F)\}$ , and a sequence of distributions  $\{f_t(n_t^F), h_t(a_t^F), g_t(n_t^F, D), f_{e,t}(a_t, n_t^F)$  and  $f_{u,t}(a_t)\}$  such that, given the initial distributions  $f_0(n_0^F)$ ,  $h_0(a_0^F)$ ,  $g_0(n_0^F, D)$ ,  $f_{e,0}(a_0, n_0^F)$  and  $f_{u,0}(a_0)$  and initial unemployment  $u_0$ ,*

- (i)  $c_{w,t}(a_t, n_t^F)$ ,  $c_{u,t}(a_t)$  and  $\sigma_t(n_t^F)$  are optimal given  $\{r_t\}$ ,  $\{P_t\}$ ,  $\{u_t\}$  and  $\{N_{v,t}\}$ ,
- (ii) vacancy posting  $\{N_{v,t}\}$  is optimal given  $\{r_t\}$ ,  $\{P_t\}$ , and  $\{u_t\}$ ,
- (iii) the transition functions  $\{\Gamma_t\}$ ,  $\{\Theta_t\}$ ,  $\{\Xi_t\}$ ,  $\{\Psi_t\}$ , and  $\{\Phi_t\}$  are consistent with  $\{c_{w,t}(a_t, n_t^F)\}$ ,  $\{c_{u,t}(a_t)\}$ ,  $\sigma_t(n_t^F)$ ,  $\{r_t\}$ ,  $\{P_t\}$ ,  $\{u_t\}$  and  $\{N_{v,t}\}$ ,
- (iv) the sequence of unemployment rates  $\{u_t\}$  are consistent with  $\{\sigma_t(n_t^F)\}$ ,  $\{N_{v,t}\}$ , and  $\{f_t(n_t^F), h_t(a_t^F), g_t(n_t^F, D), f_{e,t}(a_t, n_t^F)$  and  $f_{u,t}(a_t)\}$ ,

(v)  $\{P_t\}$  satisfies the goods market clearing condition (21), and

(vi)  $\{r_t\}$  clears the market for conglomerate shares (22) by Walras' law.

### 3 Calibration and Steady State Analysis

#### 3.1 Calibration

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. Table 1 contains a summary of all the empirical moments used to calibrate parameters, and the chosen values for the parameters are shown in Table 2.

We assume the utility function of households is isoelastic of the form

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma}, \quad (23)$$

with a risk aversion parameter  $\gamma = 0.8$ , which also determines the degree of household precautionary behavior. The chosen value is consistent with Chetty (2006), who considers a wide range of empirical estimates based on labor supply elasticities and derives average implied values of  $\gamma$  between 0.71 and 0.97. The discount factor  $\beta$  of households is 0.992, which is set to generate an annualized risk free interest rate of around 1%.<sup>13</sup>

In order to match the households' net worth as a percentage of total net worth, our model would require a strictly positive minimum saving limit  $\underline{a} > 0$ . In the next section, we consider transition dynamics after an unexpected wealth shock to the household sector. Such shock could potentially violate the borrowing constraint (18) of households if  $\underline{a} > 0$ , and would generate the need to possibly deal with household default. In order to avoid this complication we set the borrowing limit  $\underline{a} = 0$  and follow Judd (1998) to replace constraint (18) with a cost  $I(a)$  that enters households' preferences and is a convex function of the proximity of savings to  $\underline{a} = 0$ .

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<sup>13</sup>This value is below the one implied by the households' rate of time preference due to the presence of borrowing constraints and a precautionary saving motive that encourage the household sector to increase savings in equilibrium.

This requires a modification of the utility function to include such a cost, so that

$$u(c_t, a_{t+1}) = \frac{c_t^{1-\gamma}}{1-\gamma} - I(a_{t+1})$$

and

$$I(a_{t+1}) = \frac{\tau}{a_{t+1}^2}.$$

A higher value of  $\tau$  has the same effect on household wealth accumulation as increasing the minimum wealth requirement  $\underline{a}$  above 0, but it has the advantage of being compatible with unexpected shocks that reduce  $a_t$ . We set  $\tau$  in the steady state to equal 0.004 to match the ratio of total net worth of the household sector over the combined net worth of household and nonfinancial corporate sectors, calculated using Federal Reserve data from the 2014 release of the Financial Accounts of the United States.

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

$$M(N_{u,t}, N_{v,t}) = \frac{N_{u,t}N_{v,t}}{(N_{u,t}^L + N_{v,t}^L)^{\frac{1}{L}}}, \quad (24)$$

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  $\xi$  and the matching efficiency  $L$ , are set so that the worker job finding rate and the vacancy-unemployment ratio are consistent with their empirical counterparts. The workers' job finding rate,  $\lambda_w$  is estimated by den Haan, Ramey, and Watson (2000) to be 0.45, and Shimer (2012) more recently estimates it to be between 0.33 and 0.54. Hall and Milgrom (2008) and Pissarides (2009) report average vacancy-unemployment ratios ( $N_v/N_u$ ) of 0.5 and 0.72 respectively.

The parameters that describe the firms' technology are  $z$ ,  $\theta$ ,  $\varphi$  and  $k$ . We set  $z$ ,  $\theta$ , and  $k$  jointly to match a number of key empirical moments. The measure of firm profitability that matches our measure of firm profits  $\pi_t$  best is operating income before interest, tax, depreciation and amortization. The mean (median) of this value relative to total sales for the Compustat sample of publicly listed US firms is 0.02 (0.08), and the probability of negative values of this measure is 30% in the data. On both fronts we generate conservative values in our simulations, with higher average and median profitability and lower probability of negative profits relative

Table 1: Calibration - Simulated and Empirical Moments

Panel A: Main Calibration Targets

	Model	Data
Workers' job finding rate	0.39	0.33-0.54 <sup>(1)</sup>
Vacancy-unemployment ratio	0.85	0.50-0.72 <sup>(2)</sup>
Operating income/Sales: mean (median)	0.04 (0.22)	0.02 (0.08) <sup>(3)</sup>
Probability of negative profits	6.2%	30.2% <sup>(3)</sup>
Aggregate adjustment costs over total stock of capital	0.48%	0.91% <sup>(4)</sup>
Annual rate of firm bankruptcies	0.17%	0.48% <sup>(5)</sup>
Average maturity of firm debt	2.2	1.4 <sup>(6)</sup>
Costs of bankruptcy as a share of total firm assets	21%	20-36% <sup>(7)</sup>
Annual job destruction	9.6%	8-11% <sup>(8)</sup>
Households' net worth as a percentage of total net worth	86%	80% <sup>(9)</sup>

Panel B: Firm Liquidity Holdings

	Net Liquid Assets / Capital	
	Model	Data <sup>(3)</sup>
90th percentile	1.07	1.76
50th percentile	-0.44	-0.56
20th percentile	-0.82	-1.50
10th percentile	-0.91	-1.70
5th percentile	-0.96	-2.18
1st percentile	-1.00	-3.38

(1) Den Haan, Ramey, and Watson (2000) and Shimer (2012)

(2) Pissarides (2009) and Milgrom and Hall (2008)

(3) Own calculations using Compustat and Capital IQ for U.S. listed firms

(4) Cooper and Haltiwanger (2006)

(5) Own calculations based on data from the U.S. Federal Courts and the U.S. Census Bureau

(6) Bassett, Chosak, Driscoll, and Zakrajšek (2014)

(7) Altman (1984), Bris, Welch and Zhu (2006), and Alderson and Betker (1995)

(8) Den Haan, Ramey and Watson (2000) and Bilbiie, Ghironi and Melitz (2012)

(9) Data from the Financial Accounts of the United States, Federal Reserve, released December 2014

Table 2: Calibration - Parameter Choices

<b>Parameter</b>	<b>Symbol</b>	<b>Value</b>
Discount factor	$\beta$	0.992
Risk aversion	$\gamma$	0.8
Household borrowing constraint parameter	$\tau$	0.004
Vacancy cost	$\xi$	0.0125
Efficiency of matching	$L$	0.8
Productivity of firms	$z$	0.12
Size of firm productivity shock	$\theta$	0.015
Labor share of expected revenues	$\varphi$	0.9
Firm capital stock	$k$	0.6
Adjustment costs of investment parameter	$c$	275,000
Probability of collateral constraint check	$\alpha$	11.5%
Bankruptcy costs as fraction of capital	$(1 - \chi)$	0.3
Probability of exogenous exit	$\eta$	2.25%
capital resaleability constraint	$\phi$	0.5

to the data. To capture balance sheet liquidity, we calculate the ratio of net liquid assets to capital in the same sample of firms. We consider net liquid assets to include cash and short-term investments minus short and long-term debt, and capital to be property, plant and equipment. In Panel B of Table 1 we display the distribution of this value in the data and in our model. Our model produces a similar distribution of firm balance sheet liquidity as in the data. We target an annual rate of firm bankruptcies to be in line with the average bankruptcy rate in the years before the recent financial crisis, which we calculate to be 0.48% in 2005-2007 using data on total annual bankruptcy filings of businesses from the U.S. Federal Courts and on total number of businesses from the U.S. Census Bureau. Finally, we set  $\varphi = 0.90$ . Even though this parameter determines the labor share of expected revenues, we interpret wages broadly in our model to also incorporate other costs incurred by the firm (costs of inputs or services paid to other firms, for example), which justifies the wedge between the income share of labor in the data (Corrado, Hulten and Sichel (2009) estimate a value in the U.S. over the period 1993-2005 of 60%) and our value.<sup>14</sup>

We assume the following functional form for the adjustment costs of installed capital:

$$\Omega(I_t, K_t^I) = c \left( \frac{I_t}{K_t^I} \right)^2,$$

<sup>14</sup> Our results are robust to considering lower values for  $\varphi$ .

and the value of  $c$  is set to match Cooper and Haltiwanger’s (2006) estimate of aggregate adjustment costs over the stock of capital of 0.91%. The resaleability parameter  $\phi$  is set to 0.5, meaning that every period the conglomerate can sell 50% of its stock of capital received from exiting firms.

The intensity of financing frictions suffered by firms is driven by  $\alpha$  and  $\chi$ . We calibrate the likelihood  $\alpha$  of an examination of collateral constraint (4) to roughly match the average maturity of debt. Our modelling of firms’ debt contract can be interpreted as a shortcut to a lending relationships formed by banks and their borrowers: firms’ debt matures with probability  $\alpha$ , at which time the lender evaluates the collateral constraint and decides whether to roll over the debt. This type of contract is more typical of bank loans, which have a shorter maturity and are more likely to be rolled over than non-bank debt. The average maturity of debt in our model under this interpretation is 2.2 years, which is in roughly in line with the observed average maturity of bank debt, calculated by Bassett, Chosak, Driscoll, and Zakrajšek (2014) using data for the U.S. from the Survey of Terms of Business Lending (STBL) to be 1.4 years.<sup>15</sup> The costs of bankruptcy are captured in the model by the fraction  $(1 - \chi)$  of the value of capital  $Pk$  lost in liquidation. Empirical estimates for these costs as a share of total assets are in the range of 20% (Altman (1984), Bris, Welch and Zhu (2006)), to 36% (Alderson and Betker (1995)). We set  $(1 - \chi) = 0.3$ , which delivers a cost of bankruptcy relative to the total value of the firm net of cash holdings in line with empirical estimates.

Finally, we set the size of the exogenous firm exit shock  $\eta = 0.025$  to match the U.S. empirical level of 8 – 11 percent job destruction per year, following Den Haan, Ramey and Watson (2000) and Bilbiie, Ghironi and Melitz (2012).

### 3.2 Steady State

We simulate the steady state of an economy with 60,000 workers and a number of conglomerate shares  $M$  equal to 45,000.

We now briefly describe the policy functions of firms and workers. Firms’ choice variables are

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<sup>15</sup>Since the firms in our model repay the debt only when they are liquidated, another way to interpret the model is so assume that with probability  $\alpha$  the collateral of the firm is checked but the debt is not rolled over, so that average debt maturity in the model coincides with the average age of the firm. This interpretation allows us to map firms long term debt with the sum of all firm liabilities, not just banking debt. Saretto and Tookes (2013) calculate their average maturity to be 8.68 years using a sample of stock exchange listed U.S. firms during years 2002-2010. This value is very close to the life expectancy of the firms in the model (on average 10.4 years).



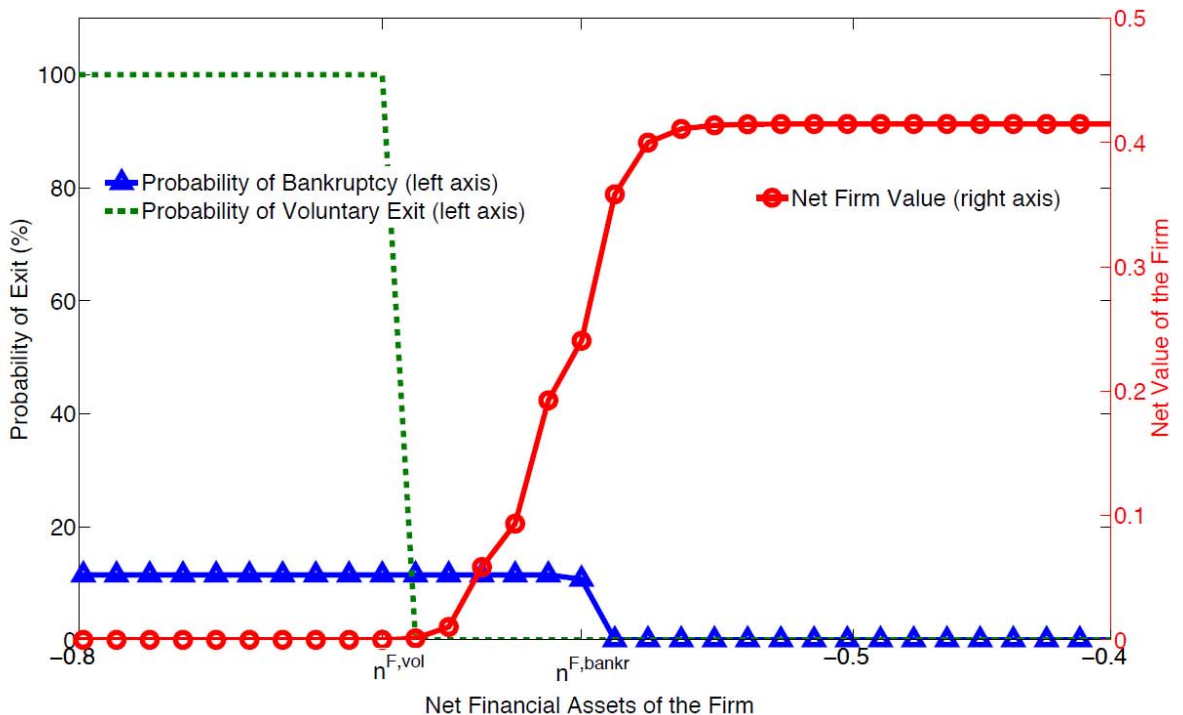


Figure 1: Firm's Optimal Voluntary Exit Decision

their dividend payouts  $d_t$  and their voluntary exit decision  $I_{vol,t}$ . It is optimal for firms to delay dividend payments until they exit, as discussed in Section 2. Figure 1 shows the real net value of the firm, which measures the real net present value of future expected profits net of future expected bankruptcy costs ( $J_t(n_t^F) - n_t^F - P_t k$ ) and also depicts the drivers of the decision of whether to exit or continue in operation every period. Firms face a constant probability of 11.5% of suffering a collateral constraint check, and this check generates the obligation to repay the debt and shut down the firm whenever condition (4) is violated, which happens when the firm's liquidity position is weak. In the steady state equilibrium under the benchmark calibration described above, firms with net real financial assets below  $n^{F,bankr}$  will have to exit if they suffer a collateral constraint check, so for those firms their ex-ante probability of bankruptcy, assuming they do not exit for voluntary reasons beforehand, is 11.5%. For firms with larger holdings of liquid assets, the ex-ante probability of having to exit this period due to bankruptcy is 0%. Firm real net value decreases as firms approach financial distress and the likelihood that they will enter bankruptcy in the near future increases. Net firm value conditional on continuation falls below 0 when firms have negative real net financial positions below  $n^{F,vol}$ ,

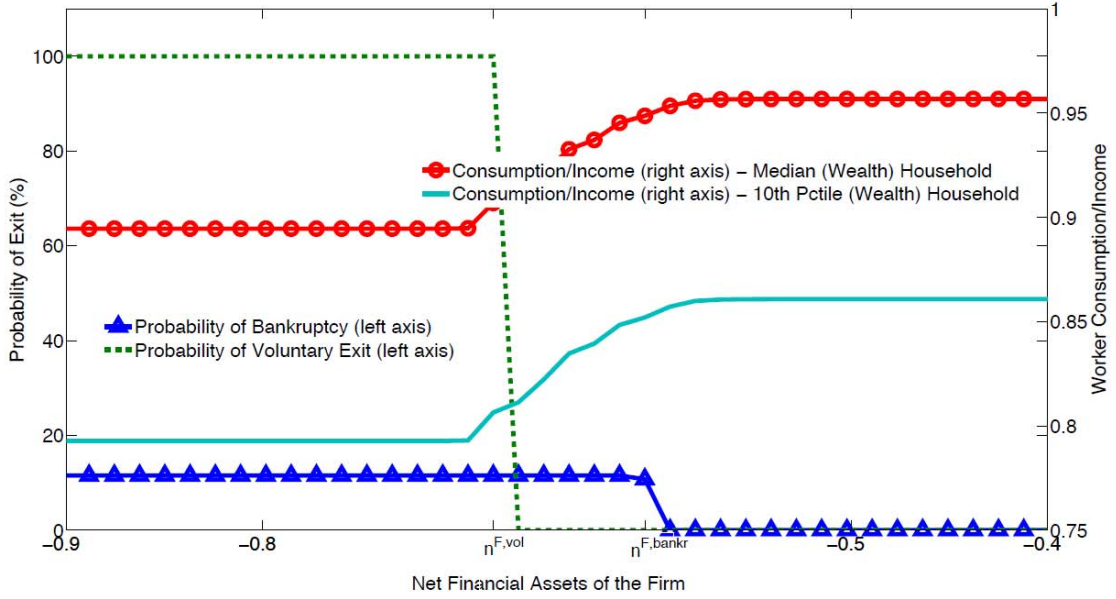


Figure 2: Employed Household’s Optimal Consumption/Savings Decision and its Employer’s Financial Strength

which is the threshold below which it is optimal for firms to exit for voluntary reasons. For these severely distressed firms, the probability of exit is 100%.<sup>16</sup>

Workers’ consumption policies as a function of the net wealth of the firm they work for are shown in Figure 2, where we plot the consumption to income ratio for the households at the median and at the 10th percentile of the households’ wealth distribution. The financial strength of the firm is a state variable for the worker because it influences the likelihood that the firm will fire the worker in the near future. Households that work for firms with sufficient liquidity have a consumption to income ratio of 0.96 (0.86) for the median (bottom decile) household in terms of wealth.<sup>17</sup> As the firm they work for approaches financial distress, they lower their consumption ratio to increase savings. The consumption ratio for the worker of the firm with the lowest possible net financial position is 6.5% (7.9%) lower relative to the maximum consumption ratio for the median (bottom decile) household. This increase in savings associated to an increase in unemployment risk can be due both to a precautionary motive and to a wealth effect.

<sup>16</sup>In the steady state equilibrium it is rarely the case that firms reach a situation of financial distress such that they choose to exit voluntarily, as the probability of sustaining a long series of negative productivity shocks and simultaneously suffering a collateral constraint check is low. In most of the transitional dynamics following negative financial shocks that we analyze in Sections 4 and 5, however, there are frequent instances in which financially weak firms find it optimal to exit voluntarily.

<sup>17</sup>Income is calculated as the sum of wages plus the dividend income from the ownership of shares.

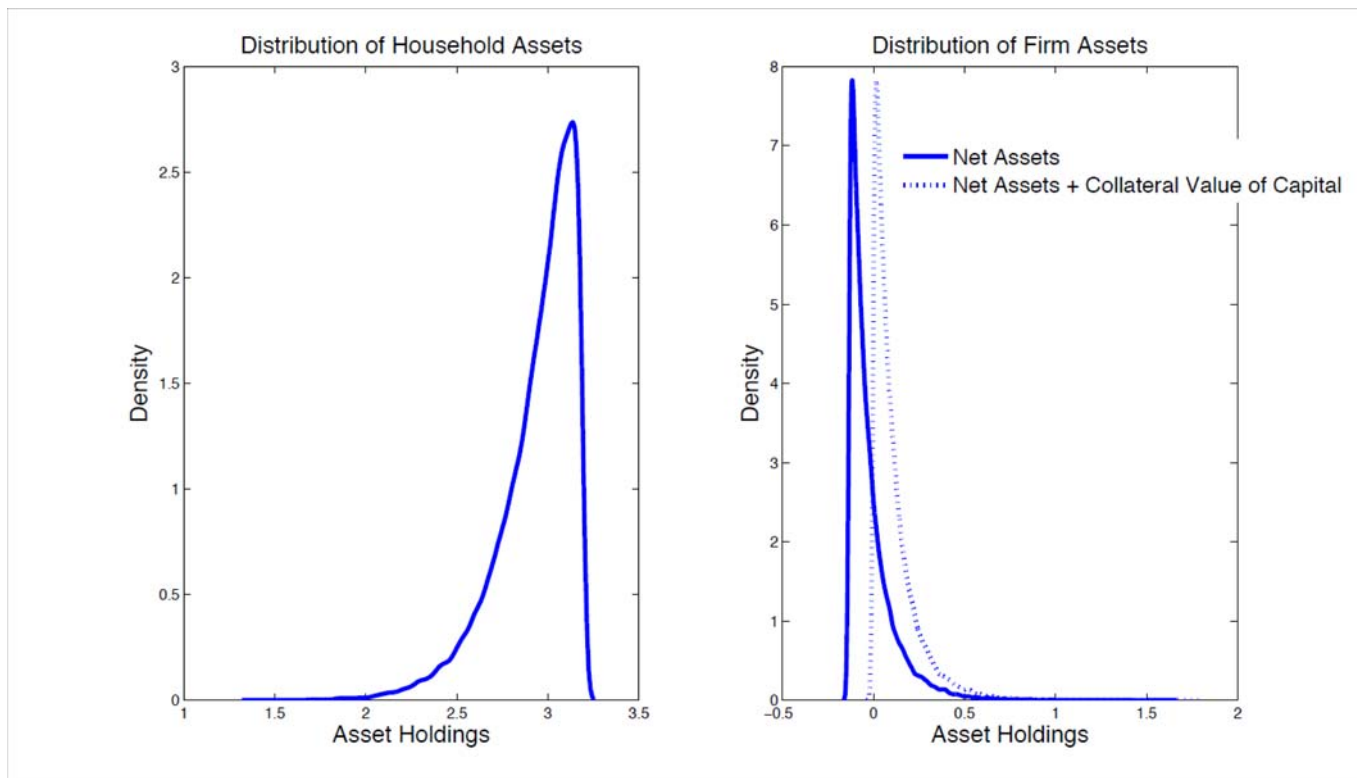


Figure 3: Household and Firm Real Net Asset Distributions

The distributions of households' and firms' asset holdings are displayed in Figure 3. Firms are created with no financial assets and some debt, and as a result with a negative net asset position. Those that do not go bankrupt during their initial periods of operation slowly accumulate financial wealth as they make positive profits, at a speed driven by firm profitability and by the equilibrium interest rate which determines the returns on their liquid asset holdings. The distribution of asset holdings of households is displayed on the left panel of Figure 3. The precautionary behavior of workers on the one hand, and their consumption smoothing motive on the other, ensure that their asset holdings converge to a smooth distribution. The source of dispersion in household wealth is the transition between employed and unemployed status.<sup>18</sup>

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<sup>18</sup>Our model is not designed to match these distributions to their empirical counterparts with precision. The firm sector distribution of liquid assets, however, does match the observed distribution relatively well, as shown in Panel B of Table 1. Achieving a closer match, particularly for the household sector, would require adding a much larger set of dimensions of heterogeneity within households and firms, which would defeat the purpose of providing a clear exposition of our mechanism.

## 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 learn about a sequence of unexpected aggregate shocks that take place between  $t = 1$  and  $t = J > 1$ ,  $\{\Psi\}_1^J$ . We study the dynamics of the economy during  $T > J$  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, and the implications of this interaction for aggregate fluctuations. For our benchmark exercise, we consider a shock to households that resembles the one that occurred during the 2007-2009 recession. We follow Mian, Rao and Sufi's (2013) view that the house price collapse in the 2007-2009 period resulted in a large negative wealth shock, which significantly affected the consumption decisions of US households. We implement this shock as a wealth redistribution from the bottom 90<sup>th</sup> percentile of the net worth distribution of households to the top decile, occurring gradually over eight quarters.<sup>19</sup> In order to measure the shock we use the data on the households surveyed in the 2007-2009 panel of the Survey of Consumer Finances (SCF).<sup>20</sup> We consider the distribution of households according to their net worth in 2007, including only households with positive net worth. For each decile of net worth we calculate the median decline in net worth in the 2007-2009 period, which ranges from a median decline of 48% for the first decile to a median decline of around 20% for the deciles above the 6th.<sup>21</sup> Then we compute a quarterly shock  $h^d$ , where  $d = 1, \dots, 8$  indicates the decile, so that in the first 8 quarters of the transition period, from  $t = 1$

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<sup>19</sup>This redistribution can be interpreted as a shortcut to a more realistic model in which the value of housing is inflated by a bubble and houses are used as collateral for mortgage loans. When an exogenous bursting of this bubble causes a decline in house prices, the resulting relative fall in net household wealth is on average higher for the less wealthy and more leveraged households. We abstract from the average fall in net wealth, and instead only consider the distributional impact. In the model, consumption is more sensitive to wealth for poorer households, both because of a precautionary saving motive and because of financing frictions, and this redistribution therefore negatively affects aggregate consumption.

<sup>20</sup>[http://www.federalreserve.gov/econresdata/scf/scf\\_2009p.htm](http://www.federalreserve.gov/econresdata/scf/scf_2009p.htm)

<sup>21</sup>These values are consistent with an alternative way to compute the shock based on the percentage decline in house prices in the 2007-2009 period multiplied by the average value of housing as a percentage of net worth in 2007 for the households in the SCF.

to  $t = 8$ , the wealth of household  $i$  in decile  $d$ ,  $a_{i,t}^d$ , is unexpectedly reduced to  $a_{i,t}^d(1 - h^d)$ .<sup>22</sup> Therefore, the corresponding quarterly wealth transfer to every household in the 10<sup>th</sup> decile of wealth is equal to

$$\frac{\sum_{d=1}^9 \sum_{i=1}^{N^d} a_{i,t}^d h^d}{N^{10}},$$

where  $N^d$  is the number of households in decile  $d$ . As an indirect confirmation that the magnitude of this shock is realistic, we calculate that real consumption expenditure in these 8 quarters falls by 5.8% in the simulated economy with both demand and credit shocks (see Figure 5). This is of a similar order of magnitude as the average drop in spending for US households from 2006 to 2009, which Mian, Rao and Sufi (2013) estimate to be 5.9%.

In our benchmark transition exercise we consider as a credit shock to firms an unexpected increase in the interest rate spread paid on net borrowing,  $\kappa_t$ , that resembles the observed spreads that occurred during the 2007-2009 crisis. Therefore we modify equation 7 as follows:

$$\begin{aligned} n_{t+1}^F(\varepsilon_t) &= n_t^F(1 + r_t + \kappa_t) + \pi_t(\varepsilon_t) - d_t \text{ if } n_t^F < 0, \\ n_{t+1}^F(\varepsilon_t) &= n_t^F(1 + r_t) + \pi_t(\varepsilon_t) - d_t \text{ if } n_t^F \geq 0. \end{aligned}$$

Our aim is for our spread shock to capture the contraction in credit supply suffered by firms during this period. Gilchrist and Zakrajsek (2012) document that the total credit spread rose from an average of around 2% before the 2007-2009 crisis to close to 8% at its peak during the recession. Their evidence is obtained from a sample of publicly listed firms with outstanding bonds traded in financial markets, a subset of firms which is likely to be at the lower end of the distribution of financial constraints, and hence a conservative estimate for the credit shock suffered by the average firm.<sup>23</sup> Accordingly, we set the value of  $\kappa_t$  equal to 5.2% in annualized

<sup>22</sup>We assume that each of the wealth shocks is unexpected at the household level. That is, even though the households can forecast the future paths of employment, prices and interest rates, they do not anticipate that their own wealth will be affected by the redistribution shock.

<sup>23</sup>Gilchrist and Zakrajsek (2012) introduce a method to extract the component of credit spread variations not associated with changes in firms' default probability, but instead associated with other factors such as financial intermediaries' balance sheet strength or changes in investors' risk tolerance. They document that about half of the total increase in the credit spread was not due to an increase in the expected probability of default. In our model, we make a simplifying assumption to ensure that firm's debt is not risky. Therefore  $\kappa_t$  can be interpreted as a shortcut to a wedge caused either by an increase firm's riskiness during the crisis, or by an exogenous increase in the cost of external finance because of a credit crunch. If we explicitly introduced risky debt in the model, the first component would arise endogenously and amplify the interest rate wedge caused by the credit crunch.

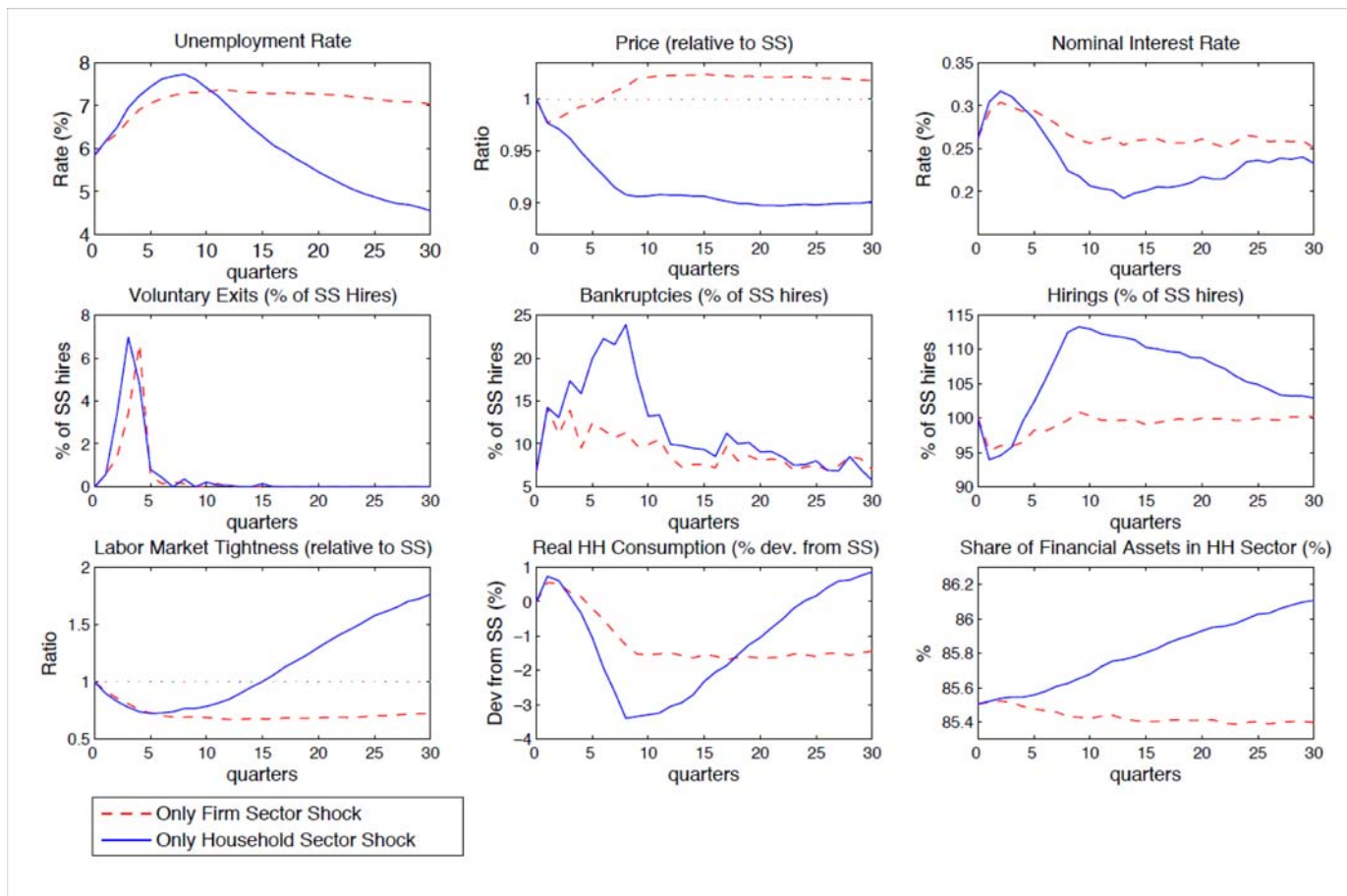


Figure 4: Transition Dynamics - Individual Shocks to Households and Firms

terms for the transition periods from  $t = 1$  to  $t = 8$ , and equal to the steady state value of 0% from period  $t = 9$  afterwards.<sup>24</sup>

Figure 4 shows transition dynamics for two simulations, one with only shocks to households and one with only shocks to firms. The upper panels show the dynamics of unemployment, the price of the consumption good relative to the financial asset, and the nominal interest rate, for the 30 periods after the shock first hits. The middle panels display the job destruction and creation dynamics, and the bottom panels describe the labor market tightness, and consumption and wealth dynamics.

In the simulation with only demand shocks the price falls gradually during the first 8 quar-

<sup>24</sup>We also computed transition dynamics considering as a credit shock to firms an increase in  $\alpha_t$ , the probability that a firm needs to provide guarantees (satisfy condition (4)) to renew its long-term debt. This shock is a shortcut to an unexpected tightening in lending conditions during the financial crisis. In this case we set the value of  $\alpha_t$  equal to 50% for the transition periods from  $t = 1$  to  $t = 8$ , and equal to the steady state value of 11.5% from period  $t = 9$  onwards. The results obtained using this alternative shock are qualitatively and quantitatively similar to those presented in this section.

ters, as households reduce consumption in response to the shock. Unemployment increases for the first 8 quarters, peaks at a value of 7.7% (1.9% higher than the steady state) and afterwards declines constantly until it reaches a level in excess of 1.4% below the steady state after 30 periods. Thus, the demand shock alone has both a contractionary effect on employment in the short term, and a very persistent expansionary effect in the medium term. These dynamics are the result of two counteracting forces. First, a drop in prices reduces both the nominal profits and the collateral value of capital of existing firms, making it more likely that these firms are unable to refinance their nominally fixed long-term debt and are forced to liquidate. The drop in collateral value of capital comes about because capital and consumption goods are perfect substitutes. This effect generates a significant increase in the number of bankruptcies during the first 10 quarters of the transition period.

Second, the drop in the price level and in the interest rate stimulate the creation of vacancies and the formation of new jobs. This happens both because lower nominal interest rates reduce the opportunity cost of capital, and because the anticipated gradual increase in the price level decreases the expected future real burden of the long-term debt issued in the present to buy capital. The middle panels of Figure 4 show that the positive effect on hiring is lagged relative to the surge in forced exits, but much more persistent. The bottom center and right graphs show the dynamics of consumption and asset accumulation by households. The latter graph shows that the shock has an effect similar to "deleveraging", because total financial assets held by the household sector constantly increase over time. This happens because the shock causes a persistent increase in the saving rate and aggregate savings, as the households below the 90th percentile save to rebuild their financial wealth. Initially this causes a drop in real consumption, which then overshoots above the steady state level as employment and production increase. In other words, by stimulating job creation, higher savings generate more resources and help the household sector quickly reach their desired levels of wealth accumulation. Summing up, in a simulation with only household wealth shocks, a reduction in the demand for consumption goods has little impact on unemployment, because higher savings and expected future inflation reduce the cost of capital and stimulate job creation.

In Figure 4 we also report the dynamics following the credit shock to firms. This shock leads to an immediate increase in bankruptcies of the most financially fragile firms, and to a

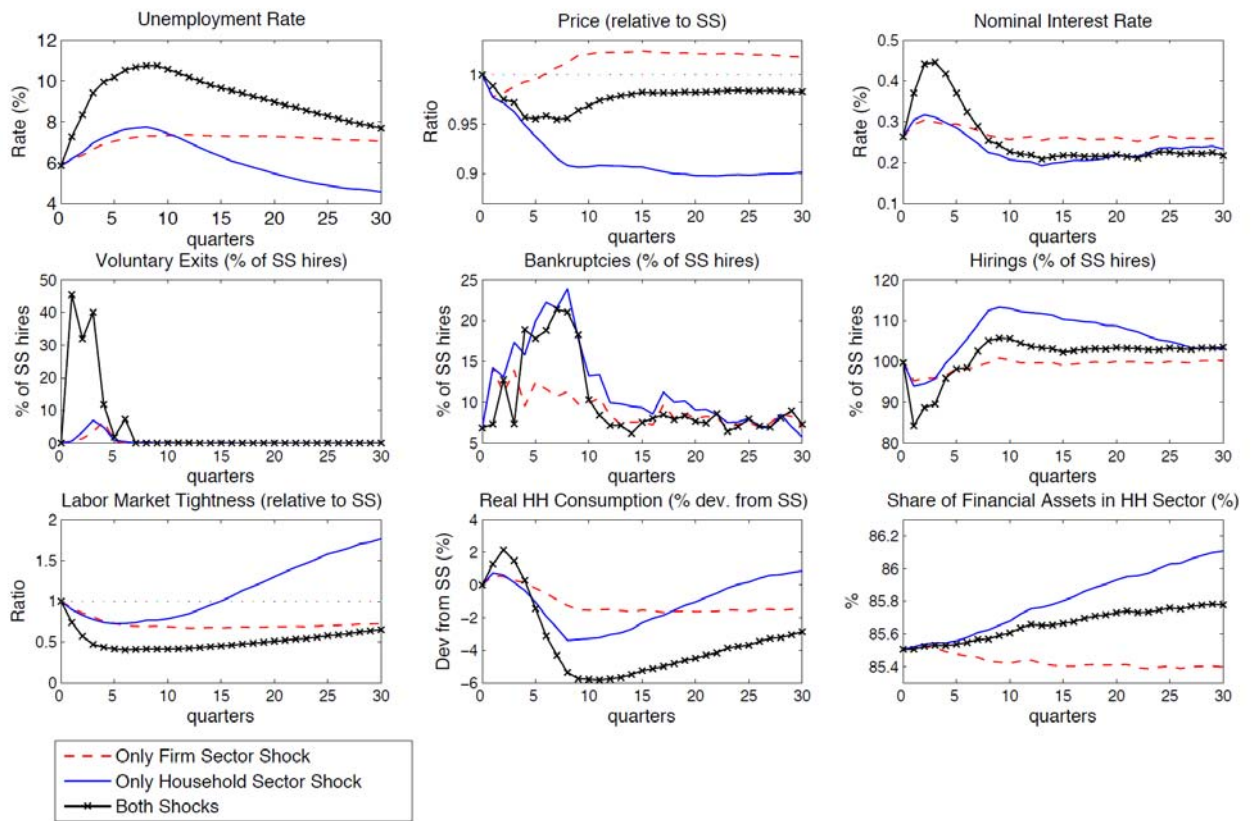


Figure 5: Transition Dynamics - Joint and Individual Shocks to Households and Firms



persistent reduction in hiring, because the higher cost of borrowing for new firms reduces the value of creating new vacancies. However, the increase in unemployment, from the steady state value of 5.9% to a peak of 7.4% after 11 quarters, is relatively small. One reason for the limited impact of the shock is the increase in the price level, which increases nominal revenues and makes it more likely that firms are able to repay their debts and avoid default. The increase in the price level is caused by a reduction in supply which is not matched by an equally large reduction in demand, because of households' desire to smooth consumption. The fall in real consumption during the first 8 quarters is about half of the size of the reduction in the demand shock simulation, and is mainly caused by a reduction in permanent income due to lower output and aggregate dividends.<sup>25</sup>

Next, we discuss the main insight of our paper, which is that when the two shocks occur simultaneously their effects interact with each other to generate a very large and persistent negative impact on output and employment. Figure 5 replicates Figure 4 and adds the simulation results when both shocks are present. In period  $t = 9$  unemployment has increased by 1.9% in the simulation with only demand shocks, by 1.5% in the economy with only the firms' credit shock, and by 4.9% in the economy with both shocks present. The two shocks interact in such a way that not only increases the peak unemployment rate to levels comparable to those observed during the recent financial crisis, but also makes it very persistent. After 17 periods, unemployment has already gone back to the steady state level of 5.85% in the simulation with only household shocks, while it is still as high as 9.32% in the simulation with both shocks. The demand shock generates declining prices, reducing nominal revenues and the collateral value of capital, at the same time as the credit shock increases the cost of servicing the debt, worsening firms' liquidity position. This additional financial fragility generates an early surge in voluntary exits. These are firms that are able to continue operating, but that 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 job creation, reducing the tightness of the labor market. On the one hand, this early surge in voluntary

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<sup>25</sup>The increase in unemployment is small but very persistent in this simulation, because the gradual and persistent decline in prices towards the steady state, from period 15 onwards, increases the real interest rate and the real value of debt, and dampens job creation.

exits and reduction in job creation generates the initial sharp increase in unemployment. On the other hand, the pattern of household deleveraging generates large propagation effects and makes unemployment very persistent. Households' attempt to improve their financial position following the negative wealth shock is hindered in the presence of firm shocks. The higher rate of unemployment relative to the case with only a shock to household wealth means that many households find it harder to accumulate savings, as shown in the bottom right panel. The price dynamics are shaped by these conflicting forces. Prices initially drop between periods 1 and 9 as a result of the combination of increased goods supply, arising from the liquidated capital from the firms that exit, and reduced demand. Afterwards there is a temporary increase in prices until period 16, because demand for investment goods from new firms increases. Then from period 16 onwards the price level does not keep increasing to converge to the steady state, but rather keeps decreasing, reflecting the need of the household sector to reduce consumption and keep deleveraging. This decline in prices is very gradual and persistent, and it generates a similar persistence in unemployment.<sup>26</sup>

The results discussed in this section show that neither negative household demand shocks nor firm credit shocks are able to generate large increases in unemployment when they occur separately, but that when these two types of shocks are combined they can amplify each other's effects to generate much larger unemployment fluctuations.

A potential concern is that the interaction effect we describe is due to the size of the combined household and firm shocks rather than to any special feedback between the effects of both shocks. If this were the case, then large shocks to either the household or the firm sector would also cause large increases in unemployment. To address this concern, we first define a simple statistic to summarize the magnitude of both the amplification and persistence effects of the shock. We interpret the steady state output level in the model as the potential output in our simulated economy, and we calculate the output gap in each quarter as the difference between potential output and actual output divided by potential output. Our summary measure of the effects of the shocks is the average output gap for the first 30 quarters of the simulated transition. We choose 30 quarters both because this is a long enough time period to capture the effect of both amplification and persistence, and because it is roughly comparable to the time it has taken the

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<sup>26</sup>Prices start to increase again towards the steady state from period 60 onwards.

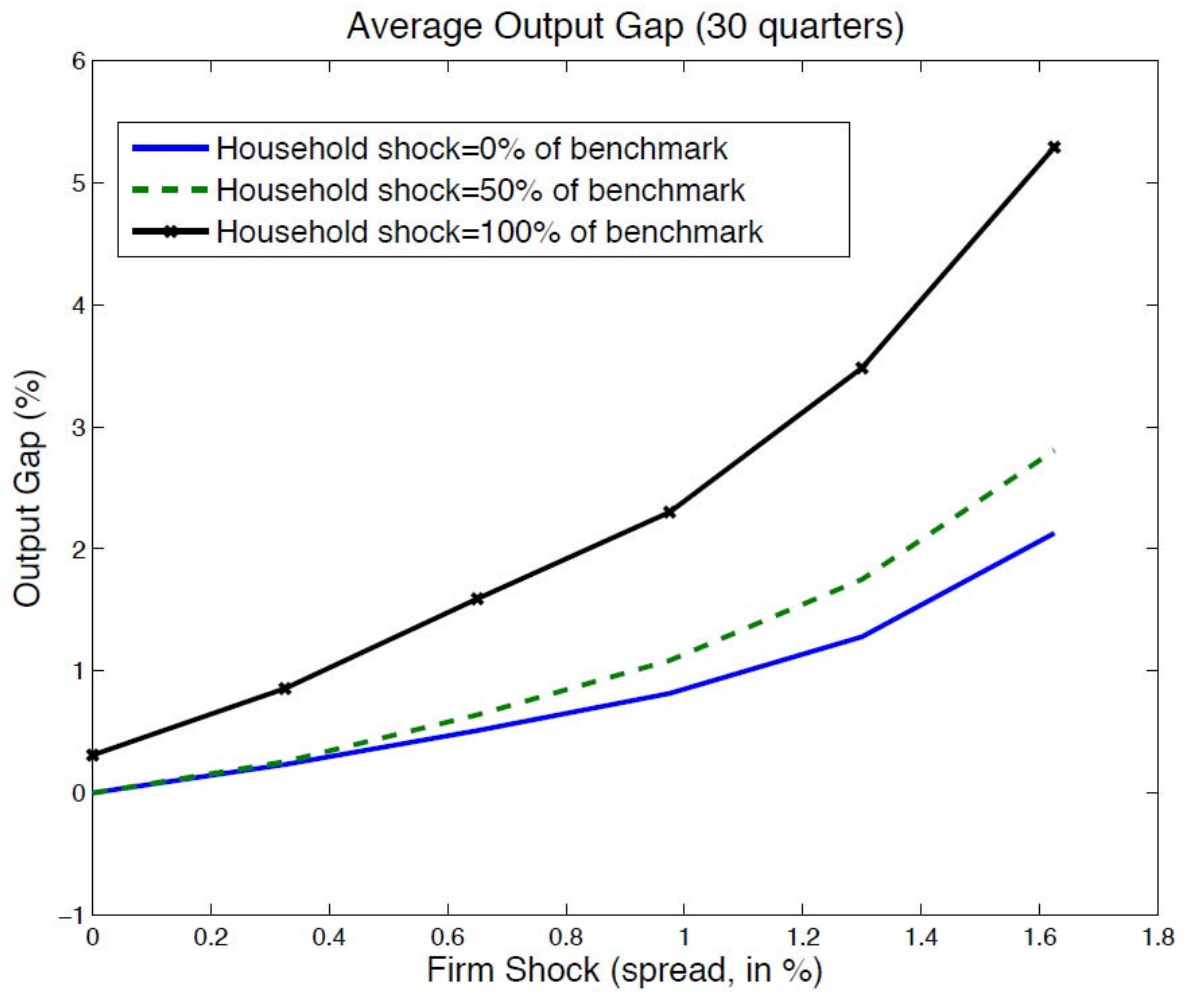


Figure 6: The Effect of Firm Credit Shocks in the Presence of Household Sector Shocks of Different Magnitudes

U.S. to recover from the Great Recession in terms of the unemployment rate.

In Figure 6, each line represents the average output gap obtained in simulations with a gradually increasing size of the firm shock, for a given size of the household shock. The figure highlights three important results of our model. First, the effect of a firm credit shock on the economy is nonlinear, since each of the three lines is convex. This means that, even in the absence of household shocks, a large enough financial shock to firms would be sufficient to generate large and persistent increases in unemployment and the output gap. However, these shocks would have to be implausibly large to generate unemployment dynamics consistent with the great recession in the US. Second, the effect of the demand shock in isolation on the average output gap, which can be computed by comparing the initial point of each line, is virtually nonexistent, because the expansionary and contractionary effects compensate each other. Third, despite the fact that the demand shock is neutral for the average output gap when it occurs in isolation, it clearly amplifies the effect of the firm credit shock, and more so the larger the firm shock is. This evidence clearly shows that the amplification and persistence results shown so far are generated by a positive interaction between the two shocks, rather than by the nonlinearity of the individual shocks. With the benchmark demand and firm shock occurring simultaneously (the point in Figure 6 that corresponds to the 1.3% firm shock on the 100% household shock line), we obtain an average output gap of 3.5%, which is close to the average output gap in the US in the 30 quarters since the beginning of the financial crisis (from the last quarter of 2007 to the first quarter of 2015), which is 4.2%.<sup>27</sup>

To gain further insight into the precise mechanisms that drive the interaction between both types of financial shocks, we conduct several exercises in which we remove some ingredients of our economy to evaluate their importance. When discussing transition dynamics above we emphasized the importance of voluntary exits in generating large increases in unemployment and of persistent endogenously low demand in affecting the persistence of unemployment. Therefore on the firm side, we eliminate the possibility of voluntary exit for firms. On the household side, we remove the endogenous feedback effect from unemployment to aggregate demand, by simulating an economy in which the same number of households receive the equilibrium wage, following any of the shocks, as during the steady state. This subsidy to a subset of the

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<sup>27</sup>Source: St. Louis Fed., <https://research.stlouisfed.org/fred2>

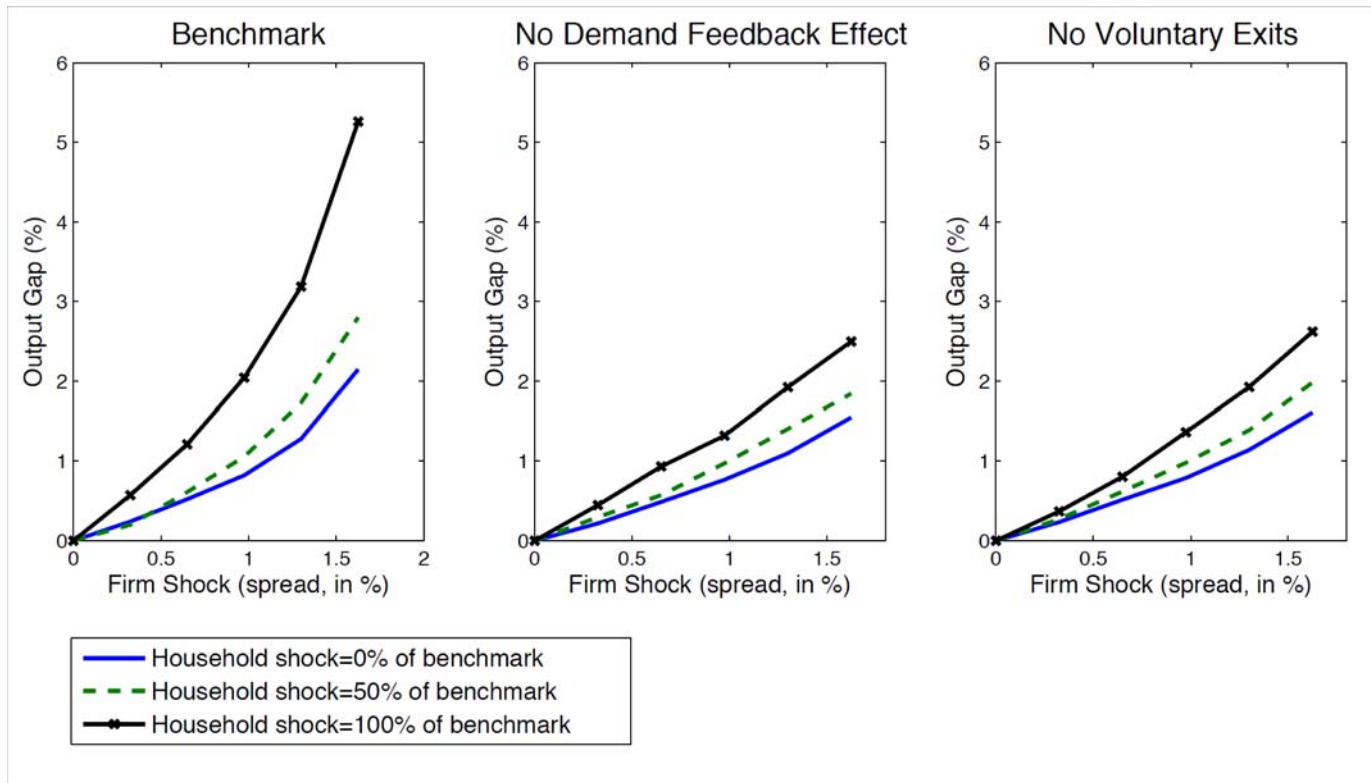


Figure 7: The Mechanisms that Generate Interaction between Household and Firm Financial Shocks

unemployed households is financed by taxing the top quintile of firms in terms asset holdings. The purpose of this exercise is to design an economy in which aggregate demand responds to the deleveraging induced by the household wealth shock, but not to the subsequent endogenous increase in unemployment.

Figure 7 displays the average output gap generated by the firm credit shock in the presence of household shocks of different sizes, in the benchmark case and in the two cases described above. To make it easier to compare the different figures we rescale them so that the average output gap for the "0% firm shock" simulation is always normalized to zero.<sup>28</sup> The figure shows that, in the absence of either firm voluntary liquidations or demand feedback effects, the "100% household shock" line is much closer to the other two lines, meaning that the size of the interaction between shocks is reduced significantly. This is further evidence that household shocks amplify the effect of firm credit shocks mainly because of a feedback between endogenous aggregate demand fluctuations and voluntary firm liquidations, as argued above.

<sup>28</sup>Nonetheless, the raw figures show qualitatively very similar results.

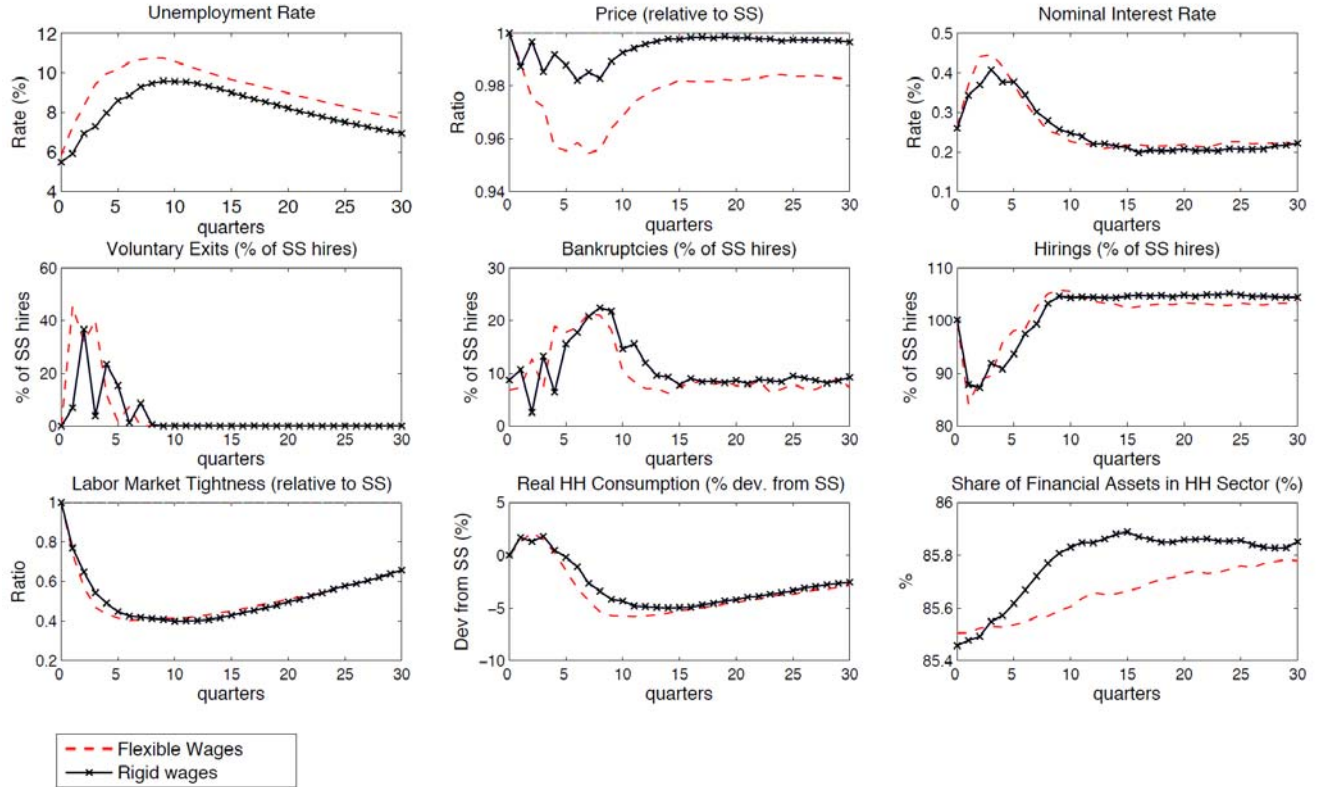


Figure 8: Transition Dynamics - Joint Shocks to Households and Firms in the Benchmark Model and in a Model With Nominally Rigid Wages

## 5 Interaction Effects in the Presence of Nominal Wage Rigidity

Our benchmark model only features nominal rigidities in debt, but nominal rigidities in wages are known to be a key ingredient for models to be able to capture important features of the business cycle, particularly for models that emphasize aggregate demand disturbances (Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007)). In this section, we repeat the simulations by making the assumption that wages are nominally rigid in the transition at their steady state level. This nominal wage rigidity affects existing firms and also new firms that are created during the transitional dynamics following shocks. While it has been shown that wages for new hires are significantly more flexible than wages of existing jobs (Haefke, Sonntag and van Rens (2013)), we make this strong assumption about nominal wage rigidity to better assess the extent of the possible implications of such a feature in our model.

The results from running this simulation are in Figure 8, in which the responses to the combined household and firm sector financial shocks are displayed for the benchmark model and

for the same model with nominally rigid wages in the transition. Wage rigidity has two effects that operate in opposite directions. Wage rigidity in the presence of declining prices reduces firm profits and job creation. Wage rigidity, however, also contributes to sustain consumption by increasing the real value of wages. This prevents a large fall in the price level and a large increase in the real value of debt, reducing both bankruptcies and especially voluntary liquidations of firms that fear future bankruptcy costs. Under our calibration, the positive effect dominates the negative effect. Given that these counteracting effects offset each other, Figure 8 shows that even this extreme form of wage rigidity does not significantly affect the main results of the analysis. This is confirmed in Figure 9 which replicates our benchmark comparison of the three simulations in Figure 5, the only difference being the nominal wage rigidity during the transitional dynamics. As was the case with flexible wages, also in this case the shock to household wealth amplifies the unemployment fluctuations caused by the firms' shock when they happen simultaneously, but the interaction effect is significantly weaker.

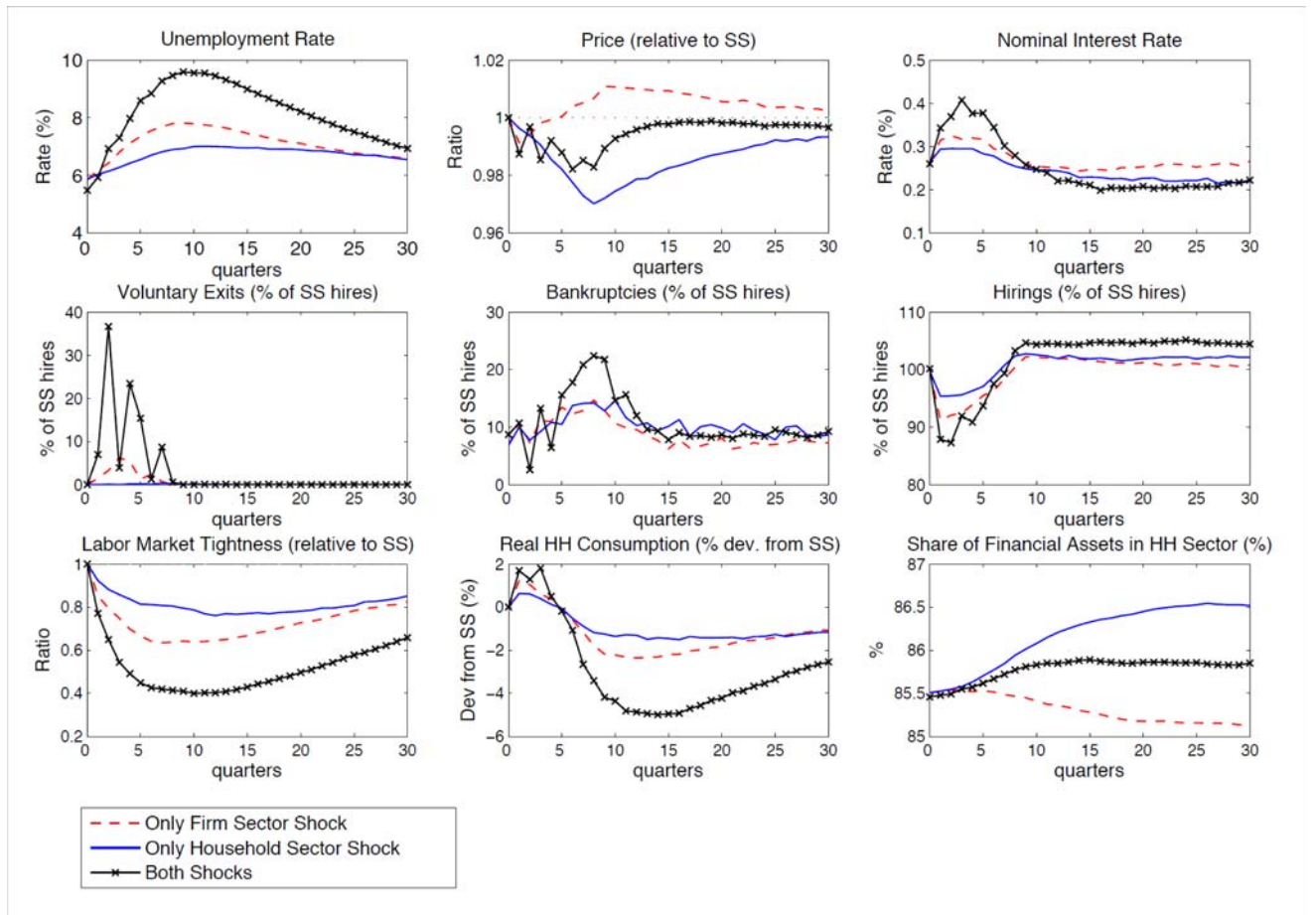


Figure 9: Transition Dynamics - Joint and Individual Shocks to Households and Firms in a Model With Nominal Wage Rigidities



## 6 Conclusions

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 matter importantly for 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.

The policy implications of the mechanisms described in this paper could be very relevant. In related work (Caggese and Perez (2015)) we explore the effects of different labor market reform policies in a similar theoretical framework, with a focus on firing costs, unemployment benefits, and subsidies to firms. Further research could also focus on the monetary policy implications of nominal debt rigidities in the context of our framework.

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## 7 Computational Appendix

### 7.1 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 (10) 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  $M = 45,000$  conglomerate 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 vacancy posting condition (11), 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 (4) to all firms with probability  $\alpha_t$ , 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 (21)). 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.

Conglomerates' net revenues are calculated using expression (13), and this net cash flow constitutes the dividend conglomerates pay out to households, which determine the equilibrium interest rate given by (15).

#### 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.

## 7.2 Transitional Dynamics

This appendix describes the numerical methods used to solve for the transitional dynamics exercises introduced in Sections 4 and 5. 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  $t = 1, \dots, T$  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.