Anatomy of a Credit Crunch: From Capital to Labor Markets

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Abstract

Why are financial crises associated with a sustained rise in unemployment? We develop a tractable model with frictions in both credit and labor markets, and use it to study the aggregate and micro-level implications of a credit crunch (a tightening of collateral constraints). In our model, a credit crunch calibrated to match the observed decline in the stock of debt to non-financial assets of the US business sector following the 2007–8 crisis leads to a sharp decline in output—explained by a drop in TFP and investment—and a protracted increase in unemployment. We then explore the micro-level consequences of the credit crunch, tracking the employment dynamics firms of different size and age. We find that credit crashes cause a reduction in the net employment growth rates of small, young establishments relative to large, old producers, consistent with the empirical findings in the literature.

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1 Introduction

Financial crises are associated with severe economic contractions and sharp deteriorations in labor market conditions. The experiences of the Great Depression and the 2007–8 financial crisis are dramatic examples. The evidence in Reinhart and Rogoff [2009] provides a broader picture of such phenomena. Despite the close connection between financial crisis and sustained rise in unemployment, there are very few models that incorporate both credit market and labor market frictions. The goal of this paper is to build one.

In our model, production is done by entrepreneurs that are heterogeneous in net worth and entrepreneurial productivity, with the former being endogeneously determined by their saving decisions. Entrepreneurs rent capital and labor from competitive factor markets subject to a collateral constraint that limits the amount of capital input to be proportional to their financial wealth. We assume that there is a centralized labor market where hiring entrepreneurs compete for available unemployed workers. The arrival of unemployed workers to this centralized hiring market is where the labor market frictions are. The friction is modeled in the form of a simple matching function that maps the number of unemployed workers into the number of matches in the hiring market. Depending on their wealth and entrepreneurial productivity, individuals choose to be entrepreneurs or to participate in the frictional labor market.

We use a quantitative version of our theory to trace out the effects of a credit crunch that is modeled as a tightening of the collateral constraint. In the model, a credit crunch leads to a sharp decline in output—explained by a large drop in TFP and a relatively small decline in investment—and a sustained increase in unemployment. The credit contractions result in a reallocation of capital from entrepreneurs with low net worth towards unconstrained entrepreneurs. The reallocation of credit and capital is accompanied by a reallocation of labor across entrepreneurs, a process that is gradually mediated by the matching function. In this process, resources are reallocated from productive but constrained entrepreneurs towards those who are relatively unproductive and unconstrained. As a result, the aggregate TFP suffers. The gradual reallocation of labor through the frictional labor market results in a protracted rise in unemployment.

We also explore the behavior of the economy in response to an aggregate TFP shock. We find that the implications for the dynamics of unemployment with such shocks are starkly different from those with a credit crunch: With the TFP shock, the unemployment rate does not change at all. The reason is that a decline in aggregate productivity affects capital and labor demands of all firms equally, and flexible wages and interest rates fully offset the contractionary effect of the TFP shock on unemployment. On the other hand, credit shocks have differential effects on firms depending on entrepreneurs’ productivity and wealth, and these heterogeneous responses of individual firms prevent the reduction in wages from achieving the same outcome. In a nutshell, it is the reallocative nature of credit shocks that is essential for realistic unemployment dynamics in the model.

The remainder of our quantitative analysis focuses on exploring the implications of a credit crunch for employment dynamics at a more disaggregate level. A large empirical literature documents that financial crises affect firms of different sizes differently. The working hypothesis of
these studies is that small businesses are more heavily reliant on credit to finance their production and capital expenditures, and hence more susceptible to recessions caused by credit contractions. Gertler and Gilchrist [1994] found evidence supporting this claim and, more recently, Fort, Haltiwanger, Jarmin and Miranda [2012] extended the analysis to highlight the role of firms’ age as well as size: During a credit crunch, the employment growth of young, small establishments declines more relative to that of old, large establishments.

Our model predictions are in line with the findings of the empirical studies. We show quantitatively that net employment growth rates fall by more for young and small firms relative to old and large firms, reflecting the reallocation of factors from constrained to unconstrained entrepreneurs. By exploring the steady state properties of the distribution of firms in terms of ages and sizes, we discover that this pattern is explained by the fact that about 90 percent of the young, small firms are financially constrained, compared to just 10 percent of the old, large firms. This information manifests itself in the distribution of returns to capital across firms, which shows an excess return of 8 percent in the former group relative to the latter, deviating from the equalization of rates of return across firms under the frictionless allocation.

In this context, our paper provides a theoretical underpinning of the working hypothesis of the empirical literature, and explains how the aggregate behavior of the economy is shaped by the heterogeneous responses at the firm level.

The rest of the paper is organized as follows. We provide a review of the literature below, and then present the model in Section 2. We present the results from our quantitative analysis in Section 3. First, we explain in detail how parameter values and time series for the credit constraint are calibrated. Then, we analyze the macroeconomic implications of a credit crunch, and compare them to those of a TFP shock. We then examine the impact of the credit crunch at the individual firm level, and evaluate how the impact varies across firms of different ages and sizes. We conclude in Section 4.

Related Literature Our paper is related to several strands of the literature. Our modeling of financial frictions closely follows the work of Kiyotaki and Moore [1997], in which credit is limited by a collateral constraint arising from a limited enforceability problem between creditor and debtor. However, we abstract from feedback effects going from asset prices to collateral constraints. Jermann and Quadrini [2009] adopts the same modeling strategy for financial frictions to study the role of credit as a driver of business cycles. The most salient difference between our work and theirs is that we introduce credit shocks in an economy where entrepreneurs are heterogeneous and, hence, the tightness of credit at any given point of time is different across producers. We show that this heterogeneity generates novel implications on how credit shocks affect the behavior of the aggregate economy, as well as rich microeconomic implications.

Producer heterogeneity is also a feature of Khan and Thomas [2011], Zetlin-Jones and Shourideh [2012], and Buera and Moll [2012]. Our contribution relative to their work is that we bring unemployment to the front and center of the analysis, and study the interaction between credit and
labor market frictions. We accomplish such interaction by incorporating matching frictions and a notion of Walrasian labor markets—as in Veracierto [2009]—into Buera and Shin’s [2013] model of occupational choices, production, savings, and financial frictions.

Our exploration of the micro-level implications of a credit crunch is motivated by a number of empirical studies in the literature. Gertler and Gilchrist [1994] were the first to document the differential dynamics of small and large firms during recession dates associated with monetary contractions. Their finding that small firms were cyclically more sensitive than large ones during monetary contractions was validated by Chari, Christiano and Kehoe [2013], although they also find the reverse to be true during other NBER recession dates. Moscarini and Postel-Vinay (2012) study the unconditional cyclical behavior of small and large firms and document that it is the large businesses whose employment declines the most during periods of economic contractions.

More recently, Fort, Haltiwanger, Jarmin and Miranda [2012] re-evaluated the cyclical behavior of firms and highlight the role of age, together with size, in characterizing the responsiveness of firms to business cycles. With respect to the small vs. large debate, their results favor the previous evidence that small firms’ employment growth rates decline more during recessions than large firms’. However, they emphasize that a joint consideration of age and size provides the clearest pattern of firms’ response to business cycles: Net employment growth rates of small, young firms decline substantially more than those of large, old firms.

Our paper is related to the empirical literature in two ways. First, we take the data as a test for the firm-level implications of our model that underly the macro-level dynamics. Second, we use the model’s forces to better understand why age and size would explain how different firms react to credit shocks. We provide a theoretical foundation to the conjecture in the empirical literature that small and young firms have the most difficult time gaining access to credit in times of tight overall credit availability.

2 Model

We model an economy populated by a continuum of individuals, who are heterogeneous with respect to their wealth $a$, entrepreneurial productivity $z$, and access to employment opportunity. In each period, an individual who has an employment opportunity chooses whether to work for a wage or to operate an individual-specific technology (entrepreneurship). Those without an employment opportunity can choose between searching for a job and operating their individual-specific technology.

Access to capital is determined by entrepreneurs’ wealth through a simple collateral constraint, motivated by the imperfect enforceability of capital rental contracts. One entrepreneur can operate only one production unit (establishment) in a given period. Entrepreneurial ideas are inalienable, and there is no market for managers or entrepreneurial talent.

We assume that there is a centralized labor market where hiring entrepreneurs compete for available unemployed workers. The arrival of unemployed workers to the centralized hiring market is
modeled with a simple matching function. We restrict wage contracts to be the same across workers and entrepreneurs. In the benchmark exercise, we assume that workers are paid in each period the wage that clears the current hiring market, and entrepreneurs may terminate the employment relationship at any time. In an extension, we also consider the case where wages have downward rigidity.

**Heterogeneity and Demographics** Individuals live indefinitely, and are heterogeneous in their wealth \( a \), entrepreneurial productivity \( z \in Z \), and employment opportunity. Their wealth is chosen endogenously by forward-looking saving decisions and their entrepreneurial productivity follows a stochastic process. In particular, an individual retains his entrepreneurial productivity from one period to the next with probability \( \psi \). With probability \( 1 - \psi \), he loses the current productivity and has to draw a new entrepreneurial productivity. The new draw is from a time-invariant distribution with a cumulative density \( \mu(z) \), and is independent of his previous productivity level.

In the following analysis, we maintain the assumption that unemployed workers receive unemployment benefits that are equal to the market wage in each period, and that leisure does not enter the utility function. As a result, individuals are indifferent between being employed and being unemployed, and we will abstract from this dimension of ex-post heterogeneity in writing down the individuals’ problem. However, the unemployment rate is an important variable for the equilibrium definition and the aggregate dynamics of the model.

The population size of the economy is normalized to one, and there is no population growth.

**Preferences** Individual preferences are described by the following expected utility function over sequences of consumption, \( c_t \):

\[
U(c) = \mathbb{E} \left[ \sum_{t=0}^{\infty} \beta^t u(c_t) \right], \quad u(c_t) = \frac{c_t^{1-\sigma}}{1-\sigma}
\]

where \( \beta \) is the discount factor and \( \sigma \) is the coefficient of relative risk aversion. The expectation is taken over the realizations of the entrepreneurial productivity \( z \).

**Technology and Occupational Choice** At the beginning of each period, an individual chooses whether to operate his own business or not. If not, he either works for the market wage \( w_t \), if he has an employment opportunity, or searches for a job, if unemployed. An entrepreneur with talent \( z \) produces using capital \( k \) and labor \( l \) according to:

\[
f_z(k, l) = zk^{\alpha}l^{\theta},
\]

where \( \alpha \) and \( \theta \) are the elasticities of output with respect to capital and labor, and \( \alpha + \theta < 1 \), implying diminishing returns to scale in variable factors at the establishment level.
**Taxes and Unemployment Subsidies**  We assume that unemployed individuals receive a transfer equal to the period wage, which is financed with a lump-sum tax \( \tau_t \) on all individuals. Given this assumption, from an individual’s point of view, there is no difference between being a wage earner and being unemployed. This allows us to formulate the individual problem as if they belonged to one of two mutually exclusive states: a worker (employed and unemployed) or an entrepreneur.

**Financial Markets**  Productive capital is the only asset in the economy. There is a perfectly-competitive financial intermediary that receives deposits and rents out capital to entrepreneurs. The return on deposited assets—i.e. the interest rate in the economy—is \( r_t \). The zero-profit condition of the intermediary implies that the rental price of capital is \( r_t + \delta \), where \( \delta \) is the depreciation rate.

We assume that entrepreneurs’ capital rental \( k \) is limited by a collateral constraint \( k \leq \lambda a \), where \( a \geq 0 \) is individual financial wealth and \( \lambda \) measures the degree of credit frictions, with \( \lambda = +\infty \) corresponding to perfect credit markets and \( \lambda = 1 \) to financial autarky where all capital has to be self-financed by entrepreneurs. The same \( \lambda \) applies to everyone in a given economy.

Our specification captures the common prediction from models of limited contract enforcement: The amount of credit is limited by an individual’s wealth. At the same time, its parsimoniousness—the fact that financial frictions are captured by one single parameter, \( \lambda \)—enables us to analyze the quantitative effects of financial frictions on aggregate transitional dynamics without losing tractability.\(^1\)

**Labor Market**  Entrepreneurs hire workers in a centralized and competitive labor market. We restrict labor contracts that entrepreneurs can offer to have the following properties: (1) they pay the wage that clears the hiring market in each period and (2) the employer may terminate the employment relationship at any time. In particular, all entrepreneurs, irrespective of their current state, are restricted to offer the same labor contract. Laid-off workers become unemployed.

We make labor markets frictional by means of a matching friction that interferes with the entry of unemployed workers into the hiring market. More specifically, we assume that instead of matching unemployed workers directly with firms, the matching function determines the fraction of the unemployed who make it into the centralized hiring market. For those in the centralized labor market, wages adjust to make supply meet demand.\(^2\)

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\(^1\)Our collateral constraint can be derived from the following limited enforcement problem. Consider an individual with financial wealth \( a \geq 0 \) deposited in the financial intermediary at the beginning of a period. Assume that he rents \( k \) units of capital. Then he can abscond with fraction \( 1/\lambda \) of the rented capital. The only punishment is that he will lose his financial wealth \( a \) deposited in the intermediary. In particular, he will not be excluded from any economic activity in the future. In fact, he is allowed to instantaneously deposit the stolen capital \( k/\lambda \) and continue on as a worker or an entrepreneur. Note that \( \lambda \) in this context measures the degree of capital rental contract enforcement, with \( \lambda = +\infty \) corresponding to perfect enforcement and \( \lambda = 1 \) to no enforcement. In the equilibrium, the financial intermediary will rent capital only to the extent that no individual will renege on the rental contract, which implies a collateral constraint \( k/\lambda \leq a \) or \( k \leq \lambda a \).

\(^2\)Our modeling of the labor market closely follows Alvarez and Veracierto [2001]. Our model can also be interpreted as a simplified version of the Walrasian equilibrium theory of establishment dynamics and matching frictions in Veracierto [2009].
More formally, letting $M_t$ denote the number of unemployed workers that enter the hiring market, our assumptions about the behavior of the matching function are represented by:

$$M_t = \gamma (U_t + JD_t)$$  \hspace{1cm} (1)

with $U_t$ being the number of unemployed workers at the end of the previous period and $JD_t$ standing for job destruction in the beginning of the current period:

$$JD_t = \int \max \{l_{-1} - l_t (a, z), 0\} \psi G_t (da, dl_{-1}, dz)$$

where $l_t$ is labor demand of an individual (positive only for entrepreneurs) and $G_t$ is the joint distribution over wealth, previous period employment, and entrepreneurial productivity.

It is critical for the stability of the dynamics of unemployment that a fraction of the laid-off workers can be employed within the period, as is implied by the participation of $JD_t$ in equation (1).

Given the matching function and the firing decision of entrepreneurs, the evolution of unemployment is governed by the following law of motion:

$$U_{t+1} = U_t - M_t + JD_t$$  \hspace{1cm} (2)

2.1 Individual’s Problem

At the beginning of a period, an individual’s state is summarized by his financial wealth $a$ and entrepreneurial productivity $z$. The value for him at this stage, $v_t (a, z)$, is the maximum over the value of being an employed/unemployed worker, $v^W_t (a, z)$, and the value of being an entrepreneur, $v^E_t (a, z)$:

$$v_t (a, z) = \max \{ v^W_t (a, z), v^E_t (a, z) \}$$  \hspace{1cm} (3)

As a worker, an individual chooses consumption $c$ and the next period’s assets $a'$ to maximize his continuation value, subject to the period budget constraint.

$$v^W_t (a, z) = \max_{c,a'} u (c) + \beta \mathbb{E} [v_{t+1} (a', z')] \hspace{1cm} (4)$$

$$\text{s.t.} \quad c + a' = w_t + (1 + r_t) a - \tau_t$$

Alternatively, individuals can choose to be entrepreneurs. The value function of being an

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4The state of an individual is also described by his access to an employment opportunity $e \in \{0, 1\}$. However, by assuming that unemployed individuals receive a transfer equal to the period’s wage, we make this information irrelevant for an individual’s problem.
entrepreneur is as follows.

\[ v_t^E (a, z) = \max_{c, k, l, a'} \{ u(c) + \beta \mathbb{E} [v_{t+1} (a', z')] \} \]

\[ s.t. \quad a' + c = zk^{\alpha} - w_{t+l} - (r_{t} + \delta) k + (1 + r_{t}) a - \tau_{t} \]

\[ k \leq \lambda_{t} a \]  \hspace{1cm} \text{(Collateral constraint)}

The occupation choice of an individual is denoted by \( o_{t} (a, z) \in \{ W, E \} \).

### 2.2 Competitive Equilibrium

Given an initial distribution of individual wealth and entrepreneurial productivity \( G_{0} (a, l_{-1}, z) \) and a sequence of collateral constraints \( \{ \lambda_{t} \}_{t=0}^{\infty} \), a competitive equilibrium is given by sequences of distributions \( \{ G_{t+1} (a, l_{-1}, z) \}_{t=0}^{\infty} \), allocations \( \{ c_{t} (a, z), a_{t+1} (a, z), k_{t} (a, z), l_{t} (a, z), o_{t} (a, z) \}_{t=0}^{\infty} \), unemployment \( \{ U_{t} \}_{t=0}^{\infty} \), and prices \( \{ w_{t}, r_{t} \}_{t=0}^{\infty} \) such that:

1. Given prices \( \{ w_{t}, r_{t} \}_{t=0}^{\infty} \), individual decisions solve (3), (4), and (5) for all \( t \geq 0 \);
2. The number of the unemployed follows the equilibrium law of motion given by (2);
3. The government budget is balanced for all \( t \geq 0 \)

\[ \tau_{t} = w_{t} U_{t+1} ; \]
4. Capital markets clear for all \( t \geq 0 \):

\[ \int k_{t} (a, z) G_{t} (da, dl_{-1}, dz) = \int a G_{t} (da, dl_{-1}, dz) , \]  \hspace{1cm} \text{(6)}

5. Hiring markets clear for all \( t \geq 0 \):

\[ \int \max\{ l_{t} (a, z) - l_{-1} , 0 \} G_{t} (da, dl_{-1}, dz) = \gamma (U_{t} + JD_{t}) , \]  \hspace{1cm} \text{(7)}

where \( l_{t} (a, z) - l_{-1} \) is the net change in labor demand between time \( t \) and \( t-1 \) for an individual whose time \( t \) state is \( a, l_{-1} \) and \( z \);
6. The joint distribution of wealth and entrepreneurial productivity \( \{ G_{t} (a, l_{-1}, z) \}_{t=0}^{\infty} \) evolves according to the equilibrium mapping:

\[ G_{t+1} (a, l_{-1}, z) = \psi \int_{a_{t+1} (\tilde{a}, z) \leq a_{t} (a, z) \leq l_{-1}} G_{t} (d\tilde{a}, d\tilde{l}_{-1}, dz) \]

\[ + (1 - \psi) \mu (z) \int_{a_{t+1} (\tilde{a}, \tilde{z}) \leq a_{t} (a, \tilde{z}) \leq l_{-1}} G_{t} (d\tilde{a}, d\tilde{l}_{-1}, d\tilde{z}) . \]
The definition of a competitive equilibrium is standard with the exception of the labor market clearing condition. Combining the hiring market clearing condition (7) and the law of motion for the number of the unemployed (2), we obtain:

\[ U_t - U_{t+1} = \int [l_t(a_t, z_t) - l_{t-1}] G_t(da, dl_{-1}, dz). \]

That is, the hiring market clearing condition and the law of motion for unemployment together imply that the overall labor market clears over time, once we start out with

\[ \int l_{-1} G_0(da, dl_{-1}, dz) = 1 - U_0. \]

3 Quantitative Exploration

We now build a quantitative version of our framework and investigate the interaction between a credit crunch—modeled as a tightening of the collateral constraint—and labor market frictions. We are interested in exploring the aggregate and micro-level implications. To hit the economy with a credit crunch of a plausible magnitude, we calibrated the tightening of the collateral constraint to match the contraction in aggregate business credit observed during the 2008 financial crisis.

3.1 Calibration

Our model is parameterized so that the stationary equilibrium matches various aggregate and establishment-level moments in the US economy. We assume a time period in the model to be one year.

Following the standard practice, we set the coefficient of relative risk aversion \( \sigma \) to 1.5, the ratio \( \frac{\alpha}{(\alpha+\theta)} = 0.33 \) to match the aggregate income share of capital, and the annual depreciation rate to \( \delta = 0.06 \). In terms of the parameter governing the matching function, we set the parameter \( \gamma = 0.667 \), so as to target an unemployment rate of 5% in the steady state.

Entrepreneurial productivity is assumed to follow a Pareto distribution, with cumulative density given by \( \mu(z) = 1 - z^{-\eta} \) for \( z \geq 1 \). Each period, an individual retains his \( z \) with probability \( \psi \), while a new ability level from the distribution is drawn with probability \( 1 - \psi \).

The remaining parameters to be calibrated are \( \alpha + \theta, \eta, \psi, \beta \) and the degree of credit market imperfection \( \lambda \). To do so, we target the following moments in the US data: employment share of the top decile of establishments, the share of earnings generated by the top 5 percent of the population, the annual exit rate of establishments, the real interest rate and the ratio of external finance to total non-financial assets of the non-financial business sector.

Table 1 shows the moments in the US data and their counterparts in the calibrated model. The decile of the largest establishments (in terms of employment) accounts for 69 percent of aggregate employment in 2000. The earnings share of the top 5 percentiles is 30 percent in 1998. The annual establishment exit rate is 10 percent in the Business Dynamics Statistics from the US Census. We
Table 1: Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>US Data</th>
<th>Model</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 10% Employment</td>
<td>0.69</td>
<td>0.69</td>
<td>$\eta = 5.25$</td>
</tr>
<tr>
<td>Top 5% Earnings Share</td>
<td>0.30</td>
<td>0.30</td>
<td>$\alpha + \theta = 0.79$</td>
</tr>
<tr>
<td>Establishment Exit Rate</td>
<td>0.10</td>
<td>0.10</td>
<td>$\psi = 0.89$</td>
</tr>
<tr>
<td>Real Interest Rate</td>
<td>0.04</td>
<td>0.04</td>
<td>$\beta = 0.91$</td>
</tr>
<tr>
<td>Credit Market Instruments to Non-Financial Assets</td>
<td>0.70</td>
<td>0.70</td>
<td>$\lambda = 7.5$</td>
</tr>
</tbody>
</table>

assume that the annual interest rate is 4 percent. Lastly, we target the ratio of credit market instruments to total non-financial assets in the non-financial business sector of 0.8, a level attained one year before the 2008 financial crisis.

Although all parameters are jointly pinned down in the model equilibrium, we can identify which objects in the data are mostly related to which parameter. For instance, the tail parameter of the Pareto distribution of entrepreneurial productivity, holding other values constant, controls the the share of employment accounted for by the decile of largest establishments. Similarly, $\alpha + \theta$ can be mapped into the earnings share of the top 5 percent of the population who, as in the data, are mostly entrepreneurs in the model. There is also a direct link between the persistence of the ability process $\psi$ and the probability that an entrepreneur exits production, and hence the annual establishment exit rate in the data. The discount factor, in turn, is closely linked to the target interest rate, and the degree of financial frictions $\lambda$ allows the model to attain a target ratio of credit market instruments to total non-financial assets in the non-financial business sector in the Flow of Funds data.

### 3.2 Aggregate Dynamics of a Credit Crunch

We simulate the aggregate dynamics of the model following a tightening in the collateral constraint $\lambda_t$ that is calibrated to generate a decline in the ratio of external finance to the capital stock,

$$\int \frac{\max \{k_t(a, z) - a, 0\} G_t(da, dz)}{K_t},$$

that matches the observed decline in the stock of credit market liabilities to nonfinancial assets of the nonfinancial business sector in the US economy from the fourth quarter of 2008 to the first quarter of 2010. We assume that $\lambda_t$ then gradually converges to its pre-crisis level. To be clear, the initial contraction in $\lambda_t$ is a completely unexpected event, but its deterministic path after the
Figure 1: Ratio of External Finance to Capital Stock

This figure shows the evolution of the ratio of external finance to capital stock in the data (dotted line) and the model (solid line). For the US data we report the percentage deviations from the trend of the HP filtered series, with a smoothing parameter of 1,600. For the model we report the percentage deviation from its steady state value. Following the fourth quarter of 2008, there is a sharp decline in the ratio of credit market liabilities to non financial assets, of the order of 10 percentage points relative to its previous peak, with the lowest point attained in early 2010. In the model we generate a similar contraction, and a smooth recovery to its original steady state.

In the model, the tightening in the collateral constraint leads to a sharp decline in output—explained by a sharp drop in TFP and a smaller decline in investment—and a protracted increase

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4 The stock of credit market instruments corresponds to line 18 in the L.101 table of the Flow of Funds. It includes the stock of bank loans of the corporate and noncorporate sectors, and the stock of commercial papers, municipal securities and corporate bonds of the corporate sector. The stock of non financial assets is measured in historical prices to avoid valuation effects, which is absent in our theory. For the corporate sector, the Flow of Funds reports the stock of nonfinancial assets at historical costs. For the noncorporate sector we impute the stock of nonfinancial assets as the sum of the stock of real estate of the corporate sector at historical value divided by its market value, plus the stock of equipment and software and inventories at current costs. These are obtained from tables B.102 and B103 of the Flow of Funds.

5 The sequence of collateral constraints that we calibrate is \( \{ \lambda_1, \lambda_2, \lambda_3, \lambda_4 \} = \{ 7.5, 4.5, 3.0, 3.5 \} \) and \( \lambda_t = 0.75 \lambda_{t-1} + 0.25 \times 7.5 \) for \( t \geq 5 \).
in unemployment. The dynamic of these series in the model (solid line), together with the corresponding series around the 2008 financial crisis (dotted line), are illustrated in Figure 2. Again, for the case of output and TFP we report percentage deviations from the steady state for the model and deviations from the HP trend for the US data. For the investment rate we present differences from the steady state for the model and from the value in the second quarter of 2008 for the US data, while for the case of the unemployment rate we simply report the raw data.\footnote{We use output, TFP and investment series for the US business sector. In particular, the output series correspond to the real gross value added of the business sector from Table 1.3.6 of the NIPA. The TFP series is constructed using an estimate of the capital stock of US businesses and an index of the hours employed by the US business sector given by the series PRS84006033 of the BLS. We estimate the capital stock of the US business sector by accumulating the gross domestic investment series for the US business sector in Table 5.1 of the NIPA deflated using the Price Indexes for Private Fixed Investment in Table 5.3.4 of the NIPA, using as an initial value the Current-Cost Net Stock of Private Fixed Assets for the US businesses in 1960 from Table 6.1 of the NIPA, and estimating a depreciation rate using the information in the Table 6.4 of the NIPA. The unemployment rate correspond to the rate for total population 16 years old and over given in series LNS14000000 of the BLS.}

The credit contraction results in a reallocation of capital from entrepreneurs with low collateral, relative to their unconstrained level of capital, towards unconstrained entrepreneurs. The reallocation of credit and capital is accompanied by the reallocation of labor across entrepreneurs, a process that is gradually mediated by the matching friction from unemployment to the hiring market. In this process, resources tend to be reallocated from productive but constrained entrepreneurs towards those who are unconstrained and relatively unproductive, which results in a decline in aggregate TFP, as described in the top right panel of Figure 2. The associated reallocation of labor, mediated by a frictional labor market, results in a protracted rise in unemployment, as illustrated in the bottom right panel of this figure.

In the left panel of Figure 3 we illustrate the reallocation of credit across entrepreneurs with different levels of collateral. In particular, we plot the evolution of the external finance to capital ratio of entrepreneurs with wealth below (solid line) and above (dashed line) the median entrepreneurial wealth. Entrepreneurs with low wealth finance a larger fraction of their capital externally, and are hit harder by the credit crunch. Both their capital stock and, more prominently, their external finance are sharply reduced following the tightening of the collateral constraint. On the contrary, during the credit crunch, wealthy entrepreneurs employ more capital and use more external finance, although the former expands at a higher rate leading to a small decline in their ratio.\footnote{The capital used by wealthy entrepreneurs, who in the steady state employ around 90 percent of the aggregate capital, increases by 7.4 percent, while their external finance increases by 6 percent.}

How does the effect of a credit contraction in our quantitative framework compare with the data from the 2007–8 financial crisis and recession? Figure 2 (dotted lines) and the right panel of Figure 3 show closely related data for the US economy around these events.

The model generates a decline in output of 5 percent, a substantial fraction of the 7 percent decline in output relative to trend observed in the US economy during the contraction that started at the end of 2007. The decline in aggregate TFP in the model is comparable to that experienced by the US economy, while the contraction in investment and the surge in unemployment in the model economy are slightly less than half of the data. Overall, the contraction of aggregate variables tends
Figure 2: Aggregate Implication of a Credit Crunch

This figure shows the evolution of output, TFP, investment and unemployment rates in the data (dotted line) and the models with flexible (solid line) and fixed wages (dashed line). For the US data we report the percentage deviations from the trend of the HP filtered series, with a smoothing parameter of 1,600, for the case of output and TFP, and the simple difference with respect to the value in the second quarter of 2008 for the case of the investment rate. See footnote 6 for a description of the sources of the data.

to be more protracted in the model than in the data.

In the right panel of Figure 3, we report the evolution of the ratio of the stock of credit market liabilities to non financial assets for the noncorporate and corporate sectors, together with disaggregated data for the corporate sector on bank and bond liabilities. Starting in the fourth quarter of 2008, there is a sharp contraction in the stock of credit market liabilities of the noncorporate sector, together with a milder contraction in the credit market liabilities of the corporate sector. Furthermore, when analyzed at a more disaggregated level, the corporate sector suffered a sharp contraction in their bank-related liabilities, which were partially substituted by a surge in the issuance of corporate bonds, at least for those corporations that had access to the corporate bond market. To the extent that we interpret corporations, and in particular, those that have access to corporate bond markets as relatively unconstrained, the dynamics of external finance in the data
Figure 3: External Finance to the Capital Stock in the Model and the US Data.

is consistent with its dynamics of external finance for rich and poor entrepreneurs in the model economy.

3.2.1 Implication of Rigid Wages

While the model successfully accounts for a large fraction of the decline in output and TFP, it underpredicts the rise in unemployment following the 2007–8 recession. A simple extension of the model, in line with arguments in Shimer [2012], is to introduce wage rigidities to the model. The effect of a credit crunch in the model with fixed wages is illustrated by the dash-dot lines in Figure 2.

A tightening of the collateral constraint in an environment with rigid wages leads to an even larger decline in output—explained by a sharp rise in unemployment—and a deeper but shorter-lived drop in TFP. The rise in unemployment is explained by a higher flow of workers into unemployment and a relatively more protracted reallocation of these workers back into employment. The dynamics of the flow of workers in and out of employment, as a fraction of employment at the beginning of the period, is illustrated in Figure 4.  

3.2.2 Comparing a Credit Crunch with an Exogenous TFP Shock

The analysis of the previous section reveals how damaging a credit crunch could be for the adjustment of the labor market. Our goal in this section is to contrast the impact of a credit shock to

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8The data series correspond to yearly aggregated flow rates using the monthly flow data from the BLS research series. See http://www.bls.gov/cps/cps_flows.htm. We construct yearly flow rates by multiplying the monthly transition matrices. We report the resulting series as deviations from their overall average.
that of a more standard source of business cycle fluctuations: a negative shock to the aggregate TFP. To implement the experiment, we start the economy at its stationary equilibrium and subject it to an unanticipated drop in aggregate TFP that mimics the endogenous TFP dynamics of the economy in response to a credit shock (top right panel, Figure 2).

Figure 5 depicts the behavior of aggregate quantities in response to the two shocks. Despite the resemblance of TFP dynamics between the two experiments, the credit-shock model exhibits a sharper and more protracted contraction in aggregate production. The bottom right panel of the figure shows that the bulk of the differential response in output can be attributed to the dynamics of unemployment. Unemployment is invariant to a TFP shock but increases by 50 percent at the peak with the credit crunch. Investment, on the other hand, seem more comparable in both cases.

The defining characteristic of a credit shock that differentiates itself from a decline in TFP is its reallocative nature. Even though all entrepreneurs face a tighter collateral constraint during a credit crunch, only a subset of them—those who have low net worth—become more constrained in their choices of labor and capital inputs. In contrast, TFP is a shock that induces a contraction in the employment of all firms equally. The real wage, which is depicted in the left panel of Figure 6, absorbs the pressure from the two shocks differently as well. In the case of the TFP shock, the aggregate reduction in labor demand is fully compensated by a reduction in the wage rate, which ultimately keeps labor demand unchanged. In the credit crunch, the wage rate tends to go down too, due to the firing incentives of the more constrained entrepreneurs. However, it does so only
Figure 5: Aggregate Implications of a Credit Crunch vs. Exogenous TFP Shock

partially, as rich entrepreneurs that remain unconstrained take advantage of low wages to increase hiring. With a labor market friction that produces insufficient matches to absorb the unemployed and recently-fired workers, and with wages that do not fully offset the drop in labor demand by constrained entrepreneurs, unemployment goes up along the transition.

The response of the interest rate is also markedly different between the two shocks, although it is less relevant for understanding the dynamics of unemployment than it is for explaining the behavior of investment. A credit crunch has a direct negative effect on entrepreneurs’ capital demand decisions, forcing more firms to restrict their scale of operation to the level allowed by the tighter collateral constraint. Furthermore, since capital is being misallocated towards unproductive but wealthy entrepreneurs, the aggregate demand for capital falls even further. To bring the rental market back to equilibrium, the interest rate has to fall sharply. This strong response of the interest rate during a credit crunch is critical for the overall dynamics of investment, which is virtually indistinguishable from that in the TFP shock case.9

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9Buera and Moll [2012] show that the isomorphism of investment between a credit crunch and a TFP shock is not only a quantitative result, but a more general implication of a certain class of models with heterogeneous entrepreneurs.
3.3 Micro-Level Implications of a Credit Crunch

The focus of our analysis is switched here to the firm-level implications of a credit crunch. A large empirical literature documents that financial crises affect firms differently depending on their size. The working hypothesis in these studies is that small business are more reliant on credit to finance their productive activities and capital expenditures, and hence should be more cyclically responsive during recessions that are driven by credit contractions. Gilchrist and Gertler (1994) found evidence supporting this claim, and more recently Fort, Haltiwanger, Jarmin and Miranda (2012) extended the analysis to highlight the role of age, as well as size, in understanding the cyclical behavior of firms: During a credit crunch, employment growth in young, small firms declines relative to that of old, large firms. The goal of this section is to provide a theoretical underpinning to the empirical literature, and understand how the aggregate behavior of the economy reflects the responses at the level of the firm.

3.3.1 Implementation and Definitions

The distinguishing characteristics of firms in the model—which ultimately determine their labor and capital demands, wealth accumulation, and the extent to which collateral constraints bind—are the productivity and wealth of the entrepreneurs. The model’s equilibrium consists of a distribution of entrepreneurs along these two dimensions, which also results in a distribution of firms in terms of age and size.

To examine the firm-level implications of the model, we simulate a sample of 1,000,000 individuals using our model. We first do so for the stationary equilibrium, which delivers an invariant
distribution of firms in terms of age and size. We then continue the simulation for a number of periods that cover the credit crunch and the ensuing recovery.\footnote{We note that the computation in the previous sections did not deploy such simulation methods: We worked with the cross-section distribution directly. As will be seen below, the disadvantage of the simulation method will show up in the form of “noisy” dynamics of job flows in the pictures below.}

Our classification of firms into small, large, young and old is done as follows. For the size category, we compute the median employment level in the employment-based size distribution and classify a firm as small if its employment at the beginning of the period is below the median and as large if it is above the median.\footnote{That is, we bin firms into employment levels according to the fraction of total employment accounted for by each bin. We also worked with the median in the number for firms across employment levels, and obtained similar patterns.} With respect to age, we follow Fort, Haltiwanger, Jarmin and Miranda (2012) and consider firms whose age is less than or equal to 5 years as young, and the others as old.

Lastly, our methodology for the aggregation of job flows for firms within each age and size category follows closely that of Davis, Haltiwanger, and Schuh (1996). That is, we define the aggregate job creation and destruction rates for a given age and size category $s$ as:

$$JC_{s,t} = \sum_{i \in s} \max \{ \frac{[L_{t+1}(i) - L_t(i)], 0}{0.5[L_{t+1}(s) + L_t(s)]} \}$$

$$JD_{s,t} = \sum_{i \in s} \max \{ \frac{[L_t(i) - L_{t+1}(i)], 0}{0.5[L_{t+1}(s) + L_t(s)]} \}$$

$$Net_{s,t} = JC_{s,t} - JD_{s,t}$$

Importantly, this methodology aggregates gross and net flows while keeping constant the set of firms that belong to each category between periods $t$ and $t + 1$, exempting the measure from so-called “re-classification bias” discussed in Davis, Haltiwanger and Schuh [1998].

### 3.3.2 Results

We start by exploring the properties of the distribution of firms in terms of age and size in the stationary equilibrium. Table 2 reports the fraction of unconstrained entrepreneurs in each group, as well as the share of aggregate employment, the fraction of firms and the average rate of return to capital. Some features of the table are a direct consequence of our calibration strategy, which targeted properties of the size distribution of firms in the US. For instance, it should not surprising that a small number of large firms account for a significantly large share of aggregate employment, consistent with the skewness of the empirical size distribution in the US.
Table 2: Properties of Firm Age-Size Distribution in Steady State

<table>
<thead>
<tr>
<th></th>
<th>Fraction Unconstr. Entrepreneur</th>
<th>Fraction of Total Employment</th>
<th>Fraction of Firms</th>
<th>Av. Productivity</th>
<th>Av. Wealth</th>
<th>Av Rate of Return</th>
<th>Net Empl. Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>YS</td>
<td>0.06</td>
<td>0.15</td>
<td>0.41</td>
<td>0.59</td>
<td>1.5</td>
<td>0.15</td>
<td>0.42</td>
</tr>
<tr>
<td>YL</td>
<td>0.04</td>
<td>0.05</td>
<td>0.004</td>
<td>1.18</td>
<td>30.49</td>
<td>0.095</td>
<td>0.28</td>
</tr>
<tr>
<td>OS</td>
<td>0.49</td>
<td>0.47</td>
<td>0.57</td>
<td>0.57</td>
<td>3.98</td>
<td>0.046</td>
<td>-0.10</td>
</tr>
<tr>
<td>OL</td>
<td>0.89</td>
<td>0.33</td>
<td>0.015</td>
<td>1.17</td>
<td>100.79</td>
<td>0.042</td>
<td>-0.12</td>
</tr>
</tbody>
</table>

However, other statistics in the table are more a virtue of the model than a consequence of the calibration. Consider the first column in the table, referring to the fraction of unconstrained firms by category. The model predicts that the likelihood of becoming financially constrained is a function of the underlying state variables of the firm: entrepreneurial productivity and wealth. Table 2 shows that age and size are indeed good predictors of such likelihood: The fraction of unconstrained entrepreneurs is lowest for the young/small group and highest for the old/large group. There exists, then, a mapping from the ability-wealth space onto the firm age-size space that provides justification for the conjecture that young and small entrepreneurs are more cyclically responsive than large and old ones during an episode of credit crunch.

The distribution of average productivity and average wealth across groups help clarify why such a mapping exists. Notice, from column 4, that average entrepreneurial productivity is correlated with size, but is not with age: Productivity is higher for large firms than small firms, but, conditional on size, they are about the same across age groups. Thus, if firms’ decisions and credit conditions were entirely dependent on productivity, age would be irrelevant. However, wealth does matter for firms’ decisions and credit conditions and is indeed correlated with age conditional on size: Entrepreneurs running older firms are wealthier on average than those running younger ones.

The last column in the table illustrates the tight connection between credit conditions for each firm type and the rate of return on capital. In a frictionless economy where credit conditions allow firms to operate at the efficient scale, rates of return on capital—i.e., the marginal product of capital net of depreciation—are equalized across production units and are equal to the real interest rate. A binding collateral constraint, on the other hand, drives a wedge between these two. The rate of return on capital for constrained entrepreneurs are higher than the equilibrium interest rate in the economy. This is why the last column of Table 2 shows a difference of 8 percentage points between the young/small group and the old/large group, consistent with the lower fraction of unconstrained entrepreneurs in the former compared to the latter.

We now explore the dynamics of net employment growth during a credit crunch for the four age-size groups under consideration. These are depicted in Figure 7. The units in the vertical axis represent absolute differences in net employment growth rates with respect to steady state levels.

The behavior of employment growth rates is in accordance with the information conveyed in Table 2. Young/small and young/large firms, whose average rates of return are the highest and whose fraction of unconstrained firms are the lowest, display the sharpest contraction in net em-
This figure shows the net employment growth during a credit crunch for four age-size groups. The units in the vertical axis represent absolute differences in net employment growth rates with respect to steady state levels. The steady state levels of these variables are: 0.42 for young/small, 0.28 young/large, -0.10 old/small, -0.12 old/large.

Employment growth rates relative to their steady state levels. This finding suggests that the direction of reallocation flows, from constrained to unconstrained entrepreneurs, is accurately captured by the age and size of the production unit. Recall that being financially constrained or not depends on firms’ characteristics that are presumably difficult to observe in the data, at least for the entire population of producers in the economy: entrepreneurial productivity and net worth. The fact that there is a clean mapping from the productivity-wealth space onto the age-size space allows us to interpret the dynamics of employment growth rates in the data through the lens of the mechanisms in our model.

4 Conclusions

We proposed a model of heterogeneous agents that integrates credit and labor market frictions to study macro and micro implications of a credit crunch. We discovered that a salient feature of a collapse in credit availability is the resulting reallocation: Firms that become more financially constrained reduce their labor and capital demands, and factors are reallocated to unconstrained producers. However, frictions in the hiring market interfere with the reallocation process. It takes time for the economy to absorb idled resources, and unemployment rates remain high for a significant period of time. Moreover, the reallocation of resources implied by the credit shock delivers an endogenous reduction in aggregate TFP, as high productivity but low wealth entrepreneurs down-
size and low ability but high wealth ones expand. Together with a contraction in investment, these effects results in a decline in aggregate economic activity.

Another finding of the paper is that credit and aggregate productivity shocks carry different implications for both micro and macro variables. Even in the presence of matching frictions, the unemployment rate remains unchanged in the case of a TFP shock, as the adjustment in wages and interest rates fully offset the decline in factor demands. They key is that an aggregate TFP shock affects all firms’ incentives to reduce labor demand equally, which is not the case when the shock is credit-driven.

Another contribution of our work is that we validate with theory the empirical findings that firms of different age and size have different responses to credit-driven business cycle fluctuations. We show that the combination of age and size is a good proxy for the combination of entrepreneurial productivity and net worth that determines the likelihood of being constrained and, hence, the dynamics of employment growth during a credit collapse.
References


