Firm-level Credit Ratings and Default in the Great Recession: Theory and Evidence*

Fernando Leibovici
Federal Reserve Bank of St. Louis

David Wiczer
Stony Brook University

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Abstract

This paper studies the role of credit constraints in accounting for the dynamics of firm-level default during the Great Recession. We present novel firm-level evidence on the role of credit ratings in exit behavior during the Great Recession. Firms with low credit rating are more likely to default than firms with high credit ratings and the difference widened substantially in the Great Recession while, in contrast, default rates did not vary much by size, age, or productivity. Because credit ratings may capture the long-term solvency of firms and their access to short-term liquidity, we interpret this evidence using a model of heterogeneous firms with endogenous default and delinquency choices, where intertemporal loans are taken to pay for working capital expenditures and loan prices depend on the firms' payment history. Our findings suggest that credit constraints played an important role in accounting for the dynamics of firm-level default during the Great Recession. We investigate the extent to which credit ratings reflect imperfect information about firms, and examine their implications for the dynamics of default as well as for the design of policies during episodes of financial distress.

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*Contact information: fleibovici@gmail.com, david.wiczer@stonybrook.edu. We thank Matthew Famiglietti for excellent research assistance. The views expressed in this paper are those of the individual authors and do not necessarily reflect official positions of the Federal Reserve Bank of St. Louis, the Federal Reserve System, or the Board of Governors.

1 Introduction

A salient feature of the Great Recession in the U.S. has been the sharp contraction among nonfinancial businesses, leading many firms to close down and declare bankruptcy. One popular view interprets this evidence as a dramatic event with large potential costs for the individuals involved as well as for society. An alternative but also popular interpretation of the surge in the exit of firms sees it as necessary yet inconvenient consequence of the cleansing nature of economic crises, where unproductive firms exit and make room for new productive firms to enter.

In this paper, we investigate the relative importance of these alternative interpretations in accounting for the dynamics of firm-level exit in the U.S. during the Great Recession. To do so, we document salient features of the relationship between firm-level credit ratings and their rate of exit during the Great Recession. We then interpret this evidence using a quantitative model with heterogeneous firms, credit constraints, as well as endogenous default and delinquency. We use the model to evaluate the extent to which credit constraints can account for the dynamics of firm-level default rates during this episode.

We begin the paper by investigating the empirical relationship between firm-level credit ratings and exit rates. To do so, we use a novel firm-level dataset with credit rating and production information on the universe of U.S. firms from 1995 to 2012. The credit variable that we focus on measures the degree to which firms pay their vendors in time. First, we document a systematic relationship between firm-level exit rates and their credit ratings during normal times: Firms that pay their vendors late have low credit ratings and much higher exit rates. Second, we find that differences in firm-level exit rates across credit ratings increased substantially during the crisis, from 2009 onwards. Finally, we show that these differences in firm-level exit rates by credit rating played an important role in accounting for the increase of the aggregate exit rate during this episode.

While these features of the data suggest that there is tight link between financial factors and firm-level exit, they might also be jointly driven by a common alternative channel. For instance, unproductive firms or ones that produce goods which are unpopular or out of fashion might struggle to pay their vendors, while also featuring high rates of exit. In such case, low credit ratings might indicate the low productivity of the firm rather than the tightness of credit constraints; that is, insolvency rather than the lack of short-term liquidity. To disentangle the role of financial factors in accounting for firm-level exit from other alternative channels, we set up a quantitative model designed to interpret the evidence that we document.

The economy consists of a continuum of firms heterogeneous in productivity that produce a homogeneous good with a decreasing returns-to-scale technology. Idiosyncratic productivity evolves stochastically over time, and firms are subject to a working capital constraint which requires them to pay a fraction of their production inputs before revenues accrue; we require these upfront payments to be financed with loans. Firms are, moreover, subject to idiosyncratic liquidity shocks that affect the fraction of production inputs that need to be paid upfront.

Given our focus on firm-level exit, we consider an economy in which firms may choose to exit endogenously, defaulting on their debt obligations. Insofar lenders expect firms to default with positive probability, they charge firms a premium to compensate for this possibility, increasing the cost of borrowing and distorting firms' production decisions.

Moreover, given our objective to use the model to interpret the empirical relationship between firm-level credit ratings and exit, we set up a model in which firms may choose to be delinquent and postpone debt repayment. While delinquency may be attractive to firms as a way to alleviate their short-term liquidity needs, it comes at the cost of increasing the fraction of production inputs that need to be paid upfront. Thus, firms that repay their debts in a timely fashion have lower working capital needs, capturing the idea that the firms' counterparties are more likely to trust firms that repay their debts on time, thus demanding lower upfront payments.

We estimate the model to capture salient features of firm-level data for year 2006, a year before the onset of the Great Recession. We then use the model to investigate the dynamics of firm-level exit rates in response to aggregate shocks chosen to resemble the aggregate dynamics of the U.S. economy during the crisis. We begin by examining the extent to which the model can account for the relationship between firm-level credit ratings and exit rates observed in the data. Then, we investigate the extent to which these findings are accounted by frictions in financial markets or whether, instead, they capture the joint relationship between productivity, credit ratings, and exit rates. We do so by contrasting the implications of our baseline model with a frictionless version of it that does not feature a working capital constraint.

Finally, we examine the extent to which credit ratings reflect imperfect information about firms. To do so, we consider an alternative version of the model in which lenders can only offer loan schedules conditional on the firms' repayment history rather than on the complete state of the firms. We contrast the implications of this version of the model with our baseline for the dynamics of default during the crisis. We conclude by investigating the design of policies to offset the exit of firms due to liquidity rather than insolvency during episodes of financial distress.

This paper contributes to a large and growing literature that investigates the role of financial factors during the Great Recession. Closely related to our work are Khan et al. [2014] and Arellano et al. [2016], who study the role of default on the dynamics of U.S. aggregate during the Great Recession. We contribute to this literature by using a novel dataset on the credit ratings of U.S. firms along with rich model of default and delinquency to investigate the role of credit market frictions on the dynamics of firm exit during the crisis. Our paper is also closely related to Dinlersoz et al. [2018], who study the impact of credit market frictions on the response of U.S. firms during the Great Recession.

Our paper is more broadly related to a literature that investigates the role of financial factors during the Great Recession, with a focus on households, firms, as well as on financial institutions. For instance, see Chodorow-Reich [2013] or Mian and Sufi [2009] for examples of studies focused on households, and Chodorow-Reich and Falato [2017] or Gertler et al. [2012] for examples of studies focused on the financial sector. For a more thorough review of this literature, see Gertler and Gilchrist [2017] and Mian and Sufi [2018].

The rest of the paper is structured as follows. In section 2, we document salient features of the relationship between firm-level credit ratings and exit rates. In section 3, we set up our model. In section 4, use the model to quantify the role of credit market frictions in accounting for the features of the data that we document. Section 5 presents the main conclusions of the paper.

2 Firm-level Default in the Great Recession

In this section we investigate the dynamics of firm-level default during the Great Recession. We begin by examining the relationship between the exit rate of firms and their credit rating. We then contrast our findings with the relationship between firm-level exit rates and other observables available in our data.

2.1 Data

The firm-level dataset that we study is the National Establishment Time-Series (NETS) database collected by Dun and Bradstreet (D&B), which contains longitudinal information on the universe of establishments in the United States over recent decades. Among many variables that are available, the dataset allows us to observe establishment-level credit ratings, and also provides information on other outcomes such as sales, employment, and age.

For each establishment i, the dataset provides information on the establishment code j that is the headquarters of the firm to which establishment i belongs to.[1] Then, we aggregate the dataset to the firm-level by identifying all establishments with a common headquarters as being part of the same firm. We aggregate all quantitative variables across establishments of a common firm by weighting their respective values by the number of workers employed

[1] Note that $i = j$ for single-establishment firms.

in each establishment and year.[2]

Throughout the rest of the paper, we abstract from very small firms by restricting attention to firms with at least 5 employees on average over the sample.

2.2 Exit rate by credit rating

We begin by examining the relationship between firm-level exit rates and their credit ratings. To do so, we focus on Paydex scores, which measure establishment-level payment performance. D&B collects establishment-level payment histories from the establishment's vendors and assigns a Paydex score to reflect the timeliness of payments.

The Paydex score of a firm is a value between 0 and 100. A score equal to 80 reflects that an establishment pays its vendors and suppliers on time. A score of 100 represents establishments that pay their vendors at least 30 days ahead of time, a score equal to 50 is associated with an establishment that is 30 days late with payment, and a score between 1 and 19 reflects payment over 120 days past due. To be assigned a Paydex score, D&B requires at least 4 payment experiences to be recorded for an establishment. This score is used by banks, vendors, and other institutions to assess the ability of establishments to make payments.

According to D&B, firms with Paydex score between 80 and 100 have "low risk of late payment," firms with Paydex score between 50 and 79 have "moderate risk of late payment," and firms with Paydex score between 0 and 49 have "high risk of late payment."[3] We abstract from this particular mapping between Paydex scores and firm-level riskiness; instead, we focus directly on the information on late vs. early payment encoded in the different values taken by Paydex scores.

The NETS database reports an establishment's minimum Paydex score and maximum Paydex score in every given year. Thus, we measure an estab-

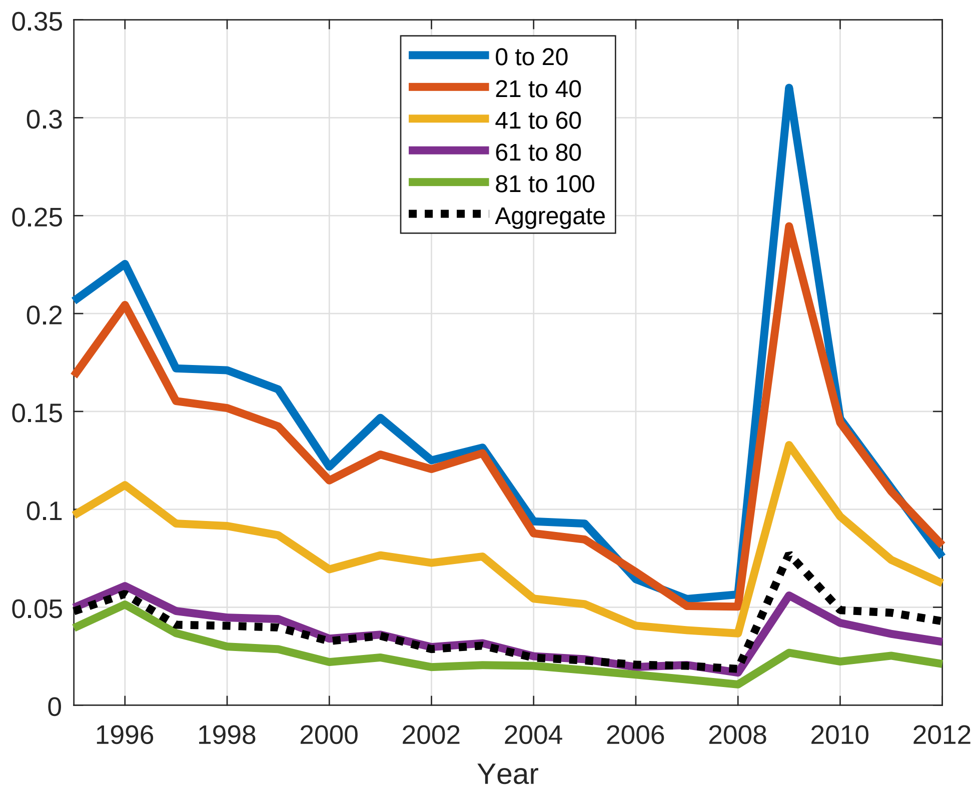
[2] Note, however, that all the findings reported in the paper are robust to examining the data at the establishment-level.

[3] For more information, see `http://www.dandb.com/glossary/paydex`.

lishment's Paydex score as the average of these two values. To analyze Paydex scores at the firm-level, we aggregate establishments that share a common headquarters and weight the average Paydex score by the number of employees across the different establishments.

Figure 1 plots the dynamics of firm-level exit rates by Paydex score from 1995 to 2012. We observe that firm-level exit rates depend systematically on the firms' Paydex scores. In particular, in every year of the sample, firms that pay their vendors on time (or ahead of time) have systematically lower exit rates than firms that pay late. This relationship is, moreover, quantitatively significant: for instance, the exit rate of firms that pay between 60 and 120 days late (with Paydex score between 0 and 40) is more than 5 percentage points higher throughout most of the sample than that of firms which pay less than 22 days late but not in advance (with Paydex score between 61 and 80).

Figure 1: Exit rate by Paydex score



The figure also shows that the exit rate of firms with subpar payment performance (with Paydex below 60) increases substantially during the Great Recession, particularly between 2009 and 2010. For instance, firms with a Paydex score between 21 and 40 exited at a 5% rate between 2008 and 2009, while they exited at a nearly 25% rate between 2009 and 2010. In contrast, the exit rates of firms with good credit standing featured a much milder increase: by less than 5 percentage points for firms with Paydex between 61 and 80.

Finally, we observe that the substantial increase of exit rates among firms with low credit ratings affected the dynamics of the aggregate exit rate of firms. On the one hand, we observe that the aggregate exit rate and the exit rate of firms with Paydex score between 61 and 80 have moved together for most of the sample up to (and including) 2008. In contrast, we observe that that this strong link between the two exit rates breaks down in 2009 and subsequent years. Our interpretation of this gap between the aggregate exit rate and the exit of firms with good credit standing is that it is accounted by the substantial increase of exit rates among firms with low credit ratings.

These findings suggest that financial factors play a key role in accounting for firms' exit decisions during both normal and crises times. Moreover, they suggest that firms' credit standing may play a particularly fundamental role in accounting for firm-level exit patterns during episodes such as the recent financial crisis. In the next sections of the paper, we use a quantitative heterogeneous firm model with endogenous default and delinquency decisions to quantify the role of financial factors in accounting for the dynamics of firm-level exit rates during both normal times as well as in financial crises.

2.3 Exit rate conditional on other observables

We now contrast these findings with the relationship between firm-level exit rates and other outcomes reported in our dataset. We restrict attention to outcomes that have been previously suggested to play an important role in accounting for firm-level exit rates. In particular, we examine the role of firm size (as proxied by number of workers and sales), productivity, and age in accounting for cross-sectional differences in firm-level exit rates.

Figure 2: Exit rate conditional on other observables

Figure 2 plots the exit rates conditional on (i) number of workers, (ii) sales, (iii) sales per worker, and (iv) age. We observe that differences along any of these dimensions generate much smaller differences in exit rates than those reported in Figure 1 based on Paydex scores. In contrast to previous studies in the literature, we conclude that differences along these dimensions are unlikely to play an important role in accounting for the dynamics and cross-sectional differences in exit rates. Thus, in the following sections of the paper we investigate the quantitative importance of financial factors as drivers of firm-level exit rates.

3 Model

In this section, we set up a dynamic model of heterogeneous firms with endogenous default and delinquency decisions to investigate the role of credit market frictions in accounting for the exit rate dynamics observed during the Great Recession. The economy is populated by two types of agents: firms and lenders, a continuum of each. Firms produce a homogeneous good using heterogeneous technologies, and have to borrow from lenders in order to finance the upfront payment of a fraction of their production inputs. Firms are subject to both productivity and liquidity shocks, which can lead firms to become delinquent on their debt repayment obligations or to default. In the next section, we quantify the quantitative role of these channels in accounting for the dynamics of U.S. firms in the recent crisis.

3.1 Firms

The economy is populated by a continuum of infinitely-lived firms that produce a homogeneous good by operating the following production technology:

$$y_t = z_t L_t^{\alpha} M_t^{\phi}$$

where $\alpha + \phi < 1$, and y_t denotes the amount produced; z_t is the idiosyncratic and time-varying productivity level; L_t is the labor input; and M_t denotes the amount of intermediate inputs used in production. Firm-level productivity z_t follows an autoregressive process of degree 1: $\ln z_{t+1} = (1-\rho)\ln\mu + \rho \ln z_t + \varepsilon_t$, where ε_t is *i.i.d.* across firms and over time.

The objective of the firm is to maximize the present discounted value of its dividends D_t, with discounting at a rate $\beta \in (0, 1)$ that captures the rate of time preference of the firms' owners.

Working capital and financial markets Firms operate subject to a working capital constraint which requires them to pay a fraction of their labor and intermediate input expenditures before the returns from production are realized. Following Arellano et al. [2017] and Neumeyer and Perri [2005], among many others, we also require these upfront expenditures to be financed using external funds.

Firms cannot issue equity (thus, dividends are such that $D_t \geq 0$), but they have access to a one-period bond issued by lenders at interest rate $r_t\left[n_t, B_t, \mathcal{I}(s_t)\right]$ where n_t denotes the number of consecutive periods that firms have repaid their loans on time, B_t denotes the amount borrowed, and $\mathcal{I}(s_t)$ denotes the information set of lenders on firms with state s_t in period t. Firms borrow to pay a fraction of the production inputs upfront, but might also borrow an additional amount X_t for other purposes such as to smooth consumption or to pay for other costs that may arise.

In contrast to previous work, we assume that the share of production inputs that needs to be paid upfront $\lambda(n)$ is a function of the number of consecutive periods n over which the firm has successfully repaid its debts. We assume that λ is weakly decreasing in n in order to capture the idea that firms build a reputation over time as they repay their debts, leading their suppliers of production inputs to demand lower upfront payments in exchange for providing labor and intermediate inputs. In the next sections, we thus interpret $\lambda(n)$ as a measure of firm credit-worthiness.

While the dynamics of λ follow a deterministic path as a function of the firms' debt repayment record, we assume that firms are subject to liquidity shocks κ which increase the share of production inputs to be paid upfront from $\lambda(n)$ to $\lambda(n) + \kappa$, where κ is assumed to be *i.i.d.* across firms and over time.

Continuation vs. default decision Firms start the period with idiosyncratic state $s_t = (n_t, B_t, z_t, \kappa_t)$, where B_t denotes the stock of debt that is due for repayment in the current period. Given these states, firms contrast the value of continuing to operate relative to the value (or cost) of default, and opt for the choice with highest value.

The value of continuing to operate is given by $V_t^c(s_t) + \varepsilon_t^c$, while the value of default is given by ε_t^d; $V_t^c(s_t)$ denotes the value function conditional on continuing to operate the firm and state s_t, and ε_t^c and ε_t^d are *i.i.d.* and distributed

Gumbel with scale parameter γ_c. We introduce these preference shocks and distributional assumptions in order to smooth the discrete choice and, thus, to simplify the quantitative solution of the problem. This approach follows closely the approach taken by recent studies in the sovereign default literature (Dvorkin et al. 2018a; Dvorkin et al. 2018b).[4] Then, the probability that a firm with state s_t continues to operate is given by:

$$\Pr\left[V_t^c(s_t) + \varepsilon_t^c > \varepsilon_t^d\right] = \frac{\exp\left[V_t^c(s_t)/\gamma_c\right]}{1 + \exp\left[V_t^c(s_t)/\gamma_c\right]}.$$

Repayment vs. delinquency decision Firms that choose to continue operating then choose whether to repay their debt, or to postpone debt repayment and become delinquent. Delinquency allows firms to postpone the repayment of the debt for one period, and entails two types of costs. First, delinquent firms are forced to pay a fixed cost F denominated in units of the homogeneous good. Second, their credit-worthiness gets lost and they are forced to pay a fraction $\lambda(0)$ of their production costs upfront instead of n_t+1 in the following period; that is, $n_{t+1} = 0$ in the period after a delinquency event.

Then, analogous to the continuation vs. default decision described above, the value of repaying the debt is given by $V_t^r(s_t) + \varepsilon_t^r$, while the value of becoming delinquent is given by $V_t^s(s_t) + \varepsilon_t^s$; $V_t^r(s_t)$ and $V_t^s(s_t)$ denote the value functions conditional on repayment and becoming delinquent, respectively, for a firm with state s_t, and ε_t^r and ε_t^s are *i.i.d.* and distributed Gumbel with scale parameters γ_r. As discussed above, these preference shocks and distributional assumptions are introduced to smooth the numerical solution of the discrete choice problem.

Then, the probability, conditional on not defaulting, that a firm with state s_t repays its debt obligations this period is given by:

$$\Pr\left[V_t^r(s_t) + \varepsilon_t^r > V_t^s(s_t) + \varepsilon_t^s\right] = \frac{\exp\left[V_t^r(s_t)/\gamma_r\right]}{\exp\left[V_t^r(s_t)/\gamma_r\right] + \exp\left[V_t^s(s_t)/\gamma_r\right]}$$

[4]This approach is akin to the one pursued by Chatterjee and Eyigungor [2012] to address a similar problem.

while the probability that a firm becomes delinquent is given by:

$$\Pr\left[V_t^r(s_t) + \varepsilon_t^r < V_t^s(s_t) + \varepsilon_t^s\right] = \frac{\exp\left[V_t^s(s_t)/\lambda_s\right]}{\exp\left[V_t^r(s_t)/\lambda_r\right] + \exp\left[V_t^s(s_t)/\lambda_s\right]}.$$

Remaining decisions After the firms choose whether to repay their debt or to become delinquent, they proceed to choose the amount of production inputs to hire, borrow to pay for working capital (and possibly for other purposes), and make an upfront payment to cover a fraction of the production input costs. Delinquent firms may issue debt, which gets combined with the stock of debt that was not repaid in the current period. Finally, after production takes place, firms pay any delinquency costs outstanding, pay the remaining fraction of the production inputs, and pay dividends (if any).

The firms' budget constraint is then given by:

$$D_t + [1 - \lambda(n_t)]\left[wL_t + p_m M_t\right] + \mathbb{I}_{\{V_t^r(s_t)+\varepsilon_t^r < V_t^s(s_t)+\varepsilon_t^s\}} \times F = z_t L_t^\alpha M_t^\phi + X_t.$$

Entry and exit process Firms that default are replaced by new firms with $n_t = 0$, $B_t = 0$, and a productivity level drawn from the ergodic distribution.

Recursive formulation While the above presentation indexes variables with a t-subscript, we now present the firm's problem in the special case of a stationary environment without aggregate uncertainty allowing us to simplify the exposition by dropping such subscripts.

Firms start the period with idiosyncratic state $s = (n, B, z, \kappa)$ and first choose whether to continue in operation or to default:

$$V(n, B, z, \kappa) = \mathbb{E}\left[\max\left\{V^c(n, B, z, \kappa) + \varepsilon^c, \varepsilon^d\right\}\right]$$

where the expectations operator integrates across the alternative draws of ε^c and ε^d. The value function from continuing to operate the firm results from the choice between repaying the outstanding debt or becoming delinquent:

$$V^c(n, B, z, \kappa) = \mathbb{E}\left[\max\left\{V^r(n, B, z, \kappa) + \varepsilon^r, V^s(n, B, z, \kappa) + \varepsilon^s\right\}\right],$$

where the expectations operator integrates across the alternative draws of ε^r and ε^s.

Firms that choose to repay their debt solve the problem whose value function is given by:

$$\begin{aligned} V^r(n,B,z,\kappa) = & \max_{D'\geq 0, B', L, M, X \geq 0} D + \beta \mathbb{E}_z \left[V(n+1, B', z', \kappa') \right] \\ & \text{subject to} \\ & D + [1-\lambda(n)] \left[wL + p_m M \right] + B = zL^\alpha M^\phi + X \\ & [\lambda(n) + \kappa] \left[wL + p_m M \right] + X \leq \frac{B'}{1 + r \left[n, B, \mathcal{I}(z,\kappa) \right]} \end{aligned}$$

where $\mathcal{I}(z,\kappa)$ denotes the lenders' information set on firms with states (z,κ). Firms that choose to become delinquent solve the problem whose value function is given by:

$$\begin{aligned} V^s(n,B,z,\kappa) = & \max_{D'\geq 0, B', \Delta, L, M, X \geq 0} D + \beta \mathbb{E}_z \left[V(0, B', z', \kappa') \right] \\ & \text{subject to} \\ & D + [1-\lambda(0)] \left[wL + p_m M \right] + F = zL^\alpha M^\phi + X \\ & [\lambda(0) + \kappa] \left[wL + p_m M \right] + X \leq \frac{\Delta}{1 + r \left[0, B, \mathcal{I}(z,\kappa) \right]} \\ & B' = B \times \left\{ 1 + r \left[0, B, \mathcal{I}(z,\kappa) \right] \right\} + \Delta. \end{aligned}$$

3.2 Lenders

A continuum of competitive risk-neutral lenders offer one-period loan contracts to the firms. The contracts specify a firm-specific interest rate $r\left[n, B', \mathcal{I}(z,\kappa)\right]$ for each amount B' borrowed. The contracts are thus such that the lenders break even in expectation:

$$\frac{B'}{1 + r\left[n, B', \mathcal{I}(z,\kappa)\right]} = \frac{1}{1+r} \mathbb{E} \left\{ B' \times \Pr(\text{Repayment}) + \frac{B' \times \Pr(\text{Delinquent})}{1 + r\left[0, B'', \mathcal{I}(z',\kappa')\right]} \right\}.$$

The left-hand-side of this expression consists of the amount borrowed by firms with states (n, z, κ). The first term in the right-hand-side consists of the present discounted value of the loan conditional on repayment in the following period, where lenders discount the future at rate r. The second term in the right-hand-side consists of the present discounted value of the loan conditional on becoming delinquent in the following period but repayment a period after.

We consider two alternative economic environments. On the one hand, we consider an economy in which lenders have perfect information about the firms that borrow from them. In particular, in this economy lenders observe the firms' state variables (n, B, z, κ) perfectly. Thus, we have that $\mathcal{I}(z, \kappa) = (z, \kappa)$. We contrast this economy with one in which lenders have imperfect information about its borrowers. In particular, we assume that in this economy lenders cannot observe the value of z and κ underlying firms' decisions. Thus, in this economy we have that $\mathcal{I}(z, \kappa) = \emptyset$.

In the imperfect information case, lenders must take expectations over z, κ conditional on n, B. Hence, while they cannot observe the z, κ of an individual firm, they price loans based on their beliefs having observed n, B. In particular, because bad realizations of these variables increases the likelihood of delinquency, a low n is a signal of a recent bad realization. Given that these are persistent, lenders price in a default premium at lower levels of n.

4 Quantitative Analysis

We now use the model presented in the previous section to quantify the role of credit market frictions on the dynamics of firm-level default during the Great Recession. To do so, we first calibrate the model to match salient features of firm-level data. Then, we use the parameterized model to examine the response of firms in the economy to a series of shocks chosen such that they imply aggregate dynamics similar to those of the U.S. during the crisis.

4.1 Functional form assumptions

We begin by specifying a functional form for $\lambda(n)$, which characterizes the relationship between the share of production inputs that need to be paid upfront and the number of consecutive periods n that individual firms have repaid their debts on time. We assume that $\lambda(n) = \max\left\{1 - \lambda_0 n^{\lambda_1}, 0\right\}$. This functional form means that at some $\bar{n}$, the firm can finance their entire input bill with trade capital. On the other hand, when $n = 0$, they have to borrow $1 - \lambda_0$ of their input bill.

4.2 Stochastic processes

We assume that idiosyncratic productivity z and liquidity shocks κ follow autoregressive processes of degree one, whose dynamics are characterized by autoregressive coefficients ρ_z and ρ_κ as well as by standard deviations σ_z and σ_κ. We approximate these processes through a finite-state discrete Markov chain following Kopecky and Suen [2010].

4.3 Calibration

Table 1 presents our parameterization of the model. We set the discount factor β to 0.94. The shares of labor and intermediates in production α and ϕ are set to 0.65 and 0.10. The delinquency cost F is set to 24% of average output.

We assume that productivity follows an autoregressive process of degree one with autocorrelation ρ_z equal to 0.95, and standard deviation σ_z equal to 0.05. Liquidity shocks follow the same process but with autocorrelation ρ_κ equal to 0.95, and standard deviation σ_κ equal to 0.1.

Finally, we set the standard deviation of the preference shocks to the default vs. continuation choice, as well as the shocks that affect the repayment vs. delinquency decision to values that are sufficiently low to guarantee that our quantitative findings are not affected by these. We normalize the wage rate and the price of intermediates to equal one.

Table 1: Calibration

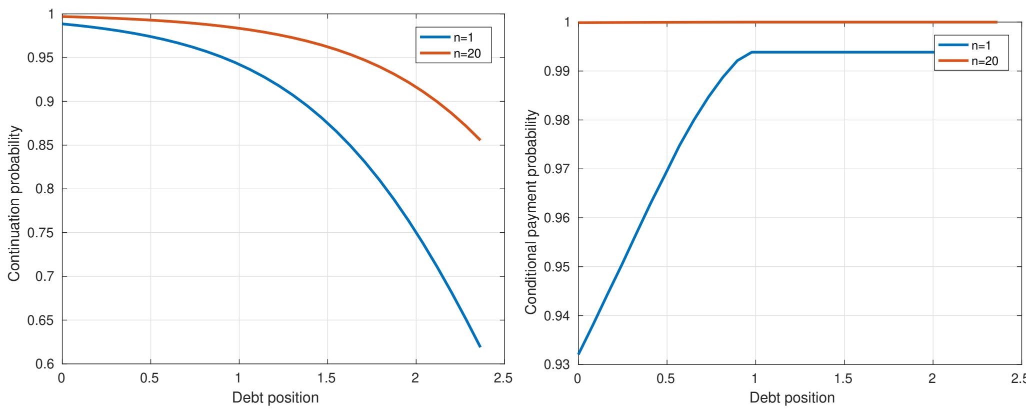
Parameter	Value	Description
β	0.94	Discount factor
α	0.65	Labor share
ϕ	0.10	Intermediates share
F	0.24	Delinquency cost (% avg output)
λ_0	0.10	1- level of working capital constraint for $n = 0$
λ_1	0.75	Curvature of working capital constraint
ρ_z	0.95	Productivity shocks: Autocorrelation
σ_z	0.05	Productivity shocks: Std. dev.
ρ_κ	0.95	Liquidity shocks: Autocorrelation
σ_κ	0.10	Liquidity shocks: Std. dev.
λ_c	0.5	Default vs. continuation shocks: Std. dev.
λ_p	0.1	Repay vs. delinquency shocks: Std. dev.

4.4 Results

We now investigate the implications of our model for the role of credit market frictions on the dynamics of firm-level default. First, we examine the policy functions that characterize the decisions of firms across the state space in our economy. Second, we report summary statistics that characterize salient features of firms in our model. Finally, we examine the response of individual firms to negative idiosyncratic shocks to productivity and liquidity.

Policy functions The most fundamental decision in our model is the discrete choice for when to close and when to be delinquent on a payment. We plot these in Figure 3 varying the number of periods a firm has paid back, n. Because the hazard of delinquency is decreasing in the number of periods of payment, once a firm has paid on time for 20 periods in a row, it is quite costly for the firm to miss a payment. Interestingly, though additional debt makes the firm less likely to continue, we are finding that delinquency is decreasing in debt load. This is because the debt simply rolls over, so this does not relieve them of the burden, however at high levels of debt, tightening the working capital constraint, by increasing $\lambda(n)$ becomes more costly. Firms with high levels of debt find it more expensive to borrow and so they lose out when n declines to 0.

Figure 3: By n, the continuation probability (LEFT) and on-time payment probability (RIGHT) as a function of the debt position (percentage of the average output).

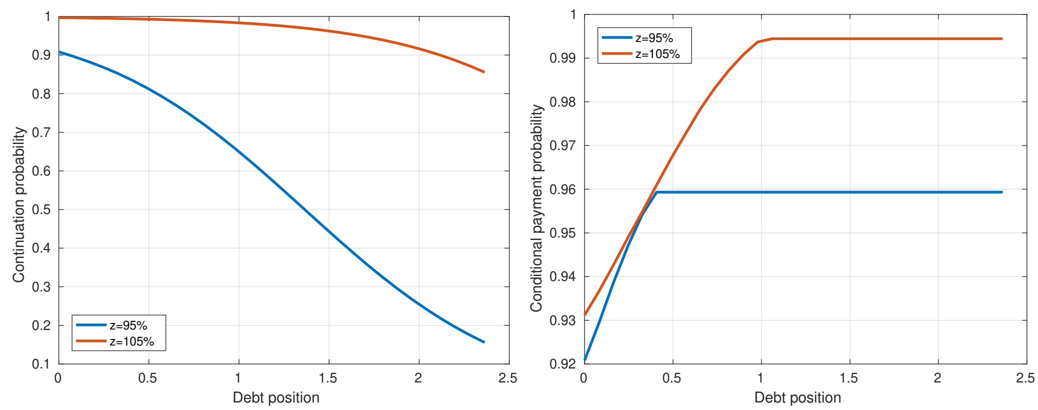


Delinquency is, however, useful as insurance against either a κ or z shock that temporarily increases costs and reduces output. In Figure 4, we plot the continuation and repayment policies for different levels of productivity, z. To illustrate the point, we evaluate this among borrowers with $n = 0$, where the chance of delinquency is largest. The bad productivity shock, of course increases the chance the firm declares bankruptcy and does not continue to the next period. A negative productivity shock also increases the chance the firm misses a payment. Here, it is useful for the firm to skip a debt payment in hopes that z will revert to the high state the next period.

Notice that a bad z shock, dropping it by 10% increase the chance of delinquency by about 4 percentage points at moderate levels of debt. The continuation probability drops sharply, 10 percentage points among firms that carry no debt and increasing amounts thereafter. For very high levels of debt, a firm with a low realization cannot continue, while they are very unlikely to exit if they had a good shock to z.

Interest rates in full and partial information In the interest rates lenders charge, they are pricing in the cost of (a) default and (b) delinquency.

Figure 4: By z, the continuation probability (LEFT) and on-time payment probability (RIGHT) as a function of the debt position (percentage of the average output).

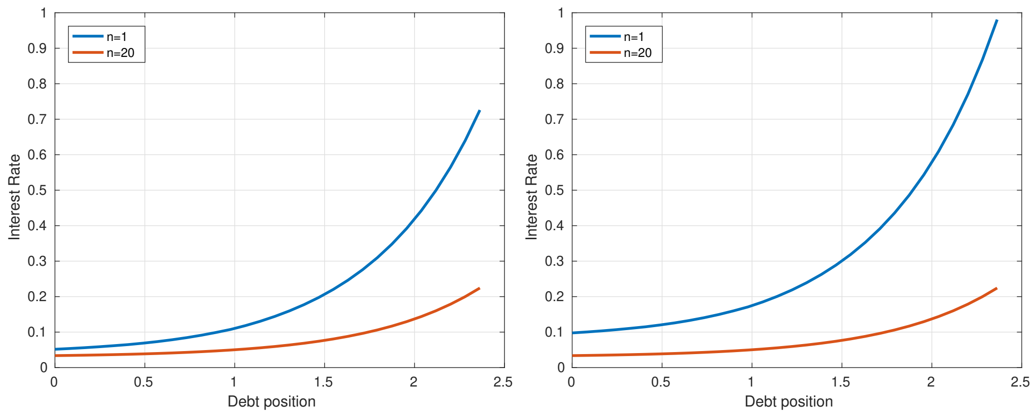


Because delinquent loans roll over with interest to the next period, delinquency does not immediately reduce the expected payment by much. However, a firm that becomes delinquent loses n, which then increases their borrowing costs in the next period and increases the likelihood they become delinquent then. This feature is captured in the pricing of rolled over debt by $r(0, B'', \mathcal{I})$.

Figure 5 plots the interest rates under $\mathcal{I} = (z, \kappa)$ and $\mathcal{I} = \emptyset$. We plot the interest rate when z is evaluated at its high point, when $z = 105\%$ of its average, so these are the least likely firms to exit. The full information case, $\mathcal{I} = (z, \kappa)$, reflects known low default rates, even when $n = 1$. However, in the partial information case, $\mathcal{I} = \emptyset$, there are higher interest rates when $n = 1$ because of pooling. The firms with the worst payment history are most likely to have low realizations of their fundamental shocks z, κ and so lenders charge them a premium.

Even for very low values of debt, the interest rate is about 4 percentage points higher for bad credit history firms than it was with full information. As the amount of debt the borrower holds increases the difference is exacerbated, slightly under 10 percentage points higher if the firm holds a debt position of 100% of average output. This pooling-induced interest rate is the effect of a "credit score" in our model: n plays the role of disseminating information about the nature of other shocks and increases the cost of debt on good-state firms who were recently unlucky.

Figure 5: Interest rates r with $z = 105\%$ of average. $\mathcal{I} = (z, \kappa)$ (LEFT) and $\mathcal{I} = \emptyset$ (RIGHT).



Summary statistics Work in progress.

Firm-level response to negative productivity shock Work in progress.

Firm-level response to negative liquidity shock Work in progress.

5 Conclusion

In this paper we investigate the role of financial factors in accounting for the dynamics of firm-level default during the Great Recession. We document a novel set of facts on the relationship between credit ratings and firm-level exit rates. We interpret this evidence from the lens of a model with heterogeneous firms, endogenous default and delinquency, and credit market frictions. Our findings suggest that credit constraints played an important role in accounting for the dynamics of firm-level default during the Great Recession.

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