Debt Overhang, Monetary Policy, and Economic Recoveries After Large Recessions*

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Abstract

This paper explores why conventional monetary policy was so ineffective in mitigating the severity of the 2007 U.S. recession and unsuccessful thereafter in stimulating aggregate demand. Linking firm-level data with predictions from a model, I show that accounting for individual firms' debt structures is crucial in explaining why business investment fell so dramatically through the recession and remained low for several years, despite the Federal Reserve repeatedly cutting its target interest rate until conventional policy tools were exhausted. Using a sample of publicly traded firms, I establish that firms with greater long-term debt exposure experienced larger contractions and slower recoveries in their investment expenditure. Next, I show that debt overhang episodes were unusually prevalent over the years following the onset of the recession, and particularly so among firms relying more heavily on long-maturing debt. To understand these microeconomic observations and their implications for aggregates, I develop a New Keynesian model where heterogeneous firms finance investment using defaultable nominal long-term debt and where the central bank faces an explicit zero lower bound constraint. There, the greater a firm's leverage, the higher its likelihood of experiencing a debt overhang episode following a large aggregate shock. Moreover, the severity of debt overhang problems, and their consequences for the distribution and level of aggregate investment, compounds with (1) an increased real value of debt, i.e., debt deflation, and (2) the monetary authority's inability to restore inflation once nominal interest rates reach the zero lower bound. Together, firms' long maturity debt positions and the binding zero lower bound are critical in transmitting the consequences of a deep recession into a remarkably anemic recovery in aggregate investment.

Keywords: debt overhang, firm investment, long-term debt, monetary policy, ZLB.
JEL Codes: E22, E32, E52.

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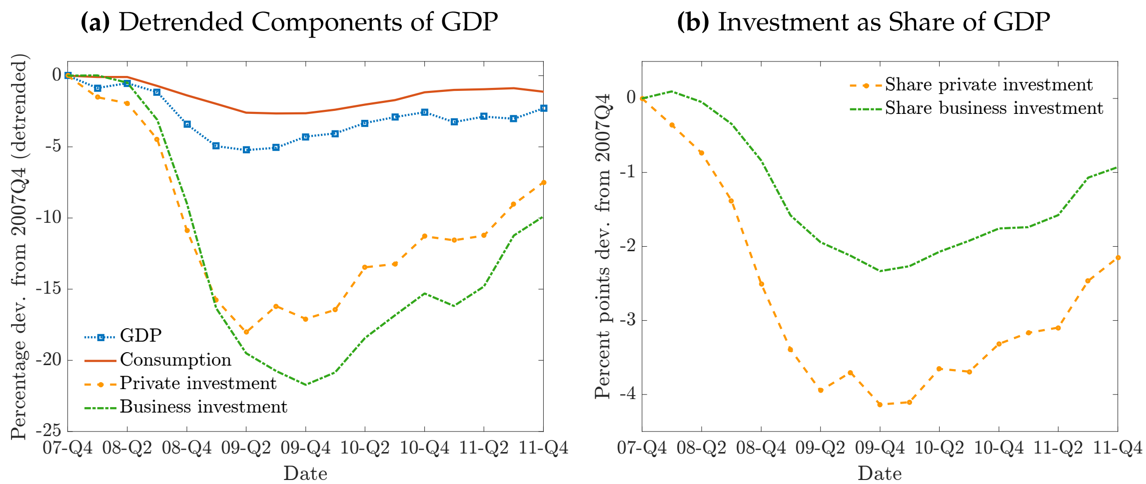
1 Introduction

The U.S. economy experienced historically severe drops in firm investment during the Great Recession, and these large declines persisted over several years. Figure 1(a) displays detrended GDP, consumption, private investment, and business investment, reporting each series as deviations relative to 2007Q4 levels. In the first two years of the crisis, private investment and business investment experienced contractions of around 20 percent. More importantly, investment recovered very slowly in the aftermath of the recession; four years after the onset of the financial crisis, private investment and business investment were still well below their pre-crisis levels, by 7.5 and 9.9 percent, respectively. A similar pattern appears when we measure these series as shares of GDP (Figure 1(b)). This evidence suggests that residential investment was not alone in driving the unusual depth and persistence of the 2007 recession, but that firm investment also contributed significantly.

The Federal Reserve responded to the downturn with a sequence of rapid reductions in nominal interest rates, taking the short-term policy rate from 5.25 percent in July 2007 to almost zero by December 2008. Thereafter, on reaching the zero-lower bound, the Federal Reserve resorted to unconventional policy measures aimed at increasing liquidity in interbank markets, in an effort to fuel the credit supply and stimulate aggregate consumption and investment (see Bernanke, 2012). Despite these strong policy interventions, investment recovered uncharacteristically gradually by comparison to the norm of previous postwar recessions.

This paper shows, both empirically and in the context of a quantitative general equilibrium model, that the interaction between heterogeneous firms' long-term debt positions and the monetary policy ramifications of the zero lower bound is crucial to understanding the persistent dynamics of investment during a large recession and in its aftermath. Long-term debt financing is prevalent in both the corporate and non-corporate sectors in the U.S., allowing firms a flexible means of smoothing their costs of investment over time. This type of external finance leaves firms more exposed to rollover risk, however, and makes rapid adjustments in their debt positions difficult given accumulated stocks. In such times of financial distress, firm investment activities may suffer. A second, debt overhang, channel associated with firm ownership and default risk compounds the problem. A firm is said to experience debt overhang when it has the opportunity to engage in positive net present value investment projects that would raise its expected value, but it decides not to undertake them due to balance sheet con-

Figure 1: The Great Recession



Notes: Data from the U.S. Bureau of Economic Analysis, retrieved from FRED - St. Louis Fed. Consumption is non-durable goods and services; business investment is non-residential investment; and private investment is business fixed investment, residential investment, and consumer durables. In panel (a), the log of each variable is detrended using an HP filter with weight 1600 and with data from 1947Q1 to 2017Q4. These series are plotted as percent deviations from their 2007Q4 values. Panel (b) reports the absolute percentage point deviations in GDP shares with respect to the shares in 2007Q4.

siderations (Myers, 1977). During a debt overhang episode, investment decisions are distorted, and firms choose sub-optimally low levels of capital. These episodes tend to occur in firms that are highly indebted and facing default risk, because cash flows accrue first to creditors in the event of default, not to shareholders. This misalignment of incentives makes new investment projects less attractive for firms' owners, lowering their investment rates.

Rollover risk and debt overhang arising from firms' long-term debt positions were large impediments to investment activity during the Great Recession, because this recession coincided with a severe contraction in the supply of credit to which firms could not rapidly re-accommodate. The consequences were particularly severe and long-lasting, because the zero lower bound prevented monetary policy from pushing inflation up, which otherwise would have eased the financial burden of affected firms. This conflated the problems posed by the stickiness in debt structures, setting the scene for a long anemic recovery in aggregate investment.

I evaluate the interaction and relative contribution of these channels in driving a sluggish economic recovery, following a deep recession, in three ways. First, I examine and quantify the role of financial factors in explaining the slow aggregate investment recovery over the post-2009Q2 U.S by means of an empirical analysis that uses firm-level data from Compustat. Second, I empirically establish that the effect of previously contracted long-term financing on firm investment is more prevalent during large recessions. Third, I explore the extent to which monetary policy interacts with these financial factors in the face of a zero lower bound on nominal interest rates. To do so, I construct a general equilibrium New Keynesian model with the essential ingredients necessary to explore the extent to which the factors listed above explain what we observed during the recession. There, I include a distribution of firms that vary in their need for external finance. These firms issue nominal long-term debt to finance their investment activities subject to competitive lending terms responsive to their individual productivity, leverage, and default risk. Alongside them, there is a monetary authority confined by a zero lower bound restriction.

My empirical results show a heterogeneous response in firm investment during the Great Recession. Using firm-level data from Compustat, I first provide evidence that long-term debt is an important influence on firm investment decisions, and next document its prevalence at the onset of the 2007 crisis. My main empirical findings are as follow. First, firms with higher fractions of long-term debt maturing at the onset of the recession experienced larger contractions in investment. Second, controlling for firm-level variables highly correlated with investment choices does not eliminate the relationship; a large fraction of debt requiring rollover still predicts a strong decline in the investment rate. Third, leverage does not completely summarize the relevance of a firm's debt position as a determinant of investment, as it does not capture the timing at which that debt matures. Fourth, during the Great Recession, the adverse incidence of long-term debt exposure increased not only relative to normal times, but also relative to other crisis episodes.

As mentioned above, I conduct my theoretical investigation using a general equilibrium New Keynesian model generalized to include defaultable long-term nominal debt and the investment and finance decisions among a rich distribution of firms. Firms face persistent idiosyncratic productivity risk and are heterogeneous in their capital stocks and outstanding debt or financial savings. They produce a homogeneous good using their own capital stocks together with labor they hire from a representative household. When their investment needs exceed their available cash, firms can finance the additional expenditure externally by issuing a defaultable nominal long-term bond purchased by a perfectly competitive financial intermediary. Alongside these distinctive new elements in the model, I embed a Phillips curve by including a set of monopolistically competitive retailers that each face adjustment costs to reset their prices, as conventional in the New Keynesian literature, and a central bank with control over the short-term nominal interest rate. Importantly, the monetary authority is explicitly subject to a zero lower bound constraint, so the policy instrument has its limits.

When calibrated and simulated, my model succeeds in capturing several of the most salient features from the most recent U.S. recession. In particular, it can explain the disproportionate drop in aggregate investment during the Great Recession as the result of a heavy burden of nominal long-term debt coming due among many firms, driving increased default risk and debt overhang problems as well as more realized default, and exacerbated by the binding zero lower bound preventing the desired policy response. More importantly, it can generate a slow recovery resembling that in the recent data.

Reductions in nominal interest rates do not stimulate investment expenditure in my model economy as much as they do in the special-case setting with one-period debt, because of the quasi-fixed nature of long maturity debt. Firms carrying long-term debt will not necessarily all respond to a given nominal rate reduction with increased investments, because they still carry the financial burden of their outstanding stock of debt. The larger is this burden, the more insensitive is a firm's investment to a short-run policy rate stimulus, and the greater is the debt overhang problem associated with default risk.

I document below that there was a rapid run-up in firm debt prior to the 2007 recession, and that it was followed by a sharp deleveraging. This readjustment confronted highly indebted firms with increased debt service payments in the context of a tight credit market. In my model, I show that the severity of a debt overhang episode under such conditions depends on the degree of financial distress experienced by highly indebted firms, and on the rise in risk premia they face.

The greater is the maturity horizon on debt, the greater the real effect of a recession, particularly one associated with a credit crisis. When firms have a sizable fraction of their debt that has not yet matured, they cannot adjust leverage as freely as in the special-case model where firms issue only short-term debt. This, paired with a non-zero probability of default, makes a debt overhang problem more likely. That likelihood rises further with nominally denominated debt, since lower inflation rates increase its real value. Furthermore, the negative investment consequences of lowered inflation rates are spread through time by the fact that debt is long-term. Throughout the recession, reduced inflation increases the real value of debt, generates debt deflation, drives up risk premia and exacerbates the overhang problem; hence, its effects are long-lived.

My extension of the traditional New Keynesian model to interact a rich distribution of firms with long-term financing arrangements delivers interesting asymmetries and state-dependent responses of investment to monetary policy interventions. These nonlinear dynamics in firm investment are a novel aspect of this paper and offer a few key insights. At the onset of a recession, we typically observe rising default rates. Firms issuing new debt at such times face higher risk premia, which makes them more susceptible to experiencing large distortions in their investment decisions due to debt overhang. This is especially true in times of large negative aggregate shocks and the recovery episodes thereafter. In those times, we observe sharp declines in aggregate investment that persist, because firms that are more prone to debt overhang problems are medium-sized firms with growth opportunities and large fractions of long-term debt. By contrast, financial frictions have more muted effects on investment in times of relatively small negative shocks to the economy as these shocks do not raise default probabilities to the same extent that large negative shocks do.

I find that the presence of debt finance with maturity structures resembling those in the data matters particularly for macroeconomic fluctuations over large recessions that are financial in nature. The average maturity of debt is five years in my calibrated baseline economy. There, when prices are fixed, a financial shock causes a recession four times deeper than happens in a setting with one-year expected debt maturity. More importantly, the recovery thereafter has three times the half-life in the baseline economy with longer-maturity debt. This is in part due to the persistent consequences of sharper rises in exit rates, and in part due to a persistently greater worsening in the allocation of capital among incumbent firms. Each of these stems from a larger and more protracted increase in default risk under longer maturity financing, which in turn generates a greater debt overhang burden. My model furthermore predicts that a debt deflation amplifies the effect of a financial shock, both in amplitude and persistence. GDP falls an extra percentage point and the recovery is even more gradual when lower than expected inflation rates accompany a financial recession. When considering changes in prices and interest rates, debt maturity does not have such a large impact on the size of the recession, but it still generates a more persistent recovery. The half-life of the recovery is between two and three times larger in the five-year maturity model when compared to a two-year expected maturity case.

While the non-government channels discussed above go some distance toward explaining the movements in aggregate business investment during and after the Great Recession, I find that monetary policy still plays a critical and complementary role. As with the U.S. Federal Reserve, the central bank in my model economy is powerless to generate inflationary pressures when it reaches the zero lower bound on nominal interest rates. This intensifies the debt deflation mechanism and exacerbates the overhang problem, making it both more severe and more persistent. It is the combination of these elements, the effective removal of the central bank's policy instrument together with the balance sheet factors raised above, that allows my model to explain a sizable portion of the sharp declines in U.S. investment during the 2007 U.S. recession and, more importantly, the confounding sluggishness in its recovery over four years beyond.

The rest of the paper is structured as follows. Section 2 describes the data and presents suggestive evidence about the role of long-term financing during the 2007 crisis. Section 3 presents the model economy and discusses its primary mechanisms Section 4 describes the calibration. Results are presented in Section 5. There, I use a series of comparisons between nested reference models (a version of the model with one-period debt, one with frictionless financing, and one with no zero lower bound restriction), both under fixed prices and in general equilibrium. This section analyzes the respective role of each principal model ingredient in driving aspects of the downturn, and the gradualism of subsequent recovery, in response to real and financial shocks. Section 6 offers concluding remarks and proposes some ideas for continuing research.

Related Literature

I contribute to four strands of the literature. First, this paper adds to the literature that studies the relationship between firm-level financial variables and investment decisions. There is a large body of research in both structural and empirical corporate finance that addresses this topic. This literature has shown that financial frictions can affect negatively investment decisions. Starting with the theoretical work in Lucas and Prescott (1971) and Hayashi (1982), the q theory of investment has claimed that q, the shadow value of capital, is a sufficient statistic for investment. Initial tests of this theory were not successful, as documented by Fazzari, Hubbard and Petersen (1988), where the authors find that investment responds more strongly to internal funds than to empirical measures of q. Other papers like Erickson and Whited (2000), Gomes (2001), Hennessy (2004), Hennessy, Levy and Whited (2007), and Moyen (2007) incorporate the effect of financial constraints into a neoclassical model of investment, showing supportive evidence for both the q theory and the impact of frictions in determining investment decisions. In particular, these works document the relevance of debt overhang in dragging down investment rates.

Kalemli-Ozcan et al. (2018) explore the role of debt overhang in explaining the sluggish recovery of investment in Europe after the concurrent 2007 recession. By matching firms with their banks, they show that during the crisis, the relationship between leverage and investment in Europe was amplified by the increased debt service and by commercial banks being exposed to sovereign risk. Almeida et al. (2011) show that firms with higher fractions of long-term debt maturing during the 2007 recession contracted their investment by more compared to otherwise similar firms not facing such a situation. Furthermore, their empirical results suggest that this amplification occurred predominantly through firms with a substantial amount of long-term debt, but not necessarily through highly leveraged firms. Hence, their empirical evidence suggest the importance of including long-term debt as an essential model ingredient. In this paper, I take these results and go further to study the interaction of long-term debt with other firm-level characteristics and macroeconomic conditions. I also find that the prevalence of debt overhang problems across firms increased significantly during the Great Recession.

Second, the model I propose in this paper is closely related to the literature studying financial frictions in contexts of heterogeneity. This includes works such as Khan and Thomas (2013), Khan, Senga and Thomas (2016), Zetlin-Jones and Shourideh (2017) and Arellano et al. (2018) which, using models of one-period debt contracts in economies without nominal rigidities, stress the importance of accounting for differences at the firm level when considering the role of financial frictions. Ottonello and Winberry (2018) extend the model in Khan, Senga and Thomas (2016) by introducing sticky prices and analyzing the response to monetary policy shocks. Gomes, Jermann and Schmid (2016) propose a New Keynesian model, in which firms can issue nominal long-term defaultable debt. Nonetheless, their model does not exhibit persistent heterogeneity across firms, so they are unable to quantify the importance of the debt overhang problem for the cross-section of firms. My model builds by considering long-maturity loans denominated in nominal terms while accounting for the cross-sectional financial heterogeneity. These additional ingredients, alongside nominal rigidities and the zero lower bound, allow me to examine the incidence of debt structure and its heterogeneity during the 2007 recession.

Third, there is now a nascent interest in understanding the transmission of monetary policy in the context of heterogeneity. This literature has mainly focused on investigating the interplay between the persistent differences across households and monetary policy. Examples include Mckay, Nakamura and Steinsson (2016), Auclert (2017), Kaplan, Moll and Violante (2018), and Wong (2018). The above-referenced work by Ottonello and Winberry (2018) is the first work in considering the interaction between firm heterogeneity and monetary policy. In this paper I build on top of this existing body of literature by modeling firm heterogeneity with long-maturity debt and focus on the role played by monetary policy during the Great Recession, while accounting for the zero-lower-bound constraint faced by the Federal Reserve. In my model, I show that the inability of reducing the short-term nominal interest rates further intensifies the impact of financial factors, and in particular of debt overhang, during this period.

Lastly, this paper contributes to the literature studying the role of conventional and unconventional monetary policy during large recessions. The renewed interest in understanding how monetary transmission changes when the economy reaches the zero bound on interest rates brought new and more quantitatively oriented research that builds on top of earlier theoretical work. This literature includes works as Eggertsson and Woodford (2003), Christiano et al. (2015), Fernández-Villaverde et al. (2015), and Del Negro et al. (2017). However, this literature has mostly been confined to representative agent models. This is due to the non-linearities that arise when including a ZLB and large crises in a model, as these are not easily circumvented by solution methods that are better suited to handle small shocks. The solution strategy I present in this paper is able to approach these types of questions and modeling features in a more appropriate manner.

2 Empirical Evidence From the Great Recession

This section provides empirical evidence to support the mechanisms discussed in the paper. Subsection 2.1 starts by presenting some aggregate facts about firm debt dynamics during the recession. Subsection 2.2 describes the micro-level data, and Subsection 2.3 studies the investment dynamics for firms with different debt structure during the Great Recession. Subsection 2.4 then provides suggestive evidence of the average impact of debt overhang and, specially, its incidence during the 2007 crisis.

2.1 Aggregates

I start by delving into firm debt dynamics during the 2007 recession. I use time-series data from the Financial Accounts of the United States (Flow of Funds). This dataset includes flow of funds and balance sheet macro-level data at a quarterly frequency for 1951Q4 - 2017Q3.[1] All the nominal variables are deflated using the consumer price index for all urban consumers.

Figure 2(a) shows the build-up of debt in the corporate sector preceding the Great Recession. The detrended total real debt increased sharply right from the onset of the recession. Figure 2(b) shows that this increased borrowing was accompanied by higher leverage, and was followed by a strong adjustment starting in 2009. Importantly, a large fraction of that adjustment came from long-term debt. Figure 2(c) shows that, after the recession ended, long-term borrowing fell and remained below trend for several years. Nevertheless, the sharp adjustment in total debt following the crisis increased the relevance of long-term debt, as seen in the increased long-term debt ratios in Figure 2(d).

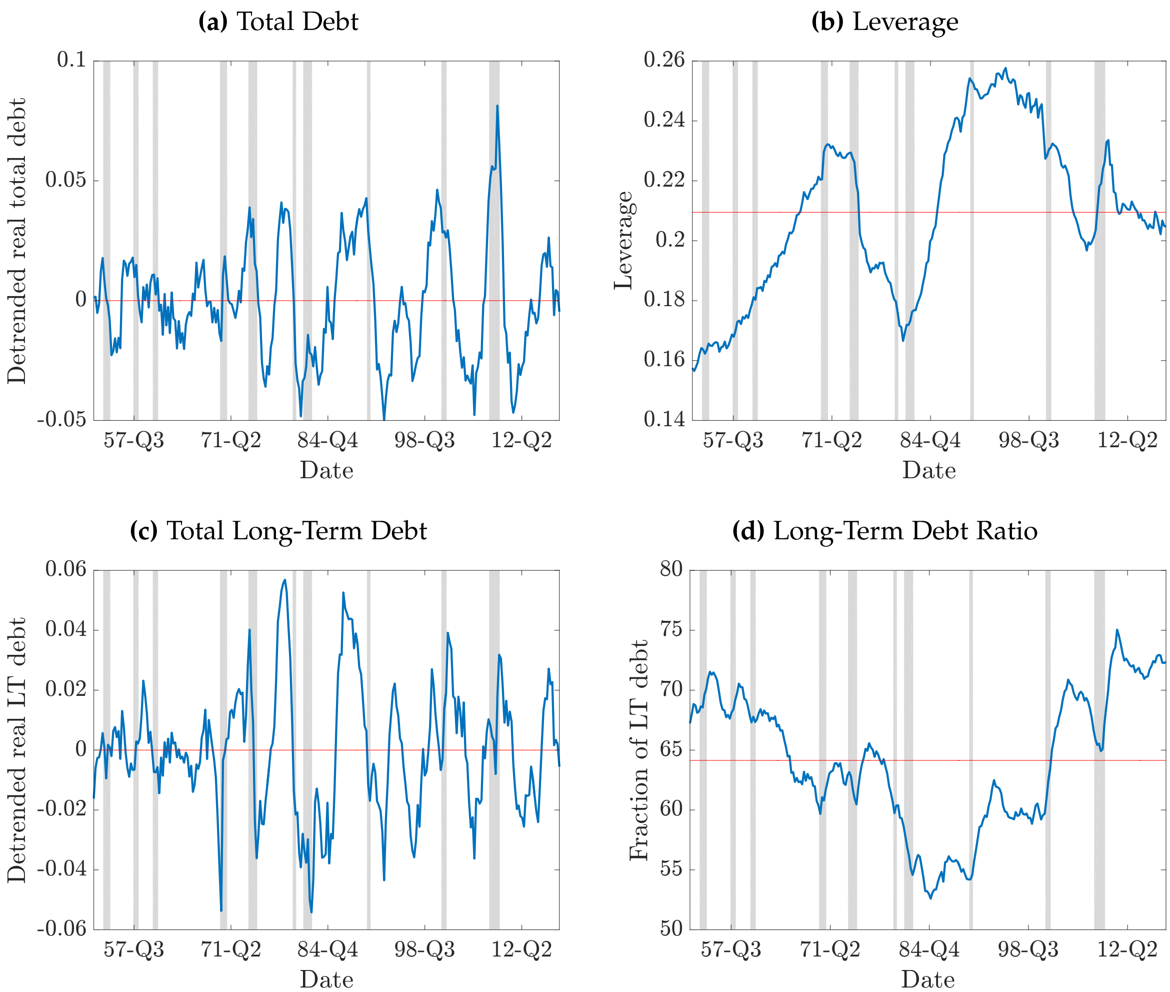
2.2 Firm-Level Data Description

In this section, I take a closer look at firm debt by using firm-level data from annual and quarterly Compustat databases for 1981-2017. This dataset contains a panel with financial information of publicly traded U.S. firms. One major advantage of this dataset over others is that it provides detailed information about firm debt composition. This is important as it allows me to better measure variables of interest. Additionally, the fact that we have a long panel allows me to better control for within-firm heterogeneity. The disadvantage of using Compustat is that we only have information for publicly traded firms. These tend to be larger and to have more access to financial markets than privately held firms. However, the firms in Compustat account for about one-quarter of total U.S. employment and 70 percent of production.

I delete observations of regulated, financial, and public service firms, as well as of foreign governments. I also eliminate observations with missing or negative values for total assets, capital expenditures, property, plant and equipment, cash holding or sales. Firms for which total assets are lower than cash holding, capital expenditures or property plant and equipment are not considered. I also drop firms for which the value of total assets is less than $0.5 million, as well as firms with asset growth or sales growth exceeding 100%. Finally, I also delete firms for which the value of long-term debt exceeds the value of total assets or the value of total debt. Finally, I only consider firms with at least 5 years (20 quarters) of investment spells. The resulting annual sample contains

[1] I focus on the dynamics of the corporate non-financial sector, as this sector has more publicly available real and financial data than its non-corporate counterpart.

Figure 2: Corporate Sector Debt Dynamics



Notes: Shaded areas represent NBER recession dates (peak to trough). Data from the Financial Accounts of the United States for the non-financial corporate sector. All variables are deflated using the Consumer Price Index for All Urban Consumers from Fred - St. Louis Fed (CPIAUCSL). The construction of the detrended variables uses an HP filter with weight 1600 and with data from 1951Q4 to 2017Q3 over the log of each variable in real terms. The Federal Reserve defines long-term credit market corporate debt outstanding as the sum of municipal bonds, corporate bonds, and mortgages. Short-term credit market debt outstanding is the sum of commercial paper, bank loans not elsewhere classified, and other loans and advances. Horizontal red lines represent sample averages for non-detrended data.

Table 1: Summary Statistics

	Mean	**Median**	**Std.**
$\Delta \log k_{i,t+1}$	0.071	0.063	0.134
$x_{i,t}/k_{i,t}$	0.119	0.094	0.094
LT debt ratio	0.899	1.000	0.198
Fraction of LT debt maturing	0.123	0.062	0.184
Fraction of all debt maturing	0.207	0.112	0.245
Leverage	0.266	0.247	0.190

Notes: Summary statistics for firm level variables. $\Delta \log k_{i,t+1}$ is the net change in the capital stock. $(x_{i,t}/k_{i,t})$ is the gross investment rate. Long-term debt ratio is total debt issued with maturity above one year divided by total debt. Fraction of long-term debt maturing is the dollar amount of long-term debt maturing during the next year relative to total long-term debt. Fraction of all debt maturing is the dollar amount of debt maturing during the next year relative to total debt. Leverage is the ratio of total debt to total assets.

data for 3,527 distinct firms across 34 years, for a total of 31,064 firm-year observations. Appendix A provides a more detailed description of the data construction.

My main measure for investment is the log change in net capital stock, $\Delta \log k_{i,t+1}$, where $k_{i,t+1}$ is the capital stock of firm i at the end of period t. Alternatively, I also use $(x_{i,t}/k_{i,t})$, where $x_{i,t}$ is the gross change in the capital stock, to measure gross investment rates. To characterize firm debt structure, I use measures related to both the fraction of debt that could generate rollover risk, as well as firm reliance on long-term financing, which, as is traditional in the literature, is defined as all debt issued with a maturity equal or longer than one year. For the latter, I use the ratio of total long-term debt to total debt. For the former, this is, debt obligations that may not be rolled over, I break this down further into two variables: (1) the fraction of total debt that matures within a year and (2) the fraction of long-term debt maturing within the year. The advantage of using this second measure is the fact that it uses the fraction of long-term debt that is due. This means that it can account for debt that has been issued prior to the current period, and hence may be less susceptible to the choice of current investment.

Table 1 reports summary statistics for the sample used in the analysis below. As seen there, the mean annual capital growth rate is about 7.1% with a standard deviation of 14.4%. The mean long-term debt ratio is 90%, but more than half of the firm-year observations in the sample have a unitary long-term debt ratio, thus highlighting the importance of long-term financing. Within that long-term debt, on average, around 12.3% matures within the next year, and 20.7% of all debt must also be paid within the next year.

2.3 Heterogeneous Response of Investment

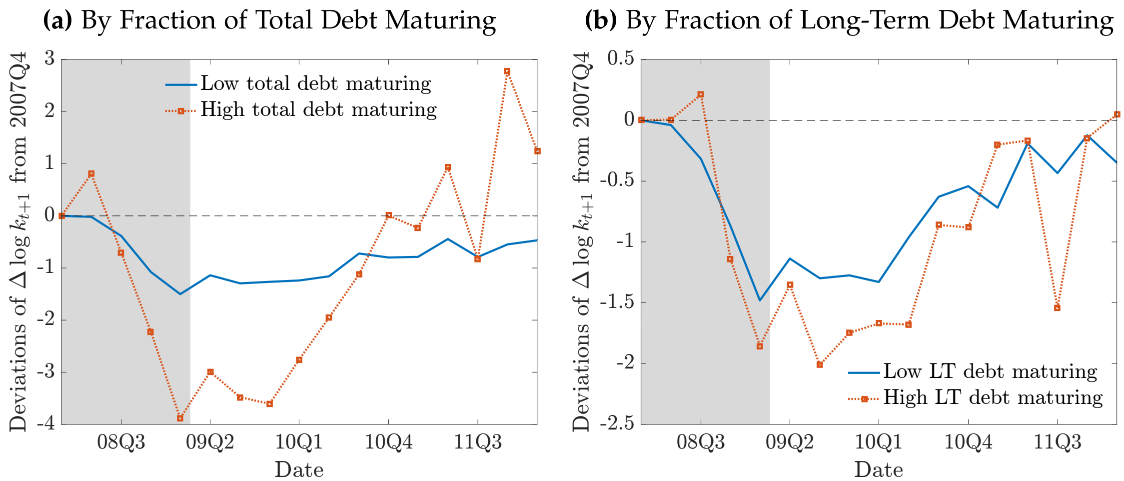
In order to have a sense of the Great Recession's effect at the firm level, I use quarterly Compustat data and track the investment dynamics of firms with different debt structures. Figure 3 depicts how investment responded during the 2007 recession for firms with high and low levels of financial burden. I use both the fraction of total debt maturing during the next year and the fraction of total long-term debt due next year to account for the financial distress arising from rollover risk. A firm with a high fraction of their total debt maturing next year is a firm for which the ratio of total debt due is above the sample mean for this variable. An analogous definition applies to firms with high long-term debt maturing ratios. I follow the dynamics of average investment for firms with high and low debt maturing ratios in 2007Q4, while keeping the same firms in each group.

Figure 3(a) shows that firms that had a high ratio of total debt maturing on the onset of the crisis contracted their average investment almost 4 times as much compared to pre-recession levels. In contrast, firms with lower ratios of total debt maturing only experienced a decline in their average investment of about 1.5 times when compared to their investment in 2007Q4. Both groups of firms reached their investment trough in 2009Q1, and started to recover afterward. Turning to firms that differ in the ratios of long-term debt maturing in 2007Q, we also observe differences in investment behavior. Figure 3(b) shows that firms with high fractions of long-term debt maturing reduced investment by more than their counterparts with low exposure to rollover risk. The largest contraction for high long-term debt maturing firms (2009Q3) was about 1.5 times the largest contraction for the low long-term debt maturing firms (2009Q1). Although these results do not control by other firm characteristics, they provide suggestive evidence about the role of debt structure for investment dynamics.

2.4 Debt Overhang at the Firm Level

Leverage and the financial burden that arises from debt repayments are critical in understanding the relevance of debt overhang on firm investment decisions. On the one hand, leverage provides an overall measure if firm indebtedness. On the other hand, firms with a larger relative size of debt obligations are more likely to experience rollover risk. Together, these two variables are useful in gauging to what extent a firm is financially constrained and how likely it is to default.

Figure 3: Firm Investment and Debt Structure During the Great Recession



Notes: Shaded areas represent NBER recession dates for the Great Recession (peak to trough). Fraction of all debt maturing is the dollar amount of debt maturing during the next year relative to total debt. Fraction of long-term debt maturing is the dollar amount of long-term debt maturing during the next year relative to total long-term debt. For both panels, the threshold between the two groups comes from the sample mean of each variable. The average investment for each group is normalized with respect to their respective values in 2007Q4.

Leverage is a financial variable that has been found to be closely related to the cost of external finance. Whited and Wu (2006), for example, document that highly leveraged firms tend to be more financially constrained. Ottonello and Winberry (2018) find that leverage is a major determinant of the response of firm investment to monetary policy shocks. Thus, can differences in investment rates, across groups of debt, be explained by differences in leverage? Table 2 presents the average, median and standard deviation of annual investment rates for firms with high and low leverage, across groups organized by fractions maturing debt. A firm-year is classified as high leverage if leverage for that year is above the sample mean for this variable. The groups across fractions of debt maturing, for total debt and long-term debt, are computed as before.

As shown in the Table, highly leveraged firms exhibit significant differences in their average and median investment rates when grouped by their fractions of debt maturing. These differences are irrespective of using total debt or long-term debt. For example, the average investment rate for firms with high leverage and high total debt maturing is 5 percent, while its counterpart for a highly leveraged firm with lower rollover risk is 7.3 percent. Further, although these same differences are smaller for firms with low leverage levels, they are still sizable: for instance, the average investment rate is 0.5 percent points larger for a firm with above-average ratios of total debt maturing than

Table 2: Investment by Groups of Leverage and Debt Maturing

	High leverage			Low leverage		
	Mean	Median	Std	Mean	Median	Std
High total debt maturing	0.050	0.049	0.155	0.073	0.067	0.131
Low total debt maturing	0.070	0.060	0.140	0.078	0.068	0.122
High LT debt maturing	0.041	0.042	0.157	0.070	0.064	0.133
Low LT debt maturing	0.071	0.062	0.140	0.079	0.070	0.121

Notes: Investment is $\Delta \log k_{i,t+1}$. High leverage is leverage above the sample mean. High fraction of total debt maturing is having this value above its sample mean. High fraction of long-term debt maturing is having this value above its sample mean. Fraction of all debt maturing is the dollar amount of debt maturing during the next year relative to total debt. Fraction of long-term debt maturing is the dollar amount of long-term debt maturing during the next year relative to total long-term debt. Leverage is the ratio of total debt to total assets.

for firms with lower-than-average debt maturing. These results suggest that, while it is necessary to account for differences in leverage across firms, we also need to look closely at their debt structure when studying the determinants of firm investment.[2]

To control for other firm level variables while taking into account the effect of high levels of leverage and, more importantly, of the financial burden associated to debt repayments, I estimate the following model

$$\Delta \log k_{i,t+1} = \alpha_i + \alpha_{s,t} + \beta_1 \omega_{i,t} + \beta_2 \mathcal{D}_{i,t} + \mathbf{\Gamma}' Z_{i,t} + \varepsilon_{i,t} \tag{1}$$

where α_i is a firm-level fixed effect, $\alpha_{s,t}$ is a sector-year fixed effect, ω is leverage, $\mathcal{D}_{i,t}$ is a debt burden proxy, and $Z_{i,t}$ is a vector of firm-level control variables. We are mostly interested in the coefficients β_1 and β_2, as they are closely related to a firm being able to borrow and repay its debt.[3] For $\mathcal{D}_{i,t}$, I use both the fraction of total debt and the fraction of long-term debt maturing within the year. Using long-term debt has an advantage: this variable is less likely to be respond to current investment. The fact that the numerator is long-term debt maturing implies that this debt is more likely to have been issued at least one year before. Here, we will also have long-term debt that was issued with a maturity between one year (by definition) and two years. Nevertheless, using this variable makes the specification in (1) less prone to have endogeneity problems. Firm-level controls

[2]Figure C1 in Appendix C shows an scatter plot for investment, leverage and the ratio of long-term debt maturing within the next year, using 2007 data as an example. The idea is similar: there is a great deal of dispersion in investment rates that cannot be captured by focusing on leverage only.

[3]The empirical specification in (1) can be motivated by means of a structural model of firm investment. I provide a derivation of such a model in Appendix B.

include the log of total assets (a proxy for firm size), sales growth, and Tobin's q.[4] It is important to note that, although this estimation provides suggestive evidence about the role of financial factors in investment decisions, it is not possible to establish causality using (1).

Table 3 reports the results of estimating different versions of Equation (1). The first three columns present the individual effects of leverage and debt burden on investment without controlling for any other variable. Both variables have negative effects on investment. An increase of one standard deviation in leverage is associated with a contraction of 0.67 percentage points in investment rates, relative to an average investment rate of 7.1 percent. An increase of one standard deviation in the debt maturing ratios is associated with investment rates that are 0.81 and 1.07 percentage points lower for total debt and long-term debt, respectively. When accounting for the fact that leverage may have a different impact on investment depending on when the firms' debt is maturing (columns 4 and 5), we still observe significant negative relations between these variables and investment.

After controlling for other firm-level variables (columns 6 and 7), the negative impact of both leverage and debt maturing on investment roughly halves, but remains significant. This means that an increase of one standard deviation in the debt to assets ratio reduces investment rates between 0.34 and 0.42 percentage points, while having a fraction of long-term debt maturing that is one standard deviation above the mean is associated with 0.59 percentage points lower investment rates.

Was the incidence of debt overhang stronger during the Great Recession? How does it compares to previous crises episodes? To this purpose, I augment the model in (1) by including the interaction of dummies for the periods comprising the Great Recession and the 2001 recession and the debt overhang proxy, $\mathcal{D}_{i,t}$. Figure 4 summarizes these results. When using the fraction of total debt maturing within the next year, the average negative effect of this variable on investment is about 1.5 percent. Importantly, this effect almost doubled during the Great Recession, but did not during the 2001 recession. When using long-term debt maturing, we obtain similar results, although the magnitudes are larger in this case.

[4] As a robustness exercise, I also estimate the baseline specification and its variants presented below using the fraction of total debt maturing within the next year. These results are in Appendix C.

Table 3: The Role of Debt Overhang on Firm Investment

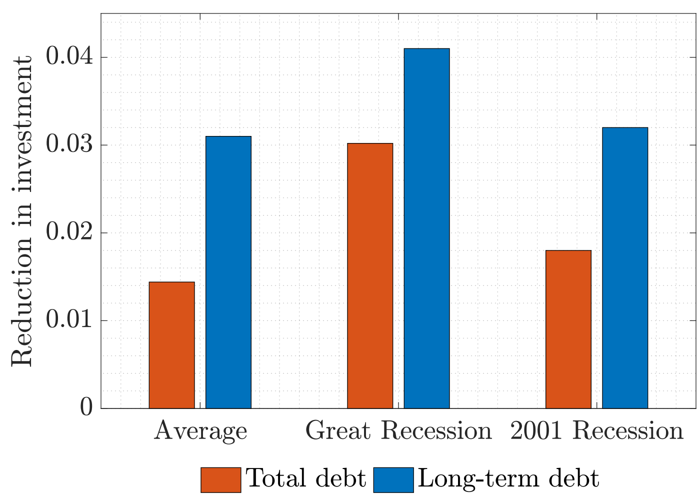
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Leverage	-0.035			-0.039	-0.046	-0.018	-0.022
	(0.011)			(0.011)	(0.011)	(0.010)	(0.010)
Total debt maturing		-0.033		-0.034		-0.016	
		(0.005)		(0.005)		(0.005)	
Long-term debt maturing			-0.058		-0.062		-0.032
			(0.006)		(0.006)		(0.006)
Firm controls	No	No	No	No	No	Yes	Yes
R^2	0.061	0.063	0.066	0.064	0.067	0.212	0.213

Notes: Results from estimating the specification

$$\Delta \log k_{i,t+1} = \alpha_i + \alpha_{s,t} + \beta_1 \omega_{i,t} + \beta_2 \mathcal{D}_{i,t} + \mathbf{\Gamma}' Z_{i,t} + \varepsilon_{i,t}$$

where α_i is a firm fixed effect, $\alpha_{s,t}$ is a sector-year fixed effect, $\omega_{i,t}$ is leverage measured as the book debt to assets ratio, $\mathcal{D}_{i,t}$ is a debt burden proxy, and $Z_{i,t}$ is a vector with firm-level controls containing, log of total assets, sales growth, and Tobin's q. Standard errors are clustered at the firm level.

Figure 4: Debt Overhang During the Great Recession



Notes: Results from estimating the model

$$\Delta \log k_{i,t+1} = \alpha_i + \alpha_{s,t} + \beta_1 \omega_{i,t} + \beta_2 \mathcal{D}_{i,t} + \beta_3 I_t^{GR} \mathcal{D}_{i,t} + \beta_4 I_t^{01} \mathcal{D}_{i,t} + \mathbf{\Gamma}' Z_{i,t} + \varepsilon_{i,t}$$

where α_i is a firm fixed effect, $\alpha_{s,t}$ is a sector-year fixed effect, $\omega_{i,t}$ is leverage measured as the book debt to assets ratio, $\mathcal{D}_{i,t}$ is a debt burden proxy, I_t^{GR} is a dummy variable taking the value of 1 for the period 2007-2009, I_t^{01} is a dummy variable taking the value of 1 for the period 2001-2002, and $Z_{i,t}$ is a vector with firm-level controls containing, log of total assets, sales growth, and Tobin's q. Standard errors are clustered at the firm level. Results are presented in absolute value. The bar for the average effect is $|\beta_2|$, while the bars for Great Recession and 2001 Recession are $|\beta_2 + \beta_3|$ and $|\beta_2 + \beta_4|$, respectively.

3 A Quantitative Model of Firm Nominal Long-Term Debt and Monetary Policy

In order to address my research objective quantitatively, I develop a New Keynesian model of heterogeneous firms that is able to capture the observed dynamics of aggregate investment during the Great Recession. The model embeds a firm investment problem with long-term non-contingent debt into an otherwise standard New Keynesian environment. I build on the work of Khan, Senga and Thomas (2016) and Ottonello and Winberry (2018), extended in three important dimensions. First, compared to Khan, Senga and Thomas (2016), I introduce nominal rigidities. Second, in contrast to both Khan, Senga and Thomas (2016) and Ottonello and Winberry (2018), I incorporate long-term financing in order to study the effect of debt overhang on investment decisions, and allow for the possibility of having a binding zero-lower-bound constraint. These are important dimensions for understanding the role of financial frictions in the Great Recession. Third, the model accounts for the possibility of having a binding zero-lower-bound constraint for the conduct of monetary policy, which was an important dimension of the Great Recession.

Time is discrete and infinite. The economy is inhabited by six types of agents: (1) a continuum of identical households, (2) a representative final goods producer, (3) a continuum of monopolistically competitive retailers, (4) infinitely-many perfectly competitive producers that are heterogeneous in their individual productivity, capital and debt positions, (5) a continuum of risk-neutral financial intermediaries operating in perfect competition, and (6) a central bank. The model considers three sources of aggregate fluctuations in a perfect foresight environment: TFP shocks, monetary shocks, and financial shocks.

Households own the firms and optimally choose their labor supply, consumption, and savings. To choose their level of savings, they buy a risk-free asset offered by the financial sector. Producers decide their optimal scale of production by choosing their demand for labor and capital to produce a single homogeneous good. These firms are also able to issue defaultable nominal long-term debt that is purchased by financial intermediaries.

Retailers buy the homogeneous good from producers and differentiate it. Since they are monopolistically-competitive, they choose the nominal price for the retail good they produce. However, in doing so, retailers are subject to price adjustment costs. Final goods producers combine all these differentiated retail goods by using a constant return to scale production function. These firms sell their homogeneous good to households and firms, as consumption and investment goods, respectively. Finally, the central bank follows a Taylor rule to determine the policy interest rate while, at the same time, being subject to a zero-lower-bound constraint. I present a detailed description of the model below.

3.1 Producers

Producers differ in their capital, k, real debt outstanding, b, and individual productivity, ε, and produce a homogeneous good by combining capital and labor, n, according to a decreasing returns-to-scale technology; $y = z\varepsilon k^{\alpha} n^{\nu}$, where $\alpha, \nu \in (0,1)$ and $\alpha + \nu < 1$. Here, z represents aggregate total factor productivity, while ε denotes an idiosyncratic productivity shock. I assume that the firm-specific shock $\varepsilon \in \mathbf{E} = \{\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_{N_\varepsilon}\}$ follows a Markov chain with transition probability $\Pr(\varepsilon' = \varepsilon_j | \ \varepsilon = \varepsilon_i) = \pi^{\varepsilon}_{i,j} \geq 0$ and $\sum_{j=1}^{N_\varepsilon} \pi^{\varepsilon}_{i,j} = 1$ for every $i = 1, 2, \ldots, N_\varepsilon$. These firms sell their output to retail firms at price p^{w}_{t}.

At the beginning of every period, a firm is identified by its capital stock, $k \in \mathbf{K} \in \mathbb{R}_{+}$, outstanding debt, $b \in \mathbf{B} \in \mathbb{R}$, and individual productivity, $\varepsilon \in \mathbf{E}$. Therefore, we have a distribution of firms $\mu_t\left(k, b, \varepsilon\right)$ over the support determined by the product space $\mathbf{K} \times \mathbf{B} \times \mathbf{E}$. This implies that the aggregate state will be a combination of this distribution as well as the aggregate shocks to the economy. For notational simplicity, I subsume the aggregate state composed by the distribution of production firms, the aggregate nominal price level, and the three aggregate disturbances in the time subscript.

Firms must choose their demand for labor and next's period capital (investment). I assume no capital adjustment frictions. To finance their investment expenditure, firms can issue nominal long-term, non-contingent defaultable bonds at the price $q_t\left(\varepsilon, k', b'\right)$. I assume that these bonds last forever (this means they are consols) and follow a repayment schedule that declines geometrically, so that, in each period any particular firm repays a fraction γ_L of its principal. Hence, for a given γ_L, the average debt maturity is $1/\gamma_L$. Note that, despite γ_L being common across firms, they will generally differ in the amount of debt that is maturing at any given period. In addition to the amortization of the principal, the firm also pays a fixed coupon κ_L per unit of outstanding debt. If, given the characteristics of the issuing firm, its debt is risk-free, its price is the risk-free discount factor $\overline{q}_{L,t}$. Importantly, while firms are operated by their shareholders, creditors are first in the pecking order when a firm defaults. This arrangement is at the heart of the debt overhang problem. In addition to issuing debt, firms can also accumulate savings. They do so using a one-period risk-free bond with price $\overline{q}_{1,t}$.[5] However, due to the cost associated with long-term bonds, firms never choose to hold both savings and debt at the same time. Therefore, we can denote negative values of debt as financial savings, $b_S = -\min\{b, 0\} \in \mathbb{R}_+$, and similarly, outstanding debt can be denoted by $b_L = \max\{b, 0\} \in \mathbb{R}_+$.

At the beginning of each period, firms decide whether to operate or exit the economy. If they choose to operate, they must pay a fixed cost ξ_0 and fulfill their debt obligations. Firms may avoid paying the fixed operating cost by exiting and defaulting on their debt. In this case, a defaulting firm (i.e., its shareholders) walks away with a value of 0, while creditors seize the firm's assets. Define cash-on-hand for an operating firm of type (ε, k, b) as

$$m_t(\varepsilon, k, b) = \Pi_t(\varepsilon, k) + \frac{1}{1+\pi_t}\left[b_S - (\kappa_L + \gamma_L)\, b_L\right] + (1-\delta)\, k - \xi_0 - \xi_{m,t}(\varepsilon) \tag{2}$$

where $\Pi_t(\varepsilon, k) = \max_n (1-\nu)\, p_t^w y_t(\varepsilon, k, n) - w_t n$ are flow profits, $1 + \pi_t = P_t / P_{t-1}$ is the inflation rate, P_t is the nominal price level, w_t is the equilibrium wage rate and $\delta \in (0, 1)$ the depreciation rate of capital. Recall that either $b_S > 0$ or $b_L > 0$, but not both. The second term in brackets in Equation (2) represents debt obligations: a firm entering the period with inflation-adjusted debt $b_L / (1 + \pi_t)$ must repay a fraction γ_L of it. In addition, it must also pay a coupon κ_L per unit of debt. The last term, $\xi_{m,t}(\varepsilon)$, is an aggregate financial shock that affects firms' balance sheets and makes them more sensitive to financial frictions. It is modeled as proportional to the realization of the idiosyncratic productivity level, so that more productive firms experience a larger disturbance than low productivity firms. This dependence on ε implies that, as firms face uncertainty about their individual productivity, financial shocks increase risk and volatility among producers.

Each firm also faces an exogenous exit shock. The probability of being exogenously forced to exit is ϑ_d. Operating firms receiving this shock sell all their capital, take no new debt, and repay their creditors. If funds are sufficient, the firm walks away with whatever is left and distributes it among its shareholders, otherwise the firm exits with a value to shareholders of 0.

[5] The prices of the one-period bond used to save, $\overline{q}_{1,t}$, and the long-maturity debt, $\overline{q}_{L,t}$, are in general different, as the latter include the expected discounted sum of future payoffs associated to the coupon and principal.

A firm that knows it will continue into the next period then faces the decision of choosing the capital level to operate in the next period, k', and the debt level (or savings), b', to take. When doing so, firms face a non-negativity restriction on their dividends that prevent them from raising funds by issuing equity. Define the set of feasible choices of (k', b') as:

$$\Phi_t(\varepsilon, k, b) = \left\{ \left(k', b'\right) \in \mathbb{R}_+ \times \mathbb{R} | D_t\left(\varepsilon, k, b, k', b'\right) \geq 0 \right\} \tag{3}$$

where dividends are given by:

$$D_t\left(\varepsilon, k, b, k', b'\right) = m(\varepsilon, k, b) - k' - \bar{q}_{1,t} b'_S + q_t\left(\varepsilon, k', b'\right) \ell \tag{4}$$

and debt issuance $\ell \in \mathbb{R}$ is:

$$\ell = b'_L - (1 - \gamma_L) \frac{b_L}{1 + \pi} \tag{5}$$

After firms exit the economy, either endogenously by defaulting or exogenously following an exit shock, a constant fraction μ_0 of potential entrants is born.[6][7] These firms start with a fixed individual productivity level ε_0, debt level b_0 and a predetermined stock of capital that is drawn from a uniform distribution. At the beginning of the next period, these potential firms must choose whether to enter the economy and become an operating firm or not. Their entry decision depends on their initial conditions and the state of the economy. Highly leveraged potential entrants may choose not to enter if interest rates are high, for example.

3.1.1 Firms Values

At the beginning of each period, a firm faces the decision to operate (and thus repay its debt obligations), or to exit the economy. Let $v_t^0(\varepsilon, k, b; s, \mu)$ denote the beginning of the period value of a firm with individual productivity ε , capital k, and debt b. If $\Phi_t(\varepsilon, k, b) = \emptyset$, the firm is unable to operate and repay its debt while paying non-negative dividends. Such firms will exit the economy immediately with a value of 0. Otherwise, the firm may operate in the current period in which it has $v_t^1(\varepsilon, k, b)$. There-

[6]Given that the model studies large recessions, assuming that the mass of potential entrants μ_0 is constant is important in capturing the increased default rates when the economy experience negative shocks.

[7]I assume that potential entrants have a common debt level b_0 and common productivity level equal to the median value for ε. The capital stock is drawn from an uniform distribution with support $[0, k_0]$. The values used for these parameters are discussed in the calibration.

fore,

$$v_t^0(\varepsilon,k,b)=\max\left\{v_t^1(\varepsilon,k,b),0\right\} \tag{6}$$

Equation (6) implicitly defines a threshold for the idiosyncratic productivity level, $\bar{\varepsilon}_t(k,b)$, solving $v_t^1(\bar{\varepsilon},k,b)=0$. If $\varepsilon\leq\bar{\varepsilon}_t(k,b)$, the firm will default on its debt and exit the economy, otherwise, the firm will repay its debt, pay the operating cost, and produce.

Firms that choose to continue, before producing, learn if they will be exogenously forced to exit at the end of the period. Firms hit with this shock are then forced to repay all their outstanding debt, and distribute any additional profits to their shareholders. Therefore, the ex-ante value of operating is:

$$v_t^1(\varepsilon,k,b)=(1-\vartheta_d)\,v_t^2(\varepsilon,k,b)+\vartheta_d\left[m(\varepsilon,k,b)-(1-\gamma_L)\,\bar{q}_{L,t}\left(\frac{1}{1+\pi_t}\right)b_L\right] \tag{7}$$

where $v_t^2(\varepsilon,k,b)$ is the continuation value of a firm that does not experience an exit shock. This continuation value represents the value of choosing the optimal levels of debt and capital $(k',b')\in\Phi(\varepsilon,k,b)$ given the aggregate state of the economy. Therefore, v_t^2 solves:

$$v_t^2(\varepsilon_i,k,b)=\max_{(k',b')\in\Phi_t(\varepsilon_i,k,b)}\left[D_t\left(\varepsilon_i,k,b,k',b'\right)+E_t\Lambda_{t,t+1}\sum_{j=1}^{N_\varepsilon}\pi_{i,j}^{\varepsilon}v_{t+1}^0\left(\varepsilon_j,k',b'\right)\right] \tag{8}$$

where $\Lambda_{t,t+1}$ is the stochastic discount factor. The solution to this problem is characterized by decision rules for capital $k'=g_{k,t}(\varepsilon,k,b)$, and debt $b'=g_{b,t}(\varepsilon,k,b)$.

In summary, producing firms produce a single homogeneous good. Entry is endogenous, and exit may be also endogenous or follow a shock. There is heterogeneity across these producing firms over three dimensions: productivity, capital, and debt holdings. These three dimensions influence the firms' choices of capital and debt for next period.

3.1.2 Debt Pricing

Let $\mathbb{1}_{R,t}(\varepsilon',k',b')$ be an indicator function for a firm entering next period with idiosyncratic productivity ε', capital stock k', and real debt b', for a given aggregate state of the economy in period t. This indicator function takes the value of 1 if that firm repays the fraction of its debt due next period, that is, when $\varepsilon'\geq\bar{\varepsilon}_{t+1}(k',b')$, and 0 otherwise. Since financial intermediaries are risk-neutral and perfectly competitive, the price of debt is such that the cost of making the loan equals the expected discounted return to the lender.

Recall that producers can issue long-term debt with a geometric repayment schedule that involves repaying a fraction γ_L of the principal, and a real coupon κ_L, per unit of outstanding debt. If the firm is forced to exit, financial intermediaries may receive payments up to total value of the remaining debt. In the case of endogenous default, the creditors seize a fraction $\rho \in [0,1]$ of the non-depreciated capital. The zero-profit condition for financial intermediaries implies that firms issuing debt face a discount price given by

$$\begin{aligned} q_t\left(\varepsilon_i, k', b'\right) b' = E_t \Lambda_{t,t+1} \sum_{j=1}^{N_\varepsilon} \pi^{\varepsilon}_{i,j} \Big\{ & \mathbb{1}_{R,t+1}\left(\varepsilon_j, k', b'\right) \\ & \times \left[\left(\kappa_L + \gamma_L\right) \left[\frac{1}{1+\pi_{t+1}}\right] b' + \mathit{\Gamma}_{L,t} + \vartheta_d \max\left\{ \min\left\{ \overline{\mathit{\Gamma}}_{L,t}, m\left(\varepsilon_j, k', b'\right)\right\}, 0\right\}\right] \\ & + \left[1 - \mathbb{1}_{R,t+1}\left(\varepsilon_j, k', b'\right)\right] \rho\left(1-\delta\right) k' \Big\} \end{aligned} \tag{9}$$

where $k'' = g_{k,t+1}\left(\varepsilon_j, k', b'\right)$ and $b'' = g_{b,t+1}\left(\varepsilon_j, k', b'\right)$ are the decision rules for capital and debt next period, and where the variables $\Gamma_{L,t}$ and $\overline{\Gamma}_{L,t}$ are defined as

$$\begin{aligned} \mathit{\Gamma}_{L,t} &= \left(1-\vartheta_d\right)\left(1-\gamma_L\right) q_{t+1}(\varepsilon_j, k'', b'') \left[\frac{1}{1+\pi_{t+1}}\right] b' \\ \overline{\mathit{\Gamma}}_{L,t} &= \left(1-\gamma_L\right) \overline{q}_{L,t+1} \left[\frac{1}{1+\pi_{t+1}}\right] b' \end{aligned}$$

Note that when $b' > 0$ and $b'' < 0$, $q_{t+1}(\varepsilon'_j, k'', b'') = \overline{q}_{L,t+1}$. This is, if the firm chooses to save in the next period, that debt is risk-free, as it involves repurchasing all debt.

The left-hand side of Equation (9) represents the real value of the whole stock of debt outstanding for a firm with current individual productivity ε_i, that chooses capital and debt levels (k', b'). On the right-hand side are two discounted, probability weighted events: repayment or default. If the firm repays, the lender receives the coupon and a fraction of the principal $(\kappa_L + \gamma_L)$ per unit of inflation-adjusted debt. The variable $\Gamma_{L,t}$ captures the value of unmatured debt conditional on the firm not receiving the exit shock. This value takes into account that the firm's creditors hold $(1-\gamma_L)$ of next period value of real its debt. The future value of its outstanding debt depends on next period's decisions. If the borrower is forced to exit, the lenders receive the minimum between that owed to them, $\overline{\Gamma}_{L,t}$, and the borrower's cash on hand. When a firm has enough resources to cover the entirety of its debt in case it is forced to exit next period, that firm's debt is risk-free and hence is valued at the risk-free rate $\overline{q}_{L,t+1}$. In contrast, in case of endogenous default, the lender obtains a fraction ρ of non-depreciated capital.

3.2 Retailers

There is a continuum of mass 1 of ex-ante identical retailers indexed by i.[8] Each retailer produces the differentiated variety $\tilde{y}_{i,t}$ using the linear production function $\tilde{y}_{i,t} = y_{i,t}$, where $y_{i,t}$ is a wholesale good purchased from the production firms by retailer i at price p^w_t. These firms operate in a monopolistically competitive market, so they set the price of their variety, $P_{i,t}$, subject to its demand curve (from final goods producers). When choosing their optimal price, these firms are subject to quadratic adjustment costs:

$$\frac{\psi_p}{2}\left(\frac{P_{i,t}}{P_{i,t-1}} - 1\right)^2 Y_t \tag{10}$$

3.3 Final Goods Producers

The representative firm producing final goods combines the continuum of differentiated goods produced by retailers and then sells a homogeneous good in a perfectly competitive market at price P_t to households (as consumption) and producing firms (as investment). Its production technology is:

$$Y_t = \left[\int_0^1 y_{i,t}^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}} \tag{11}$$

where θ is the elasticity of substitution over varieties of the retail good. These firms maximize profits subject to (11).

[8] Including these retail firms implies that there is an extra layer in how we model production in this economy when compared to New Keynesian models without production heterogeneity. As discussed in Bernanke et al. (1999), including retail firms allows us to incorporate price rigidities in a tractable manner. In presence of heterogeneity and financial frictions, this set up lets us separate the production-investment problem and the price-setting problem in a simple way.

3.4 Households

There is a continuum of identical households that consume, c, and supply labor to producers, n. They discount the future at the rate $\beta \in (0,1)$ and save by means of a nominal risk-free bond that pays the interest rate i_{t-1}. Let a denote real holdings of the risk-free asset. Households also own all firms in the economy. More specifically, they hold shares, s, of each production firm. These shares have a real price $m_{0,t}$, which includes the value of dividends, and an ex-dividend real price $m_{1,t}$. As households also own the retailers, they also receive their profits, denoted by Π_t^r, which are paid in a lump-sum fashion.

Their preferences are summarized by the period utility function $U(c, 1-n)$ and solve the following problem

$$W_t(s,a) = \max_{c,n,s',a'} \left\{ U(c, 1-n) + \beta E_t W_{t+1}(s', a') \right\} \tag{12}$$

subject to their budget constraint, which in real terms is given by:

$$\begin{aligned} c + a' + \int m_{1,t}(\varepsilon', k', b') \, s' \left(d\left[\varepsilon', k', b'\right]\right) \\ \leq w_t n + \left(\frac{1+i_{t-1}}{1+\pi_t}\right) a + \int m_{0,t}(\varepsilon, k, b) \, s\left(d\left[\varepsilon, k, b\right]\right) + \Pi_t^r \end{aligned} \tag{13}$$

3.5 Central Bank

The central bank of this economy sets the short-term nominal interest rate following a Taylor rule and is subject to a zero-lower-bound constraint:

$$1 + i_t = \max\left\{1,\ (1+\bar{i}) \left(\frac{1+\pi_t}{1+\overline{\pi}}\right)^{\phi_\pi} \left(\frac{y_t}{\overline{y}}\right)^{\phi_y} \exp\left(\epsilon_t^i\right)\right\} \tag{14}$$

Here, i_t is the nominal policy rate, $\bar{i}$ is its stationary value, $\overline{\pi}$ is the inflation target, $\overline{y}$ is the steady state level of output, and ϵ_t^i is an i.i.d. shock to the nominal interest rate that satisfies $\epsilon_t^i \sim N\left(0, \sigma_i^2\right)$. The parameters ϕ_π and ϕ_y measure the response of monetary policy to deviations in inflation with respect to its targeted value, and deviations in output with respect to its stationary value, respectively.

3.6 Equilibrium

Definition 1. The competitive equilibrium of this model is a set of functions for values $v_t^0(\varepsilon, k, b)$, $v_t^1(\varepsilon, k, b)$, $v_t^2(\varepsilon, k, b)$, decision rules $k' = g_{k,t}(\varepsilon, k, b)$, $b' = g_{b,t}(\varepsilon, k, b)$, $\bar{\varepsilon}_t(k, b)$, $n(\varepsilon, k, b)$, allocations Y_t, X_t, Ξ_t, Π_t^r, prices p_t^w, w_t, $\bar{q}_{1,t}$, $\bar{q}_{L,t}$, π_t, $q_t(\varepsilon, k', b')$, and a distribution $\mu_t(\varepsilon, k, b)$, such that, given the aggregate shocks $(z_t, \xi_{m,t}, \epsilon_t^i)$:

1. The values $v_t^0(\varepsilon, k, b)$, $v_t^1(\varepsilon, k, b)$, and $v_t^2(\varepsilon, k, b)$, and the decision rules $k' = g_{k,t}(\varepsilon, k, b)$, $b' = g_{b,t}(\varepsilon, k, b)$, $\bar{\varepsilon}_t(k, b)$, and $n(\varepsilon, k, b)$ solve the production firm problem described by (2) - (8), given prices p_t^w, w_t, $\bar{q}_{1,t}$, $\bar{q}_{L,t}$, π_t, and $q_t(\varepsilon, k', b')$.

2. Financial intermediaries price debt priced according to Equation (9).

3. Retailers solve their price optimization problem and final goods producers determine the optimal demand for varieties of the retail good, taking prices as given.

4. Households solve their problem in (12) and (13).

5. The central bank sets nominal short-term interest rates according to (14).

6. The distribution of firms is consistent with the production firms' and potential entrants' decision rules:

$$\mu_{t+1}(\varepsilon', k', b') = (1 - \vartheta_d) \sum_{i=1}^{N_\varepsilon} \int_{\{(g_{k,t}(\varepsilon_i, k, b), \tilde{g}_{b,t}(\varepsilon_i, k, b)) = (k', b')\}} \mathbb{1}\{\varepsilon_i \geq \varepsilon_t(k, b)\} \mu([dk \times db])$$
$$+ \int_{\{(k_0, b_0) = (k', b')\}} \mathbb{1}\{\varepsilon_0 \geq \varepsilon_t(k, b)\} \mu_0([dk_0 \times db_0]) \tag{15}$$

   where $\tilde{g}_{b,t}(\varepsilon, k, b) = g_{b,t}(\varepsilon, k, b) \,/\, (1 + \pi_{t+1})$.

7. Markets clear: markets for goods, labor and assets clear. Denoting aggregate investment by X_t, and total operating costs for production firms by Ξ_t, the aggregate resource constraint holds:

$$Y_t = C_t + X_t + \Xi_t + \frac{\psi_p}{2} \pi_t^2 Y_t \tag{16}$$

Households and Risk-Free Rates

Imposing market clearing, households' labor-leisure condition and the Euler equation for bonds pin down the equilibrium wage and the stochastic discount factor:

$$\lambda_t = D_1 U\left(C, 1-N\right) \tag{17}$$

$$w_t = D_2 U\left(C, 1-N\right) / \lambda_t \tag{18}$$

$$\Lambda_{t,t+1} = \beta \lambda_{t+1} / \lambda_t \tag{19}$$

The Euler equation for bonds also implies that the risk-less discount factor for the one-period bond is $\bar{q}_{1,t} = E_t \Lambda_{t,t+1} / \left(1 + \pi_{t+1}\right)$. Finally, considering a risk-less bond on the debt pricing equation (9) yields the following risk-free discount factor for long-term debt:

$$\bar{q}_{L,t} = E_t \Lambda_{t,t+1} \left(\frac{1}{1+\pi_{t+1}}\right) \left[\left(\kappa_L + \gamma_L\right) + \left(1 - \gamma_L\right) \bar{q}_{L,t+1}\right] \tag{20}$$

This means that the current price of risk-less long-term debt is equal to the the expected discounted sum of payments next period (coupon and a fraction of principal) and the next period price of the remaining outstanding fraction of the bond.

Retailers and Final Goods Producers

The solution to the final good producers' problem is a demand function for each variety $i \in [0, 1]$:

$$y_{i,t} = \left(\frac{P_{i,t}}{P_t}\right)^{-\theta} Y_t \tag{21}$$

where $P_{i,t}$ is the price of variety i, and

$$P_t = \left(\int_0^1 P_{i,t}^{1-\theta} di\right)^{\frac{1}{1-\theta}} \tag{22}$$

is the price index. Note that the price index of the retail goods is equal to the price of the final good, as final goods producers set their price equal to their marginal cost.

Taking the demand function in (21) as given, and noting that retailers are symmetric, the solution to their problem yields the following New Keynesian Phillips curve:

$$\pi_t (1 + \pi_t) = \frac{1}{\psi_p} \left[\theta p_t^w - (\theta - 1)\right] + E_t \Lambda_{t,t+1} \pi_{t+1} (1 + \pi_{t+1}) \frac{Y_{t+1}}{Y_t} \tag{23}$$

Producers

Given that production firms are owned by households, their marginal valuation of retained earnings is consistent with the marginal utility of consumption, λ. Firms that are not sensitive to financial conditions, having outgrown financial frictions, have a marginal valuation of internal funds that is equal to λ, and hence are indifferent between financial savings and dividends. To resolve this indeterminacy, I assume that these firms implement a zero-dividend policy, so that their borrowing is exactly determined by their budget constraint, while their optimal capital decision is to set $k' = k^* (\varepsilon)$, the frictionless level of capital.[9]

Firms that will remain in the economy with probability one (i.e. because their default risk is 0) but that have not outgrown financial constraints, have a valuation of retained earnings that exceeds the marginal utility of consumption. Therefore, for these firms it is optimal to implement a zero-dividend policy while setting $k' = k^* (\varepsilon)$ and b' as implied by their budget constraint. Conversely, firms with high risk of default, knowing that it is likely for them to exit the economy in the near future, may not find it optimal to implement a policy that sets $D = 0$. This subset of firms solve the problem in (6) - (8).

Conditional on operating and not receiving the exit shock, a firm could be either safe or risky. Safe firms can either be savers or risk-free borrowers. Given that in both cases their default risk is 0, they will implement the zero-dividend policy discussed above. If a safe firm chooses to save, it faces $\overline{q}_{1,t}$ and sets $b' \leq 0$; if a safe firms is a borrower, it faces $\overline{q}_{L,t}$ and sets $b' > 0$. Safe firms have enough internal resources to implement a capital policy which entails setting k' equal to the frictionless level of capital $k_t^* (\varepsilon)$, while guaranteeing that if forced to exit, they can repay any debt in full next period. This means that a borrower is considered to be risk-free if

$$m'_{t+1} \left(\varepsilon_j, k^*, \tilde{b}' (k^*; \varepsilon_i, k, b)\right) \geq (1 - \gamma_L) \overline{q}_{L,t+1} \tilde{b}' (k^*; \varepsilon_i, k, b) \tag{24}$$

[9] The frictionless level of capital, $k_t^* (\varepsilon)$, solves

$$k_t^* (\varepsilon_i) = \underset{k'}{\operatorname{argmax}} \left\{ -k' + \Lambda_{t,t+1} \sum_{j=1}^{N_\varepsilon} \pi_{i,j}^{\varepsilon} \left[\Pi_{t+1} (\varepsilon_j, k') + (1 - \delta) k'\right] \right\}$$

for all j such that $\pi^{\varepsilon}_{i,j} > 0$ and for any possible aggregate state, and where

$$\tilde{b}'\left(k^*;\varepsilon,k,b\right) = \frac{k^*\left(\varepsilon\right) - m\left(\varepsilon,k,b\right)}{\overline{q}_{L,t}} + \left(1-\gamma_L\right)b_L > 0$$

is the borrowing implied by setting $D = 0$ and k' equal to its frictionless level.

If a firm does not satisfy condition (24), it is considered a risky borrower. Risky firms face a positive risk premium, so that $q_t\left(\varepsilon,k',b'\right) < \overline{q}_{L,t}$. Such firms, having a higher shadow value of internal funds, will not pay dividends. Risky firms must solve (6) - (8) subject to (9) and, in general, will not adopt the frictionless capital stock.

4 Calibration and Stationary Equilibrium

In the model economy, one period represents a year. The calibration is such that the stationary equilibrium of the model replicates some aggregate and firm-level moments when the the economy is absent of aggregate uncertainty. The real interest rate is set to 4 percent and the annual inflation rate is fixed to 2 percent. The depreciation rate is set to 7.68 percent, consistent with the average between 1947 and 2016 for current-cost depreciation in the Fixed Asset Tables from NIPA. The parameters of the production function, α and ν are set to obtain a capital to output ratio of 2.3 and a labor share of output of 0.6. The scale parameter that measure the preference for leisure, φ is used to replicate that households work one-third of their unit of available time.

The stochastic process for idiosyncratic productivity is obtained after approximating the following autoregressive process for ε: $\log\varepsilon' = \rho_\varepsilon \log\varepsilon + \eta'_\varepsilon$, where η_ε is i.i.d. distributed $N\left(0,\sigma^2_\varepsilon\right)$. The approximation uses the Tauchen method for $N_\varepsilon = 15$ grid points. The characteristics of potential entrants are fixed so that they have individual productivity $\varepsilon = \varepsilon_7$ and initial debt $b = 0.08$, while their capital is drawn from a uniform distribution with support on $\left[0,\overline{k}\right]$. The calibration also targets the average debt to book asset ratio. Using a panel constructed with the micro data from the Quarterly Financial Reports, Crouzet and Mehrotra (2018) document that the average gross leverage at the firm-level is 0.35. Dinlersoz et al. (2018), using a dataset that matches firm-level data from the LBD database with balance sheet data for privately held and publicly listed firms, find that the average firm-level gross leverage is 0.46 and 0.56 for private and public firms, respectively. These estimates of leverage for U.S. firms are higher than the value of 0.27 reported in Table 1. I chose to target this latter value despite it may under-estimate the effect of financial frictions and long-term debt, so that the other moments of the model can be directly comparable to the sample used in Section 2.

Annual Compustat data, despite having information about debt maturity structure, lumps all debt with maturity longer than, or equal to, five years together. Guedes and Opler (1996), using a database with corporate debt issues between 1982 and 1993, document that the average and median maturity are 12 and 10 years, respectively. They also find that the average Macaulay duration (computed by weighting the average maturity of cashflows) of corporate debt issues is 6 years. Using data from the Mergent Fixed Income Securities Database (FISD), a database that reports issue details on corporate debt issues (among others), I find that the mean and median maturity of corporate debt at the offering date for the period 1984-2018 is 10.1 and 8.2 years, respectively.[10] I therefore set the value for the parameter γ_L to 0.2, which implies an average maturity of 5 years. This value is conservative in measuring the incidence of long-term financing, but it is consistent with the fact that, on average, firms have 20 percent of their debt maturing each year, as reported in Section 2. It also accounts for the fact that the durations obtained from Guedes and Opler (1996) and the FISD database are computed for public corporate debt issues, which tend to have longer maturity. The coupon rate, κ_L, is chosen to imply a price of risk-free debt equal to 1 in steady state, as in Gomes et al. (2016). The capital recovery rate is set to 45.7 percent, according to what the Moody's Default Risk Service reports to be the average of recovery rate for the period 1978-2010.

The parameters $\left(\xi_0, \rho_\varepsilon, \sigma_\varepsilon, \vartheta_d, \bar{k}\right)$ are jointly set to replicate (i) a default rate of 2%, (ii) an exit rate of 10%, (iii) a debt to capital ratio of 0.266, (iv) an average employment of entrants relative to incumbents of 10%, (v) an average investment rate across continuing firms of 0.122, and (vi) a standard deviation is those investment rate of 0.337. The elasticity of substitution between varieties of the retail good is set to 11, so that the steady state markup is 10 percent. As in Kaplan et al. (2018), the adjustment cost parameter, ψ_p, is fixed to 100 to imply a slope of 0.1 in the Phillips curve. Finally, the response of monetary policy to deviations in the inflation rate, ϕ_π, is set to 1.5.

Using this calibration, Figure 5 presents the distribution of production firms over capital and leverage as firms enter any given period in the stationary equilibrium. Capital increases from left to right, and leverage raises front to back along the left axis. Negative

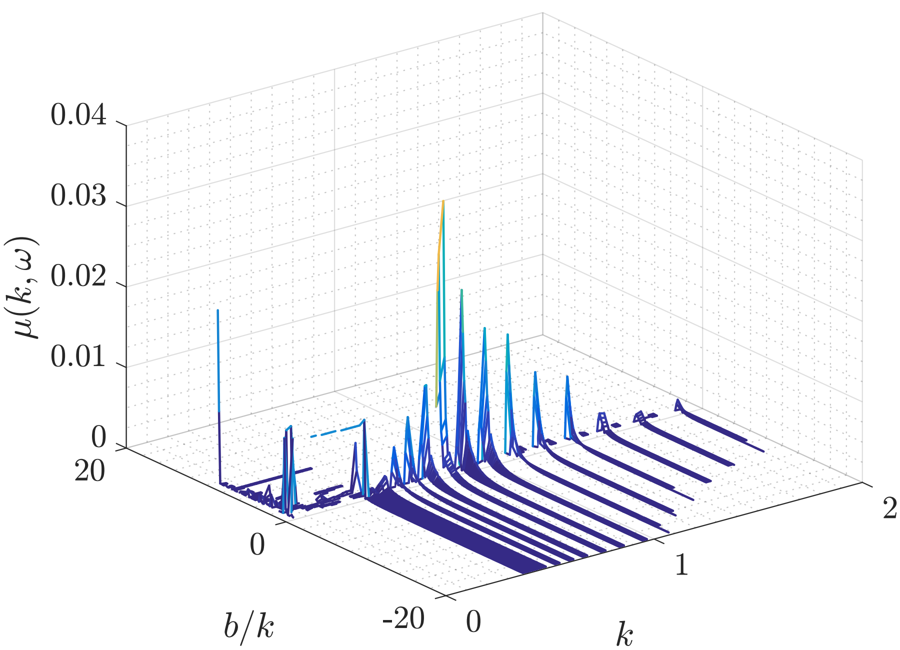
[10] I use the Mergent FISD data from 1984 to 2018 and apply the same filters used with Compustat data in Section 2. This means that utilities, financial institutions, public administration entities and foreign governments are excluded from the sample. I also exclude issues not denominated in U.S. dollars, convertible bonds, asset-backed bonds and preferred bonds, as well as issues of firms that are not incorporated in the U.S.

levels of leverage represent savings relative to capital. Safe firms are directly identifiable. They are along each one of the 15 (one per realization of ε) lines in which capital remains constant. Each one of these lines contains firms that are implementing the efficient level of capital associated to their idiosyncratic productivity. Among those safe firms there is sizable heterogeneity, as we have move from safe borrowers in the regions with higher concentration, to firms with large amounts of savings. Right behind each one of these lines there are firms that are transitioning from facing a positive default premia to safe borrowing. Those firms, however, cannot yet implement their frictionless level of capital.

Near the right side of the figure, we have a concentration of firms that can be divided into two groups. The first group is comprised by entrants and by asset poor firms holding low levels of capital and high levels of debt, with leverage levels between 1 and 3. These firms, despite being in a very vulnerable position and facing high credit spreads (see Figure 6), are not guaranteed to exit this period or the next as the long maturity of financing eases their financial burden compared to a one-period debt model in which all debt is due. The second group of firms are also capital poor, but their leverage levels are so high that they will exit without producing. They arrived in to this region after implementing a risky strategy in which they were betting on a small probability of drawing a high level of productivity, while holding previously issued debt.

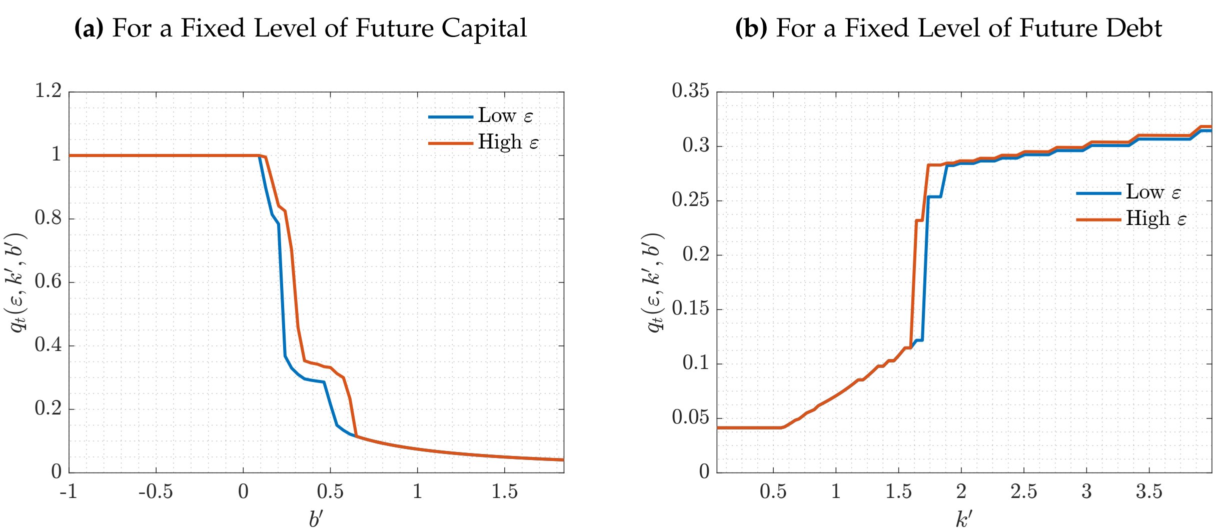
The endogenous determination of an schedule for the price of debt is at the core of the model. In Equation (9), the price of debt increases in capital and idiosyncratic productivity, and decreases in debt. Equivalently, the more leverage (because of increased debt or reduced capital) the lower the price of debt. Figure 6 depicts this result. Figure 6(a) considers the case of high productivity and a low productivity firms for which the choice of capital, k', is fixed. The price of debt for these firms (at which all their debt is valued, including new issues) falls as b' increases to account for the increased default risk. However, having higher productivity counteracts, at least partially, part of the increased risk, as more productive firms have a higher likelihood of drawing a high productivity level next period. Figure 6(b) examines the complementary case. For a fixed level of next period debt, firms choosing higher levels of capital receive better lending terms as there are more assets backing that debt level.

Figure 5: Distribution of Production Firms



Notes: Distribution of production firms over capital k, and leverage ω, where leverage is the ratio of outstanding debt, b, to capital. Negative leverage represents the ratio of savings to capital.

Figure 6: Price of Debt



Notes: Panel (a) shows the price of debt for a low productivity and high productivity firm choosing the same level of capital as the firms move along the debt axis. Panel (b) does the same but for firms choosing the same level of debt, as the firms move along the capital axis.

5 Understanding the Great Recession

I now analyze the importance of each one of the model mechanisms to explain the dynamics of investment during the Great Recession. Focusing on perfect foresight responses, in Subsection 5.1 I first show the implications arising from having long-term financing and nominal debt in a partial equilibrium context. Then, Subsection 5.2 considers the price effects in the transmission of real and financial shocks, and evaluates in what extent the model captures the unusual investment dynamics observed during the 2007 episode.

5.1 Dynamics Under Fixed Prices

To have a first approximation to the relevance of accounting for firms' long-term debt positions, I simulate a large panel of firms using the solution of the model presented above at the stationary equilibrium. Table 4 presents the correlation of several model variables for two different values of average debt maturity: five years, as in the benchmark calibration and one year, as in a model with short-term debt. The importance of idiosyncratic productivity and capital in determining firms' choices falls when including multi-period financing. For example, the correlation between individual productivity and investment rates falls from 0.43 to 0.35 when moving from a model of short-term debt to one of long-term debt. Conversely, the incidence of debt is larger with multi-period debt. The correlation of leverage and output is 0.22 in the model with long-term debt and nearly half for the case short-term debt. The relationship between investment rates and leverage is also stronger, with a correlation 3.5 points higher (in absolute value) in the model with multi-period debt.

What does this result imply for the transmission of real and financial shocks? To start addressing this question, I begin with a series of fixed prices experiments designed to gauge the relevance of accounting for long-maturity debt to explain the Great Recession. Figures 7 and 8 summarize the perfect foresight partial equilibrium response of the multi-period-debt economy to a persistent shock to the total factor productivity and a persistent negative balance sheet shock. For each shock, I consider two different cases of average debt maturity. The balance sheet shock increases the financial costs of operation, $\xi_{m,t}(\varepsilon)$, in 5 percent of the value of the efficient level of output.[11] These responses assume

[11] The efficient output level, $y^*(\varepsilon)$, is obtained by a firm that is not subject to financial frictions and that, hence, can implement the frictionless level of capital, $k^*(\varepsilon)$.

Table 4: Correlations Between Firm-Level Variables: Multi-Period vs One-Period Debt

Correlation		Average maturity 5 years	1 year
Productivity and debt issuance	$\rho(\varepsilon, \ell)$	0.792	0.839
Productivity and investment rate	$\rho(\varepsilon, x/k)$	0.351	0.430
Capital stock and issuance	$\rho(k, \ell)$	-0.252	-0.283
Leverage and output	$\rho(\omega, y)$	0.222	0.126
Leverage and debt issuance	$\rho(\omega, \ell)$	0.524	0.847
Leverage and investment rate	$\rho(\omega, x/k)$	-0.175	-0.14

Notes: Firm-level correlations obtained from a panel simulation of the model under the benchmark calibration. Firms with less than 10 years of data are not taken into account. Idiosyncratic productivity is denoted by ε, capital stock by k, investment rate by x/k, debt issuance by ℓ, and leverage by $\omega = b/k$, where b is outstanding debt.

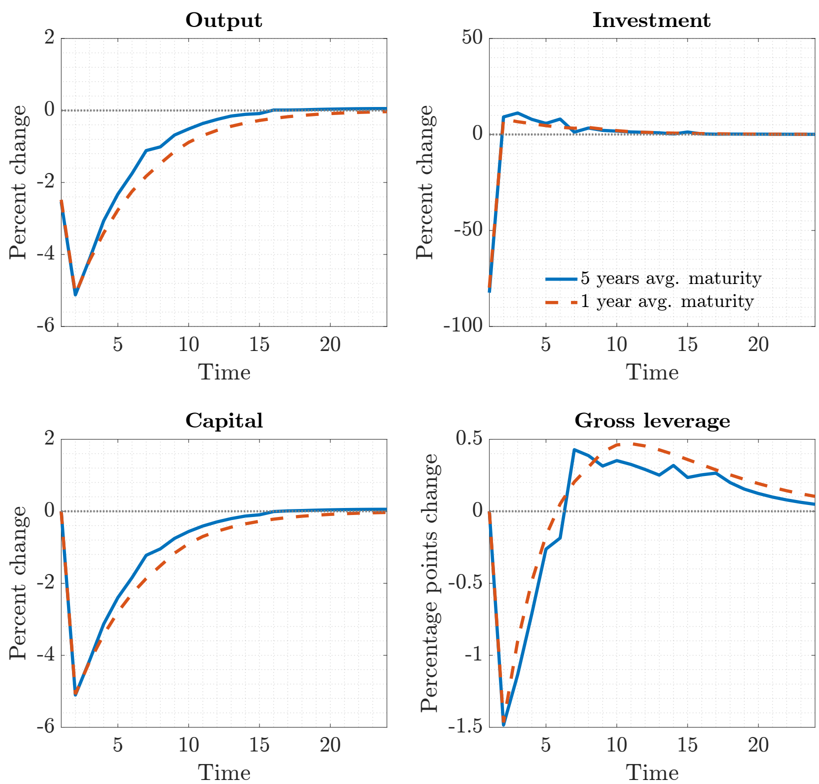
that prices and the short-term policy rate are fixed while solving the firm problem in (6) - (8) subject to the debt pricing schedule (9).

A productivity shock generates a large contraction in output, which then is followed by a mild recovery, as shown in Figure 7. Notably, despite investment falls sharply on impact because of the reduced marginal product of capital, it recovers one period later without showing major differences between a model in which the average maturity of debt is 5 years versus one in which is 1 year.

When the average maturity is 5 years, a 1 percent TFP shock only raises the default rate 0.2 percentage points. The small impact of negative technology shocks in increasing default risk explains the lack of an amplification mechanism, as the role of financial frictions is not determinant in the transmission of the shock. This implies that firms still have relatively unchanged access to long-term financing issued in a way that allows them to smooth the repayment of their obligations. These credit conditions result in borrowing increasing 6 periods after the impact date of the TFP shock, as shown in the increased leverage in the lower right panel.

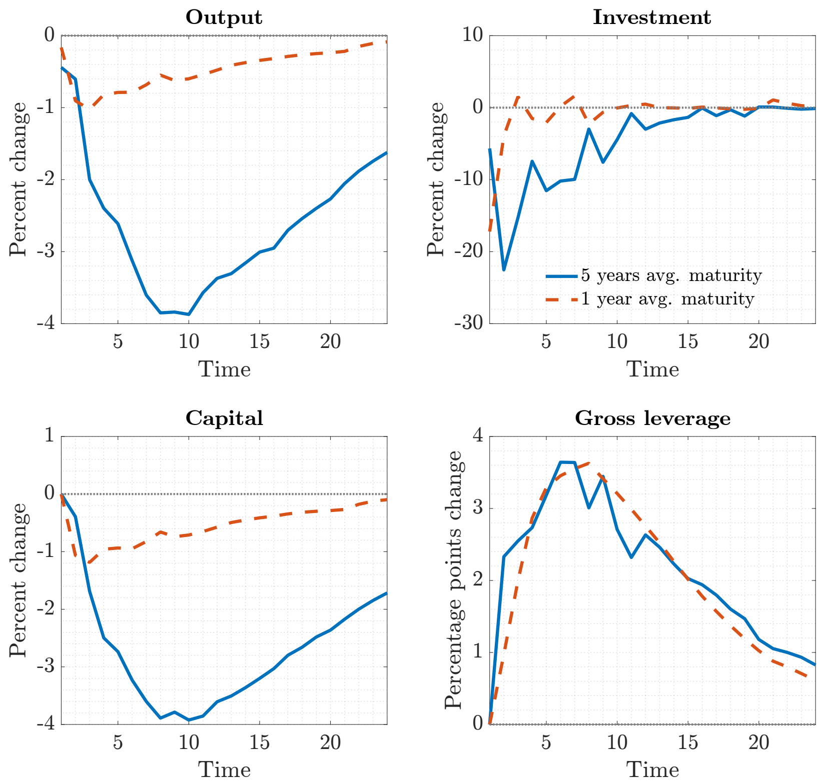
Balance sheet shocks have strong and persistent effects. Figure 8 depicts the partial equilibrium response of the model to a 5-percent persistent financial shock. For safe firms, the lower cash levels generate a need for external finance. Hence, these firms reduce their financial savings while increasing their borrowing. Risky firms, on the other hand, face a steeper loan rate schedule as the default rate raises more than 1.5 percentage points and remains high for several periods. The combination of incumbent firms leaving the economy, a contraction of 6 percentage points in the entry rate, and the

Figure 7: Partial Equilibrium Response to a Technology Shock



Notes: Response to a 1 percent technology shock. The persistence of the shock is set to ρ_z. Responses are in percentage deviations with respect to the stationary equilibrium, while prices are kept constant.

Figure 8: Partial Equilibrium Response to a Balance Sheet Shock



Notes: Response to a balance sheet shock with size equals to 5 percent of $y^* (\varepsilon)$. The persistence of the shock is set to 0.9. Responses are in percentage deviations with respect to the stationary equilibrium, while prices are kept constant.

more indebted safe firms precipitates a strong and prolonged recession.

Debt maturity exacerbates the magnitude of recessions driven by financial shocks, as well as their long-lasting effects. The recession is four times deeper in the case on long-maturity debt. Investment falls 23 percentage points one period after the impact date when the average debt maturity is 5 years (top right panel). In contrast, when debt is short-term, investment falls 17 percentage points on impact and, importantly, recovers rapidly, so that we have investment fluctuating around its stationary level 3 periods after the balance sheet shock hits the economy. When debt is issued with a five-year average maturity, investment converges back to its steady-state value after more than 15 periods, so that the half-life of a financial shock increases three-fold when compared to the short-term debt economy. Such a sluggish recovery of investment causes persistent dynamics in capital and output, variables that do not reach their trough until after 10 periods. These differences between the two models are explained by the incidence of debt overhang episodes. The longer the maturity of debt, increases in the leverage ratio (bottom right panel) are more persistent and have larger effects on investment. This occurs because the debt issued in a given period lasts longer and, hence, the compounded probability of future defaults hinders investment decisions by making shareholders more cautious when undertaking new investment projects.

Another dimension of the Great Recession was the presence of lower inflation rates.[12] Although inflation was in negative territory for about a year (from December 2008 to October 2009), it remained low during the crisis, while some were advocating for the potential benefits of having higher levels of inflation. If the Federal Reserve had been able to keep lowering the short-term nominal rate, there would have been more room to have inflationary pressures. Higher inflation rates tend to alleviate the financial burden that arises from nominal debt, as the real value of such obligations falls.

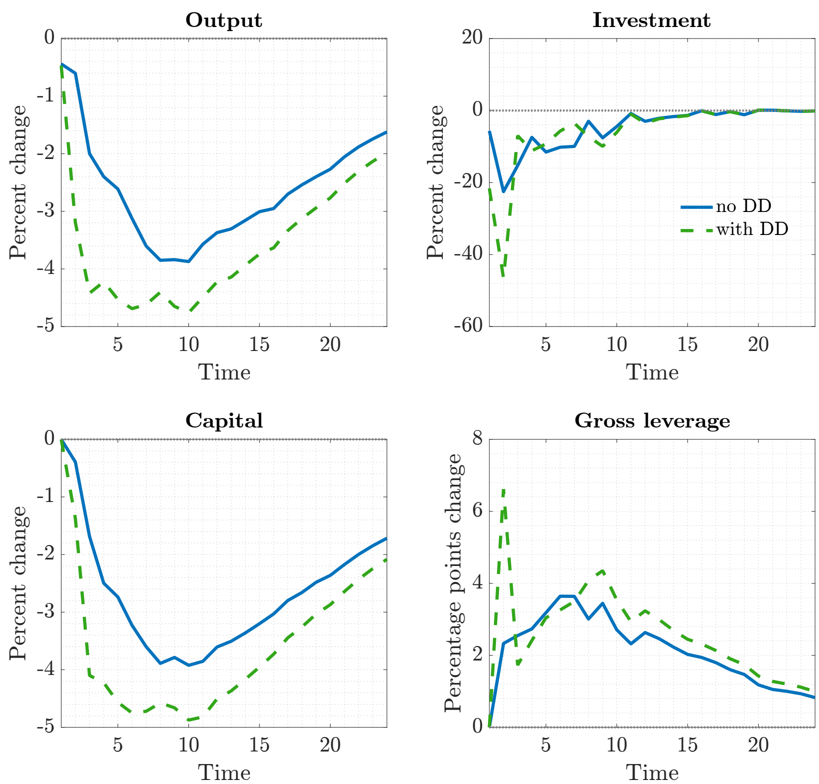
Debt deflation amplifies the effect of financial shocks. Figure 9 presents the response of the economy to a balance sheet shock (as in Figure 8) paired with an exogenous drop of 1 percentage points in inflation during 8 periods. This experiment, represented by the dashed green lines, captures the existence of debt deflation during a recession. The figure also presents an exercise in which inflation remains unchanged (solid blue lines). In both cases, the average maturity of debt is set to 5 years. As the figure shows, when accounting for the possibility of debt deflation during a recession, financial shocks are amplified without affecting much the persistence in the response. This follows the intuition discussed above: the larger the contraction in the price level (with respect to what was expected), the higher the relative values of debt and the stronger the debt overhang problems.

5.2 General Equilibrium Dynamics

Having examined the transmission mechanism implied by each one of the key ingredients of the model in isolation, I now discuss the general equilibrium responses of the model to real and financial shocks. Figure 10 presets the response of the economy to a 2 percent balance sheet shock for two different average maturity levels. Under the benchmark calibration with five-year average maturity, the shock is assumed to be large enough on impact to generate a recession with a drop in output similar to the one

[12] Although the Great Recession was not characterized as a period of large negative inflation rates, inflation experienced modest and protracted declines. Del Negro et al. (2015) show that a medium-scale New Keynesian model augmented with financial frictions can account for this behavior following a period of financial distress.

Figure 9: Partial Equilibrium Response to a Balance Sheet Shock and an Inflation Shock



Notes: Response to a joint shock to balance sheets with size equals to 5 percent of $y^* (\varepsilon)$, and an inflation shock that exogenously keeps inflation 1 percentage point below its stationary value for 8 periods. The persistence of the balance sheet shock is set to 0.9. Responses are in percentage deviations with respect to the stationary equilibrium, while prices are kept constant.

observed during the Great Recession. Output contracts 7.5 percentage points. This contraction is mainly driven by the sharp decline in investment following a sizable outflow of firms leaving the economy. These firms, after experiencing financial distress decide to exit. Thereafter, investment recovers at a slow pace, and its not only year 10 that it starts to get closer to its steady state leave.

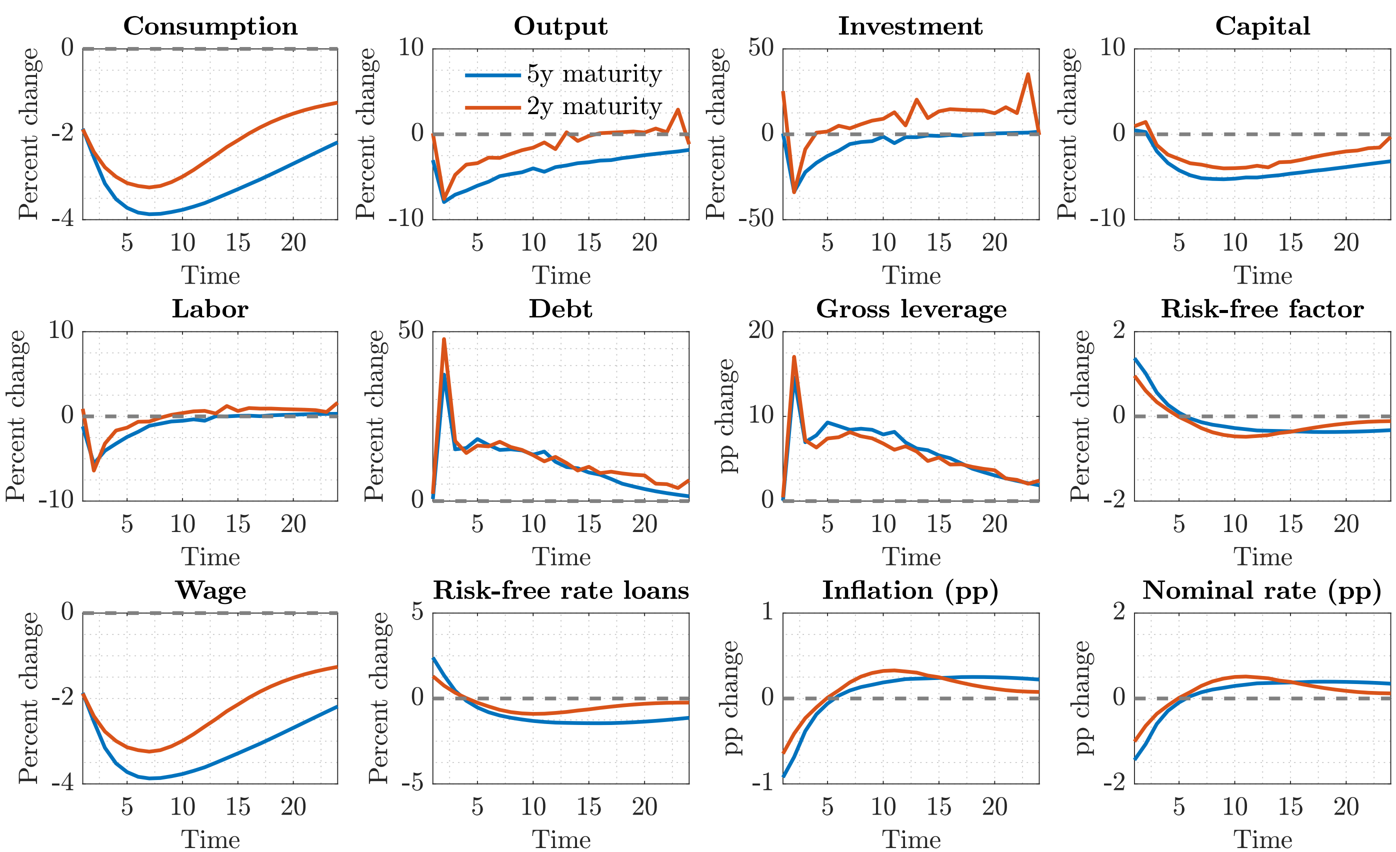
The price effects arising in general equilibrium are important in driving the response of the economy. When compared to the partial equilibrium case, the magnitudes of the responses differ significantly (the shock used in partial equilibrium is 2.5 times larger than the one used here). The drop in inflation amplifies the response of producing firms, as it becomes more difficult for them to honor their debt contracts following the increase in the real value of debt. This goes along the same line of the debt deflation effects discussed, in a partial equilibrium setting, in Subsection 5.1.

When considering the response in a model with two-year average maturity, we see that the longer the maturity of debt, the more slower the recovery to a financial shock. This is consistent with the results discussed in Subsection 5.1. For the two-year case, investment return to its steady-state level just after 5 periods. In the five-year case, however, the model economy need almost 15 years for investment to converge to its pre-recession levels. Despite the implied response elasticities are considerably lower than in the partial equilibrium experiment, the influence of average maturity still determines the pace at which the economy recovers.

6 Concluding Remarks

In this paper, I explored the reasons behind the unusually slow recovery of investment following the Great Recession. I presented empirical evidence suggesting that firms with large financial burden arising from previously issued debt experience larger contractions in their investment expenditure. Importantly, this form of financial distress was more prevalent during the 2007 recession. I then presented a quantitative stochastic general equilibrium model to examine the mechanisms underlying the empirical results. Critically, the quantitative framework stresses the importance of accounting for the interaction between the debt maturity structure across heterogeneous firms and the binding zero constraint for monetary policy. To obtain these results, the model incorporates new elements, namely, nominal and defaultable long-term financing in an New Keynesian model with heterogeneous firms, and a quantitative strategy that allows me to consider

Figure 10: General Equilibrium Response to a Balance Sheet Shock



Notes: Response to a balance sheet shock with size equals to 5 percent of $y^*(\varepsilon)$. The persistence of the shock is set to 0.9, and its size is chosen to generate a contraction of around 4 percent in output. Responses are in percentage deviations with respect to the stationary equilibrium.

large shocks and the zero lower bound simultaneously. I used this framework to show that firms with large debt positions at the onset of large recession are more likely to experience debt overhang episodes. Importantly, the severity of these episodes increases when accounting for debt deflation effects and the inability of monetary policy of lowering interest rates below the zero bound.

References

Almeida, Heitor, Murillo Campello, Bruno Laranjeira, and Scott Weisbenner, "Corporate Debt Maturity and the Real Effects of the 2007 Credit Crisis," *Critical Finance Review*, 2011, *1*, 3–58.

Arellano, Cristina, Yan Bai, and Patrick J. Kehoe, "Financial Frictions and Fluctuations in Volatility," 2018. Manuscript.

Auclert, Adrien, "Monetary Policy and the Redistribution Channel," 2017. Manuscript, Stanford University.

Bernanke, Ben S., "Opening Remarks: Monetary Policy Since the Onset of the Crisis," in "Proceedings: Economic Policy Symposium Jackson Hole" 2012.

_ , Mark Gertler, and Simon Gilchrist, "The Financial Accelerator in a Quantitative Business Cycle Framework," in John B. Taylor and Michael Woodford, eds., *Handbook of Macroeconomics*, Vol. 1 1999, pp. 1341–1393.

Christiano, Lawrence J., Martin S. Eichenbaum, and Mathias Trabandt, "Understanding the Great Recession," *American Economic Journal: Macroeconomics*, 2015, *7* (1), 110–167.

Crouzet, Nicolas and Neil R. Mehrotra, "Small and Large Firms Over the Business Cycle," 2018. Manuscript, Kellogg School of Management, Northwestern University.

Del Negro, Marco, Marc P. Giannoni, and Frank Schorfheide, "Inflation in the Great Recession and New Keynesian Models," *American Economic Journal: Macroeconomics*, 2015, *7* (1), 168–196.

Dinlersoz, Emin, Sebnem Kalemli-Ozcan, Henry Hyatt, and Veronika Penciakova, "Leverage Over the Life Cycle and Implications for Firm Growth and Shock Responsiveness," Technical Report 25226, NBER Working Paper 2018.

Eggertsson, Gauti and Michael Woodford, "The Zero Bound on Interest Rates and Optimal Monetary Policy," *Brookings Papers on Economic Activity*, 2003, (1).

Erickson, Timothy and Toni M. Whited, "Measurement Error and the Relationship between Investment and q," *Journal of Political Economy*, 2000, *108* (5), 1027–1057.

Fazzari, Steven M., R. Glenn Hubbard, and Bruce C. Petersen, "Financing Constraints and Corporate Investment," *Brookings Papers on Economic Activity*, 1988, *1988* (1), 141–206.

Fernández-Villaverde, Jesús, Grey Gordon, Pablo Guerrón-Quintana, and Juan F. Rubio-Ramírez, "Nonlinear Adventures at the Zero Lower Bound," *Journal of Economic Dynamics and Control*, 2015, *57*, 182–204.

Gomes, Joao F., "Financing Investment," *American Economic Review*, 2001, *91* (5), 1263–1285.

_ , Urban Jermann, and Lukas Schmid, "Sticky Leverage," *American Economic Review*, 2016, *106* (12), 3800–3828.

Guedes, Jose and Tim Opler, "The Determinants of the Maturity of Corporate Debt Issues," *Journal of Finance*, 1996, *51* (5), 1809–1833.

Hayashi, Fumio, "Tobin's Marginal q and Average q: A Neoclassical Interpretation," *Econometrica*, 1982, *50* (1), 213–224.

Hennessy, Christopher A., "Tobin's Q, Debt Overhang, and Investment," *Journal of Finance*, 2004, *59* (4), 1717–1742.

_ , Amnon Levy, and Toni M. Whited, "Testing Q Theory with Financing Frictions," *Journal of Financial Economics*, 2007, *83* (3), 691–717.

Kalemli-Ozcan, Sebnem, Luc Laeven, and David Moreno, "Debt Overhang, Rollover Risk, and Corporate Investment: Evidence from the European Crisis," Technical Report 24555, NBER Working Paper 2018.

Kaplan, Greg, Benjamin Moll, and Giovanni L. Violante, "Monetary Policy According to HANK," *American Economic Review*, 2018, *108* (3), 697–743.

Khan, Aubhik and Julia K. Thomas, "Credit Shocks and Aggregate Fluctuations in an Economy with Production Heterogeneity," *Journal of Political Economy*, 2013, *121* (6), 1055–1107.

__ , **Tatsuro Senga, and Julia K. Thomas**, "Default Risk and Aggregate Fluctuations in an Economy with Production Heterogeneity," 2016. Manuscript, Ohio State University.

Lucas, Robert E. Jr. and Edward C. Prescott, "Investment Under Uncertainty," *Econometrica*, 1971, *39* (5), 659–681.

Mckay, Alisdair, Emi Nakamura, and Jón Steinsson, "The Power of Forward Guidance Revisited," *American Economic Review*, 2016, *106* (10), 3133–3158.

Moyen, Nathalie, "How Big is the Debt Overhang Problem?," *Journal of Economic Dynamics and Control*, 2007, *31* (2), 433–472.

Myers, Stewart, "Determinants of Corporate Borrowing," *Journal of Financial Economics*, 1977, *5*, 147–175.

Negro, Marco Del, Gauti Eggertsson, Andrea Ferrero, and Nobuhiro Kiyotaki, "The Great Escape? A Quantitative Evaluation of the Fed's Liquidity Facilities," *American Economic Review*, 2017, *107* (3), 824–857.

Ottonello, Pablo and Thomas Winberry, "Financial Heterogeneity and the Investment Channel of Monetary Policy," 2018. Manuscript, University of Chicago Booth School of Business.

Whited, Toni M. and Guojun Wu, "Financial Constraints Risk," *Review of Financial Studies*, 2006, *19* (2), 531–559.

Wong, Arlene, "Population Aging and the Transmission of Monetary Policy to Consumption and Population Aging," 2018. Manuscript, Princeton Univeristy.

Zetlin-Jones, Ariel and Ali Shourideh, "External Financing and the Role of Financial Frictions Over the Business Cycle: Measurement and Theory," *Journal of Monetary Economics*, 2017, *92*, 1–15.

A Data

A.1 Flow of Funds

The Statistical Release Z.1, Financial Accounts of the United States, is published by the Federal Reserve Board. It includes flow of funds, balance sheet, and integrated macroeconomic account data. It reports data on transaction and levels of financial assets and liabilities for, among others, nonfinancial corporate and noncorporate businesses, by sector and financial instrument. This data is at a quarterly frequency and comprises the period 1951Q4 - 2017Q3.

I use quarterly data seasonally adjusted annual rates covering nonfinancial corporate business. Total debt (Table B.103) is defined as the sum of debt in securities (FL104122005.Q) and loans (FL104123005.Q). Leverage (Table B.103) is total debt divided by total assets (FL102000005.Q). Total long-term debt (Table L.103) is computed as the sum of municipal securities (FL103162000.Q), corporate bonds (FL103163003.Q), and total mortgages (FL103165005.Q). Total short-term debt is total debt minus total long-term debt. LT debt ratio is (Table L.103) constructed as: 100 minus short-term debt as a percentage of total debt (FL104140006.Q). I deflate all nominal variables using the Consumer Price Index for All Urban Consumers from Fred (CPIAUCSL).

A.2 Compustat

The empirical analysis uses firm-level data from the Fundamentals Quarterly dataset from Compustat for the period 1984Q1 to 2017Q4. The construction of the variables follows standard practices in the literature of firm investment and corporate finance.

Starting with Compustat Fundamentals Annual, I apply several filters to this data. First, I drop observations for utilities (SIC codes between 4900 and 4999), financial institutions (SICS codes 6000 to 6799), public administrations (SIC codes 9100 to 9799), ADRs (SIC code 8880), and foreign governments (SIC code 8888). I also delete firms not incorporated in the U.S. (`fic` code different from `USA`). Regarding financial variables, I eliminate firm-year observations with acquisitions (`aqc`) larger than 5% percent of assets (`at`); firms with missing or negative values for total assets (`at`), capital expenditures (`capx`), property, plant, and equipment (`ppegt`), cash holdings (`che`), or sales (`sale`); firms for which cash holdings (`che`), capital expenditures (`capx`) or property, plant and equipment (ppent) are larger than total assets (at); firms for which the value of total assets (at) is less than \$0.5 million; and firms displaying asset growth or sales growth exceeding 100%.

When using annual data, the main measure of investment used int the paper $\Delta \log k_{i,t+1}$ is constructed as the log difference between property, plant and equipment (ppegt) and its lagged value. The alternative measure used for robustness exercises, $(x_{i,t}/k_{i,t})$, is computed as the ratio of capital expenditures (capx) to the lagged value of property plant and equipment (ppegt). For quarterly data, given that the gross value of property, plant and equipment (ppentq) is so sparsely populated, I follow Ottonello and Winberry (2018) and construct $k_{i,t}$ by adding the changes in net property, plant and equipment (ppentq) on top of the firms observation for each firm with non missing value for ppentq.

As is standard in the literature, all debt issued with maturity above one year is considered long-term. In the annual database, dollar amounts of long-term debt maturing in between 1 and five or more years after the annual report are denoted by dd1 to dd5. Debt maturing in more than one year is denoted by dltt. Consequently, I drop firms with total long-term debt (dd1+dltt) greater than total assets (at), and firms for which debt maturing in more than one year (dltt) is lower than the sum of debt maturing in two, three, four, and five years (dd2+dd3+dd4+dd5). Finally, I keep observations with non-missing values in all variables used and winsorize at the 0.1% to eliminate outliers.

Total debt is the sum of debt in current liabilities (dlc) and total long-term debt maturing in more than 1 year (dltt). Firm leverage is computed as the ratio of total debt to total assets (at). The long-term debt ratio is total long-term debt (dd1+dltt) divided by total debt. The fraction of total debt maturing within the next year is computed as debt in current liabilities (dlc) divided by total debt. The fraction of long-term debt maturing within the next year is computed as dd1 divided by total long-term debt.

As for control variables, cash flow is defined as the ratio of net income (ib) plus depreciation and amortization (dp) to the lag of quarterly property, plant and equipment (ppegt). Tobin's q is the ratio of total assets (at) plus market capitalization (prcc$\times$csho) minus common equity (ceq) minus deferred taxes and investment tax credit (txditc), to total assets (at). Size is proxied by the log of total asset (at).

Finally, sectors are defined as follows: Agriculture, forestry and fishing (SIC code 0100-0999), Mining (1000-1499), Construction (1500-1799), Manufacturing (2000-3999), Transportation, communications, electric, gas and sanitary services (4000-4999), Wholesale trade (5000-5199) Retail trade (5200-5999), and Services (7000-8999).

B Reduced-Form Model of Firm Investment

Consider the decision-theoretic problem of a firm that optimally chooses investment and how to finance that expenditure with debt. Time is discrete and infinite. The firm carries out production using a decreasing return to scale technology: $y = \varepsilon k^{\alpha}$, where ε is a productivity shock that follows a Markov process and k is the capital stock owned by the firm and $\alpha\,(0,1)$. When adjusting their capital stock, the firm is subject to adjustment costs $\Psi\,(k,k')$. The adjustment cost function satisfies $\Psi_2 > 0$ and $\Psi_{22} > 0$.

To finance investment expenditure, the firm can issue a long-term defaultable bond $b \in [0,\infty)$. Each period, each bond is amortized at the rate γ, and pays a coupon κ. $p\,(\varepsilon,k',b')$ denotes the price of firm debt. I assume that $p_{k'} \geq 0$ and $p_{b'} \leq 0$. These assumptions are a useful form of capturing the effects of default risk on interest rates in an reduce form manner. Implicitly, they mean that, as the firm increases it capital stock, the expected output next period will be higher; and as the firm has less debt, the more likely is for it to be able to repay. Finally, I further assume that the firm cannot save. The firm maximizes its value:

$$v\,(\varepsilon,k,b) = \max_{k,b}\left[D\left(\varepsilon,k,b,k',b'\right) + \beta E v\left(\varepsilon' k',b'\right)\right] \tag{25}$$

where dividends are given by

$$D\left(\varepsilon,k,b,k',b'\right) = \varepsilon k^{\alpha} - (\kappa+\gamma)\,b + (1-\delta)\,k - k' - \Psi\left(k,k'\right) + p\left(k',b'\right)\ell \tag{26}$$

and where debt issuance ℓ is

$$\ell = b' - (1-\gamma)\,b \tag{27}$$

The optimality condition for capital is given by

$$1 + \Psi_2\left(k,k'\right) = p_{k'}\left[b' - (1-\gamma)\,b\right] + \beta E D_1 v\left(\varepsilon',k',b'\right) \tag{28}$$

The left-hand side of the condition captures the marginal cost of investment, which includes the price per unit of k' and the associated adjustment costs. On the right-hand side, we have the marginal benefit of investment, which is the sum of the marginal revenue for a fixed level of debt issuance and the marginal shadow value of capital. From the envelope condition, this shadow value is the marginal return on capital, next of adjustment cost

$$D_1 v\left(\varepsilon,k,b\right) = \alpha\varepsilon k^{\alpha-1} + (1-\delta) - \Psi_1\left(k,k'\right) \tag{29}$$

The optimality condition for debt is

$$p_{b'}\left[b' - (1-\gamma)\,b\right] + p = -\beta D_2 Ev\left(\varepsilon' k',b'\right) \tag{30}$$

In this condition, the left-hand side is the marginal revenue from issuing more debt. It takes into account change in p (negative), and the extra resources p per unit of ℓ. On the right-hand side we have the marginal cost of increasing debt, noting that $D_2 v\left(\varepsilon,k,b\right) < 0$ as the envelope condition for debt is

$$D_2\left(\varepsilon,k,b\right) = -\left(\kappa+\gamma\right) - p\left(1-\gamma\right) \tag{31}$$

Then, the marginal cost of increasing debt is the sum of payments in coupon and the fraction γ of the principal, plus the cost of debt (valued at p) that has not yet matured. Combining (28) and (30) yields[13]

$$\begin{aligned} 1+\Psi_2\left(k,k'\right) = {} & p_{k'}\frac{1}{p_{b'}}\left\{\beta\left[\left(\kappa+\gamma\right)+p\left(1-\gamma\right)\right]-p\right\} \\ & + \beta E\left[\alpha\varepsilon'\left(k'\right)^{\alpha-1} + (1-\delta) - \Psi_1\left(k',k''\right)\right] \end{aligned} \tag{32}$$

Now, I derive an investment equation that will be used to motivate the empirical specification in Section 2. Define the shadow value of capital as

$$q\left(\varepsilon,k,b\right) = \beta ED_1 v\left(\varepsilon',k',b'\right) \tag{33}$$

Therefore, equation (32) can be rewritten as

$$1+\Psi_2\left(k,k'\right) = p_{k'}\frac{1}{p_{b'}}\left\{\beta\left[\left(\kappa+\gamma\right)+p\left(1-\gamma\right)\right]-p\right\} + q\left(\varepsilon,k,b\right)$$

Since the first partials derivatives of Ψ are homogeneous of degree 0, and as Ψ_2 is

[13] Note that, in absence of default risk, the price of debt is $p = \beta\left(\kappa+\gamma\right)/\left[1-\beta\left(1-\gamma\right)\right]$ and, hence, the condition (32) becomes

$$1+\Psi_2\left(k,k'\right) = \beta E\left[\alpha\varepsilon'\left(k'\right)^{\alpha-1} + (1-\delta) - \Psi_1\left(k',k''\right)\right]$$

This is the frictionless optimality condition for capital in a neoclassical model of investment.

monotone, the above expression becomes

$$\frac{k'}{k} = (\Psi_2)^{-1} \left\{ 1, p_{k'} \frac{1}{p_{b'}} \{ \beta [(\kappa + \gamma) + p(1-\gamma)] - p \} + q(\varepsilon, k, b) - 1 \right\} \tag{34}$$

Assume the following functional form for Ψ:

$$\Psi(k, k') = \frac{\psi_k}{2} \left(\frac{k'}{k} - 1 \right)^2 k \tag{35}$$

This function satisfies $\Psi_2 > 0$ and $\Psi_{22} > 0$, as required. Substituting this functional form in (34) we obtain

$$\left(\frac{k'}{k} - 1 \right) = \frac{1}{\psi_k} \left\{ p_{k'} \frac{1}{p_{b'}} \{ \beta [(\kappa + \gamma) + p(1-\gamma)] - p \} + q(k, b) - 1 \right\} \tag{36}$$

From the capital accumulation equation $k'/k = (1-\delta) + (x/k)$. Then, we can solve for investment as

$$\frac{x}{k} = \frac{1}{\psi_k} \left\{ p_{k'} \frac{1}{p_{b'}} \{ \beta [(\kappa + \gamma) + p(1-\gamma)] - p \} + q(k, b) - 1 \right\} + \delta \tag{37}$$

This equation can be rewritten as follows:

$$\frac{x}{k} = \beta \frac{1}{\psi_k} \frac{\zeta_{p,k'}}{\zeta_{p,b'}} \omega' (\kappa + \gamma) - \frac{1}{\psi_k} \frac{\zeta_{p,k'}}{\zeta_{p,b'}} \omega' [1 - \beta(1-\gamma)] p + \frac{1}{\psi_k} q(k, b) - \frac{1}{\psi_k} + \delta$$

where $\zeta_{p,k'}$ and $\zeta_{p,b'}$ are the elasticities of the price of debt with respect to the chosen levels of capital and debt, and $\omega' = b'/k'$ is leverage. We can further simplify this as

$$\frac{x}{k} = \tilde{\beta}_0 + \tilde{\beta}_1 \omega' (\kappa + \gamma) + \tilde{\beta}_2 \omega' p + \tilde{\beta}_3 q(k, b) \tag{38}$$

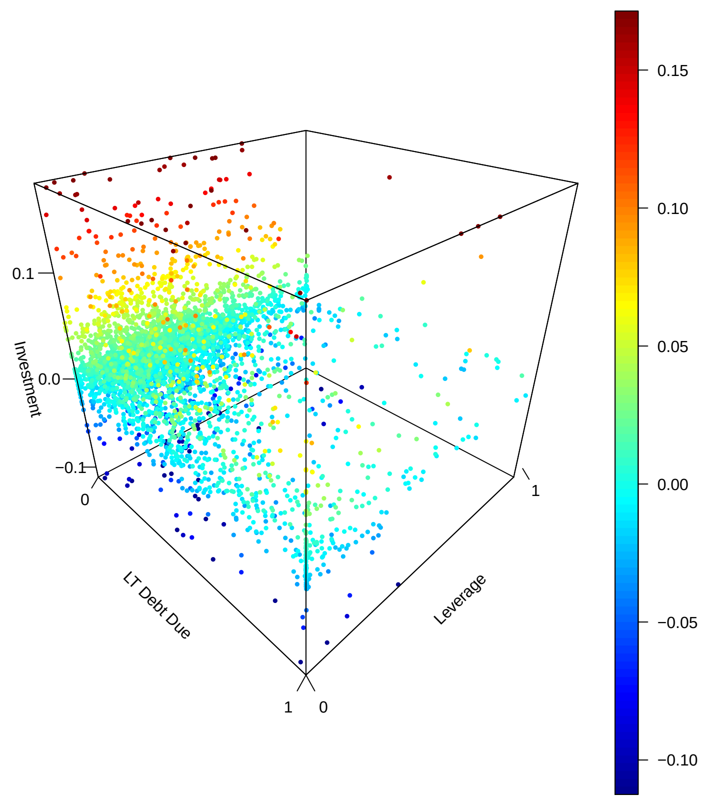
where

$$\begin{aligned}
\tilde{\beta}_0 &= \delta - \frac{1}{\psi_k} \\
\tilde{\beta}_1 &= \beta \psi_k^{-1} \left(\zeta_{p,k'} / \zeta_{p,b'} \right) \\
\tilde{\beta}_2 &= -[1 - \beta(1-\gamma)] \psi_k^{-1} \left(\zeta_{p,k'} / \zeta_{p,b'} \right) \\
\tilde{\beta}_3 &= \frac{1}{\psi_k}
\end{aligned}$$

The coefficient $\tilde{\beta}_1$ measures the sensitivity of investment to changes in the financial burden of debt $(\kappa + \gamma)$ scaled by how leveraged the firm is. Note that $\tilde{\beta}_1 \leq 0$, as the price of debt is weakly increasing in capital and weakly decreasing in debt. The coefficient $\tilde{\beta}_2 > 0$ captures the effect of the firm's ability to raise funds.

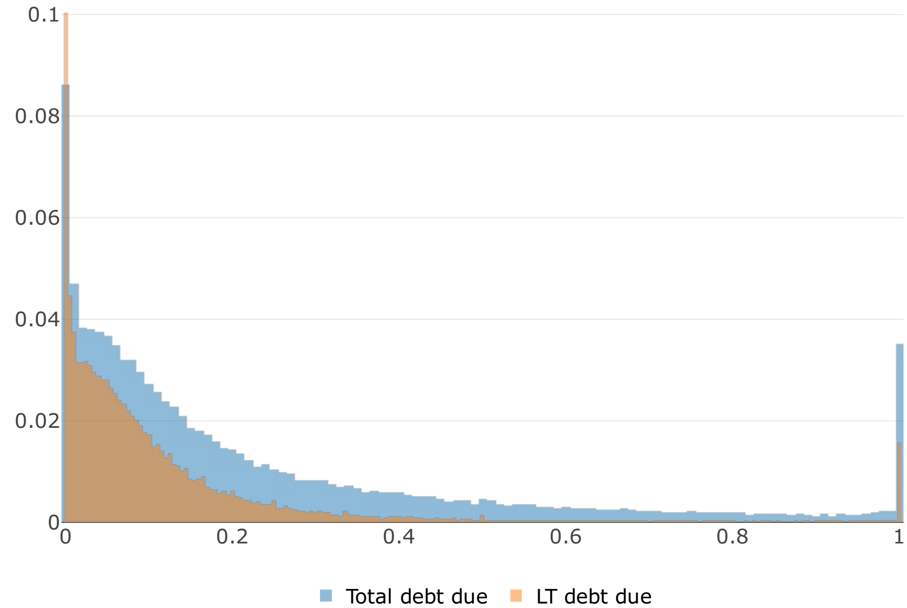
C Extra Figures and Tables

Figure C1: Investment, Leverage and Long-Term Debt Maturing, 2007



Notes: Data from Compustat for 2007. Investment is $\Delta \log k_{i,t+1}$. Fraction of long-term debt maturing is the dollar amount of long-term debt maturing during the next year relative to total long-term debt. Leverage is the ratio of total debt to total assets.

Figure C2: Histograms for Fraction of Total Debt Maturing and Fraction of Long-Term Debt Maturing



Notes: Fraction of all debt maturing is the dollar amount of debt maturing during the next year relative to total debt. Fraction of long-term debt maturing is the dollar amount of long-term debt maturing during the next year relative to total long-term debt.

Table C1: The Role of Debt Overhang on Firm Investment - Gross Investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Leverage	−0.043			−0.044	−0.048	−0.033	−0.036
	(0.008)			(0.008)	(0.008)	(0.007)	(0.007)
Total debt maturing		−0.012		−0.013		−0.007	
		(0.003)		(0.003)		(0.003)	
Long-term debt maturing			−0.027		−0.030		−0.020
			(0.004)		(0.004)		(0.003)
Firm controls	No	No	No	No	No	Yes	Yes
R^2	0.116	0.114	0.116	0.117	0.120	0.182	0.183

Notes: Results from estimating the specification

$$\frac{x_{i,t}}{k_{i,t}} = \alpha_i + \alpha_{s,t} + \beta_1 \omega_{i,t} + \beta_2 \mathcal{D}_{i,t} + \mathbf{\Gamma}' Z_{i,t} + \varepsilon_{i,t}$$

where α_i is a firm fixed effect, $\alpha_{s,t}$ is a sector-year fixed effect, $\omega_{i,t}$ is leverage measured as the book debt to assets ratio, $\mathcal{D}_{i,t}$ is a debt burden proxy, and $Z_{i,t}$ is a vector with firm-level controls containing, log of total assets, sales growth, and Tobin's q. Standard errors are clustered at the firm level.