Financial constraints, firm heterogeneity, and the cyclicality of employment growth

Jan Möller*

Job Market Paper

December 27, 2015

[CLICK HERE FOR THE LATEST VERSION]

Abstract

This paper examines the interconnection of financial constraints and employment dynamics in the cross-section of firms. Using firm-level data, I document that employment growth at more financially constrained firms is more sensitive to macroeconomic conditions. I then develop a tractable dynamic general equilibrium model to capture this fact and I analyze the role of credit market frictions for cyclical sensitivities. The key ingredients in my framework are (i) the responsiveness of borrowing costs to expected default rates, and (ii) heterogeneity in the benefits of debt financing. Firms choose different capital structures with associated credit spreads and default risk, and firms with higher spreads respond more strongly to aggregate shocks. I show that the model can account for the different elasticities of employment growth in the data, provided that wages are sufficiently rigid. I consider other dimensions of firm heterogeneity, such as differences in productivity risk, and I find that the level of leverage does not necessarily imply greater cyclicality. Finally, I use the model to study the implications of monetary policy, financial shocks and risk shocks for different firms.

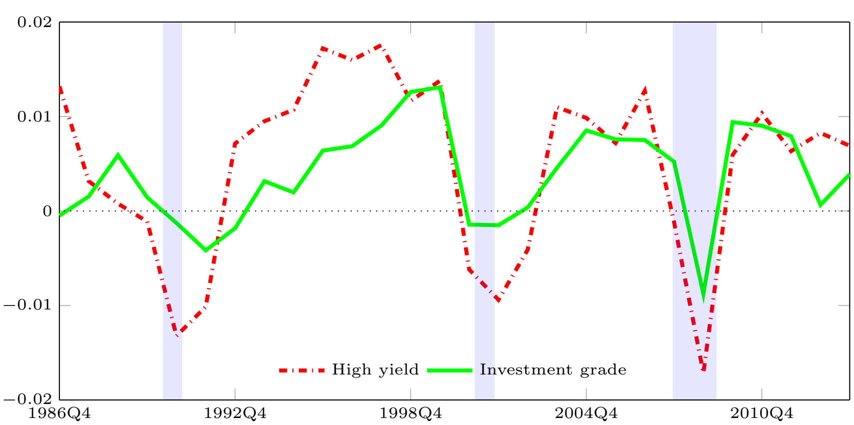
*New York University. Email: jan.moeller@nyu.edu. I am extremely grateful to my thesis advisor Mark Gertler, and my Ph.D. committee member Jess Benhabib and Edouard Schaal. I also want to thank Jarda Borovička, Katka Borovičková, Daniel Greenwald, Virgiliu Midrigran, Simon Mongey, Diego Perez, and participants at the NYU Macro Student Lunch Seminar for helpful comments.

1 Introduction

Credit constraints play a key role for the hiring and investment behavior of businesses. The loosening of constraints in periods of economic growth and their tightening in recessions has motivated a large literature on the amplifying effects of financial frictions: easier borrowing conditions reinforce booms, while more restrictive conditions aggravate and prolong downturns. However, much of this research has focused on aggregate outcomes. In this paper I explicitly account for the fact that the severity of financing constraints differs across firms, and I widen the focus to cross-sectional dynamics. How does a recession affect firms which are more and less constrained to begin with? Which of the many dimensions of firm heterogeneity can help understand heterogeneous employment dynamics in the data? And what role does leverage play in the transmission of aggregate shocks?

The contribution of my paper is twofold. On the empirical side I document that employment growth at more financially constrained firms is more sensitive to macroeconomic conditions. Specifically, I consider the dynamics of firms with an investment grade bond rating relative to the group of firms with a speculative grade rating (high yield). High yield firms rank below investment grade firms on a number of indicators for financial constraints. Figure 1 illustrates that the mean employment growth rate among more constrained high yield firms drops precipitously during the three recessions 1990-1991, 2001, and 2008-2009. Less constrained investment grade firms see a much less pronounced decline. Moreover, high yield firms appear to expand faster in expansions. My regression analysis corroborates this impression as I show that high yield firms have a significantly higher elasticity of employment growth with respect to aggregate output growth. This result is not driven by industry effects or age-specific cyclical sensitivities.

Figure 1: Employment growth



Sources: Compustat Fundamentals Annual. Financial firms (SIC codes 60 to 67) and utilities (SIC code 49) excluded. Rating is S&P long term credit rating coded from AAA (=1) to D (=22). Mean employment growth rate ($0.5(Emp_{i,t} - Emp_{i,t-1})/(Emp_{i,t} + Emp_{i,t-1})$) among investment grade firms (AAA to $BBB-$ rating, green solid line), and non-investment grade firms ($BB+$ to D, red dash-dotted line).

The technical contribution of this paper is the introduction of firm heterogeneity into an otherwise standard general equilibrium model with credit and labor market frictions. Similar to the costly state verification problem in Bernanke and Gertler (1989) and Carlstrom and Fuerst (1997) firms face idiosyncratic productivity risk and may default on their debts.

In consequence, they borrow at a premium over the risk free rate and thus compensate lenders for expected default losses. The novelty in my environment is that - in addition to productivity risk - firms exhibit differences in a cash flow cost. Despite this second dimension of heterogeneity, the distribution of firms can be easily characterized because in equilibrium all firms with the same cost choose the exact same capital structure. The tractability of my setup is a major advantage since it allows the model to be estimated on macroeconomic data and makes it suited for policy analysis.

The firm's cost - also referred to as its "type" - is observed by lenders and affects the financing decision via default incentives. In particular, a lower cost diminishes the firm's incentives to default in the future and allows borrowing at lower rates. Provided with cheaper credit, in the stationary equilibrium these firms assume higher leverage, have higher expected default rates and pay higher interest rates. Thus, firms of this type correspond to the more constrained high yield firms notwithstanding their cost advantage in borrowing.

The idea behind this particular form of heterogeneity is that investment grade firms may be concerned with their credit rating (Graham and Harvey (2001)) and may face distress costs even prior to default (Elkamhim et al. (2012)), namely when being downgraded. Given these explicit or implicit costs they want to use debt more cautiously. High yield firms on the other side have fewer costs (or larger benefits) from debt financing, possibly because they are already recognized low credit quality firms.

Under the structure of my model the borrowing costs of high yield firms rise disproportionally in a recession. In consequence, these firms reduce debt financing, sell-off more capital, and hire fewer workers compared to investment grade firms. To evaluate the model performance I estimate cyclical sensitivities from model-implied employment series over the sample period. I compare these with the empirical elasticity estimates and I find that the model can match both aggregate employment dynamics and the greater cyclicality of high yield firms. Three features are essential for these results. First, wage rigidity which leads to a noticeable drop in aggregate employment; second, the production cost which is denominated in units of capital and therefore behaves procyclically; finally, the endogenous price of debt which drives the sharp capital and employment adjustments at high yield firms. This latter point can be illustrated in a counterfactual scenario in which borrowing costs are exogenously fixed at steady state levels, and thus the accumulation of capital is not being disciplined by the external finance premium. In a recession the more leveraged high yield firms would reduce capital and employment much less than investment grade firms - despite the fact that this behavior implies an elevated risk of default. In light of these counterfactual dynamics the responsiveness of borrowing costs proves to be key to the success of the model.

Subsequently, I use the model to investigate the role of alternative dimensions of heterogeneity. Motivated by the high return volatility of high yield firms, I add heterogeneity in productivity risk to the model and I document counterfactual implications for leverage. Namely, lenders charge the more risky high yield firms much higher interest rates, and in consequence these firms choose to operate at low levels of leverage. Nevertheless, high yield firms are found to be more sensitive to aggregate shocks as their default risk rises more strongly in a recession. This finding runs counter to the intuition from average (economy-wide) leverage which determines the strength of the fire-sale externality. Namely, when comparing two economies that differ in the average level of corporate leverage, the more leveraged economy does respond stronger to aggregate shocks. Yet, according to the finding above, when comparing two firms within the same economy, the firm's level of leverage is not necessarily an indicator for cyclical sensitivity. This insight can be particularly useful in the context of smaller and younger firms which often have low leverage but high return volatility.

In extensions to the basic framework I study the effects of monetary policy, financial shocks and variation in idiosyncratic firm risk. The disruption to financial intermediation during and after the financial crisis of 2007-2009 has arguably been a key element for recession dynamics. I introduce shocks to credit spreads to proxy for a reduction in intermediation capacity. Consistent with evidence on employment creation during the financial crisis, I find that the more financially constrained firms in the model are hit the hardest by such shocks. The role of fluctuations in risk (or uncertainty) for macroeconomic dynamics has been discussed in policy circles and academia alike, and the effects on aggregate investment and employment have been widely documented.[1] Through the lens of my model I can consider the effects for the different types of firms. I document that in response to an economy-wide increase in idiosyncratic risk the more constrained high yield firms (less constrained investment grade firms) would experience a very persistent decrease (increase) in employment and investment. This results hints at potentially large benefits from risk-sharing that are overlooked when studying risk shocks in representative firms models. Finally, I consider the implications of monetary policy for the different firm types. In line with empirical findings, I obtain that the more financially constrained type reacts more strongly to contractionary monetary policy.

Disproportional employment losses at more financially constrained firms may help explain why employment growth is more dispersed across firms in recessions.[2] Along with the countercycliality of other cross-sectional dispersion measures - such as sales growth, equity returns, etc. - this empirical pattern can be related either to time-variation in the volatility of idiosyncratic shocks, or to real and financial frictions that endogenously generate more dispersed outcomes in bad times.[3] This paper adds to the latter approach and suggests that differences in financing frictions result in heterogeneous cyclical sensitivities and ultimately may generate more dispersed employment growth in a downturn.

The paper is organized as follows. The remainder of this section summarizes the related literature. In section 2, I corroborate the evidence about differential elasticities. I present the model in section 3. Section 4 contains the quantitative evaluation. Section 5 concludes with some observations and directions for future research.

Related Literature: This paper connects to research on macroeconomic models with credit frictions, and to the empirical work on the role of financing constraints for firm-level employment dynamics. The core of my model builds on credit market frictions as in the financial accelerator model by Bernanke et al. (1999), and also used in Christiano et al. (2014), Del Negro et al. (2003), Gilchrist et al. (2009). While I share with these papers the presence of productivity heterogeneity after the capital structure is set (ex-post), I add heterogeneity prior to the capital structure choice (ex-ante). Unlike ex-post heterogeneity which induces default of a share of firms for a given capital structure, ex-ante heterogeneity

[1] See Bloom (2009), Gilchrist et al. (2014), Christiano et al. (2005), Jurado et al. (2013) and others.

[2] See Bloom et al. (2012) and Ilut et al. (2014).

[3] The literature discusses mechanisms such as endogenous risk taking as in Tian (2012) and Navarro (2014); Price experimentation as in Bachmann and Moscarini (2012); Learning as in Benhabib et al. (2015); Diversification as in D'Erasmo and Boedo (2013); Asymmetric hiring responses as in Ilut et al. (2014).

makes firms choose different debt-to-assets ratios in equilibrium. Model features such as wage rigidity and further extensions are based on the large literature that uses DSGE models to study the driving forces of aggregate fluctuations, including Christiano et al. (2005), Smets and Wouters (2007).

Importantly, under the financial contract in the tradition of Bernanke and Gertler (1989) and Carlstrom and Fuerst (1997) the external finance premium depends on the firm's decision to issue debt. This is in contrast to another line research that builds on collateral constraints in the tradition of Kiyotaki and Moore (1997), for instance Jermann and Quadrini (2012). Brunnermeier et al. (2013) point out that "with costly state verification, the cost of external financing is increasing in the borrowing" but with a collateral constraint the "cost of external financing is constant [...] up to the constraint and then becomes infinite". While the propagation effects of the two constraints can be very similar in the context of a representative firm, there are important differences once heterogeneity is taken into account. First, in my framework firms have different costs of credit due to default risk, yet under exogenous collateral constraints there is no default in equilibrium and all firms borrow at the risk-free rate. Second, my setup allows for different elasticities of borrowing costs with respect to aggregate conditions. In contrast, under collateral constraints the credit costs of all firms move symmetrically with the risk-free rate. This would hold true even if firms had different leverage limits.[4]

There is a number of papers that share the focus on financing frictions and firm-level heterogeneity. The key idea in this line of work is that in a recession the efficiency-enhancing transfer of capital from low to high productivity firms slows down, thereby aggravating misallocation. Gomes et al. (2014) and Khan et al. (2013) study models with equilibrium default and overlap with my work regarding the debt financing decision. Other papers, including Buera et al. (2015), Khan and Thomas (2013), Shourideh and Zetlin-Jones (2014), Cui (2013), feature exogenous collateral constraints which tighten in recessions. Models of either type are governed by life-cycle dynamics, with the small and productive firms being most constrained on average, and also suffering disproportionally in recessions. Abstracting from firm dynamics allows me to reduce the state space dramatically and to keep the model tractable. Therefore, I can address various dimensions of heterogeneity, including but not limited to productivity, and I can study their distinct implications for the capital structure and cross-sectional dynamics.

In most models with credit market frictions - including mine -, default risk affects employment outcomes only indirectly via the complementarity with capital. In contrast, in Gourio (2014) default risk directly affects the hiring decision because workers need to be compensated for expected earnings losses in case of default (analogous to an external finance premium). I see this channel as complementary, yet the lack of capital in Gourio (2014) means that the amplification via investment and asset price dynamics is absent.

On the empirical side, my paper connects to work on the role of leverage for employment dynamics, including Giroud and Mueller (2015), Sharpe (1994), Cantor (1990). Sharpe (1994) documents that firms with a higher level of leverage were more cyclical from the 1960s to the mid-1980s, but Giroud and Mueller (2015) argue that in case of the Financial Crisis it

[4] This could be implemented through heterogeneity in the collateral constraint parameter which limits debt as a multiple of capital (see Khan and Thomas (2013)), or alternatively capital as a multiple of net worth (see Buera et al. (2015)).

was the increase of leverage prior to the downturn that made some firms more vulnerable. My results can inform this apparent conflict between levels versus changes of leverage as a proxy for financing constraints. Namely, I show that high risk firms would choose low debt, but nevertheless react strongly to aggregate shocks. Hence, sorting by the level of leverage may group together firms with high debt but low risk - i.e., the less constrained firms -, while sorting on the changes of leverage as in Giroud and Mueller (2015) may also pick up more volatile firms with lower, but rising debt, - i.e., the more constrained.

Regarding the firm size dimension there is substantial evidence about the greater cyclicality of smaller firms, including Gertler and Gilchrist (1994), Fort et al. (2013). Also, Chodorow-Reich (2014) documents that the employment effects of credit supply shocks in the 2007-2009 crisis were large at small and medium-sized firms. Focusing on the worker side, Duygan-Bump et al. (2015) find that unemployment risk in the 2007-2009 recession increased particularly for workers of smaller firms operating in industries that have high financing needs. Further evidence about the importance of firm financing for hiring around the Financial Crisis comes from the survey study by Campello et al. (2010).

2 Employment elasticities

Figure 1 suggests that firms with a speculative grade rating are more sensitive to macroeconomic conditions. In this section I present the underlying micro data and discuss firm characteristics in the two subgroups. Then, I estimate the elasticity of employment with respect to output growth in dependence of the rating status. The regression analysis serves two main purposes: First, I can control for potential compositional effects due to observable characteristics such as industry and age. Second, I can use the estimated elasticities to assess the fit of my quantitative model, namely by replicating the regressions using model-generated series in section 4.4.

The sample consists of US public firms with a bond credit rating, using financial information from the Compustat database and equity returns from CRSP. Firms in the sample have been assigned a bond credit rating, usually from multiple major credit rating agencies, and can raise funds through bond issuance.[5] The bond rating is a credit risk assessment based on a variety of factors, such as earnings, leverage, funding structure, liquidity, cash flow, industry profile, etc. Ratings are expressed as letter grades, ranging from AAA for firms of the highest credit quality to D for firms that are in default on their debts.For the purposes of this paper I only consider two broad categories: investment grade firms which have a rating of $BBB-$ or better and high yield (speculative grade) firms with a rating $BB+$ or worse. The sample covers the years 1986 to 2014 since rating information via Compustat is available only since the mid-1980s.

Table 1 compares investment grade and high yield firms in the Compustat database. The table entries refer to means from the pooled sample. The variables related to firm financing all point to high yield firms as the more financially troubled firms. They pay higher interest

[5]Issuing bonds without a credit rating is possible, however non-rated bonds are rare in practice. Firms without a rating usually obtain debt financing through bank loans, private debt from other institutions, or - for larger corporations - via the syndicated loan market.

rates,[6] have more debt, pay dividends less frequently, and score higher on the KZ index proxying for financing constraints. Not surprisingly, their (historical) default rates are higher as the (ex-ante) default risk assessment is the main factor for the rating.

Moreover, the cross-sectional dispersion of quarterly equity returns is higher among high yield firms.[7] The difference between the asset return dispersion of investment grade and high yield firms would likely be smaller since high yield firms have higher leverage. Both TFP and profitability are higher for investment grade firms. Finally, investment grade firms are larger and older than high yield firms, yet the latter are all but young.[8] The lower average age of high yield firms is partially due to entry dynamics in the 1990s, an issue that I will revisit below.

The regression analysis is based on the reduced-form specification by Sharpe (1994). Firm-level employment growth is regressed on GDP growth and the interaction between GDP growth and the firm-level variable of interest, i.e., the firm characteristic related to macroeconomic sensitivity. In departure from Sharpe (1994) who used the level of leverage as a continuous variable, I consider a dummy for high yield status (HY). A positive coefficient on the interaction between GDP growth and the rating status, $\beta_3 > 0$, indicates greater cyclicality of high yield firms.

$$\Delta Employment_{i,t} = \beta_0 \ + \ \beta_1 \Delta Y_t \ + \ \beta_2 HY_{i,t-1} + \beta_3 HY_{i,t-1} \times \Delta Y_t \ + \ \beta_4 TFP_{i,t-1} \ + \cdots + \ \epsilon_{i,t}$$

As a measure of productivity I also include firm-level TFP which is expected to contribute to greater employment growth, $\beta_4 > 0$. While employment data in Compustat is available only at yearly frequency, I follow Sharpe (1994) and take advantage of the fact that the fiscal year end differs across firms. I therefore match employment growth at firms whose fiscal year ends in quarter q with aggregate output growth from year $t-1$ quarter q to year t quarter q.[9]

In column (1) the coefficient on the interaction term is large and significant, but the coefficient on output growth is relatively small. This is surprising given that employment growth at both investment grade and high yield firms dropped precipitously during the three recessions depicted in Figure 1. I add controls for industry to address two main concerns. First, I suspect that cyclical dynamics at the sectoral level may not be well synchronized with aggregate output growth and bias the coefficient downward. Second, the greater cyclicality of high yield firms may be driven by compositional effects. Namely, if high yield firms were concentrated in industries that are more cyclical, for instance durable goods industries, then the greater cyclicality would emerge irrespective of differences in financing constraints (or it may simply reflect differences in financing constraints at the sectoral level). Therefore, in columns (2)-(4) I include time-industry effects, with industry defined at the 3-digit NAICS

[6] Notice that this interest rate measure is inferred from income statement and balance sheet data. To compare this to yields in the bond market, consider the Aaa (AAA equivalent) (Baa (BBB equivalent)) Corporate Credit Spread relative to the Treasury yield of 130 (230) bps over the period 1986 to 2014.

[7] See section D.2 in the appendix. The same result is obtained when computing the standard deviation of daily equity returns by firm over a quarter and comparing the mean among investment grade and high yield firms. Alternatively, implied equity volatilities derived from option prices yield a similar picture.

[8] The age variable in Compustat refers to the first appearance in the database rather than the founding year of the company.

[9] Sharpe (1994) uses six semi-annuals lags of output growth (three years).

Table 1: Summary statistics

	Investment grade	**High yield**
Financing		
Credit spreads	155 bps	367 bps
Default rate (% ann.)	0.14	4.49
Leverage	0.58	0.68
KZ score	-1.36	0.90
Dividend payer	0.87	0.43
Productivity		
TFP	0.037	-0.033
Return on assets	0.14	0.07
Risk		
Equity return dispersion	0.17	0.32
Size & Age		
Employment	49,400	11,400
Assets	18,200	2,900
Age	30.8	18.2
Observations (per year)	550	647

Notes: Compustat Fundamentals Annual & CRSP (1986 to 2014). Financial firms (SIC codes 60 to 67) and utilities (SIC code 49) excluded. Credit spreads are interest expenses (`XINT`) divided by total long-term and short-term debt (`DLTT` and `DLC`) minus the yield on a ten year constant maturity Treasury. Default rates for investment grade and high yield firms are average default rates on corporate bonds between 1981 and 2011 (see 2011 Annual US Corporate Default Study by S&P, the average includes financial firms). Leverage is total liabilities divided by total assets. KZ score is the Kaplan-Zingales measure for financial constraints, constructed according to Lamont et al. (2001). Table entries are means over the sample period, except for the KZ index (median). Dividend payer is the share of firms with positive dividends among total firms in a rating group. TFP is the residual of a regression of sales (`SALE`) on employment (`EMP`) and capital (`PPEGT`) by year and 3-digit NAICS industry. Return on assets is operating income before depreciation (`OIBDP`) minus interest expense (`XINT`) divided by total assets. Assets are in thousands deflated to 2009 dollars.

Table 2: Employment growth cyclicality

	$\Delta Employment_{i,t}$			
	(1)	(2)	(3)	(4)
ΔY_t	0.082***	0.117***	0.139***	0.153***
	(3.64)	(5.61)	(6.14)	(6.39)
$HY_{i,t-1}$	-0.000	-0.000	-0.002***	-0.002***
	(-0.17)	(-0.55)	(-3.52)	(-2.61)
$HY_{i,t-1} \times \Delta Y_t$	0.238***	0.166***	0.102***	0.063*
	(6.51)	(5.12)	(3.00)	(1.73)
$Age_{i,t-1}$			-0.003***	
			(-7.50)	
$Age_{i,t-1} \times \Delta Y_t$			-0.089***	
			(-3.92)	
$Size_{i,t-1}$				-0.001***
				(-3.60)
$Size_{i,t-1} \times \Delta Y_t$				-0.060***
				(-4.89)
$TFP_{i,t-1}$	0.005***	0.005***	0.004***	0.005***
	(4.79)	(4.29)	(4.21)	(4.71)
R^2	0.01	0.01	0.01	0.01
N	28,209	28,209	28,209	28,209
$Time \times Industry$	No	Yes	Yes	Yes

Notes: Compustat Fundamentals Annual, years 1986 to 2014. Financial firms (SIC codes 60 to 67) and utilities (SIC code 49) excluded. ΔY_t is the growth rate of real GDP from year $t-1$ to t. Employment is $\Delta Employment_{i,t} = 0.5(Emp_{i,t} - Emp_{i,t-1})/(Emp_{i,t} + Emp_{i,t-1})$. Firm size is measured as the log of total assets. TFP is the residual of a regression of sales (`SALE`) on employment (`EMP`) and capital (`PPEGT`) by year and 3-digit NAICS industry. I control for time-industry effects by subtracting mean employment growth by 3-digit NAICS industry. Values in parentheses are t-statistics computed using robust standard errors. ($^{***}/^{**}/^{*}$) indicate significance at the (1/5/10) percent level.

level. Specifically, for each year t and quarter q I take out the average employment growth rate by 3-digit NAICS industry and add back the average overall employment growth rate. Column (2) shows that with time-industry effects the coefficient on output growth rises to 0.12 while the coefficient on the interaction term drops to 0.17. This indicates that indeed some of the differences in cyclicality are driven by industry. However, a substantial difference in the employment elasticities remains.

I further include age as an explanatory variable and I allow the effect of age to differ over the business cycle. The rationale behind this is twofold: First, evidence by Fort et al. (2013) indicates that young firms have greater cyclicality of employment, possibly related to financing constraints. If the rating status merely captures firm age and the severity of financing frictions that correlates with age, then the interacted rating status dummy should become insignificant. Second, there is concern that the different elasticities suggested by Figure 1 stem from compositional effects, in particular in light of the high employment growth rates among non-investment grade firms during the 1990s. The boom period was characterized by a succinct increase in the number of non-investment grade firms, and the average age among these firms dropped from 19 years in 1991 to 14 years in 1999. In contrast, the increase in the number of investment grade firms was smaller and the average age declined only by little. In column (3) I find that young firms grow faster, consistent with life-cycle behavior. Moreover, employment growth at young firms is more sensitive to changes in aggregate output while the interaction term on high yield remains positive and significant.

Finally, I add firm size measured as total assets and the respective interaction term with aggregate output growth. As was shown in Table 1 investment grade firms are much larger than high yield firms. Similarly as with the addition of age, one can see that large firms grow slower and have a lower elasticity of employment growth. In column (4), the main coefficient of interest remains positive and significant but drops in magnitude.

In summary, employment at firms with a high yield rating grows by more in expansions and drops sharper in recessions. This result is not driven by different sectoral cyclicalities. Moreover, firm age may partially capture differences in financial constraints, but the rating status still remains important.

As an assessment of credit risks for investors the rating collapses many firm characteristics into a single measure. The model will focus on replicating the core information of the rating, namely the default risk and the corresponding yields. Once the model has shown to perform well, I will return to the different layers of firm heterogeneity which are subsumed in the rating and I will try to derive implications for cross-sectional dynamics.

3 Model

Time is discrete and the horizon is infinite. The economy consists of (i) a continuum of firms, (ii) a representative household, (iii) financial intermediaries, (iv) labor agencies, (v) capital goods producers, and (vi) a government sector.

3.1 Firms

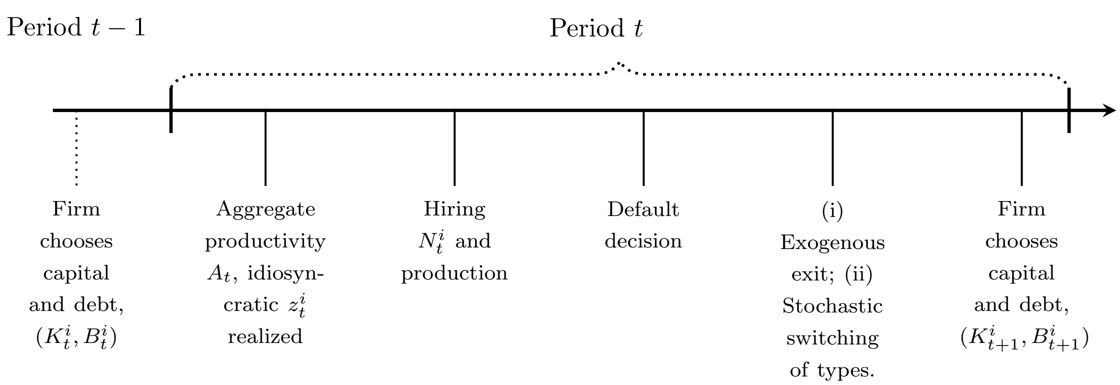
There is a unit measure of firms, indexed by $i \in [0,1]$. Firms produce output using a constant returns technology.

$$Y_t^i = \ (z_t^i K_t^i)^{\alpha} (A_t \ N_t^i)^{1-\alpha}$$

Aggregate productivity A_t follows a first order Markov process, while the idiosyncratic productivity/ return component z_t^i is an i.i.d. draw (across firms and across time) from a distribution F.

The timing of events for a firm i is displayed in Figure 2. The capital stock K_t^i is chosen at the end of the previous period. The firm needs to finance capital purchases either through their own end-of-period net worth or through debt issuance B_t^i. Crucially, the firm is not allowed to raise new equity from household to purchase capital, or equivalently, it cannot pay a negative dividend. In the beginning of the period the exogenous state s is revealed, as well as the idiosyncratic component z_t^i. The firm chooses employment N_t^i and produces output and pays wages. Then, it either repays its outstanding debt B_t^i or declares default. Upon default the firm exits the economy immediately and forfeits all claims to the firm's assets. Instead if it does repay its debt, next it is hit by an exogenous exit shock with probability σ. The share σ of non-defaulting firms that is hit by this shock is forced to exit after selling their capital and paying the proceeds to the household. Both defaulting and exiting (though non-defaulting) firms are replaced by new firms as to keep the measure of firms constant. Finally, continuing firms and new firms choose the capital stock for next period and the financing thereof. I assume that default is socially costly. Namely, a fraction θ of the output and capital stock of defaulting firms is destroyed.

Figure 2: Timeline for firm i



In departure from this standard setup, I assume that firms are heterogeneous with respect to a production cost parameter - c^{HY} (for high yield) or c^{IG} (for investment grade). I will refer to a firm's cost parameter as its "type". The production cost is linear in capital and similar to the wage payment it has to be paid before the default decision. For firm i with parameter $c_t^i \in \{c^{IG}, c^{HY}\}$, the time t production cost is $c_t^i Q_t K_{t-1}^i$ where Q_t denotes the price of capital. Importantly, the time t cost parameter of a firm can be observed by lenders at the end of time $t-1$ when the borrowing contract is written. Since the cost affects default incentives at time t, firms with different costs will face different interest rate schedules.

While the cost is linear in capital it does not depend on firm i's employment decision at time t, and thus can be seen as a fixed cost. When a firm of a certain type defaults or exits exogenously, it is replaced by a new firm of the same type. I allow for stochastic switching of types. After the default decision, but before the choice of next period's capital stock and debt, firms with type HY (IG) transition to type IG (HY) with probability p. Due to symmetric transition probabilities between types, the two types have equal shares in the population of firms.

Importantly, the draw from the idiosyncratic productivity distribution is independent of the cost type. Since the cost parameter is known prior to the capital structure choice, I refer to this heterogeneity as ex-ante heterogeneity. In contrast, idiosyncratic productivity is realized only after the capital structure has been chosen, namely in the beginning of the next period; therefore it is denoted as ex-post heterogeneity.

3.1.1 The firm's problem

One can separate the firm's problem into a static one - the optimal choice of employment -, and a dynamic one - the optimal choice of capital and the financing decision. Regarding the employment choice, consider a firm with capital stock K_t^i and idiosyncratic productivity z_t^i, and current cost type $c_t^i \in \{IG, HY\}$. It chooses employment N_t^i to maximize profits taking as given the wage W_t.

$$\Pi_t^i = \max_{N_t^i} \, (z_t^i K_t^i)^\alpha (A_t N_t^i)^{1-\alpha} - W_t N_t^i$$

The optimal choice of employment equates the marginal product of labor with the wage and yields $N_t^{i*} = \left(\frac{A_t(1-\alpha)}{W_t}\right)^{\frac{1}{\alpha}} \frac{z_t^i K_t^i}{A_t}$.[10] The resulting profits are $\Pi_t^i = \Pi_t z_t^i K_t^i$, where $\Pi_t = \alpha \left(\frac{A_t(1-\alpha)}{W_t}\right)^{\frac{1-\alpha}{\alpha}}$. Moreover, I define the gross payoff per unit of capital as the sum of profits plus the residual value of capital: $\Xi_t^i = \Xi_t z_t^i$, where $\Xi_t = \Pi_t + (1-\delta)Q_t$. As in Bernanke et al. (1999) and Christiano et al. (2014) the idiosyncratic component z_t^i also multiplies the residual value of capital, giving the idiosyncratic component the interpretation of a capital quality or return shock.

For studying the dynamic problem I define the net worth after wages, production costs, and debt repayment. Notice that the production cost $c_t^i Q_t K_t^i$ enters in the net worth equation as a cash flow cost.

$$NW_t^i = \Xi_t z_t^i K_t^i - B_t^i - c_t^i Q_t K_t^i$$

Let $V_t^{type}(NW_t^i)$ denote the value in the end of period t for a firm with net worth NW_t^i and period $t+1$ cost parameter $c_{t+1}^i = c^{type}$, $type \in \{IG, HY\}$. The firm now chooses capital K_{t+1}^i and debt B_{t+1}^i to maximize the present discounted value of dividends, using the stochastic discount factor of the household, $m_{t,t+1}$, to price future cash flows.

[10] On the balanced growth path aggregate productivity as well as capital and the wage grow at rate μ_A, therefore employment is constant.

$$V_t^{type}(NW_t^i) = \max_{\{K_{t+1}^i, B_{t+1}^i\}} \left\{ Div_t^i + \mathbb{E}\left[m_{t,t+1} \int \max(0, \bar{V}_{t+1}^{type}) dF z_{t+1}^i \right] \right\} \tag{1}$$

where the dividend paid today, Div_t^i, must be non-negative and is the sum of current net worth and new borrowing minus expenditures for capital purchases. The price of debt with face value B_{t+1}^i is $q_t^{type}(K_{t+1}^i, B_{t+1}^i)$ and is taken as given by firms.

$$Div_t^i = NW_t^i - Q_t K_{t+1}^i + q_t^{type}(K_{t+1}^i, B_{t+1}^i) B_{t+1}^i \geq 0. \tag{2}$$

Depending on the realizations of aggregate and idiosyncratic uncertainty the firm may want to default in period $t+1$. If it does so it obtains a zero payoff while continuation yields $\bar{V}_{t+1}^{type}$.

$$\bar{V}_{t+1}^{type} = (1-\sigma) \left((1-p)\, V_{t+1}^{type}(NW_{t+1}^i) + p\, V_{t+1}^{\neg type}(NW_{t+1}^i) \right) + \sigma NW_{t+1}^i \tag{3}$$

The continuation value reflects that the firm is forced to exit with probability σ in which case the net worth NW_{t+1}^i is paid as a dividend to the household. With the complementary probability it continues beyond period $t+1$, either retaining its type with probability $1-p$ or switching to the opposite type with probability p.

3.1.2 Characterizing the default decision

I now characterize the default decision and subsequently turn towards the optimal choice of capital and debt. I proceed by guess and verify that broadly follows Nuño and Thomas (2012).

I first guess that the firm's value function is linear in net worth NW_t^i and that there exists a non-negative λ_t^{type} such that

$$V_t^{type}(NW_t^i) = \lambda_t^{type} NW_t^i$$

The multiplier λ_t^{type} is a forward-looking variable summarizing the value of a dollar net worth inside the firm. It depends only on aggregate conditions and the firm-specific type for period $t+1$, but not on current idiosyncratic variables, i.e., the period t cost parameters and idiosyncratic productivity z_t^i.

Under the guess the default decision follows a simple cutoff rule. According to (1), the firm will default whenever the continuation value $\bar{V}_{t+1}^{type}$ is negative, or equivalently, whenever net worth is negative, $NW_{t+1}^i < 0$. Conditional on the aggregate state in period $t+1$, the cutoff for idiosyncratic productivity z_{t+1}^i writes as

$$z_{t+1}^i < \bar{z}_{t+1}^i = \frac{l_{t+1}^i + c_t^i Q_{t+1}}{\Xi_{t+1}}$$

where I define (book) leverage l_{t+1}^i as debt over assets $l_{t+1}^i = \frac{B_{t+1}^i}{K_{t+1}^i}$. All else equal, firms with higher leverage l_{t+1}^i have a higher likelihood of default, $F(\bar{z}_{t+1}^i)$. Moreover, conditional on leverage firms with a larger cost parameter have a higher likelihood of default as well. In fact, this feature will play a key role in the pricing of debt and the capital structure choice.

3.1.3 Characterizing the debt and capital choice

In the appendix I show that under the guess for the value function the dynamic problem (1) can be restated as a problem with the choice variables leverage l^i_{t+1} and capital growth $\iota^i_{t+1} = \frac{K^it+1}{K^i_t}$. The solution consists of a first order condition for leverage and a corner solution for capital growth. First, the optimality condition for leverage choice l^i_{t+1} balances the benefits and costs of debt issuance.

$$
\begin{aligned}
[l^i_{t+1}:]\ \lambda^{type}_t & \left(q^{type}_t(l^i_{t+1}) + \frac{\partial q^{type}_t(l^i_{t+1})}{\partial l^i_{t+1}} l^i_{t+1} \right) \\
& - \mathbb{E}\left[m_{t,t+1}(1 - F(\bar{z}^i_{t+1}))((1-\sigma)((1-p)\lambda^{type}_{t+1} + p\lambda^{\neg type}_{t+1}) + \sigma) \right] = 0. \qquad (4)
\end{aligned}
$$

While the second term reflects the expected discount repayment tomorrow, the first term summarizes the benefits and cost of debt today. More debt allows purchasing more capital but it also changes the price of debt via expected default risk, $\frac{\partial q^{type}_t(l^i_{t+1})}{\partial l^i_{t+1}} < 0$. Notice that the first order condition does not depend on the current realization of idiosyncratic productivity z^i_t, but only on the expectation over future values z^i_{t+1}. This means that the capital structure choice will be the same for all firms that share the same cost type for period $t+1$, but firms with different cost types may choose different capital structures. I denote the leverage decision for each type as l^{type}_{t+1}.

Second, the firm sets ι^i_{t+1} as high as possible, the only constraint being the requirement for non-negative dividends. Thus, the firm retains all earnings to purchase more capital rather than paying out dividends to the household.

$$
\iota^i_{t+1} = \frac{nw^i_t}{Q_t - q^{type}_t(l^{type}_{t+1}) l^{type}_{t+1}} \qquad (5)
$$

In contrast to the leverage decision the acquisition of capital does depend on the realization z^i_t. Firms with a higher z^i_t and higher net worth $nw^i_t = \frac{NW^i_t}{K^i_t}$ and can buy more capital. The interpretation of the denominator is the fraction of assets that is financed with internal funds.

This concludes the description of the firm's static and dynamic problems.

3.2 Financial intermediaries

Competitive financial intermediaries channel funds from savers (households) to borrowers (firms). I assume that the firm's debt is non-contingent, thus the promised repayment cannot be conditioned on aggregate or idiosyncratic productivity. The financial contract is motivated by a costly state verification problem in which lenders are unable to observe the idiosyncratic realization z^i_{t+1} unless they pay a monitoring cost. Since I assume that lenders recover none of the firm's assets in case of default the implicit monitoring cost is 1 (private cost of default).[11] Notice, however, that assets and output of defaulting firms are not destroyed in default. Rather they are seized by the government and rebated to the household net of a fraction $\theta \leq 1$ (deadweight loss or social cost of default).

Due to the above assumption the price of debt with face value B^i_{t+1} issued by a firm with capital stock K^i_{t+1} and cost type c^{type} simply reflects the default probability: $q^{type}_t(K^i_{t+1}, B^i_{t+1}) = \mathbb{E}\left[m_{t,t+1}\left(1 - F\left(\bar{z}^i_{t+1}\right)\right)\right]$. Notice that capital K^i_{t+1} and B^i_{t+1} enters the price of debt only as a ratio via the default threshold $\bar{z}^i_{t+1}$. That is the price of debt can be expressed as a function of leverage alone. $q^{type}_t(l^i_{t+1}) = \mathbb{E}\left[m_{t,t+1}(1 - F(\bar{z}^i_{t+1}))\right]$

Intermediaries raise deposits from household to fund their lending activity. Deposits are non-contingent debt contracts that are due in the end of period $t+1$ and that pay the risk-free interest rate r_t. The risk-free rate will be determined through the households Euler equation, $1 = \mathbb{E}[m_{t,t+1}(1 + r_t)]$, and it is taken as given by intermediaries.

Competition among intermediaries drives expected profits to zero, i.e., in equilibrium

$$\mathbb{E}\left[m_{t,t+1}\left\{(1 - F(\bar{z}^i_{t+1}))q^{type}_t(l^i_{t+1})^{-1} - (1 + r_t)\right\}\right] = 0. \tag{6}$$

The interest rate on corporate debt $q^{type}_t(l^i_{t+1})^{-1}$ is a spread over the risk-free rate that reflects expected default risk. It is increasing with leverage for a given cost parameter c^{type}. Moreover, conditional on leverage firms with a higher cost parameter pay a higher interest rate, i.e., their entire interest rate schedule is shifted upwards.

While expected profits of intermediaries are always zero, realized profits are zero only in steady state. With aggregate uncertainty, profits can be positive or negative and will be disbursed to the household. Let D_t (for deposits) denote the amount of deposits raised in the previous period, then

$$\Pi^{Int}_t = \int_0^1 B^i_t \mathbb{I}_{\{z^i_t \geq \bar{z}^i_t\}} di - (1 + r_{t-1})D_t$$

where the first term reflects debt repayments from non-defaulting firms. The cash flows from newly raised deposits and new corporate debt always balance each other.

3.3 Labor agencies

Firms hire workers via monopolistically competitive labor agencies. Each firm i uses a Dixit-Stiglitz composite of different labor varieties $N^i_t = \left(\int_0^1 (n^i_{g,t})^{\frac{\epsilon_W - 1}{\epsilon_W}} dg\right)^{\frac{\epsilon_W}{\epsilon_W - 1}}$, where $n^i_{g,t}$ is the amount of the variety provided by agency $g \in [0, 1]$. Each labor agencies purchases raw labor services from the household at price $\tilde{W}_t$ and costlessly differentiates raw labor into its respective variety g. Then, it sells the specialized labor variety to firms at price $W_{g,t}$.

[11] The recovery value of zero helps generating realistic default rates and credit spreads at the same time. In this class of models corporate credit spreads are determined through expected default costs alone, and a high recovery value does not yield sizeable credit spreads with the empirically observed low default rates. In Del Negro et al. (2003), for instance, the calibrated default rate is relatively high with 3% annually, while the estimated credit spread is only 111 bps.

The resulting labor demand from firm i for variety g is $n^i_{r,t} = \left(\frac{W_{g,t}}{W_t}\right)^{-\epsilon_w} N^i_t$. Aggregating over all firms yields

$$n_{g,t} = \left(\frac{W_{g,t}}{W_t}\right)^{-\epsilon_w} N_t$$

where $n_{g,t} = \int_0^1 n^i_{g,t} di$ and $N_t = \int_0^1 N^i_t di$. The wage index for composite labor, W_t, is defined by $W_t N_t = \int_0^1 W_{g,t} n_{g,t} dg$. Plugging in labor demand this yields $W_t = \left(\int_0^1 W_{g,t}^{1-\epsilon_w} dg\right)^{\frac{1}{1-\epsilon_w}}$.

Labor agencies take as given labor demand from firms and choose the price of their labor variety to maximize the present discounted value of profits, using the household's stochastic discount factor between periods t and $t+j$, $m_{t,t+j}$. Labor agencies can adjust the price of the labor variety only infrequently. Every period a random fraction $1-\lambda_w$ of agencies is allowed to freely reset their price $W_{g,t}$, while the complementary fraction λ_w has to retain the price from last period. When the agency can reset its price it takes into account all future states in which it is stuck with the current price. I assume that the wage mark-up over marginal costs is corrected by a subsidy ν_w.[12]

$$\max_{W^*_{g,t}} \mathbb{E}\left[\sum_{j=0}^{\infty} \lambda_w^j m_{t,t+j} \left(W^*_{g,t} n_{g,t+j} - \tilde{W}_{t+j}(1-\nu_w) n_{g,t+j}\right)\right]$$

The first-order condition for the optimal reset price $W^*_{g,t}$ is

$$\mathbb{E}\left[\sum_{j=0}^{\infty} \lambda_w^j m_{t,t+j} N_{t+j} W_{t+j}^{\epsilon_w} \left(W^*_{g,t} - \tilde{W}_{t+j}\right)\right] = 0$$

where the input subsidy ν_w has been set to $\nu_w = \frac{1}{\epsilon_w}$ as to eliminate the mark-up over marginal costs. The reset price is symmetric for all firms which are able to reset, such that $W^*_{g,t} = W^*_t$, $\forall g$. Finally, the wage index W_t writes as

$$W_t = \left[(1-\lambda_w)(W^*_t)^{1-\epsilon_w} + \lambda_w (W_{t-1})^{1-\epsilon_w}\right]^{\frac{1}{1-\epsilon_w}}$$

If $\lambda_w = 0$ all labor agencies can reset the wage every period and the wage is fully flexible. This special case is equivalent to a centralized labor market in which households and firms interact directly and the wage clears the market. Finally, profits of labor agencies, $\Pi^{LA}_t = \left(W_t - (1-\nu_w)\tilde{W}_t\right) N_t$ are rebated to the household.

[12] Due to market power agencies set the price of their variety as a mark-up over marginal costs, i.e., the compensation $\tilde{W}_t$ paid to the household, implying that labor in equilibrium would be lower than under perfect competition. This inefficiency is not central to the analysis I assume that unions receive a subsidy that resolves the inefficiency and leads to optimal output in steady state. For every unit of labor purchases from the household the agency pays only $(1-\nu_w)\tilde{W}_t$. The subsidy is financed through lump-sum taxes.

3.4 Representative household

The representative household maximizes the present discount utility $\sum_{\tau=t}^{\infty} \beta^{\tau-t} U(C_\tau, L_\tau)$ by choosing consumption C_t, labor supply L_t, and savings in deposits D_{t+1}. The choice is subject to the following budget constraint.

$$\tilde{W}_t L_t + D_t(1 + r_{t-1}) + \Pi_t + Div_t \geq C_t + D_{t+1} + T_t$$

Labor is supplied to the employment agencies and compensated at rate $\tilde{W}_t$. Savings in deposits from last period pay the risk-free rate r_{t-1}. Besides, the household is the recipient of profits from capital producers, financial intermediaries, and labor agencies: $\Pi_t = \Pi_t^{CP} + \Pi_t^{Int} + \Pi^{LA}$. Moreover, the household pays lump-sum taxes T_t and receives dividends of exiting firms Div_t. The optimality conditions for the household consists of the Euler equation for deposits, $1 = \mathbb{E}[m_{t,t+1}(1 + r_t)]$, where $m_{t,t+1} = \beta \frac{U_C(C_{t+1}, L_{t+1})}{U_C(C_t, L_t)}$. The labor-consumption trade-off writes as $-\frac{U_L(C_t, L_t)}{U_C(C_t, L_t)} = \tilde{W}_t$. Since the household cannot inject equity into firms there are no firm specific variables in the household's problem, and accordingly no asset pricing equation for equity shares.

3.5 Capital producers

Capital producers take the price of capital goods, Q_t, as given, and buy I_t units of the output good to produce new capital. Their production technology $\Phi\left(\frac{I_t}{K_t}\right)$ features positive, but decreasing returns ($\Phi' > 0, \Phi'' < 0$), and output of new capital goods is $\Phi\left(\frac{I_t}{K_t}\right) K_t$. The problem of capital producers is given by

$$\Pi_t^{CP} = \max_{I_t} \left\{ Q_t \Phi\left(\frac{I_t}{K_t}\right) K_t - I_t \right\}.$$

The first order condition yields the optimal investment rate as a function of the price of capital.

$$Q_t = \frac{1}{\Phi'\left(\frac{I_t}{K_t}\right)}$$

3.6 Government

The government collects profits and capital net of depreciation from defaulting firms, whereof a fraction θ is lost as a deadweight cost of default. On the expenditure side the government pays the input subsidy ν_w to labor agencies. The government balances the budget period-by-period through lump-sum taxes T_t - or transfers if the balance is positive.

$$T_t = \nu_w \tilde{W}_t N_t - (1 - \theta) \int_0^1 (Y_t^i + (1 - \delta) Q_t K_t^i z_t^i) \mathbb{I}_{\{z_t^i \leq \bar{z}_t^i\}} di$$

3.7 Aggregation and equilibrium

The resource constraint of this economy is

$$Y_t = C_t + I_t$$

where Y_t is output net of deadweight loss of defaulting firms.

$$Y_t = \int_0^1 Y_t^i \left\{ \mathbb{I}_{\{z_t^i \geq \bar{z}_t^i\}} + (1-\theta)\mathbb{I}_{\{z_t^i < \bar{z}_t^i\}} \right\} di$$

The law of motion for capital writes as

$$K_{t+1} = \int (1-\delta) K_t^i \left(\mathbb{I}_{\{z_t^i \geq \bar{z}_t^i\}} + (1-\theta)\mathbb{I}_{\{z_t^i < \bar{z}_t^i\}} \right) di + \Phi\left(\frac{I_t}{K_t}\right)$$

Dividend payments to the household come from the share σ of non-defaulting firms that are forced to exit exogenously. Each of these firms has positive net worth NW_t^i and pays it out to the household, $Div_t^i = NW_t^i$. Therefore, aggregate dividends are

$$Div_t = \sigma \int_0^1 NW_t^i \mathbb{I}_{\{NW_t^i \geq 0\}} di.$$

Conceptually, the economy features two representative firms indexed by their $type \in \{IG, HY\}$. Each such stand-in firm represents the measure of firms that share the same cost parameter (after transitions) and therefore chooses the same leverage each period. There is heterogeneity within each stand-in firm due to the idiosyncratic productivity component z_t^i and different levels of capital and net worth. However, the exact distribution of capital and net worth is irrelevant for equilibrium dynamics.

I therefore denote as NW_t^{type} the net worth in the end of period t of all firms with period $t+1$ cost parameters c^{type}.

$$NW_t^{type} = (1-\sigma) \int_0^1 NW_t^i \mathbb{I}_{\{c_{t+1}^i = c^{type}, z_t^i \geq \bar{z}_t^i\}}, \quad type \in \{IG, HY\}$$

Notice that NW_t^{type} encompasses net worth from all firms i for which either (i) $c_{t+1}^i = c_t^i = c^{type}$, or (ii) $c_t^i = c^{\neg type}$, but $c_{t+1}^i = c^{type}$. The share of type-switching firms is given by the switching probability p. The parameter therefore determines how changes in net worth in among one type of firms spill over to the other type.

Moreover, the aggregation of equation (5) yields total capital among firms with period $t+1$ cost parameters c^{type}, denoted as K_{t+1}^{type}:

$$K_{t+1}^{type} = \frac{NW_t^{type}}{Q_t - q_t^{type}(l^{type}) l^{type}}, \quad type \in \{IG, HY\} \tag{7}$$

The aggregate state S_t consists of (i) aggregate productivity, (ii) the distribution of debt and capital over firms with cost parameters IG and HY, (iii) the wage W_{t-1}, and it is denoted as $S_t = \{A_t, \{l_t^{type}, K_t^{type}\}_{type \in \{IG,HY\}}, W_{t-1}\}$. In equilibrium all agents behave optimally and the markets for labor, capital and deposits clear.

4 Quantitative analysis

In this section I calibrate the model using the sample of rated Compustat firms. Investment grade firms and high yield firms are distinguished through the different cost types c^{IG} and c^{HY}. I evaluate the model fit against the estimated employment elasticities, and I study alternative forms of firm heterogeneity and aggregate uncertainty.

4.1 Functional forms and parameter choices

The time period is a quarter. Aggregate productivity A_t follows an AR(1) process along a deterministic growth trend μ_A.

$$\log A_t = \mu_A + \log A_{t-1} + a_t$$

where $a_t = \rho_a a_{t-1} + \eta_{a,t}$ and $\eta_{a,t} \sim \mathcal{N}(0, \sigma_a^2)$. The target for μ_A is the annual growth rate of per capital real GDP between 1966Q1 and 2012Q4, 1.63%. Given the trend growth rate I set the discount factor β to 0.994 to obtain an annual risk-free rate on the balance growth path of 4%.[13]

The household utility function is separable in consumption and labor, $U(C_t, L_t) = \frac{C_t^{1-\gamma}}{1-\gamma} - \chi e^{(1-\gamma)\mu_A} \frac{L_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}}$. I set the risk aversion parameter γ to 1, and the elasticity of labor supply η to 0.5. The relative disutility of labor, χ, scales the size of the economy and is set to obtain steady state output $\bar{Y}$ of 1.

The capital share in the production function is set to $\alpha = 0.33$, and the depreciation rate is chosen as 10% annually. For the production function of new capital I follow Jermann (1998) and specify $\Phi\left(\frac{I_t}{K_t}\right) = \frac{\varphi_2}{1-\varphi_1}\left(\frac{I_t}{K_t}\right)^{1-\varphi_1} + \varphi_3$.[14] Parameters (φ_2, φ_3) are set to yield a steady state investment rate $\frac{\bar{I}}{\bar{K}}$ of 2%, and a steady state price of capital $\bar{Q}$ of 1. The elasticity of the price of capital with respect to the investment rate, $\varphi_1 > 0$, regulates the importance of adjustment costs of capital. High adjustment costs imply less volatile investment, but a more volatile price of capital and therefore more net worth volatility. There is some disagreement in the literature about the admissible range of values. I follow Bernanke et al. (1999) with $\varphi_1 = 0.25$, noting that this value delivers a better fit for the relative volatility of investment than the value of 2.5 used by Guvenen (2009). The deadweight cost of default θ is set to 0.15 which is close to the value in Bernanke et al. (1999).

The switching probability between firm types, p, is related to the incentives for capital accumulation and determines how quickly a shock to the net worth of one firm type spills over to the other type. I set $p = 0.5$, implying a steady state employment share of high yield firms of about 55%.

The Calvo parameter $\lambda_w = 0.75$ implies that wages are set on average every year. Thus, the reset probability is somewhat larger than the estimated value from Smets and Wouters (2007) and Christiano et al. (2005), yet smaller than the value by Christiano et al. (2014).

[13]The assumption of trend growth in TFP implies that the following variables grow at rate μ_A: Y_t, C_t, I_t, $\{K_t^{type}\}_{type\in\{IG,HY\}}$, $\{NW_t^{type}\}_{type\in\{IG,HY\}}$, W_t, D_t, T_t. I redefine detrended variables as $\tilde{X}_t = X_t e^{-t\mu_A}$.

[14]The optimal investment rate under this specification satisfies $\frac{I_t}{K_t} = (Q_t\varphi_2)^{\frac{1}{\varphi_1}}$.

I now discuss the set of parameters that are jointly calibrated in the steady state. The distribution of the idiosyncratic productivity shock, $F(z_t^i)$, is assumed to be log-normal, $\log z_t^i \sim \mathcal{N}\left(-\frac{1}{2}\sigma_z^2, \sigma_z^2\right)\ \forall i$. I normalize the cost parameter for high yield firms $c^{HY} = 0$. The dispersion parameter σ_z, together with the remaining cost parameter c^{IG} and the exit probability σ jointly determine (i)/(ii) the credit spreads for investment grade and high yield firms, and (iii) the average level of leverage.

Table 3: Parameters and targets

Parameter	**Value**	**Description**	**Target**
β	0.994	Discount factor	Risk-free rate 4% ann.
μ_A	0.004	Trend growth rate	GDP growth 1.63% ann.
γ	1	Risk aversion	Standard
η	0.5	Elasticity of labor supply	Standard
α	0.33	Capital share	Standard
δ	0.026	Depreciation rate	10% ann.
θ	0.15	Social cost of default	Bernanke et al. (1999)
φ_1	0.25	Elasticity of Q w.r.t. $\frac{I}{K}$	Bernanke et al. (1999)
p	0.5	Switching probability	Types i.i.d. ex-ante
λ_w	0.75	Calvo parameter labor	Av. wage duration 1 year
χ	4.99	Disutility of labor	$\bar{Y} = 1$
φ_2, φ_3	0.40,-0.004	Investment technology	$\bar{Q} = 1$, $\bar{I}/\bar{K} = 0.02$
σ	0.10	Exogenous exit	$\bar{l}^{av} = 0.63$
σ_z	0.19	Disp idiosyncratic shock	HY spread 367 bps
c^{HY}, c^{IG}	0 , 0.03	Cost parameter	IG spread 155 bps

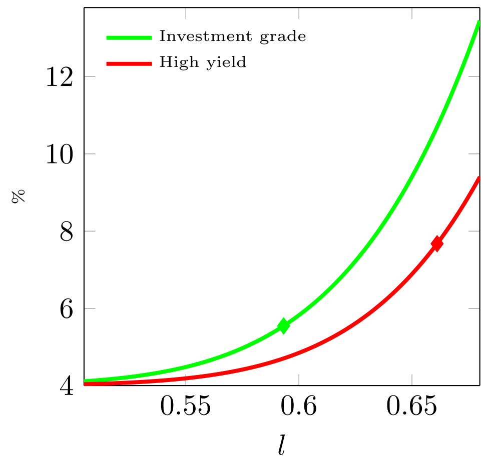
4.2 Steady state properties

The interest rate schedules for investment grade and high yield firms illustrate how the production cost drives a wedge between the credit costs of the two types (Figure 3). Conditional on leverage investment grade firms borrow at a higher interest rate, yet in equilibrium, they use debt more cautiously. With lower leverage, they pay lower interest rates and have lower default probabilities.

The calibrated cost parameter for investment grade firms is $c^{IG} = 0.03$. Thus, the cost is 3% of total assets value or 6.3% of firm value. This is high relative to the pre-bankruptcy distress costs in Elkamhim et al. (2012), which are reported as 1-2% of firm value. Notice however, that the cost parameter serves as a stand-in for various frictions and features that are not explicitly modeled. For instance, some of the difference in debt and default risk between investment grade and high yield firms may be related to legacy debt, or else the firm's debt levels may adjust only slowly to some target due to adjustment costs, etc.

Table 4 reports steady state moments for the two types of firms. The credit spreads of 155 bps and 367 bps (in italics) were targeted. As discussed earlier the default rates in the model mirror the borrowing costs. In the data one-year default rates of investment grade firms are much lower and, in fact, very close to zero. On the one hand, firms are usually downgraded before defaulting and thus few recorded defaults occur while a firm has an investment grade

Figure 3: Annualized interest rate



Note: Red (green) line shows interest rate schedule of high yield (investment grade) firms. Markers show actual leverage choice and corresponding interest rate in steady state.

rating. On the other hand, high credit spreads despite low default rates indicate that credit spreads contain a premium over the actual default risk.

The implied difference in leverage is 0.07 and comes close to the difference of 0.1 in the data. The success in matching leverage will allow to closely examine the driving forces behind cyclical sensitivities. Namely, in an extension of the model (see 4.5) I will study a case in which the leverage is counterfactually low among high yield firms. There are no productivity differences between the two types in the model, however the return on assets differs due to the higher cost of capital by yield firms. The profit differential is not as pronounced as in the data, indicating that there may be technological differences between investment grade and high yield firms.

The level of the cross-sectional equity return dispersion is much higher in the model than in the data. This is in line with the results by Christiano et al. (2014)[15]. Aside from the level, the model generates higher dispersion among high yield firms. In section D.2 of the appendix I show that return dispersion in the model consists of two components: First, the dispersion of idiosyncratic productivity, σ_z, which is the same for high yield and investment grade firms. Second, on a term related to the leverage of the firm. It is this second term which gives the more leveraged high yield firms greater equity return dispersion.

4.3 Impulse response to a productivity shock

I explore the model dynamics with an impulse response to a 0.5% aggregate productivity shock. Aggregate variables (rows 1&2) respond as in standard DSGE models, i.e., output, consumption, investment, employment, and wages fall, while the risk free rate rises. Notice that under flexible wages (rows 1&2, dash-dotted line) employment does barely decline due to the wealth effect on labor supply. Wage rigidity undoes this effect by preventing the quick downward adjustment of the wage. Consequently, the fall in aggregate variables is more

[15] See their Figure 7 on page 60.

Table 4: Steady state properties

	Data		Model	
	Investment	**High yield**	**Investment**	**High yield**
Financing				
Credit spreads	*155 bps*	*367 bps*	*155 bps*	*367 bps*
Default rate (% ann.)	0.14	4.49	1.52	3.56
Leverage	0.58	0.68	0.59	0.66
Productivity				
TFP	0.037	-0.033	0	0
Return on assets	0.14	0.07	0.31	0.29
Difference	$\Delta = 0.07$		$\Delta = 0.02$	
Risk				
Equity return dispersion	0.17	0.32	0.47	0.52
Difference	$\Delta = 0.15$		$\Delta = 0.05$	

Notes: Compustat Fundamentals Annual and CRSP. Targeted moments in italics. Default rates for investment grade and non-investment grade firms are average default rates on corporate bonds between 1981 and 2011 (see 2011 Annual US Corporate Default Study by S&P, the average includes financial firms). In the Compustat data, leverage is total liabilities over total assets, return on assets is operating income before depreciation (`OIBDP`) minus interest expenses (`XINT`) over total assets. TFP is the residual of a regression of sales (`SALE`) on employment (`EMP`) and capital (`PPEGT`) by year and 3-digit NAICS industry. In the model, leverage is debt relative to capital. Return dispersion is the standard deviation of quarterly equity return (includes dividends).

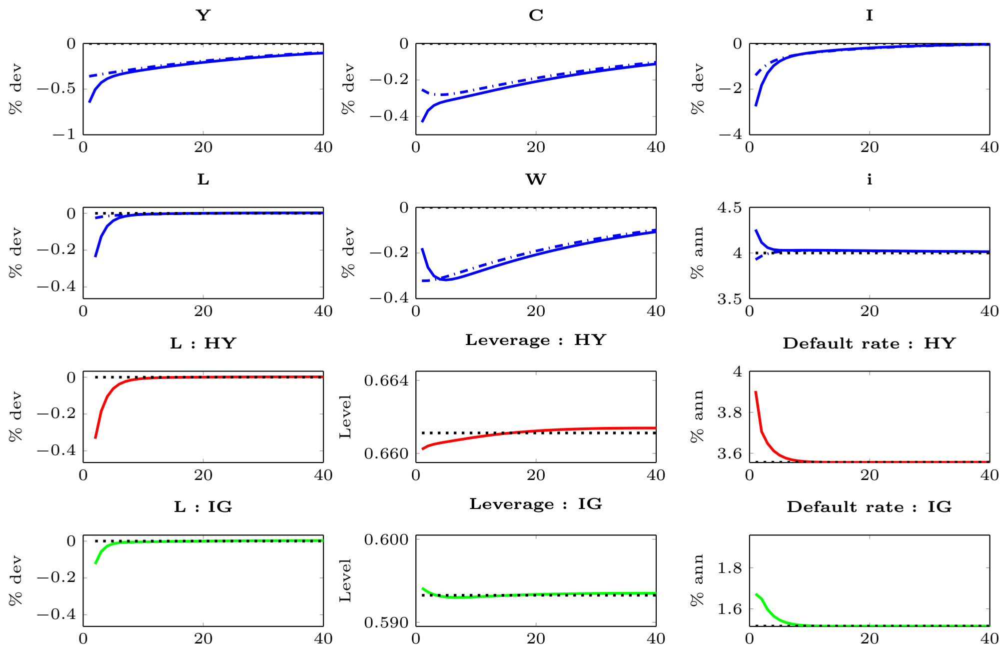
pronounced with rigid wages.

The responses of high yield and investment grade firms are in stark contrast (rows 3&4). With the fall of productivity and asset prices the interest rates on corporate debt rise due to heightened default risk. Under the assumption for idiosyncratic productivity, this increase in borrowing costs is more pronounced at high yield firms. Also, the net worth multiplier which serves as a model-based measure for the severity of constraints rises most for high yield firms (not shown).

With the precipitous increase in borrowing costs high yield firms also have the larger benefits from deleveraging. They divest assets and reduce debt in order to rebalance their capital structure. Investment grade firms on the other side increase leverage slightly and increase their capital holdings. This response has to be seen in the general equilibrium context. Namely, due to capital adjustment costs at the aggregate level, total capital falls only mildly in a recession, yet high yield firms have very strong incentives to divest. In equilibrium the drop in asset prices makes capital attractive for investment grade firms. Accordingly, they absorb some of the capital that is shed by high yield firm and finance these purchases through debt issuance. Aggregate leverage, i.e., total debt to total assets, falls in response to the negative aggregate productivity shock (not shown).

These divergent responses are also reflected in employment. High yield firms reduce employment precipitously, while investment grade firms slightly increase employment relative to steady state. Thus, both production factors, capital and labor, shift from financially more constrained high yield firms to less constrained investment grade firms.

Figure 4: Impulse response for negative productivity shock (0.5%)



Note: Impulse response to a 0.5% productivity shock. Log productivity follows an AR(1) process with autocorrelation $\rho_a = 0.95$. Rows 1&2 show responses of aggregate variables. Rows 3&4 show responses for high yield and investment grade firms. In rows 1&2 solid line displays IRF with rigid wages, $\lambda_W = 0.75$. Dash-dotted line displays IRF with flexible wages, $\lambda_W = 0$ (-·-·-).

4.4 Employment elasticities revisited

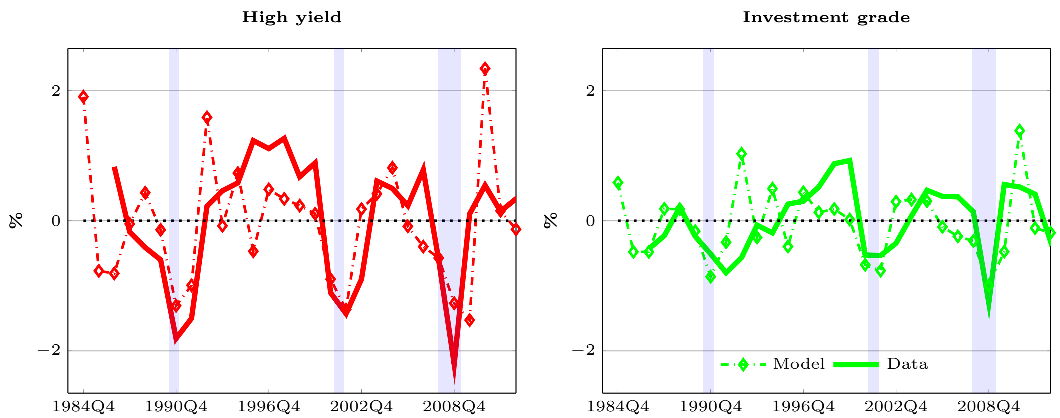
I go one step further and ask whether the model can reproduce the employment elasticities estimated from the micro data (Table 2). An affirmative answer would underscore the relevance of this class of models for aggregate dynamics as well as selected aspects of cross-sectional dynamics.

For this exercise I infer aggregate productivity shocks such that the model replicates the dynamics of US real GDP,[16] and I extract the implied employment series for the two types of firms. Figure 5 graphs these series alongside employment growth of Compustat firms. Comparing the left and the right panel we see that the more constrained high yield firms grow faster in expansions and decline sharper in downturns. It is striking that the model can replicate the differential drop of employment growth during the three recessions. The main deviation of the model employment series is the too quick recovery after the 1990-1991 and 2008-2009 recessions, particularly among the more constrained firms. Also, real GDP dynamics do not mirror the employment boom among public firms in the late 1990s and mid-2000s. This suggest that rated public firms may have received more favorable shocks in these phases than the economy as a whole.

Next, I regress employment growth in the model (aggregated to yearly frequency) on output growth, a high yield dummy, and the interaction of this dummy with output growth. Table 5 shows that the baseline specification comes close in matching the employment elas-

[16] The observable in this procedure is real GDP in deviations from a linear trend. See Figure E.1 and section E in the appendix for details.

Figure 5: Model fit - Employment growth



Note: Data series (solid) as in Figure 1, mean employment growth rate for firms with investment grade/ non-investment grade rating. Model series (dash-dotted).

ticities from the data (column (2) from Table 2, controls for time-industry effects). Both the coefficients on output growth and on the interaction with the high yield dummy are positive and significant.[17] The model's ability to match both the aggregate employment dynamics and the greater cyclicality of high yield firms is the product of three key ingredients: First, the wage rigidity which permits aggregate employment to drop noticeably in recessions; second, the endogenous price of debt which induces greater capital and employment adjustments at high yield firms; finally, the production cost that is denominated in units of capital and therefore behaves procyclically. I proceed by repeating the inference exercise in three different scenarios and I re-estimate the elasticities from the model-implied series. For each scenario the model dynamics are altered relative to the baseline scenario while the steady state remains unchanged.

Table 5: Employment growth cyclicality - Key model features

	$\Delta Employment_{i,t}$				
	Data	**Baseline**	**Flexible wage**	**Credit spread fix**	**Output cost**
ΔY_t	0.117***	0.171*	-0.018	0.374***	0.210***
	(5.61)	(2.45)	(-1.19)	(5.33)	(3.04)
$HY_{i,t-1} \times \Delta Y_t$	0.166***	0.177**	0.112***	-0.201**	0.106
	(5.12)	(1.79)	(5.33)	(-2.10)	(1.08)

Notes: Data column reports the regression results from Table 2, column (2). Model regressions use inferred series from the estimation, time span 1986Q1 to 2012Q4, transformed into annualized growth rates. Values in parentheses are t statistics computed using robust standard errors. (***/**/*) indicate significance at the (1/5/10) percent level.

As indicated in the impulse response in Figure 4 under flexible wages aggregate employ-

[17]The coefficient on high yield dummy itself (not reported) is not significant since both types of firms have zero employment growth in the long run. The trend growth rate μ_A does not affect the regression since employment is constant along the balanced growth path. Since there are differences in TFP between the two types I omit TFP in the model-based regressions.

ment falls only by little in response to an aggregate productivity shock. This observation is echoed in the regressions results with the inferred employment series under flexible wages, $\lambda_w = 0$. Namely, the HY-dummy still indicates substantial higher cyclicality at high yield firms, yet the coefficient on output growth becomes negative. The latter reflects that employment at investment grade firms in fact becomes countercyclical due to the strong response of high yield firms. In summary, this experiment demonstrates that wage rigidity helps reconciling the model with aggregate employment dynamics, but is not instrumental in generating the qualitative difference in the responses of high yield and investment grade firms. Notice also that the volatility of wages (relative to the volatility of productivity) is 0.83 under rigid wages (with $\lambda_w = 0.75$), and therefore in the range of values that can be derived from aggregate data.

The central decision problem in the model is the firm's debt choice (see equation (4)). Firms trade-off the benefits of debt against the agency cost of borrowing, the latter being summarized by the external finance premium which is increasing in debt. In the column "Credit spread fix" I explore the model dynamics when this link is cut off. To be precise, I assume that borrowing costs remain fixed at the calibrated steady state credit spreads. Yet, with a constant borrowing cost the debt choice (4) does not have a well-defined solution. I therefore assume throughout this exercise that firms maintain leverage as in the steady state of the baseline scenario. The resulting employment elasticities in this modified setup are very much in contrast to the baseline setup. The elasticity of employment growth with respect to output growth is still positive and significant, yet the coefficient on the high yield interaction term turns negative. That means in a recession investment grade firms would actually reduce employment by more than high yield firms. This pattern emerges because under a fixed credit spread more leveraged firms benefit more from the drop in asset prices.

In the baseline setup the production cost is denominated in units of capital and thus comoves with the price of capital goods Q_t. This captures the idea of a net present value cost as in the analysis by Elkamhim et al. (2012). Effectively, in a boom when firm values are high the associated cost that induces firms to use debt cautiously also rises in sync. In fact, it rises somewhat less than the firm value due to leverage. In the column "Output cost" I explore the model dynamics when the cost is instead denominated in terms of the output good. This would be relevant, for instance, if the difference between firms was in their tax rates or in the tax advantage of debt. Tax rates are time-invariant, that is they do not fall in recessions and thus the cost as a share of firm value would become more countercyclical. As it is investment grade firms which face the larger cost, they are hit harder than under the baseline scenario and reduce capital and employment much sharper. In consequence, the estimated employment elasticity with respect to GDP growth increases and the difference between high yield and investment grade firms shrinks and loses statistical significance.

4.5 Risk heterogeneity and the role of leverage

The assumption of cost types aims at replicating the differences in credit spreads as investment grade firms - the high cost type - are more cautious about using debt financing. As shown in Table 4 the model-implied differences in leverage come very close to their empirical counterpart. Yet, high yield firms not only pay higher interest rates and have higher debt levels, but they also have higher equity return dispersion which the model was unable to match. In this section I focus on this feature of the data, and I introduce differences in the dispersion of the idiosyncratic productivity shock to match the difference in equity return dispersion.[18] Notice that I study implications of the difference of cross-sectional dispersion between two groups of firms, not time-variation in volatility. The latter will be addressed in an extension of the model in section 4.5. Finally, section B in the appendix discusses the role of productivity differences between investment grade and high yield firms.

In departure from the baseline economy, I assume that firms differ along two dimensions. They have (i) a type-specific cost c^{type}, and (ii) a type-specific dispersion of idiosyncratic productivity σ_z^{type}. Still, there are only two types of firms, i.e., high yield firms with parameters (c^{HY}, σ_z^{HY}) and investment grade firms with parameters (c^{IG}, σ_z^{IG}). As high yield and investment grade firms draw their idiosyncratic productivity realizations from different distributions, their decisions about debt issuance and capital accumulation will be altered. Accordingly, the stationary equilibrium will change relative to the baseline economy.

Table 6: Steady state - Cost & Risk heterogeneity

	Data		**Model**	
	Investment	**High yield**	**Low risk**	**High risk**
Financing				
Credit spreads	*155 bps*	*367 bps*	*155 bps*	*367 bps*
Default rate (%)	0.14	4.49	1.52	3.56
Leverage	0.58	0.68	0.71	0.48
Productivity				
TFP	0.037	-0.033	0	0
Return on assets	0.16	0.11	0.28	0.26
Difference	$\Delta = 0.05$		$\Delta = 0.02$	
Risk				
Equity return dispersion	0.17	0.32	0.44	0.59
Difference	$\mathit{\Delta = 0.15}$		$\mathit{\Delta = 0.15}$	

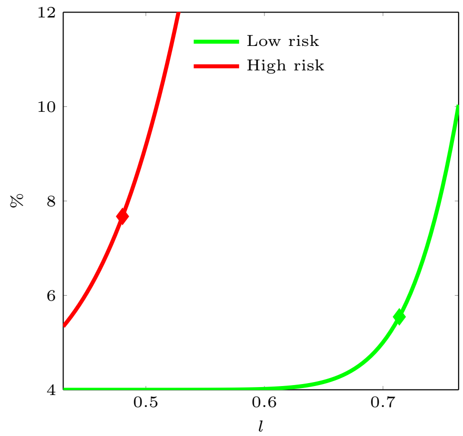
Notes: Compustat Fundamentals Annual and CRSP. Targeted moments in italics. See notes to Table 4.

I again normalize the cost of high yield firms to zero, $c^{HY} = 0$. The key parameters in the joint calibration are the exogenous exit probability, σ, the production cost of investment grade firms, c^{HY}, and the two dispersion parameters σ_z^{HY} and σ_z^{IG}. In addition to the previous target moments I use the difference of equity return dispersion among high yield and investment grade firms: $std(R^{eq,HY}) - std(R^{eq,IG}) = 0.15$. In comparison to the baseline economy, the calibrated value for the exit probability declines, $\sigma = 0.09$, as does the production cost of investment grade firms, $c^{IG} = 0.02$. The productivity dispersion for high yield firms, $\sigma_z^{HY} = 0.31$, is more than twice as large as the investment grade dispersion, $\sigma_z^{IG} = 0.13$.

[18] Aside from the specific application to rated firms here, there is a more general interest in firm-level volatility in different groups of firms. With respect to employment growth, for instance, Davis et al. (2006) document that firm-level volatility has evolved differently for private and public firms, and starting with Dunne et al. (1989) the dependence of volatility on firm size and age is well documented.

Moreover, Table 6 displays the new steady state moments among which leverage at low risk, investment grade firms (see column "Low risk") stands out as counterfactually large.

Figure 6: Annualized interest rate



Note: Red line shows interest rate schedule of high yield, high risk firms, green line shows schedule for investment grade, low risk firms. Markers show actual leverage choice and corresponding interest rate in steady state.

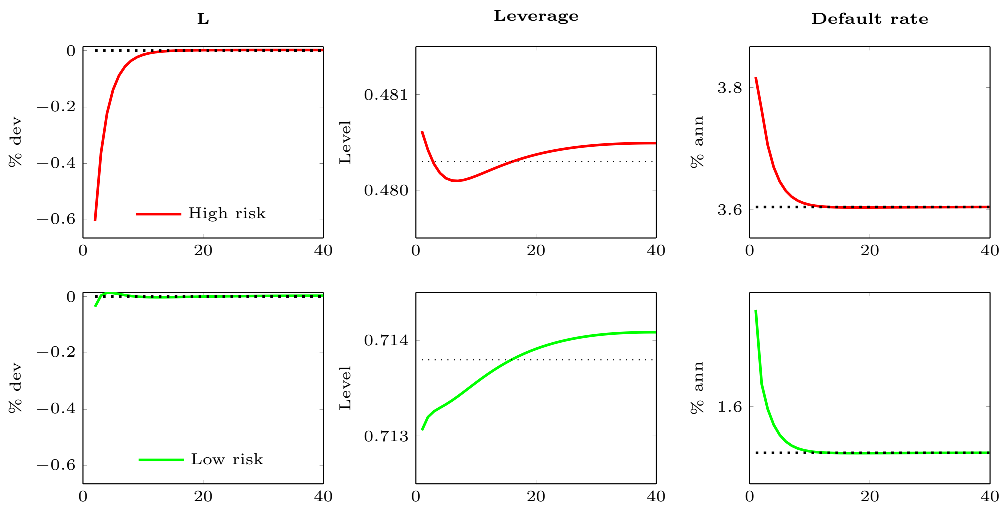
To interpret these differences recall that equity return dispersion consists of two components. While an increase in idiosyncratic productivity dispersion has a direct positive effect on equity return dispersion via the variability of profits, it also has an indirect negative effect through the endogenous debt choice. This can be seen in Figure 6 which shows the interest rate schedules of the two types of firms and their corresponding leverage choice. High risk, high yield firms face higher interest rates and choose lower leverage which diminishes the positive direct effect. To match the target moment the idiosyncratic dispersion of high yield firms has to increase sharply to offset the mitigating effect of lower leverage. In consequence, in the new stationary equilibrium, leverage of high risk, high yield firms is dramatically lower.

Figure 7 shows the impulse response from the newly calibrated steady state to a negative aggregate productivity shock. The moderately leveraged, more risky, high yield firms experience a precipitous drop in employment, while the response of highly leveraged, low risk, investment grade firms is barely different from zero. With respect to default rates there is a succinct initial increase among low risk, investment grade firms due their high leverage. Yet, default risk subsides faster than for high risk, high yield firms. Correspondingly, credit spreads for these firms are higher and drive the sharp decrease in capital accumulation and employment.

The counterfactual steady state levels of leverage allow to disentangle to role of leverage and default risk. If leverage was the main determinant of the cyclicality of employment growth, one would see the low risk, investment grade firms drop strongly. Yet, the impulse response shows otherwise and suggests that large employment losses are rather related to the responsiveness of default risk. This result becomes very intuitive when considering Figure 6: Rather than steady state leverage it is the slope of the interest rate schedule at steady state leverage that determines the cyclicality of a firm's employment growth.

This finding may be of particular relevance for the dynamics of smaller and younger firms, for instance, the group of non-rated firms in the Compustat database. In fact, these firms have low leverage and a high dispersion of equity returns, thus fitting the pattern of a firm that chooses low leverage *because* of high risk.[19]

Figure 7: Impulse response for negative productivity shock (0.5%)



Note: Impulse response to a 0.5% productivity shock. Log productivity follows an AR(1) process with autocorrelation $\rho_a = 0.95$. Top row shows responses of high yield, high risk firms. Bottom row shows responses of investment grade, low risk firms.

Finally, notice that this result hinges to some extent on the persistence of types. When the persistence is high (low p) the net worth drop of the more leveraged firms does not spill over quickly to less leveraged firms. In turn the initial employment drop at low risk, more leveraged, investment grade firms can be larger.

In summary, this exercise shows that the sensitivity of default rates and borrowing costs is a key determinant of employment dynamics in the cross-section. Even when leverage is low, firms may be very sensitive to macroeconomic conditions.

4.6 Alternative sources of aggregate uncertainty

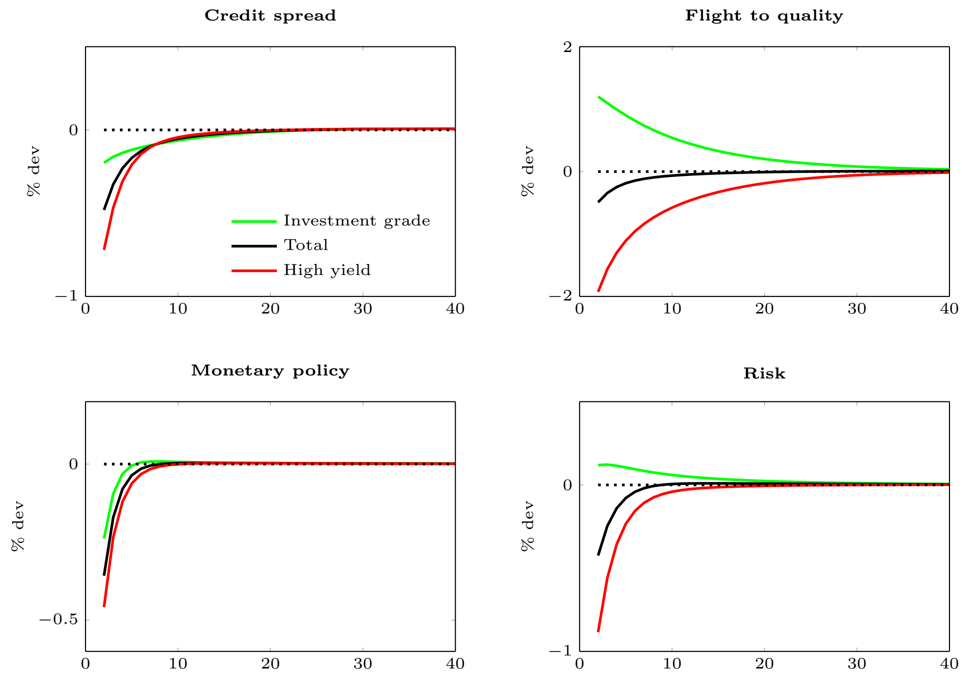
Aggregate productivity risk is a useful benchmark to study the model mechanism and to assess the elasticities of employment growth. Yet, other sources of uncertainty arguably contribute to economic activity over the business cycle. In this section I study three alternative sources of aggregate uncertainty: Shocks to credit spreads, monetary policy shocks, and shocks to idiosyncratic risk. I relegate the technical details to section C in the appendix and focus on the description of the responses of the two types of firms.

Figure 8 shows the response of employment (in deviations from steady state) to four different shocks, all scaled such that the output drop on impact is 0.5%.

The credit spread shock increases borrowing costs irrespective of default risk, i.e., in partial equilibrium high yield and investment grade firms would experience the exact same rise in credit costs. Yet, in general equilibrium the response is all but symmetric since lower investment pushes down asset prices. This induces an endogenous rise of credit spreads via default risk which affects high yield firms disproportionally. When the exogenous rise in

[19]See section D.1 in the appendix for a discussion of the characteristics of non-rated firms.

Figure 8: Employment response to various shocks



Note: "Credit spread" is shock to borrowing cost of all firms. "Flight to quality" is shock to the borrowing costs of high yield firms only. "Risk"" is shock to the dispersion of idiosyncratic productivity. All responses scaled to yield a 0.5% drop in aggregate output on impact. Additional parameters: Probability of price adjustment $\lambda_p = 0.75$; elasticity of substitution between varieties $\epsilon_p = 6$; Taylor rule coefficient on inflation $\alpha_\pi = 1.5$; autocorrelations $\rho_r = \rho_\zeta = \rho_\sigma = 0.9$.

borrowing costs is limited to high yield firms (flight to quality) the resulting employment growth differential between the two firm types is even more pronounced. Capital reallocates towards the investment grade firms which have access to cheap funding, and high yield firms deleverage strongly to decrease default risk.

Similarly to the credit spread shock, the contractionary monetary policy shock has a symmetric partial equilibrium effect on the credit costs of firms. Once more, due to general equilibrium effects the borrowing costs of high yield firms rise by more and employment drops sharper. These responses are consistent with empirical evidence on firm dynamics after tight monetary policy (Gertler and Gilchrist (1994)). More generally, monetary policy has distributional effects that spread the burden of higher (or benefits of lower) borrowing costs unequally. This will be of particular relevance when heterogeneity in the firms' productivities is taken into account. Namely, the reallocation of production factors induced by monetary policy will either increase or diminish aggregate productivity. Moreover, the effects of monetary policy may fall unevenly on firms in the presence of long-term nominal debt since surprise inflation would provide a greater boost to more leveraged firms (Gomes et al. (2014)).

Finally, a mean-preserving spread of the idiosyncratic productivity distribution increases default risk and thus credit spreads rise as in the representative agent setup by Christiano et al. (2014). The very pronounced difference in the response of high yield and investment grade firms reflects risk-sharing between the two types. The shift of production factors to investment grade firms allows high yield firms to deleverage and to reduce default risk.

Investment grade firms in turn accept a somewhat higher default risk. Notice that this is in stark contrast to the response to a productivity shock, etc., where such a pattern was not present. Due to the absence of capital adjustment costs at the firm level, the model likely overstates the role of capital and labor reallocation. Nevertheless, the insights point here at an important role for firm heterogeneity in the propagation of risk shocks.

5 Conclusion

In this paper, I have analyzed corporate credit constraints with a particular focus on the interconnection of time series and cross section. High yield firms are shown to have greater cyclicality of employment growth. A standard DSGE model augmented by firm heterogeneity can capture this fact, and helps deriving new implications for cross-sectional dynamics and policy.

While aggregate leverage determines the economy's sensitivity to cyclical shocks as in a representative firm model, firm-level leverage does not necessarily predict the cyclical dynamics of a firm. Namely, under the structure of my model riskier firms would assume lower leverage but nevertheless respond stronger to aggregate shocks. This insight hints at challenges in assessing vulnerabilities in the nonfinancial sector.

In the presence of heterogeneity monetary policy has distributional effects because it relaxes (or tightens) financial constraints differentially. For instance, risky and less productive firms may benefit most from a drop in credit costs and thus the allocation of capital may worsen. Analyzing how monetary policy alleviates or aggravates distortions in the economy is a priority for future work.

Beyond the specific context of this paper, the framework that I develop is applicable to a variety of settings. For instance, it could be useful for studying firm financing in emerging economies where only few firms access foreign debt markets. Provided that the ability to raise funds abroad correlates with the firm's risk profile and capital structure, the modeling framework predicts different employment cyclicalities in such an economy. Additionally, exchange rate dynamics would become relevant as they inflate or deflate the real value of external debt.

Finally, the mechanism presented in this paper can help explain the countercyclicality of cross-sectional dispersion measures. In fact, the model features an endogenous dispersion channel via heterogeneous employment sensitivities, while it also allows incorporating exogenous variation in the magnitude of idiosyncratic shocks. Accordingly, this framework may serve to assess the contributions of the endogenous and exogenous margins to the cross-sectional dispersion dynamics. A quantitative assessment of these channels would require a more fine-grained representation of firm-level heterogeneity than is possible in the current setup. I leave this as a perspective for future research.

A Dynamic problem of the firm

Recall that the guess for the value function is $V_t^{type}(NW_t^i) = \lambda_t^{type} NW_t^i$. Inserting this guess as well as the solution for the default threshold $\bar{z}_{t+1}^i$ into the firm's dynamic problem (1) yields the following expression.

$$\begin{aligned}\lambda_t^{type}\ NW_t^i = NW_t^i + \max_{\{K_{t+1}^i, B_{t+1}^i\}} \Bigg\{ & -Q_t K_{t+1}^i + q_t^{type}(K_{t+1}^i, B_{t+1}^i) B_{t+1}^i \\ & + \mathbb{E}\left[m_{t,t+1} \int_{\bar{z}_{t+1}^i} NW_{t+1}^i dF((1-\sigma)((1-p)\lambda_{t+1}^{type} + p\lambda_{t+1}^{\neg type}) + \sigma) \right] \Bigg\}\end{aligned}$$

with the non-negativity constraint on dividends

$$Div_t^i = \ NW_t^i - Q_t K_{t+1}^i + q_t^{type}(K_{t+1}^i, B_{t+1}^i) B_{t+1}^i \geq 0$$

I then define net worth per unit of capital $nw_t^i = \frac{NW_t^i}{K_t^i}$ and capital growth $\iota_{t+1}^i = \frac{K_{t+1}^i}{K_t^i}$, and I use that the price of debt depends only of the ratio of debt to capital, i.e., on leverage. Then, I divide both sides by K_t^i and rewrite the problem.

$$\begin{aligned}\lambda_t^{type}\ nw_t^i = nw_t^i + \max_{\{\iota_{t+1}^i, l_{t+1}^i\}} \iota_{t+1}^i \Bigg\{ & -Q_t + q_t^{type}(l_{t+1}^i) l_{t+1}^i \\ & + \underbrace{\mathbb{E}\left[m_{t,t+1} \int_{\bar{z}_{t+1}^i} nw_{t+1}^i dF((1-\sigma)((1-p)\lambda_{t+1}^{type} + p\lambda_{t+1}^{\neg type}) + \sigma) \right]}_{v_{cont}} \Bigg\}\end{aligned} \tag{8}$$

and associated non-negativity constraint on dividends is

$$nw_t^i - \iota_{t+1}^i (Q_t - q_t^{type}(l_{t+1}^i) l_{t+1}^i) \geq 0$$

As stated in the text leverage is determined by the first order condition (4). The term inside the max operator in equation (8), v_{cont}, is non-negative[20]. Therefore, the firm wants to set ι_{t+1}^i as high as possible while not violating the non-negative constraint on dividends. This leads to the corner solution (5).

Finally, under this solution the net worth multiplier writes as

$$\lambda_t^{type} = \frac{\mathbb{E}\left[m_{t,t+1} \int_{\bar{z}_{t+1}^i} nw_{t+1}^i dF((1-\sigma)((1-p)\lambda_{t+1}^{type} + p\lambda_{t+1}^{\neg type}) + \sigma) \right]}{Q_t - q_t^{type}(l_{t+1}^{type}) l_{t+1}^{type}},$$

confirming that it is independent of period t cost type and idiosyncratic productivity.

[20]Formally, this can be shown by deriving the first-order condition for capital K_{t+1}^i and acknowledging that the Lagrange multiplier on the non-negativity constraint on dividends (2) is non-negative.

B Productivity heterogeneity

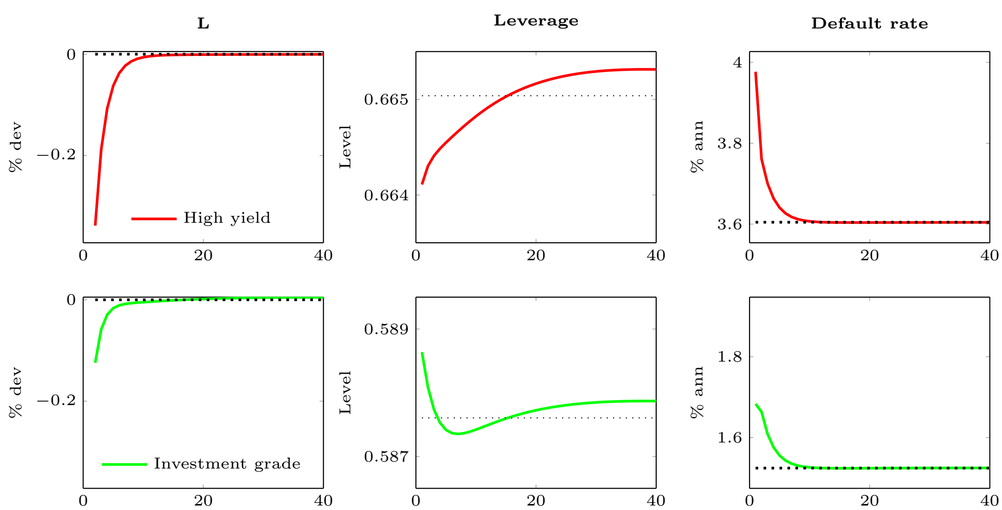
In this extension I allow for differences in the productivity level of high yield and investment grade firms. Specifically, I assume that the stationary component of aggregate productivity has a type dependent mean:

$$a_t^{type} = (1 - \rho_a)\mu_a^{type} + \rho_a a_{t-1}^{type} + \sigma_a \eta_{a,t},$$

Notice that the innovation to aggregate productivity, $\eta_{a,t}$, is common to all firms. Otherwise, the calibration targets are as in the baseline economy. In particular, the production cost of investment grade firms, c^{IG}, is set with the other internally calibrated parameters to match the credit spreads. Since investment grade firms are more productive now, they want to borrow more and purchase more capital. Thus, in order to achieve the targeted credit spreads, the calibrated production cost needs to be higher now ($c^{IG} = 0.05$). The exit probability and the dispersion rate remain close to the calibrated values from the baseline economy ($\sigma = 0.1$, $\sigma_\epsilon = 0.19$). Also, steady state leverage is very similar to the baseline economy.

Figure B.1 then shows the impulse response to a 0.5% negative aggregate productivity shock. The responses resemble the ones from the baseline economy (Figure 4). Employment at less productive, high yield firms drops more sharply, accompanied by slight deleveraging and a succinct increase in the default risk. Again, the key determinant of employment dynamics is the responsiveness of credit spreads to aggregate conditions. Productivity differences do not appear to alter these sensitivities.

Figure B.1: IRF - Productivity heterogeneity



Note: Response of employment, leverage and default rates among low productivity, high yield firms in upper panel; high productivity, investment grade firms in lower panel. Negative 0.5% aggregate productivity shock.

C Model extensions

Adding nominal rigidities to the model is not only essential to study the effects of monetary policy, but it is equally important for the propagation of shocks to credit spreads and risk. As these shocks affect corporate borrowing costs, under flexible prices demand would simply shift from investment to consumption with only small effects on aggregate output and employment. With price rigidities a reduction in investment demand cannot be compensated by higher consumption since the real interest rate does not drop sufficiently.

C.1 Nominal rigidities

Recall that firms of either type produce the same homogeneous good. I relabel this good as "wholesale good", thereby indicating that it is no longer the final output/ consumption good. Rather the wholesale good is purchased by intermediate goods producers at price P_t^w. Intermediate good producers are monopolistically competitive, indexed by $r \in [0,1]$ (r for retailers), each intermediate good firms transforms the wholesale into its respective variety r. Finally, a CES aggregate of these different varieties is assembled by competitive final good produces. The price of the final good, used for consumption by households and in the production of new capital, is denoted as P_t. Inflation is define as $\bar{\pi}_t = \frac{P_t}{P_{t+1}}$.

C.1.1 Final goods producers

The final output Y_t is a CES aggregate of intermediate goods, where ϵ_p is the elasticity of substitution between the different varieties.

$$Y_t = \left(\int y_{r,t}^{\frac{\epsilon_p - 1}{\epsilon_p}} \, dr \right)^{\frac{\epsilon_p}{\epsilon_p - 1}}$$

Final goods producers choose the amount of each variety r, taken as given the price of output P_t and the price of intermediate goods, $P_{r,t}$, $r \in [0,1]$.

$$\max_{\{y_{r,t}\}} P_t Y_t - \int P_{r,t} y_{r,t} dr$$

Demand for variety r is

$$y_{r,t} = \left(\frac{P_{r,t}}{P_t} \right)^{-\epsilon} Y_t$$

Plugging the demand equation back into the firm's problem and imposing the zero profit condition yields the prices index $P_t = \left(\int P_{r,t}^{1-\epsilon} dr \right)^{\frac{1}{1-\epsilon}}$.

C.1.2 Intermediate good firms

Intermediate good firms take demand from final goods producers as given, and choose their price $P_{r,t}$ to maximize the presented discount value of profits. However, they can reset prices on infrequently. Every period a random fraction $1 - \lambda_p$ is selected and can freely reset its price. The remaining fraction λ_p retains the price from the previous period. An intermediate good firm r that is allowed to adjust its price in period t choose its price taking into account expected profits in all future states in which it is not allowed to adjust its price.

Due to market power intermediate good producers set prices as a mark-up over marginal costs, implying that equilibrium quantities are lower than under perfect competition. In the stationary equilibrium this inefficiency is not central to the analysis, therefore I assume that intermediate good producers receive an input subsidy that eliminates the inefficiency in steady state. This implies that the steady state of the economy remains unchanged to the baseline economy. The effective price per unit of wholesale good is $(1-\nu_p)P_t^w$. The subsidy is financed through lump-sum taxes.

$$
\begin{aligned}
&\max_{P^*_{r,t}} \mathbb{E}\left[\sum_{j=0}^{\infty} \lambda_p^j m_{t,t+j} \frac{P_t}{P_{t+j}} \left(P^*_{r,t} y_{r,t+j} - P^w_{t+j}(1-\nu) y_{r,t+j}\right)\right] \\
\Leftrightarrow &\max_{P^*_{r,t}} \mathbb{E}\left[\sum_{j=0}^{\infty} \lambda_p^j m_{t,t+j} \frac{P_t}{P_{t+j}} \left(P^*_{r,t} \left(\frac{P^*_{r,t}}{P_{t+j}}\right)^{-\epsilon_p} Y_{t+j} - P^w_{t+j}\left(\frac{P^*_{r,t}}{P_{t+j}}\right)^{-\epsilon_p} Y_{t+j}(1-\nu_p)\right)\right]
\end{aligned}
$$

$p_t^w = \frac{P_t^w}{P_t}$, $p_{r,t} = \frac{P_{r,t}}{P_t}$.

The first-order condition to the firm's problem writes as follows.

$$
\begin{aligned}
&\mathbb{E}\left[\sum_{j=0}^{\infty} \lambda_p^j m_{t,t+j} Y_{t+j} P_{t+j}^{\epsilon_p}\left(p^*_{r,t}\frac{P_t}{P_{t+j}} - \frac{\epsilon_p}{\epsilon_p - 1} p^w_{t+j}(1-\nu_p)\right)\right] = 0 \\
\Leftrightarrow &\mathbb{E}\left[\sum_{j=0}^{\infty} \lambda_p^j m_{t,t+j} Y_{t+j} X_{t,j}^{-\epsilon_p}\left(p^*_{r,t} X_{t,j} - p^w_{t+j}\right)\right] = 0
\end{aligned}
$$

In the last line the input subsidy ν_p has been set to $\nu_p = \frac{1}{\epsilon_p}$ as to eliminate the mark-up over marginal costs, i.e., $\bar{p}^*_r = \bar{p}^w$. Under this subsidy intermediate good producers make positive profits, but the output is efficient in steady state. In particular

The addition of nominal rigidities and aggregate uncertainty with respect to credit spreads and idiosyncratic risk does not change the steady state of the economy, provided that the inefficiency emerging from mark-up pricing is undone through an input subsidy for intermediate goods producers. Moreover, I define $P_{t+j} = P_t \cdot \bar{\pi}_{t+1} \cdots \bar{\pi}_{t+j-1} + \bar{\pi}_{t+j}$, and $X_{t,j} = \frac{1}{\bar{\pi}_{t+1} \cdots \bar{\pi}_{t+j-1} \bar{\pi}_{t+j}}$ if $j > 0$. $X_{t,j} = 1$ if $j = 0$.

All firms which are allowed to adjust their price will choose the same targets P_t^*, or $p_t^* = \frac{P_t^*}{P_t}$.

The aggregate price index writes as

$$
\begin{aligned}
P_t &= \left[(1-\lambda_p) P_t^{*(1-\epsilon_p)} + \lambda_p P_{t-1}^{1-\epsilon_p}\right]^{\frac{1}{1-\epsilon_p}} \\
1 &= (1-\lambda_p) p_t^{*(1-\epsilon_p)} + \lambda_p \bar{\pi}_t^{\epsilon_p - 1}
\end{aligned}
$$

C.1.3 Central bank

The nominal interest rate is set by the central bank according to a Taylor rule that responds to contemporaneous inflation.

$$r_t = \bar{r} + \alpha_\pi \log \bar{\pi}_t + \epsilon_{r,t}$$

The deviation from the interest rate rule, $\epsilon_{r,t}$, follows an AR(1) process $\epsilon_{r,t} = \rho_r \epsilon_{r,t-1} + \eta_{r,t}$ where $\eta_{r,t} \sim \mathcal{N}(0, \sigma_r^2)$ is the interest rate shock.

C.1.4 Household

The household's Euler equation for deposits now also takes into account inflation:

$$1 = \mathbb{E}\left[m_{t,t+1}\frac{1+r_t}{\pi_{t+1}}\right]$$

C.1.5 Wage rigidity revisited

In the baseline economy labor agencies were essentially setting real wages. With price rigidities labor agencies are now setting nominal wages. This means that wages are not indexed to inflation, and thus unexpected inflation does affect labor costs because not all labor agencies can reset wages.

The equation characterizing the nominal wage target relative to the price level, w_t^*, is given by:

$$\mathbb{E}\left[\sum_{j=0}^{\infty} \lambda_w^j m_{t,t+j} N_{t+j} w_{t+j}^{\epsilon_w} X_{t,j}^{-\epsilon_w} \left(w_t^* X_{t,j} - \tilde{w}_{t+j}\right) \middle| S_t\right] = 0$$

where nominal variables W_t^*, W_t and $\tilde{W}_t$, have been normalized by the price level $w_t^* = W_t^*/P_t$, $w_t = W_t/P_t$ and $\tilde{w}_t = \tilde{W}_t/P_t$.

The nominal and real wage indices are

$$W_t = \left[(1-\lambda_w)(W_t^*)^{1-\epsilon_w} + \lambda_w W_{t-1}^{1-\epsilon_w}\right]^{\frac{1}{1-\epsilon_w}}$$
$$w_t = \left[(1-\lambda_w)(w_t^*)^{1-\epsilon_w} + \lambda_w (w_{t-1})^{1-\epsilon_w} \bar{\pi}_t^{\epsilon_w - 1}\right]^{\frac{1}{1-\epsilon_w}}$$

C.2 Financial intermediaries and discount factor shocks

In the baseline economy credit spreads are determined by expected default rates. I introduce a "credit spread shock" which distorts the stochastic discount factor of intermediaries' and thus creates a wedge corporate borrowing costs and expected default rates. More precisely, I assume that the stochastic discount factor of financial intermediaries is the household's discount factor twisted by some persistent component ζ_t:

$$\tilde{m}_{t,t+1} = e^{\zeta_t} m_{t,t+1}$$

where $\zeta_t = \rho_\zeta \zeta_{t-1} + \sigma_\zeta \eta_{\zeta,t}$, and $\eta_{\zeta,t} \sim \mathcal{N}(0, \sigma_\zeta^2)$.

Recall the zero profit condition for intermediaries (6) and plug in the stochastic discount factor $\tilde{m}_{t,t+1}$.

$$\mathbb{E}\left[m_{t,t+1}\left\{e^{\zeta_t}(1-F(\bar{z}^i_{t+1}))q_t^{type}(l^i_{t+1})^{-1}-\frac{1+r_t}{\bar{\pi}_{t+1}}\right\}\right]=0. \tag{9}$$

The interest rate on corporate debt, $q_t(l^{type}_{t+1})^{-1}$, is a spread over the risk-free rate that reflects not only expected default risk, but also the relative impatience of financial intermediaries. If ζ_t is negative, the intermediary is more impatient than the household, and the spread between the interest rate on corporate debt and the risk-free rate will increase (see equation (6)). This reduced form shock is similar to the risk premium shock in Smets and Wouters (2007). Some papers explicitly model financial constraints at the intermediary level. In such models the drop in the stochastic discount factor of can be obtained endogenously through a fall in bank capital (see Gertler and Kiyotaki (2010), for instance).

While the "credit spread shock" raises borrowing costs for all firms, I also consider a variant that I call "flight to quality shock". Such a shock raises only spreads of the high yield firms and is motivated by the precipitous increase of yields for non-investment grade corporates relative to yields of investment grade firms during the Financial Crisis.[21]

C.3 Shocks to idiosyncratic firm risk

I follow Christiano et al. (2014) and capture time-variation in risk through changes in the dispersion of the idiosyncratic productivity distribution. Dispersion is no longer constant, but it follows an AR(1) process around its mean $\bar{\sigma}_z$:

$$\sigma_{z,t}=(1-\rho_\sigma)\bar{\sigma}_z+\rho_\sigma\sigma_{z,t-1}+\eta_{\sigma,t}$$

where $\eta_{\sigma,t}\sim\mathcal{N}(0,\sigma^2_\sigma)$. The distribution of idiosyncratic productivity then writes as $\log z^i_t\sim\mathcal{N}\left(-\frac{1}{2}\sigma^2_{z,t-1},\sigma^2_{z,t-1}\right)$. Notice that the dispersion of productivity in period t is already known in period $t-1$.

D Data appendix

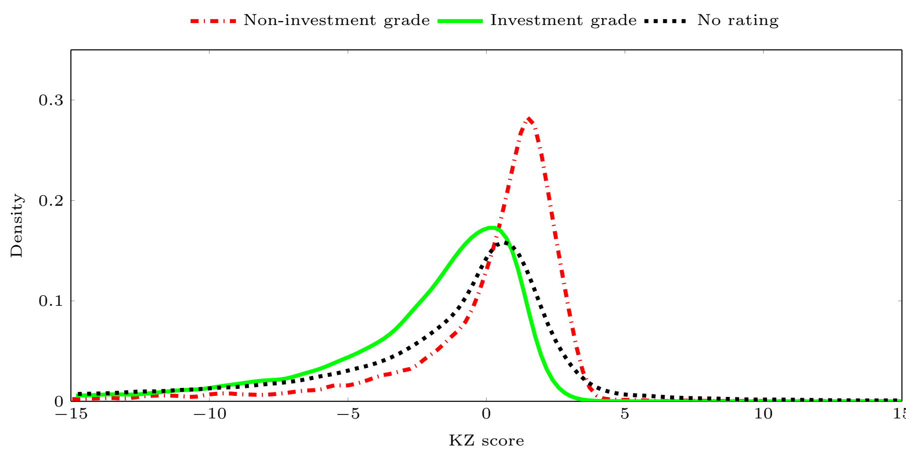
D.1 Non-rated firms

Several studies have used a classification scheme in which non-rated firms are considered more financially constrained in comparison to rated firms (see Whited (1992), Gilchrist and Himmelberg (1995), Almeida et al. (2004)). According to this argument non-rated firms have no access to public debt markets and therefore have to procure external financing through more costly bank debt. Yet, Farre-Mensa and Ljungqvist (2013) have raised concerns whether this and other popular classification schemes reliably measure financing constraints. Moreover, for the purposes of my study I see several advantages in focusing on rated firms. First, the decision to obtain a rating may be driven by unobserved heterogeneity. Considering

[21] See right panel in Figure D.2.

only rated firms likely reduces the influence of unobserved factors because these firms - both investment grade and high yield - have decided for a rating while non-rated firms have decided against. Second, as debt of rated firms is publicly traded bond yields as well as default rates can be observed and can be used to discipline the severity of constraints in the model. Third, there is substantial heterogeneity among non-rated firms that may make a classification rated-vs.-non-rated problematic. In Figure D.1 of the appendix I plot the distribution of KZ scores among investment grade, high yield, and non-rated firms. It supports an interpretation of investment grade and high yield firms as extreme points with respect to the severity of financing constraints, while the average non-rated firm falls in between these two extremes. On the one hand many non-rated firms are as constrained as the majority of high yield firms. But on the other hand there are also many non-rated firms which appear as unconstrained as investment grade firms. In addition, while the financing measures listed in Table 1 provide an intuitive and unequivocal ranking of high yield firms as the more constrained firms, non-rated firms cannot easily be categorized along these measures. They appear less burdened by debt than rated firms (mean leverage of 0.43), more restricted or cautious with dividends (dividend payer share 0.28), yet the interest rate ranks in between investment grade and high yield firms (credit spread 311 bps over Treasury note).

Figure D.1: KZ score and bond ratings



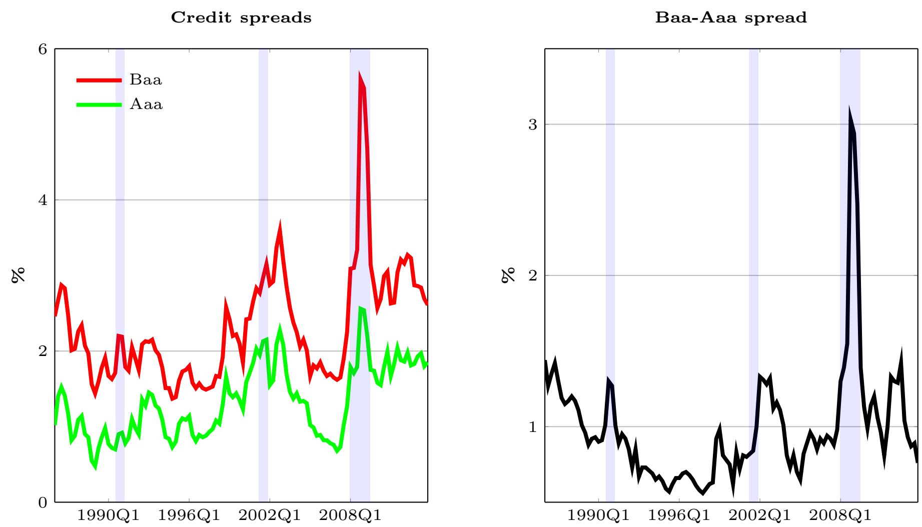
Sources: Compustat Fundamentals Annual, 1986 to 2014. Financial firms (SIC codes 60 to 67) and utilities (SIC code 49) excluded. Rating is S&P long term credit rating coded from AAA (=1) to D (=22). KZ score is the Kaplan-Zingales measure for financial constraints, constructed according to Lamont et al. (2001). Graph shows density of KZ score among investment grade firms (AAA to $BBB-$ rating, green solid line), and non-investment grade firms ($BB+$ to D, red dash-dotted line), and firms without rating (black dotted line).

D.2 Equity return dispersion

Equity dispersion in the data is computed from monthly holding returns (including dividends) for a firm's common stock using the CRSP NYSE/AMEX/NASDAQ Monthly Stock File. I aggregate returns to quarterly frequency and compute the cross-sectional standard deviation by group (investment grade and high yield).

In the model, I define the return on equity as the cum-dividend firm value in period t

Figure D.2: Data - Bond yields



Note: Moody's Seasoned Aaa/ Baa Corporate Bond Yield Relative to Yield on 10-Year Treasury Constant Maturity via FRED. Notice that Moody's Baa rating grade is equivalent to S&P's BBB rating, and is the bottom of investment grade ratings.

divided by the ex-dividend firm value in the end of period $t-1$.

$$R_{i,t}^{eq,type} = \frac{nw_t^i((1-\sigma)((1-p)\lambda_t^{type} + p\lambda_t^{\neg type}) + \sigma)}{\lambda_{t-1}^{type} nw_{t-1}^{type}}$$

Notice that the idiosyncratic productivity shock z_t^i affects the return only through the profit component $\Xi_t^i = \Xi_t z_t^i$ since debt and production cost are independent of the period t realization of the idiosyncratic component. Therefore, the standard deviation of returns (by type) writes as

$$std(R_{i,t}^{eq,type}) = \Xi_t \; \frac{(1-\sigma)((1-p)\lambda_t^{type} + p\lambda_t^{\neg type}) + \sigma}{\lambda_{t-1}^{type} nw_{t-1}^{type}} \; std(z_t^i)$$

where $std(z_{t+1}^i) = \sqrt{e^{(\sigma_z^{type})^2} - 1}$ under the log-normal assumption for the idiosyncratic productivity shock.

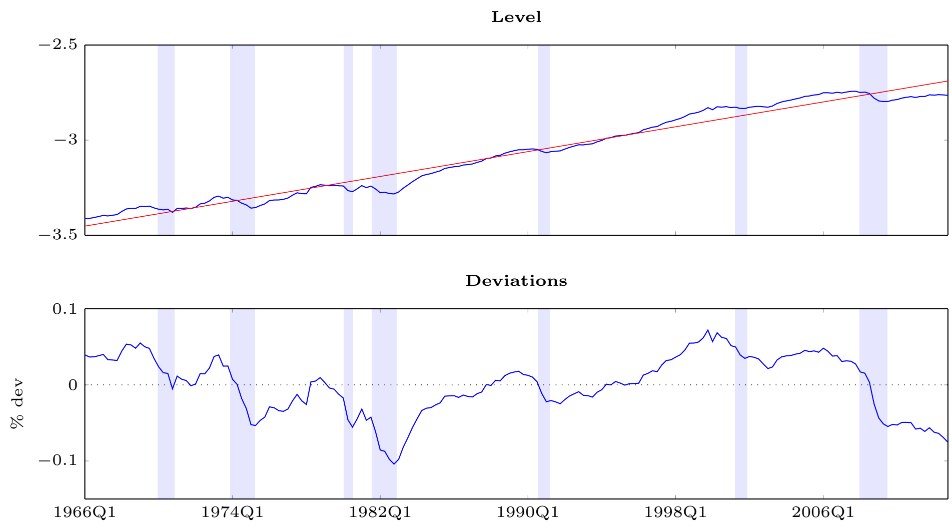
E Model inference

Figure E.1 displays US real GDP per capita in levels and in deviations from a linear trend. The series of trend deviations is used as an observable to trace out productivity shocks and to infer the employment dynamics in section 4.4. More precisely, I estimate the autocorrelation and standard deviation of the productivity process with Bayesian methods. In the first step, the algorithm finds the parameter vector that maximizes the sum of log likelihood and priors on parameters. In the second step, a Metropolis-Hastings algorithm is run to simulate the posterior distribution of the parameters vector. Table E.1 reports the priors and moments of the posterior distribution.

For each model specification listed in Table 5 the estimation has to be repeated since the change of parameters affects the responsiveness of variables to aggregate shocks. The results for the posterior distribution are very similar, however.

The smoothed shocks from the estimation imply dynamics for all other model variables. I take the yearly average of the implied employment series to be consistent with the yearly frequency of Compustat data. Then I compute year-on-year growth rates that are used for Figure 5 and Table 5.

Figure E.1: Real GDP



Note: Upper panel: Logarithm of real GDP per capita and the linear trend, 1966Q1 to 2012Q4. Lower panel: percentage deviations from trend.

Table E.1: Estimated parameters

	Posterior		**Prior**		
Parameter	**Mean**	**[5%,95%]**	**Distribution**	**Mean**	**Std**
ρ_a	0.9796	[0.9633, 0.9995]	Beta	0.90	0.10
σ_a	0.0073	[0.0067, 0.0080]	Inverse Gamma	0.005	0.005

References

Almeida, H., M. Campello, and M. S. Weisbach (2004). The cash flow sensitivity of cash. *The Journal of Finance 59*(4), 1777–1804.

Bachmann, R. and G. Moscarini (2012). Business cycles and endogenous uncertainty. *Working paper*.

Benhabib, J., X. Liu, and P. Wang (2015). Endogenous information acquisition and countercyclical uncertainty. *Working paper*. [LINK HERE].

Bernanke, B. S. and M. Gertler (1989). Agency costs, net worth, and business fluctuations. *The American Economic Review 79*(1), 13–31.

Bernanke, B. S., M. Gertler, and S. Gilchrist (1999). The financial accelerator in a quantitative business cycle framework. *Handbook of Macroeconomics 1, Part C*, 1341 – 1393.

Bloom, N. (2009). The Impact of Uncertainty Shocks. *Econometrica 77*(3).

Bloom, N., M. Floetotto, N. Jaimovich, I. Saporta-Eksten, and S. J. Terry (2012). Really Uncertain Business Cycles. *NBER Working paper 18245*.

Brunnermeier, M. K., T. Eisenbach, and Y. Sannikov (2013). Macroeconomics with financial frictions: A survey.

Buera, F. J., R. N. F. Jaef, and Y. S. Shin (2015). Anatomy of a credit crunch: From capital to labor markets. *Review of Economic Dynamics 18*(1), 101 – 117.

Campello, M., J. R. Graham, and C. R. Harvey (2010). The real effects of financial constraints: Evidence from a financial crisis. *Journal of Financial Economics 97*(3), 470 – 487.

Cantor, R. (1990). Effects of leverage on corporate investment and hiring decisions. *FRBNY Quarterly Review/ 1990 Summer*.

Carlstrom, C. T. and T. S. Fuerst (1997). Agency costs, net worth, and business fluctuations: A computable general equilibrium analysis. *The American Economic Review 87*(5), 893–910.

Chodorow-Reich, G. (2014). The Employment Effects of Credit Market Disruptions: Firm-level Evidence from the 2008-9 Financial Crisis. *The Quarterly Journal of Economics 129*(1), 1–59.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy 113*(1), 1–45.

Christiano, L. J., R. Motto, and M. Rostagno (2014). Risk shocks. *American Economic Review 104*(1), 27–65.

Cui, W. (2013). Delayed Capital Reallocation. *Working paper (Princeton University)*.

Davis, S. J., J. Haltiwanger, R. S. Jarmin, and J. Miranda (2006). Volatility and dispersion in business growth rates: Publicly traded versus privately held firms. *NBER Working paper 12354*.

Del Negro, M., S. Eusepi, M. Giannoni, A. Sbordone, A. Tambalotti, M. Cocci, R. Hasegawa, and M. H. Linder (2003). The frbny dsge model. *Federal Reserve Bank of New York Staff Reports* (647).

D'Erasmo, P. N. and H. J. M. Boedo (2013). Intangibles and endogenous firm volatility over the business cycle. *Working paper*.

Dunne, T., M. J. Roberts, and L. Samuelson (1989). The growth and failure of u. s. manufacturing plants. *The Quarterly Journal of Economics 104*(4), 671–698.

Duygan-Bump, B., A. Levkov, and J. Montoriol-Garriga (2015). Financing constraints and unemployment: Evidence from the great recession. *Journal of Monetary Economics* (0). [LINK HERE].

Elkamhim, R., J. Ericsson, and C. A. Parsons (2012). The cost and timing of financial distress. *Journal of Financial Economics 105*(1), 62 – 81.

Farre-Mensa, J. and A. Ljungqvist (2013). Do measures of financial constraints measure financial constraints? (19551).

Fort, T., J. Haltiwanger, R. S. Jarmin, and J. Miranda (2013). How firms respond to business cycles: The role of firm age and firm size. *IMF Econ Rev 61*(3), 520–559.

Gertler, M. and S. Gilchrist (1994). Monetary policy, business cycles, and the behavior of small manufacturing firms. *Quarterly Journal of Economics 109*(2), pp. 309–340.

Gertler, M. and N. Kiyotaki (2010). Financial intermediation and credit policy in business cycle analysis. *Handbook of Monetary Economics 3*, 547 – 599.

Gilchrist, S. and C. P. Himmelberg (1995). Evidence on the role of cash flow for investment. *Journal of Monetary Economics 36*(3), 541 – 572.

Gilchrist, S., A. Ortiz, and E. Zakrajsek (2009). Credit risk and the macroeconomy: Evidence from an estimated dsge model. *Working Paper*.

Gilchrist, S., J. Sim, and E. Zakrajsek (2014). Uncertainty, financial frictions, and investment dynamics. *Working paper*.

Giroud, X. and H. Mueller (2015). Firm leverage and unemployment during the great recession. *Working paper*.

Gomes, J., U. Jermann, and L. Schmid (2014). Sticky leverage. *Working paper*.

Gourio, F. (2014). Financial distress and endogenous uncertainty. *Working paper*.

Graham, J. R. and C. R. Harvey (2001). The theory and practice of corporate finance: evidence from the field. *Journal of Financial Economics 60*(23), 187 – 243.

Guvenen, F. (2009). A parsimonious macroeconomic model for asset pricing. *NBER Working Paper 15243*.

Ilut, C., M. Kehrig, and M. Schneider (2014). Slow to hire, quick to fire: Employment dynamics with asymmetric responses to news. *Working paper*.

Jermann, U. and V. Quadrini (2012). Macroeconomic Effects of Financial Shocks. *American Economic Review 102*(1), 238–71.

Jermann, U. J. (1998). Asset pricing in production economies. *Journal of Monetary Economics 41*(2), 257 – 275.

Jurado, K., S. C. Ludvigson, and S. Ng (2013). Measuring uncertainty. *Working paper*.

Khan, A., T. Senga, and J. K. Thomas (2013). Default risk and aggregate fluctuations in an economy with production heterogeneity. *Working paper*.

Khan, A. and J. K. Thomas (2013). Credit shocks and aggregate fluctuations in an economy with production heterogeneity. *Journal of Political Economy 121*(6), 1055–1107.

Kiyotaki, N. and J. Moore (1997). Credit cycles. *The Journal of Political Economiy 105*(2), 211–248.

Lamont, O., C. Polk, and J. Saa-Requejo (2001). Financial constraints and stock returns. *Review of Financial Studies 14*(2), 529–554.

Navarro, G. (2014). Financial Crises and Endogenous Volatility. *Working paper*.

Nuño, G. and C. Thomas (2012). Bank leverage cycles. *Working paper*.

Sharpe, S. A. (1994). Financial market imperfections, firm leverage, and the cyclicality of employment. *The American Economic Review 84*(4), pp. 1060–1074.

Shourideh, A. and A. Zetlin-Jones (2014). External financing and the role of financial frictions over the business cycle: Measurement and theory. *Working paper*.

Smets, F. and R. Wouters (2007). Shocks and frictions in us business cycles: A bayesian dsge approach. *American Economic Review 97*(3), 586–606.

Tian, C. (2012). Riskiness choice and endogenous productivity dispersion over the business cycle. *Working paper*.

Whited, T. M. (1992). Debt, liquidity constraints, and corporate investment: Evidence from panel data. *The Journal of Finance 47*(4), 1425–1460.