

# Corporate Debt Structure, Precautionary Savings, and Investment Dynamics

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## Abstract

Micro-level evidence indicates that firms which substituted bank loans with bond issues during the Great Recession did not experience a large contraction in their total borrowing, but they have hoarded more cash and experienced a slower recovery in investment than firms that did not substitute. This suggests that firms' balance sheet adjustment played a key role in the transmission of aggregate shocks. To evaluate the importance of this mechanism in the propagation of the Great Recession, I build a quantitative general equilibrium model of firm dynamics that jointly endogenizes the composition of borrowing on the liability-side, and the portfolio allocation between savings and investment on the asset-side. Bond issuances have lower intermediation costs than bank debt, but the latter can be restructured when firms are in financial distress. In response to a contraction in bank credit supply, firms substitute bank loans with bond issues and thus become more exposed to the risk of financial distress. This strengthens firms' precautionary incentive to increase cash holdings at the expense of investment, as they optimally trade-off growth against self-insurance via cash holdings. Model simulations suggest that this "precautionary savings" channel can account for 40 percent of the decline in aggregate investment in the first two years of the Great Recession, and more than one-half of the decline in the following five years.

**KEYWORDS:** corporate debt; corporate saving; investment; costly external finance; firm heterogeneity; financial shocks; financial frictions; irreversibilities; firm dynamics; general equilibrium

**JEL CLASSIFICATION:** E22, E32, E44, G31, G33

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## 1 Introduction

The 2007–2009 recession and anemic recovery have reinvigorated the study of financial frictions and their impact on macroeconomic fluctuations. This fundamental issue motivates an extensive theoretical literature, whose central goal is to understand the propagation mechanisms. Much of the literature assumes that firms borrow from a single financial intermediary, and overlooks the substitutability between different types of debt instruments. However, recent empirical contributions by [Becker and Ivashina \(2014\)](#), and [Adrian, Colla and Shin \(2012\)](#) suggest that firms with access to public debt markets actively substitute corporate bonds for bank loans when credit conditions tighten: the surge in bond financing during the recent crisis could make up approximately 70% of the total decline in bank lending.<sup>1</sup> Such evidence raises questions on the mechanism through which financial frictions affect real activities, if it is not via a contraction in the total quantity of credit. It also points out the importance of understanding the potential role of debt substitution in the propagation of aggregate shocks over time.

In this paper, I first provide new evidence that firms which substituted bond issues for bank loans during the Great Recession have been hoarding higher fractions of assets as cash and experienced a slower recovery in investment than firms which did not substitute. This is a surprising result: in principle, these firms should have been less affected by adverse shocks to bank credit supply, as they did not suffer from a large decline in total leverage. The fact that their investment was more affected suggests that debt substitution may play a complex and previously unexplored role in the propagation and amplification of aggregate shocks. To identify and understand the mechanisms that explain this empirical pattern, subsequently, I build a quantitative general equilibrium model of firm dynamics, that jointly endogenizes the composition of borrowing, as well as the allocation of assets between savings and capital investment. The model captures two channels in the firms' response to an unanticipated increase in the bank lending cost. The first is the traditional "financial constraint" channel, whereby firms that relied heavily on bank loans react to the shock by deleveraging and reducing investment. The second channel reflects the fact that, following an unanticipated increase in the bank lending cost, firms adjust the composition of their balance sheets at two margins: on the liability side, they substitute bank loans with bond issues; on the asset side, given leverage, they reallocate assets from productive capital to cash holdings. These decisions jointly give rise to a novel "precautionary savings" channel that is quantitatively relevant especially through the balance sheet adjustment of firms with intermediate size and default risk, as they are the most likely to switch from a mixed-debt to a bond-only financial regime following a negative bank credit supply shock. Key for the mechanism is the assumption that bonds are more difficult to restructure than loans. Switching to a bond-only debt structure thus exposes firms to a higher risk of default, to which firms respond

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<sup>1</sup>In absolute terms, aggregate bank loans dropped by USD 577 billions from 2008Q3 to 2010Q1, and aggregate bond issues increased by USD 389 billions in the same period. Data is from the Flow of Funds; see Appendix A.1 for a complete list of data sources and details for construction.

by increasing their cash holdings for self-insurance at the expense of investment. By explaining why the large quantities of bond issues have been saved rather than invested, the model suggests one potential reason for the slow recovery from the Great Recession.<sup>2</sup>

With firm-level data on the debt structure of public firms between 2006 and 2015, I begin by documenting a novel set of empirical regularities on the correlation between firms' debt choices and their allocation of assets between savings and productive capital. The first key finding is that for a given leverage, increasing the fraction of bonds in total debt has a significantly positive effect on a firm's cash-to-asset ratio, but a significantly negative effect on its capital expenditures-to-asset. Second, firms with higher fractions of bonds are reluctant to use cash to finance investment, indicating that substituting bank loans with bond issues could introduce additional frictions that increase the adjustment costs of cash. These two findings suggest that changes in debt composition can affect a firm's investment decisions either by directly changing the firm's asset allocation between cash and productive capital, or by influencing how quickly the firm uses its cash to finance investment. Finally, the relation between debt composition and cash holdings is stronger among firms that are more financially constrained, but not necessarily among firms that belong to industries with greater investment inflexibility. This suggests that financial frictions play a more prominent role than investment frictions in explaining why debt composition is an economically important determinant of a firm's asset allocation decision.

In the second part of the paper, I propose a quantitative general equilibrium model of firm dynamics that formally illustrates and quantifies the role of debt composition in explaining firms' cash holdings and investment dynamics. The model is characterized by three key features. First, firms that are heterogeneous in the risk of default need to raise debt in order to finance investment, but are subject to agency costs associated with default (see [Cooley and Quadrini \(2001\)](#); [Gilchrist, Sim and Zakrajšek \(2014\)](#); [Khan and Thomas \(2013\)](#); among others). Second, there are two types of financial intermediaries: market lenders and bank lenders. Crucially, they differ in their ability to deal with firms in financial distress, as in [Crouzet \(2015\)](#). Third, while firms experience sequentially two idiosyncratic shocks in a period, they can only reoptimize their choice of assets, but not liabilities, after the first productivity shock. Subsequently, a demand shock is realized after production and determines the profitability of a firm and its default decision.<sup>3</sup>

The mechanism of the model hinges upon the following trade-offs faced by the firms. In

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<sup>2</sup>This ratio compares total investment of rated nonfinancial firms in Compustat with total investment of nonfinancial corporate businesses from the Flow of Funds. The Great Recession was marked by a dramatic 20.4% collapse in gross fixed capital formation in 2007-09, followed by a slow recovery thereafter, whereby capital formation was still 9.1% below the pre-crisis level in 2014. See Appendix A.1 for a description of all data sources.

<sup>3</sup>This assumption essentially divides one period into subperiods, such as in [Christiano and Eichenbaum \(1995\)](#); and [De Fiore and Uhlig \(2011, 2015\)](#). The assumption that firms can adjust their cash holdings more easily than debt is adopted in other similar studies such as [Acharya, Davydenko and Strebulaev \(2012\)](#). Dynamic capital structure theories (e.g. [Fischer, Heinkel and Zechner \(1989\)](#); [Hackbarth, Miao and Morellec \(2006\)](#)) show that waiting times to restructure debt optimally could be substantial, even for small transaction costs, an implication supported by recent empirical evidence (e.g. [Leary and Roberts \(2005\)](#)). I provide further evidence in Section 3.7 to show that cash is indeed significantly more variable than both equity and debt.

choosing the optimal debt structure, firms trade-off the ability to restructure bank debt in financial distress, with the lower intermediation costs offered by markets in normal times. In choosing the optimal portfolio of assets, firms face a trade-off between investing more and getting higher profits in the future—conditional on receiving a favorable demand shock and not defaulting—and holding more cash, which implies that returns have a lower variance and firms have a higher chance of survival. As a result of this combination of trade-offs, for a comparable leverage, replacing bank debt with market debt exposes firms to larger default risks, thus incentivizing them to reallocate assets from capital to cash holdings. The model prediction matches well with the empirical stylized fact on the robustly positive correlation between cash holdings and corporate bond spreads, shown in [Acharya, Davydenko and Strebulaev \(2012\)](#). Moreover, the results imply that the precautionary motives for saving could be of first-order importance even for public firms with relatively good ratings, and suggest that when the less risky firms switch to bond financing, there could be a convergence in firm dynamics among firms of different default risks. Indeed, the “precautionary savings” channel, through which aggregate shocks affect macroeconomic outcomes, plays a crucial role in explaining the convergence in investment dynamics among the financially unconstrained and constrained firms, which is observed in the data since the 2007-09 financial crisis and at odds with the intuition suggested by the traditional “financial constraint” channel.

The model endogenously generates a distribution of firms across levels of productivity in the steady state. I calibrate the model to target firm size distribution as well as the average fraction of bank debt to total debt among U.S. non-financial and non-utility firms with credit ratings. Three pervasive aspects of corporate financial policy characterize variation in the scale and composition borrowing across the distribution. First, firms employing debt financing simultaneously hold cash balances, and the stock of internal finance is negatively related to the productivity level of the firm. This is consistent with the findings of [Riddick and Whited \(2009\)](#), that firms hold higher precautionary cash balances when external finance is costly. Second, focusing on the liabilities, some firms choose to borrow simultaneously from bank and market lenders. This is a key empirical finding of [Rauh and Sufi \(2010\)](#), who nevertheless emphasize that few models of debt structure have this feature, with the notable exception of [Crouzet \(2015\)](#). Third, a firm’s productivity is negatively related to its bank share, defined as the ratio of bank loans to total debt. Therefore, the model also predicts a tight link between the likelihood of financial distress and the composition of debt, echoing the findings of [Rauh and Sufi \(2010\)](#), that firms tend to increase their reliance on bank loans as credit quality declines.

The model provides a useful framework to study the transmission of aggregate shocks and the macroeconomic implications of debt heterogeneity. In response to a financial shock that reduces the effective supply of bank credit, firms reduce their borrowing from banks, increase their cash holdings, and scale down investment. This is the traditional “financial constraint” channel, and is particularly relevant to firms of high default risks that relied heavily on bank loans before the shock. This channel can account for about 60% of the decline in output in the first two years

of the crisis, but only less than half of the decline in the following five years. The remaining response of output is accounted for by a novel “precautionary savings” channel that is particularly significant for firms which respond to the shock by switching from a mixed-debt to a bond-only debt regime, since the latter strips away the possibility to restructure debt in times of financial distress, in the absence of bank lenders. Qualitatively, these predictions match well with the micro-level evidence on the cross-sectional changes in cash holdings and firm growth since the Great Recession. Quantitatively, this “precautionary savings” channel plays a significant role in the contraction of aggregate investment and output. The fraction of firms employing a bond-only debt structure more than triples after the shock, with each of these firms reallocating a significant fraction of assets towards cash reserves.<sup>4</sup> Furthermore, the general equilibrium framework with firms facing non-convex capital adjustment costs as well as frictions in the debt markets allows me to quantify the relative importance of financial frictions, relative to investment frictions, in determining the economic significance of the balance sheet adjustment mechanism. In a counterfactual exercise without capital illiquidity, the total decline in investment is only 20% less than the baseline scenario, pointing to financial distortions as the main mechanism—through debt substitution at the firm-level—that affects macroeconomic outcomes. Furthermore, a related counterfactual exercise shows that reducing credit market frictions by 10% can result in a 25% smaller decline in output, mostly due to a reduction in the increase in cash holdings.

Notably, the model can generate a persistent response in output that exceeds the degree of persistence of the financial shock. Persistence arises from the model itself because both the debt composition and portfolio allocation decisions are endogenously determined. Once a firm increases cash holdings in response to its substitution towards bond financing, this partially offsets the higher default risk associated with the change in debt structure. Consequently, the flexibility of bank debt would appeal less to the firm compared to the scenario where it was not allowed to adjust its asset allocation, and this in turn slows down the adjustment of bank borrowing, and triggers another high cash-to-asset ratio in the following period. Therefore, turning off cash holdings by firms produces the counterfactual results of a larger decline in total debt during the crisis but a faster recovery in output thereafter.

It is worth emphasizing that the results of this paper by no means dispute the idea that capital markets could act as a “spare tyre” to traditional, bank-based intermediation at times when the latter is impaired (Greenspan (1999)). In fact, in line with the findings by Kashyap, Lamont and Stein (1994) and De Fiore and Uhlig (2015), this paper lends supports to the hypothesis that firms’ ability to substitute among alternative debt instruments is important to shield the economy from adverse real effects of a financial crisis. In a counterfactual exercise where substitution towards bond financing is not allowed, the decline in aggregate output is significantly higher than in the baseline scenario. What this paper emphasizes, however, is that *imperfect* substitutability

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<sup>4</sup>Changes at both the extensive and intensive margins match with the firm-level evidence on changes in debt structures and cash holdings. Data is obtained from Capital IQ and Compustat; section 2 discusses the dataset in detail.

between bank and bond debt can significantly reduce the effectiveness of the “spare tyre”. In particular, the model predicts that substitution towards bond financing has adverse effects for the investment by firms of intermediate default risk. Hence the results suggest that policies supporting the corporate bond market with the goal of sustaining firms growth during a financial crisis may have some unintended implications for investment, unless complemented by further measures, such as investment tax credit, to contain firms’ cash hoarding incentives and to offset the “precautionary savings” channel analyzed in this paper.

Lastly, I examine through the lens of the model whether financial frictions manifest themselves through shocks to the demand for credit or to its supply in the Great Recession. Specifically, I compare the transmission of a financial shock with that of an uncertainty shock, where firms face time-varying idiosyncratic technology uncertainty, in the spirit of, for instance, [Bloom \(2009\)](#); [Bloom, Bond and Van Reenen \(2007\)](#); [Bachmann and Bayer \(2013\)](#); and [Gilchrist, Sim and Zakrajšek \(2014\)](#). The aggregate responses of total leverage and investment to an uncertainty shock are in line with the existing literature: by widening the credit spreads, unanticipated increases in uncertainty lead to a large decline in investment. Nonetheless, a closer look at the debt structure and heterogeneity in firm dynamics reveals two results that are at odds with the data. First, instead of retiring bank loans whilst increasing bonds—as shown in the data—all firms increase the fraction of their bank debt following an unanticipated increase in volatility, as they value the flexibility associated with bank debt more when uncertainty is high. Second, an increase in aggregate uncertainty induces the smaller firms with higher default probabilities to increase their cash holdings much more than the larger firms. This is the opposite of the empirical evidence, and implies that the larger firms would invest higher proportions of their assets after the shock. These counterfactual results suggest that shocks to the supply of intermediated credit are the key driver of financial frictions, echoing the findings by [Adrian, Colla and Shin \(2012\)](#) and [Kashyap, Stein and Wilcox \(1993\)](#). Therefore, introducing corporate balance sheet adjustment to an otherwise standard business cycle model can serve as one way to disentangle shocks to credit demand from shocks to credit supply.

**Related Literature** This paper relates to a number of existing literatures. First, I contribute to a growing literature on the macroeconomic implications of debt heterogeneity, which have been addressed by relatively few papers thus far, but have received increasing attention since the 2007-09 financial crisis. In a model of procyclical bank leverage and the co-existence of bank loans and bonds, [Adrian, Colla and Shin \(2012\)](#) argue that the impact on real activity comes from the sharp increase in risk premiums, rather than contraction in the total quantity of debt. [De Fiore and Uhlig \(2011, 2015\)](#) build an asymmetric information model of bond and bank borrowing, and provide a model-based assessment of the changes in corporate debt composition in the U.S. during the Great Recession, following an increase in firm-level uncertainty and in the intermediation costs of banks. Closest to this paper, [Crouzet \(2015\)](#) studies the transmission of financial shocks in a firm dynamics model with debt substitution. [Crouzet \(2015\)](#) shows that the imperfect

substitutability between different debt instruments can generate simultaneous borrowing in the cross-section as well as amplification in the dynamic model, whereby firms replace one unit of bank debt with less than one unit of market debt in response to financial shocks. I contribute to this literature by proposing a new “precautionary savings” channel associated with debt substitution that is supported by micro-level evidence, in order to explain the severity of the recession and the slow recovery thereafter, if it is not solely due to a contraction in the total quantity of debt. In doing so, I bring firm’s precautionary cash holdings to the forefront to argue the importance of precautionary responses to changes in credit conditions. Moreover, the full-fledged general equilibrium framework in this paper allows me to study the propagation of unanticipated shocks and quantitatively evaluate the role of “precautionary savings” channel.

The microfoundations of the key assumptions in this paper speak to an extensive theoretical literature on corporate debt structure, since the seminal contributions of [Diamond \(1991\)](#), [Rajan \(1992\)](#), and [Bolton and Scharfstein \(1996\)](#). [Chemmanur and Fulghieri \(1994\)](#) and [Boot, Greenbaum and Thakor \(1993\)](#) show that by acquiring information about firms, banks minimize the probability of inefficient liquidation, build a reputation for financial flexibility, and attract firms that are less likely to face temporary situations of distress. The precise cause of banks’ greater flexibility in distress is not explicitly modelled in this paper; rather, the focus is on the implications of this difference in flexibility for firms’ investment and cash holding decisions. Nevertheless, the assumption in this paper that bank and market lending differ in their degree of flexibility in times of financial distress builds on the insight of [Bolton and Scharfstein \(1996\)](#) that the dispersion of market creditors reduces individual incentives to renegotiate debt payments, and may create holdout problems that impede efficient restructuring.

This paper also contributes to an important literature on the role of financial frictions in the propagation of aggregate shocks, following the seminal contributions of [Bernanke and Gertler \(1989\)](#); [Bernanke, Gertler and Gilchrist \(1999\)](#); [Kiyotaki and Moore \(1997\)](#). In particular, this paper studies the role of financial frictions in a model of firm dynamics, and one key friction is limited liability, as in [Cooley and Quadrini \(2001\)](#), [Clementi and Hopenhayn \(2006\)](#), and [Hennsey and Whited \(2007\)](#), among other models of firm dynamics. In particular, one key result of this paper—that a shock to the availability of bank credit can, on its own, generate a large and prolonged recession, by disrupting the allocation of capital further from that implied by firm productivities—echoes the findings in [Khan and Thomas \(2013\)](#) in a firm dynamics model with debt finance. Moreover, there has been a growing literature on the substitution between debt and equity finance, such as [Jermann and Quadrini \(2012a\)](#); [Covas and Den Haan \(2012\)](#); and [Begenau and Salomao \(2016\)](#) in a firm dynamics model. Nevertheless, these papers only allow for one type of debt and hence do not address the implication of debt substitution. The novel empirical evidence presented in this paper poses a challenge to many of these models in explaining the Great Recession and the slow recovery thereafter, as it suggests that a significant fraction of the contraction in output cannot be explained by the decline in total debt, thus pointing to the importance of modelling debt substitution and studying the propagation of aggregate shocks through

firms' balance sheet adjustment—a gap that this paper aims to fulfil.

Finally, the facts presented in the paper also speak to a stream of papers in corporate finance on the determinants of the rise in U.S. corporate cash holdings. On the empirical side, several explanations have been put forth such as, for example, precautionary motives in the face of uncertainty (Bates, Kahle and Stulz (2009)), rising intangible capital and the share of R&D-intensive firms in the U.S. (Falato, Kadyrzhanova and Sim (2013); Begenau and Palazzo (2016)). These papers focus on explaining the secular trend in U.S. corporate cash holdings over the last decades, whereas this paper focuses on explaining firm heterogeneity in their cash holding behaviors since the recent 2007-2009 recession. On the theory side, the motivation for cash holding in much of the literature arises from the existence of external finance costs (Riddick and Whited (2009); Bolton, Chen and Wang (2011); Gamba and Triantis (2008)). The simultaneous existence of cash and debt is featured in Gamba and Triantis (2008) and Acharya, Almeida and Campello (2007), with both arguing that cash is not the same as negative debt. I contribute to this literature by introducing a model framework whereby firms simultaneously save and borrow using only short-term debt that firms can default upon in equilibrium. Moreover, by introducing an endogenous debt structure choice, I illustrate its implications for the allocation of assets between savings and capital expenditures. To this end, the paper suggests that firms' allocation of external finance between productive capital and liquid assets in turn depends on the properties of the external finance raised by firms—an idea that is also featured in Eisfeldt and Muir (2016), who focus on the cost of external funds, whereas the focus here is on the type of funds.

I begin the remainder of the paper by documenting in section 2 the main empirical regularities on which the paper is based. In section 3, I develop a model framework to investigate the economic mechanisms that could explain the empirical patterns observed in the data. In section 4, I assess quantitatively the role of these economic mechanisms in explaining the documented empirical facts. Section 5 concludes.

## **2 Corporate Debt Structure and Cash Holdings: Empirical Evidence**

In this section I summarize a novel set of stylized facts on corporate debt choices, cash holdings and investment since the Financial Crisis of 2007-09. To this end, I retrieve firm-level data from Compustat and Capital IQ to assemble a panel of public firms with Standard & Poor's ratings and debt capital structure data from 2006Q1 to 2015Q4. I document that firms with higher fractions of market debt have higher cash to asset ratios, and are less likely to use the cash for investment and growth.

### **2.1 Sample Description and Characteristics**

The sample consists of non-financial (SIC codes 6000-6999) and non-utility (SIC codes 4900-4949) firms incorporated in the U.S. that lie in the intersection of the Compustat and Capital IQ

database on debt structure.<sup>5</sup> For a firm to be included in the analysis, I require the firm-quarter observations in Compustat to (1) have positive total assets (203,033 observations); (2) have data available on debt structure from Capital IQ (67,908 observations); (3) have Standard & Poor's ratings (21,759 observations). In order to capture any firm heterogeneity in cash holdings, debt structures and investment dynamics, I split the sample into investment-grade issuers ('BBB-' and higher) and speculative-grade issuers. Furthermore, I remove the 25 largest cash holders from the sample of investment-grade firms, as there is substantial evidence that their cash-versus-debt dynamics are significantly different from the remaining investment-grade firms.<sup>6</sup> The final sample comprises 21,402 firm-quarter observations involving 938 unique firms.<sup>7</sup> The sample covers approximately 63% (in terms of dollar amount) of all U.S. non-financial and non-utilities public firms by total assets during the sample period, and 92% of those with S&P ratings and debt structure data. Firm-level characteristic variables are from Compustat. To remove outliers, all firm characteristic variables are winsorized at the 1<sup>st</sup> and 99<sup>th</sup> percentiles (Bates, Kahle and Stulz (2009)). Appendix A.1 provides a detailed description of the firm characteristic variables used in the analysis.

Figures 1 and A.1 illustrate the main point of this paper: that the debt structure of a firm affects its asset allocation, whereby higher fractions of market debt motivate firms to hold proportionally more cash. Figure 1 highlights, at the aggregate level, the balance sheet adjustment of the rated nonfinancial and nonutility firms in the U.S. since the 2007-09 financial crisis. The left and right panels show the changes, relative to 2008Q3, in the firms' debt choices (panel (a)) and portfolio choices (panel (b)). On the liability side, whereas the total bank debt has been consistently below the pre-crisis level, corporate bond issuance has been rapidly rising since the crisis. In other words, capital markets have been playing an important role in financing U.S. nonfinan-

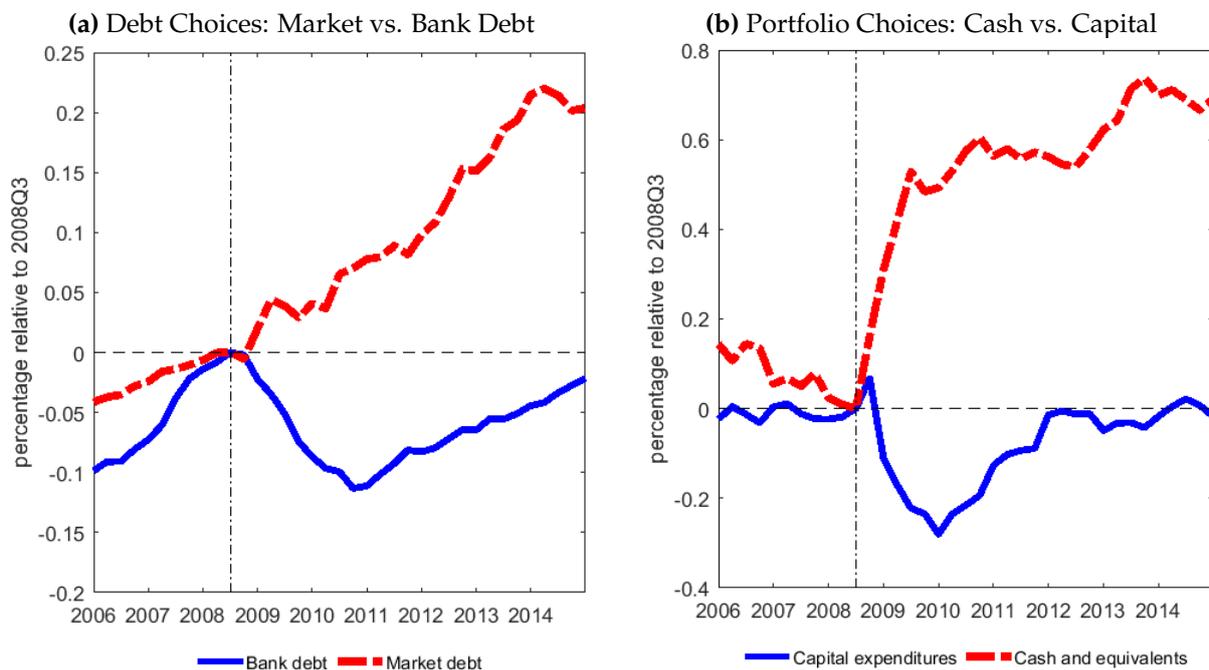
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<sup>5</sup>Regulation S-X of the Securities Act of 1933 requires firms to detail their long-term debt instruments. Regulation S-K of the same act requires firms to discuss their liquidity, capital resources, and operating results. As a result of these regulations, firms provide detailed information on their long-term debt issues and drawn credit lines. Capital IQ has been compiling detailed information on capital structure and debt structure by going through financial footnotes contained in firms' 10K SEC filings since then. However, coverage by Capital IQ is comprehensive only from 2006 onwards.

<sup>6</sup>A report released by S&P Global Ratings on 20 May 2016 shows that the top 25 U.S. nonfinancial corporations now control just over half of the total amount of cash held by all nonfinancial U.S. corporations, an increase from just 38% five years ago, and that "such extreme wealth of a handful of U.S. corporations is masking a liquidity problem—the worst in a decade—for the vast majority of companies." These firms include: Apple, Microsoft, Alphabet, Cisco Systems, Oracle, Pfizer, Johnson & Johnson, Amgen, Intel, Qualcomm, Merck & Co., Gilead Sciences, Ford Motor, General Motors, Coca-Cola, Amazon, Medtronic, EMC, Procter & Gambler, Schlumberger, FCA US, Boeing, PepsiCo, Chevron, and The Priceline Group.

<sup>7</sup>Out of the 938 firms, 880 of them belonged to either the investment-grade subsample or the speculative-grade subsample throughout the period 2006Q1-2015Q4, whereas 58 firms (6.2%) have switched between the two groups at least once. I classify these firms according to the length of time period that they had a certain rating, e.g. if a firm had an investment grade for more than half of the sample, then it is considered an investment grade firm. The results on the differences between the investment-grade and speculative-grade firms do not change if I use only the 880 firms that consistently belonged to the same ratings group in the sample.

**Figure 1: Aggregate Evidence on Debt Composition and Firms' Balance Sheet Policies**

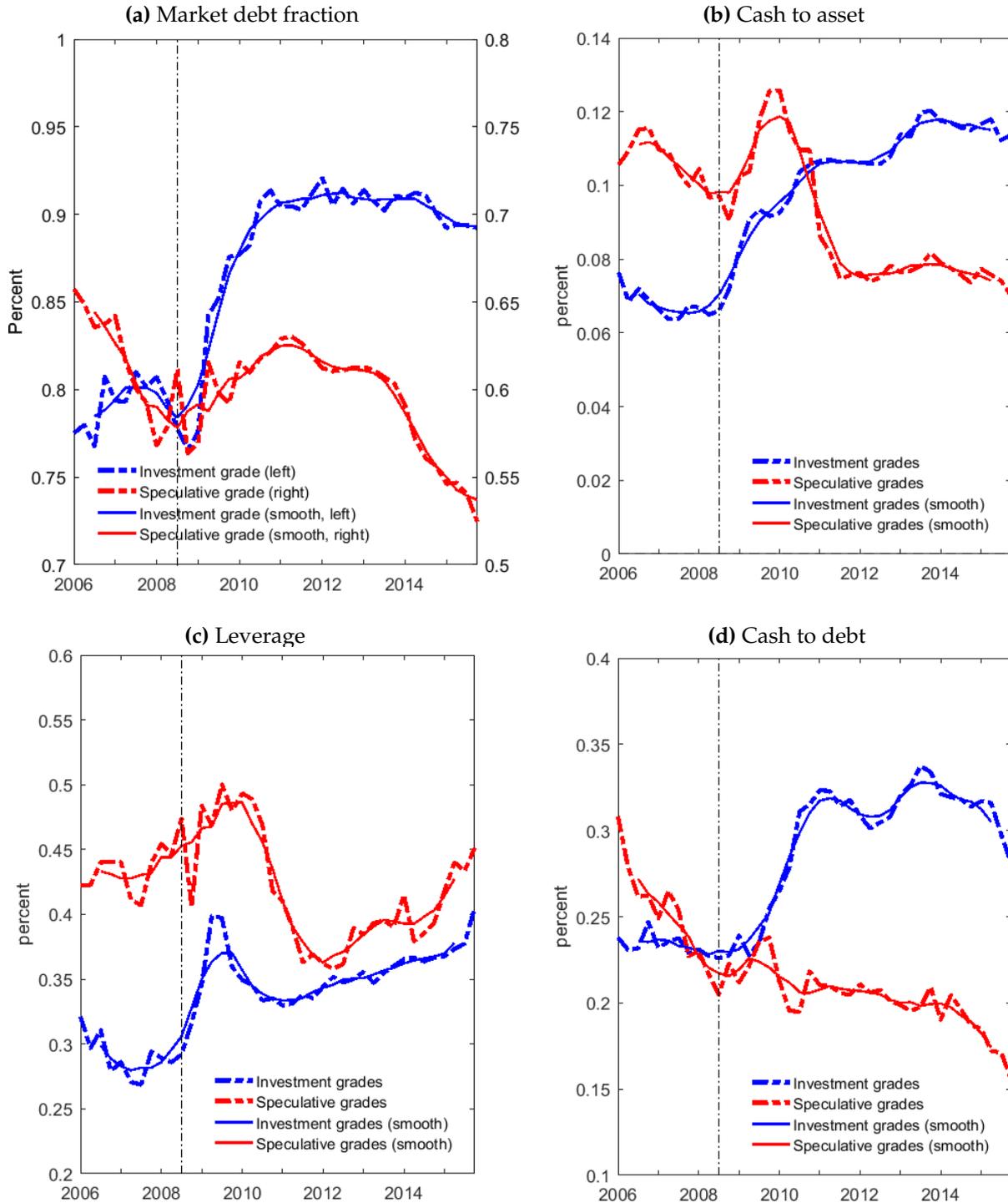


**Note:** The figure shows the changes in debt choices (panel (a)) and portfolio choices (panel (b)), relative to 2008Q3. The sample includes all Compustat firm-quarter observations from 2006Q1 to 2015Q4 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the largest 25 cash holders are excluded from the sample, yielding a panel of 21,402 firm-quarter observations for 938 unique firms. Variable definitions are provided in Appendix A.1.

cial corporations, such that by 2012, the relative increase in market debt has exceeded the relative decline in bank debt. Nevertheless, aggregate investment in capital expenditures has remained weak, and instead, there has been a substantial reallocation of portfolio from illiquid capital to liquid assets, especially in the first two years after the crisis. Moreover, cash holdings show no sign of returning to the pre-crisis level even after seven years. Investment in capital, on the other hand, has been severely subdued before 2012, and only returned to the pre-crisis level in 2014.

Figure A.1 corroborates the aggregate evidence, and shows that there is also significant heterogeneity in the balance sheet adjustment across firms. It plots, for investment-grade and speculative-grade firms, the quarterly averages across firms of the key metrics related to the hypothesis, including: fraction of market debt per firm (a), cash holdings to book assets (b), debt to book assets (c), and cash to debt (d). I begin by highlighting the different degrees of substitution from bank debt to market debt between the two groups of firms in panel (a). Investment grade firms have largely replaced bank debt with market debt since 2009, and the fraction of market debt remains high even after the financial crisis. On the contrary, such substitution has been much more moderate for the speculative grade firms. Panel (b) illustrates the divergence in cash hoarding behaviors between the two groups of firms. Investment grade firms have been holding an increasing proportion of their assets as cash since 2009, such that even though the speculative grade firms had higher cash-to-asset ratio than the investment grade firms before the crisis, the latter rapidly increased their cash holdings and overtook by 2011, with a 5 percentage point lead

**Figure 2: Firm Heterogeneity in Debt Composition and Firms' Balance Sheet Policies**



**Note:** The sample includes all Compustat firm-quarter observations from 2006Q1 to 2015Q4 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the largest 25 cash holders are excluded from the sample, yielding a panel of 21,402 firm-quarter observations for 938 unique firms. To remove seasonality in financing activities, all panels report the raw series (dashed lines) and its smoothed version (solid lines) as a moving average straddling the current term with two lagged and two forward terms. Variable definitions are provided in Appendix A.1.

**Table 1: Stylized Facts on Financial Policies and Firm Dynamics**

	Pre-crisis mean (2006Q1-2008Q2)			Post-crisis mean (2008Q3-2015Q4)			Difference between pre- and post-crisis means			
	Investment	Speculative	p-value	Investment	Speculative	p-value	Investment	p-value	Speculative	p-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Assets	18.68	4.71	0.00	24.42	4.19	0.00	5.74	0.00	-0.52	0.00
Market fraction	0.76	0.60	0.00	0.91	0.62	0.00	0.15	0.00	0.02	0.00
Market only	0.10	0.07	0.00	0.27	0.12	0.00	0.17	0.00	0.05	0.00
Cash to asset	0.07	0.10	0.00	0.11	0.08	0.00	0.05	0.00	-0.02	0.00
Leverage	0.28	0.45	0.00	0.36	0.41	0.00	0.08	0.00	-0.04	0.00
Capex to asset	0.04	0.04	0.23	0.03	0.04	0.00	-0.02	0.00	0.00	0.08
Sales to asset	0.26	0.19	0.00	0.21	0.20	0.00	-0.05	0.00	0.01	0.01
# Observations	1,318	1,452		9,253	9,379					

**Note:** This table presents the means aggregated across all quarters before the crisis (columns (1)–(3)) and after the crisis (columns (4)–(6)), among all investment grade firms (columns (1) and (4)) and speculative grade firms (columns (2) and (5)). The p-values for the differences in means between the two groups of firms are reported in columns (3) and (6) for the pre- and post-crisis subsamples, respectively. The differences in means between the pre- and post-crisis subsamples are reported in column (7) for the investment grade firms, and column (8) for the speculative grade firms, and the corresponding p-values are reported in columns (9) and (10), respectively. The sample includes all Compustat firm-year observations from 2006Q1 to 2015Q4 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor’s ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the largest 25 cash holders are excluded from the sample, yielding a panel of 21,402 firm-quarter observations for 938 unique firms. *Assets* are in billions of 2009 dollars. *Market fraction* is the percentage of market debt to the sum of bank and market debt. *Market only* is the fraction of firms with only have market debt. *Cash to asset*, *Leverage*, *Capex to asset*, and *Sales to asset* are expressed as percentages of book assets. All firm characteristic variables are winsorized at the 1<sup>st</sup> and 99<sup>th</sup> percentiles. Detailed variable definitions are provided in Appendix A.1.

by 2015. As the decline in bank debt was largely replaced by a significant increase in market debt, investment grade firms did not suffer from any steep decline in leverage compared to their speculative grade counterparts, both during the crisis and in the recovery period, as shown in panel (c). In fact, the investment grade firms have increased their leverage ratios by almost 10 percentage points from 2008 to 2014. Nonetheless, panel (d) suggests that they have been saving a high proportion of the new funds available as cash, and that the rate of saving is increasing at a faster rate than the rate at which its leverage is growing. Moreover, even though the two groups of firms had similar cash to debt ratios at the onset of the financial crisis, the investment grade firms had an over 15 percentage point lead by 2014.

Table A.1 shows additional univariate evidence on cross-firm variation between the investment grade and speculative grade firms that corroborates the observations in Figure A.1. To focus on the change in debt structure and cash holdings since the financial crisis, I split the sample into two periods: Columns (1)–(3) provide the summary statistics for the pre-crisis period of 2006Q1-2008Q2, including the p-values for the differences in sample means between the two groups of firms; and columns (4)–(6) present those for the post-crisis period of 2008Q3-2015Q4.<sup>8</sup> To highlight any firm heterogeneity, columns (1) and (4) present the means for the investment grade firms for the two subsample periods, whereas columns (2) and (5) report those for the specula-

<sup>8</sup>The key observations discussed below also hold if one compares the sample medians between the two groups of firms, as reported in Appendix A.2.

tive grade firms. In addition, columns (7) and (8) report the differences in means between the pre- and post-crisis subsamples for the investment grade firms and the speculative grade firms, respectively; the corresponding p-values are reported in columns (9) and (10).

The first key observation is that the mean fraction of market debt in the post-2009 subsample is 15 percentage points higher than the pre-crisis subsample for the investment grade firms, but only 2 percentage points higher for the speculative grade firms, which is about one-eighth of the increase for the investment grades. Moreover, focusing on the fraction of firms with bond-only financing, it has more than tripled for the investment grade firms since the crisis, whereas the increase for the speculative grade firms has been milder in comparison. Therefore, whilst both types of firms have increased market debt and retired bank debt since the crisis, the degree of substitution has been much stronger for the investment grade firms than for the speculative grade firms. Second, although the average cash-to-asset ratio was 3 percentage points higher for the speculative grade firms in the years preceding the crisis, the investment grade firms' cash ratio increased by approximately 4 percentage points whilst the average ratio for the speculative firms actually declined by 2 percentage point after 2008Q3. Thus in the post-crisis subsample, the cash-to-asset ratio for the investment grades has exceeded that for the speculative grades, by 3 percentage points. Third, the average capital expenditures as a percentage of book assets decreased by almost 2 percentage points for the investment grades but increased slightly for the speculative grades after the crisis. While the difference in capital expenditures between the two groups of firms was not significantly different from zero before the crisis, the speculative grades have actually devoted a higher proportion of their assets to capital expenditures than the investment grades since then. As a result, the investment grade firms have experienced negative growth—as proxied by the sales to asset ratio—unlike the speculative grade firms. Last, despite the steady increase in cash holdings, the investment grade firms have shown little sign that they are replacing debt finance with internal finance since the crisis. Instead, they have experienced an average increase of 8 percentage points in the leverage ratio, whereas the speculative grade firms have shrunk their pre-crisis debt level by 10 percent.

To sum up, the financial policies and dynamics of the two groups of firms have significantly diverged since the the investment grade firms substituted largely towards market debt after the 2007-09 financial crisis.<sup>9</sup> On the asset side, the investment grade firms have been hoarding increasing amounts of cash, at the cost of reducing capital expenditures and investment. On the liability side, besides the compositional shift from bank debt to market debt, the leverage ratio has also increased for the investment grade firms, suggesting that cash has not been a substitute for debt; instead, debt and cash have increased simultaneously.

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<sup>9</sup>As shown in Appendix A.3, the heterogeneity in firms' balance sheet policies reported in this section is robust to other definitions of sample split, e.g. by the size of a firm's total assets.

## 2.2 Panel Evidence

In the remainder of this section, I corroborate the descriptive stylized facts using panel data analysis. To evaluate the impact of debt composition on firm’s balance sheet policies, I start by regressing cash holdings, as a percentage of total assets, on a measure of debt structure (discussed below), while controlling for a set of standard determinants of cash holdings (e.g., [Bates, Kahle and Stulz \(2009\)](#); [Opler, Pinkowitz, Stulz and Williamson \(1999\)](#)). In order to be in line with the empirical literature on the determinants of corporate cash holdings, I use the annual counterpart to the quarterly dataset described in the previous section in these regressions, and one period lagged explanatory variables are used to reduce endogeneity concerns associated with using contemporaneous explanatory variables.<sup>10</sup>

The baseline specification is as follows:

$$\text{Cash}_{i,t} = \beta_1 \text{DebtStructure}_{i,t-1} + \theta' \text{Controls}_{i,t-1} + \eta_i + \lambda_t + \epsilon_{i,t}, \quad (1)$$

where the independent variable of interest,  $\text{DebtStructure}_{i,t-1}$ , is a proxy for firm  $i$ 's debt structure in year  $t - 1$ , and  $\text{Controls}_{i,t-1}$  is a vector of firm-level controls including firm size, cash flow, leverage, market-to-book ratio, capital expenditures, net working capital, R&D, acquisition expenditures, asset tangibility, and a dummy for whether the firm pays dividend in any given year. Equation (1) also includes a firm fixed effect  $\eta_i$  and a time fixed effect  $\lambda_t$ . For robustness, I consider two measures of debt structure. The first measure,  $\text{MarketFraction}_{i,t}$ , is the ratio of market debt to the sum of market debt and bank debt for firm  $i$  in year  $t$ . In addition, I also construct an indicator variable  $\text{MarketOnly}_{i,t}$  for each firm-year  $(i, t)$  in the sample, which is equal to one if  $\text{MarketFraction}_{i,t}$  is one and zero otherwise. Statistical significance is evaluated using robust clustered standard errors adjusted for non-independence of observations within firms. In order to reduce the “within group bias” on explanatory variables due to the unbalanced panel, firms with less than five years of data are excluded.

I report the estimates of  $\beta_1$  in [Table 2](#) for the overall sample, and for the subsets of investment grade and speculative grade firms.<sup>11</sup> For each sample, columns (1) and (2) report the estimates on the proxies for debt structure,  $\text{MarketFraction}_{i,t-1}$  and  $\text{MarketOnly}_{i,t-1}$ , respectively. The coefficients on both proxies are robustly positive and statistically significant at the 5% level across the samples, indicating that debt composition is a significant determinant of the within-firm time-series evolution of cash holdings. Specifically, a one unit increase in the fraction of market debt is associated with an approximately 3 percentage point increase in the cash-to-asset

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<sup>10</sup>The regression specifications in this section follow the standard approach in the empirical finance literature on corporate cash holdings. It is important to note that since debt composition is an endogenous variable, an estimate of  $\beta_1$  cannot be interpreted as a causal or structural relation at face value. The results in this section are for illustrating the correlation between firms’ debt structures and cash holdings.

<sup>11</sup>The results are robust to using median regressions that address the concern that firm-year outlier observations with very high levels of cash may be driving the estimates, as well as using variables in first differences that address the nonstationarity concern.

**Table 2:** Panel Evidence on Corporate Debt Composition and Firm Financing

	Full sample		Investment grades		Speculative grades	
	(1)	(2)	(1)	(2)	(1)	(2)
DebtStructure <sub>t-1</sub>	0.027*** (0.002)	0.019** (0.010)	0.023*** (0.003)	0.015** (0.023)	0.034** (0.012)	0.024** (0.028)
# Observations	4,683	4,683	2,178	2,178	2,505	2,505
# Clusters (firms)	867	867	327	327	540	540
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Within R <sup>2</sup>	0.775	0.756	0.820	0.796	0.746	0.718

**Note:** The sample includes all Compustat firm-year observations from 2006 to 2015 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the largest 25 cash holders are excluded from the sample. Columns (1) report the estimates from panel regressions of cash holdings to book assets on MarketFraction<sub>i,t-1</sub>, and columns (2) report estimates from similar regressions but replaces MarketFraction<sub>i,t-1</sub> by the indicator variable MarketOnly<sub>i,t-1</sub>. Year dummies as well as firm-level controls for standard determinants of cash holdings are included in all regressions. p-values are in parentheses and are clustered at the firm level. Detailed variable definitions are in Appendix A.1. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5% and 10% levels, respectively.

ratio for the full sample. Moreover, this estimate is higher for the subsample of speculative grade firms, suggesting that debt structure is particularly important for the cash holding decision of firms with lower ratings and higher default probabilities, after controlling for the real size of firm among other firm-level characteristics.<sup>12</sup> Replacing MarketFraction<sub>i,t</sub> with the indicator variable MarketOnly<sub>i,t-1</sub> obtains results that support the previous findings. Inclusion of firm fixed effects demeans firm level variables, and hence the firm average is not used to identify any coefficients. This means that the coefficient in front of MarketOnly<sub>i,t-1</sub> can be identified only if individual firms switch between market-only and mixed (or bank-only) debt structures. Non-switchers do not add identification power to our key estimate.<sup>13</sup> Switching from a mixed-finance or bank-only debt structure to a market-only debt structure entails a 2 percentage point increase in the cash-to-asset ratio in the full sample. Consistent with the results above, the impact of a switch is larger for the speculative grade subsample than the investment grade subsample.

**Debt Composition and Cash Dynamics** Before examining the impact of debt composition on the real decisions of the firms, I further investigate the role of corporate debt structure in driving the time-series dynamics of corporate cash management by adding a lagged dependent variable

<sup>12</sup>Signs and statistical significance of coefficients on control variables are unchanged across specifications and are in line with the findings of the previous literature (e.g. Bates, Kahle and Stulz (2009)). Large firms, firms that pay dividends or have more tangible assets, net working capital, and capital expenditures hold less cash; firms with higher market-to-book and more cash flow hold more. Detailed coefficient estimates for the control variables are available upon request.

<sup>13</sup>A firm that only appears once also does not contribute to statistical identification and does not affect the economic magnitude of the coefficient in front of MarketOnly<sub>i,t-1</sub> because it will be taken out by the firm fixed effects.

**Table 3: System GMM Estimates of Cash Dynamics By Quartiles of MarketFraction<sub>*i,t*</sub>**

	Full	Q1	Q2	Q3	Q4
	[0,100]	[0,25]	[25,50]	[50,75]	[75,100]
Cash <sub><i>i,t-1</i></sub>	0.508** (0.012)	0.350** (0.025)	0.537** (0.021)	0.612** (0.046)	0.654** (0.038)
MarketFraction <sub><i>i,t-1</i></sub>	0.021** (0.035)	0.028** (0.047)	0.019* (0.068)	0.013** (0.043)	0.010* (0.079)
Half-life (years)	0.98	0.66	1.12	1.41	1.63
# Observations	3,297	640	642	677	584
# Clusters (firms)	681	143	157	138	103
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes

**Note:** The sample includes all Compustat firm-quarter observations from 2006 to 2015 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the largest 25 cash holders are excluded from the sample. Reported coefficients are the GMM estimates of  $1-\alpha$  and  $\beta$ , for the full sample and the different sub-samples based on quartiles of the fraction of market debt. Speed of adjustment is  $\alpha$ . Cash half-life, calculated by  $\ln(0.5) / \ln(1 - \alpha)$ , is the time (in years) that it takes a firm to adjust back to the target cash after a one-unit shock to  $\epsilon$ . Year dummies as well as firm-level controls for standard determinants of financial policies are included. p-values are in parentheses and are clustered at the firm level. Detailed variable definitions are in Appendix A.1. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5% and 10% levels, respectively.

to our baseline specification (1):

$$\text{Cash}_{i,t} = (1 - \alpha)\text{Cash}_{i,t-1} + \beta_1\text{DebtStructure}_{i,t-1} + \theta'\text{Controls}_{i,t-1} + \eta_i + \lambda_t + \epsilon_{i,t}, \quad (2)$$

where  $\text{DebtStructure}_{i,t-1}$  is either the continuous proxy  $\text{MarketFraction}_{i,t-1}$  or the indicator variable  $\text{MarketOnly}_{i,t-1}$ , as in regression (1). This dynamic panel serves two purposes: first, the baseline results in Table 2 are robust to allowing for imperfections in cash rebalancing or partial adjustment in cash ratios (Lemmon, Roberts and Zender (2008)); second, I gather additional evidence on the role of financing frictions. In particular, I examine the hypothesis that a higher fraction of market debt lowers the speed of adjustment of cash, which is captured by  $\alpha$  in the dynamic model (2): for a given amount of total debt, if a higher fraction of market debt makes firm default more likely—due to, for instance, the inflexibility of market debt compared to bank debt—and hence higher overall cost of external finance, then it should be expected to increase adjustment costs of cash—thus leading to a lower speed of adjustment—since the value of holding more safe assets effectively lowers the default probability and hence the cost of debt.

Table 3 reports the system GMM estimates based on Blundell and Bond (1998) of the coefficients on  $\text{Cash}_{i,t-1}$  and  $\text{DebtStructure}_{i,t-1}$ , which is proxied by  $\text{MarketFraction}_{i,t-1}$ .<sup>14</sup> The full sample is split into four subsamples, based on quartiles of the fraction of market debt. To

<sup>14</sup>The coefficient estimates for the dynamic panel with  $\text{MarketOnly}_{i,t-1}$  are consistent with the baseline results in Table 2; they are not reported here for brevity, but are available upon request.

provide economic intuition, I translate these speeds of adjustment into half-lives, calculated by  $\ln(0.5)/\ln(1 - \alpha)$ , the time (in years) that it takes a firm to adjust one-half the distance to its target cash after a one unit shock to  $\epsilon_{i,t}$ . The half-life ranges from about 8 months to 20 months, with the speeds of adjustment declining monotonically with the fraction of market debt. For instance, the GMM estimate in column (4) imply that the half-life of 1.6 year for firms in the top quartile of the distribution of market debt fraction is roughly three times as long as the half-life for firms in the bottom quartile. Hence these results are consistent with the hypothesis that a higher fraction of market debt increases adjustment costs of cash.

**Corporate Investment and Firm Dynamics** Next, I document the empirical regularities that pertain to the real side decisions of firms. To illustrate the different rates of recovery in investment and sales between the investment grade and speculative grade firms, Figure 3 plots, for each group of firms, the quarterly averages across firms of the metrics related investment dynamics: total investment (the sum of capital expenditures and R&D expenditures) to book assets (a), and sales to book assets (b). As indicated by both measures, the speculative grade firms have recovered faster than the investment grade firms since 2009, suggesting that the latter group’s large sum of new market debt issues and cash holdings since the onset of the crisis (see Figure A.1) have not been channelled into productive uses to boost investment and growth. Specifically, although the two types of firms had similar investment rates before the crisis and suffered from similar magnitudes of a decline in investment during the crisis, the speculative grade firms recovered much more quickly and their investment was back to the pre-crisis level by 2012, leading the speculative grade firms by a percentage point. Turning to sales, despite having a lead of more than 5 percentage points in the pre-crisis period, the investment grade firms suffered from a larger decline in sales during 2008-09, and have shown no trend of recovery since.

To examine systematically the effects of a change in debt composition on firm’s investment and growth, I regress these two measures of firm growth, in turn, on lagged cash holdings and lagged debt composition, whilst controlling for a set of standard determinants of investments (e.g. Gomes (2001)):

$$\text{FirmGrowth}_{i,t} = \beta_1 \text{DebtStructure}_{i,t-1} + \beta_2 \text{Cash}_{i,t-1} + \theta' \text{Controls}_{i,t-1} + \eta_i + \lambda_t + \epsilon_{i,t}, \quad (3)$$

where  $\text{FirmGrowth}_{i,t}$  is either  $\text{Investment}_{i,t}$  or  $\text{Sales}_{i,t}$  as defined above,  $\text{DebtStructure}_{i,t-1}$  is proxied by  $\text{MarketFraction}_{i,t-1}$  or  $\text{MarketOnly}_{i,t-1}$ ,  $\text{Controls}_{i,t-1}$  include firm size, cash flow, leverage, market-to-book ratio, capital expenditures, net working capital, R&D, acquisition expenditures, asset tangibility, and a dummy for whether the firm pays dividend in any given year. Similar to the baseline regressions, equation (3) also includes a firm fixed effect  $\eta_i$  and a time fixed effect  $\lambda_t$ . I evaluate statistical significance using robust clustered standard errors adjusted for non-independence of observations within firms.

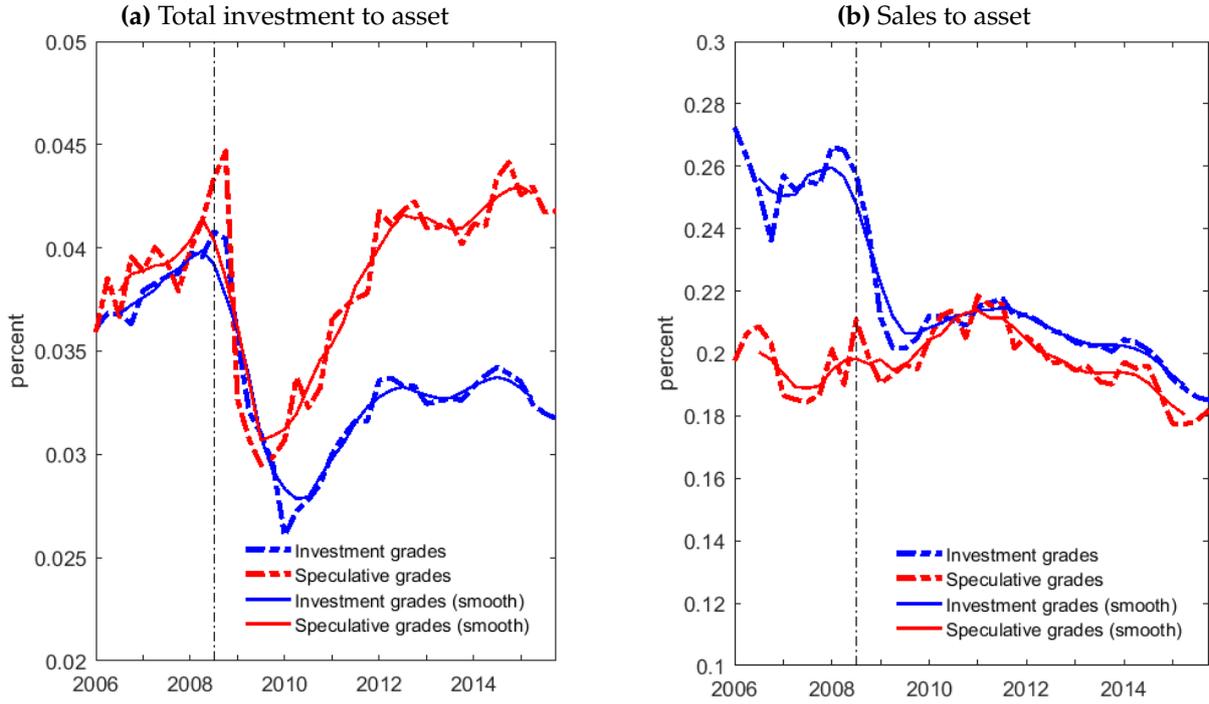
This framework allows one to study both the direct and indirect effects of a change in debt composition on firm’s investment and growth. Specifically, I ask two questions: (1) whether in-

**Table 4:** Panel Evidence on Corporate Debt Composition and Investment Dynamics

Panel A: Fixed-Effects Panel Regressions of Capital Expenditures on Cash Holdings						
	Full sample		Investment grades		Speculative grades	
	(1)	(2)	(1)	(2)	(1)	(2)
DebtStructure <sub>t-1</sub>	-0.008** (0.043)	-0.004* (0.071)	-0.007* (0.061)	-0.003* (0.089)	-0.010** (0.028)	-0.006* (0.077)
Cash <sub>t-1</sub>	0.013** (0.018)	0.009* (0.086)	-0.035*** (0.001)	-0.024** (0.046)	0.046** (0.013)	0.039** (0.037)
# Observations	4,683	4,683	2,178	2,178	2,505	2,505
# Clusters (firms)	867	867	327	327	540	540
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Within R <sup>2</sup>	0.826	0.813	0.834	0.821	0.814	0.798
Panel B: Fixed-Effects Panel Regressions of Sales on Cash Holdings						
	Full sample		Investment grades		Speculative grades	
	(1)	(2)	(1)	(2)	(1)	(2)
DebtStructure <sub>t-1</sub>	-0.013** (0.039)	-0.006* (0.082)	-0.011* (0.075)	-0.007* (0.094)	-0.017** (0.036)	-0.009* (0.089)
Cash <sub>t-1</sub>	0.107** (0.020)	0.038* (0.079)	-0.526*** (0.009)	-0.103** (0.044)	0.783** (0.028)	0.189** (0.047)
# Observations	4,683	4,683	2,178	2,178	2,505	2,505
# Clusters (firms)	867	867	327	327	540	540
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Within R <sup>2</sup>	0.938	0.921	0.930	0.911	0.943	0.929

**Note:** The sample includes all Compustat firm-year observations from 2006 to 2015 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the largest 25 cash holders are excluded from the sample. Columns (1) in Panel A(B) report the estimates from panel regressions of capital expenditures (sales) to book assets on Cash<sub>i,t-1</sub> and MarketFraction<sub>i,t-1</sub>, and columns (2) report estimates from similar regressions but replaces MarketFraction<sub>i,t-1</sub> by the indicator variable MarketOnly<sub>i,t-1</sub>. Year dummies as well as firm-level controls for standard determinants of cash holdings are included in all regressions. p-values are in parentheses and are clustered at the firm level. Detailed variable definitions are in Appendix A.1. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5% and 10% levels, respectively.

**Figure 3: Firm Heterogeneity on Capital Expenditures and Sales**



**Note:** The sample includes all Compustat firm-year observations from 2006Q1 to 2015Q4 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the largest 25 cash holders are excluded from the sample, yielding a panel of 21,402 firm-quarter observations for 938 unique firms. To remove seasonality in financing activities, all panels report the raw series (dashed lines) and its smoothed version (solid lines) as a moving average straddling the current term with two lagged and two forward terms. Variable definitions are provided in Appendix A.1.

creasing the proportion of market debt in period  $t - 1$  affects firm's investment decisions in period  $t$  (*direct effect*); and (2) given that firms tend to increase their cash holdings after switching to a more market-based debt structure, do they use their cash holdings in the subsequent period to finance investment and growth, whether this varies systematically with their debt composition (*indirect effect*). Specifically, these two effects are captured by the estimates of  $\beta_1$  and  $\beta_2$ , respectively. The resulting estimates are reported in Table 4, where FirmGrowth $_{i,t}$  is Investment $_{i,t}$  in Panel A, and Sales $_{i,t}$  in Panel B.

Consistent across all samples, the coefficient on DebtStructure $_{i,t-1}$  is negative and statistically significant. Together with the results in Table 2, I have shown that a proportional increase in market debt in period  $t - 1$  is associated with an reallocation of assets from productive capital to cash holdings in period  $t$ , and the substitution appears to be stronger among firms with higher risks and hence greater precautionary motive. However, there is significant heterogeneity regarding how firms use the cash accumulated in period  $t - 1$ . The coefficient on lagged cash holdings is statistically significant in all samples, and positive in the full sample, indicating that cash holdings, on average, have been a relevant source of financing for firm growth in the sample period. However, it has opposite signs in the two subsamples, whereby it is robustly positive in the speculative grade sample, but negative for the investment grade firms, indicating that cash has only been an important source of financing growth opportunities for the speculative grade firms. Investment grade firms, instead, seem to have set aside the liquid assets for collateral

purposes, which would relax their borrowing constraint in the future. One possible explanation is that investment grade firms have, on average, much higher fractions of market debt than the speculative grade firms, and the findings in Table 3 suggest that firms with higher fractions of market debt tend to adjust their cash balances more slowly, whether the adjustment is through investing cash for productive purposes or through altering the amount of holdings in the subsequent period.<sup>15</sup>

**The Role of Financial and Real Frictions** In the last set of final results, I use sample-split analysis to enhance the understanding of why debt structure is an economically important determinant of corporate cash holdings. In particular, I examine both financial and real frictions, which are key ingredients of the model presented in Section 3. If firms with proportionally more market debt hold more cash because of financial frictions, one would expect that the relation between debt composition and cash should be stronger among firms for which financial frictions are more severe. As for the real frictions, insights of the vast literature on real options (e.g. [Abel and Eberly \(1996\)](#)) suggest that firms make large and lumpy investments in the presence of non-convex capital adjustment frictions. Thus, if a debt structure tilted towards market debt increases firms' default probabilities and consequently the costs of external finance, these real frictions may induce firms with proportionally more market debt to accumulate even more cash, partly as safe assets to reduce default probabilities, and partly to finance their large and lumpy investments.

The left-hand side of Table 5 shows evidence supporting the role of financial frictions. I follow the standard approach in the literature (see, for example, [Hennessy and Whited \(2007\)](#)), and in every year over the sample period, I rank firms based on five ex-ante indicators of their financial constraint status, which include firm size, dividend payer status, the WW-Index by [Whited and Wu \(2006\)](#), and a measure of asset liquidation value by [Berger, Ofek and Swary \(1996\)](#). I assign to the financially constrained (unconstrained) groups those firms in the bottom (top) quartile of the annual distribution of each of these measures in turn, and regress  $Cash_{i,t}$  on  $DebtStructure_{i,t}$  for each of the subsample, employing the same set of controls as in equation (1). Consistently across specifications and irrespective of which indicator of ex-ante financing status is chosen, I find that the economic significance of the coefficient on  $DebtStructure_{i,t-1}$  is much stronger in the sub-samples of firms that are more likely to face financial frictions. For instance, going from the top (column (2) or (4)) to the bottom (column (1) or (3)) quartile of the firm size distribution (row (1)), the coefficient on either proxy of  $DebtStructure_{i,t-1}$  more than doubles.

The right-hand side of Table 5 splits the sample between bottom and top quartiles of the following four (time-invariant) proxies of real frictions: 4-SIC industry frequency of investment inaction and an indicator for whether there are investment spikes in the industry, which are both defined following [Cooper and Haltiwanger \(2006\)](#); and the time-series skewness and kurtosis of annual aggregate industry investment, both based on [Caballero \(1999\)](#). The intuition underlying

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<sup>15</sup>Table A.1 shows that in the post-crisis period, the fraction of market debt on the investment grade firms' balance sheets are, on average, 30 percent higher than on the speculative firms' balance sheets.

**Table 5: Panel Evidence on Financial and Real Frictions**

Financial Frictions				Real Frictions			
MarketFraction <sub><i>i,t-1</i></sub>		MarketOnly <sub><i>i,t-1</i></sub>		MarketFraction <sub><i>i,t-1</i></sub>		MarketOnly <sub><i>i,t-1</i></sub>	
(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
<b>Firm Size</b>				<b>Frequency of Investment Inaction</b>			
Q1	Q4	Q1	Q4	Q1	Q4	Q1	Q4
0.082**	0.038**	0.029**	0.012**	0.041**	0.069***	0.021*	0.030**
(0.019)	(0.028)	(0.021)	(0.048)	(0.023)	(0.008)	(0.066)	(0.041)
Prob > $\chi^2$				Prob > $\chi^2$			
0.019		0.025		0.089		0.102	
<b>Dividend Payer Status</b>				<b>Investment Spikes in the Industry</b>			
No	Yes	No	Yes	Q1	Q4	Q1	Q4
0.108**	0.056**	0.038**	0.017**	0.067**	0.103**	0.017**	0.025**
(0.029)	(0.034)	(0.023)	(0.038)	(0.018)	(0.026)	(0.048)	(0.038)
Prob > $\chi^2$				Prob > $\chi^2$			
0.005		0.007		0.091		0.114	
<b>WW-Index</b>				<b>Skewness of Industry Investment</b>			
Q1	Q4	Q1	Q4	Q1	Q4	Q1	Q4
0.079**	0.042**	0.021**	0.010*	0.074**	0.109**	0.029*	0.035**
(0.024)	(0.028)	(0.041)	(0.078)	(0.041)	(0.038)	(0.082)	(0.039)
Prob > $\chi^2$				Prob > $\chi^2$			
0.022		0.028		0.123		0.130	
<b>Asset Liquidation Value</b>				<b>Kurtosis of Industry Investment</b>			
Q1	Q4	Q1	Q4	Q1	Q4	Q1	Q4
0.114**	0.061**	0.047**	0.022*	0.076**	0.102**	0.013*	0.018**
(0.027)	(0.031)	(0.028)	(0.059)	(0.024)	(0.033)	(0.087)	(0.041)
Prob > $\chi^2$				Prob > $\chi^2$			
0.043		0.039		0.087		0.135	

**Note:** The sample includes all Compustat firm-year observations from 2006 to 2015 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the largest 25 cash holders are excluded from the sample. Columns (1) and (2) report the estimates from panel regressions of cash holdings to book assets on MarketFraction<sub>*i,t-1*</sub>, and columns (3) and (4) report estimates from similar regressions but replaces MarketFraction<sub>*i,t-1*</sub> by the indicator variable MarketOnly<sub>*i,t-1*</sub>. Year dummies as well as firm-level controls for standard determinants of cash holdings are included in all regressions. p-values are in parentheses and are clustered at the firm level. Detailed variable definitions are in Appendix A.1. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5% and 10% levels, respectively.

these proxies is that, due to technological differences, the extent to which firms face nonconvex adjustment costs varies across industries. Thus, industries where these costs are higher are those where firms are more likely to adjust investment infrequently, and conditional on adjusting, by a proportionally larger amount. In addition, in these industries the adjustment costs lead to a time-series distribution of aggregate investment that is sharply right-skewed and fat-tailed. Thus, I assign to the high (low) investment friction groups those firms in the top (bottom) quartile of the distribution of each of these measures in turn. Consistently across specifications and irrespective of the indicator chosen, the economic significance of the coefficient on  $\text{DebtStructure}_{i,t}$  is bigger in the sub-samples of firms that are more likely to face investment frictions, though the differences between the subsamples are not as much as the differences when we split the sample according to the metrics of financial frictions.

To further analyze the relative importance of the two types of frictions, I compute the chi-squared statistic for the regression coefficients across the subsample bins, for each friction indicator, and the p-values are reported in Table 5. Consistent across all indicators and specifications, we can reject, at the 5% significance level, the hypothesis of equality of coefficients in front of  $\text{DebtStructure}_{i,t}$  across groups of firms with different degrees of financial frictions. However, this is not true for firms with different degrees of real frictions. These results suggest that financial frictions play a more prominent role than real frictions in determining the impact of debt structure on cash holdings.

### 2.3 Summary of the New Stylized Facts

The full range of results in the present section can be pieced together to draw some tentative conclusions on the patterns of debt composition, financial policies, and investment decisions, across firms of different default probabilities since the 2007-09 financial crisis. First of all, even though bank debt contracted for all firms during the crisis, the substitution towards market debt has been much stronger among firms with better credit ratings, i.e. the investment grade firms. Hence these firms suffered from a smaller decline in leverage during the crisis and a faster recovery in borrowing afterwards. Nonetheless, despite their readily available external finance, these firms experienced a steeper decline on the real side and a much slower recovery in investment and sales.

Fixed-effects panel regressions suggest that changes in their debt compositions can provide one possible explanation for the divergence in their financial and investment policies. I show that increasing the fraction of market debt on a firm's balance sheet lagged one year has a positive and significant effect on its cash to asset ratio, but a negative and significant effect on its capital expenditures to asset or sales to asset. Furthermore, I also find that firms with higher fractions of market debt are reluctant to adjust their cash holdings, or use cash to finance investment. These two findings suggest that changes in debt composition can affect a firm's investment decisions either by directly changing the firm's asset allocation between cash and productive capital,

or by influencing how quickly the firm uses its cash to finance investment. Both channels can explain the much slower recovery in investment and growth among the investment grade firms compared to the speculative grade counterparts, despite that the former group had more external finance available, having tapped into the bond markets in large quantities. Moreover, the relation between debt composition and cash is stronger among firms that are more financially constrained, but not necessarily among firms that belong to industries with greater investment inflexibility. Motivated by these empirical results, I build a structural model in the next section that accommodates the following features, in order to capture the channels through which corporate debt choices can affect firm's investment:

1. Firms' cash holdings are positively related to the fraction of market debt in the time series and in the cross section;
2. Firms with more market debt are less likely to use their cash holdings to finance investment;
3. The adjustment dynamics of cash is more sluggish for firms with higher fractions of market debt;
4. The link between cash and debt composition is stronger for the firms that are financially constrained and those that belong to industries with greater investment inflexibility, though financial frictions appear to play a more prominent role in shaping a firm's financial policies.

### **3 Structural Model of Firm Dynamics with Debt Composition and Cash Holdings**

In this section I develop a quantitative general equilibrium model with heterogeneous firms that optimize the composition and amount of borrowing on the liability side, and the portfolio allocation between savings and investment on the asset side. The main departure from the majority of existing firm dynamics models with financial frictions (e.g. [Khan and Thomas \(2013\)](#); [Gilchrist, Sim and Zakrajšek \(2014\)](#)) is twofold: first, debt financing in this model can take two forms: bank debt and market debt; second, firms simultaneously borrow and hold cash, even though the return on cash is less than or equal to the interest rate on risky debt.

The model has a continuum of identical households, a continuum of heterogeneous intermediate goods firms, final goods firms, and two types of financial intermediaries. Households solve a standard consumption-savings problem, and are the owners of all firms. The final goods firms are competitive and have a technology that converts intermediate goods into a final good. Crucially, this technology is subject to a demand shock, which affects the relative demand of the final goods firms for different types of intermediate goods. As the intermediate goods firms can only borrow state-uncontingent debt, they cannot insure away the fluctuations in demand that they face.

The intermediate goods firms—that face heterogeneous productivity and demand—are the key agents in the model. They produce using decreasing returns-to-scale production technology, which guarantees that they have a finite optimal scale of operation. However, there are three sources of financial frictions that prevent them from investing to their optimal scale. First, firms have limited liability and can default on their debt obligations, and if they do, they exit the market. However, liquidation is inefficient: it involves deadweight losses, so debt finance commands an external finance premium. Second, unlike assets, liabilities cannot be reoptimized after the productivity shock is realized. Third, I assume that firms can only issue equity at entry, but not thereafter, in order to focus solely on the impact of debt substitution.<sup>16</sup> These frictions not only restrict a firm’s ability to obtain external finance to invest to its optimal scale, but also incentivize them to transfer resources from capital accumulation to savings, for a given leverage.

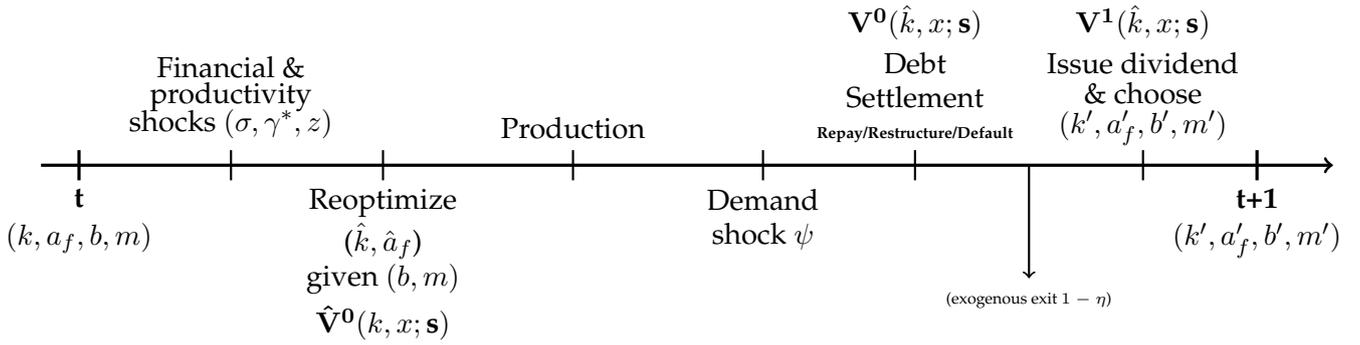
Within this framework, I analyze the role of firms’ balance sheet adjustment in the propagation of aggregate shocks. More specifically, I focus on two sources of aggregate fluctuations. Disturbances from the first source increase the costs of bank intermediation, and hence capture “financial” shocks by affecting the availability of credit to firms. The study of financial shocks have received increasing attention since the Great Recession (see, for example, [Christiano, Motto and Rostagno \(2010\)](#); [Del Negro, Eggertsson, Ferrero and Kiyotaki \(2011\)](#); [Jermann and Quadrini \(2012b\)](#)). In these studies, financial shocks are typically modelled as shocks to the liquidation value of capital. As this paper distinguishes between bank debt and market debt, and evidence from the crisis points overwhelmingly to a shock in the supply of intermediated credit by banks (e.g. [Adrian, Colla and Shin \(2012\)](#)), the departure from [Jermann and Quadrini \(2012b\)](#) and other studies of financial shocks is that I model a financial shock that asymmetrically affects the supply of bank debt and not market debt, rather than a shock to the liquidation value of capital that affects the supply of both types of debt.<sup>17</sup>

The second type of disturbances alter the dispersion of the idiosyncratic technology shock across all firms and hence capture (technology) “uncertainty” shocks in the aggregate sense, as in [Bloom \(2009\)](#); [Bloom, Bond and Van Reenen \(2007\)](#); [Bachmann and Bayer \(2013\)](#); [Gilchrist, Sim and Zakrajšek \(2014\)](#)). In the presence of irreversibilities and nonconvex capital adjustment costs, uncertainty and financial shocks have real consequences for macroeconomic outcomes, regardless of the structure of the financial markets. Distortions in financial markets, however, can significantly amplify the initial impact of each shock on aggregate investment via two channels:

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<sup>16</sup>The assumption that firms cannot issue equity *at all* is not necessary for the main results of the paper to hold, but allows the paper to focus on debt finance—especially its composition—instead of equity finance, because Compustat data shows that, on average, the substitution from bank debt towards market debt during the 2007-09 crisis was much stronger than the substitution towards equity finance. Moreover, the investment-grade and the speculative grade firms show very similar patterns in equity issuance since the crisis, so one should search elsewhere for explanation of their divergence in firm dynamics. A version of the model that allows firms to issue new shares after entry is available upon request.

<sup>17</sup>It is difficult to observe directly from the data the resale value of fixed capital at the macro level, whereas financial intermediation costs are a more tangible measure.



**Figure 4:** Overview and Timing of Intermediate Goods Firms' Problem

one is by reducing the effective supply of credit (“financial constraint” channel), and the other is by inducing firms to accumulate safe assets for precautionary reasons instead of investing in productive capital (“precautionary savings” channel). To streamline exposition, I layout the structure of the model in sections 3.1–3.6, leaving a joint discussion of the key assumptions to section 3.7.

### 3.1 Overview of Firms' Problem

**Timing** Figure 4 summarizes the timing of each intermediate goods firm's problem. At the beginning of each period, all shocks pertaining to the production and borrowing decisions—including the level of idiosyncratic uncertainty ( $\sigma$ ), the relative supply of bank credit ( $\gamma^*$ ), and the level of idiosyncratic technology ( $z$ )—are realized. The volatility level  $\sigma$  determines the distribution of  $z'(\sigma)$  in the next period, so from the agents' perspective, an increase in  $\sigma$  represents “news” regarding the distribution of profits tomorrow (Bloom (2009); Gilchrist, Sim and Zakrajšek (2014)). Before production, firms can re-optimize their allocation of assets  $(\hat{k}, \hat{a}_f)$ , given the predetermined level and composition of debt  $(b, m)$ , in order to maximize their expected profits by taking into account of the realized financial and productivity shocks. This motivates the first key assumption of the paper:

**Assumption 1.** (Portfolio adjustment) *The portfolio of assets (cash holdings versus capital) can be adjusted after the realization of productivity and financial shocks, but the portfolio of liabilities cannot be.*

In other words, upon observing the productivity shock, the firm can either invest some or its cash on hand in capital for production later this period, or liquidate its capital—subject to an adjustment cost (discussed below)—and retain within the firm as cash reserve and carry over to the next period.<sup>18</sup> The firm then produces output using the re-optimized amount of capital  $\hat{k}$ . After production, idiosyncratic demand shocks ( $\psi$ ) are realized, which are shocks to the profit

<sup>18</sup>The assumption that a firm can only re-optimize its cash holdings but not debt levels in the middle of a period implies that variations in cash holdings are likely to be much larger than those in leverage ratios. To test this conjecture, I use the same annual Compustat dataset between 2006 and 2015 as described in Section 2, focusing on non-financial firms with non-trivial debt amounts (book leverage above 5%). I find that for the median firm in each quartile of the

functions of the intermediate goods firms. At the debt settlement stage, the firm can either repay both types of debt, restructure bank debt, or default, in which case it exits endogenously.<sup>19</sup>

To capture the pattern that firms grow slowly because of the lack of internal funds, I impose an exogenous exit rate (see, for example, [Khan and Thomas \(2013\)](#)): Firms reach the end of their life cycle and exogenously exit the economy after debt settlement with probability  $1 - \eta$ . Firms that receive this exit signal leave the economy immediately and pay any remaining profits as dividends to the households. This assumption prevents that in the model all firms become financially unconstrained and also allows the model to exhibit a life cycle for firms. The exiting firms are replaced by new firms at the beginning of the next period, whose initial state will be discussed in Section 3.5. Finally, upon surviving the exit shock, firms choose the amount of capital  $k'$ , cash holdings  $a'_f$ , bank debt  $b'$ , and market debt  $m'$  that they want to take into next period.

To streamline notation, I define the idiosyncratic state of a firm as  $s = [z, \hat{k}, x, \psi]$ , including a firm's idiosyncratic productivity ( $z$ ), end-of-period capital ( $\hat{k}$ ), net liquid asset position ( $x$ , to be defined below), and idiosyncratic demand shock ( $\psi$ ). Moreover, I define the aggregate state of the economy as  $\mathbf{s} = [\sigma, \gamma^*, \mu]$ , where  $\mu$  is the distribution of the firms across the idiosyncratic state  $s$ . Following the [Arellano, Bai and Kehoe \(2012\)](#), it is convenient to record the idiosyncratic demand shock in the beginning-of-period aggregate state, even though an individual firm's  $\psi$  is not realized until the middle of the period. This approach is permissible, as there is a continuum of firms of each type  $(z, \hat{k}, x)$  at the beginning of the period, so the fraction of these firms that will experience each level of  $\psi$  is known. Moreover, the evolution of the firm distribution  $\mu$  is determined in part by the actions of continuing firms and in part by the potential entrants, as discussed in Section 3.6.

**Production** The intermediate goods firms produce the output ( $y$ ) using a production technology that has decreasing returns to capital ( $\hat{k}$ ).<sup>20</sup> Production is subject to idiosyncratic technology shock ( $z$ ), and also requires a payment of fixed operating costs that are proportional to firm size as measured by its existing capital stock, with the proportionality factor denoted by  $F_o > 0$ . Formally, these assumptions are summarized by a production function:

$$y = z\hat{k}^\alpha - F_o\hat{k}; \quad 0 < \alpha < 1, \quad (4)$$

where  $\alpha$  is the degree of decreasing returns in production. The idiosyncratic technology shock  $z$  evolves according to an  $N$ -state Markov chain with *time-varying* volatility. I assume a Markov sample, the coefficient of variation (standard deviation divided by the mean) for cash as a proportion of total assets is 0.80, compared with 0.36 for total debt over total assets, with differences significant at the 1% level. See section 3.7 for detailed discussion on this assumption.

<sup>19</sup>Besides introducing a demand shock, one can also introduce a second idiosyncratic productivity shock before production, after firms re-optimize their asset allocations. The assumption of either having either a demand shock ([Arellano, Bai and Kehoe \(2012\)](#)), or a sequence of idiosyncratic productivity shocks ([De Fiore and Uhlig \(2011, 2015\)](#)), is not new in the literature, in order to rationalize the existence of risky debt.

<sup>20</sup>The assumption of decreasing returns-to-scale implies that given the stochastic state, there exists an optimal firm size and it allows one to think about the distribution of firms.

chain with  $N$  states, and let  $p_{i,j}$  denote the transition probability of moving from state  $i$  in the current period to state  $j$  in the subsequent period. Importantly, the Markov chain of the idiosyncratic technology shock is constructed in such that: (1) its conditional mean is not affected by fluctuations in volatility; and (2) its conditional variance, however, is a linear function of the realization of the time-varying volatility process, given by:

$$\log \sigma'_z = (1 - \rho_\sigma) \log \bar{\sigma} + \rho_\sigma + \log \epsilon'_\sigma; \quad \log \epsilon'_\sigma \sim N(-0.5\omega_\sigma^2, \omega_\sigma^2). \quad (5)$$

Therefore, by construction, the aggregate shock to the uncertainty level does not alter the economy-wide mean productivity level, hence there is no aggregate technology shock. Moreover, a shock to the uncertainty level is an aggregate shock in that all firms have the same uncertainty level.<sup>21</sup>

**Capital Accumulation** Capital adjustment is subject to a combination of convex and non-convex frictions, that are critical to generate a more realistic firm size distribution by inducing slow convergence to the optimal firm size implied by the decreasing returns to scale assumption. Formally, the total costs of capital adjustment for inter-period optimization is given by:

$$g(k', \hat{k}) = F_{k_0} \hat{k} + \frac{F_{k_1,t}}{2} \left( \frac{k' - (1 - \delta)\hat{k}}{\hat{k}} \right)^2 \hat{k} \quad (6)$$

where

$$F_{k_1,t} \equiv p_k^+ \times \Xi_{(k' - (1 - \delta)k) > 0} + p_k^- \times \left( 1 - \Xi_{(k' - (1 - \delta)k) < 0} \right),$$

and  $0 < \delta < 1$  denotes the depreciation rate.  $\Xi_{(k' - (1 - \delta)k) < 0}$  is an indicator that equals one when the firm dis-invests, and  $0 \leq p_k^- < p_k^+$  captures the costly reversible investment framework of [Abel and Eberly \(1996\)](#).

I assume that firms face the same adjustment cost for intra-period optimization, which is given by:

$$g(\hat{k}, k) = F_{k_0} k + \frac{F_{k_1,t}}{2} \left( \frac{\hat{k} - k}{k} \right)^2 k, \quad (7)$$

where

$$F_{k_1,t} \equiv p_k^+ \times \Xi_{(\hat{k} - k) > 0} + p_k^- \times \left( 1 - \Xi_{(\hat{k} - k) < 0} \right).$$

Findings by [Cooper and Haltiwanger \(2006\)](#) suggest that a model that mixes both convex and non-convex adjustment costs fits the data best. To that end, there are two components of capital adjustment frictions. First, the term  $F_k k$  represents the fixed costs associated with capital expenditures—which are assumed to be proportional to the initial capital stock  $k$  to eliminate any size effect—capture the inherent indivisibility of physical capital and potential increasing returns to

<sup>21</sup>In this framework, the number of states of the Markov chain is constant over time. However, because the volatility of the chain is time-varying, the nodes in the support of the distribution of the idiosyncratic technology shock change in such a way that firms face a greater dispersion of the idiosyncratic technology levels when volatility increases. Hence, the index  $j$  in the expression  $z'_j(\sigma_z)$  signifies only the relative position, rather than the absolute value, in the support of the realized distribution of  $z$  that is associated with the volatility level  $\sigma_z$ . See [Appendix B.1](#) for technical details on the construction of the Markov chain.

both the installation of new capital and restructuring of productive capacity during periods of intensive investment.<sup>22</sup> The second term is a quadratic adjustment cost that is related to the rate of adjustment, such that the cost of investment is higher for more rapid changes. This term is responsible for smoothing investment over time. Moreover, I use asymmetric adjustment costs as in Zhang (2005), and Begenau and Salomao (2016). The irreversibility assumption  $p_k^+ > p_k^-$  implies that investment is more risky because firms cannot react to positive shocks without taking into account that a future negative shock can make it very expensive to become smaller. This assumption also means that firms may have to sit out several negative shocks without immediately choosing to downsize.

**Final Goods Firms** Final goods firms buy the products from intermediate goods firms, and produce the final good  $Y$  via the technology:<sup>23</sup>

$$Y = \left( \int \psi y(s)^{\frac{\zeta-1}{\zeta}} \mu(ds) \right)^{\frac{\zeta}{\zeta-1}}, \quad (8)$$

where  $y$  denotes the intermediate goods produced by a firm with idiosyncratic state  $(z, \hat{k}, x, \psi)$ ,  $\zeta > 1$  is the elasticity of substitution across goods, and  $\psi$  is the idiosyncratic demand shock, that follows a continuous Markov process:

$$\log \psi' = \rho_\psi \log \psi + \log \epsilon'_\psi; \quad \log \epsilon'_\psi \sim N(-0.5\sigma_\psi^2, \sigma_\psi^2), \quad (9)$$

and the distribution is independent of that of the idiosyncratic productivity shock. The final goods firms choose the intermediate goods to solve:

$$\max_{y(s)} Y = \left( \int_s \psi y(s)^{\frac{\zeta-1}{\zeta}} \mu(ds) \right)^{\frac{\zeta}{\zeta-1}}, \quad (10)$$

subject to (8). This yields the demand  $y(s)$  for any good with idiosyncratic state  $s = [z, \hat{k}, x, \psi]$ :

$$y(s) = \left( \frac{\psi}{p(s)} \right)^\zeta Y, \quad (11)$$

with  $Y(\mathbf{s}) = \left( \int \psi y(s)^{\frac{\zeta-1}{\zeta}} \mu(ds) \right)^{\frac{\zeta}{\zeta-1}}$ , and  $p(s)$  is the price of the good, which is determined after the demand shock  $\psi$  is realized. Next I turn to the details of the problem faced by an intermediate goods firm, including the prices of debt  $(q^b, q^m)$  and the firm's optimization problem.

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<sup>22</sup>Note that  $g((1-\delta)\hat{k}, \hat{k}) = g(\hat{k}, k) = F_k k$  even when gross investment is equal to zero. This specification of capital adjustment cost, however, does not imply that the firm pays the fixed costs  $F_k k$  in every period—that is, irrespective of its investment action/inaction status. As discussed below, the capital adjustment costs  $g(\cdot)$  enter the firm's problem multiplied by a decision variable  $v \in \{0, 1\}$ , and when the firm finds it optimal to set  $v = 0$ , it avoids paying the fixed costs of adjustment (see Abel and Eberly (1996)).

<sup>23</sup>In the model, the final goods producer has no value added, and hence this producer is a simple device to aggregate the output of the heterogeneous firms—referred to as intermediate goods firms—into a single value. Equivalently, one can think of these heterogeneous firms as final goods producers, and equation (8) reflects agents' preferences over these final goods.

### 3.2 Debt Settlement Outcomes

To finance investment projects, firms use a combination of internal and external funds, where the sources of internal funds are operating income and cash holdings ( $a_f$ ), whilst external funds consist of bank debt ( $b$ ) and market debt ( $m$ ). Relative to internal finance, debt finance commands a premium because of the agency costs associated with default. The debt contracts specify the par values of issues ( $b', m'$ ) and the prices ( $q^b, q^m$ ), yielding the total amount of debt financing to the sum of  $q^b b'$  and  $q^m m'$  in each period. By combining the proceeds from debt issuance with other sources of funds, the firm purchases capital ( $k'$ ) to be used in production, or accumulates safe assets ( $a'_f$ ) to gain financial flexibility. In the subsequent period after observing the realization of shocks, the firm decides whether to fulfil its debt obligations. The firm has three options: full repayment of its liabilities, debt restructuring, or liquidation. If the firm fully repays its creditors, it pays the face values of the debt  $b'$  and  $m'$  to the bank lender and market lender, respectively. If it chooses to restructure its debt, it enters a debt-renegotiation process with the bank lenders. If it defaults, the firm is liquidated and its resources are passed onto creditors, subject to a dead-weight loss. I next discuss in more details each of these three options, and the key trade-offs that firms face in choosing the debt composition. I delay the discussion of the key assumptions embodied in this description to section 3.7.

**Repayment** At the debt settlement stage, whether the firm repays, restructures or defaults depends on its net worth.<sup>24</sup> Define the net worth of a firm, after the realization of the demand shock, as:

$$\begin{aligned} n' &= p'(\psi')y' + p_k^-(1 - \delta)\hat{k}' - F_o\hat{k}' + \hat{a}'_f - b' - m' \\ &= \pi' - b' - m', \end{aligned} \quad (12)$$

where  $\pi' = p'(\psi')y' + p_k^-(1 - \delta)\hat{k}' - F_o\hat{k}' + \hat{a}'_f$  represents the sum of the firm's profit from sales, the market value of undepreciated capital, and the return from savings. Note that the value of capital in place is evaluated at the resale value  $p_k^-$ , rather than its book value  $p_k^+$ . The firm can only fully repay its liabilities if the price of the good  $p(\psi)$  is high enough such that its resources exceed its total liabilities, i.e.  $\pi' \geq b' + m'$ . Otherwise it must liquidate and exit, or it can enter a renegotiation process with its lenders to restructure its debt in order to avoid liquidation. Impor-

<sup>24</sup>Similar net-worth based rules can be found in Gilchrist, Sim and Zakrajšek (2014). It is worth noting that the debt contracts in this paper depart from those in Cooley and Quadrini (2001) and Hennessy and Whited (2007), in which a firm defaults when its equity value  $V$ —rather than the net worth—hits a lower bound. If the technology shock follows an i.i.d. process and the analysis is conducted in partial equilibrium, the two assumptions are equivalent. However, if the technology shock is persistent or the firm's value function has other arguments (e.g. aggregate state variables), as is the case here, the two assumptions are no longer equivalent. The decision to use a lower bound for the *net worth* to determine the default threshold is a simplifying assumption that avoids the computationally intensive task of inverting the value function to compute the default boundary in each iteration of the dynamic programming routine, which is very costly in a general equilibrium framework. Moreover, it is not clearly empirically whether firms declare bankruptcy when the market values of their equity or the net asset values become negative.

tantly, with the restructuring option, sometimes the firm chooses *not* to repay its liabilities in full even if in principle it can (i.e.  $\pi' \geq b' + m'$ ).

**Liquidation** A firm is forced into liquidation by the lenders, if its realized net worth  $n'$  is sufficiently low. A key assumption is that the transfer of the firm's resources to creditors involves a deadweight loss.

**Assumption 2.** (Deadweight loss in default) *The liquidation value of the firm is given by  $\chi\pi'$ , where  $0 \leq \chi < 1$ .*

Therefore, lenders charge the firm a liquidation premium in equilibrium. With multiple creditors, one must first take a stance on how liquidation resources are allocated among stakeholders. I assume that the split follows a rule similar to the Absolute Priority Rule governing corporate bankruptcies in the US: a claim by a stakeholder to liquidation resources can be activated only if all stakeholders placed higher in the priority structure have been made whole. In this model, there are three stakeholders: bank lenders, market lenders, and the firm itself. The firm is the residual claimant. In this paper, I assume that bank lenders are more senior than market lenders in the priority structure, as empirical evidence documented by [Rauh and Sufi \(2010\)](#) shows that bank debt tends to be placed on top of firms' priority structures or secured against assets.<sup>25</sup>

As a result of the existence of multiple debt instruments in the model and this assumed priority structure, the firm can either default completely—such that it cannot pay either lender—or in part, where the firm repays the more senior bank lender but defaults on the less senior market debt. If no debt restructuring occurs, or if the renegotiation process fails, the payoffs to the bank lender ( $\mathcal{R}_b$ ) and market lender ( $\mathcal{R}_m$ ) upon liquidation of the firm can be summarized as:

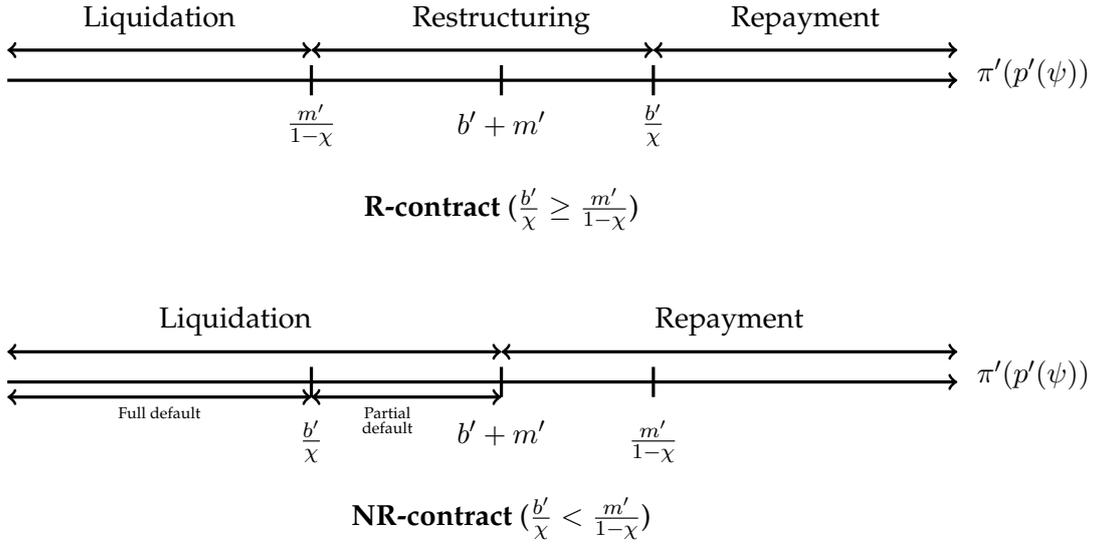
$$\begin{aligned}\mathcal{R}_b &= \min(b', \chi\pi') \\ \mathcal{R}_m &= \max(\chi\pi' - b', 0);\end{aligned}\tag{13}$$

in other words, in the case of a complete default, the bank seizes the resources of the firm, subject to the deadweight loss ( $\mathcal{R}_b = \chi\pi'$ ), and the market gets nothing ( $\mathcal{R}_m = 0$ ); in the case of a partial default, the bank gets the face value of the debt ( $\mathcal{R}_b = b'$ ), and the market gets the rest of the firm's resources subject to the deadweight loss ( $\mathcal{R}_m = \chi\pi' - b'$ ).

**Restructuring** The firm can renegotiate with its lenders, to pay a lower amount of its liabilities, in order to avoid default.<sup>26</sup> The crucial distinction between banks and market lenders lies with

<sup>25</sup>In other closely related papers, such as [Hackbarth, Hennessy and Leland \(2007\)](#) and [Crouzet \(2015\)](#), bank debt seniority is the optimal priority structure from the perspective of the firm. Moreover, in other models of debt structure where the role of banks is to provide ex-ante monitoring of firms' projects, the optimality of bank seniority is also a feature of other models of debt structure (e.g. [Besanko and Kanatas \(1996\)](#); [De Marzo and Fishman \(2007\)](#)), the optimality of bank debt is also an important feature as it increases the return of banks to monitoring.

<sup>26</sup>In reality, debt renegotiations need not involve a reduction in principal or interest payments, but could involve an extension of the maturity in the loan (see, for example, [Chava and Roberts \(2008\)](#); [Roberts and Sufi \(2009\)](#)). Since



**Figure 5:** Debt settlement outcomes

their ability to participate in the renegotiation process, which constitutes a key assumption of the paper:

**Assumption 3.** (Debt flexibility) *Only bank debt can be restructured; market debt cannot.*

I follow [Crouzet \(2015\)](#) in modelling the restructuring process as a two-stage Nash bargaining game between the firm and the bank. The firm first makes an offer  $b'_R$  to the bank, which is a new amount of repayment instead of the promised amount  $b'$ . The bank can choose to accept or reject the offer. In case the offer is rejected, liquidation ensues, and all parties receive the liquidation payoffs described by (13). In this process, market lenders only have an indirect role, as the amount of market debt remains untouched in any successful restructuring agreement.<sup>27</sup>

The optimal response of the bank is to accept the offer, if and only if it exceeds the bank's reservation value given in (13)—that is, if and only if  $b'_R \geq \min(b', \chi\pi')$ . Since the firm has all the bargaining power as the first mover, it has no incentive to offer anything above the bank's reservation value. Hence if the firm enters renegotiation with the bank lenders, the restructured bank debt amount is  $b'_R = \min(b', \chi\pi')$ . Given the realization of the idiosyncratic and aggregate shocks, the firm chooses between liquidation, restructuring and repayment. The following proposition describes the equilibria in pure strategies, and Figure 5 provides a graphical representation.

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all debt contracts in this model are one-period contracts, renegotiations involving the *dynamic* relationship between creditor and debtor are not possible. Nevertheless, both ways of modelling debt renegotiations allow the firm to continue operating in the face of low income realizations, and mitigate the risk of default and liquidation.

<sup>27</sup>This equilibrium outcome echoes the findings in the literature on sovereign debt restructuring, such as [Bolton and Jeanne \(2007, 2009\)](#), that the sovereign borrowers have often restructured their bank debt while staying current on their bond liabilities, as bank debt is more easily renegotiable.

**Proposition 1.** (Debt settlement outcomes) *There are two types of debt settlement outcomes, depending on the relative amount of the market debt vis-à-vis bank debt in the firm's portfolio:*

- **(R-contract)** *If  $\frac{b'}{\chi} \geq \frac{m'}{1-\chi}$ , the firm chooses to repay its creditors in full if and only if  $\pi' \geq \frac{b'}{\chi}$ . It successfully restructures its debt if and only if  $\frac{b'}{1-\chi} \leq \pi' < \frac{b'}{\chi}$ , and it is liquidated when  $\pi' < \frac{b'}{1-\chi}$ . The restructured amount of bank debt is  $b'_R = \chi\pi'$ .*
- **(NR-contract)** *If  $\frac{b'}{\chi} < \frac{m'}{1-\chi}$ , the firm repays its creditors in full if and only if  $\pi' \geq b' + m'$ , and it is liquidated otherwise.*

where  $\pi' = p'(\psi')y' + p^-(1-\delta)\hat{k}' + \hat{a}'_f$ . In all debt settlement outcomes resulting in liquidations, the firm's payoff is  $V' = 0$ .

*Proof.* See Appendix B.3. ■

The proposition states that there are two sets of possible equilibria, such that restructuring may occur in one (R-contract) and never occurs in the other (NR-contract); which of the two arises in equilibrium depends on the relative amount of bank debt on the firm's balance sheet. Put differently, restructuring does not always save the firm from liquidation in the model. In the case of a NR-contract ( $\frac{b'}{\chi} < \frac{m'}{1-\chi}$ ), no restructuring ever occurs, and bankruptcy losses cannot be avoided when the firm's operating profits  $\pi'$  falls below the threshold at which the firm prefers declaring bankruptcy over repayment  $b' + m'$ . Intuitively, this occurs because the stake of the flexible creditors,  $b'$ , is too small for restructuring to bring about sufficient gains for the firm to avoid default on market debt. On the other hand, in the case of an R-contract ( $\frac{b'}{\chi} \geq \frac{m'}{1-\chi}$ ), the flexibility of bank debt sometimes allows the firm to make good on its payments on market debt, and restructuring can be the best option for the firm.<sup>28</sup> In some R-equilibrium—the region between  $\frac{m'}{1-\chi}$  and  $b' + m'$ —restructuring allows the firm to avoid liquidation. In other R-equilibria—the region between  $b' + m'$  and  $\frac{b'}{\chi}$ —the firm restructures for opportunistic reasons: the bank will be forced to accept a lower restructured amount, even though the firm has enough resources at hand to repay both lenders. Such strategic restructuring arises in equilibrium because the firm has all the bargaining power in the two-stage game, and takes advantage of the fact that the bank can never extract more than its reservation value  $\chi\pi'$  under restructuring.

### 3.3 Debt Pricing

Financial intermediaries receive deposits from households and firms, and use them to extend credit to firms. Each lender faces perfect competition, so their expected total profits are driven down to zero in each period. Assuming that lenders cannot cross-subsidize firms, lenders must

<sup>28</sup>Note that even with the restructuring option, firms still have an incentive to repay both types of debt in full in some R-equilibria, where  $\pi' \geq \frac{b'}{\chi}$ , as the repayment amount is less than the restructured amount, which depends on the value of collateral  $\pi\chi'$ . In other words, in these equilibria, firms have too much collateral that they would want to walk away with, such as in Kiyotaki and Moore (1997).

earn zero profit in expectation on each lending. Both bank lenders and market lenders face identical cost of deposits  $q^a(\mathbf{s})$ , but different intermediation costs.<sup>29</sup>

**Assumption 4.** (Financial intermediation costs) *The cost of intermediation per unit of lending is  $\gamma^b$  for bank lenders, and  $\gamma^m$  for market lenders. Define the wedge between the intermediation costs as  $\gamma^* = \gamma^b - \gamma^m$ , and  $\gamma^*$  follows a continuous Markov process:*

$$\log \gamma^{*'} = (1 - \rho_\gamma) \log \bar{\gamma}^* + \rho_\gamma \log \gamma^* + \epsilon'_\gamma; \quad \log \epsilon'_\gamma \sim N(-0.5\sigma_\gamma^2, \sigma_\gamma^2), \quad (14)$$

so the wedge between bank- and market-specific intermediation costs is always strictly positive:  $\gamma^b > \gamma^m$ .

Thus in this paper  $\gamma^*$  is a financial shock that captures the relative supply of bank loans. I come back to the assumptions about intermediation costs in Section 3.7. The prices of bank debt  $q^b$  and market debt  $q^m$  depend on whether the firm faces an R-contract, or a NR-contract, given values of  $b'$  and  $m'$ . Before describing the debt pricing formulae, I first express the threshold values of  $z'$ , which determine the debt settlement outcomes, and the payoffs to the lenders.

**NR-contract** If  $\frac{m'}{1-\chi} > \frac{b'}{\chi}$ , the firm repays its liabilities in full if  $\pi \geq b + m$ ; partially defaults (i.e. repays the more senior bank debt but defaults on market debt) if  $\frac{b'}{\chi} \leq \pi' < b' + m'$ ; and defaults on both types of debt if  $\pi' < \frac{b'}{\chi}$ . Hence one can define a pair of thresholds for the demand shock  $(\bar{\psi}'_{NR}, \underline{\psi}'_{NR})$ —conditional on tomorrow's aggregate state  $\mathbf{s}'$  and the individual state  $(k', b'_R, m', a'_f, z', \psi)$ —that are the inverse functions of  $(\bar{p}'_{NR}, \underline{p}'_{NR})$ , such that a firm defaults fully in the next period if  $\psi' < \underline{\psi}'_{NR}$ , and defaults partially if  $\underline{\psi}'_{NR} \leq \psi' < \bar{\psi}'_{NR}$ :

$$\begin{aligned} \bar{\psi}'_{NR} &= \bar{p}'_{NR}{}^{-1}(y) \\ \underline{\psi}'_{NR} &= \underline{p}'_{NR}{}^{-1}(y), \end{aligned} \quad (15)$$

where

$$\begin{aligned} \bar{p}'_{NR}(b', m', \hat{k}', \hat{a}_f, z'_j(\sigma)) &= \frac{b' + m' + F_o \hat{k}' - p^-(1 - \delta) \hat{k}' - \hat{a}'_f}{z'_j(\sigma) \hat{k}'^\alpha}, \\ \underline{p}'_{NR}(b', \hat{k}', \hat{a}_f, z'_j(\sigma)) &= \frac{\frac{b'}{\chi} + F_o \hat{k}' - p^-(1 - \delta) \hat{k}' - \hat{a}'_f}{z'_j(\sigma) \hat{k}'^\alpha}. \end{aligned} \quad (16)$$

<sup>29</sup>Since the financial intermediaries are perfectly competitive, they earn zero profit from total lending in expectations, i.e.:

$$\int (q^b(b, \hat{k}, \hat{a}_f, z_{-1}, \psi_{-1}; \mathbf{s}) + \gamma^b) b' \mu(dz, d\psi, dk, dx) = q^a(\mathbf{s}) a_b(\mathbf{s}),$$

and

$$\int (q^m(b, m, \hat{k}, \hat{a}_f, z_{-1}, \psi_{-1}; \mathbf{s}) + \gamma^m) m' \mu(dz, d\psi, dk, dx) = q^a(\mathbf{s}) a_m(\mathbf{s}).$$

Assuming that lenders do not cross-subsidize firms, they also earn zero profit in expectation from lending to each firm, i.e.:

$$(q^b(b, \hat{k}, \hat{a}_f, z_{-1}, \psi_{-1}; \mathbf{s}) + \gamma^b) b' = q^a(\mathbf{s}) b',$$

and

$$(q^m(b, m, \hat{k}, \hat{a}_f, z_{-1}, \psi_{-1}; \mathbf{s}) + \gamma^m) m' = q^a(\mathbf{s}) m'.$$

The payoffs to the bank and market lender are  $\tilde{\mathcal{R}}'_{b, NR}$  and  $\tilde{\mathcal{R}}'_{m, NR}$ , respectively, such that:

$$\tilde{\mathcal{R}}'_{b, NR} = \begin{cases} b' & \text{if } \psi' \geq \underline{\psi}'_{NR} \\ \chi\pi' & \text{if } \psi' < \underline{\psi}'_{NR}, \end{cases}$$

and

$$\tilde{\mathcal{R}}'_{m, NR} = \begin{cases} m' & \text{if } \psi' \geq \bar{\psi}'_{NR} \\ \chi\pi' - b' & \text{if } \underline{\psi}'_{NR} \leq \psi' < \bar{\psi}'_{NR} \\ 0 & \text{if } \psi' \leq \underline{\psi}'_{NR}. \end{cases}$$

Hence the price of debt on each lending is a weighted average of the discounted returns in default and non-default states tomorrow, minus the cost of intermediation today, thus implying the following debt pricing formulae in a NR-contract, for bank debt ( $q_{NR}^b(b', \hat{k}', \hat{a}'_f, z_i, \psi; \mathbf{s})$ ) and market debt ( $q_{NR}^m(b', m', \hat{k}', \hat{a}'_f, z_i, \psi; \mathbf{s})$ ), respectively:

$$q_{NR}^b(\hat{k}', b', \hat{a}'_f, z_i, \psi; \mathbf{s}) + \gamma^b = \mathbb{E} \left\{ \lambda(\mathbf{s}, \mathbf{s}') \left[ 1 + \sum_{j \in \mathcal{D}'_{NR}} p_{i,j} \left[ \frac{\chi\pi'}{b'} - 1 \right] \right] \middle| \mathbf{s} \right\} \quad (17)$$

and

$$q_{NR}^m(\hat{k}', b', m', \hat{a}'_f, z_i, \psi; \mathbf{s}) + \gamma^m = \mathbb{E} \left\{ \lambda(\mathbf{s}, \mathbf{s}') \left[ 1 + \sum_{j \in \bar{\mathcal{D}}'_{NR}} p_{i,j} \left[ \frac{\chi\pi' - b'}{m'} - 1 \right] + \sum_{j \in \mathcal{D}'_{NR}} p_{i,j} [-1] \right] \middle| \mathbf{s} \right\} \quad (18)$$

where  $\gamma^b$  and  $\gamma^m$  are the costs of intermediation,  $\lambda(\mathbf{s}, \mathbf{s}')$  is the stochastic discount factor of the households, and

$$\begin{aligned} \bar{\mathcal{D}}'_{NR} &= \left\{ j | j \in 1, \dots, N \text{ and } \underline{\psi}'_{NR}(\hat{k}', b', m', \hat{a}'_f, z'_j(\sigma), \psi; \mathbf{s}) \leq \psi' < \bar{\psi}'_{NR}(\hat{k}', b', m', \hat{a}'_f, z'_j(\sigma), \psi; \mathbf{s}) \right\} \\ \mathcal{D}'_{NR} &= \left\{ j | j \in 1, \dots, N \text{ and } \psi' < \underline{\psi}'_{NR}(\hat{k}', b', m', \hat{a}'_f, z'_j(\sigma), \psi; \mathbf{s}) \right\} \end{aligned} \quad (19)$$

are, respectively, the sets of states of the demand shocks  $\psi'$ , in which the firm will default on market debt only and on both types of debt, with  $\bar{\psi}'_{NR}$  and  $\underline{\psi}'_{NR}$  defined in (15).

**R-contract** If  $\frac{m'}{1-\chi} \leq \frac{b'}{\chi}$ , one can also define a pair of thresholds for demand ( $\bar{\psi}'_R, \underline{\psi}'_R$ ), that are the inverse functions of ( $\bar{p}'_R, \underline{p}'_R$ ), such that the firm repays its liabilities in full if  $\psi' \geq \bar{\psi}'_R$ ; restructures its bank debt while repaying its market debt if  $\underline{\psi}'_R \leq \psi' < \bar{\psi}'_R$ ; and defaults if  $\psi' < \underline{\psi}'_R$ :

$$\begin{aligned} \bar{\psi}'_R &= \bar{p}'_R^{-1}(y) \\ \underline{\psi}'_R &= \underline{p}'_R^{-1}(y), \end{aligned} \quad (20)$$

where

$$\begin{aligned} \bar{p}'_R(b', \hat{k}', \hat{a}'_f, z'_j(\sigma)) &= \frac{\frac{b'}{\chi} + F_o \hat{k}' - p^-(1-\delta)\hat{k}' - \hat{a}'_f}{z'_j(\sigma) \hat{k}'^\alpha}, \\ \underline{p}'_R(m', \hat{k}', \hat{a}'_f, z'_j(\sigma)) &= \frac{\frac{m'}{1-\chi} + F_o \hat{k}' - p^-(1-\delta)\hat{k}' - \hat{a}'_f}{z'_j(\sigma) \hat{k}'^\alpha}. \end{aligned} \quad (21)$$

The payoffs to the bank and market lender in an R-contract are  $\tilde{\mathcal{R}}'_{b,R}$  and  $\tilde{\mathcal{R}}'_{m,R}$ , respectively, such that:

$$\tilde{\mathcal{R}}'_{b,R} = \begin{cases} b' & \text{if } \psi' \geq \bar{\psi}'_R \\ \chi\pi' & \text{if } \psi' < \bar{\psi}'_R, \end{cases}$$

and

$$\tilde{\mathcal{R}}'_{m,R} = \begin{cases} m' & \text{if } \psi' \geq \underline{\psi}'_R \\ 0 & \text{if } \psi' < \underline{\psi}'_R. \end{cases}$$

Hence, the debt pricing formulae in an R-contract, for bank debt ( $q_R^b(\hat{k}', b', \hat{a}'_f, z_i, \psi; \mathbf{s})$ ) and market debt ( $q_R^m(\hat{k}', m', \hat{a}'_f, z_i, \psi; \mathbf{s})$ ), respectively:

$$q_R^b(\hat{k}', b', \hat{a}'_f, z_i, \psi; \mathbf{s}) + \gamma^b = \mathbb{E} \left\{ \lambda(\mathbf{s}, \mathbf{s}') \left[ 1 + \sum_{j \in \bar{\mathcal{D}}'_R} p_{i,j} \left[ \frac{\chi\pi'}{b'} - 1 \right] \right] \middle| \mathbf{s} \right\} \quad (22)$$

and

$$q_R^m(\hat{k}', m', \hat{a}'_f, z_i, \psi; \mathbf{s}) + \gamma^m = \mathbb{E} \left\{ \lambda(\mathbf{s}, \mathbf{s}') \left[ 1 + \sum_{j \in \underline{\mathcal{D}}'_R} p_{i,j} [-1] \right] \middle| \mathbf{s} \right\} \quad (23)$$

where

$$\begin{aligned} \bar{\mathcal{D}}'_R &= \left\{ j \mid j \in 1, \dots, N \text{ and } \underline{\psi}'_R(\hat{k}', m', \hat{a}'_f, z'_j(\sigma), \psi; \mathbf{s}) \leq \psi'_j(\sigma) < \bar{\psi}'_R(\hat{k}', b', \hat{a}'_f, z'_j(\sigma), \psi; \mathbf{s}) \right\} \\ \underline{\mathcal{D}}'_R &= \left\{ j \mid j \in 1, \dots, N \text{ and } \psi'_j(\sigma) < \underline{\psi}'_R(\hat{k}', m', \hat{a}'_f, z'_j(\sigma), \psi; \mathbf{s}) \right\} \end{aligned} \quad (24)$$

are, respectively, the sets of the idiosyncratic demand shock  $\psi'$ , in which the firm will restructure and default on their debt, with  $\bar{\psi}'_R$  and  $\underline{\psi}'_R$  defined in (20).<sup>30</sup>

### 3.4 Optimization of the Intermediate Goods' Firms

At the end of period  $t$ , if the firm has survived the exogenous exit shock  $1 - \eta$ , it chooses the optimal cash ( $a'_f$ ) and investment policies ( $k'$ ), as well as the amount of bank debt ( $b'$ ) and market debt ( $m'$ ) for period  $t + 1$ . I formulate the firm's profit maximization problem recursively in this section, starting with the definition of dividend, after debt settlement:

$$d_l = \begin{cases} p(\psi)y(z_i(\sigma_{-1})) - vg(k', \hat{k}) - b - m + \hat{a}_f - q^a a'_f + q_l^b b' + q_l^m m', & \text{if firm repays both } b \text{ and } m \\ p(\psi)y(z_i(\sigma_{-1})) - vg(k', \hat{k}) - b_R - m + \hat{a}_f - q^a a'_f + q_l^b b' + q_l^m m', & \text{if firm restructures } b \text{ and repays } m \end{cases} \quad (25)$$

where the subscript  $l \in \{NR, R\}$  denotes whether the firm chooses a NR-contract or an R-contract for the next period, which has implications for the prices of debt, as shown in the previous section, and  $b_R$  is defined in Proposition 1.  $y$  and  $p(\psi)$  are defined in equations (4) and (11), and

<sup>30</sup>Note that the exogenous exit rate  $1 - \eta$  does not enter the debt pricing formulae. This reflects the assumption that the exit shock is realized after the firms settle their debt payments. Consequently, the exit shock does not directly affect the returns to the lenders.

$v \in \{0, 1\}$  is the choice variable indicating whether the firm is in the investment inaction ( $v = 0$ ) or action ( $v = 1$ ) regime. Moreover, firms can save at the risk-free rate  $q^a$ :

$$q^a(\mathbf{s}) = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \mid \mathbf{s} \right]. \quad (26)$$

As there is no tax advantage to debt, in order to motivate firms to take on debt, I posit that firms face a non-negative dividend constraint as in [Khan and Thomas \(2013\)](#):<sup>31</sup>

$$d \geq 0. \quad (27)$$

I define a composite state variable, the net liquid asset position of the firm ( $x$ ):

$$x \equiv \begin{cases} p(\psi)y(z_i(\sigma_{-1})) - F_o\hat{k} - b - m + \hat{a}_f, & \text{if firm repays both } b \text{ and } m \\ p(\psi)y(z_i(\sigma_{-1})) - F_o\hat{k} - b_R - m + \hat{a}_f, & \text{if firm restructures } b \text{ and repays } m \end{cases} \quad (28)$$

so the firm's dividend (25) can be rewritten as:  $d = x - v g(k', \hat{k}) + q^b b' + q^m m' - q^a a'_f$ . The firm's problem can be formulated recursively backwards within each period. As noted in the timeline (Figure 4), let  $V_i^1(\hat{k}, x; \mathbf{s})$  denote the value function of the firm at the dividend issuance stage,  $V_i^0(\hat{k}, x; \mathbf{s})$  denote the value function of at the debt settlement stage, and  $\hat{V}_i^0(k, x; \mathbf{s})$  denote the value function of at the asset reallocation stage. The subscript  $i$  denotes the firm's relative position in the discrete distribution of the idiosyncratic technology level  $z$  in the current period.<sup>32</sup>

**Asset reallocation stage** Upon observing the productivity and financial shocks, and given the amount and composition of debt ( $b, m$ ), the firm choose whether or not to reallocate their assets ( $k, a_f$ ), either by purchasing more capital at price  $p^+$  using the cash on hand upon observing a favorable shock, or by liquidating some of its capital at price  $p^-$  when a negative shock is realized. Therefore, it solves the following problem at the asset reallocation stage:

$$\hat{V}^0(k, a_f, \psi, z; \mathbf{s}) = \max_{\hat{k}, \hat{a}_f} V^0(\hat{k}, x; \mathbf{s}) \quad (29)$$

$$\text{subject to: } \hat{k} + \hat{a}_f + g(\hat{k}, k) = k + a_f, \quad (30)$$

where  $x$  is defined in (28) and  $g(\hat{k}, k)$  is defined in (7). The constraint implies that the firm cannot issue additional debt during the asset allocation stage. If the firm chooses not to reallocate its assets, it proceeds to production and subsequently debt settlement with value function  $V^0(\hat{k}, x; \mathbf{s})$ ,

<sup>31</sup>There are various reasons under which firms can be required to issue debt. Firms can have negative profits as capital  $k$  is predetermined, because they incur operational costs  $F_o k$  that are larger than their profits, or because they adjust capital and have to pay adjustment costs  $g(k, k')$ . Finally, firms that enter the period with debt may have to roll over some debt if their profits and savings are insufficient to fully repay. An alternative way to induce firms to be exposed to debt is a working capital requirement. Introducing this requirement to the model does not significantly alter the implications of the model, as shown in Appendix B.4. Nonetheless, a working capital requirement only affects the constrained firms that tend to be small. In a framework with intra-temporal and inter-temporal debt, a working capital requirements can have more significant effects on the economy (e.g. [Jermann and Quadrini \(2012b\)](#)).

<sup>32</sup>In combination with the realized level of volatility  $\sigma_{-1}$ , this relative position is the only information needed to predict the subsequent values of the idiosyncratic technology shock.

with  $\hat{k} = k$ , and  $\hat{a}_f = a_f$  in the net liquid asset position  $x$ .

**Debt settlement stage** At the debt settlement stage, the firm has three options: liquidation, restructuring, and full payment of its liabilities. Let  $V_P^0$  and  $V_R^0$  denote, respectively, the value function of a firm that repays and restructures its liabilities today. By assumption, firm that liquidates exits with its resources being passed to its creditors, so its continuation value in liquidation is 0. Therefore, the firm solves the following discrete choice problem at the debt settlement stage:

$$V^0(\hat{k}, x; \mathbf{s}) = \max \left\{ V_P^0(\hat{k}, x; \mathbf{s}), V_R^0(\hat{k}, x; \mathbf{s}), 0 \right\}. \quad (31)$$

The firm knows that with probability  $1 - \eta$  that it is not going to survive until the next period and with probability  $\eta$  it survives and has value  $V^1$  (defined below). Thus, today's value of the firm—depending on if the firm repays or restructures its liabilities—is either:

$$V_P^0(\hat{k}, x; \mathbf{s}) = (1 - \eta)n + \eta V^1(\hat{k}, x; \mathbf{s}), \quad (32)$$

or

$$V_R^0(\hat{k}, x; \mathbf{s}) = (1 - \eta)n_R + \eta V^1(\hat{k}, x; \mathbf{s}), \quad (33)$$

where  $n$  is the realized net worth defined in (12), and  $n_R$  is

$$\begin{aligned} n_R &= p(\psi)z_i(\sigma_{-1})\hat{k}^\alpha - F_o\hat{k} + p^-(1 - \delta)\hat{k} - b_R - m + \hat{a}_f \\ &= \pi - b_R - m, \end{aligned}$$

where the restructured amount is  $b_R = \chi\pi'$ , as defined in Proposition 1.

**Dividend issuance stage** Firms that do not default in period  $t$  and survive can choose between a NR-contract and an R-contract, with value functions  $V_{i,NR}^1$  and  $V_{i,R}^1$  respectively:

$$V^1(\hat{k}, x; \mathbf{s}) = \max \left\{ V_{i,NR}^1(\hat{k}, x; \mathbf{s}), V_{i,R}^1(\hat{k}, x; \mathbf{s}) \right\}. \quad (34)$$

The optimization problem for the firm that chooses a NR-contract ( $\frac{b'}{\chi} < \frac{m'}{1-\chi}$ ) takes the following form:

$$\begin{aligned} V_{i,NR}^1(\hat{k}, x; \mathbf{s}) &= \max_{v,k',b',m',a'_f} \left\{ d_{NR} + \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \sum_{j=1}^N p_{i,j} \hat{V}^0(k', a'_f, \psi', z'; \mathbf{s}') \middle| \mathbf{s} \right] \right\} \\ &= \max_{v,k',b',m',a'_f} \left\{ d_{NR} + \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \sum_{j=1}^N p_{i,j} \max_{\hat{k}', \hat{a}'_f} V^0(\hat{k}', x'; \mathbf{s}') \middle| \mathbf{s} \right] \right\} \\ &= \max_{v,k',b',m',a'_f} \left\{ d_{NR} + \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \sum_{j=1}^N p_{i,j} \max_{\hat{k}', \hat{a}'_f} \left\{ \max \left\{ V_P^0(\hat{k}', x'; \mathbf{s}'), 0 \right\} \right\} \middle| \mathbf{s} \right] \right\} \end{aligned} \quad (35)$$

subject to (4), (6), (17), (18), (25), (26), (27), (30), (32), and  $\mathbf{s}' = \Gamma(\mathbf{s}); \quad i, j = 1, 2, \dots, N$ ,

where  $\mathbf{s}' = \Gamma(\mathbf{s})$  is the law of motion governing the evolution of the aggregate state vector, which I describe below. For a firm that chooses an R-contract ( $\frac{b'}{\chi} \geq \frac{m'}{1-\chi}$ ), the Bellman equation becomes:

$$\begin{aligned} V_{i,R}^1(\hat{k}, x; \mathbf{s}) &= \max_{v, k', b', m', a'_f} \left\{ d_R + E \left[ \lambda(\mathbf{s}, \mathbf{s}') \sum_{j=1}^N p_{i,j} \hat{V}^0(k', a'_f, \psi', z'; \mathbf{s}') \mid \mathbf{s} \right] \right\} \\ &= \max_{v, k', b', m', a'_f} \left\{ d_R + E \left[ \lambda(\mathbf{s}, \mathbf{s}') \sum_{j=1}^N p_{i,j} \max_{\hat{k}', \hat{a}'_f} V^0(\hat{k}', x'; \mathbf{s}') \mid \mathbf{s} \right] \right\} \\ &= \max_{v, k', b', m', a'_f} \left\{ d_R + E \left[ \lambda(\mathbf{s}, \mathbf{s}') \sum_{j=1}^N p_{i,j} \max_{\hat{k}', \hat{a}'_f} \left\{ \max \left\{ V_P^0(\hat{k}', x'; \mathbf{s}'), V_R^0(\hat{k}', x'; \mathbf{s}'), 0 \right\} \right\} \mid \mathbf{s} \right] \right\} \end{aligned} \quad (36)$$

subject to (4), (6), (22), (23), (25), (26), (27), (30), (32), (33), and  $\mathbf{s}' = \Gamma(\mathbf{s})$ ;  $i, j = 1, 2, \dots, N$ .

The set of state variables is compact because  $k, z$  and  $\psi$  are bounded, and from equation (28), it is straightforward to see that the net liquid asset position  $x$  lies in a closed and bounded interval  $[\underline{x}, \bar{x}]$ . The continuation value of the firm is bounded below at zero—the value of the firm upon its default and exit—due to its limited liability. The next proposition states the dividend payout policy pursued by firms.

**Proposition 2.** (Theoretical results on dividends) *It is optimal that continuing firms do not pay dividends to households, unless they assign a zero probability to a binding dividend constraint in the future.*

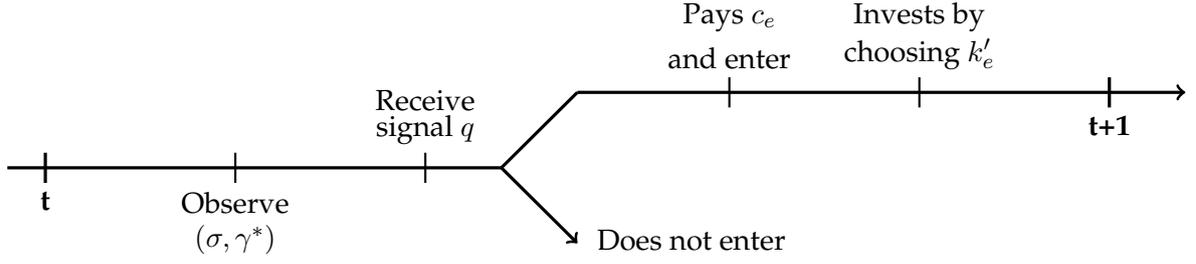
*Proof.* See Appendix B.3. ■

This finding is similar to Khan and Thomas (2013), and the intuition is as follows. For firms that borrow to finance investment (either  $b' > 0$  or  $m' > 0$ , or both), since the price of debt is less (or equal to) the stochastic discount factor of firms, debt is on average costly and thus firms are better off by paying back their debt. Moreover, for firms that do not borrow and only save ( $a'_f > 0$ ), as firms and households share the same stochastic discount factor, firms are at most indifferent between paying dividends and saving. Firms want to avoid to be in the situation in the future that their dividend constraint might be binding and thus want to save for precautionary reasons and pay zero dividends.

### 3.5 Firm Entry and Exit

**Exit** There are two sources of firm exit in this economy. First, some firms are endogenously liquidated at the debt settlement stage. Denote the fraction of exiting firms by  $F(\underline{\psi}(\hat{k}', b', m', \hat{a}'_f, z', \psi; \mathbf{s}))$ , where  $\underline{\psi}(\hat{k}', b', m', \hat{a}'_f, z', \psi; \mathbf{s})$  is the default threshold of the demand shock.<sup>33</sup> Second, a fraction

<sup>33</sup>For an individual firm, the threshold depends on whether the firm employs a NR-contract or an R-contract, whereby  $\underline{\psi} = \bar{\psi}_{NR}$  with  $\bar{\psi}_{NR}$  defined in (15) denoting the threshold such that firms employing NR-contracts and with a productivity  $\psi < \bar{\psi}_{NR}$  default—either fully or partially—and are liquidated. For a firm employing an R-contract, the default threshold is given by  $\underline{\psi} = \underline{\psi}_R$  with  $\underline{\psi}_R$  defined in (20), such that firms with productivity  $\psi < \underline{\psi}_R$  defaults.



**Figure 6:** Overview and Timing of Potential Entrants' Problem

$1 - \eta$  of firms are exogenously destroyed after production debt settlement. Firms that receive the exogenous exit signal leave the economy immediately after paying back their debt and pay any remaining profits as dividends to the households. Let  $\mu(dz, d\psi, dk, dx)$  denote the joint distribution of the idiosyncratic technology, demand, capital, and net liquid asset positions across heterogeneous firms at the beginning of period  $t$ , and  $\delta^e(\mu(s))$  denote the total mass of firms exiting during period  $t$ , which is given by:

$$\delta^e(\mu(s)) \equiv \int \left( \underbrace{F(\underline{\psi}(\hat{k}, b, m, \hat{a}_f, z, \psi_{-1}; \mathbf{s}_{-1}))}_{\text{liquidations}} + \eta \underbrace{\left(1 - F(\underline{\psi}(\hat{k}, b, m, \hat{a}_f, z, \psi_{-1}; \mathbf{s}_{-1}))\right)}_{\text{exogenous exits}} \right) \mu(dz, d\psi, dk, dx). \quad (37)$$

**Entry** The entry decision in this model amounts to the decision of a firm to go public. The set-up of the potential entrant's problem is similar to models of firm dynamics with endogenous entry, such as Clementi and Palazzo (2016); Begenau and Salomao (2016); and Clementi, Khan, Palazzo and Thomas (2015). The timing of decisions for potential entrants is illustrated in Figure 6. At the beginning of each period, there is a constant mass  $M > 0$  of potential entrants. Potential entrants first observe aggregate shocks in the current period  $\{\sigma, \gamma^*\}$ . Then each potential firm draws a productivity signal  $q$  that follows a Pareto distribution  $q \sim Q(q)$ . More specifically, I posit that  $q \geq \underline{q} \geq 0$  and that  $Q(q) = (\underline{q}/q)^\omega$ ,  $\omega > 1$ . Each potential entrant chooses whether to pay a fixed entry cost  $c_e > 0$ , which ensures that not all firms find it optimal to go public. Consequently it helps to pin down the size distribution of the entering firms.

The entrant only starts operating next period but must decide today with which capital stock  $k'_e$  it wants to start production tomorrow, conditional on having paid the fixed entry cost  $c_e$ . The initial investment can only be financed with equity, (and in the baseline version of the model, entry is the only occasion on which a firm can issue equity). The realization of the idiosyncratic productivity shock and demand shock in the first period of operation depends on the signal  $q$  today and thus follows these processes, respectively:

$$\log z = \rho_z \log q + \log \epsilon_z; \quad \log \epsilon_z \sim N(-0.5\sigma_z^2, \sigma_z^2), \quad (38)$$

and

$$\log \psi = \rho_\psi \log q + \log \epsilon_\psi; \quad \log \epsilon_\psi \sim N(-0.5\sigma_\psi^2, \sigma_\psi^2), \quad (39)$$

and both shocks are independently distributed of each other. Therefore, the value of an entrant can be written as:

$$V_e(q; \mathbf{s}) = \max_{k'_e} \left\{ -\gamma^e k'_e + \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \sum_{j=1}^N p_{i,j} V_j^1(z', k'_e, x'_e; \mathbf{s}') \mid \mathbf{s} \right] \right\} \quad (40)$$

subject to (28), (34), (38), (39) and  $\mathbf{s}' = \Gamma(\mathbf{s})$ ;  $i, j = 1, 2, \dots, N$ ,

where  $\gamma^e$  is the initial cost of issuing equity. Note that  $x'_e = p'(\psi')y'$ , as the entrant firm does not hold any financial asset ( $a_f = 0$ ), or debt ( $b = 0, m = 0$ ). Each potential entrant compares the value of entering  $V_e$  with the cost of entering  $c_e$ , after receiving signal  $q$  about its future productivity. Therefore, it will choose to incur the fixed entry cost, and start operating, if and only if:

$$V_e(q; \mathbf{s}) \geq c_e.$$

Note that  $V$  is weakly increasing in the idiosyncratic level of productivity  $z$ , as well as the idiosyncratic level of demand  $\psi$ . In other words, a higher signal  $q$  means that the productivity realization  $z$  and the demand realization  $\psi$  are likely to be high. This in turn implies that the conditional distributions of  $z'$  and  $\psi'$  are (independently) decreasing in  $q$ . Thus there exists a threshold  $q^*$  such that:

$$V_e(q^*; \mathbf{s}) = c_e. \quad (41)$$

If  $q \geq q^*$ , the potential entrant is going to enter, and does not enter otherwise. This entry process repeats every period. The entry decision occurs at the end of each period, after financial contracts between existing firms and intermediaries have been settled. Finally, in the next period, the problem of the entrants is identical to the problem of an incumbent firm.

### 3.6 Market Clearing and Aggregation

This section closes the model by specifying conditions required to clear the goods and financial markets. I begin with the problem of the representative household, who solves a standard consumption-savings problem:

$$W(a_h; \mathbf{s}) = \max_{c, a'_h} \left\{ u(c) + \beta \mathbb{E} \left[ W(a'_h; \mathbf{s}' | \mathbf{s}) \right] \right\}, \quad (42)$$

subject to the budget constraint:

$$c + q^a a'_h + \int c_e \mu_e(ds) \leq \int a_h + [d + F_o k] \mu(ds), \quad (43)$$

where  $ds = [dz, d\psi, d\hat{k}, dx]$ , where  $s$  summarizes the idiosyncratic state of a firm  $s = [z, \psi, \hat{k}, x]$ . The period-specific utility function  $u(c)$  is assumed to be strictly increasing and strictly concave in consumption ( $c$ ). To maintain tractability, I assume a simple functional form:  $u(c) = \log(c)$ . The household's intertemporal decisions are determined by the stochastic discount factor,  $\lambda(\mathbf{s}, \mathbf{s}') = \frac{u'[c'(\mathbf{s}')]}{u'[c(\mathbf{s})]}$ , where  $u'(\cdot)$  is the marginal utility of consumption.

The budget constraint (43) shows that the household enters the period saving  $a_h$ , which is allocated among the financial intermediaries at the end of the previous period together with firms' savings  $a_f$ , and earns a risk-free return  $q^a(\mathbf{s})$ . The household is also the owner of firms and the financial intermediaries. It takes the amount of dividends  $d$ , the investment in new firms  $c_e$ —which is determined by the condition (41)—as given. Note that the fixed costs of operation are rebated to the household in a lump-sum fashion, hence these costs do not affect the economy-wide resource constraint.

The goods market clearing condition can be expressed as:

$$c(\mathbf{s}) = Y(\mathbf{s}) - \int v(s; \mathbf{s}) \left[ g(k'(s; \mathbf{s}), \hat{k}) + g(\hat{k}(s; \mathbf{s}), k) \right] \mu(ds) - \gamma^b \int b'(s; \mathbf{s}) \mu(ds) \quad (44)$$

$$- \gamma^m \int m'(s; \mathbf{s}) \mu(ds) - \int c_e \mu_e(ds) - \int \mathbf{1}_{\psi' \leq \underline{\psi}} \times (1 - \chi) y(s; \mathbf{s}) \mu(ds),$$

where the last term captures the deadweight loss of default; in other words, aggregate consumption plus capital adjustment cost (from both inter- and intra-period optimization), intermediation costs, investment in new firms, and bankruptcy cost equal aggregate output. The deposit market clears at the end of period  $t$  by:

$$\underbrace{a'_h(\mathbf{s})}_{\text{households' savings}} + \underbrace{\int a'_f(s; \mathbf{s}) \mu(ds)}_{\text{firms' savings}} = a'_b(\mathbf{s}) + a'_m(\mathbf{s}), \quad (45)$$

where the left-hand side of (45) is the total deposits collected from household and firms, and the right-hand side is the allocation of deposits to the financial intermediaries, whereby the bank lenders receive  $a'_b$ , and the market lenders receive  $a'_m$ . The allocation of deposits are determined by the total demands for bank debt and market debt from the firms. The market clearing conditions for bank debt and market debt are, respectively:

$$\int b'(s; \mathbf{s}) \mu(ds) = a'_b(\mathbf{s}), \quad (46)$$

and

$$\int m'(s; \mathbf{s}) \mu(ds) = a'_m(\mathbf{s}), \quad (47)$$

where the left-hand side of each condition denotes the total demand for each type of debt from all firms. The recursive equilibrium in this economy can be defined as follows.

**Definition 1.** (Recursive competitive equilibrium) *A recursive competitive equilibrium in this economy is given by:*

- policy functions  $C(a_h; \mathbf{s})$  and  $A_h(a_h; \mathbf{s})$ , and value function  $W(a_h; \mathbf{s})$  for the representative household;
- policy functions  $B(z, \hat{k}, x, \psi; \mathbf{s})$ ,  $M(z, \hat{k}, x, \psi; \mathbf{s})$ ,  $A_f(z, \hat{k}, x, \psi; \mathbf{s})$ ,  $K(z, \hat{k}, x, \psi; \mathbf{s})$ ,  $\hat{A}_f(z, k, a_f, \psi_{-1}; \mathbf{s})$ , and  $\hat{K}(z, k, a_f, \psi_{-1}; \mathbf{s})$ , and value function  $V^1(z, k, x; \mathbf{s})$  for the incumbent firm;
- prices  $q^m$ ,  $q^b$ , and  $q^a$ ;

- an entry scale  $k^e$ ;
- a measure of incumbent firms  $\mu$ ;
- a measure of entrants  $\mu_e$ ;
- a transition mapping for the distribution of firms  $\Gamma$ ;

such that:

1. the policy functions and value function of the household solve its optimization problem (42) subject to the budget constraint, taking  $q^m, q^b, q^a, \Gamma$  as given;
2. the policy functions and value function of the incumbent firm solve its optimization problem (34), taking  $q^m, q^b, q^a, \Gamma$  as given;
3. the financial intermediaries (bank lenders and market lenders) make expected zero profits for each firm, and determine the optimal asset prices  $q^m, q^b, q^a$  using (17), (22), (18), (23), and (26), taking the household discount factor as given;
4. goods market clearing condition (44) is satisfied;
5. deposits market clearing condition (45) is satisfied;
6. the market clearing conditions for bank debt (46) and market debt (47) are satisfied;
7. the entry scale  $k_e$  and measure of entrants  $\mu_e$  satisfy (40) and (41);
8. the evolution of the distribution of firms follows:

$$\mu' = \Gamma(\sigma, \gamma^*, \mu, \mu_e)$$

where  $\mu(z, k, x, \psi)$ ,  $z \in \mathbb{Z} \subset \mathbb{R}$ ,  $k \in \mathbb{K} \subset \mathbb{R}$ ,  $x \in \mathbb{X} \subset \mathbb{R}$ , and  $\psi \in \Psi \subset \mathbb{R}$  is the distribution of firms over idiosyncratic technology, capital, net liquid asset position, and idiosyncratic demand shock.  $\Gamma$  is consistent with the policy functions of the firms;

9. Given  $\mu_e$  and  $\Gamma$ , the firm measure  $\mu$  is invariant.

### 3.7 Discussion of the Key Assumptions

I now come back to discussing the key assumptions that generate the three key results in this paper, which are: (1) firms take on short-term debt and save a fraction of the borrowing as cash, even though the return on cash is weakly dominated by the cost of debt; (2) on the asset-side, firms trade-off between investing more and getting higher profits in the future and holding more cash, which implies zero variance of return and thus a higher chance of survival; and (3) on the liability-side, firms trade-off the ability to restructure bank debt in financial distress, with the

lower marginal costs associated with issuing bonds in normal times.

**Portfolio adjustment** The first key assumption is that upon observing the productivity and financial shocks  $(z, \sigma, \gamma^*)$ , a firm can adjust its cash holdings level—either increasing it by liquidating its capital stock to increase cash, or decreasing it by using it to purchase additional capital—but it cannot adjust its debt levels intra-temporarily; in other words, there must be some financing frictions in the debt markets at the asset reallocation stage. If the firm can adjust its cash holdings and debt levels simultaneously *at all times*, there would be little role for precautionary savings of cash, since the return on cash holdings is at most equal to the cost of debt, so firms have little incentive to save a fraction of the borrowing.<sup>34</sup> In a three-period investment model that analyzes the optimal portfolio allocation between cash and investment, [Acharya, Davydenko and Strebulaev \(2012\)](#) adopt the same assumption and treat the level of debt as exogenous with respect to asset allocation decisions. In this model, firms have the incentive to save both before the realization of shocks (i.e. the predetermined level of cash  $a_f > 0$ ) as well as at the asset reallocation stage ( $\hat{a}_f > 0$ ). At the beginning of a period, firms have an incentive to save the debt borrowed and delay investment, until uncertainty about the productivity and financial conditions are resolved later in the period, and use the savings to finance capital investment then.<sup>35</sup> At the asset reallocation period, even after the realization of productivity and financial shocks, firms' incentive to save a non-trivial fraction of assets as cash, instead of investing in production that is subject to demand (profit) shocks, arises from their incentive to avoid default and continue operation in the next period.

One implication of this assumption is that variations in cash holdings is larger than variations in leverage ratios. To test this conjecture, I compute, for the median firm of each quartile of firms by assets, the coefficient of variation (standard deviation divided by the mean) for: (i) cash as a proportion of total assets (column (1)), (ii) market debt as a proportion of total assets (columns (2)–(3)), (iii) bank debt as a proportion of total assets (columns (4)–(5)), (iv) total debt as a proportion of total assets (columns (6)–(7)), using the annual Compustat dataset between 2006 and 2015 as described in Section 2. The results are reported in Table 6, which shows that the coefficient of variation for cash is consistently higher than the correlation of variation for debt, across all definitions of debt and all quartiles of firms, and the differences are significant at the 1% level (with the p-values reported in columns (3), (5), and (7), respectively). As shown in Table 6, market debt has the lowest coefficient of variation. Intuitively, this is because market debt cannot be renegotiated due to high bargaining costs; for example, it might be held by dispersed bondholders prone to coordination problems. As discussed below, although it is easier to renegotiate bank debt than

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<sup>34</sup>In the presence of aggregate shocks, the only incentive for saving part of the borrowing would come from the the households' stochastic discount factor, which implies a risk premium term and some degree of risk aversion on the firms' behalf.

<sup>35</sup>In the absence of quadratic adjustment costs that smooth out investment over time, firms would hoard all borrowing at the beginning of the period as cash, and only invest at the asset reallocation stage. The relative amounts of savings at the two stages depend on the parameterization of the capital adjustment costs.

**Table 6:** Variations in Cash Holdings and Debt Finance

	Cash	Market debt		Bank debt		Total debt	
	$\frac{\text{stdev}}{\text{mean}}$	$\frac{\text{stdev}}{\text{mean}}$	p-value	$\frac{\text{stdev}}{\text{mean}}$	p-value	$\frac{\text{stdev}}{\text{mean}}$	p-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Q1	0.57	0.21	(0.00)	0.43	(0.00)	0.20	(0.00)
Q2	0.53	0.24	(0.00)	0.41	(0.00)	0.18	(0.00)
Q3	0.54	0.26	(0.00)	0.39	(0.00)	0.19	(0.00)
Q4	0.58	0.31	(0.00)	0.42	(0.00)	0.22	(0.00)
<b>Full sample</b>	0.56	0.28	(0.00)	0.40	(0.00)	0.19	(0.00)

**Note:** The data sample includes all Compustat firm-year observations from 2006 to 2015 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the top 1% of companies (the largest 25 cash holders) are excluded from the sample. Columns (1), (2), (4) and (6) report the coefficient of variation (standard deviation divided by the mean) for the variable of interest as a proportion of total assets. Columns (3), (5) and (7) report the p-values of the differences between the coefficients of variation of the corresponding type of debt and cash. Results also hold using the quarterly sample counterpart.

market debt, bank debt also has a lower coefficient of variation than cash, due to, for example, screening and monitoring of borrowers in need of debt restructuring by banks.

**Liquidation** The key assumption about the liquidation process is that default involves bankruptcy costs that are proportional to the amount of output (assumption 2).<sup>36</sup> This is a common assumption in many models in which the underlying financial friction is limited liability. As in [Townsend \(1979\)](#), the bankruptcy costs reflect a loss of resources expended by creditors to prevent managers of a defaulting firm from behaving opportunistically. As a result of the agency costs associated with default, debt finance commands a “liquidation risk premium” relative to internal finance. Hence firms have an incentive to accumulate savings to reduce the dependence on external finance.

The other assumption about the liquidation process is the priority structure among the stakeholders. This paper assumes, for two reasons, that bank lenders are more senior than market lenders, even though this assumption is not essential for the main results of the paper to hold. First, empirically, bank loans tend to be either senior, or secured against assets, as documented by [Rauh and Sufi \(2010\)](#). Second, in a closely related setting, [Crouzet \(2015\)](#) establishes that putting bank debt ahead in the priority structure allows firms to operate at a larger scale early on. The rationale is that the seniority enhances the bank's claim in liquidation and hence enables firms to issue bank debt more cheaply. This is particularly valuable to firms with high default risks and allows them to expand faster. Hence, the seniority of bank lenders is optimal from the firm's perspective.<sup>37</sup>

<sup>36</sup>The costliness of the bankruptcy proceedings is documented in [Bris, Welch and Zhu \(2006\)](#).

<sup>37</sup>In a similar setting, [Hackbarth, Hennessy and Leland \(2007\)](#) also establish that bank debt seniority is the optimal priority structure. This result also arises in other models of debt structure, in which banks' role is to provide ex-ante monitoring of projects, such as [Besanko and Kanatas \(1996\)](#), and [De Marzo and Fishman \(2007\)](#). The rationale in

**Bank flexibility** A strikingly robust message from contemporaneous theories of financial intermediation is that banks make more flexible financial decisions which prevent a firm's projects from going awry (assumption 3). Within an optimal contracting framework, [Bolton and Scharfstein \(1996\)](#) provide a microfoundation to this result, by noting that as the ownership of market debt tends to be more dispersed than ownership of bank debt, market creditors face a free-rider problem and have little individual incentive to participate in debt renegotiations. Moreover, as banks build a closer relationship with firms than dispersed investors, they have an informational advantage by assessing and monitoring information about firms—as noted by [Rajan \(1992\)](#); [Boot, Greenbaum and Thakor \(1993\)](#); [Chemmanur and Fulghieri \(1994\)](#)—and hence they are more precisely aware of the going concern value of the firm and can offer greater contractual flexibility.<sup>38</sup> Therefore, firms with higher risks of default choose to sign a contract with banks, as they value the flexibility and hence the lower liquidation premium more ([Berlin and Mester \(1992\)](#)).

In addition, there is also substantial support in the data for the assumption that banks are more flexible in distress than markets. [Gilson, Kose and Lang \(1990\)](#) show that firms are more likely to restructure their debt privately if they owe more of their debt to banks; [Denis and Mihov \(2003\)](#), using a sample of 1560 new debt financings, show that firms with lower credit quality tend to borrow from banks, as bank debt offers greater flexibility of renegotiation in default. The assumption of bank flexibility maintained in this model thus captures the consequences of differences in creditor concentration between classes of debt, for firms' ability to successfully restructure debt contracts.

**Intermediation costs** The assumption that the intermediation costs are larger for banks than for market lenders (assumption 4) is key to motivate a trade-off between bank debt and market debt in the model: whilst firms with higher default risks find the option offered by banks to renegotiate more valuable, this type of credit is also associated with a higher marginal cost than market debt ( $\gamma^b \geq \gamma^m$ ).<sup>39</sup> The wedge in marginal costs is a reduced-form way to capture the following three differences between bank and market lending, and is a proxy for the relative supply of bank credit in this economy.

First, banks have closer relationships with firms than market lenders, but acquiring information about the firms via screening and borrowing is costly, as banks spend resources to acquire information and arrange financing accordingly (see, for example, [Houston and James \(1996\)](#)), or

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this model is that bank seniority increases banks' return on monitoring, by allowing them to seize more output in liquidation.

<sup>38</sup>This is also consistent with the role taken by banks as originators of asset-backed securities, which requires screening of the firms' projects.

<sup>39</sup>Financial intermediation costs consist of all non-interest costs that intermediaries undertake to operate. The assumption that financial intermediation is costly is not controversial. [Philippon \(2015\)](#) provides recent and comprehensive evidence that overall intermediation costs in the U.S. financial sector have averaged approximately 2% between 1870 and 2012.

Mester, Nakamura and Renault (2007)). The positive lending wedge thus captures the costs associated with these bank-specific activities. Second, banks place stricter debt covenants on loans that are designed to protect the banks' interests by reducing the risks to which a bank is exposed when they lend to firms, as documented empirically by Rauh and Sufi (2010), and Demiroglu and James (2010). As a result, firms, especially those with low default risks, often view borrowing from a bank as more restrictive and expensive than selling debt on the open market through a bond issue. Third, banks face specific regulatory framework, such as the Basel III capital adequacy framework, that have an impact on their lending standards. Nevertheless, Adrian and Shin (2011) and Adrian, Colla and Shin (2012) show that banks are reluctant to adjust their equity base ("sticky" equity), resulting in procyclical leverage of the banking sector. Thus, provided that bank capital requirements are positive that force banks to issue additional equity and that issuing equity is costly, this contributes to making marginal loan issuance more costly for banks.

## 4 Quantitative Results

This section describes the numerical results of the model. I first provide details on the calibration of the model, the computation procedure, and the financial policies and firm distribution in the steady state. Then I present the impulse response functions for the economy under two aggregate shocks: (1) financial shocks to the effective supply of bank; (2) time-varying volatility shocks.

### 4.1 Calibration

The choice of parameters can be divided into three different categories. The first category consists of parameters that are picked according to the literature, such as the decreasing returns to scale parameter. The second group of parameters has a natural data counterpart, such as the volatility and persistence of aggregate shocks. The last group of parameters is calibrated to jointly target moments in the data. The standard approach in the literature (see, for example, Bachmann, Caballero and Engel (2013); Khan and Thomas (2013)) is to match heterogeneous firm models to establishment-level data. As the paper focuses on firm-level financial constraints, the relevant distribution is the firm size distribution.<sup>40</sup>

**Standard calibration** The time period in the model equals one quarter; accordingly, I set the household's rate of time preference  $\beta = 0.99$ , implying an annualized risk-free rate of 4 percent. The decreasing returns to scale parameter  $\alpha$  is set equal to 0.8, a value within the range of values used in the literature. This value is on the lower end of the range of estimates of the returns to scale in manufacturing recovered by Lee (2005) using plant-level data. The quarterly depreciation rate  $\delta$  is set equal to 0.025. The fixed investment adjustment cost is calibrated to be  $F_{k,0} = 0.01$ , a value estimated by Cooper and Haltiwanger (2006). The purchase value of capital

<sup>40</sup>Table B.1 of the model appendix summarizes the calibration of the model.

$p_k^+$  is normalized to 1, whilst the resale value of capital  $p_k^-$  is calibrated to match the steady-state level of leverage (discussed below).

**Calibration to data** The integration of all exogenous AR(1) processes in the model is approximated by Gaussian quadratures. In the model, fluctuations in uncertainty—by changing the underlying distribution of the idiosyncratic productivity shocks—have a direct effect on future profits. I use an uncertainty proxy computed directly from the estimated shocks to the firms' profit function to calibrate the Markov chain for the idiosyncratic technology shock  $z$  and the process governing its stochastic volatility (see, for example, [Gilchrist, Sim and Zakrajšek \(2014\)](#)).<sup>41</sup> In all model simulations, I assume four states for the idiosyncratic technology shock. The resulting four nodes of  $z$  are functions of time-varying volatility, such that an increase in volatility generates a greater dispersion in the nodes without changing the conditional expectation of the idiosyncratic technology shock. I use the Markov-chain approximation method of [Tauchen \(1986\)](#) and calibrate the persistence of the idiosyncratic technology process  $\rho_z$  to be 0.8. The steady-state level of uncertainty  $\bar{\sigma}_z$  is set to 15 percent (30 percent annualized), which is equal to the sample mean of the uncertainty measure between 2006 and 2014, as shown in [Figure A.2](#) of the data appendix. Using this proxy, I also estimate an empirical counterpart to equation (5), which yields  $\hat{\rho}_\sigma = 0.82$ , with the 95-percent confidence interval of [0.69,0.93]; I set  $\rho_\sigma = 0.90$ , which is within the estimated range and in line with [Bloom \(2009\)](#). To generate fluctuations in uncertainty in the range between 25 and 50 percent (annualized)—a range consistent with the variability of the uncertainty proxy over the 2006-2014 period—I set the standard deviation of uncertainty shocks  $\omega_\sigma$  to 0.05 percent of the steady-state level of uncertainty (1.75 percent annualized). Following [Arellano, Bai and Kehoe \(2012\)](#), I calibrate the persistence of the demand shock to be  $\rho_\psi = 0.7$ , which is in line with the estimated value by [Foster, Haltiwanger and Syverson \(2008\)](#), whilst the volatility of the demand shock  $\sigma_\psi$  is calibrated to target microeconomic data on firms (see below).

Financial intermediation costs consist of all non-interest costs that a lender undertakes to operate. As a proxy for the intermediation cost of market debt  $\gamma^m$ , I use existing estimates of underwriting fees for corporate bond issuances. [Fang \(2005\)](#) studies a sample of bond issuances in the U.S., and finds an average underwriting fees of 0.95%, while [Altınkılıç and Hansen \(2000\)](#), in a sample including lower-quality issuances, find an average underwriting fee of 1.09%. Given this evidence, I set market debt intermediation costs to  $\gamma^m = 0.01$ . However, measuring analogously intermediation costs of banks, for example from operating expenses reported in income statements of commercial banks, has two potential drawbacks. First, operating expenses of banks can be associated with a number of non-lending activities. Second, operating expenses may miss some costs associated with credit intermediation by banks, such as equity issuance costs associated with capital and liquidity requirements. Therefore, instead of trying to construct a direct measure of the wedge between bank and market debt intermediation costs in the steady state

<sup>41</sup>See [section A.5](#) of the data appendix for details.

( $\bar{\gamma}^*$ ), I match the average fraction of bank debt among non-financial corporations in the U.S., as discussed below.

To calibrate the persistence  $\rho_\gamma$  and standard deviation  $\sigma_\gamma$ , I follow Bassett, Chosak, Driscoll and Zakrajšek (2012), and utilize data from the Federal Reserve’s Senior Loan Officer Opinion Survey of Bank Lending Practices (SLOOS), which queries participating banks to report whether they have changed their standards during the survey period.<sup>42</sup> Nevertheless, in assessing the supply-side implications of changes in bank lending policies, it is important to bear in mind that the changes in bank lending standards reported in the SLOOS reflect the confluence of demand and supply factors. Recognizing this endogeneity problem, I follow Lown and Morgan (2006) and use VAR-based identification strategies to identify the component of the change in lending standards that is orthogonal to the determinants of loan demand. Specifically, I estimate a VAR(4) specification with quarterly data on four macroeconomic variables—including log real GDP, log GDP deflator, log commodity prices, and the federal funds rate—and the net percent of banks reporting tightening standards. I order the credit variable after the macro variables. Summing the coefficients on lags of the lending standard variables in the lending standard equation itself yields  $\rho_\gamma = 0.81$  and  $\sigma_\gamma = 0.085$ , which are within the range reported in Lown and Morgan (2006).<sup>43</sup>

**Calibration to target moments** The last seven parameters—including parameters governing firm entry  $\{\omega, c_e\}$ , the volatility of the idiosyncratic demand shock,  $\sigma_\psi$ , the resale value of capital  $p_k^-$ , the quasi-fixed costs of production  $F_o$ , the bankruptcy cost parameter  $\chi$ , and the steady state level of the positive wedge between the bank and market intermediation costs  $\bar{\gamma}^*$ —are calibrated to jointly target seven moments. To find these parameters, I first solve the model under a specific set of parameters. Then I simulate data using the policies of the model and compute the target moments. Next, I compare the model implied moments implied by this specific parameter combination. This procedure is repeated until the difference between the data and the model implied target moments has been minimized. The nonlinearities of the model do not allow exact matching of all moments. Nevertheless, Table 7 shows that the model generates target moments similar to those in the data. Six of these moments use Compustat data and are salient features of the microeconomic data on firms: the share of bank debt in the U.S., the mean leverage ratio, the relative sizes of entrants (to the public debt markets) and exiters, and the exit and entry rates. In addition, I also target the mean credit spread on corporate bonds in aggregate data, since the paper focuses on the aggregate impact of firms’ switch to bond financing during the crisis.

The steady state level of the positive wedge between the bank and market intermediation

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<sup>42</sup>See Figure A.3 in appendix A.6 for the Net Percentage of Domestic Banks Tightening Standards, and the Net Percentage of Domestic Banks Increasing Spreads of Loan Rates.

<sup>43</sup>As a robustness check, I replaced the net percent of loan officers reporting tightening commercial credit standards with the volume of commercial loans at banks, as an alternative measure of bank credit supply. Simulation results based on this measure of the calibration are available upon requests.

**Table 7: Calibration Targets (Data vs. Model)**

Statistic	Parameter	Model	Target
<i>Firm-level data</i>			
[1] Fraction of bank debt (mean)	$\bar{\gamma}^*$ (Wedge in intermediation costs)	35%	31%
[2] Leverage (mean)	$p_k^-$ (Resale value of capital)	39%	37%
[3] Exit rate	$F_o$ (Operating cost)	9.6%	8.8%
[4] Entry rate	$c_e$ (Entry cost)	9.6%	9.6%
[5] Entrants' relative size	$\omega$ (Pareto exponent)	21%	18%
[6] Exiters' relative size	$\sigma_\psi$ (Vol. of idiosyncratic demand)	39%	41%
<i>Aggregate data</i>			
[7] Spread on corporate bonds	$\chi$ (liquidation efficiency)	2.6%	2.8%

costs  $\bar{\gamma}^*$ , which captures the relative supply of bank credit, is calibrated to match the bank share of the sample described in Section 2, of U.S. non-financial and non-utility corporations with S&P ratings. The resale value of capital  $p_k^-$  is set equal to 0.45, which implies a steady-state level of leverage of 0.39, which is close to the leverage ratio in the Compustat data for this sample of firms over the 2006:Q1-2014:Q4 period. The quasi-fixed operating cost  $F_o$  is calibrated to match the exit rate in the data. According to the survey of Business Employment Dynamics, the average yearly survival rate for the establishments that were established between 1994 and 2009 is 0.784, which implies a quarterly survival rate of 0.912. Together with the exogenous exit rate of  $1 - \eta = 0.05$ ,  $F_o = 0.12$  implies a total exit rate of 9.6% in the steady state, which implies that 4.6% of firms endogenously exit through financial distress. The entry cost  $c_e$  has the largest impact on entry rate, which in equilibrium must equal the exit rate.

The relative sizes of entrants and exiters with respect to survivors are calculated from the Compustat data, according to the definitions of these metrics in Dunne, Roberts and Samuleson (1988). I follow Clementi and Palazzo (2016) and assume that the distribution of the entry signal  $q$  is Pareto,  $F(q) = (q/q)^\omega$ , where  $\omega > 1$ . Given  $\{c_e, \gamma^e\}$ , the Pareto exponent  $\omega$  is calibrated to target the relative size of entrants with respect to incumbents, whereby the data parallel for entry in the model is the decision of a firm to go public, as in Begenau and Salomao (2016). Furthermore, the relative size of exiters is pinned down by the volatility of the idiosyncratic demand shock  $\sigma_\psi$ . Lastly, given the calibration of the processes for the idiosyncratic uncertainty and the liquidation value of capital assets, I set the degree of frictions in the financial markets—the bankruptcy cost parameter  $\chi$ —to generate an average credit spread that is close to the mean of the credit spread on Moody's BAA-rated corporate bonds between 2006 and 2014 shown in Figure A.2. Accordingly, I set  $\chi = 0.43$ , a value close to the micro-level evidence of Bris, Welch and Zhu (2006).<sup>44</sup>

<sup>44</sup>The median estimate of the change in asset values before and after chapter 7 liquidation is 38%, adjusting for the

## 4.2 Computation

The model requires tracking the distribution of firms over idiosyncratic technology, capital and net liquid asset positions, which in principle is an infinitely dimensional object. Following the literature on computable general equilibrium with heterogeneous agents (see, for example, [Krusell and Smith \(1998\)](#), and [Khan and Thomas \(2008, 2013\)](#)), I adopt the assumption of bounded rationality—that is, the agents use only a finite number of moments of the joint distribution to forecast equilibrium prices. Specifically, I assume that the agents use only the first moments of log-linearized laws of motions to predict the marginal utility of the representative household ( $u_c(\mathbf{s})$ ). I also assume that the agents use only the first moment of the distributions of capital ( $\tilde{k}$ ) and cash holdings ( $\tilde{a}_f$ ) to gauge the productive capacity of the economy and the liquidity of the firms, and only the first moments of the distributions of the post-renegotiation values of bank debt ( $\tilde{b}$ ) and market debt ( $\tilde{m}$ ), to infer the indebtedness of the corporate sector. Formally, the agents in the model use the following system of log-linear equations to forecast the equilibrium price:

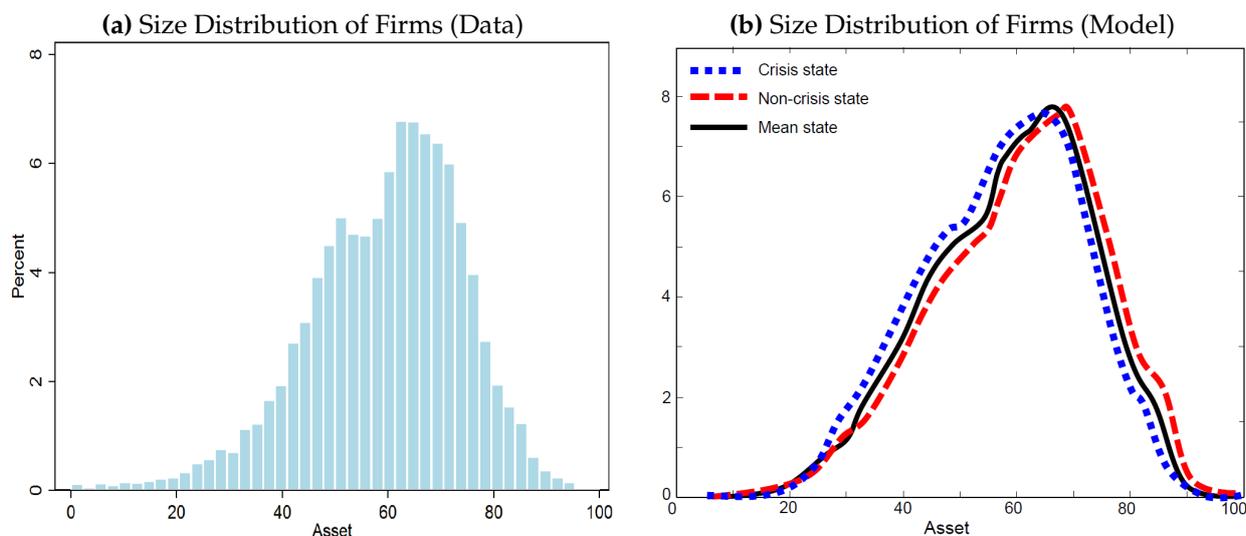
$$\begin{bmatrix} \log \tilde{b}' \\ \log \tilde{m}' \\ \log \tilde{a}'_f \\ \log \tilde{k}' \\ \log c \end{bmatrix} = \mathbf{\Gamma}_0 + \mathbf{\Gamma}_1 \begin{bmatrix} \log \tilde{b}' \\ \log \tilde{m}' \\ \log \tilde{a}'_f \\ \log \tilde{k}' \end{bmatrix} + \mathbf{\Gamma}_2 \begin{bmatrix} \log \sigma_z \\ \log \gamma^* \\ \log \psi \end{bmatrix}, \quad (48)$$

Consistency with the general equilibrium conditions requires that these perceived laws of motion are accurate, in the sense that the forecast errors implied by the system (48) are arbitrarily small. To achieve this consistency, I initialize  $\mathbf{\Gamma}_0$  ( $5 \times 1$ ),  $\mathbf{\Gamma}_1$  ( $5 \times 4$ ), and  $\mathbf{\Gamma}_2$  ( $5 \times 3$ ) with arbitrary values and then simulate the model using Monte Carlo methods with randomly drawn aggregate and idiosyncratic shocks. In the simulation, I let the agents “learn” from their errors and update the forecasting rules until full convergence. An important aspect of this algorithm involves letting all markets clear, even when the agents’ perceived laws of motion are “inaccurate”, that is, before full convergence. As [Proposition 2](#) shows that firms would only want to pay dividends if they assign zero probability to being financially constrained in the future, to simplify the computation, I therefore assume that firms never pay out dividends unless they exit. Details on the computation procedure can be found in [Appendix B.5](#).

## 4.3 Firm Distribution and Financial Policies in the Steady State

**Size distribution** [Figure 7](#) plots the firm size distribution over the normalized assets. Panel (a) presents the density of logged assets for the full sample of firms described in [Section 2](#). Notably, the sample distribution by assets is negatively skewed, i.e. the mass of the distribution is concentrated on the right; in other words, the investment grade firms account for more than half of value of collateralized assets that creditors may have seized outside of the formal bankruptcy proceedings.

**Figure 7: Firm Size Distribution**



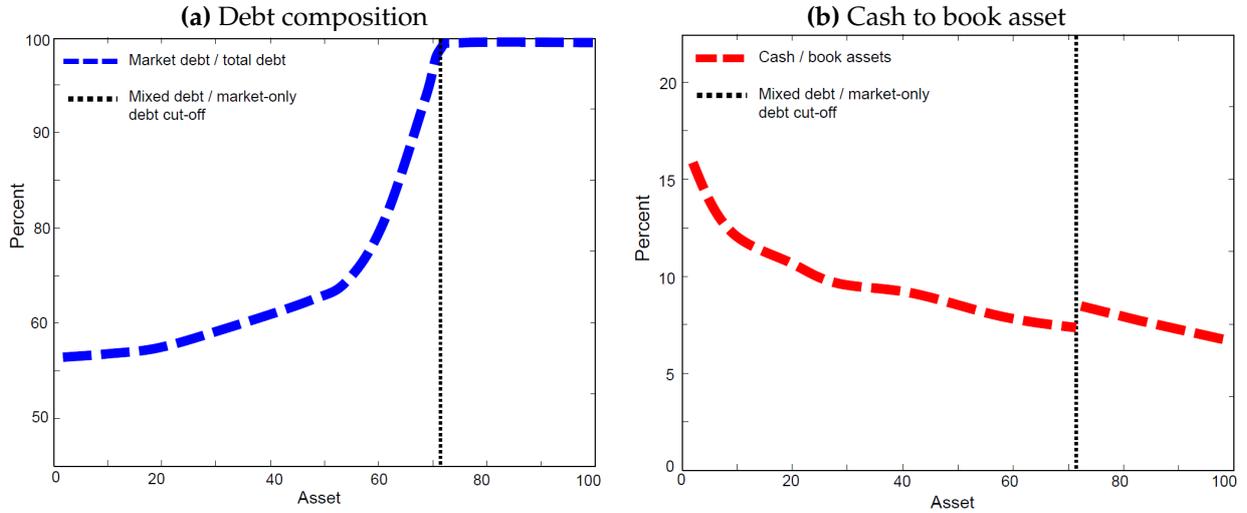
**Note:** Panel (a) presents the density of logged assets for the sample including all Compustat firm-quarter observations from 2006Q1 to 2015Q4 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the top 1% of companies (the largest 25 cash holders) are excluded from the sample. Panel (b) plots the average firm size distribution over the normalized assets for different states of the economy: crisis state (blue dotted), non-crisis state (red dashed), and the mean state (black solid).

the (logged) asset share, even after removing the top 1% of firms. Panel (b) plots the average firm size distribution over the normalized assets for different states of the economy in the model.<sup>45</sup> Endogenous entry and exit affect the firm size distribution over time. Firms tend to enter small and more firms enter in non-crisis times during which the distribution gets flatter: the larger firms are larger compared to crisis states during which the size distribution is more concentrated and shifts to the left.

**Optimal debt structure** As shown in Panel A of Figure 8, a firm's asset size is positively related to its share of market debt, defined as the ratio of market debt to total debt. Firms' debt structures fall under two categories: on the one hand, firms below a certain level of assets (denoted  $a^*$ ) choose a "mixed" debt structure, involving a combination of bank debt and market debt (interior solution); larger firms with assets strictly above the threshold choose a "market-only" debt structure (corner solution). As firms grow, they will eventually switch from a mixed debt structure to a market-only debt structure. This result corresponds to the two types of debt contracts in the model, as indicated in Proposition 1. When a firm optimally chooses the corner solution of using all market debt, it chooses a NR-contract, whereas when it chooses a mixed-debt structure, it chooses an R-contract. This optimal debt structure in steady state echoes the results in Crouzet (2015), as well as the evidence provided by Rauh and Sufi (2010), that the degree to which the debt structure of firms is "spread out" across types and priorities is strongly related to firms' credit ratings: investment-grade firms mostly use senior unsecured debt (bond and program debt), while the speculative grade firms use a combination of secured bank debt,

<sup>45</sup>The book value of assets in the model is defined as  $\pi + p^+ \hat{k}$ , where  $\pi$  is the gross profit, and  $p^+ \hat{k}$  is the book-value of (gross) property, plant, and equipment.

**Figure 8: Optimal Composition of Debt and Cash Holdings in the Steady State**



Note: Panel (a) presents the steady-state fraction of market debt  $\frac{m}{b+m}$  across the distribution of firms by logged assets, while panel (b) plots the (intra-temporal) cash-to-book-asset  $\frac{\hat{a}_f}{\pi+p+k}$  across the distribution.

senior unsecured debt, and subordinated bonds.

The intuition for this result is as follows. As borrowing from the bank reduces the expected losses associated with financial distress, smaller firms have a stronger incentive to use bank debt, and hence their debt composition is more tilted towards bank loans. If a firm's default probabilities is sufficiently small, it never restructures bad debt. In that case, the flexibility associated with bank debt is irrelevant to these firms since, in equilibrium they never use that flexibility. But borrowing from banks results in higher intermediation costs. Hence the largest firms always choose the corner solution of a market-only debt structure. Therefore, the trade-off between bank flexibility in times of financial distress and the costs associated with using bank loans in normal times changes with the firm's size and ultimately its default probability, and hence affect the firm's choice of debt structure.

**Cash holdings** Panel (b) of Figure 8 plots the (intra-temporal) cash-to-book-asset ratio in the cross-section. First, it indicates that firms employing debt financing simultaneously hold cash balances, and that the stock of internal finance is negatively related to the productivity level of the firm. Intuitively, because of decreasing returns, firms have an ex-ante optimal investment scale. More productive firms are less likely to face financial distress as well as the bankruptcy costs associated with debt financing, and are thus more inclined to avoid the low return of cash holdings and use debt financing to reach the optimal investment scale. This echoes the findings of [Riddick and Whited \(2009\)](#), that firms hold higher precautionary cash balances when external finance is costly.

Figure 8 also shows that when a firm crosses the threshold  $a^*$  above which it switches to a market-only debt structure, its cash-to-asset ratio also "jumps" up. This can be interpreted

as the “precautionary savings” response of a firm that migrates from a mixed to a market-only debt structure. Intuitively, since under the market-only debt structure, firms have no option to restructure debt in financial distress, their ex-ante likelihood of liquidation would be higher than under the mixed debt structure, *ceteris paribus*. As a result of such imperfect substitutability between bank debt and market debt, when a firm crosses  $a^*$ , it increases their proportion of safe assets in their portfolio, to optimally offset the higher likelihood of default associated with the switch between financial regimes.

#### 4.4 Macroeconomic Implications of Financial Shocks to Bank Credit Supply

This section analyzes the dynamics of the model’s key endogenous variables in response to a negative shock to the effective supply of bank credit ( $\gamma^*$ ). The benchmark model economy features a full set of frictions. Subsequently, I add four counterfactual exercises. To assess the magnitude of “precautionary savings” channel in the amplification and propagation of aggregate shocks, I first construct a counterfactual scenario whilst firms can still borrow from both lenders, but cannot optimize the allocation of assets (i.e. holding constant the cash-to-asset ratio). Next, to understand the role of the corporate bond market in a financial crisis, I solve a version of the model that shuts down the effect of debt substitution by holding constant the composition of debt across firms. Third, in order to assess the quantitative role of financial versus real frictions, I solve a version of the model with only financial frictions; in this case, the firms face the same costs of intermediation and deadweight loss in default, as in the benchmark case, except that the firms do not face any capital adjustment frictions, i.e.  $p^- = p^+ = 1$ ,  $F_{k,0} = 0$  and  $F_{k,1} = 0$ . Fourth, I construct a counterfactual scenario with a lower degree of financial market frictions—in other words, a higher degree of liquidation efficiency  $\chi$ —in order to examine the extent to which the severity of the recession, as well as the consequent slow recovery, would be alleviated if frictions in the corporate debt market were lower.

In computing the model-implied impulse response functions, I take into account the nonlinearities in the firms’ investment and financial policies that arise naturally in an economy with irreversible investment, fixed capital adjustment costs, and financial distortions.<sup>46</sup> As described more fully in Section B.5 of the model appendix, the impulse response functions are constructed as follows: (1) simulate the model twice—first with the idiosyncratic shocks only and then with an aggregate shock layered on top the same set of idiosyncratic shocks; (2) for each simulation,

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<sup>46</sup>As shown in Table B.2 in Section B.5 of the model appendix, the linear laws of motion used by the agents to forecast equilibrium prices are fairly accurate in a statistical sense. In other words, although the agents’ policy functions are highly nonlinear at the micro level, the model’s key endogenous quantities exhibit fairly linear aggregate dynamics. In fact, the existence of such “aggregation smoothing” is typically used to justify the use of an algorithm that uses only a small number of moments to characterize the dynamics of the joint distribution  $\mu$  (see Khan and Thomas (2008)). In principle, therefore, the response of the key endogenous aggregate quantities to aggregate shocks could be constructed using the estimated perceived laws of motion. While computationally straightforward, this approach is limited in scope. For example, the responses of the credit spreads cannot be constructed in such a linear fashion.

aggregate across each group of firms (defined below) the micro-level impulse responses of endogenous variables of interest; and (3) take the difference between the two sets of aggregate endogenous quantities. To eliminate any sampling bias that may have arisen from drawing idiosyncratic shocks, I repeat these three steps a large number of times and then average the aggregate impulse response functions across replications.

**Firm Heterogeneity in Impulse Responses** Figure 9 depicts the behavior of the model's main endogenous variables in response to an adverse shock of about two standard deviations to the bank lending costs in period  $t = 5$ , which can be interpreted as a negative shock to the effective bank credit supply. Upon impact, the unanticipated increase in bank lending costs reduces the bank debt by 10 percent on average (panel (a)), in line with the Flow of Funds data on aggregate bank lending to non-financial corporations in 2008Q3. In order to maintain comparability with the stylized facts in Section 2, I define two groups of firms, using a fixed threshold on successive cross-sections to characterize their asset sizes, such that in each period, firms with assets more than the threshold amount are the "investment-grade" firms, whereas those with assets less than the threshold amount are the "speculative-grade" one (see Appendix B.5 for details).<sup>47</sup>

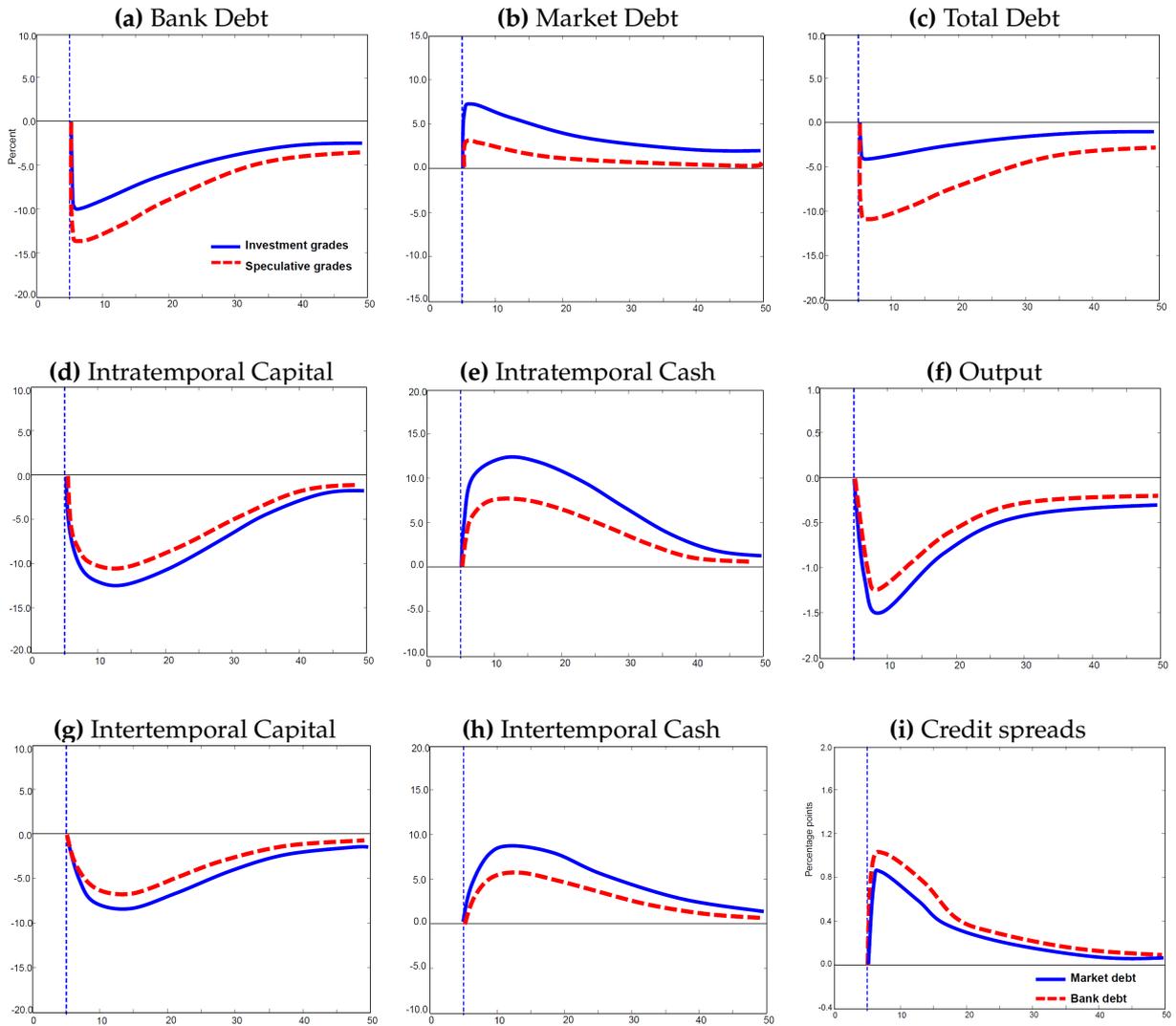
Whilst bank lending has declined for all firms (panel (a)), the investment grade firms have substituted towards market debt to a much larger degree (panel (b)). Hence changes in debt composition differ substantially across firms, such that debt substitution is only salient for the larger firms with lower default probabilities. For the speculative grade firms with higher default probabilities, the substitution towards market debt is weak, with bank debt showing the largest decline upon impact. These echo other evidence on the 2007-2009 recession, most notably [Adrian, Colla and Shin \(2012\)](#) and [Becker and Ivashina \(2014\)](#). As a result of the heterogeneity in debt composition after a bank credit supply shock, the speculative grade firms suffer from a much sharper fall in leverage than the investment grade firms (panel (c)).

The striking result is that despite having suffered from a smaller decline in external finance available, the investment grade firms reallocate significantly more of their assets towards cash than productive capital upon the shock, compared to the speculative grade firms, as shown in panels (d) and (g). As a result, firms' output falls by proportionally more for the investment grade firms (panel (f)). Notably, firms adjust their portfolio of assets before as well as after the realization of idiosyncratic productivity and financial shocks in each period. At the asset reallocation stage (see timing in Figure 4), firms reoptimize their asset portfolio, for a given leverage, by building up precautionary savings in order to avoid costly default (panels (e) & (h)). The investment grade firms increase their cash holdings more than the speculative grade firms, as substitution from a mixed-debt to market-only debt structure entails the loss of ability to restruc-

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<sup>47</sup>Over the 2006–2014 period, the total assets of investment grade firms is on average 68% of the total assets of all nonfinancial firms with S&P ratings (excluding the top 1%) by this measure. The number of investment grade firms, according to this definition, fluctuates between 45 and 50 percent of the total number of firms in the model, which is consistent with the fraction (48%) of investment grade firms in the data sample.

**Figure 9: Impact of a Financial Shock to Bank Credit Supply  
(Baseline with Firm Heterogeneity)**



**Note:** A shock reduces the supply of bank loans ( $\gamma^*$ ) 10 percent upon impact (period 5) on average, a shock of approximately 2 standard deviations; the bank loan supply is then allowed to revert back to its steady-state value following the process in equation (14). The impulse responses are averages of 50,000 simulations, where each simulation is an aggregation of the impulse responses of 10,000 firms. In panels (a)–(h), the blue solid lines depict the impulse response functions of the investment-grade firms, while the red dashed lines depict the impulse responses of the speculative-grade firms; in panel (i), the blue solid line indicates the impulse response function of the spread on corporate bonds, while the red dotted line indicates the spread on bank loans. The vertical axis denotes percentage deviation from the steady state and the horizontal axis denotes quarters. See Section B.5 of the model appendix for computational details.

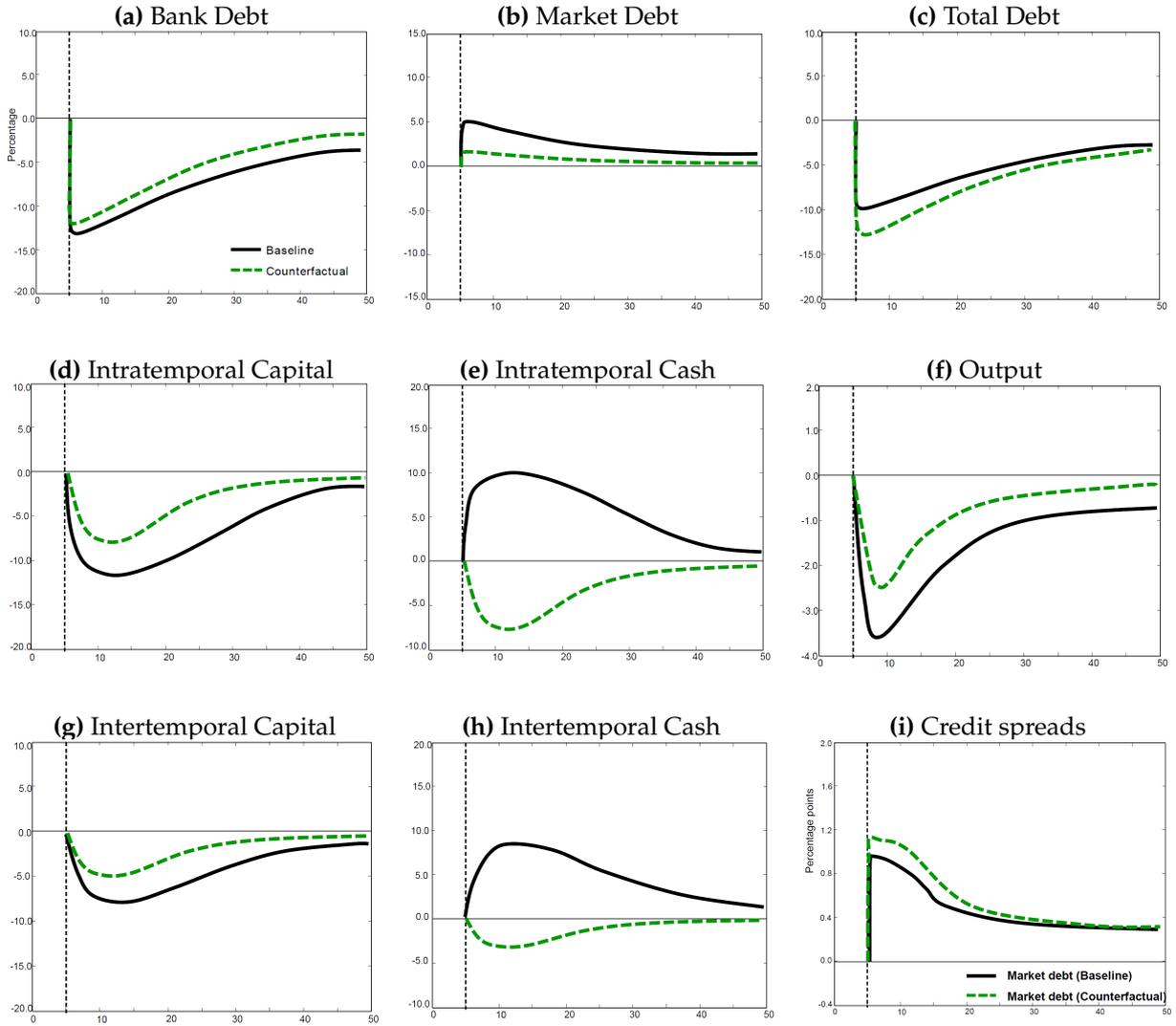
ture debt. Choosing a safer portfolio of assets by holding proportionally more cash, for a given leverage, would optimally offset this. Moreover, due to the presence of convex capital adjustment costs, firms have an incentive to smooth out (dis)investment over time, and hence also adjust the predetermined levels of capital and cash (panels (g) & (h)). Nevertheless, the magnitudes of adjustments are larger at the asset reallocation stage, after the realization of shocks.

In general equilibrium, the increase in precautionary savings depresses the risk-free interest rate, especially in the short run. It is important to note that although the types of credit diverged in quantity, the spreads on both rose sharply, as shown in panel (i)—an empirical feature documented by [Adrian, Colla and Shin \(2012\)](#) and captured in other models of debt substitution such as [De Fiore and Uhlig \(2015\)](#). Market debt has become more costly as now firms of higher default probabilities have switched to an all-market debt structure, as they find the flexibility provided by banks too costly following a bank credit supply shock. With the presence of partial irreversibility of capital, the results here also echo the findings in other models with liquid and illiquid assets (e.g. [Guerrieri and Lorenzoni \(2015\)](#)) that a credit shock can lead, simultaneously, to an increase in demand for the liquid asset and to a reduction in demand for the illiquid asset. This captures a form of “flight to liquidity” on the firm’s side. Nevertheless, as shown below (Figure 12), the presence of real frictions can only explain a small fraction of the increase in cash, whereas the majority of the increase come from the precautionary motive to rebalance asset portfolio towards safe assets.

**Precautionary Savings Channel** The model captures two channels in the firms’ response to a contraction in the supply of bank credit. The first is the traditional “financial constraint” channel, by which constrained firms are forced to deleverage and reduce investment. The second is the “precautionary savings” channel, by which unconstrained firms that substitute bank loans with bond issues reallocate their assets from productive capital to savings as a buffer against future shocks. To isolate the component of the shock’s aggregate effect that is attributable to this new channel, I compare the aggregate impulse responses—without differentiating between different types of firms—in the baseline model with the aggregate impulse responses of an alternative economy in which firms are allowed to switch debt instruments, but holding constant the fraction of assets that is saved. The corresponding impulse responses are reported in Figure 10.

There are two key differences from the baseline model. First, without the ability to optimize asset allocation, the fall in total debt is larger than in the baseline. This is in line with the results in [Crouzet \(2015\)](#), that switching to a market-only debt structure while keeping total leverage constant would expose firms to a larger risk of financial distress; they offset this by reducing total borrowing further, in addition to the reduction in leverage associated with the tradition “financial constraint” channel. Intuitively, holding safe assets increases the survival probability of the firm, and thus partially offsets the higher default risks associated with the change in debt structure, so the need for deleverage is lower. Moreover, without the ability to hold more safe assets, for a given leverage, the substitution towards market debt is of a smaller magnitude, as firms

**Figure 10: Impact of a Financial Shock to Bank Credit Supply  
(Counterfactual: Precautionary Savings Channel)**



**Note:** A shock reduces the supply of bank loans ( $\gamma^*$ ) 10 percent upon impact (period 5) on average, a shock of approximately 2 standard deviations; the bank loan supply is then allowed to revert back to its steady-state value following the process in equation (14). The impulse responses are averages of 50,000 simulations, where each simulation is an aggregation of the impulse responses of 10,000 firms. The black solid lines depict the impulse response functions in the baseline, while the green dashed lines depict the impulse responses in the counterfactual exercise. The vertical axis denotes percentage deviation from the steady state and the horizontal axis denotes quarters. See Section B.5 of the model appendix for computational details.

would value the flexibility of the bank debt more. Second, even though total debt falls by more, capital and output actually fall by less in the counterfactual example than in the baseline, as all the external finance raised is allocated towards capital. Therefore, this counterfactual exercise shows that the precautionary savings channel is quantitatively important for generating the amplification and persistence of an aggregate financial shock, as debt substitution induces firms to hoard large amounts of cash for precautionary purpose, and not use them to finance investment. Quantitatively, this channel can account for about 40% of the total decline in aggregate output in the first two years of the crisis, and more than one-half of the decline in the following five years.

Furthermore, this counterfactual exercise also shows that introducing endogenous asset allocation generates a more persistent response in output than a model without cash holdings.<sup>48</sup> Persistence arises because both the debt composition and portfolio allocation decisions are endogenously determined. Once the firm increases the proportion of cash holdings in response to switching to a market-only debt structure, this partially offsets the change in default risk associated with the change in debt structure. Consequently, the flexibility of bank debt would appeal less to the firm compared to the scenario where the only asset is productive capital, and this in turn slows down the adjustment of bank borrowing, and triggers another high cash-to-asset ratio in the following period. Therefore, turning off cash holdings by firms produces the counterfactual results of a larger decline in total leverage during the crisis but a relatively faster recovery in output thereafter.

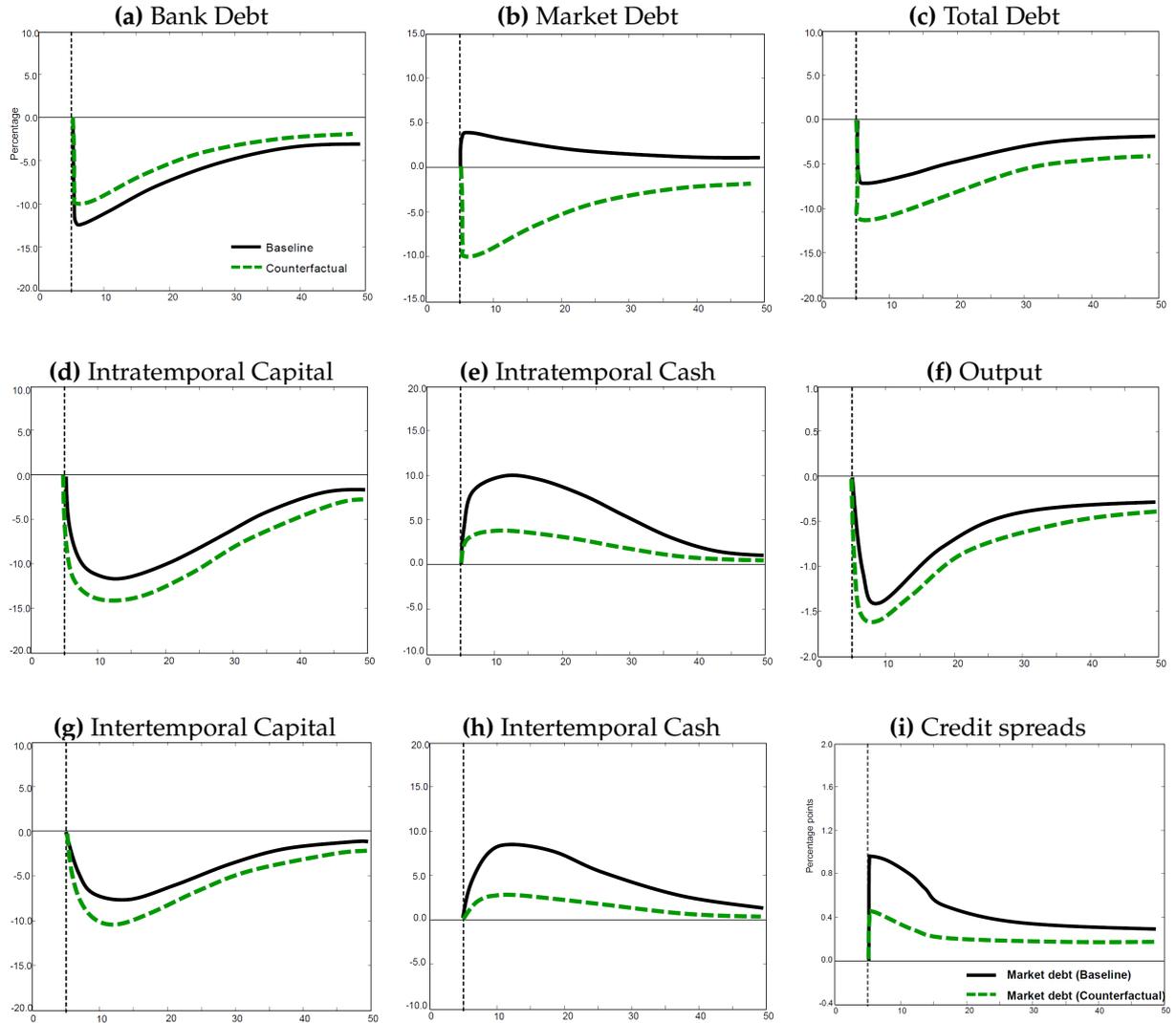
**The Role of the Bond Market** The next counterfactual exercise investigates the role of the bond market as a “spare tyre” to the traditional, bank-based intermediation at times when the latter is impaired. To do so, I compute the aggregate impulse responses of an alternative economy in which the debt composition is held constant at the steady state level; in other words, firms are not allowed to switch to bonds after the bank credit supply shock (but are allowed to save). As shown in Figure 11, there is no substitution towards market debt following a bank credit supply shock; instead, bank debt and market debt fall by the same proportion.

There are three key observations from this counterfactual exercise. First, without the ability to substitute into bonds, total debt falls by more. Intuitively, both types of firms are affected by the “financial constraint” channel. Second, cash holdings increase in the economy, but by significantly less, indicating that a significant proportion of the increase in cash in the baseline is associated with changes in debt structure. Third, the negative impact of the large fall in total external finance available outweighs the counteractive force associated with a milder reallocation of funds into cash. As a result, capital and output fall by significantly more in the counterfactual example. Therefore, the model lends support to the conventional wisdom that firms’ ability to substitute among alternative debt instruments is important to shield the economy from adverse real effects of a financial crisis. Nevertheless, as indicated in the Figure 10, containing firms’ cash

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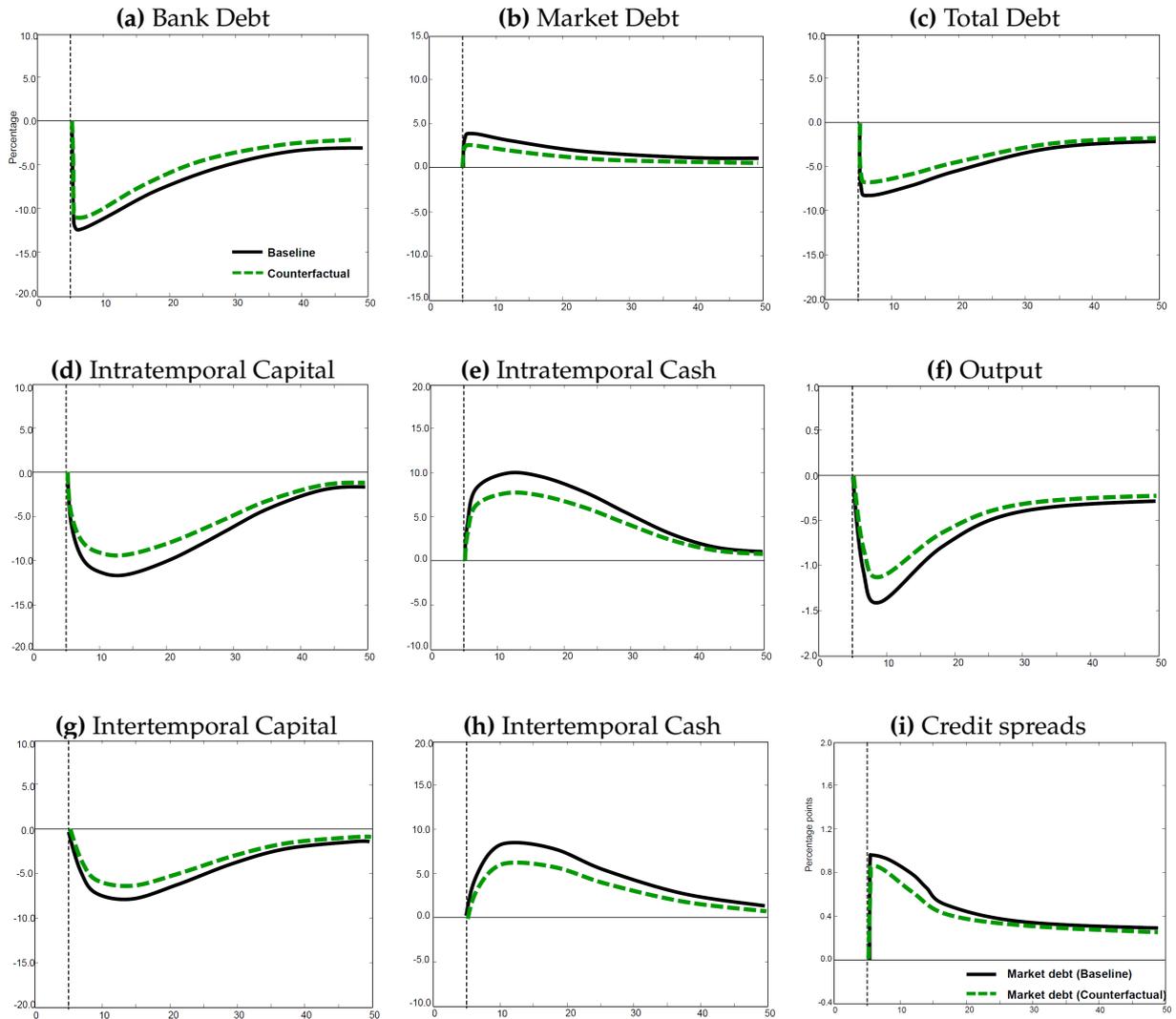
<sup>48</sup>The persistence effect of introducing cash holdings is more prominent in a model where firms are not allowed to save at all, and the results are available upon request.

**Figure 11: Impact of a Financial Shock to Bank Credit Supply  
(Counterfactual: The Role of Bond Market)**



**Note:** A shock reduces the supply of bank loans ( $\gamma^*$ ) 10 percent upon impact (period 5) on average, a shock of approximately 2 standard deviations; the bank loan supply is then allowed to revert back to its steady-state value following the process in equation (14). The impulse responses are averages of 50,000 simulations, where each simulation is an aggregation of the impulse responses of 10,000 firms. The black solid lines depict the impulse response functions in the baseline, while the green dashed lines depict the impulse responses in the counterfactual exercise. The vertical axis denotes percentage deviation from the steady state and the horizontal axis denotes quarters. See Section B.5 of the model appendix for computational details.

**Figure 12: Impact of a Financial Shock to Bank Credit Supply  
(Counterfactual: No Capital Illiquidity)**



**Note:** A shock reduces the supply of bank loans ( $\gamma^*$ ) 10 percent upon impact (period 5) on average, a shock of approximately 2 standard deviations; the bank loan supply is then allowed to revert back to its steady-state value following the process in equation (14). The impulse responses are averages of 50,000 simulations, where each simulation is an aggregation of the impulse responses of 10,000 firms. The black solid lines depict the impulse response functions in the baseline, while the green dashed lines depict the impulse responses in the counterfactual exercise. The vertical axis denotes percentage deviation from the steady state and the horizontal axis denotes quarters. See Section B.5 of the model appendix for computational details.

holdings incentive to offset the “precautionary savings” channel associated with the change in debt structure can improve the efficacy of the corporate bond markets in times of financial crisis.

**The Role of Financial Frictions** The general equilibrium framework with firms facing nonconvex capital adjustment costs as well as frictions in the debt markets allows me to quantify the relative importance of financial frictions, relative to investment frictions, in determining the economic significance of this balance sheet restructuring channel. The next counterfactual exercise mutes capital illiquidity, by setting  $p^- = p^+ = 0$ , in order to examine if this significantly weakens the demand for cash in the presence of debt substitution. As in the previous counterfactual exercise, I focus on the impulse responses of the investment grade firms. As shown in Figure 12, the demand for cash remains high, suggesting that financial frictions plays a more prominent role than investment frictions in determining the impact of a firm’s debt composition on its cash holdings. This corroborates the empirical findings in Table 5 of Section 2. Moreover, the decline in investment is only 20% less than the baseline scenario, pointing to financial distortions as the main mechanism through debt substitution at the firm-level that affects macroeconomic outcomes.

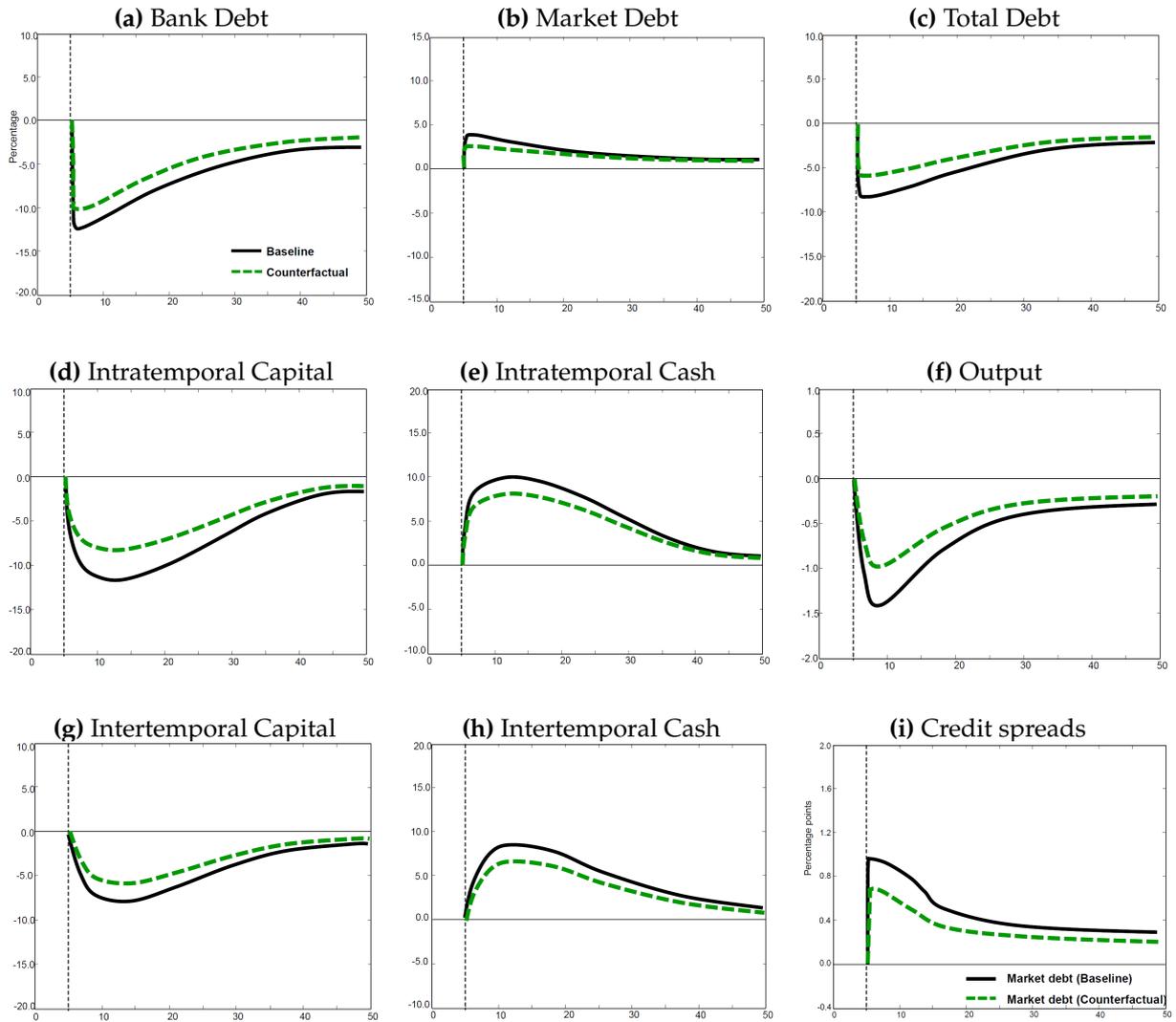
In the last counterfactual scenario, I study the impact of a bank credit supply shock of the same magnitude but in an environment where financial frictions is lowered by 10%, i.e. the efficiency of liquidation parameter  $\chi$  is increased to 0.473. Figure 13 shows that in this scenario, the decline in output is about 25% lower than in the baseline case. This significant reduction is due to a combination of a lower reduction in total debt and a lower increase in cash holdings. This confirms the findings in Figure 12 that financial frictions play a quantitatively important role in determining the impact of a bank credit supply shock on aggregate variables.

Finally, it is worth mentioning that a higher liquidation value  $\chi$  also alters debt composition, as it captures the fraction of current output that creditors can claim in liquidation. On the one hand, when banks are senior—as is assumed in the model—they are the main claimants of the liquidation proceeds if a firm with mixed debt structure defaults. As a result, lower deadweight liquidation losses would make bank borrowing less costly, and result in less substitution towards market debt. On the other hand, for large firms that rely little on bank debt, a higher liquidation efficiency also decreases the cost of market debt, as it increases the claims of market creditors in liquidation, thus increasing market debt issuance. In the calibration here, the latter effect dominates and the increase in market debt issuance exceeds the fall in bank debt.

#### 4.5 Macroeconomic Implications of Uncertainty Shocks

A common explanation for the slow recovery from the 2007-2009 recession is that uncertainty over business conditions limits investment—either through the “real options” effects on the demand for capital, or via changes in credit spreads—and induces firms to hoard cash and cut debt to hedge against future shocks. To formalize the mechanism, much of the literature has focused

**Figure 13: Impact of a Financial Shock to Bank Credit Supply**  
**(Counterfactual: Reduce Financial Frictions (Increase  $\chi$ ) by 10%)**



**Note:** A shock reduces the supply of bank loans ( $\gamma^*$ ) 10 percent upon impact (period 5) on average, a shock of approximately 2 standard deviations; the bank loan supply is then allowed to revert back to its steady-state value following the process in equation (14). The impulse responses are averages of 50,000 simulations, where each simulation is an aggregation of the impulse responses of 10,000 firms. In panels (a)–(h), the blue solid lines depict the impulse response functions of the investment-grade firms, while the red dashed lines depict the impulse responses of the speculative-grade firms; in panel (i), the blue solid line indicates the impulse response function of the spread on corporate bonds, while the red dotted line indicates the spread on bank loans. The vertical axis denotes percentage deviation from the steady state and the horizontal axis denotes quarters. See Section B.5 of the model appendix for computational details.

on total debt issued by firms. This paper, however, highlights the importance of looking at debt composition, and doing so reveals that it is not clear that fluctuations in idiosyncratic uncertainty are the sources of the 2007-2009 recession or the slow recovery thereafter.

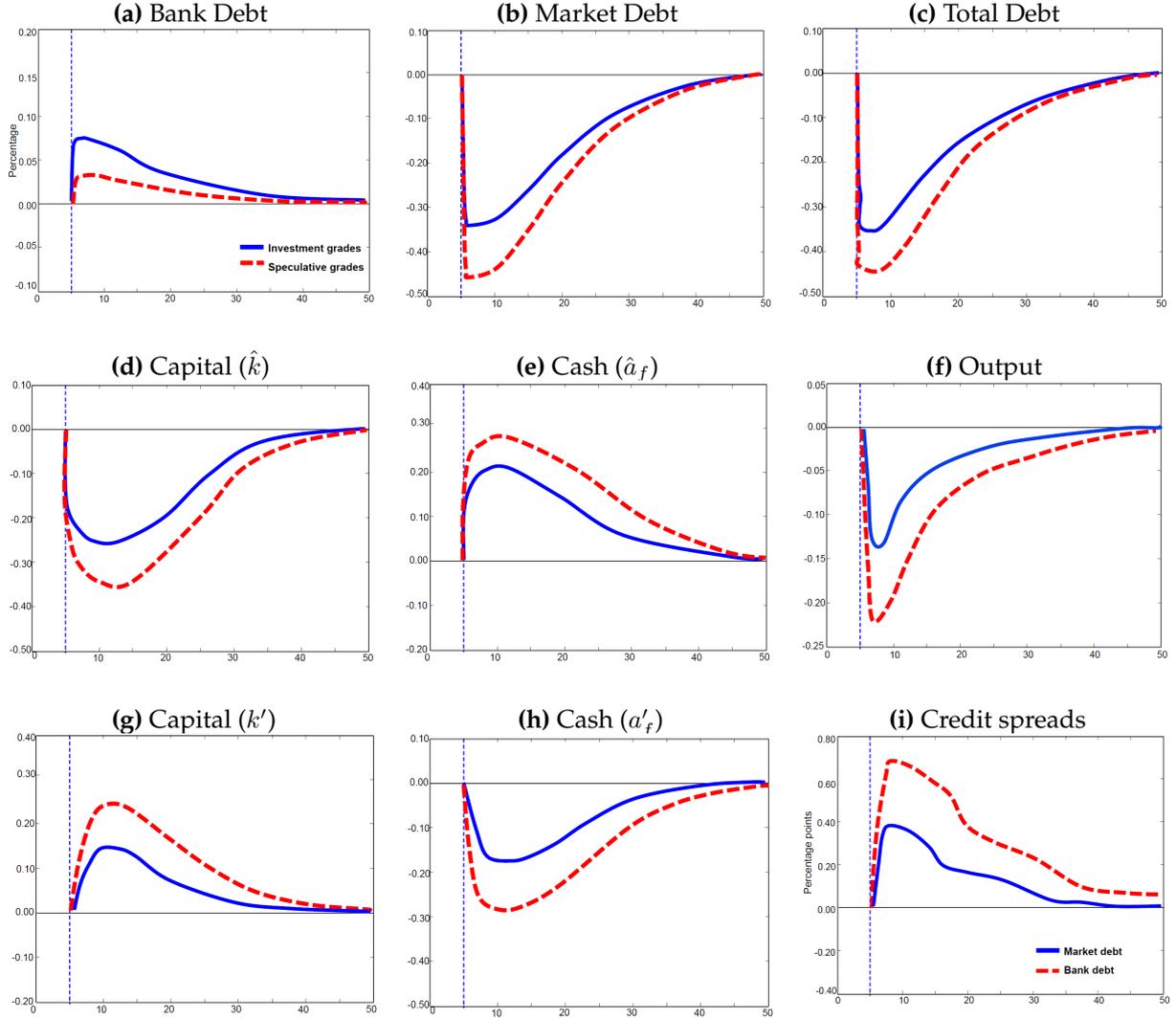
The macroeconomic implications of uncertainty shocks are presented in Figure 14. Even though the aggregate impulse responses are in line with the conventional wisdom—that an increase in volatility is associated with less debt, higher cash holdings, lower investment and output—a closer look at the impulse responses by subsets of firms reveals that a recession driven by an increase in idiosyncratic volatility generates two striking results in the model that are odds with the data. First, instead of retiring bank loans whilst increasing bonds—as shown in the data—all firms increase the fraction of their bank debt following an increase in idiosyncratic volatility. Moreover, both types of firms significantly retire their market debt, which is at odds with the evidence in Section 2. This reflects the greater demand for debt flexibility from both small and large firms when firm-level uncertainty is high.

Second, as an increase in idiosyncratic volatility is an aggregate shock that affects all firms, it induces the smaller firms with higher default probabilities to increase their cash holdings much more than the larger firms. At the aggregate level, this is in line with the conventional wisdom: higher uncertainty raises the importance of waiting and staging flexibility when making investment decisions; consequently, the proportion of firms in the inactive region rises, and all firms find it optimal to hold proportionally more cash. However, again, a closer look at the heterogeneity in firm dynamics reveals that the results are the opposite of the empirical evidence: the stylized facts in Figures A.1 and 3 show that the investment grade firms increased their cash holdings much more, and had a slower recovery than the speculative grade firms. The impulse responses to an uncertainty shock, however, suggest that the investment by larger firms would recover faster. Therefore, the model generates firm dynamics that are consistent with the data following a credit supply shock, but not an increase in the volatility of the idiosyncratic technology process.

## 5 Conclusion

This paper has explored the role of firms' balance sheet adjustment on the propagation of aggregate shocks. Using a micro-level dataset on the public U.S. firms' debt compositions between 2006 and 2015, I find that the substitution of corporate bonds for bank loans since the Great Recession has been associated with a substantial reallocation of firms' assets from capital to cash holdings. Panel evidence reveals that increasing the fraction of market debt on a firm's balance sheet has a significantly positive effect on its cash to asset ratio, but a significantly negative effect on its capital expenditures or sales. Moreover, firms with higher fractions of market debt are reluctant to adjust their cash holdings, or use cash to finance investment. As a result, remarkably, firms that had tapped the bond market in large quantities since the 2007-2009 recession have experienced a more severe recession and a slower recovery.

**Figure 14: Impact of an Uncertainty Shock**



**Note:** A shock increases the volatility of the idiosyncratic technology shock ( $\sigma_z$ ) 3 percentage points (annualized) upon impact (period 5), a shock about 2.5 standard deviations; the volatility is then allowed to revert back to its steady-state value following the process in equation (5). The impulse responses are averages of 50,000 simulations, where each simulation is an aggregation of the impulse responses of 10,000 firms. In panels (a)–(g), the blue dashed lines depict the impulse response functions of the investment-grade firms, while the red dashed lines depict the impulse responses of the speculative-grade firms; in panel (i), the blue dotted line indicates the impulse response function of the spread on corporate bonds, while the red dotted line indicates the spread on bank loans. See Section B.5 of the model appendix for computational details.

I evaluate the economic mechanisms that mediate the above relationship using a quantitative general equilibrium model of firm dynamics, where firms choose both the scale and composition of debt, and simultaneously hold cash balances. In choosing between bank and bond financing, firms trade-off the greater flexibility of banks in case of financial distress against the lower marginal costs of bond issuances. Moreover, for a given debt structure, firms face a trade-off between investing more and getting higher profits in the future—conditional on receiving a favorable demand shock and not defaulting—and holding more cash which implies a lower variance of return and thus a higher chance of survival. As a result, the model endogenously generates a distribution of firms across levels of productivity in the steady state, and predicts a tight link between the likelihood of financial distress, the level of cash balances, and the composition of debt, consistent with the evidence that firms hold higher precautionary cash balances when external finance is costly, and that firms tend to increase their reliance on bank loans as credit quality declines. Furthermore, substituting market debt for bank debt exposes firms to a larger default risk, thus incentivizing them to reallocate assets from capital to cash holdings.

The model provides a useful framework to study the transmission of aggregate shocks and the macroeconomic implications of debt heterogeneity. In studying the transmission of a financial shock that alters the effective supply of bank credit, I use the model to quantitatively evaluate the “precautionary savings” channel associated with the change in debt composition, vis-à-vis the more traditional “financial constraint” channel that manifests itself in the decline of total quantity of debt. The counterfactual scenario in which I isolate the “precautionary savings” channel by not allowing firms to reallocate assets suggests that the channel of balance sheet restructuring can account for 40% of the decline in aggregate investment in the first two years of the crisis, and more than one-half of the decline in the following five years. Moreover, financial frictions play a much more important role than investment frictions in determining the economic significance of this “precautionary savings” channel. The results of this analysis reinforce the policy relevance of the empirical fact that I document in this paper. I find that lowering credit market frictions by 10% would entail a 25% smaller decline in investment and output during the recession, as firms would experience not only a smaller decline in total leverage (“financial constraint” channel) but also a lesser degree of asset reallocation from capital to cash holdings (“precautionary savings” channel).

Finally, I examine through the lens of the model whether financial frictions manifest themselves through shocks to the demand for credit or to its supply in the Great Recession. A recession driven by an increase in idiosyncratic volatility generates results in the model that are odds with the data. Therefore, the model generates firm dynamics that are consistent with the data following a credit supply shock, but not an increase in the volatility of the idiosyncratic technology process, suggesting that financial frictions have manifested themselves mainly through shocks to the supply of credit rather than the demand for credit during the Great Recession.

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# Appendices

## A Data Appendix

In this appendix, I describe the data used in the empirical analysis and provide additional regression results. Subsection A.1 provides the details of the sources and construction of the data series. Subsection A.2 shows the univariate evidence on cross-firm variation between the investment grade and speculative grade firms using medians of the series shown in Table A.1 of the main text. Subsection A.3 illustrates that the stylized facts on firm heterogeneity captured in Section 2 are robust to alternative definitions of sample split. Subsection A.4 present three sets of robustness checks for the baseline regressions that (1) use alternative measures of cash; (2) use quarterly instead of annual data; (3) use data on debt issues rather than in levels. Section A.5 describes the estimation procedure used to construct the proxy for idiosyncratic uncertainty based on firm-level profitability shocks.

### A.1 Description of Variables

Aggregate balance sheet data for the U.S. is from Table L.102 of the Flow of Funds, the balance sheet of the nonfinancial corporate sector. Data on aggregate investment is from Table F.103 of the Flow of Funds, and credit spread data is from the Bureau of Economic Analysis, and Federal Reserve Bank of St. Louis. Firm characteristics are from Compustat (numbers in parentheses refer to the corresponding Compustat data item). Debt structure variables are from Capital IQ, which decomposes total debt into seven mutually exclusive debt types: commercial paper, drawn credit lines, term loans, senior bonds and notes, subordinated bonds and notes, capital leases, and other debt.

In the Compustata dataset, for firms with a fiscal year ending in the beginning of the year, i.e. in the months January through May, we shift the observation to align it better with the observation for the macroeconomic variables. A year  $t$  observation for a firm with a fiscal year ending in May corresponds to the period from June of year  $t - 1$  to May of year  $t$ . This observation enters our sample in year  $t - 1$ . The same change in date is used for firms with a fiscal year ending in the months January through April. Details of the data series are listed below.

#### Aggregate data

- *Corporate bonds outstanding* is the sum of corporate bonds (line 23, Table L.102) and commercial paper (line 21, Table L.102)
- *Bank loans outstanding* is the sum of depository institution loans (line 27) and other loans and advances (line 18, Table L.102)
- *Debt outstanding* is total credit market instruments outstanding (line 23, Table L.102)

- *Investment* is capital expenditures of private nonfinancial corporations (line 11, Table F.103)
- *Credit Spread* is Moody's Seasoned Baa Corporate Bond Yield Relative to Yield on 10-Year Treasury Constant Maturity

### Compustat data on firm characteristics

- *Cash-to-asset* is the ratio of cash and marketable securities (#1) to book assets (#6)
- *Cash-to-debt* is the ratio of cash and marketable securities (#1) to the sum of long-term debt (#9) and debt in current liabilities (#34)
- *Firm size* is the natural logarithm of book assets (#6) in 2009 dollars (using GDP deflator)
- *Leverage* is the ratio of long-term debt (#9) plus debt in current liabilities (#34) to book assets (#6)
- *Net leverage* is the ratio of long-term debt (#9) plus debt in current liabilities (#34) minus cash and marketable securities (#1) to book assets (#6)
- *Total investment-to-asset* is the ratio of the sum of capital expenditures (#128) and acquisitions (#129) less the sale of property (#107), to book assets (#6)
- *Capital expenditures-to-asset* is the ratio of the sum of capital expenditures (#128) and R&D expenditures (#46) to book assets (#6)
- *Cash flow* is earnings after interest, dividends, and taxes before depreciation divided by book assets  $((\#13-\#15-\#16-\#21)/\#6)$
- *Market-to-book* is the ratio of the book value of assets (#6) minus the book value of equity (#60) plus the market value of equity ( $\#199 \times \#25$ ) to the book value of assets (#6)
- *Net working capital* is the ratio of net working capital (#179) minus cash and marketable securities (#1) to book assets (#6)
- *Tangibility* is the ratio of net property, plant and equipment (#8) to book assets (#6)
- *R&D* is the ratio of R&D expenditures (#46) to book assets (#6)
- *Dividend* is a dummy variable equal to one in years in which a firm pays a common dividend (#21)
- *Acquisitions* is the ratio of acquisitions (#129) to book assets (#6)
- *Rating* is the yearly average of the monthly S&P long-term issuer rating (splticrm), where we assign an integer number ranging from 1 (SD or D) to 22 (AAA) to each monthly rating and take the yearly average

- *WW-Index* is based on [Whited and Wu \(2006\)](#) and is computed as follows:  $-0.091 \times \text{Cash flow} - 0.062 \times \text{Dividend} + 0.021 \times \text{Leverage} - 0.044 \times \text{Size} + 0.102 \times \text{Industry Growth} - 0.035 \times \text{Growth}$ , where *Industry Growth* is the 4-SIC industry sales growth, *Growth* is own-firm's real sales growth, and the other variables are as defined above
- *Asset Liquidation Value* is based on [Berger, Ofek and Swary \(1996\)](#), and is computed as follows:  $0.715 \times \text{Receivables (\#2)} + 0.547 \times \text{Inventory (\#3)} + 0.535 \times \text{Capital (\#8)}$
- *Industry Frequency of Investment Inaction* is defined at the firm level based on [Cooper and Haltiwanger \(2006\)](#) as the number of firm-year observations with  $|\text{Total investment / book assets}| < 0.01$ , over the total number of observations in the 4-SIC industry
- *Investment Spikes in the Industry* is defined as the number of firm-year observations with  $|\text{Total investment / book assets}| \geq 0.2$
- *Time-Series Skewness (Kurtosis) of Industry Investment* is based on [Caballero \(1999\)](#) and calculated as the skewness (kurtosis) of average annual capital expenditures to book asset ratios in each 4-SIC industry

#### Capital IQ data on debt structure

- *Market debt* is the sum of commercial paper, senior bonds and notes, and subordinated bonds and notes. In panel (a) of Figure 1, the series "market debt" is given by:  $\frac{m_{t_0}}{b_{t_0} + m_{t_0}} \left( \frac{m_t}{m_{t_0}} - 1 \right)$ , where  $t_0$  corresponds to the level in 2008Q3.
- *Bank debt* is the sum of drawn credit lines and term loans. In panel (a) of Figure 1, the series "bank debt" is given by:  $\frac{b_{t_0}}{b_{t_0} + m_{t_0}} \left( \frac{b_t}{b_{t_0}} - 1 \right)$ , where  $t_0$  corresponds to the level in 2008Q3.
- *Market fraction* is the ratio of market debt to the sum of market debt and bank debt
- *Market only* is a dummy variable equal to one if the current year's fraction of market debt is 100 percent and the previous year's fraction is less than 100 percent

## A.2 Additional Univariate Evidence on Financial Policies and Firm Dynamics

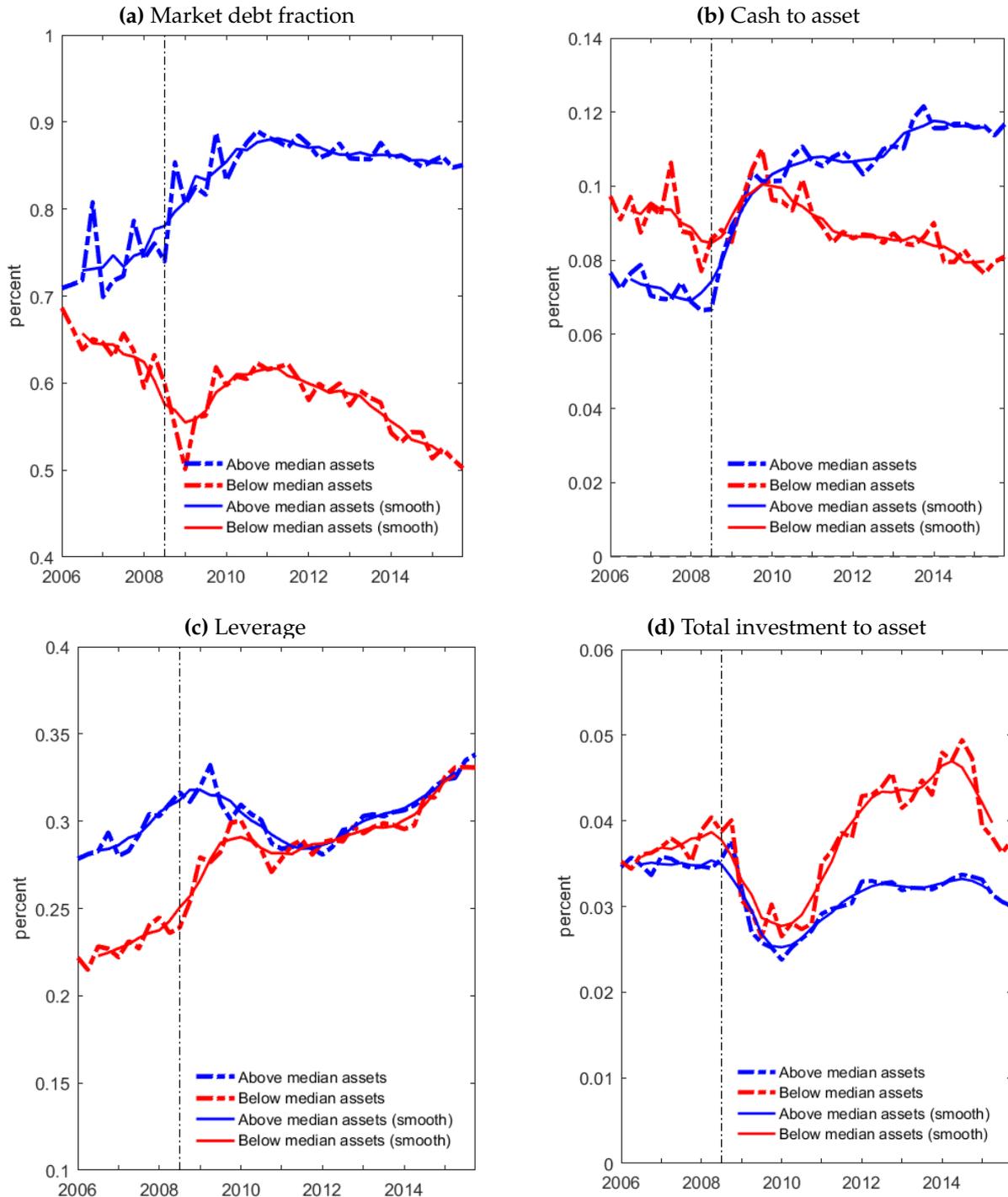
**Table A.1:** Stylized Facts on Financial Policies and Firm Dynamics

	Pre-crisis median (2006Q1-2008Q2)			Post-crisis median (2008Q3-2015Q4)			Difference between pre- and post-crisis medians			
	Investment	Speculative	p-value	Investment	Speculative	p-value	Investment	p-value	Speculative	p-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Assets	7.55	1.83	0.00	9.06	1.94	0.00	1.51	0.00	0.11	0.00
Market fraction	0.80	0.61	0.00	0.94	0.64	0.00	0.14	0.00	0.03	0.00
Market only	0.10	0.07	0.00	0.27	0.12	0.00	0.17	0.00	0.05	0.00
Cash to asset	0.08	0.09	0.06	0.11	0.08	0.00	0.03	0.00	-0.01	0.05
Leverage	0.30	0.43	0.00	0.39	0.39	0.00	0.09	0.00	-0.04	0.00
Capex to asset	0.05	0.04	0.06	0.03	0.05	0.00	-0.02	0.00	0.01	0.06
Sales to asset	0.24	0.18	0.00	0.20	0.21	0.00	-0.04	0.00	0.03	0.00
# Observations	1,318	1,452		9,253	9,379					

**Note:** This table presents the medians aggregated across all quarters before the crisis (columns (1)–(3)) and after the crisis (columns (4)–(6)), among all investment grade firms (columns (1) and (4)) and speculative grade firms (columns (2) and (5)). The p-values for the differences in medians between the two groups of firms are reported in columns (3) and (6) for the pre- and post-crisis subsamples, respectively. The differences in medians between the pre- and post-crisis subsamples are reported in column (7) for the investment grade firms, and column (8) for the speculative grade firms, and the corresponding p-values are reported in columns (9) and (10), respectively. The sample includes all Compustat firm-year observations from 2006Q1 to 2015Q4 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the largest 25 cash holders are excluded from the sample, yielding a panel of 21,402 firm-quarter observations for 938 unique firms. *Assets* are in billions of 2009 dollars. *Market fraction* is the percentage of market debt to the sum of bank and market debt. *Market only* is the fraction of firms with only have market debt in a particular quarter. *Cash to asset*, *Leverage*, *Capex to asset*, and *Sales to asset* are expressed as percentages of book assets. Detailed variable definitions are provided in Appendix A.1.

### A.3 Splitting the Sample by Asset Size: Firm Heterogeneity in Balance Sheet Policies

Figure A.1: Firm Heterogeneity in Debt Composition and Firms' Balance Sheet Policies



**Note:** The sample includes all Compustat firm-quarter observations from 2006Q1 to 2015Q4 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the largest 25 cash holders are excluded from the sample, yielding a panel of 21,402 firm-quarter observations for 938 unique firms. To remove seasonality in financing activities, all panels report the raw series (dashed lines) and its smoothed version (solid lines) as a moving average straddling the current term with two lagged and two forward terms. Variable definitions are provided in Appendix A.1.

#### A.4 Robustness Checks of Empirical Evidence

In this section, I present three sets of robustness checks for the baseline regression (1):<sup>49</sup>

$$\text{Cash}_{i,t} = \beta_1 \text{DebtStructure}_{i,t-1} + \theta' \text{Controls}_{i,t-1} + \eta_i + \lambda_t + \epsilon_{i,t}.$$

First, I adopt three other common measures of cash in the literature, besides cash to book asset, as the dependent variable (see, for example, [Bates, Kahle and Stulz \(2009\)](#)). These cash measures include (with numbers in parentheses referring to the corresponding Compustat data item):

- *Cash to net book asset* is cash and marketable securities (#1) divided by book assets (#6) minus cash and marketable securities (#1)
- *Cash to market value of assets* is cash and marketable securities (#1) divided by long-term debt (#9) plus debt in current liabilities (#34) plus market value of equity (#199  $\times$  #25)
- *Log of cash to net book assets* is the natural logarithm of the ratio of cash and marketable securities (#1) to book assets (#6) minus cash and marketable securities (#1)

Although cash to book asset is the most traditional measure, [Opler, Pinkowitz, Stulz and Williamson \(1999\)](#) use the cash to net asset ratio. This measure generates extreme outliers for firms with most of their assets in cash. [Foley, Hartzell, Titman and Twite \(2007\)](#) use the logarithm of the cash to net asset. Their measure reduces the magnitude of the problem of extreme outliers but does not eliminate it in my sample, which includes speculative grade firms with assets less than \$100 million. Thus, I focus primarily on regressions using the cash to asset as the dependent variable, but [Table A.3](#) reports the results for the baseline regression (1) using the other measures of cash. The main conclusion from the empirical analysis—that the debt composition of a firm affects its asset allocation, such that higher fractions of market debt motivate firms to hold proportionally more cash—is robust across different measures of cash.

Second, for consistency with the empirical literature on cash holdings (see, for example, [Bates, Kahle and Stulz \(2009\)](#); [Opler, Pinkowitz, Stulz and Williamson \(1999\)](#); [Falato, Kadyrzhanova and Sim \(2013\)](#)), I use annual variables in the panel regressions in [Section 2.2](#) of the main text. For consistency with the theoretical section, which calibrates to quarterly data, the second robustness test re-estimates the baseline regression using quarterly data. [Table A.4](#) reports the results, which are qualitatively similar to the results in [Table 2](#) of the main text as well as statistically significant at the 5% level, thus showing the robustness of the relation between debt composition and cash holdings.

Third, while the majority of the analysis focuses on the balance-sheet debt-level data, I also use the issuance-level data from SDC Platinum and Dealscan for robustness checks. In particular, I examine whether new bond issues are associated with higher cash holdings. The sample

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<sup>49</sup>The research in this section was conducted when I was a Research Associate at the Center for Macroeconomics at the London School of Economics, where the data on loan and bond issuances was obtained from.

consists of non-financial (SIC codes 6000-6999) and non-utility (SIC codes 4900-4949) firms incorporated in the U.S. that (a) have positive total assets (henceforth, Compustat sample); (b) have data available for its incremental financing from Dealscan and SDC Platinum; and (c) have S&P rating (and therefore have access to the bond market). This sample construction procedure identifies 3,124 unique firms (out of the 17,013 in the Compustat sample) with new debt issues between 1987 and 2011. Firm-quarter observations with new financing and S&P ratings amounts to 2.7% of the Compustat sample, and represents 25.1% of their total assets.

Loan information comes from the May 2013 extract of Dealscan, and includes information on loan issuances (from the facility file: amount, issue date, type, purpose, maturity and cost), and borrowers (from the borrower file: identify, country, type, and public status). I apply the following filters: (1) the issue date is between October 1987 and December 2011; (2) the loan amount, maturity, and cost are non-missing; (3) and the loan type and purposes are disclosed; (4) the loan is extended for real investment purposes. I then use Dealscan-Compustat link provided by [Chava and Roberts \(2008\)](#) to match loan information with the Compustat sample, and end up with 22,042 firm-quarters with loan issues, by 6,860 unique firms.<sup>50</sup> The screening of bond issuances follows similar steps. I retrieve from SDC Platinum information on non-financial and non-utility firms' bond issuances (amount, issue date, cost, purpose, and maturity) and apply the following filters: (1) the issue date is between October 1987 and December 2011; (2) the bond amount, maturity, and cost are non-missing; (3) the bond is issued for real investment purposes. I then merge bond information with the Compustat sample using issuer CUSIPs, and obtain 214,503 firm-quarters with bond issues, by 2,132 unique firms (see [Table A.2](#)).<sup>51</sup>

The aim is to study if different types of debt issues (loans or bonds) have any different impact on firms' cash holdings. To that end, I replace  $DebtStructure_{i,t-1}$  in the baseline regression (1) by an indicator variable  $Bondissue_{i,t-1}$ , that is equal to one if firm  $i$  issues a bond during quarter  $t-1$ , and zero if it takes out a loan. For a firm issuing both types of debt during a given quarter, I set the indicator variable to be one if the total bond issuance exceeds the total loan issuance, and zero otherwise. All firm characteristics are measured in the quarter prior to issuance and winsorized at the 1<sup>st</sup> and 99<sup>th</sup> percentiles. In [Table A.5](#), Panel A of report the coefficients of  $Bondissue_{i,t-1}$  in the baseline regression (1); Panel B reports the results of augmenting the baseline regression by a crisis dummy  $Crisis_{i,t-1}$  and an interaction dummy  $Bondissue_{i,t-1} \times Crisis_{i,t-1}$ , in order to highlight the impact of debt composition on cash holdings during crises; Panel C reports the coefficients of interest from the cash dynamics regression (2).<sup>52</sup>

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<sup>50</sup>Loans used for real investment are defined as those with the following primary purposes: capital expenditures, corporate purposes, equipment purchase, infrastructure, real estate, trade finance, and working capital. The dataset provided by Michael Roberts links between company names in Dealscan and Computstat in 1983–2012.

<sup>51</sup>Mirroring the classification for loans, I define a real investment bond as having the following primary purpose (based on the SDC field "primary use of proceeds"): buildings, capital expenditures, construction, general corporate purpose, property development, railways, and working capital.

<sup>52</sup>The crisis dummy is defined according to the NBER Recession Indicators for the U.S.

**Table A.2:** Frequency of new debt finance (1987:Q3—2011:Q4)

	Firm-quarters		Firms
	Observations	Total assets (Mil of 2009 USD)	
<b>Starting Compustat sample</b>	654,903 (100%)	1,137,863 (100%)	17,013 (100%)
With S&P credit rating	12,694 (1.9%)	963,336 (84.7%)	3,637 (21.4%)
<b>Debt-issuing firms</b>	30,059 (4.6%)	292,432 (25.7%)	7,196 (42.3%)
<b>Dealscan:</b> new loan issues	22,042 (3.4%)	108,228 (9.5%)	6,860 (40.3%)
<b>SDC Platinum:</b> new bond issues	9,234 (1.4%)	214,503 (18.9%)	2,132 (12.5%)
<b>Firms with access to bond market</b> (with S&P rating or bond issues)	17,601 (2.7%)	284,945 (25.0%)	3,124 (18.4%)

**Table A.3: Robustness Check Using Alternative Measures of Cash**

Panel A: Fixed-Effects Panel Regression Using Cash to Net Book Asset						
	Full sample		Investment grades		Speculative grades	
	(1)	(2)	(1)	(2)	(1)	(2)
DebtStructure <sub>t-1</sub>	0.034*** (0.003)	0.028** (0.036)	0.019** (0.030)	0.013* (0.076)	0.046** (0.037)	0.037* (0.068)
# Observations	4,683	4,683	2,178	2,178	2,505	2,505
# Clusters (firms)	827	827	327	327	540	540
Within R <sup>2</sup>	0.746	0.718	0.820	0.796	0.713	0.704
Panel B: Fixed-Effects Panel Regression Using Cash to Market Value of Assets						
	Full sample		Investment grades		Speculative grades	
	(1)	(2)	(1)	(2)	(1)	(2)
DebtStructure <sub>t-1</sub>	0.018** (0.013)	0.010** (0.041)	0.011** (0.043)	0.007* (0.084)	0.025* (0.071)	0.018* (0.094)
# Observations	4,683	4,683	2,178	2,178	2,505	2,505
# Clusters (firms)	806	806	362	362	428	428
Within R <sup>2</sup>	0.621	0.604	0.647	0.625	0.605	0.589
Panel C: Fixed-Effects Panel Regression Using Log of Cash to Net Book Asset						
	Full sample		Investment grades		Speculative grades	
	(1)	(2)	(1)	(2)	(1)	(2)
DebtStructure <sub>t-1</sub>	0.436*** (0.007)	0.236** (0.021)	0.217** (0.027)	0.143** (0.039)	0.611** (0.031)	0.508* (0.050)
# Observations	4,683	4,683	2,178	2,178	2,505	2,505
# Clusters (firms)	827	827	327	327	540	540
Within R <sup>2</sup>	0.847	0.823	0.895	0.881	0.798	0.774

**Note:** The sample includes all Compustat firm-year observations from 2006 to 2015 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the top 1% of companies (the largest 25 cash holders) are excluded from the sample. Columns (1) report the estimates from panel regressions of cash holdings to book assets on MarketFraction<sub>i,t-1</sub>, and columns (2) report estimates from similar regressions but replaces MarketFraction<sub>i,t-1</sub> by the indicator variable MarketOnly<sub>i,t-1</sub>. p-values are in parentheses and are clustered at the firm level. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5% and 10% levels, respectively.

**Table A.4: Robustness Check Using Quarterly Dataset**

Panel A: Fixed-Effects Panel Regressions of Cash Holdings on Debt Composition						
	Full sample		Investment grades		Speculative grades	
	(1)	(2)	(1)	(2)	(1)	(2)
DebtStructure <sub>t-1</sub>	0.049*** (0.000)	0.032*** (0.000)	0.036*** (0.001)	0.022** (0.016)	0.058*** (0.002)	0.047** (0.024)
# Observations	14,846	14,846	7,261	7,261	7,585	7,585
# Clusters (firms)	843	843	357	357	583	583
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Within R <sup>2</sup>	0.815	0.807	0.829	0.816	0.749	0.737
Panel B: Fixed-Effects Panel Regressions of Capital Expenditures on Cash Holdings						
	Full sample		Investment grades		Speculative grades	
	(1)	(2)	(1)	(2)	(1)	(2)
DebtStructure <sub>t-1</sub>	-0.017*** (0.000)	-0.009*** (0.002)	-0.015*** (0.001)	-0.007** (0.024)	-0.023*** (0.004)	-0.012** (0.031)
Cash <sub>t-1</sub>	0.020*** (0.000)	0.014*** (0.001)	-0.050*** (0.002)	-0.038** (0.028)	0.071*** (0.007)	0.059** (0.031)
# Observations	14,846	14,846	7,261	7,261	7,585	7,585
# Clusters (firms)	843	843	357	357	583	583
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Within R <sup>2</sup>	0.828	0.817	0.836	0.829	0.809	0.798

**Note:** The sample includes all Compustat quarter-year observations from 2006Q1 to 2015Q4 with positive values for the book value of total assets, and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the United States. Financial firms (SIC code 6000-6999), utilities (SIC 4900-4949) and the top 1% of companies (the largest 25 cash holders) are excluded from the sample. Columns (1) report the estimates from panel regressions of cash holdings to book assets (Panel A), or capital expenditures to book assets (Panel B) on MarketFraction<sub>i,t-1</sub>, and columns (2) report estimates from similar regressions but replaces MarketFraction<sub>i,t-1</sub> by the indicator variable MarketOnly<sub>i,t-1</sub>. Year dummies as well as firm-level controls for standard determinants of cash holdings are included in all regressions. p-values are in parentheses and are clustered at the firm level. Detailed variable definitions are in Appendix A.1. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5% and 10% levels, respectively.

**Table A.5: Robustness Check Using Firm-Level Data on Debt Issues**

Whole Sample (1987:Q3-2011Q4)

S&P Sample (1987:Q3-2011Q4)

Panel A: Panel Evidence on Bond Issues and Cash Holdings by Percentiles of Asset Size								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	[0,100]	[0,50]	[50,75]	[75,90]	[90,100]	[0,100]	[0,50]	[50,100]
BondIssue <sub>t-1</sub>	0.326**	2.191**	0.608**	0.529**	0.269**	0.314**	0.702**	0.256**
	(0.143)	(1.081)	(0.297)	(0.221)	(0.113)	(0.129)	(0.272)	(0.134)
# Observations	10,129	2,574	2,407	2,085	2,760	1,482	359	1,104
Within R <sup>2</sup>	0.758	0.782	0.716	0.701	0.791	0.778	0.705	0.793
Panel B: Panel Evidence on Bond Issues and Cash Holdings During Crises by Percentiles of Asset Size								
	[0,100]	[0,50]	[50,75]	[75,90]	[90,100]	[0,100]	[0,50]	[50,100]
BondIssue <sub>t-1</sub>	0.213**	1.602**	0.408**	0.308**	0.144*	0.277**	0.648**	0.108**
	(0.104)	(0.729)	(0.195)	(0.156)	(0.089)	(0.124)	(0.194)	(0.057)
BondIssue <sub>t-1</sub> × Crisis <sub>t-1</sub>	0.167*	0.863*	0.276*	0.248**	0.152**	0.138**	0.157**	0.148**
	(0.113)	(0.627)	(0.195)	(0.117)	(0.681)	(0.063)	(0.072)	(0.068)
Panel C: Panel Evidence on Cash Dynamics by Percentiles of Bond Issues								
	[0,100]	[0,50]	[50,75]	[75,90]	[90,100]	[0,100]	[0,50]	[50,100]
Cash <sub>t-1</sub>	0.716***	0.491***	0.657***	0.779***	0.855***	0.740***	0.589***	0.871***
	(0.045)	(0.182)	(0.078)	(0.066)	(0.037)	(0.073)	(0.032)	(0.081)
BondIssue <sub>t-1</sub>	0.471***	1.336**	0.882**	0.607**	0.434***	0.316***	1.083**	0.321***
	(0.143)	(0.615)	(0.403)	(0.256)	(0.159)	(0.165)	(0.494)	(0.185)
SOA, Half-life	2.075	0.974	1.650	2.775	4.425	2.302	1.309	5.019

**Note:** Columns (1)-(5) report the panel regression results using the whole sample at the intersection of Compustat, Dealscan, and SDC Platinum, as described in Appendix A.4; columns (6)-(8) report the results using only firm-quarters with S&P ratings. Panels A and B report the regression results in the full sample (columns (1) and (6)), as well as the subsamples by bins of firm asset size (with the percentiles of assets in square brackets). Panel C reports the regression results by bins of bond issue size (with the percentiles of bond issues in square brackets). Year dummies as well as firm-level controls for standard determinants of cash holdings are included in all regressions. p-values are in parentheses and are clustered at the firm level. \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5% and 10% levels, respectively.

## A.5 Uncertainty Proxy Based on Profit Shocks

In this section, I describe the procedure used to calibrate the curvature of the profit function and the parameters governing the stochastic volatility process of the idiosyncratic technology shock, following the procedure described in [Gilchrist, Sim and Zakrajšek \(2014\)](#). Assuming that the production function is Cobb-Douglas, gross profits (profits before fixed operation costs) and sales only differ by up to a constant. Hence, the returns to scale can be estimated using data on either sales or gross profits, and this paper chooses to use the data on sales to ensure that all observations are non-negative.

Specifically, the sample includes all Compustat firm-quarter observations from 2006:Q1-2015:Q4, with positive values for net sales (#2) and net property, plant and equipment (#42), and data available on debt structure from Capital IQ, for firms with Standard & Poor's ratings incorporated in the U.S. Financial firms (SIC code 6000-6999), utilities (SIC code 4900-4949), and the top 1% of companies (the largest 25 cash holders) are excluded from the sample, yielding a panel of 21,759 firm-quarter observations for 921 unique firms. To ensure that the results are not driven by a small number of extreme observations, I dropped from the sample all observations with the sales-to-capital below 0.01 and above 20.0, and observations with quarterly growth rates of sales and capital above and below 100 percent.

To calibrate the process for the idiosyncratic technology shock, I first estimate the profit function in equation (4) in Section 3.1 of the main text using:

$$\log Y_{i,t} = c_{i,t} + \alpha_s \log K_{i,t-1} + \lambda_{s,t} + u_{i,t}, \quad (\text{A.1})$$

where  $Y_{i,t}$  denotes the sales of firm  $i$  in quarter  $t$ , and  $K_{i,t-1}$  is the capital stock at the end of quarter  $t - 1$ . The subscript  $s$  indicates that the curvature of the profit function is allowed to differ across industries as defined by the 4-digit SIC codes. To remove the seasonal pattern in the quarterly firm-level sales, regression (A.1) also includes a full set of firm-specific quarterly dummies  $c_{i,t}$ . Moreover, industry-specific time fixed effects—denoted by  $\lambda_{s,t}$ —are included to control for persistent nature of cyclical profitability shocks within an industry.

Next, I use the residuals from the estimation of equation (A.1) to obtain the persistence of the process for the idiosyncratic technology shock  $\rho_z$ , by estimating the following pooled OLS regression:

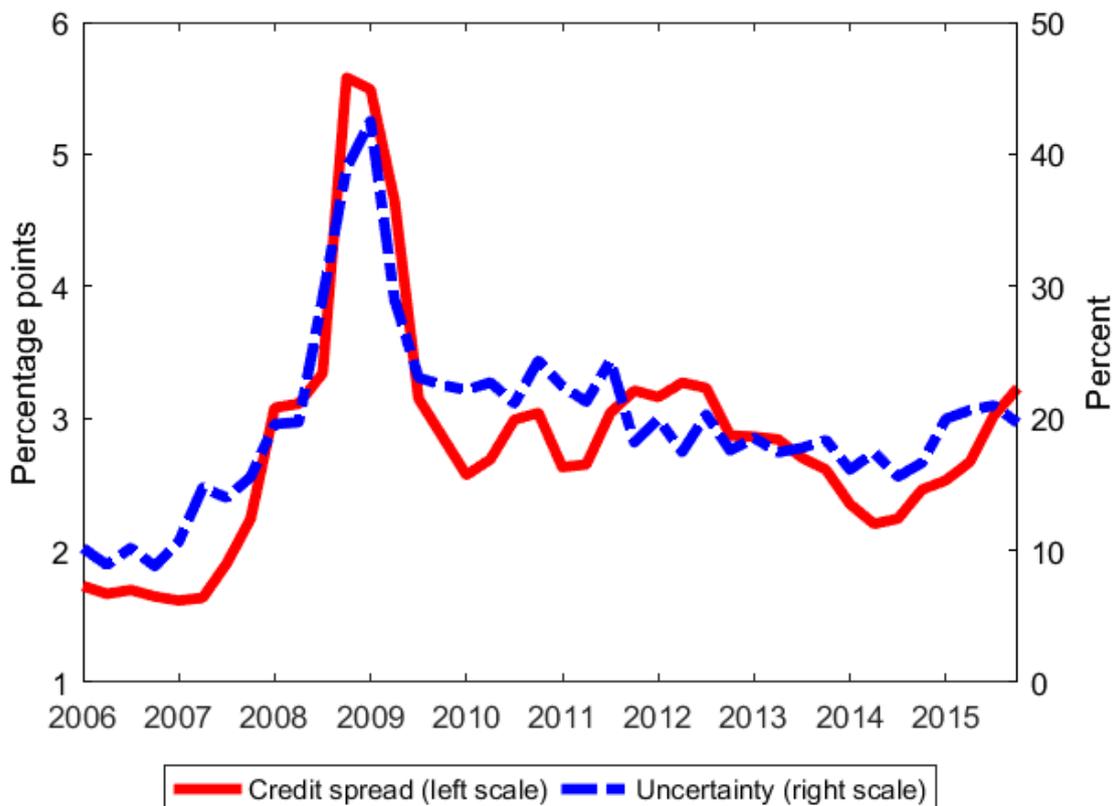
$$\hat{u}_{i,t} = \rho_z \hat{u}_{i,t-1} + \epsilon_{i,t}. \quad (\text{A.2})$$

This approach estimates the persistence of the idiosyncratic technology shock  $\rho_z$  to be about 0.93 for the sample. To obtain a proxy for the time-varying uncertainty of productivity shocks, the last step involves estimating a panel regression of the form:

$$\log \hat{\sigma}_{\epsilon,i,t} = \sum_{k=1}^4 \log \hat{\sigma}_{\epsilon,i,t-k} + \eta_i + v_t + \zeta_{i,t}, \quad (\text{A.3})$$

where  $\hat{\sigma}_{\epsilon,i,t}$  denotes the unbiased estimator of the true standard deviation  $\epsilon_{i,t}$  in (A.2) that is given by  $\hat{\sigma}_{\epsilon,i,t} = \sqrt{\frac{\pi}{2}} |\hat{\epsilon}_{i,t}|$ ,  $\eta_i$  is the firm fixed effect, and  $v_t$  is the time fixed effect, which captures

**Figure A.2: Uncertainty Based on Shocks to the Profit Function**



**Note:** Sample period: 2006:Q1-2015:Q4. The solid line (left scale) depicts the credit spread, which is the Moody’s Seasoned BAA corporate bond yield relative to yield on 10-year Treasury Constant Maturity (see Appendix A.1 for data source). The dotted line (right scale) depicts the estimate of the idiosyncratic uncertainty (in annualized percent) based on shocks to the profit function.

common fluctuations in the idiosyncratic uncertainty regarding the profitability prospects in the nonfinancial corporate sector. Figure A.2 below plots its estimate  $\hat{v}_t$ .

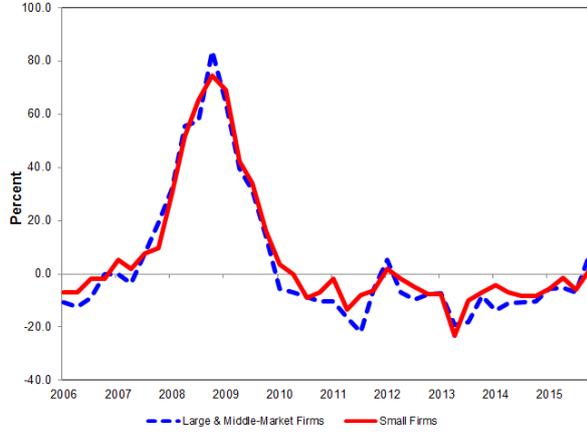
### A.6 Indicators of Changes In the Supply of Bank Intermediated Credit

The data used to calibrate the persistence and standard deviation of the bank credit supply shock comes from the Federal Reserve’s Senior Loan Officer Opinion Survey of Bank Lending Practices (SLOOS). This survey has queried banks about changes in their lending standards for the major categories of loans to households and businesses beginning with the April 1990 survey and about changes in demand for most of those types of loans starting with the October 1991 survey. The SLOOS is usually conducted four times per year by the Federal Reserve Board, and up to 80 U.S. commercial banks participate in each survey. Participating banks are asked to report whether they have changed their standards during the survey period in several categories of core loans.

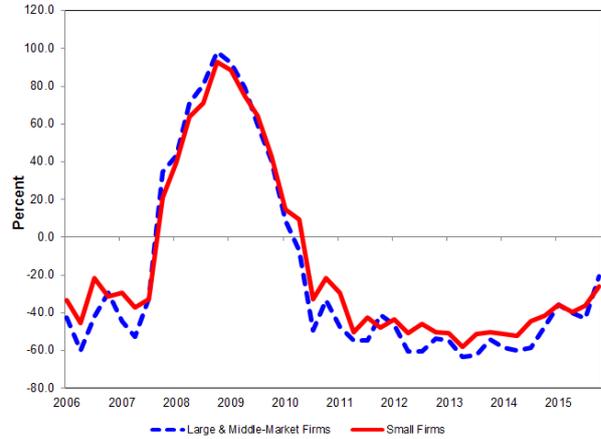
Nevertheless, in assessing the supply-side implications of changes in bank lending policies, it is important to bear in mind that the changes in bank lending standards reported in the SLOOS reflect the confluence of demand and supply factors. Recognizing this endogeneity problem, I use VAR-based identification strategies to identify the component of the change in lending stan-

**Figure A.3: Proxy for Bank Credit Supply**

**(a) Net Percentage of Domestic Banks Tightening Standards**



**(b) Net Percentage of Domestic Banks Increasing Spreads of Loan Rates**



**Note:** Quarterly data is obtained from the Senior Loan Officer Opinion Survey on Bank Lending Practices release of the Board of Governors of the Federal Reserve System. Panel (a) plots the net percentage of domestic banks tightening standards for commercial and industrial loans to large and middle-market firms (dashed blue line) and small firms (solid red line), where “net percentage” refers to the fraction of banks that reported having tightened (“tightened considerably” or “tightened somewhat”) minus the fraction of banks that reported having eased (“eased considerably” or “eased somewhat”). Panel (b) plots the net percentage of domestic banks increasing spreads of loan rates over banks’ cost of funds for large and middle-market firms (dashed blue line) and small firms (solid red line), where “net percentage” refers to the fraction of banks that reported having increased the spreads minus the fraction of banks that reported having reduced the spreads.

dards that is orthogonal to the determinants of loan demand (see, for example, [Lown and Morgan \(2006\)](#)). Specifically, I estimate for the relative supply of bank credit  $\gamma^b$  using a VAR(4) specification with four quarterly macroeconomic variables—including log real GDP, log GDP deflator, log commodity prices, and the federal funds rate—and the net percent of banks reporting tightening standards. I order the credit variable after the macro variables. Summing the coefficients on lags of the lending standard variables in the lending standard equation itself yields  $\hat{\rho}_\gamma = 0.81$  and  $\hat{\sigma}_\gamma = 0.085$ , which are the values used in the calibration. For robustness, I also estimate an AR(1) estimation using the change in the loan spreads (panel (b)), which gives  $\hat{\rho}_\gamma = 0.89$  and  $\hat{\sigma}_\gamma = 0.072$ .

## B Model Appendix

In this appendix, I provide details regarding the key elements of the model in Section 3. Subsection B.1 describes the construction of the Markov chain with time-varying volatility, which governs the evolution of the idiosyncratic technology shock. Subsection B.2 summarizes the calibration of the model. Subsection B.3 presents the proofs for the theoretical results in Section 3. Subsection B.4 presents the robustness results for other versions of the theoretical model. Subsection B.5 elaborates on the computational details.

### B.1 Markov Chain with Time-Varying Volatility

This paper assumes an  $N$ -state Markov chain with transition matrix:

$$\mathbf{P} = \begin{bmatrix} p_{i,1} & \cdots & p_{i,N} \\ \vdots & \ddots & \vdots \\ p_{N,1} & \cdots & p_{N,N} \end{bmatrix}; \quad \text{with } \sum_{j=1}^N p_{i,j} = 1, \quad (\text{B.1})$$

and let  $p_i = 1, 2, \dots, N$  denote its ergodic distribution. Assume, without loss of generality, that  $N$  is an even number, and that the ergodic distribution is symmetric, in the sense that  $p_i = p_{N-(i-1)}$ , for all  $i = 1, 2, \dots, N$ .

This paper constructs the Markov chain as follows. Conditional on observing  $\sigma_t$  in period  $t$ , the  $N$ -equispaced states in period  $t + 1$  are given by:

$$z_{j,t+1} = \bar{z} - \frac{\mu_i}{2}(\sigma_t - \bar{\sigma}) + \left[ 2 \left( \frac{j-1}{N-1} \right) - 1 \right] \frac{\sigma_t}{2}; \quad j = 1, \dots, N. \quad (\text{B.2})$$

where

$$\mu_i = 2 \sum_{j=1}^N p_{i,j} \left( \frac{j-1}{N-1} \right) - 1,$$

and  $\bar{z}$  and  $\bar{\sigma}$  are the unconditional mean and unconditional variance of the process, respectively.  $\sigma_t$  is the variance of the Markov process that follows a stationary distribution.

I next show that in this formulation, the support of the distribution of the idiosyncratic technology shock  $z$  evolves stochastically over time, with an increase in  $\sigma_t$  today inducing a greater dispersion in  $z$  tomorrow. Under the assumption of a symmetric ergodic distribution ( $p_i = p_{N-(i-1)}, i = 1, \dots, N$ ), it is straightforward to show that the realization of the volatility process  $\sigma_t$  does not alter the unconditional mean and variance of  $z$ . The conditional mean of this

Markov process is given by:

$$\begin{aligned}
E(z_{t+1}|z_t = z_i) &= \bar{z} + \frac{\mu_i}{2}\bar{\sigma} + \frac{\sigma_t}{2} \sum_{j=1}^N p_{i,j} \left[ 2 \left( \frac{j-1}{N-1} \right) - 1 - \mu_i \right] \\
&= \bar{z} + \frac{\mu_i}{2}\bar{\sigma} + \sigma_t \sum_{j=1}^N p_{i,j} \left[ \frac{j-1}{N-1} - \sum_{k=1}^N p_{i,k} \left( \frac{k-1}{N-1} \right) \right] \\
&= \bar{z} + \frac{\mu_i}{2}\bar{\sigma} + \sigma_t \sum_{j=1}^N p_{i,j} \left( \frac{j-1}{N-1} \right) - \sigma_t \sum_{j=1}^N p_{i,j} \left[ \sum_{k=1}^N p_{i,k} \left( \frac{k-1}{N-1} \right) \right] \\
&= \bar{z} + \frac{\mu_i}{2}\bar{\sigma} + \sigma_t \sum_{j=1}^N p_{i,j} \left( \frac{j-1}{N-1} \right) - \sigma_t \sum_{k=1}^N p_{i,k} \left( \frac{k-1}{N-1} \right) \\
&= \bar{z} + \frac{\mu_i}{2}\bar{\sigma}.
\end{aligned}$$

Hence, an increase in volatility represents a mean-preserving-spread of  $z$ , a property reflecting the presence of the mean-correction term  $-\frac{\mu_i}{2}(\sigma_t - \bar{\sigma})$ . The conditional variance of the process is given by:

$$\begin{aligned}
\text{Var}(z_{t+1}|z_t = z_i) &= \sigma_t^2 \sum_{j=1}^N p_{i,j} \left[ \frac{j-1}{N-1} - \sum_{k=1}^N p_{i,k} \left( \frac{k-1}{N-1} \right) \right]^2 \\
&= \Xi \sigma_t^2;
\end{aligned}$$

where

$$\Xi = \sum_{j=1}^N p_{i,j} \left[ \frac{j-1}{N-1} - \sum_{k=1}^N p_{i,k} \left( \frac{k-1}{N-1} \right) \right]^2.$$

Thus the conditional volatility of this process depends linearly on the realization of the stochastic process  $\sigma_t$ .

## B.2 Calibration Summary

**Table B.1:** Baseline Calibration of the Model

<b>Model Parameter</b>	<b>Value</b>
<i>Production and capital accumulation</i>	
Value-added share of capital ( $\alpha$ )	0.30
Decreasing returns to scale ( $\alpha$ )	0.80
Depreciation rate ( $\delta$ )	0.025
Quasi-fixed costs of production ( $F_o$ )	0.12
Quasi-fixed costs of investment ( $F_{k,0}$ )	0.01
Purchase price of capital ( $p^+$ )	1.00
Resale price of capital ( $p^-$ )	0.45
<i>Firm entry and exogenous exit</i>	
Survival probability ( $\eta$ )	0.95
Pareto distribution ( $\omega$ )	3.43
Initial equity issuance cost ( $\gamma^e$ )	1.00
Entry cost ( $c_e$ )	1.47
Mass of potential entrants ( $M$ )	134.65
<i>Financial markets</i>	
Market debt intermediation cost ( $\gamma^m$ )	0.01
Efficiency of liquidation ( $\chi$ )	0.43
<i>Representative household</i>	
Discount factor ( $\beta$ )	0.99
<i>Exogenous shocks</i>	
Persistence of the shock to the wedge in intermediation costs ( $\rho_\gamma$ )	0.81
Volatility of the innovations of the wedge in intermediation costs ( $\sigma_\gamma$ )	0.085
Steady state level of the wedge in intermediation costs ( $\bar{\gamma}^*$ )	0.025
Persistence of the idiosyncratic technology shock process ( $\rho_z$ )	0.80
Steady-state level of idiosyncratic uncertainty ( $\bar{\sigma}_z$ )	0.18
Persistence of the idiosyncratic uncertainty ( $\rho_\sigma$ )	0.90
Volatility of innovations of the idiosyncratic uncertainty process ( $\omega_\sigma$ )	0.05
Persistence of the idiosyncratic demand shock process ( $\rho_\psi$ )	0.70
Volatility of the idiosyncratic demand shock process ( $\sigma_\psi$ )	0.23

### B.3 Proofs for Theoretical Results

#### Proof of Proposition 1

*Proof.* The proof proceeds by comparing the value of the firm at the debt settlement stage, under repayment  $V_P^{0'}$ , restructuring  $V_R^{0'}$ , and liquidation  $V_L^{0'}$ . Recall that:

$$\begin{aligned} V_P^0(\hat{k}', x'; \mathbf{s}') &= (1 - \eta)(\pi' - b' - m') + \eta V^1(\hat{k}', x'; \mathbf{s}') \\ &\geq (1 - \eta)(\pi' - b' - m'), \end{aligned}$$

and

$$\begin{aligned} V_R^0(\hat{k}', x'_R; \mathbf{s}') &= (1 - \eta)(\pi' - b'_R - m') + \eta V^1(\hat{k}', x'; \mathbf{s}') \\ &\geq (1 - \eta)(\pi' - b'_R - m'). \end{aligned}$$

By assumption, the firm is forced into liquidation by the lenders if its current period resources  $\pi'$  cannot repay both types of debt, even with restructuring. As the firm is the last residual claimant, the payoff to the firm in liquidation is given by:

$$V_L^0(\hat{k}', x'_R; \mathbf{s}') = \max(0, (1 - \eta)(\chi\pi' - b' - m')),$$

where  $V^1(k', x'; \mathbf{s}')$  is the continuation value of the firm that does not default in period  $t + 1$  (i.e. after debt settlement), and  $b'_R = \min(b', \chi\pi')$ . There are two types of contracts:

1. **R-contract:**  $\frac{m'}{1-\chi} \leq \frac{b'}{\chi}$

- when  $\pi' \geq \frac{b'+m'}{\chi}$ :  
 $V_L^{0'} = (1 - \eta)(\chi\pi' - b' - m') < (1 - \eta)(\pi' - b' - m') \leq V_P^{0'}$ , and  $V_P^{0'} = V_R^{0'}$ , as  $b'_R = \min(b', \chi\pi') = b'$ ;  $\implies$  Repayment;
- when  $\frac{b'+m'}{\chi} > \pi' \geq \frac{b'}{\chi}$ :  
 $\pi' \geq \frac{b'}{\chi} \geq b' + m'$ , so  $V_P^{0'} \geq (1 - \eta)(\pi' - b' - m') > 0 = V_L^{0'}$ , and  $V_R^{0'} = V_P^{0'}$  as  $b'_R = b'$ ;  $\implies$  Repayment;
- when  $\frac{b'}{\chi} > \pi' \geq b' + m'$ :  
 $V_R^{0'} \geq (1 - \eta)((1 - \chi)\pi' - m')$ , as  $b'_R = \min(b', \chi\pi') = \chi\pi'$ , so  $V_R^{0'} > (1 - \eta)(\pi' - b' - m') \geq 0$  and thus  $V_R^{0'} \geq V_P^{0'}$ ;  $V_L^{0'} = 0 < V_R^{0'}$ ;  $\implies$  Restructuring;
- when  $b' + m' \geq \pi' \geq \frac{m'}{1-\chi}$ :  
 $V_L^{0'} = 0 < (1 - \eta)((1 - \chi)\pi' - m') \leq V_R^{0'}$ , as  $b' = \min(\chi\pi', b') = \chi\pi'$ , and  $V_P^{0'} < V_R^{0'}$ ;  $\implies$  Restructuring;
- when  $\frac{m'}{1-\chi} > \pi'$ :  
 $V_L^{0'} = 0$  and again  $V_P^{0'} < V_R^{0'}$ ; moreover,  $b'_R = \chi\pi'$ , but  $(1 - \eta)((1 - \chi)\pi' - m') < 0$ , so even with restructuring, firm cannot repay both types of debt with the current period's resources;  $\implies$  Liquidation.

2. **NR-contract:**  $\frac{m'}{1-\chi} > \frac{b'}{\chi}$ :

- when  $\pi' \geq \frac{b'+m'}{\chi}$ :  
 $V_L^{0'} = (1-\eta)(\chi\pi' - b' - m') < (1-\eta)(\pi' - b' - m') \leq V_P^{0'}$ ;  $b'_R = \min(b', \chi\pi') = b'$  so  
 $V_P^{0'} = V_R^{0'}$ ;  $\implies$  Repayment.
- when  $\frac{b'+m'}{\chi} > \pi' \geq b' + m'$ :  
again  $b'_R = \min(b', \chi\pi') = b'$  so  $V_R^{0'} = V_P^{0'} > 0$ ;  $V_L^{0'} = 0$   $\implies$  Repayment.
- when  $b' + m' > \pi'$ :  
 $V_L^{0'} = 0$ ;  $b'_R = \min(b', \chi\pi') = b'$ , so  $V_P^{0'} = V_R^{0'}$ , but  $(1-\eta)(\pi' - b' - m') < 0$  i.e. there is no gain from restructuring, and the firm cannot repay both types of debt with the current period's resources;  $\implies$  Liquidation.

Therefore, in an R-contract, the firm repays when  $\pi' \geq \frac{b'}{\chi}$ , restructures when  $\frac{b'}{\chi} \geq \pi' > \frac{m'}{1-\chi}$  with the renegotiated amount of bank debt equal to  $b'_R = \chi\pi'$ , and liquidated otherwise; in a NR-contract, the firm repays when  $\pi' \geq b' + m'$ , and liquidates otherwise. In default,  $V_L^0 = 0$ , regardless the contract chosen, because otherwise  $\pi' - b' - m' \geq \chi\pi' - b' - m' > 0$ , in which case the firm would be better off by paying its creditors. ■

## Proof of Proposition 2

*Proof.* For the sake of argument, assume that the optimal borrowing conditions can be obtained directly by differentiating the Bellmann equation (34) with respect to  $b'$  and  $m'$ , thus ignoring any nondifferentiabilities. Let  $\mu$  denote the multiplier to the non-negativity dividend constraint.

First, suppose that the firm takes on positive amount of debt ( $b' > 0$  or  $m' > 0$ ). If it chooses a **NR-contract**, and the first order condition by differentiating (35) with respect to  $b'$  is:<sup>53</sup>

$$(1 + \mu) \left[ q^b + \frac{\partial q^b}{\partial b'} b' + \frac{\partial q^m}{\partial b'} m' \right] + \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( \int_{\bar{\psi}'_{NR}}^{+\infty} \frac{\partial V^{0'}}{\partial b'} dF(\psi') - V^{0'}(\bar{\psi}'_{NR}) f(\bar{\psi}'_{NR}) \frac{\partial \bar{\psi}'_{NR}}{\partial b'} \right) \right] = 0. \quad (\text{B.3})$$

It has to be true that  $V^{0'}(\bar{\psi}'_{NR}) = 0$ , as Proposition 1 established that the firm value default is zero, and  $\bar{\psi}'_{NR}$  is the threshold value of the demand (profit) shock  $\psi'$  below which the firm starts to default. Moreover, the associated Benveniste-Scheinkman condition is given by:

$$\frac{\partial V^{0'}}{\partial b'} = -(1 + \eta\mu'),$$

so the first order condition (B.3) becomes:

$$(1 + \mu) \left[ q^b + \frac{\partial q^b}{\partial b'} b' + \frac{\partial q^m}{\partial b'} m' \right] = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( \int_{\bar{\psi}'_{NR}}^{+\infty} \left( (1 + \eta\mu') dF(\psi'_z) \right) \right) \right]$$

$$(1 + \mu) \left[ q^b + \frac{\partial q^b}{\partial b'} b' + \frac{\partial q^m}{\partial b'} m' \right] = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( 1 - F(\bar{\psi}'_{NR}) \right) + \lambda(\mathbf{s}, \mathbf{s}') \eta\mu' \left( 1 - F(\bar{\psi}'_{NR}) \right) \right]. \quad (\text{B.4})$$

Recall that the prices of bank debt  $q^b$  and market debt  $q^m$  in a NR-contract are:

$$q^b(k', b', a'_f, z, \psi; \mathbf{s}) = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( \left( 1 - F(\underline{\psi}'_{NR}) \right) + \int_{-\infty}^{\underline{\psi}'_{NR}} \frac{\chi\pi'}{b'} dF(\psi') \right) \right] - \gamma^b, \quad (\text{B.5})$$

and

$$q^m(k', b', m' a'_f, z, \psi; \mathbf{s}) = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( \left( 1 - F(\bar{\psi}'_{NR}) \right) + \int_{\underline{\psi}'_{NR}}^{\bar{\psi}'_{NR}} \frac{\chi\pi' - b'}{m'} dF(\psi') \right) \right] - \gamma^m, \quad (\text{B.6})$$

and  $\underline{\psi}'_{NR}$  and  $\bar{\psi}'_{NR}$  are the full default and partial default thresholds, respectively. Note that  $\underline{\psi}'_{NR} \leq \bar{\psi}'_{NR}$ , as the firm defaults upon market debt first (if  $\underline{\psi}'_{NR} \leq \psi' < \bar{\psi}'_{NR}$ ), given the assumption that bank debt is more senior than market debt.

$\frac{\partial q^b}{\partial b'}$  and  $\frac{\partial q^m}{\partial b'}$  can be determined using the Leibniz rule:

$$\frac{\partial q^b}{\partial b'} b' = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( - \int_{-\infty}^{\underline{\psi}'_{NR}} \frac{\chi\pi'}{b'} dF(\psi') - \left( 1 - \frac{\chi\pi'}{b'} \right) b' f(\underline{\psi}'_{NR}) \frac{\partial \underline{\psi}'_{NR}}{\partial b'} \right) \right], \quad (\text{B.7})$$

<sup>53</sup>If firm only takes on positive market debt  $m' > 0$ , the proof goes through by differentiating (35) with respect to  $m'$ . The results of are available upon request.

and

$$\frac{\partial q^m}{\partial b'} m' = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( - \left( F(\bar{\psi}'_{NR}) - F(\underline{\psi}'_{NR}) \right) - \left( m' - (\chi\pi' - b') \right) f(\bar{\psi}'_{NR}) \frac{\partial \bar{\psi}'_{NR}}{\partial b'} - (\chi\pi' - b') f(\underline{\psi}'_{NR}) \frac{\partial \underline{\psi}'_{NR}}{\partial b'} \right) \right]. \quad (\text{B.8})$$

Substitute equations (B.5), (B.7), and (B.8) in the first order condition (B.4), and simplify:

$$\mu \left( q^b + \frac{\partial q^b}{\partial b'} b' + \frac{\partial q^m}{\partial b'} m' \right) = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( \eta\mu' (1 - F(\bar{\psi}'_{NR})) + \left( 1 - \frac{\chi\pi' - b'}{m'} \right) m' f(\bar{\psi}'_{NR}) \frac{\partial \bar{\psi}'_{NR}}{\partial b'} \right) \right] + \gamma^b. \quad (\text{B.9})$$

Thus, condition (B.9) implies that unless the firm puts probability 1 on  $\mu' = 0$ ,  $\mu$  can never be 0 for the first order condition to hold; in other words, if the firm chooses an NR-contract, the dividend constraint has to bind at all times.

The proof for the case of **R-contract** goes through by the same logic. The first order condition by differentiating (36) with respect to  $b'$  is:

$$(1 + \mu) \left[ q^b + \frac{\partial q^b}{\partial b'} b' \right] + \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( \int_{\underline{\psi}'_R}^{+\infty} \frac{\partial V^{0'}(k', x'; \mathbf{s}')}{\partial b'} dF(\psi') - V^{0'}(\bar{\psi}'_R) f(\bar{\psi}'_R) \frac{\bar{\psi}'_R}{\partial b'} \right. \right. \quad (\text{B.10}) \\ \left. \left. + \int_{\underline{\psi}'_R}^{\bar{\psi}'_R} \frac{\partial V^{0'}(k', x'_R; \mathbf{s}')}{\partial b'} dF(\psi') + V^{0'}(\bar{\psi}'_R) f(\bar{\psi}'_R) \frac{\bar{\psi}'_R}{\partial b'} - V^{0'}(\underline{\psi}'_R) f(\underline{\psi}'_R) \frac{\underline{\psi}'_R}{\partial b'} \right) \right] = 0.$$

As  $\underline{\psi}'_R$  is the default threshold in the R-contract, so  $V^{0'}(\underline{\psi}'_R) = 0$ , and the first order condition (B.10) can be simplified to:

$$(1 + \mu) \left[ q^b + \frac{\partial q^b}{\partial b'} b' \right] + \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( \int_{\underline{\psi}'_R}^{+\infty} \frac{\partial V^{0'}(k', x'; \mathbf{s}')}{\partial b'} dF(\psi') + \int_{\underline{\psi}'_R}^{\bar{\psi}'_R} \frac{\partial V^{0'}(k', x'_R; \mathbf{s}')}{\partial b'} dF(\psi') \right) \right] = 0.$$

The associated Benveniste-Scheinkman conditions are:

$$\frac{\partial V^{0'}(k', x'; \mathbf{s}')}{\partial b'} = -(1 + \eta\mu'), \\ \frac{\partial V^{0'}(k', x'_R; \mathbf{s}')}{\partial b'} = 0,$$

and the latter arises because  $x'_R = p'(\psi')y' - F_o\hat{k}' - b'_R - m' + \hat{a}_f$ , and  $b'_R = \chi\pi'$  as shown in Proposition 1. Therefore, the first order condition can be further simplified to:

$$(1 + \mu) \left[ q^b + \frac{\partial q^b}{\partial b'} b' \right] = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( \int_{\underline{\psi}'_R}^{+\infty} \left( (1 + \eta\mu') dF(\psi') \right) \right) \right] \\ (1 + \mu) \left[ q^b + \frac{\partial q^b}{\partial b'} b' \right] = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( 1 - F(\bar{\psi}'_R) \right) + \lambda(\mathbf{s}, \mathbf{s}') \eta\mu' \left( 1 - F(\bar{\psi}'_R) \right) \right]. \quad (\text{B.11})$$

The price of bank debt  $q^b$  in an R-contract is:

$$q^b(k', b', a'_f; \mathbf{s}) = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( \left( 1 - F(\bar{\psi}'_R) \right) + \int_{-\infty}^{\bar{\psi}'_R} \frac{\chi\pi'}{b'} dF(\psi') \right) \right] - \gamma^b, \quad (\text{B.12})$$

and  $\bar{\psi}_R$  is the restructuring threshold, and the bank lender's payoff is the same under restructuring and default, due to the combination of bank seniority in default and the bargaining outcome in renegotiation. Again,  $\frac{\partial q^b}{\partial b'}$  can be determined using the Leibniz rule:

$$\frac{\partial q^b}{\partial b'} b' = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( - \int_{-\infty}^{\bar{\psi}'_R} \frac{\chi \pi'}{b'} dF(\psi') - \left( 1 - \frac{\chi \pi'}{b'} \right) b' f(\bar{\psi}'_R) \frac{\partial \bar{\psi}'_R}{\partial b'} \right) \right]. \quad (\text{B.13})$$

Substitute equations (B.12) and (B.13) in the first order condition (B.11), and simplify:

$$\mu \left( q^b + \frac{\partial q^b}{\partial b'} b' \right) = \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \left( \eta \mu' (1 - F(\bar{\psi}'_R)) + \left( 1 - \frac{\chi \pi'}{b'} \right) b' f(\bar{\psi}'_R) \frac{\partial \bar{\psi}'_R}{\partial b'} \right) \right] + \gamma^b. \quad (\text{B.14})$$

Again, condition (B.14) implies that unless the firm puts probability 1 on  $\mu' = 0$ ,  $\mu$  can never be 0 for the first order condition to hold. Thus regardless the contract chosen, for a firm with positive debt, the dividend constraint has to bind at all times, i.e. firms are always better off paying back their debt than issuing dividends.

Next, consider the case where the firm only saves ( $a'_f > 0$ ) at price  $q^a = \mathbb{E}[\lambda(\mathbf{s}, \mathbf{s}')] and does not borrow ( $b' = m' = 0$ ). The Bellman equation becomes:$

$$\begin{aligned} V^1(\hat{k}, x; \mathbf{s}) &= \max_{v, k', a'_f} \left\{ d + \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \hat{V}^0(k', a'_f, \psi', z'; \mathbf{s}') \middle| \mathbf{s} \right] \right\} \\ &= \max_{v, k', a'_f} \left\{ d + \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \max_{\hat{k}', \hat{a}'_f} V^0(\hat{k}', x'; \mathbf{s}') \middle| \mathbf{s} \right] \right\} \\ &= \max_{v, k', a'_f} \left\{ d + \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \max_{\hat{k}', \hat{a}'_f} \left\{ (1 - \eta) \left( p'(\psi') z' \hat{k}'^\alpha - F_o \hat{k}' + p^- (1 - \delta) \hat{k}' + \hat{a}'_f \right) + \eta V^1(\hat{k}', x'; \mathbf{s}') \right\} \middle| \mathbf{s} \right] \right\} \\ &= \max_{v, k', a'_f} \left\{ d + \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \max_{\hat{k}'} \left\{ (1 - \eta) \left( p'(\psi') z' \hat{k}'^\alpha - F_o \hat{k}' + p^- (1 - \delta) \hat{k}' + (a'_f + k' - \hat{k}'_f - g(k', \hat{k}')) \right) \right. \right. \right. \\ &\quad \left. \left. \left. + \eta V^1(\hat{k}', x'; \mathbf{s}') \right\} \middle| \mathbf{s} \right] \right\} \end{aligned} \quad (\text{B.15})$$

subject to (4), (6), (25), (26), (27), (30), and  $\mathbf{s}' = \Gamma(\mathbf{s}); \quad i, j = 1, 2, \dots, N.$

The first order condition with respect to  $a'_f$  yields:

$$\begin{aligned} (1 + \mu) q^a &= \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') (1 + \eta \mu') \right] \\ \mu \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') \right] &= \mathbb{E} \left[ \lambda(\mathbf{s}, \mathbf{s}') (\eta \mu') \right] \end{aligned}$$

Therefore,  $\mu = 0$  if and only if the firm assigns zero probability to the event that the dividend constraint will be binding in the next period. Therefore, firms with no borrowing are at most indifferent between paying dividends and savings, as they share the same discount factor as households.  $\blacksquare$

## B.4 Robustness: Working Capital Constraint Set-up

In this section, I present an alternative set-up of the theoretical framework that motivates firms to borrow and simultaneously hold cash balances. The model builds on [Jermann and Quadrini \(2012b\)](#), and the key assumption is that firms have to finance their working capital before they receive revenues from sales, and can do so through accumulated cash holdings, or by issuing two types of debt: bank loans and market debt. Due to the separation between the time of financing and the receipt of revenues, any idiosyncratic shocks, such as demand shocks, that occur between these times can cause costly default of firms. In choosing the optimal composition of debt, firms trade-off the ability to restructure bank debt in financial distress, with the lower marginal costs associated with issuing bonds in normal times. In choosing the optimal allocation of assets between capital and savings, firms take into consideration that increasing cash holdings reduces the probability of default and hence low the cost of future borrowing, but requires cutting back on capital investment. With partially irreversible capital, precautionary savings in cash arise endogenously from the interaction between real and financial frictions.

As the majority of the model is the same as the one presented in Section 3 of the main text, I focus on the differences here.

**Production** The intermediate goods firms produce the output ( $y$ ) using a decreasing returns-to-scale production technology that combines labor ( $h$ ) and capital ( $k$ ).<sup>54</sup> The production is subject to idiosyncratic technology shock ( $z$ ). Formally, these assumptions are summarized by a production function:

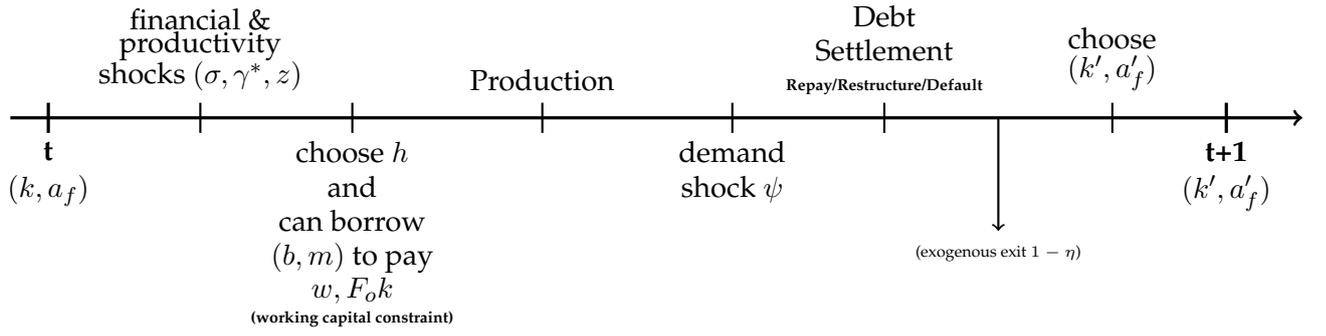
$$y = z^{(1-\alpha)\chi} (k^\alpha h^{1-\alpha})^\chi; \quad 0 < \alpha < 1, \text{ and } \chi < 1, \quad (\text{B.16})$$

where  $\alpha$  is the degree of decreasing returns in production, and  $\chi$  governs the degree of decreasing returns in production. The normalization factor  $(1 - \alpha)$  associated with the exogenous technology shocks ensures that the firm's profit function is linear in  $z$ , as in [Gilchrist, Sim and Zakrajšek \(2014\)](#) (see equation (B.17) below).

**Timing** Figure B.4 summarizes the timing of each intermediate goods firm's problem. At the beginning of each period, all shocks pertaining to the production and borrowing decisions—including the level of idiosyncratic uncertainty ( $\sigma$ ), the relative supply of bank credit ( $\gamma^*$ ), and the level of idiosyncratic technology ( $z$ )—are realized. The volatility level  $\sigma$  determines the distribution of  $z'(\sigma)$  in the next period ([Bloom \(2009\)](#); [Gilchrist, Sim and Zakrajšek \(2014\)](#)). Thus, from the agents' perspective, an increase in  $\sigma$  represents "news" regarding the distribution of profits tomorrow. Consistent with the typical timing convention, capital ( $k$ ) is predetermined, whereas the

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<sup>54</sup>The assumption of decreasing returns-to-scale implies that given the stochastic state, there exists an optimal firm size and it allows one to think about the distribution of firms.



**Figure B.4:** Overview and Timing of Intermediate Goods Firms' Problem

input of labor ( $h$ ) is chosen after the realization of shocks ( $z, \sigma, \gamma^*$ ), from:

$$\begin{aligned}\tilde{\pi}(z, w, k) &= \max_{h \geq 0} \left\{ z^{(1-\alpha)\chi} (k^\alpha h^{1-\alpha})^\chi - F_o k - wh \right\} \\ &= z \Phi(w) k^\phi - F_o k - wh,\end{aligned}\tag{B.17}$$

$$\text{where : } \phi = \frac{\alpha\chi}{1 - (1-\alpha)\chi} \quad \text{and} \quad \Phi(w) = [1 - (1-\alpha)\chi] \left[ \frac{(1-\alpha)\chi}{w} \right]^{\frac{(1-\alpha)\chi}{1-(1-\alpha)\chi}}$$

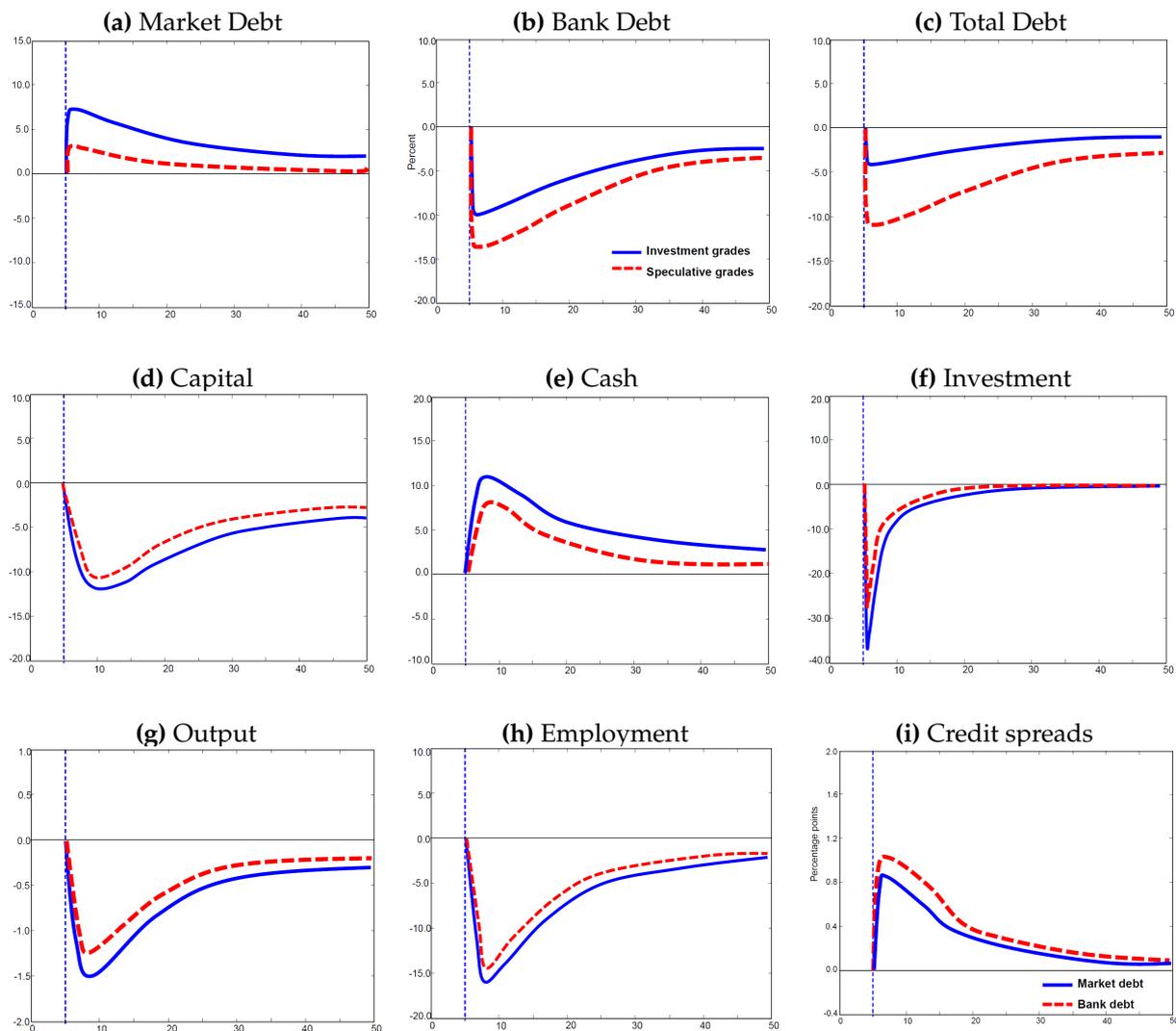
subject to:

$$\underbrace{a_f}_{\text{internal funds}} + \underbrace{q^b b + q^m m}_{\text{external funds}} \geq wh + F_o k.\tag{B.18}$$

Hence, equation (B.18) is a working capital constraint that motivates firms to borrow, if accumulated savings cannot cover the payments fully (Jermann and Quadrini (2012b)). Specifically, firms have to pay the wage bill and operating costs that are proportional to the predetermined capital stock  $F_o k$  before their revenues are realized, using a combination of the predetermined accumulated cash ( $a_f$ ), and external funds consisting of a combination of (intra-temporal) bank debt ( $b$ ) and market debt ( $m$ ), at prices ( $q^b$ ) and ( $q^m$ ), respectively.

After the payments of wage bill and operating costs, the firm produces output using the technology described in (4). After production, idiosyncratic demand shocks ( $\psi$ ) are realized. At the debt settlement stage, the firm can either repay both types of debt, restructure bank debt, or default, in which case it exits endogenously. As the terms of debt contracts ( $q^b, q^n$ ) cannot be indexed by  $\psi$ , they demand a premium because of the agency costs associated with default. Finally, firms choose the amount of capital  $k'$  and cash holdings  $s'$  that they want to take into next period. Importantly, as cash holdings decisions are made before the realization of shocks, this gives rise to precautionary incentive to accumulate cash. Even though this incentive would be softened by the possibility to issue intra-temporal debt after the realization of production and financial shocks, the presence of financial and real frictions act in the opposite direction, amplifying firms' incentive to save pre-emptively in order to reduce their reliance on external finance. The impulse response functions to a financial shock are presented in Figure B.5.

**Figure B.5: Impact of a Financial Shock to Bank Credit Supply**  
(Baseline: Working Capital Constraint Version)



**Note:** A shock reduces the supply of bank loans ( $\gamma^b$ ) 10 percent upon impact (period 5) on average, a shock of approximately 2 standard deviations; the bank loan supply is then allowed to revert back to its steady-state value following the process in equation (14). The impulse responses are averages of 50,000 simulations, where each simulation is an aggregation of the impulse responses of 10,000 firms. In panels (a)–(g), the blue dashed lines depict the impulse response functions of the investment-grade firms, while the red dashed lines depict the impulse responses of the speculative-grade firms; in panel (i), the blue dotted line indicates the impulse response function of the spread on corporate bonds, while the red dotted line indicates the spread on bank loans

## B.5 Computational Details

The model is solved using the inner-and-outer-loop algorithm developed by [Krusell and Smith \(1998\)](#), whereby I iterate between an inner loop step and an outer loop step until I isolate forecasting rules consistent with the equilibrium outcomes. The algorithm consists of the following steps:

1. In the inner loop, guess values for the parameters governing the aggregate laws of motion implied by the system of equations (48) that are used by the agents to predict future prices in the model ( $\Gamma_0, \Gamma_1, \Gamma_2$ );
2. Solve the incumbent firms' expected value functions (34), taking as given the current set of forecasting rules, by combining value function iteration with tensor product spline approximation that allows firms to evaluate and select off-grid options;
3. Next, move to the outer loop to simulate the economy for  $T = 2,100$  (quarters) and  $N = 10,000$  (firms), using the current set of forecasting rules. Each period in the simulation begins with the distribution of firms over productivity, demand, capital, and net liquid asset position implied by the decisions of the previous period;
4. Given the incumbent firms' value functions from the most recent inner loop and the market clearing conditions in Section 3.6, I determine equilibrium prices and quantities, and thus the subsequent period's distribution;
5. Once the simulation has finished, I use the resulting data to update the forecasting rules, with which I return to the inner loop. In updating the agents' perceived aggregate laws of motion, the initial 100 quarters are dropped and the remaining observations are used to estimate the aggregate laws of motion. Repeat until the new forecasting rules ( $\hat{\Gamma}_0, \hat{\Gamma}_1, \hat{\Gamma}_2$ ) are close to the previous one.

**Inner-loop computation** Under the bounded rationality assumption, I solve the inner-loop problem using value function iteration, which allows for a fully nonlinear global solution under several occasionally binding constraints, including the dividend constraint, partial irreversibility, and nonconvex capital adjustment costs. Moreover, a nonlinear solution method allows the possibility that the occasionally binding constraints may interact with endogenous entry and exit over the business cycle in a way that delivers aggregate nonlinearities. Agents predict market clearing prices using log-linear laws of motion for the aggregate moments.

I start by defining grids for the state variables  $\{z, \psi, \hat{k}, x, \sigma_{-1}, \gamma^*, \tilde{k}, \tilde{b}, \tilde{m}, \tilde{a}_f\}$ . For the endogenous state variables  $\{\hat{k}, x\}$ , I allow for 30 equispaced grid points; for the decision variables  $\{k', b', m', a'_f\}$ , I use 100 equispaced grid points; for the state variables that are exogenous from the perspective of the firms in the economy, that is  $\{\psi, \sigma_{-1}, \gamma^*, \tilde{k}, \tilde{b}, \tilde{m}, \tilde{a}_f\}$ , I use 3 grid points. For the exogenous aggregate state variables  $\{\sigma_{-1}, \gamma^*\}$ , I use a Gauss-Hermite quadrature method, so

that the value function and policy variables can be computed for continuous variation in these state variables. I use two points for the Gauss-Hermite quadrature integration for each shock associated with the exogenous aggregate state variables. The continuation values off the grid points for  $\{z, \psi, \hat{k}, x, \sigma_{-1}, \gamma^*, \tilde{k}, \tilde{b}, \tilde{m}, \tilde{a}_f\}$  then need to be evaluated using a tensor product spline approximation. Moreover, I specify a 4-state Markov chain for the idiosyncratic technology shock  $z$ .<sup>55</sup>

**Outer-loop computation** In the outer loop, I update the aggregate laws of motion using a Monte Carlo simulation. It is important to ensure that at this stage, all markets clear, even when the perceived laws of motion are “inaccurate”. To this end, I solve for the marginal utility of consumption—hence the household’s stochastic discount factor—that is consistent with the market clearing conditions, using a nonlinear root finder for each  $t = 1, \dots, T$  of the Monte Carlo simulation. This step substantially slows down computations in the outer loop but allows for a maximum amount of learning by the agents in the economy. Once the economy is simulated, I use OLS to update the aggregate laws of motion.

Within this framework, it is important to check how well does the aggregation methodology used to compute the solution of the model approximate the model’s true rational expectations equilibrium. Table B.2 shows the estimates of the parameters governing the aggregate laws of motion implied by the system of equations (48) that are used by the agents to predict future prices in the benchmark model.<sup>56</sup> As shown by the high  $R^2$  values, the agents’ perceived aggregate laws of motion are highly accurate. According to this commonly used metric, the solution of the model is thus a good approximation of the model’s true rational expectations equilibrium.

The coefficients of the forecasting rules used by the agents to forecast equilibrium prices also have a number of intuitive properties. For example, the negative coefficients on the stock of bank debt ( $\tilde{b}$ ) and market debt ( $\tilde{m}$ ) in the law of motion for the aggregate capital (row #4) reflect the effect of debt overhang on macroeconomic outcomes; in other words, all else equal, the existence of prior debt acts as a disincentive to new investment.<sup>58</sup> In contrast, the positive coefficients on  $\tilde{b}$  and  $\tilde{m}$  in the law of motion for aggregate savings (row #3) reflect the precautionary motive for higher saving as debt rises. Moreover, both higher aggregate stocks of capital and higher ag-

<sup>55</sup>The dimension of the inner-loop problem is very large, compared with most models of this type. Specifically, under the defined gridpoints, the dimension of the problem  $\{z, \psi, \hat{k}, x, \sigma_{-1}, \gamma^*, \tilde{k}, \tilde{b}, \tilde{m}, \tilde{a}_f, k', b', m', a'_f, z', \sigma\}$  is given by  $4 \times 4 \times 30 \times 30 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 100 \times 100 \times 100 \times 100 \times 4 \times 2 \times 2 \approx 1.68e + 16$ .

<sup>56</sup>The perceived aggregate laws of motion for the counterfactual models are not reported here, but are available upon request.

<sup>58</sup>The mechanism of debt overhang is as follows. When a firm has outstanding debt on which the likelihood of default is significant, any investment that improves the firm’s future profit potential also increases the value of outstanding debt. All else equals, an increase in the value of outstanding debt reduces the value of equity in the firm; that is, it results in a wealth transfer from equity owners to existing creditors. Since equity owners are the ones who make investment decisions, the transfer acts like a tax on the return on new investment. This “tax” results in a drop in the rate of investment in business capital.

**Table B.2:** Agents' Perceived Aggregate Laws of Motion (Baseline Model)

Dep. Variable	Explanatory Variables						$R^2$
	$\log \tilde{b}$	$\log \tilde{m}$	$\log \tilde{a}_f$	$\log \tilde{k}$	$\log \sigma_z$	$\log \gamma^*$	
[1] $\log \tilde{b}'$	0.0412	0.0176	0.5473	0.3182	-0.0571	-0.7176	0.9907
[2] $\log \tilde{m}'$	0.0151	0.0380	0.5519	0.2794	-0.0726	0.2131	0.9912
[3] $\log \tilde{a}'_f$	0.0164	0.0179	0.7510	-0.0104	0.1028	0.0917	0.9908
[4] $\log \tilde{k}'$	-0.0202	-0.0231	0.0632	0.8276	-0.0614	-0.0738	0.9887
[5] $\log \tilde{c}$	0.0067	0.0052	0.3653	0.2715	-0.0408	-0.0176	0.9891

**Note:** The simulation assumes that there are 10,000 heterogeneous firms at any point in time and are simulated for 2,100 quarters by feeding into the specified model randomly drawn aggregate and idiosyncratic shocks. In updating the agents' perceived aggregate laws of motion, the initial 100 quarters are dropped and the remaining observations are used to estimate the aggregate laws of motion.<sup>57</sup> The updated laws of motion are then used to update the individual policy rules in a numerical dynamic programming problem. The algorithm stops when the changes in the aggregate laws of motion in the subsequent iteration are smaller than the pre-specified tolerance criterion.

gregate savings today expand the debt capacity tomorrow (rows #1 and #2), but as cash is more liquid, it expands the debt capacity by more—the coefficient on  $\tilde{a}_f$  is almost twice as large as the coefficient on  $\tilde{k}$ , especially for the law of motion for aggregate market debt  $\tilde{m}'$ . Turning to the law of motion for aggregate consumption  $\tilde{c}$  (rows #5), the aggregate debt stocks have positive effect, reflecting that outstanding corporate debt are part of the representative household's wealth. Nevertheless, the coefficients on the stocks of debt are very small compared to the coefficient on aggregate capital stock, suggesting that at the general equilibrium level, the drag from debt overhang in the corporate sector significantly reduces the marginal propensity to consume out of claims on corporate debt. Evidently from the relatively large coefficients on the wedge in intermediation costs ( $\gamma^*$ ) in the laws of motion for capital, cash and debt, shocks to the effective supply of bank credit exert an important influence on the dynamics of capital, cash, and debt accumulation in the model.

**Stationary distribution** The policy functions  $b' = B(z, \psi, \hat{k}, x; \sigma, \gamma^*)$ ,  $m = M(z, \psi, \hat{k}, x; \sigma, \gamma^*)$ , and  $a_f = A_f(z, \psi, \hat{k}, x; \sigma, \gamma^b)$  can be obtained using the result from the value function iteration in the inner loop. Let  $\mu(z_0, \psi_0, k_0, x_0)$  measure the proportion of firms with idiosyncratic technology  $z_0$ , idiosyncratic demand  $\psi_0$ , capital  $k_0$  and net liquid asset position  $x_0$ . The stationary distribution can be determined by iterating on the following equation:

$$\mu'(z_0, \psi_0, k_0, x_0) = \int \mathbf{1}_{B(z, \psi, \hat{k}, x)} \int \mathbf{1}_{M(z, \psi, \hat{k}, x)} \int \mathbf{1}_{A_f(z, \psi, \hat{k}, x)} Q(z, \psi, \hat{k}, x) \left( \mu(dz, d\psi, d\hat{k}, dx) + \mu_e(dz, d\psi, d\hat{k}, dx) \right), \quad (\text{B.19})$$

where  $\mu$  is a measure on the space  $Z \times \Psi \times K \times X$ , where  $Z \in \mathcal{Z}$ ,  $\Psi \in \mathcal{S}$ ,  $K \in \mathcal{K}$ ,  $X \in \mathcal{X}$ .  $\mathcal{Z}$ ,  $\mathcal{S}$ ,  $\mathcal{K}$ , and  $\mathcal{X}$  are the Borel  $\sigma$ -algebras generated by the subsets of  $Z$ ,  $\Psi$ ,  $K$ , and  $X$ , respectively. I start iterating from a uniform distribution as an initial guess, and  $Q$  denotes the transition matrix

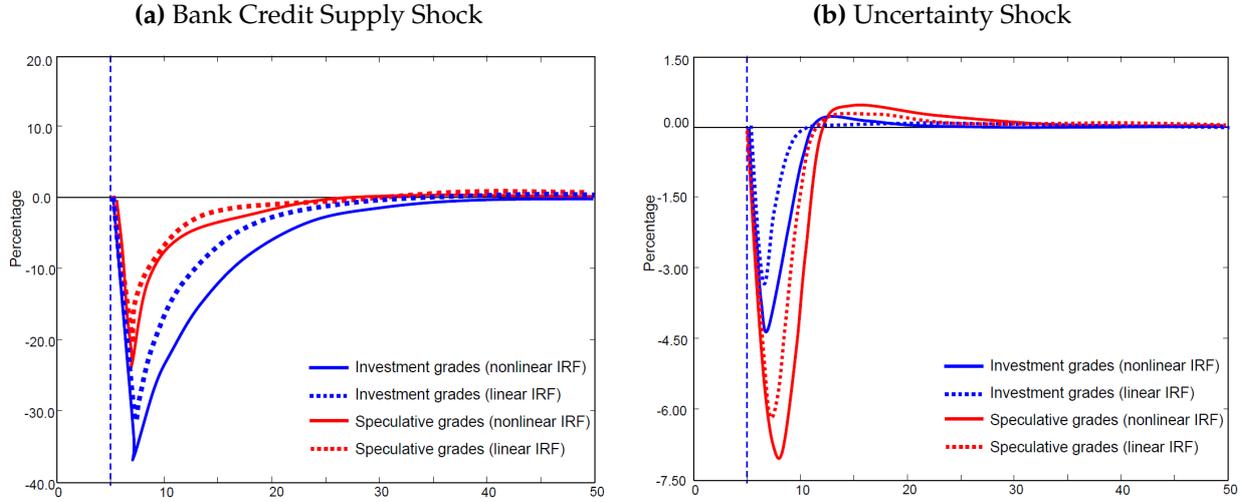
implied by the exogenous technology process  $z$ , the exogenous demand process  $\psi$ , and the policy functions.

**Computation with endogenous entry** With endogenous entry and a fixed mass of potential entrants  $M$ , the inner-and-outer loop algorithm described above is modified as follows:

1. In the inner loop, guess values for the parameters governing the aggregate laws of motion implied by the system of equations (48) that are used by the agents to predict future prices in the model  $(\Gamma_0, \Gamma_1, \Gamma_2)$ ;
2. Solve the incumbent firms' expected value functions (34), taking as given the current set of forecasting rules, by combining value function iteration with tensor product spline approximation that allows firms to evaluate and select off-grid options;
3. Solve the entrant's expected value functions (40), given signal  $q \sim Q(q)$ , and taking into account that the transition matrix for potential entrants is the same as the transition matrix for the incumbent firms. Since the value of the incumbent is weakly increasing in idiosyncratic productivity, there exists a unique threshold  $q^*$ . Given a mass of potential entrants  $M$ , the actual mass of entrants becomes  $N_e = M(1 - F(q^*))$ , where  $F(\cdot)$  is the c.d.f of the signal  $q$ ;
4. Given the mass of entrants and policy functions of the incumbent and entering firms from above, compute the stationary distribution  $\mu^*$  according to (B.19);
5. Next, move to the outer loop to simulate the economy for  $T = 2,100$  (quarters) and  $N = 10,000$  (firms), using the current set of forecasting rules. Each period in the simulation begins with the stationary distribution of firms  $\mu^*$  over productivity, capital, and net liquid asset position implied by the decisions of the incumbents and entrants in the previous period;
6. Given the firms' value functions from the most recent inner loop and the market clearing conditions in Section 3.6, I determine equilibrium prices and quantities, and thus the subsequent period's distribution;
7. Once the simulation has finished, I use the resulting data to update the forecasting rules, with which I return to the inner loop. In updating the agents' perceived aggregate laws of motion, the initial 100 quarters are dropped and the remaining observations are used to estimate the aggregate laws of motion. Repeat until the new forecasting rules  $(\hat{\Gamma}_0, \hat{\Gamma}_1, \hat{\Gamma}_2)$  are close to the previous one.

**Computation of the impulse response functions** Let  $i = 1, \dots, N$  denote the  $N$  heterogeneous firms in the economy;  $t = 1, \dots, T$  denote the  $T$  periods of the impulse response horizons;  $\mathcal{Z} =$

**Figure B.6:** Linear vs. Nonlinear Impulse Response Functions of Investment



**Note:** The solid lines depict the impulse response functions of investment to the specified shock implied by the benchmark model, which are computed taking into account the nonlinearities of the firms' investment and financial policies; the dashed lines are the corresponding impulse response functions based solely on the agents' perceived aggregate laws of motion in the log-linear form.

$\{z_{i,t} | i = 1, \dots, N \text{ and } t = 1, \dots, T\}$  denote the associated set of idiosyncratic technology states implied by the Markov chain with time-varying volatility;  $x_{i,t}$  denote a generic model variable (e.g. bank debt  $b_{i,t}$ ). I use the following algorithm to compute impulse responses for a wider set of endogenous aggregate variables than those implied by the system of equations (48), and to fully take into account the nonlinearities of the firms' investment and financial policies at the micro level, while maintaining the assumption of bounded rationality:

- Using the set  $\mathcal{Z}$ , I construct two model simulations over the  $T$  periods: one perturbed by an aggregate shock, and one without an aggregate shock. Index the aggregate variables from these two simulations by  $x_{i,t}^1$  (with aggregate shock) and  $x_{i,t}^0$  (without aggregate shock), respectively.<sup>59</sup> The only difference between these two simulations is that I introduce an aggregate shock at a specified time  $t = t^*$  in the first simulation, which is then allowed to die out according to its specified law of motion over the remainder of the impulse response horizon;
- To remove the effects of sampling variation associated with the simulation of the idiosyncratic technology shock, I remove the above procedure  $M$  times. The model-implied impulse response function of the aggregate variable  $x$  in response to an aggregate shock—denoted

<sup>59</sup>The same set of idiosyncratic technology states  $\mathcal{Z}$  underlies the construction of  $x_{i,t}^1$  and  $x_{i,t}^0$ . The bank credit supply shock has no effect on the set of idiosyncratic technology states  $\mathcal{Z}$ , i.e.  $z_{m,it}^1 = z_{m,it}^0$ . For uncertainty shocks,  $z_{m,it}^1 \neq z_{m,it}^0$ ; instead, an uncertainty shock today has an effect on the dispersion of the idiosyncratic technology shocks in the future by design. Nonetheless, the relative position of each individual firm in the distribution of the idiosyncratic technology shock will be the same as in the case when the economy is not perturbed by an uncertainty shock.

by  $\hat{x}_h$ —is calculated according to

$$\hat{x}_t = 100 \times \log \left[ \frac{\sum_{m=1}^M \sum_{i=1}^N x_{m,it}^1}{\sum_{m=1}^M \sum_{i=1}^N x_{m,it}^0} \right]; \quad t = 1, \dots, T; \quad (\text{B.20})$$

where  $N = 10,000$ ,  $T = 45$ , and  $M = 50,000$  in this procedure.

This computationally intensive approach to computing impulse responses was chosen instead of using the responses based solely on the agent’s perceived aggregate laws of motion, because the response of the model to aggregate shocks may not be reflected fully by the log-linear specification of the agents’ perceived aggregate laws of motion. For example, the quantitative significance of failing to account for the model’s inherent nonlinearities is illustrated in Figure B.6, where the dotted lines depict the corresponding responses based solely on the agents’ perceived aggregate laws of motion. The differences in impulse responses suggest that the agents’ perceived laws of motion may be misspecified despite the high  $R^2$  values reported in Table B.2.

**Definition of speculative-grade and investment-grade firms** In order to maintain comparability with the empirical evidence in Section 2, I compute the impulse responses of “speculative-grade” and “investment-grade” firms, using a threshold for assets to define categories. The threshold  $a_{\frac{I}{S}}$  is defined such that, in quarter 0, firms with  $a_0 > a_{\frac{I}{S}}$  account for a fraction  $s_{\frac{I}{S}}$  of the total assets in the economy. In the dataset used in Section 2, the ratio of assets averaged across all investment-grade firms to assets averaged across all, is 0.68 in 2007. I use this as the cut-off threshold in the model,  $s_{\frac{I}{S}} = 0.54$ . For  $t \geq t^*$ , the impulse responses of aggregate variable  $\hat{x}_t$  for “speculative-grade” and “investment-grade” firms are defined, respectively, as:

$$\hat{x}_t^S = 100 \times \log \left[ \frac{\sum_{m=1}^M \sum_{i=1}^{N_t^S} x_{m,it}^1}{\sum_{m=1}^M \sum_{i=1}^{N_t^S} x_{m,it}^0} \right], \quad \hat{x}_t^I = 100 \times \log \left[ \frac{\sum_{m=1}^M \sum_{i=1}^{N_t^I} x_{m,it}^1}{\sum_{m=1}^M \sum_{i=1}^{N_t^I} x_{m,it}^0} \right]; \quad t = 1, \dots, T; \quad (\text{B.21})$$

where  $N_t^S$  and  $N_t^I$  are the numbers of firms in period  $t$  with  $0 \leq a_t < a_{\frac{I}{S}}$  and  $a_t \geq a_{\frac{I}{S}}$ , respectively, and  $T = 45$ , and  $M = 50,000$ , as in (B.20).