Corporate Debt Maturity and Output Price Dynamics*

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Abstract

This paper investigates the effect of firms' debt maturity composition on their product pricing behaviors. To empirically examine this, we construct a novel micro-level dataset that links product prices with data on manufacturers' debt maturity schedules. By leveraging both a quasi-exogenous credit supply shock and a monetary policy shock, we show that firms with higher short-term debt ratios increase product prices more substantially when refinancing of maturing debt becomes more costly and refinancing options are limited. Our findings suggest that firms respond to refinancing challenges by strategically raising prices to mitigate rollover risk. To rationalize these results, we develop a dynamic firm model where firms issue both short- and long-term debt to finance operations in the face of negative cash-flow shocks. In our model, firms set prices strategically, which in turn affects the accumulation of customer capital. The results indicate that under increased debt repayment pressure and unfavorable refinancing conditions, firms raise product prices to mitigate rollover risk, even at the cost of losing future customers. Overall, our findings underscore the critical role of debt maturity profiles in shaping firms' product pricing decisions.

JEL classification: D11, D12, D21, D22, E31, G32

Keywords: Credit Supply, Customer Capital, Debt Maturity, Product Pricing, Rollover Risk

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"Our conclusion is, once again, at variance with conventional views, so much so as to be easily misinterpreted (...) seems to imply that the capital structure of a firm is a matter of indifference; and that consequently, one of the core problems of corporate finance - the problem of the optimal capital structure for a firm - is no problem at all."

– Franco Modigliani, Merton H. Miller (1958): *The Cost of Capital, Corporation Finance and the Theory of Investment*, *The American Economic Review*, 48(3), page 291.

1 Introduction

This paper investigates the effect of a firm's debt maturity structure on its pricing strategies. There has long been an interest among economists and policymakers in the effects of financial frictions on firms' pricing decisions. Previous studies exploring this question have primarily focused on financial frictions such as liquidity, leverage, credit access, and firm characteristics like size or age. However, there is a lack of evidence on how a firm's debt maturity structure affects its pricing strategies. Our study aims to fill this gap by examining the effect of a firm's maturity structure on its output pricing, providing important insights into the broader economic implications of financial conditions.

A firm's debt maturity structure is a particularly important aspect of financial frictions, as it can impose substantial financial pressures in two key ways. First, as firms approach their debt repayment dates, they face considerable pressure to either repay or refinance their obligations, which increases rollover risk. When financial conditions worsen, credit suppliers may become reluctant to offer new loans or refinance existing debt, raising the firm's default risk due to limited access to funding. Second, the cost of refinancing or issuing new debt can become burdensome. If unfavorable market conditions force firms to rollover maturing debt at significantly higher interest rates or issuance costs, this creates additional financial burdens. These two dimensions of debt management highlight the substantial pressures debt maturity structures can introduce, which may ultimately shape firms' pricing decisions.

During periods of severe financial distress, increased concerns about firms' default risk lead financial intermediaries to become increasingly reluctant to extend medium- to long-term loans, as such lending is perceived as highly risky. In our data, we observe a nearly 30% decline in the weighted average of firms' remaining debt maturities. As a result, firms face significant refinancing challenges during financial turmoil, particularly those with substantial short-term debt or obligations maturing in the near term. Firms with a high concentration of short-term debt experience acute distress, as refinancing becomes difficult, and even when achievable, it comes at a significantly higher cost. This is further exacerbated by rising borrowing costs, as evidenced by a steep increase in corporate bond spot rates during periods of financial crisis. For instance, during the 2008-2009 financial crisis, the high-quality market (HQM) corporate bond spot rates surged substantially across all maturities.

Our empirical findings indicate that firms exposed to elevated levels of credit supply shock exhibit distinct pricing responses based on their debt maturity profile. Specifically, firms with significant debt obligations maturing within one year tend to raise their product prices in reaction to negative credit supply shocks. In contrast, firms with less short-term repayment obligations are more likely to reduce their prices when facing negative credit supply shocks. This divergence in pricing strategies highlights the significant role of imminent debt repayment obligations in shaping firms' strategic pricing responses to adverse financial conditions.

Our findings help reconcile the varied results in recent literature examining the relationship between financial frictions and firms' product pricing strategies. Recent papers including Gilchrist et al. (2017), Renkin and Züllig (2024), and Balduzzi et al. (2024) find that firms facing financial constraints tend to increase product prices as a revenue—boosting strategy to mitigate financial distress. In contrast, Kim (2020) and Lenzu et al. (2022) find that firms facing credit constraints tend to lower product prices to boost internal cash flows, thus increasing liquidity during credit crunch periods. Our findings indicate that firms facing imminent debt repayment obligations adopt a more short-term outlook by raising prices to quickly increase cash flow. In contrast, firms without immediate debt repayment pressures avoid raising their product prices, aiming to retain future customers and protect their market share. By highlighting the role of debt maturity structures, our analysis clarifies how immediate debt repayment pressures may drive firms to adjust pricing differently in response to financial constraints, thereby offering a unifying perspective on the divergent outcomes in previous studies.

We develop a dynamic heterogeneous firm model incorporating endogenous default, debt maturity, and customer capital to explain the empirical relationship between corporate debt maturity schedules and pricing decisions. Our model results indicate that firms with more short-term debt repayment pressure raises their product pricing even this will happen at the cost of losing future customer base. Moreover, even when two firms have the same amount of total outstanding debt, the firm which has more proportion of short-term debt tend to increase their product pricing more which shows the importance of debt maturity schedule even when they have the same amount of outstanding debts. Also, the model shows that firms with more severe exposure to cash-flow shock tend to raise product prices more because the severity of cash-flow shock will increase the firm's default risk if they could not collect sufficient amount of revenues immediately.

Moreover, we perform a counterfactual analysis by comparing two economies with differing required repayment ratios on outstanding debt principals. We find that in economies with a higher required debt repayment ratio, the stationary equilibrium becomes more dependent on short-term debt, resulting in a reduced average debt maturity in the economy. This, in turn, resulted in a higher economy-wide price level associated with the shortened average debt maturity observed in our counterfactual analysis.

These findings have significant implications regarding the Federal Reserve's Maturity Extension Program (MEP). Following the Fed's implementation of MEP, our data indicate that firms substantially extended their average debt maturities, with overall inflation remaining notably low after the crisis. Our counterfactual analysis aligns with this observation, suggesting that the Fed's intervention facilitated debt maturity extensions across firms, thereby alleviating pressures related to imminent repayment schedules and contributing to reduced inflationary pressures economy-wide.

Several challenges arise in examining how a firm's debt maturity schedule affects its product pricing decisions. A first challenge in our research is the need for extensive data to effectively examine this issue. This requires detailed information on both firms' debt maturity structures and their product pricing behavior in customer markets. The scarcity of such granular data presents a significant hurdle to empirical analysis.

We construct a novel dataset that links firms' debt maturity schedules, their banking relationships, and product pricing across various outlets. Specifically, our dataset integrates the following sources: (1) Firm-level debt maturity data from Capital IQ, which provides comprehensive coverage of the debt capital structure of all U.S. public firms. Capital IQ includes detailed information on all debt types, such as security type, interest rate, borrowing capacity, maturity dates, outstanding amounts, and seniority. Crucially, the dataset specifies exact maturity dates, enabling us to construct detailed maturity schedules at any point in time. (2) We combine this with Dealscan data to capture firm-level credit supply shocks, following the methodology in Chodorow-Reich (2014) and Kim (2020). Dealscan tracks firms' borrowings from the syndicated loan market, allowing us to analyze each firm's banking relationships and exposure to credit market disruptions. (3) For product pricing, we utilize Nielsen Retail Scanner data, which records point-of-sale information from various retail outlets. This dataset provides UPC-level data on prices and quantities sold by store and week, offering granular insights into firms' pricing behavior. Since Nielsen data lacks manufacturer identifiers, we use GS1 US Data Hub to link each UPC to its corresponding manufacturer. (4) Finally, we merge this dataset with Compustat to obtain firm-level balance sheet and income statement data, allowing us to control for key financial characteristics.

The second challenge in our analysis lies in the fact that debt maturity is an endogenous variable that firms actively manage. Since a firm's debt structure influences its cost of financing, it is critical for firms to optimize their debt structure to maximize profits while minimizing financing costs. Colla et al. (2020) provides a comprehensive survey on firms' capital structure decisions. This endogeneity complicates identification, making it difficult to establish a causal link between a firm's debt maturity profile and its impact on product pricing. Without addressing this identification issue, isolating the effect of debt maturity on pricing remains elusive.

To address the endogeneity issue in firms' debt maturity schedules, we construct firm-level credit supply shocks, following the approach of Chodorow-Reich (2014) and Kim (2020). Using Dealscan data, which provides detailed loan-level information from the syndicated loan market, we identify the banks involved in each firm's financing arrangements. In the credit market, switching banks is costly due to inefficiencies and information asymmetries-a phenomenon widely documented in the literature on bank switching costs (Kim et al. (2003), Vesala (2007), Liaudinskas (2023), Gopalan et al.

(2011)). As a result, firms find it difficult to switch financial intermediaries when their relationship banks face distress. We exploit this rigidity to construct an exogenous measure of firm-level credit supply shocks by tracking the health of banks and firms' exposure to these banks based on prior lending relationships. This approach enables us to identify, with precision, the impact of a firm's debt maturity structure on its product pricing behavior during periods of financial distress.

We find that corporate debt maturity profiles significantly influence firms' product pricing behavior. Using firm-level credit supply shocks during the 2008-2009 financial crisis as an exogenous shock to financial conditions, we observe that firms with concentrated near-term debt repayment schedules exhibit markedly different pricing strategies compared to firms with longer, more flexible repayment schedules. Specifically, firms facing tighter repayment constraints tend to raise product prices more than those with extended repayment horizons. To quantify this, we construct a firm-by-store-by-product-group price difference index, comparing the pre-Lehman period (2007.Q4 to 2008.Q2) with the post-Lehman period (2008.Q4 to 2009.Q2). Our results strongly indicate that firms with imminent debt repayment deadlines adjust prices more aggressively than firms with longer-term repayment obligations, highlighting the significant impact of debt maturity structure on pricing decisions.

We also conduct an event study comparing price changes between two groups of firms too investigate the dynamic impact of debt maturity schedules on firms' product pricing behaviors. The treatment group consists of firms with a high level of short-term debt-defined as debt maturing within one year-while the control group comprises firms with relatively lower levels of short-term debt. Specifically, we construct a short-term debt ratio, calculated as the ratio of debt maturing in less than one year to total outstanding debt. Firms with a short-term debt ratio above 60% are classified into the treatment group, and those below 60% into the control group. Our findings reveal that firms with a short-term debt ratio exceeding 60% tend to increase their product prices, while those with a lower ratio reduce prices. These results underscore the significant role of debt maturity schedules in shaping product pricing strategies. Notably, our findings reconcile with the mixed evidence in the literature regarding the effect of financial constraints on pricing behavior, highlighting the crucial importance of debt maturity in influencing these dynamics.

To further isolate the role of debt maturity profiles in firms' product pricing decisions and examine their pricing responses to rising refinancing costs, we leverage monetary policy shocks for our analysis. Firms with different maturity schedules are likely to respond differently to interest rate changes depending on the term structure of their debt. Short-term interest rate fluctuations are expected to have a greater impact on firms with significant short-term borrowing, whereas medium- to long-term interest rates more strongly affect firms with long-term debt. To address this, we employ the monetary policy shock decomposition from Swanson (2021), which separates monetary policy shocks into a federal funds rate factor (target) and a forward guidance factor (path). Firms with predominantly short-term debt are likely to be more sensitive to the target factor, while those with more long-term debt should respond more to the path factor. This approach allows us to identify how monetary policy transmission varies across firms with different debt structures.

Using local projection estimation as in Jordà (2005), we find that the target factor of a monetary policy shock primarily influences firms' pricing behavior through the short-term debt channel. In contrast, the path factor of monetary policy impacts pricing decisions via medium- to long-term debt. Our results demonstrate that firms with concentrated debt maturities are more sensitive to monetary policy shocks, as these shocks exert differential effects across interest rate maturities. Consequently, firms with shorter-term debt schedules exhibit the most pronounced adjustments in their product pricing.

Lastly, a key challenge in developing a dynamic heterogeneous model lies in the model's requirement for firms to set strategic pricing dynamically while simultaneously selecting optimal capital structures, which introduces heterogeneity into firms' debt maturity schedules.

To analyze the role of a firm's debt maturity structure in its product pricing behavior, we develop a dynamic firm model that incorporates corporate debt maturity profiles into pricing decisions. Our model incorporates the deep habit framework from Ravn et al. (2006) and Gilchrist et al. (2017), which allow firms to build customer capital based on their pricing strategies. Since future customer capital depends on current pricing decisions, firms face a dynamic trade-off: they can either exploit their existing customer base to maximize current profits or sacrifice short-term profits to accumulate more customer capital for future periods. This dynamic framework enables firms to strategically set prices while accounting for the long-term effects on customer capital. To integrate pricing decisions with debt maturity management, we introduce two types of financing: short-term debt, which must be repaid in the subsequent period, and long-term debt, which requires only partial repayment in each period. To maintain tractability while incorporating both short-term and long-term debt into the model, we follow a capital structure framework similar to that in Leland (1994). Firms are also subject to cash-flow shocks, and upon observing the realized cash-flow shock and their current debt obligations, they make strategic pricing decisions. Specifically, firms may choose to leverage their existing customer base to mitigate rollover risk or reduce prices to build future customer capital at the expense of current profits. This model allows us to analyze firms' pricing strategies under different conditions, including financial market shocks, varying debt obligations, the optimal accumulation of customer capital, and the risk of default.

Related Literature Our paper is closely related to several strands of the literature. First, we build on existing research examining the relationship between financial frictions and firms' product pricing behaviors (see, e.g., Gilchrist et al. (2017); Kim (2020); Lenzu et al. (2022); Renkin and Züllig (2024); Balduzzi et al. (2024)). Prior studies have largely explored how financial constraints influence pricing through factors such as liquidity, leverage, credit access, and firm characteristics like size or age. Our study extends this literature by investigating the role of a firm's debt maturity structure in shaping its pricing strategies. To our knowledge, this is the first study to examine product pricing through the lens of debt maturity structures, providing a novel perspective on how the timing of debt repayment pressures influences firms' pricing decisions. As Farre-Mensa and Ljungqvist (2016) notes, traditional measures of financial constraints, such as those developed in Kaplan and Zingales (1997) and Whited and Wu (2006), may not fully capture the complexities of financial pressure. Our study highlights how debt repayment schedules and the structure of a firm's debt maturities introduce a critical dimension to understanding financial constraints, influencing firms' product pricing decisions.

Our paper also helps reconcile differing findings in the existing literature on how financial constraints impact firms' pricing decisions. Some studies (e.g., Gilchrist et al. (2017); Renkin and Züllig (2024); Balduzzi et al. (2024)) suggest that financial constraints lead firms to raise prices, while others (e.g., Kim (2020); Lenzu et al. (2022))

report the opposite effect. We bridge these findings by showing that firms without imminent debt repayment obligations tend to lower their prices to boost revenue—consistent with the "inventory firesale" channel discussed in Kim (2020). In contrast, firms facing substantial debt repayment pressure within the coming year increase their prices to generate immediate revenue, even if this strategy risks eroding future customer capital and market share.

Furthermore, existing studies that use dynamic firm models to explore how financial constraints impact pricing decisions frequently rely on simplified assumptions, such as limiting firms to equity issuance as their sole source of financing (e.g., Gilchrist et al. (2017); Dou and Ji (2021)), largely for the sake of model tractability. Such assumptions, however, may mask the influence of diverse debt maturity structures on firms' pricing strategies and, consequently, on aggregate inflation dynamics. Our model addresses this gap by incorporating both short-term and long-term debt as distinct financing options, thereby capturing the implications of diverse debt maturity structures on firm-level pricing behaviors and economy-wide price dynamics.

Our paper also connects to the literature on the "missing deflation puzzle" during the financial crisis and the "missing inflation puzzle" after the crisis. Studies like Coibion and Gorodnichenko (2015) and Bianchi and Melosi (2017) examine the missing deflation by focusing on inflation expectations, while Christiano et al. (2015) and Del Negro et al. (2015) attribute the missing deflation to financial frictions. Additionally, Mineyama (2023) and Iwasaki et al. (2021) analyze downward wage rigidities as explanations for these inflation puzzles.

This paper offers a unified framework to explain these inflation puzzles through shifts in firms' average debt maturity during and after the financial crisis, linking debt maturity structures to firms' pricing decisions. A shorter debt maturity horizon can increase debt repayment pressures, potentially driving firms to raise prices and thereby muting the expected deflationary effects during the crisis. Conversely, the lengthened average debt maturities—supported by the Fed's unconventional monetary policies, such as quantitative easing and the Maturity Extension Program—eased repayment pressures after the crisis, contributing to lower-than-expected inflation for an extended period. Additionally, our study sheds light on how Fed policies, specifically the Maturity Extension Program, shaped inflation dynamics after the financial crisis.

Lastly, our paper is related to the literature examining the impact of firms' debt maturity profiles on investment decisions and the transmission channels of monetary policy shocks. For instance, Poeschl (2023) and Jungherr and Schott (2021) study optimal debt maturity and its implications over the business cycle. Jungherr et al. (2022) shows that firms with more maturing debt are more responsive to monetary policy shocks, while Deng and Fang (2022) finds that firms holding more long-term debt exhibit lower sensitivity to monetary policy shocks. While most of the existing literature focuses on how debt maturity structures influence firms' investment decisions, our paper examines a new perspective by highlighting the role of debt maturity structures in shaping firms' product pricing behavior.

2 Stylized Facts

The debt maturity structure has large variation not only among different firms at a given point in time but also within individual firms over time. The financial crisis of 2008 presents a valuable opportunity to investigate this relationship as it caused a significant shock to firms' debt maturity profiles as well as firms' refinancing issues. This section provides stylized facts on how the financial crisis impacted firms' debt maturity structure, offering insights into the changes and challenges that emerged during that period.

The facts and background discussed here are critical as they outline a plausible mechanism through which a firm's debt maturity structure can influence its strategic product pricing behavior. This section presents evidence that when financial market conditions become unfavorable, firms face increasing difficulty in maintaining their optimal debt maturity profiles. As balancing repayment schedules becomes more challenging, firms experience heightened pressure to meet their debt obligations. This pressure compels them to raise product prices to secure sufficient liquidity, thereby adhering to their repayment commitments and reducing the risk of default.

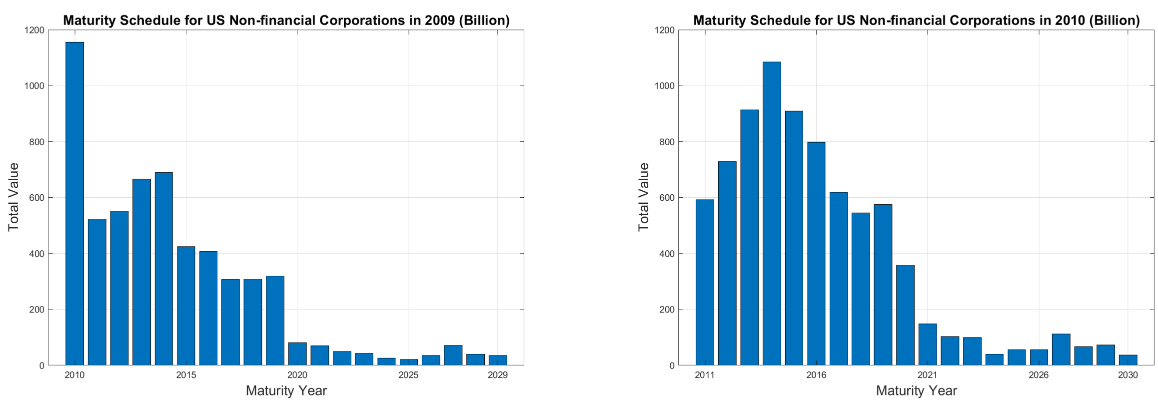
In this section, we first demonstrate that, during periods of financial turmoil, firms face significant challenges in securing funding from financial intermediaries, as the elevated risks associated with the crisis deter lenders. The heightened uncertainties make it particularly difficult to obtain medium- to long-term financing, as such commitments are perceived to carry greater risk compared to short-term borrowing. Consequently, firms struggle to maintain their optimal debt maturity structures and balance their repayment schedules.

Second, even when firms manage to secure financing, the cost of borrowing rises substantially compared to stable periods. The increased refinancing costs, especially as existing debt matures, impose additional burdens on firms, complicating their efforts to sustain a preferred debt maturity profile necessary for smooth operations. As a result, firms are incentivized to adjust their product pricing strategies upward to generate the necessary liquidity, ensuring they meet their financial obligations and remain solvent in challenging market conditions.

The financial crisis refers to a period of severe economic disruption characterized by a widespread and prolonged downturn in various financial markets and economic activities. During such crises, banks and financial institutions often become more cautious in extending long-term loans to borrowers due to heightened default risk and uncertainty in the economic environment. As a consequence, there is a significant shift in the debt maturity structure of firms, leading to substantial fluctuations. Firms experience changes in the composition of their debt, with a reduction in long-term debt and a relative increase in short-term debt to cope with the constraints on obtaining long-term financing.

Figure 1: Cumulative Corporate Debt Maturity Schedule

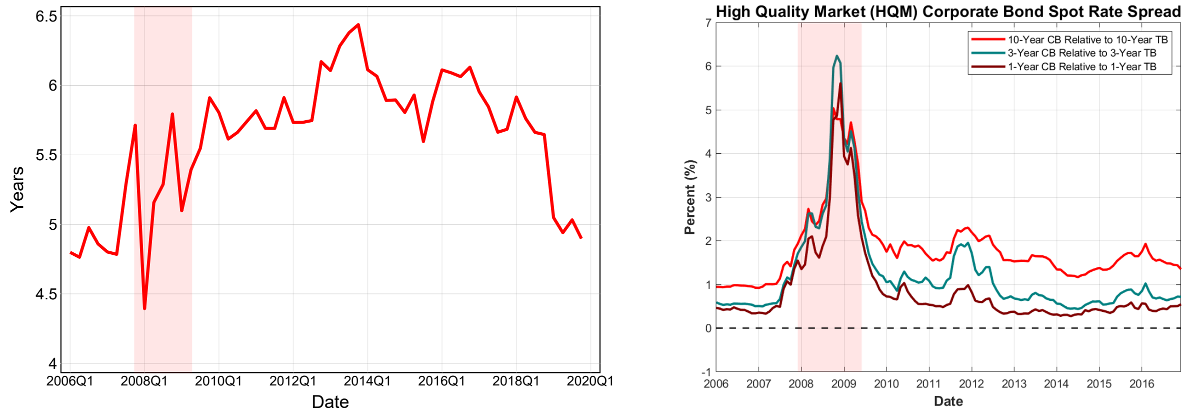
(a) Year 2009 (b) Year 2010



Notes: This figure shows the cumulative amount of corporate debt maturing each year. Panels (a) and (b) display the debt maturity schedules based on snapshots from the end of 2009 and 2010, respectively. Each bar represents the total amount of debt (in billions) maturing in a given year. The data is sourced from the Capital IQ database, with observations lacking maturity date information excluded from the analysis. Only non-financial corporations are included in the analysis.

Figure 2: Debt Maturity Trend and Corporate Bond Spreads

(a) Maturity Due Remaining (Years) (b) Trends of Corporate Bond Spread



Notes: Panel (a) in this figure displays the time trend of the weighted average remaining maturity, measured in years, where weights are based on debt amounts. Data is sourced from the Capital IQ database, excluding observations without maturity date information, and includes only non-financial corporations. Panel (b) shows the trend in corporate bond spreads, calculated as the difference between the high-quality market (HQM) corporate bond spot rate and the treasury bond rate, with data obtained from FRED. The shaded areas in both panels indicate recession periods as identified by the NBER.

Panels (a) and (b) in Figure 1 present snapshots of the maturity schedules of U.S. non-financial firms. Each bar in the graphs represents the total remaining outstanding debt in each year, measured in USD billions. Panel (a) displays the maturity profile as of the end of 2009, revealing a significant concentration of debt maturing in 2010. The large volume of debt set to mature within one year underscores the potential stress on firms, raising concerns about their ability to refinance or roll over their upcoming debt obligations.

In contrast, Panel (b) shows the maturity profile at the end of 2010, following a period of gradual financial recovery. Here, the skewness observed in Panel (a) is reduced, with a lower concentration of debt maturing in 2011. The distribution is more balanced, with a substantial portion of debt maturing between 2013 and 2015. This shift suggests that firms have been able to extend their debt maturities, alleviating immediate rollover risks and providing them with greater financial flexibility. The more evenly distributed maturity schedule in Panel (b) indicates a reduction in short-term debt pressures, allowing firms more room to manage their obligations and mitigate the risk of default.

The heightened rollover risk during the financial crisis is further evidenced in Panels (a) and (b) of Figure 2. Panel (a) illustrates the time trends in firms' weighted average remaining debt maturities, measured in years. The shaded area indicates the recession period as defined by the NBER. A notable observation is the significant shortening of the average remaining maturity during periods of financial distress. Particularly in the first quarter of 2008, there was a sharp decline in the average debt maturity, likely driven by increased caution from banks in extending long-term loans and refinancing for firms needing to roll over their debt.

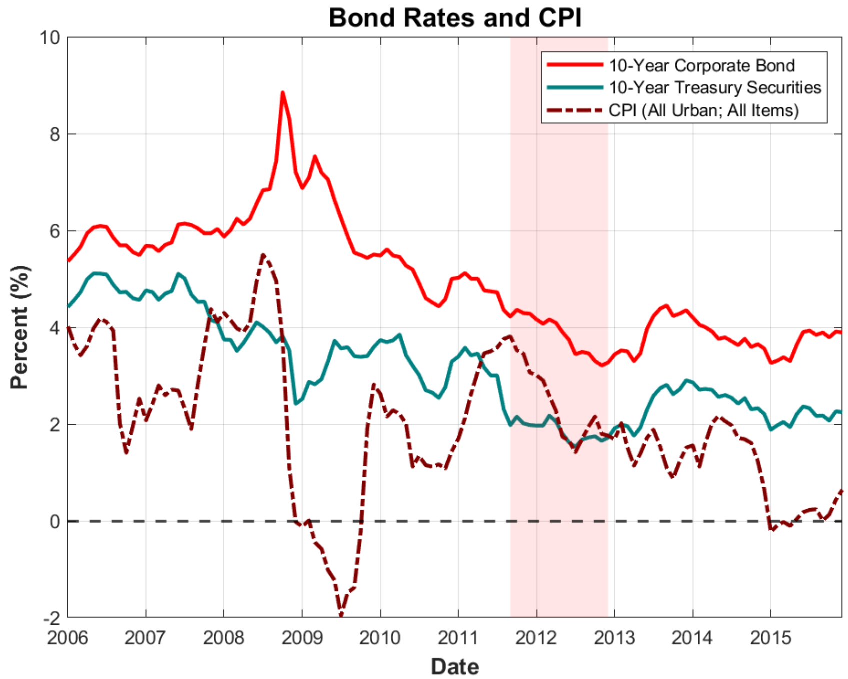
As the financial distress subsided, the remaining years to debt maturity gradually increased, with a marked extension from the first quarter of 2012 onward. This extension in debt maturities suggests that firms faced less rollover risk compared to the crisis period, benefiting from a more favorable financial environment with reduced pressures to meet short-term obligations.

Moreover, in addition to the difficulties firms face in finding lenders willing to roll over their debt and extend their maturity profiles, the situation is exacerbated by the rising rollover costs during periods of financial distress. This is illustrated in Panel (b) of Figure 2, which displays the spread between spot rates of corporate bonds in the high-quality market (HQM) and treasury bond across various maturities. The figure shows a significant increase in spreads for corporate bonds across all maturities during adverse economic conditions. This surge in borrowing costs indicates that firms not only struggle to secure financing from intermediaries but also face significantly higher costs even when they succeed in obtaining the necessary financial resources.

Furthermore, the increase in spreads is more pronounced for medium-term (3-year) and long-term (10-year) corporate bonds compared to short-term (1-year) bonds. This disparity suggests that it is particularly costly for firms to smooth their debt repayment schedules to avoid a concentration of obligations maturing within a short time frame. Such conditions impose additional challenges on firms trying to maintain their desired debt maturity structures during times of economic uncertainty.

Lastly, we present suggestive evidence suggesting that firms' debt maturity structures are closely tied to their pricing behavior, offering insights into the "missing deflation puzzle" during the financial crisis and the "missing inflation puzzle" in the post-crisis period. Figure 3 shows a sharp decline in the CPI rate during the financial crisis, followed by a swift rebound, stabilizing around 2% in the subsequent years. From the perspective of firms' debt maturity management, this pattern can be partly attributed to the

Figure 3: Corporate Bond Spot Rates and CPI



Notes: This figure shows the time trends of the 10-year corporate bond spot rate in the high-quality market (HQM), the 10-year Treasury bond rate (both sourced from FRED), and the Consumer Price Index (CPI) for all urban consumers and items, obtained from the Bureau of Labor Statistics (BLS). The shaded area indicates the periods when the Federal Reserve's Maturity Extension Program (MEP) was in effect. In September 2011, the Federal Open Market Committee (FOMC) announced a $400 billion MEP, scheduled for completion by the end of June 2012. In June 2012, the FOMC extended the program through the end of 2012, involving an additional $267 billion in treasury securities purchases, sales, and redemptions.

challenges firms face in sustaining prolonged periods of low pricing. The financial market conditions during the crisis made it difficult for firms to maintain balanced debt maturity structures at low financing costs.

In the post-crisis period, as depicted in Figure 3, the environment is characterized by persistently low corporate bond spot rates, accompanied by firm's longer average debt maturities as shown in Panels (a) of Figure 1. This change can be linked to the Federal Reserve's accommodative monetary policies, including quantitative easing and the Maturity Extension Program (MEP), which put downward pressure on long-term interest rates. These policies created a more favorable financial environment, enabling firms to manage their debt maturities more effectively and access longer-term financing at lower costs.

The shaded region in Figure 3 marks the period of the MEP, during which the Federal Reserve aimed to support economic recovery by easing financial conditions for firms. This program allowed firms to more easily balance their debt maturities and reduce refinancing costs, providing a "golden period" where firms could issue long-term debt with minimal financial strain. A notable feature of the post-crisis CPI trend in this figure is the persistent containment of inflation below 2%, coinciding with the accommodative financial conditions during the quantitative easing and MEP period. This suggests that the more favorable financing environment reduced firms' incentives to raise prices, as they were better able to maintain optimal maturity structures and access low-cost funding when refinancing or rolling over maturing debt.

3 Data

In this section, we describe in detail the sources of data to investigate the relationship between debt maturity profile and product pricing empirically. We construct a novel dataset that links detailed firm-level borrowing data, including maturity information, with the firm's product pricing data.

3.1 Capital IQ Data

We utilize the S&P Capital IQ database to provide a detailed, quarterly snapshot of each firm's debt maturity schedule. S&P Capital IQ database records extensive information on companies' debt capital structure. The data provides item-level information, which includes a description of the debt, the start date of the debt, the period end date (the ending date of the financial reporting period), debt seniority level, outstanding amounts, maturity dates, interest rate, interest rate type, among many others. We implement several steps to enhance the accuracy and reliability of the data. The S&P Capital IQ data contains many duplicate entries, making it crucial to filter out duplicates and retain a single unique observation per loan, company, and quarter. The specific steps taken to eliminate numerous duplicate entries using the available information are detailed in the Appendix. To validate this cleaning process, we cross-checked the total loan amount obtained from Capital IQ data with the data from

Compustat. We find that the information obtained from Capital IQ data could accurately replicate the total debt amount from Compustat, with only minor errors. The details of the data cleaning steps are provided in Appendix A.1. After cleaning the Capital IQ data, we constructed a quarter-by-firm maturity profile dataset. For each firm in a given quarter, we can track the detailed maturing schedule of its total debt. Figure 4 illustrates that each firm has a unique maturity schedule over time, showing substantial variation not only between firms within the same quarter but also across quarters within the same firm.

3.2 Nielsen Retail Scanner & GS1 Data

The source of product pricing information is Nielsen Retail Scanner data. The data record point-of-sale information of weekly pricing, product details, and some store-related variables obtained from participating retail stores in all US markets. Each year there are approximately 30,000 to 50,000 participating stores, and the categories of these stores include convenience stores, drug stores, food stores, mass merchandisers, and liquor stores. The earliest year of Nielsen Retail Scanner data goes back to 2006, and we use the year from 2006 to 2019 in my analysis.

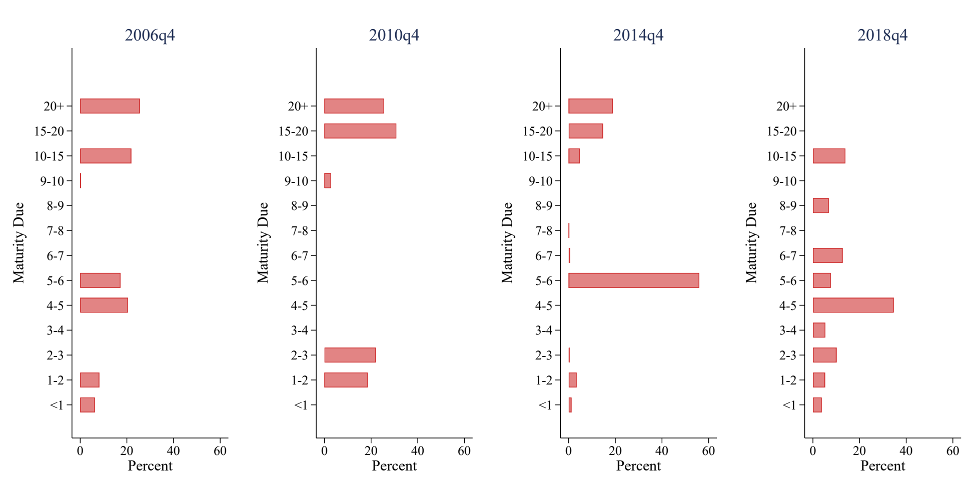
One of the most useful variables in the data is the UPC code of each product observed in the Nielsen Retailer Scanner data. UPC code is a unique identifier for each product, and it is managed by GS1 US. The producers normally register a unique UPC code for each of the products they produce through the GS1 US system. However, in the Nielsen data, only the UPC code can be observed with missing producer identification. In order to identify the producer information, we linked Nielsen data with the producer name and location information using GS1 US data through the UPC code.

UPC code consists of 13 digits of the number, and each UPC code can identify a unique product registered by the producer through the GS1 US system. Among the 13 digits of the number, the first 6 to 11 digits are company prefix that corresponds to the producer who registered UPC codes to their products through the GS1 system. Since the company prefix can vary from 6 to 11 digits and there are no common rules for each of the UPC. For each UPC code, I checked that only one of the numbers from all possible company prefixes could be matched to unique producer information for the validity of the matching.

Figure 4: Maturity Structure

(a) Maturity Structure of Kimberly-Clark and P&G

(b) Maturity Structure of The Kraft Heinz Company

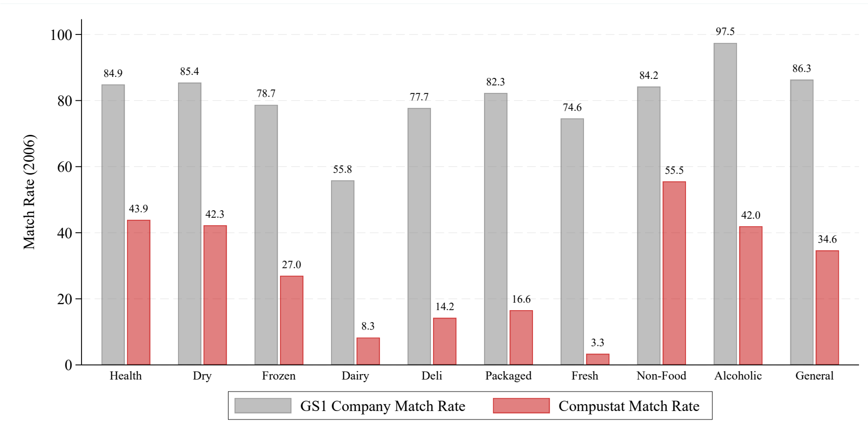


Notes: This figure presents the maturity structures of Kimberly-Clark and P&G across different quarters. The maturity data in each graph reflects the snapshot at the specified quarter. Each bar represents the ratio of debt maturing within a specified year range to the total debt held by the firm at the time of the snapshot. The data is calculated from Capital IQ.

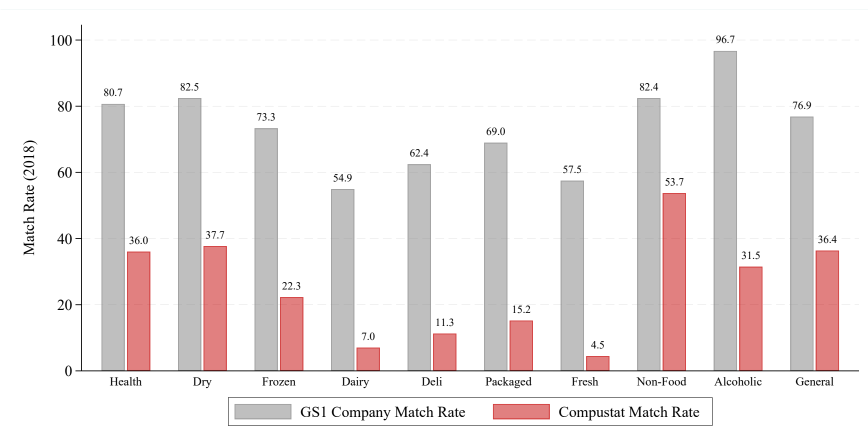
GS1 data hub provides the producer's name, city, and address information. We use this information to link Nielsen data to Compustat data and Capital IQ data through fuzzy matching. To find a correct match between the producer in GS1 and Compustat, we first use company name information in both of the data and calculate the name matching score to find some potential match combinations between the two data sets. After this, we also used address information in both of the data and calculated the address matching score to find potential matches between GS1 and Compustat. Finally, we make use of all of the name-matching scores, address-matching scores, and city information to find the final match between the two data sets. I also manually checked the validity of the matching in the final step of the matching. The matching rate of is shown in the Figure 5.

Figure 5: Match Rate Between Nielsen & GS1 & Compustat

(a) Match Rate of Year 2006



(b) Match Rate of Year 2018



Notes: This figure presents the matching rates between Nielsen, GS1 US Data Hub, and Compustat. The gray bar represents the percentage of UPCs matched between Nielsen Retail Scanner Data and GS1, while the red bar represents the percentage of UPCs matched between Nielsen and Compustat. Panels (a) and (b) show the matching percentages for the years 2006 and 2018, respectively.

The consistency of the matching rate over time (comparing the matching rates from 2006 to 2018) shown in Figure 5 confirms the robustness of our matching algorithm. The figure demonstrates that a substantial number of UPC barcodes in the Nielsen data can be linked to their manufacturers. However, as not all manufacturers are public companies, only a portion of them can be matched with Compustat, which provides balance sheet data for U.S. public companies. Categories such as Dairy, Deli, and Fresh generally have lower match rates, likely due to the difficulty in identifying manufacturers for products like bread and fresh vegetables.

Since only a portion of the Nielsen barcode-level data is matched to the public firms analyzed in this paper, questions may arise regarding the representativeness of our dataset. Does our data reflect the overall economy? To address this, we construct a firm-level price index and compare it with the official CPI rate released by the Bureau of Labor Statistics (BLS) to assess the representativeness of our data.

We follow an approach similar to Leung (2021) to construct store-by-firm-by-product-group and firm-by-product-group price indices using the matched sample. However, unlike Leung (2021), which does not match the Nielsen Retail Scanner data with Compustat, our analysis takes an additional step by constructing firm-level price indices based on the matched data. In our dataset, we exclude UPCs that do not appear consistently throughout the entire sample period to ensure that results are not biased by store entry and exit. We also retain only those UPCs that are observed continuously across each year. Given that Nielsen Retail Scanner data is recorded weekly, we aggregate the prices of each UPC to a quarterly level by calculating the quarterly price as the total sales in each quarter divided by the total quantity sold. The store-by-product-group price index $P^S_{j,t,y}$ at quarter t and year y for product group j for each store is computed as:

$$P^L_{j,t,y} = P^L_{j,t-1,y} \times \frac{\sum_{i \in j} p_{i,t} q_{i,y-1}}{\sum_{i \in j} p_{i,t-1} q_{i,y-1}} \tag{1}$$

Similarly, the store-by-firm-by-product-group price index $P^S_{f,j,t,y}$ is constructed as:

$$P^L_{f,j,t,y} = P^L_{f,j,t-1,y} \times \frac{\sum_{i \in j} p_{f,i,t} q_{f,i,y-1}}{\sum_{i \in j} p_{f,i,t-1} q_{f,i,y-1}} \tag{2}$$

Following Leung (2021), the quantity weights $q_{i,y}$, and $q_{f,i,y}$ are updated annually to prevent chain drift. We additionally use one-year lagged quantity weights to ensure that price changes are not driven by shifts in product demand or consumption patterns in response to price fluctuations and local shocks. The store level price index is computed in both of chain method and Tornqvist method:

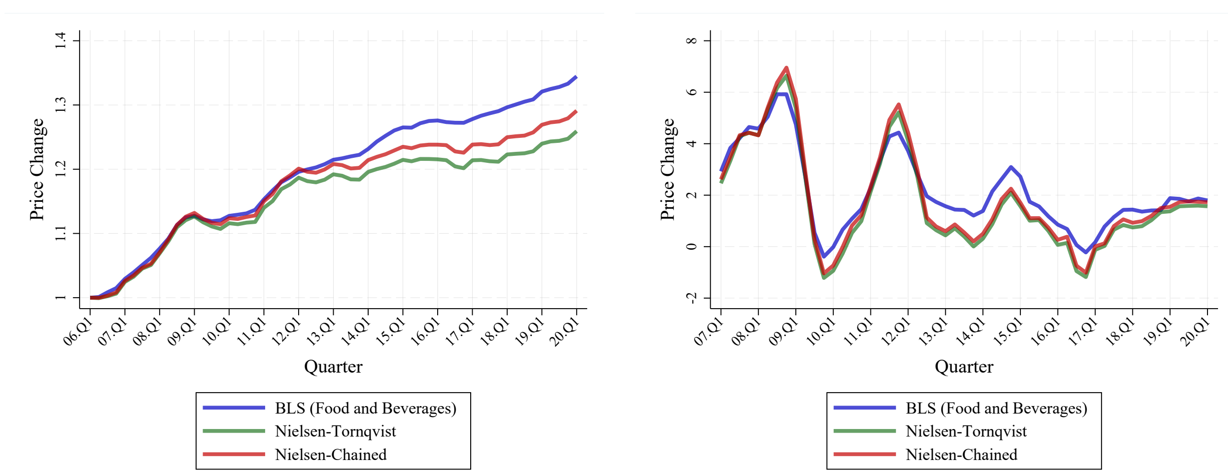
$$
\begin{aligned}
\frac{P_t}{P_{t-1}} &= \sum_{j=1}^{N} s_{j,y-1}\left(\frac{P^S_{j,t,y}}{P^S_{j,t-1,y}}\right) \\
\frac{P_t}{P_{t-1}} &= \prod_{j=1}^{N}\left(\frac{P^S_{j,t,y}}{P^S_{j,t-1,y}}\right)^{\frac{s_{j,t}+s_{j,t-1}}{2}}
\end{aligned} \tag{3}
$$

The store-firm level price index is computed in both of chain method and Tornqvist method:

$$
\begin{aligned}
\frac{P_{f,t}}{P_{f,t-1}} &= \sum_{j=1}^{N} s_{f,j,y-1}\left(\frac{P^S_{f,j,t,y}}{P^S_{f,j,t-1,y}}\right) \\
\frac{P_{f,t}}{P_{f,t-1}} &= \prod_{j=1}^{N}\left(\frac{P^S_{f,j,t,y}}{P^S_{f,j,t-1,y}}\right)^{\frac{s_{f,j,t}+s_{f,j,t-1}}{2}}
\end{aligned} \tag{4}
$$

To check the validity of the constructed price data, we compare the CPI index that we construct from Nielsen Retail Scanner data to the official CPI index from Bureau of Labor Statistics (BLS). Figure 6 shows that the constructed CPI index from Nielsen Retail Scanner data closely replicates the official index from BLS which shows the representativeness of the scanner data.

Figure 6: Price Index Comparisons



Notes: This figure illustrates the price index constructed from Nielsen Retail Scanner data using both the chained and Tornqvist methods. The index is based on store-firm level data, weighted by store sales. For comparison, the BLS price index is included, using the "Food and Beverages" series for U.S. city averages across all urban consumers, obtained from the Bureau of Labor Statistics.

3.3 Dealscan Data

To construct a firm-level idiosyncratic credit supply shock, we incorporate Dealscan data into our analysis. Dealscan provides detailed information on firms' borrowings from the syndicated loan market, offering valuable insights into firms' existing lender relationships and how they might be impacted by the financial health deterioration of these lenders. We retain only observations for loans where the primary borrowing purpose is 1) General Purpose, 2) Equipment Upgrade/Construction, 3) Purchase of Software/Services, or 4) Working Capital. Additionally, we include only original deals, excluding observations that record amendments to the original loans. Following Chodorow-Reich (2014), we identify the lead agent and participants for each deal and use lender role information to estimate each lender's loan share within the tranche when specific tranche share data is unavailable.

3.4 Compustat Data

Firms' financial information is sourced from Compustat data, which comprises comprehensive records of public firms' balance sheet and statement of income data. Following the established standards in the literature, we drop observations with missing gvkey and date. We include only US established firms in my analysis. We merged Capital IQ with Compustat data using gvkey as the identifier. In the Compustat dataset, some firms have more than four observations in a year due to fiscal year changes. In such cases, we keep observations that correspond to the current fiscal year to maintain consistency in the analysis.

4 Empirical Analysis

4.1 Descriptive Analysis

In this section, we present the heterogeneity in the dynamics of output prices based on the firm's baseline debt ratio. Figure 7 illustrates the trends in price outputs for firms with high short-term debt ratios in the baseline period (in red) and firms with low short-term ratios (in gray). Two different thresholds are used to define high versus lower debt ratios.

Panel (a) uses a threshold of 75%, defining firms with short-term ratios exceeding 75% of their total debt as having a high debt ratio. In contrast, panel (b) uses a threshold of 90%.

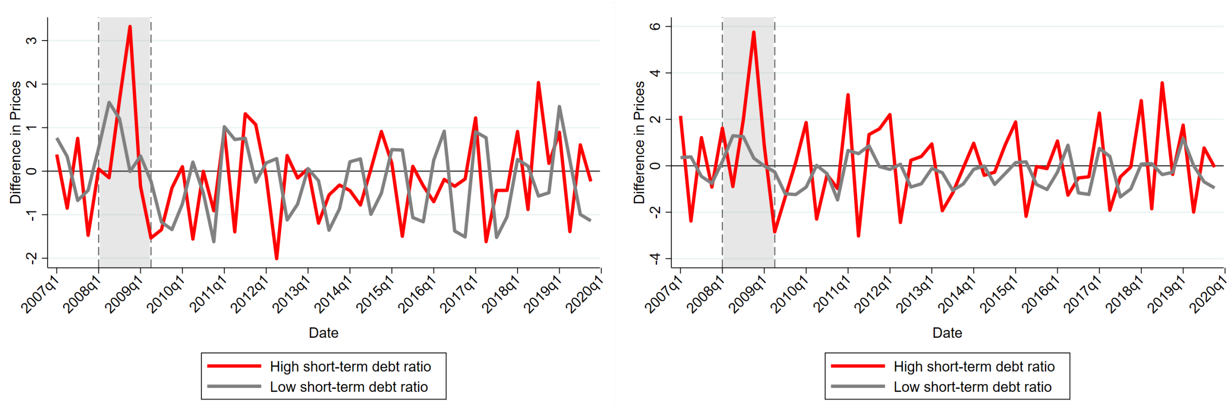
Figure 7 illustrates that firms' price-setting behavior varies a lot depending on their share of the short-term debt ratio. Firms with a high proportion of short-term debt experienced a remarkably sharp increase in their output prices during the financial crisis. One possible explanation for this change is their strategic intent to increase revenue and mitigate rollover risk during the financial crisis.

This evidence provides new and valuable insights into how firms with different short-debt ratios adjust their prices during a crisis. Remarkably, to the best of my knowledge, this is the first paper to document this pricing pattern using a large-scale dataset. By shedding light on the price-setting behavior of firms with varying short-debt ratios, this research contributes to a deeper understanding of how financial conditions impact firms' pricing decisions.

Figure 7: Heterogeneity in the Dynamics in Output Prices Based on Short-term Debt Ratio

(a) QoQ Price Change, Threshold: 75%

(b) QoQ Price Change, Threshold: 90%



Notes: This figure shows quarter-on-quarter price changes for two different firm groups, based on matched data from the Nielsen and Capital IQ databases. Firms are categorized into "high short-term debt ratio" and "low short-term debt ratio" groups. In Panel (a), the "high short-term debt ratio" group consists of firms with more than 75% of their total debt maturing within one year, while the "low short-term debt ratio" group includes firms with less than 75% of their debt maturing within one year. In Panel (b), the classification threshold between "high" and "low" short-term debt ratios is set at 90%.

4.2 Global Financial Crisis

The main specification to investigate the importance of debt maturity in a firm's price-setting behaviors during the financial crisis is as follows:

$$\Delta P_{if} = \lambda_g + \beta D_f + \theta X_f + \varepsilon_{fg}, \tag{5}$$

where we included different controls in the specification. The key coefficient of interest is β, while D_f measures the firm $f's$ maturity structure. To incorporate the debt maturity structure, we created different debt maturity bins using the maturity date information from Capital IQ. We then calculated the ratio of debt to total debt in each maturity bin. To emphasize the debt maturity channel in the firm's price setting behaviors, we control for a variety of firm characteristics, as commonly done in previous literature. In Gilchrist et al. (2017), the analysis emphasizes the liquidity channel's influence on the firm's price-setting behaviors. In contrast to their study, we aim to validate my findings by employing various alternative specifications. These specifications enable us to investigate whether the debt maturity channel retains its statistical significance even after accounting for other factors and channels.

In Table 1, we present the results that I obtain using different specifications of the model. The time horizon is in quarters, and the dependent variable is the change in prices between the pre-crisis period (2007.Q4–2008.Q2) and the post-crisis period (2008.Q4–2009.Q2). Prices are measured at the individual UPC level, denoted by ΔP_{if}, representing the price change of the product of i produced by firm f before and after the financial crisis.

In all of the columns, we control for standard firm controls commonly used in the corporate finance literature, such as firm size, book leverage, Tobin's Q, cash holding, and the total debt-to-asset ratio of a firm. We also add additional controls following Gilchrist et al. (2017), such as liquidity, inventory-to-sales ratio, sales growth, and cost of goods sold growth. All control variables are computed as averages between the period 2007.Q4 and 2008.Q2. More detailed information on how these variables were constructed is included in Appendix Table A2.

The main results are highlighted in columns (1)–(5) of Table 1, in which the debt maturity structure is taken into account. As shown in columns (1)–(5) of Table 1, the ratio of short-term debt is statistically significant at the 1% or 5% significance level across all

Table 1: Effects of Debts with Various Maturities on Price Change

	(1)	(2)	(3)	(4)	(5)
Debt Due in 1 Year	0.059***	0.072***	0.070***	0.094***	0.112***
	(0.019)	(0.020)	(0.020)	(0.020)	(0.027)
Debt Due in 1 to 2 Years		-0.056	-0.049	-0.010	-0.006
		(0.035)	(0.041)	(0.040)	(0.038)
Debt Due in 2 to 3 Years			-0.029	-0.063	-0.037
			(0.070)	(0.076)	(0.085)
Debt Due in 3 to 4 Years				0.039**	0.046**
				(0.019)	(0.021)
Debt Due in 4 to 5 Years					0.052
					(0.052)
Firm Controls	Y	Y	Y	Y	Y
Store Fixed Effects	Y	Y	Y	Y	Y
Product Group Fixed Effects	Y	Y	Y	Y	Y
Observations	3,781,504	3,781,504	3,781,504	3,781,504	3,781,504
R^2	0.369	0.371	0.371	0.374	0.375

Notes: Standard errors are two-way clustered at the firm and product group levels are in parentheses. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively. The standard errors are two-way clustered by firm and product group. The regression includes store and product group fixed effect and is weighted by total sales. Each observation is a store-by-firm-by-product-group price index. The dependent variable is the change of price index between two periods (07.Q4:08.Q2 and 08.Q4:09.Q2).

columns, even after controlling for various firm controls. Specifically, in column (1), the result indicates that a 1 percent point increase in short-term debt ratio, due within one year, is associated with an approximate 0.06 percent point increase in product prices. This finding aligns with my previous results in section 4, where firms with a higher short-term debt ratio showed a substantial increase in product prices compared to those with a lower short-term debt ratio. This effect becomes even more pronounced when considering other debt maturity structure variables, such as debt ratios due within 1 to 2 years, 2 to 3 years, 3 to 4 years, and 4 to 5 years.

Columns (1) and (2) reveal interesting findings, as the short-term debt ratio due within one year consistently displays a statistically significant positive relationship with the firm's price change behaviors. Strikingly, the signs of the estimated results are opposite to those of the total debt ratio, where the total debt ratio tends to decrease the firm's product prices. These contrasting signs emphasize the significance of considering the firm's debt maturity profile beyond the simple effects of its total debt ratio.

Table 2 presents the results when employing an accumulated measure of debt ratio instead of using debt maturity bins to test the robustness of my findings. The results are consistent with my previous observations, indicating that short-term debt has positive effects on a firm's price change. In particular, the results of the Table 2 demonstrates that this positive relationship becomes less significant when we include relatively long-term debt.

Table 2: Effects of Debts with Various Maturities on Price Change

	(1)	(2)	(3)	(4)	(5)
Debt Due in 1 Year	0.062***				
	(0.019)				
Debt Due in 2 Years		0.026*			
		(0.013)			
Debt Due in 3 Years			0.018		
			(0.012)		
Debt Due in 4 Years				0.034**	
				(0.015)	
Debt Due in 5 Years					0.039*
					(0.020)
Firm Controls	Y	Y	Y	Y	Y
Store Fixed Effects	Y	Y	Y	Y	Y
Product Group Fixed Effects	Y	Y	Y	Y	Y
Observations	3,781,504	3,781,504	3,781,504	3,781,504	3,781,504
R^2	0.369	0.366	0.365	0.367	0.367

Notes: Standard errors are two-way clustered at the firm and product group levels are in parentheses. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively. The standard errors are two-way clustered by firm and product group. The regression includes store and product group fixed effect and is weighted by total sales. Each observation is a store-by-firm-by-product-group price index. The dependent variable is the change of price index between two periods (07.Q4:08.Q2 and 08.Q4:09.Q2).

4.3 Credit Supply Shock

In this section, we use a credit supply shock during the financial crisis to study the effects of debt maturity profile on each firm's price-setting behavior. To do this, we expand the previous equation by introducing a credit supply shock measure, wherein the idiosyncratic firm-level credit supply shock is interacted with the short-term debt ratio. The specification incorporating the credit supply shock is as follows:

$$\Delta P_{if} = \lambda_g + \beta(-\Delta L_f)D_f + \theta X_f + \varepsilon_{fg} \tag{6}$$

Following the approach of Chodorow-Reich (2014) and Kim (2020), we construct the credit supply shock at the firm level. We use the failure of Lehman Brothers, which occurred on September 15, 2008. The financial crisis had a significant impact on the health of banks, leading us to define two distinct periods: the pre-Lehman period and the post-Lehman period for constructing the credit supply shock. The post-Lehman period is defined as the time between 2008.Q4 and 2009.Q2, which immediately follows Lehman's failure. On the other hand, the pre-Lehman period is selected from 2007.Q4 to 2008.Q2. To test the robustness of my findings, I also conduct a sensitivity analysis by using the period between 2006.Q4 and 2007.Q2 as an alternative pre-Lehman period for comparison.

We use Dealscan data to construct a firm-level credit supply shock. The Dealscan database contains information on firms' bank borrowings from the syndicated loan market. An example deal from Dealscan is illustrated in Appendix Figure A1, where The Procter & Gamble Company acts as the borrower, and the loan involves ten different banks serving as lead agents, co-agents, or participants. The lead agent typically handles the largest portion of the syndicated loan. Given that each syndicated loan deal involves multiple banks, we can investigate the banks with which a specific firm has established a relationship. To identify the list of banks that a particular firm had engaged with before the Lehman failure, I use the last syndicated loan that the firm borrowed before the Lehman failure and denoted it as S_f.

After identifying the list of banks that a specific firm had established a relationship with prior to the Lehman failure, the firm-level credit shock is defined in Equation 7 as follows:

$$\begin{aligned} \Delta L_f &= \sum_{b \in S_f} \alpha_{fb,\text{ last}} \Delta(\text{ Bank Health })_{-f,b} \\ \Delta(\text{ Bank Health })_{-f,b} &= \frac{\sum_{j \neq f} \alpha_{jb,\text{ post}} \times \mathbb{1}(b \text{ lent to } j \text{ post-Lehman })}{\frac{1}{2} \sum_{j \neq f} \alpha_{jb,\text{ pre}} \times \mathbb{1}(b \text{ lent to } j \text{ pre-Lehman })} \end{aligned} \tag{7}$$

The firm-level credit shock is calculated as the weighted average of the changes in bank health with whom the firm had constructed a relationship through the last syndicated loan before Lehman's failure. The weight $\alpha_{fb,last}$ is determined by the proportion of the loan that a specific bank had borrowed to the firm in the last syndicated loan. By the definition of ΔL_f, a firm's credit supply shock is represented as a weighted average of the exposures to the changes in the health of the banks upon which it relied for borrowings.

The change in bank health is calculated at the bank level, measuring the extent to which a bank has reduced its borrowings after the Lehman failure. In the bank health change equation, the indicator function $\mathbb{1}$ takes a value of zero if the bank b provided loans to the firm j either in the pre-Lehman period or the post-Lehman period through a syndicated loan deal. To account for the bank's proportion in each syndicated loan deal, the weights $\alpha_{jb,post}$ and $\alpha_{jb,pre}$ are multiplied in front of the indicator function $\mathbb{1}$.

The bank health equation focuses on quantifying the total number of firms that bank b has provided loans to. The equation involves two summations: one in the numerator, which considers all the firms that bank b extended loans to in the syndicated loan market during the pre-Lehman period, and another in the denominator, which includes all the borrowers to whom bank b provided loans during specific time intervals (2007.Q4 to 2008.Q2 & 2006.Q4 to 2007.Q2). We multiply the denominator by $\frac{1}{2}$ to account for the differences in the length of quarters for the two periods. We exclude firm f from the summation when measuring the credit supply shock in order to prevent the measure of credit supply shock to firm f is compounded by neglecting the demand side of the loan. By excluding firm f from the calculation of bank health change, we focus solely on the pure credit supply shock to firm f without attributing any changes in the number of loans provided by bank b to firm f solely to fluctuations in firm $f's$ credit demand. This ensures a more accurate assessment of the credit supply shock experienced by firm f.

Table 3 presents the estimation results of Equation 7, incorporating the credit supply shock constructed as described above. Additionally, we interacted this shock with different maturities of the debt, as shown in Equation 7. Comparing these results with those in Table 1, we find notable differences. Columns (1)–(5) reveal a positive relationship between the firm's price change and the short-term debt ratio due in 1 year. In particular, although the coefficient of the short-term debt due in 1 year interacted with the credit supply shock is less statistically significant in column (1), it becomes much more statistically significant when other debt maturities are included. In columns (2) to (5), it is evident that a one standard deviation increase in the credit supply shock interacted with 1 percentage point increase of the short-term debt ratio due in one year generally leads to a rise in the firm's product price by approximately 1.1 to 1.3 percentage points. These results indicate a meaningful impact of the credit supply shock and short-term debt ratio on the firm's price dynamics.

Table 3: Effects of Debts with Various Maturities on Price Change (Credit Supply Shock)

	(1)	(2)	(3)	(4)	(5)
Shock X Debt Due in 1 Year	0.557*	1.062***	1.254***	1.249***	1.226***
	(0.321)	(0.392)	(0.408)	(0.415)	(0.399)
Shock X Debt Due in 1 to 2 Years		-0.406**	-1.174**	-0.814*	-0.667
		(0.192)	(0.525)	(0.432)	(0.474)
Shock X Debt Due in 2 to 3 Years			1.160	0.634	0.433
			(0.723)	(0.587)	(0.647)
Shock X Debt Due in 3 to 4 Years				0.244**	0.192*
				(0.109)	(0.115)
Shock X Debt Due in 4 to 5 Years					0.323***
					(0.111)
Firm Controls	Y	Y	Y	Y	Y
Store Fixed Effects	Y	Y	Y	Y	Y
Product Group Fixed Effects	Y	Y	Y	Y	Y
Observations	3,708,820	3,708,820	3,708,820	3,708,820	3,708,820
R^2	0.376	0.379	0.380	0.387	0.388

Notes: Standard errors are two-way clustered at the firm and product group levels are in parentheses. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively. The standard errors are two-way clustered by firm and product group. The regression includes store and product group fixed effect and is weighted by total sales. Each observation is a store-by-firm-by-product-group price index. The dependent variable is the change of price index between two periods (07.Q4:08.Q2 and 08.Q4:09.Q2).

In Table 4, we explore an alternative measure of accumulated debt ratio due in two years, three years, four years, and five years. The results reveal an intriguing pattern: the effects of debt ratio interacted with the credit supply shock on price change show a positive relationship when the debts are due in less than two years, but the sign becomes negative when the debts are due in three years or more. This finding suggests that debts that are due in the near future (within one or two years) serve as a motivation for firms to increase their product prices. This observation indicates that the debt maturity structure significantly influences a firm's price-setting behaviors. One possible explanation for this pattern is that firms are sensitive to their maturity profiles when determining their pricing strategies. Firms with a higher proportion of short or medium-term debt due within the one-year or two-year window tend to increase product prices to boost their revenue and mitigate rollover risks. The strategic adjustment of prices allows these firms to address their upcoming debt obligations more effectively.

In essence, the findings highlight how firms take into account their debt maturity profiles strategically, adapting their pricing decisions to manage rollover risk and optimize their financial positions. The observed relationship between debt maturity structure and price-setting behavior underscores the importance of considering the interplay between debt characteristics and firm decisions in understanding pricing dynamics.

In addition to this, we investigate the dynamic impact of a firm's pricing behavior by utilizing the global financial crisis as an exogenous shock to the firm's refinancing conditions on the financial market. As we explained previously, the constructed idiosyncratic firm-level credit supply shock measures the exposure of a firm to banks' health deterioration of which its has close tie with. As previously mentioned, the constructed idiosyncratic firm-level credit supply shock quantifies a firm's vulnerability to the deteriorating health of banks with which it has a close relationship. In the existing literature, numerous papers have explored how, due to switching costs, firms may face challenges in transitioning to other banks when the banks they have established close relationships with encounter financial difficulties. Taking these facts into account, we estimate a difference-in-differences model which takes the following form:

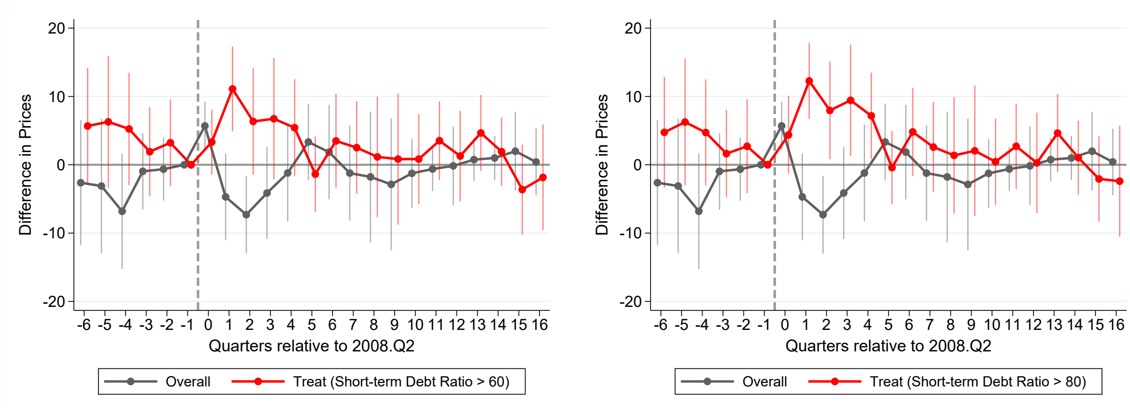
$$100 * \left(\frac{P_{fjt} - P_{fjt-4}}{P_{fjt-4}}\right) = \sum_{t \neq 2008.Q2} \left\{ \underbrace{\alpha_t}_{\text{Overall}} + \underbrace{\gamma_t}_{\text{Heterogeneous}} \times 1\{\text{ShortTerm\_Debt}^{Pre} > \text{Cutoff}\}_f \right\} \times \underbrace{(-L_f)}_{\text{Credit Shock}} \times \mathbf{1_t}$$
$$+ \kappa' \underbrace{X_{ft}}_{\text{Firm Controls}} + \sigma_f + \delta_t + \varepsilon_{fjt} \tag{8}$$

Each observation in Equation 8 is the year-over-year price change of individual firm f for product group j during quarter t. We divide firms into the treated group and the control group based on the average short-term debt ratio for each firm during the pre-financial-crisis period, spanning from 2007.Q4 to 2008.Q2. Specifically, the treated group consists of firms with a baseline short-term debt ratio above a specific threshold. $\mathbf{1_t}$ refers to time dummies and $(-L_f)$ indicates the firm-level idiosyncratic credit supply shock. The equation includes firm fixed effects (σ_f) and time fixed effects (δ_t). We also control for the firm-level time-varying covariates which include: firm size, book leverage, market value, Tobin's Q, total debt ratio, cash holding, and liquidity. In the estimation, standard errors are clustered at the firm and product group level.

Figure 8 clearly shows the difference of price response to credit supply shock depending

Figure 8: Heterogeneous Effect of Credit Supply Shock

(a) Threshold: 60%   (b) Threshold: 80%



Notes: This figure shows the estimated results from Equation 8. The red line represents the heterogeneous effects of a negative credit supply shock on price changes for the group of firms with more than 60% (or 80%) of their debt maturing within one year, while the grey line represents the heterogeneous effects on price changes for firms with less than 60% (or 80%) of their debt maturing within the same period.

on the ratio of firm's short-term debt ratio. The gray line shows how the shock affects price over time, while the red line shows the effect of the shock on prices among the treatment group relative to the control group. This pattern highlights the differential effect of the shock depending on firms' short-term debt ratio. This indicates that firms with high levels of short-term debt find themselves compelled to either maintain or raise their product prices in order to boost their revenues and mitigate the risk of default. This emphasizes the channel in which firms, when confronted with the choice between risking customer attrition by raising prices and increasing revenue to avoid default, opt to prioritize revenue generation to fulfill their imminent debt obligations. For the robustness check, we use different threshold of short-term debt ratio for the treated group. Figure A7 shows that the channel is still valid with different threshold of short-term debt ratio.

4.4 Monetary Policy Shock

In this section, we investigate the influence of debt maturity profiles on a firm's price-setting behaviors using monetary policy shocks. As a firm's debt burdens are sensitive to changes in borrowing interest rates, analyzing the firm's response to debts with different maturities becomes relevant, and monetary policy shocks serve as a valuable source of exogenous variation in this context. This result also illustrates how variations in debt

Table 4: Effects of Debts with Various Maturities on Price Change (Credit Supply Shock)

	(1)	(2)	(3)	(4)	(5)
Shock X Debt Due in 1 Years	0.557*				
	(0.321)				
Shock X Debt Due in 2 Years		0.078			
		(0.074)			
Shock X Debt Due in 3 Years			0.059		
			(0.052)		
Shock X Debt Due in 4 Years				0.102	
				(0.064)	
Shock X Debt Due in 5 Years					0.099*
					(0.051)
Firm Controls	Y	Y	Y	Y	Y
Store Fixed Effects	Y	Y	Y	Y	Y
Product Group Fixed Effects	Y	Y	Y	Y	Y
Observations	3,708,820	3,708,820	3,708,820	3,708,820	3,708,820
R^2	0.376	0.373	0.373	0.376	0.378

Notes: Standard errors are two-way clustered at the firm and product group levels are in parentheses. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively. The standard errors are two-way clustered by firm and product group. The regression includes store and product group fixed effect and is weighted by total sales. Each observation is a store-by-firm-by-product-group price index. The dependent variable is the change of price index between two periods (07.Q4:08.Q2 and 08.Q4:09.Q2).

burden during normal times, influenced by differing debt maturity structures, can impact a firm's product pricing behavior.

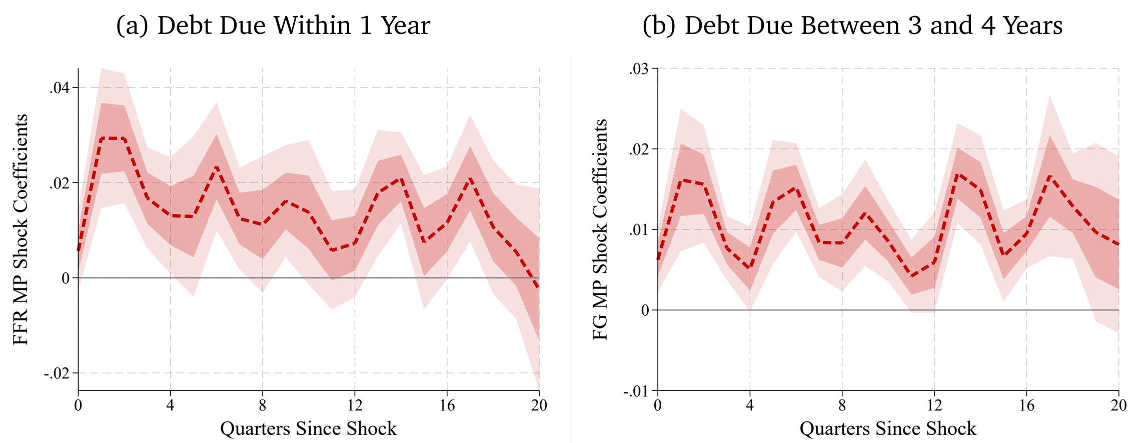
First, we use the monetary policy proposed by Swanson (2021) which extends the approach of Gürkaynak et al. (2005). Both of the papers use factor model to extract the unexpected component of change in federal funds rate, forward guidance, large scale asset purchase (LSAP). This approach offers the advantage of decomposing a monetary policy shock into distinct components that can impact the asset prices of various maturities. Because various announcements of monetary policy have asymmetric effects on asset prices with varying horizons, it is essential to distinguish each component of monetary policy to analyze its unique impacts on debt burdens with differing maturities.

We follow Jordà (2005) to estimate the impacts of monetary policy shock on the firm's price change using local projection method.

$$\log \frac{P_{fjt+h}}{P_{fjt-1}} = \beta_1^h \, \text{Debt}_{ft} \, \varepsilon_t^{\text{MP}} + \alpha_j^h + \alpha_t^h + \alpha_f^h + \varepsilon_t^{\text{MP}} + \Gamma_1^h X_{ft-1} + \varepsilon_{it} \tag{9}$$

The dependent variable is log price change of product group j produced by firm f between time $t+h$ and $t-1$. $\varepsilon_t^{\mathrm{MP}}$ denotes the monetary policy shock. I focus on two types of monetary policy shock constructed by Swanson (2021): the target component, and the path component. The target component of monetary policy shock is the surprise of change in federal funds rate, and the path component of monetary policy shock is the surprise of change in forward guidance. Hence, the target component of monetary policy shock is more closely related to the debt burden with short-term maturities and the path component of monetary policy shock is more closely related to the debt burden with medium-term or long-term debt maturities. In the regression, the product group FEs (α_j^h), time FEs (α_t^h), and firm FEs (α_f^h) are included. The observations are weighted by total sales and standard errors are two-way clusterd at the firm and product group level. β_1^h is main coefficient of interest in this estimation. In the left panel of 9, the contractionary monetary policy shock

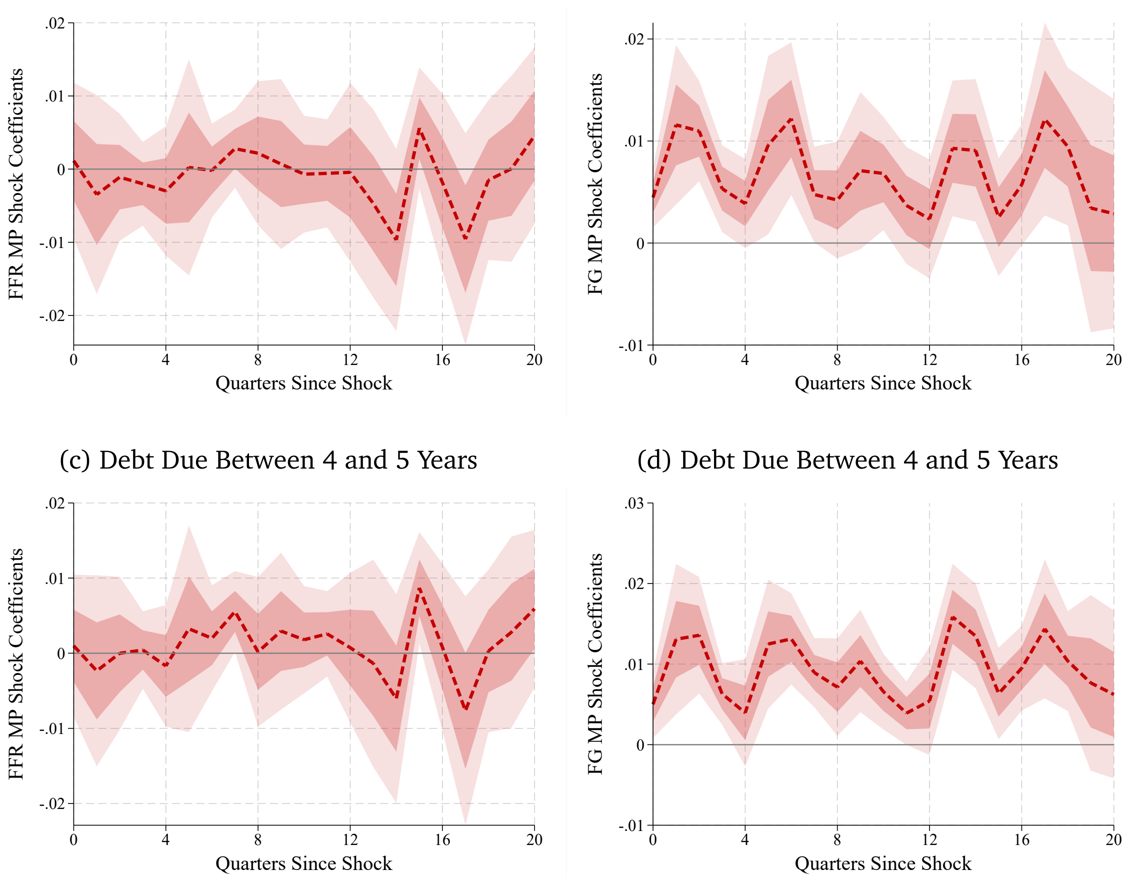
Figure 9: Response of Price to Target And Path of Monetary Policy Shock



Notes: This figure presents the estimated results from Equation 9. Panel (a) illustrates the response of price changes to the FFR (target) monetary policy shock (as in Swanson (2021)), interacted with the ratio of debt maturing within one year to total debt. Panel (b) shows the response of price changes to the FG (path) monetary policy shock (as in Swanson (2021)), interacted with the ratio of debt maturing between three to four years to total debt.

in target component has immediate response to price change for firms with high ratio of short-term debt maturing within 1 year. Compared to this, the contractionary monetary policy shock in path component has more impacts on price change for firms with more debt burdens maturing in the medium-term. Figure 10 also shows the similar story. The

Figure 10: Response of Price to Target And Path of Monetary Policy Shock



(a) Debt Due Between 3 and 4 Years

(b) Debt Due Between 3 and 4 Years

(c) Debt Due Between 4 and 5 Years

(d) Debt Due Between 4 and 5 Years

Notes: This figure presents the estimated results from Equation 9. Panel (a) and (b) illustrates the response of price changes to the FFR (target) and FG (path) monetary policy shock (as in Swanson (2021)), interacted with the ratio of debt maturing between three to four years to total debt. Panel (c) and (d) illustrates the response of price changes to the FFR (target) and FG (path) monetary policy shock (as in Swanson (2021)), interacted with the ratio of debt maturing between four to five years to total debt.

first row of the figure shows that target component of monetary policy attributes to price increases only to firms with elevated level of debt burden maturing in medium-term or long-term. In comparison, the second row of Figure 10 shows that the path component of monetary policy attributes to price increases only to firms with high level of debt budern maturing in short-term. This finding is interesting because it shows the different response of the firm's price change depending on their debt burdens of different maturities.

For the robustness check, We use the local projection approach, following Jordà

(2005), to examine the response of price changes to monetary policy shocks. The model specification is as follows:

$$\sum_{h=0}^{H} \log \frac{P_{it+h}}{P_{it-1}} = + \beta_1^h \text{ Debt } 1_{it}\varepsilon_t^{\text{MP}} + \beta_2^h \text{ Debt } 2_{it}\varepsilon_t^{\text{MP}} + \beta_3^h \text{ Debt } 3_{it}\varepsilon_t^{\text{MP}}$$
$$+ \beta_4^h \text{ Debt } 4_{it}\varepsilon_t^{\text{MP}} + \beta_5^h \text{ Debt } 5_{it}\varepsilon_t^{\text{MP}} + \alpha_g^h + \alpha_t^h + \alpha_{\text{firm}}^h + \varepsilon_t^{\text{MP}} + \Gamma_1^h X_{ft} + \varepsilon_{it}, \tag{10}$$

where we interact the monetary policy shock with different debt maturity due dates to investigate whether firms increase their product prices as the loan's due date approaches. In the equation, $\text{Debt}1_{it}$ represents the ratio of debt due within one year, while $\text{Debt}2_{it}$ represents the ratio of debt due between one and two years. Similarly, the variables $\text{Debt}3_{it}$, $\text{Debt}4_{it}$, and $\text{Debt}5_{it}$ are defined accordingly. We control for X_{ft}, which includes basic firm characteristics, as well as fixed effects for firm, product-group, and time.

In Appendix Figure A5, we present the price change responses to various debt maturities, and the corresponding coefficients β_1^h, β_2^h, β_3^h, β_4^h, and β_5^h are displayed in subsequent panels. Notably, in panel (a) of the figure, a distinct price increase is observed in response to debts that are due within one year. Moreover, firms consistently raise their product prices as the due date of the debt approaches in two years and three years. While the response may appear somewhat muted in the pattern of β_4^h, firms still initiate a price increase starting from the 4th year as the due date of the debt due in 5 years approaches, as shown in panel (e).

In the Capital IQ data, we can also observe whether the debt is fixed-rate or floating-rate. Using this information, we run the above specification using only debts of the floating-rate type. The rationale behind this choice is that floating-rate debt is directly linked to the federal funds rates set by monetary policy, potentially resulting in firms' price changes being more responsive to short-term floating-rate debts. The observed pattern is presented in Appendix Figure A6, where the fluctuations are noticeably more dynamic when compared to Figure A5. Of particular interest is panel (b) of the figure, which clearly demonstrates a pattern indicating that firms gradually increase their product pricing as the due date of the debt that matures within two years approaches. This trend is also observable in the case of debts due in three years and five years.

5 Quantitative Model

5.1 Households

(Household's Maximization Objective) We assume there exist a representative household who consumes a variety of differentiated consumption goods indexed by $i \in [0, 1]$. The representative household's objective is to maximize its expected utilities

$$E_0 \sum_{t=0}^{\infty} \beta^t U(X_t, L_t) \tag{11}$$

where X_t is a composite of habit-adjusted consumption of a continuum of differentiated goods. It is expressed in the constant elasticity of substitution (CES) aggregation

$$X_t \equiv \left[\int_0^1 \left(\frac{c_{it}}{m_{i,t}^{\theta}} \right)^{1-\frac{1}{\eta}} di \right]^{\frac{1}{1-\frac{1}{\eta}}}; \quad \theta < 0 \text{ and } \eta > 0, \tag{12}$$

where $c_{i,t}$ is differentiated consumption goods, $m_{i,t}$ is stock of external habit, which can be interpreted as customer capital that producer of goods i accumulated. We denote the price of product i as $p_{i,t}$ in terms of aggregate consumption. Given the CES aggregation, we can solve the consumer's consumption expenditure minimizing problem of $\int_0^1 P_{i,t} c_{i,t} di$ subject to constraint $X_t \equiv \left[\int_0^1 \left(\frac{c_{it}}{m_{i,t}^{\theta}} \right)^{1-\frac{1}{\eta}} di \right]^{\frac{1}{1-\frac{1}{\eta}}}$. From which we can derive the consumer's demand for product i which can be expressed as

$$c_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\eta} m_{i,t}^{\theta(1-\eta)} X_t \tag{13}$$

in which $P_t \equiv \left[\int_0^1 P_{it}^{1-\eta} di \right]^{\frac{1}{1-\eta}}$ is aggregate price index.

(Evolution of Customer Capital) Given the demand function for individual product i, firms can attract additional consumers by undercutting product prices. The mechanism we need to build is that, due to the existence of consumption inertia, firms can enjoy the persistent positive effects on their product demand by reducing their product pricing or providing discounts. This idea is captured in the influential paper Phelps and Winter (1970) and Ravn et al. (2006). In order to incorporate this channel in our model, we assume the following law of motion of evolution of customer base

$$m_{i,t+1} = \rho m_{i,t} + (1 - \rho) c_{i,t} \tag{14}$$

The evolution of customer base indicates that the household's current consumption is weighted sum of all of its past consumption. The parameter ρ captures the speed of customer base depreciation. Firms' revenues are influenced by their accumulated customer capital and the strategic pricing decisions they implement, both of which stem from the dynamic nature of customer capital as modeled in household utility functions. Figure 11 illustrates the evolution of these dynamics.

Panel (a) of Figure 11 demonstrates that firms with greater accumulated customer capital can charge higher prices and achieve higher maximized revenues. The dotted dark red line in panel (a) illustrates the relationship between a firmâs pricing strategy and its corresponding revenues, with the firm possessing higher customer capital compared to those represented by the dark green and red lines. This advantage allows the firm to set higher prices and attain greater revenue. However, several factors deter firms from charging the maximum possible price or extracting the maximum current-period revenues. These considerations arise from the dynamic evolution of customer capital, as shown in Equation 14. A firm that fully exercises its market power by charging the maximum price today risks eroding its future customer capital and consequently reducing its ability to exert market power in subsequent periods. Therefore, firms may choose to restrain their current market power by setting lower prices to preserve or enhance customer capital for future periods. This restraint can be motivated either by a precautionary approach to safeguard against potential future adverse conditions or by a strategic objective to expand market share and strengthen their future market power in the customer market.

The strategic nature of firms' pricing behavior is further illustrated in panel (b) of Figure 11. At period 1, all firms are assumed to have the same initial level of accumulated customer capital. However, the firm represented by the red line is assumed to fully exercise its market power each period by charging the maximum possible price, while the firms represented by the dark green and dark red lines only exercise partial market power, charging 80% and 60% of the maximum possible prices, respectively. Over time, the figure reveals that firms fully exercising their market power (red line) experience a decline in customer capital in subsequent periods. In contrast, the firm in the dark green line, which charges a lower price, also experiences a decline in customer capital, but at a slower rate than the red line. Interestingly, the firm adopting the most conservative pricing strategy, represented by the dark red line, manages to increase its customer capital over time, enhancing its market power further. These starkly different patterns in the evolution of customer capital, driven by the firms' strategic pricing decisions, underscore the dynamic motivations underlying firms' price-setting behavior.

Panel (c) of Figure 11 highlights the significance of the parameter ρ in shaping the evolution of customer capital in response to firms' strategic pricing behavior. In this panel, all firms are assumed to charge the maximum possible price, and the figure illustrates how the dynamics of customer capital vary depending on the value of ρ. The parameter $(1-\rho)$ reflects the speed at which customer capital accumulates, with a higher value of ρ indicating that the evolution of customer capital is less sensitive to the current level of demand, $c_{i,t}$. As shown in panel (c), when ρ is larger, firms experience a smaller reduction in future customer capital even when fully exercising their market power.

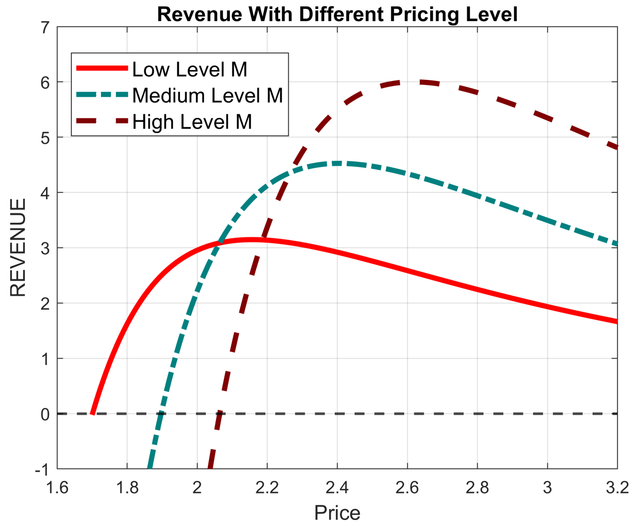
(Household's Budget Constraint) There are four sources of income which can be used to finance the household's consumption: (i) labor income from hours worked, (ii) investment in firms' stocks, (iii) purchase of firms' short-term bonds, (iv) purchase of firms' long-term bonds. The details on the financial instruments will be introduced in the subsequent sections. The household's budget constraint is

$$\mathcal{X}_t + \mathcal{B}^S_{t+1} + \mathcal{B}^L_{t+1} + \mathcal{Q}_t = \mathcal{W}_t \mathcal{L}_t + \mathcal{R}^S_t \mathcal{B}^S_t + \mathcal{R}^L_t \mathcal{B}^L_t + \mathcal{R}^{stock} \mathcal{Q}_{t-1} \tag{15}$$

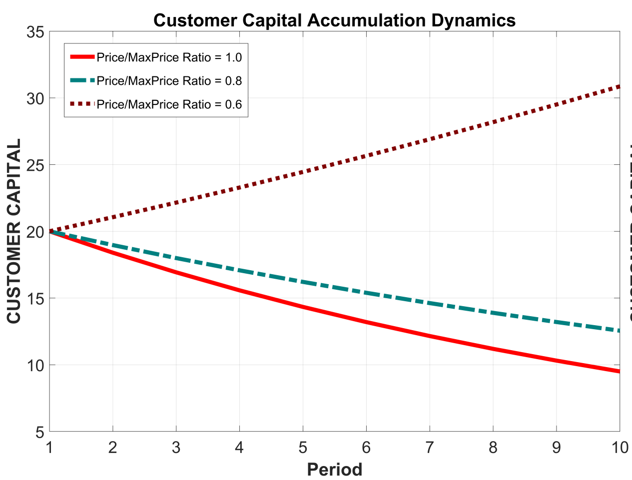
where $\mathcal{R}^S_t$, $\mathcal{R}^L_t$, $\mathcal{R}^{stock}$ are returns on short-term bond, long-term bond, and stocks which will be defined in the subsequent sections. $\mathcal{W}_t \mathcal{L}_t = W_t \int_i L_{i,t} di$ is the household's total labor income, $\mathcal{B}^S_{t+1} = \int_i Q^S_{i,t} B^S_{i,t+1} di$ is the total investment in short-term debt, $\mathcal{B}^L_{t+1} = \int_i Q^L_{i,t} B^L_{i,t+1} di$ is the total investment in long-term debt, and $\mathcal{Q}_t = \int_i Q_{i,t} di$ is total stock holdings. From the household's optimization problem, the stochastic discount factor is given as $\Lambda_{t,t+1} = \beta \frac{U'(C_{t+1})}{U'(C_t)}$.

Figure 11: Dynamics of Customer Capital

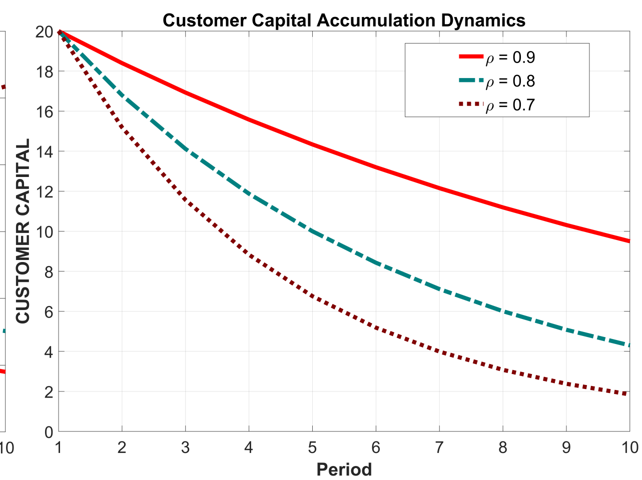
(a) Customer Capital and Firm Revenues



(b) Dynamics with Different Pricing Strategies



(c) Stickiness of Customer Capital



Notes: This figure illustrates the dynamics of customer capital accumulation. Panel (a) shows the relationship between pricing levels and corresponding firm revenue, highlighting how the relationship between price and revenue varies for firms with different levels of customer capital. Panel (b) depicts the relationship between pricing strategy and the evolution dynamics of customer capital, assuming all firms begin with the same level of customer capital. The red line represents the trajectory of customer capital when firms consistently charge the maximum possible price. In contrast, the dotted green line and dark red line illustrate the evolution of customer capital when firms charge only 80% and 60% of the maximum price, respectively. Panel (c) illustrates the evolution of customer capital, assuming all firms start with the same initial level of customer capital and charge the maximum possible price, but experience different rates of customer capital depreciation.

5.2 Heterogeneous Producers

Each firm $i \in [0,1]$ produces differential goods using labor as input and linear production technology. The production function of firm i at period t is given by

$$Y_{it} = A(L_{it})^{\alpha}; \quad 0 < \alpha < 1 \tag{16}$$

where $y_{i,t}$ is firm produced differentiated good, A denotes constant productivity and $L_{i,t}$ is labor input. Then the firm's operating profit $\Pi_{i,t}$ can be expressed as

$$\Pi_{it} = P_{it}Y_{it} - W_t L_{it} \tag{17}$$

where prices for differentiated goods $p_{i,t}$ and wages for labor w_t are both expressed in time t composite good X_t. From the market clearing condition of each differentiated good, we can further express the operating profit $\Pi_{i,t}$ as

$$\Pi_{it} = P_{it}Y_{it} - W_t L_{it} = P_{it}\left[(\frac{P_{it}}{P_t})^{-\eta} m_{it}^{\theta(1-\eta)} X_t\right] - W_t(\frac{Y_{it}}{A})^{\frac{1}{\alpha}} \tag{18}$$

Firms can optimally set $p_{i,t}$ to maximize their profits given the nominal aggregate price index $P_t \equiv \left[\int_0^1 P_{it}^{1-\eta} di\right]^{1/(1-\eta)}$, demand for composite good X_t, and the firm's accumulated customer capital $m_{i,t-1}$.

5.3 Debt Financing

In this framework, firms are assumed to have access to financial markets, enabling them to raise capital through debt issuance. To capture the impact of varying debt maturity structures on product pricing, we allow firms to issue two distinct types of debt: short-term bonds and long-term bonds.

(Short-term Debt) Short-term debt represents a commitment to repay one unit of the composite good, along with a coupon payment c, after one period. At the start of each period t, the outstanding stock of short-term debt is denoted by $B_{i,t}^S$. The firm is required to repay the total amount, $(1+c)B_{i,t}^S$, at the beginning of the subsequent period $t+1$.

(Long-term Debt) Long-term debt entails a commitment to repay a fraction $\gamma \in (0,1)$ of the principal, along with a coupon payment c, after one period. At the start of each period t, the outstanding balance of long-term debt is denoted by $B^L_{i,t}$. In the subsequent period $t+1$, a fraction $(1-\gamma)$ of the bond remains unpaid. The portion of long-term debt rolled over at the beginning of period t is denoted by $(1-\gamma)B^L_{i,t}$.

(Debt Issuance Cost) Debt issuance incurs a cost. We assume a linear issuance cost ζ per unit for both short-term and long-term debt. Additionally, we assume that repurchasing outstanding long-term debt is costless. The functional form of the debt issuance cost is expressed as follows:

$$DIC(B^S_{i,t+1}, B^L_{i,t+1}) = \zeta \left(B^S_{i,t+1} + \ max\{B^L_{i,t+1} - (1-\gamma)B^L_{i,t}, 0\} \right)^2 \tag{19}$$

5.4 Equity Value

Equity holders of firms have the right to collect the firms' dividends as long as the firms are in operation. The dividend is the sum of firm's operating profit $\Pi_{i,t}$ net of debt obligations. Also, the dividend is subject to cash-flow shock which are proportional to the firm's customer capital $m_{i,t-1}$. The dividend can be written by

$$\begin{aligned} d_{i,t} = \Pi_{i,t} &- (1+c)B^S_{i,t} - (c+\gamma)B^L_{i,t} - \sigma z_{i,t} m_{i,t} + Q^S_{i,t} B^S_{i,t+1} + Q^L_{i,t}(B^L_{i,t+1} - (1-\gamma)B^L_{i,t}) \\ &- \zeta \left(B^S_{i,t+1} + \ max\{B^L_{i,t+1} - (1-\gamma)B^L_{i,t}, 0\} \right)^2 \end{aligned}$$

where $\Pi_{it} = P_{it}\left[(\frac{P_{it}}{P_t})^{-\eta} m_{it}^{\theta(1-\eta)} X_t \right] - W_t(\frac{Y_{it}}{A})^{\frac{1}{\alpha}}$ and $z_{i,t}$ is an idiosyncratic firm specific cash-flow shock which follows i.i.d log-normal distribution.

The objective of the firm's managers is to maximize the value of the firm for its shareholders. Managers compare the continuation value of the firm with the exit value, which is zero. If the continuation value falls below zero, the managers opt to default, leading the firm to exit the market. The value firms to its shareholder can be expressed as

$$\begin{aligned} V\left(z_{i,t}, m_{i,t}, B^S_{i,t}, B^L_{i,t}\right) &= \max_{\mathcal{D}_{i,t}} \left[0, V^C(z_{i,t}, m_{i,t}, B^S_{i,t}, B^L_{i,t})\right] \\ = \max_{\mathcal{D}_{i,t}} \Bigg\{ 0, & \max_{P_{i,t}, B^S_{i,t+1}, B^L_{i,t+1}} \underbrace{P_{it}\left[(\frac{P_{it}}{P_t})^{-\eta} m_{it}^{\theta(1-\eta)} X_t \right] - W_t(\frac{Y_{it}}{A})^{\frac{1}{\alpha}}}_{\text{operating profit}} - \underbrace{(1+c)B^S_{i,t} - (c+\gamma)B^L_{i,t}}_{\text{repayment of debt}} - \underbrace{\sigma z_{i,t} m_{i,t}}_{\text{cash-flow shock}} \\ &+ \underbrace{Q^S_{i,t} B^S_{i,t+1} + Q^L_{i,t}(B^L_{i,t+1} - (1-\gamma)B^L_{i,t})}_{\text{new debt issuance}} - \underbrace{\zeta \left(B^S_{i,t+1} + \ max\{B^L_{i,t+1} - (1-\gamma)B^L_{i,t}, 0\} \right)^2}_{\text{debt issuance cost}} \\ &+ E_t\left[\Lambda_{t,t+1} V\left(z_{i,t+1}, m_{i,t+1}, B^S_{i,t+1}, B^L_{i,t+1}\right)\right] \Bigg\} \end{aligned} \tag{20}$$

where $m_{i,t+1} = \rho m_{i,t} + (1-\rho)C_{i,t} = \rho m_{i,t-1} + (1-\rho)\left[(\frac{P_{it}}{P_t})^{-\eta} m_{it}^{\theta(1-\eta)} X_t\right]$. Additionally, firms face financial frictions that require them to maintain a positive cash flow at all times, and they are subject to an upper limit on borrowing (This condition resembles the upper limit constraint on dividend payouts, where equity issuance is permitted in the model. In the presence of equity issuance, firms are restricted from depleting their existing capital by distributing excessive dividends). The financial friction is expressed as below:

$$\begin{aligned} &\underbrace{P_{it}\left[(\frac{P_{it}}{P_t})^{-\eta} m_{it}^{\theta(1-\eta)} X_t\right] - W_t(\frac{Y_{it}}{A})^{\frac{1}{\alpha}}}_{\text{operating profit}} - \underbrace{(1+c)B_{i,t}^S - (c+\gamma)B_{it}^L}_{\text{repayment of debt}} - \underbrace{\sigma z_{it} m_{it}}_{\text{cash-flow shock}} \\ &+ \underbrace{Q_{it}^S B_{it+1}^S + Q_{it}^L (B_{it+1}^L - (1-\gamma)B_{it}^L)}_{\text{new debt issuance}} \geq 0 \end{aligned} \tag{21}$$

5.5 Model Timing

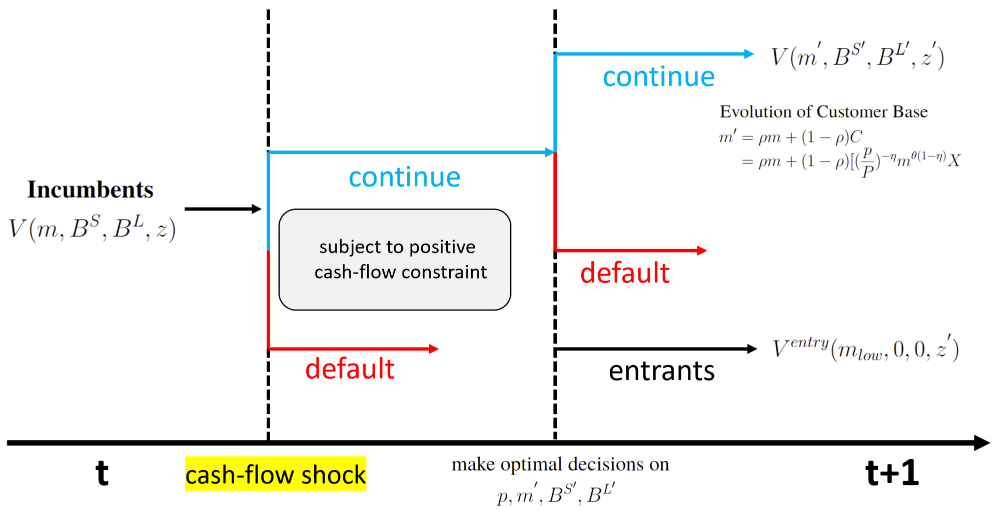
Each period, the firm's profits are subject to a cash-flow shock, which is observed at the beginning of the period. Firms are required to repay the entire outstanding stock of short-term debt $B_{i,t}^S$ plus coupon, along with a fraction $\gamma B_{i,t}^L$ of their long-term debt plus coupon. These debt obligations, combined with the realized cash-flow shock, compel firms to strategically determine their product pricing and optimize their financial resource acquisition by issuing both short-term and long-term debt. After making decisions regarding optimal pricing and financing, firms must also decide whether to default.

There are two potential triggers for default: (1) Financial frictions necessitate that the firm maintains a positive cash-flow and operates under a borrowing limit. The firm exits the market if this constraint is violated, i.e., it defaults if it cannot satisfy Equation 21. (2) Even if the firm satisfies the positive cash-flow constraint, it will choose to default and exit the market if the optimized continuation value falls below zero. The timing of the model proceeds as follows:

(i) **(Default Decision)** Each firm begins period t with a cash-flow shock, customer capital, outstanding short-term debt, and long-term debt $(z_{i,t}, m_{i,t-1}, B_{i,t}^S, B_{i,t}^L)$. At the start of the period, the firm assesses whether it can satisfy the positive cash-flow constraint; if this condition cannot be met, the firm defaults.

(ii) **(Price Setting and Financing Decision)** If the firm is able to satisfy the positive cash-flow constraint, it then sets strategic pricing and optimizes its financial resource allocation by determining the optimal levels of short-term and long-term debt issuance. Following this optimization, if the firm's continuation value falls below zero, the firm defaults and exits the market. However, if the continuation value remains positive, the firm proceeds to the next period.

Figure 12: Timing of the Model



5.6 Financial Markets

Firms can finance their productions through the financial markets. Creditors in the financial market are assumed to be risk neutral. They invest in firm's short-term debt and long-term debt as long as the break-even condition of the debt is satisfied. The short-term debt and long-term debt have equal seniority. If the firm chooses to default, we assume the creditors get zero profits. The lenders' zero-profit conditions give the debt pricing kernel as below:

$$
\begin{aligned}
&Q^S_{it}(z_{it}, m_{it}, B^S_{it+1}, B^L_{it+1}) \\
&= E_t\Lambda_{t,t+1}\int_{z_{it+1}}\left\{(1-\mathbb{D}_{it+1})(1+c) + \mathbb{D}_{it+1}\times 0\right\}d(z_{it+1}) \\
&Q^L_{i,t}(z_{i,t}, m_{i,t}, B^S_{i,t+1}, B^L_{i,t+1}) \\
&= E_t\Lambda_{t,t+1}\int_{z_{i,t+1}}\left\{(1-\mathbb{D}_{i,t+1})(\gamma + c + (1-\gamma)Q^L_{i,t+1}) + \mathbb{D}_{i,t+1}\times 0\right\}d(z_{i,t+1})
\end{aligned}
\tag{22}
$$

5.7 General Equilibrium

We now turn to the equilibrium of the economy. A firm maximizes its shareholder value by maximizing the objective function in Equation 20 subject to the positive cash-flow constraint 21. In the equilibrium we restrict our interest to Markov perfect equilibrium in which firms take their future best responses as given and choose its best response today. The value function of continuation $V^C(z_{i,t}, m_{i,t}, B^S_{i,t}, B^L_{i,t})$ is a function of the firm's state at the beginning of each period. At the beginning of each period, the firms observes the cash-flow shock $z_{i,t}$ which will has impacts on the revenues that the firm can collect after a production cost. Also, in order for firms to continue operation, firms need to repay all of its existing debt. This includes all of the outstanding amount of short-term debt $B^S_{i,t}$ and a fraction of its outstanding amount of long-term debt $\gamma B^L_{i,t}$. Given these considerations, firms choose a set of optimal policy $\phi(m_{i,t}, B^S_{i,t}, B^L_{i,t}, z_{i,t}) = \{P_{i,t}, m_{i,t+1}, B^S_{i,t+1}, B^L_{i,t+1}, \mathbb{D}_{i,t}\}$ to maximize its shareholder profits. The recursive formulation of the firm's problem is defined as follows:

Firm Eqity Value $$V(m, B^S, B^L, z) = \max_{\mathbb{D}} \left[\underbrace{V_D(m, B^S, B^L, z)}_{=0},\ V_C(m, B^S, B^L, z) \right]$$

Continuation Value

$$\begin{aligned}V_C(m, B^S, B^L, z) = \max_{p, B^{S'}, B^{L'}} & p[(\frac{p}{P})^{-\eta} m^{\theta(1-\eta)} X] - W(\frac{Y}{A})^{\frac{1}{\alpha}} - (1+c)B^S - (1+\gamma)B^L \\ & - \sigma m z + Q^S B^{S'} + Q^L(B^{L'} - (1-\gamma)B^L) - \zeta \left(B^{S'} +\ max\{B^{L'} - (1-\gamma)B^L, 0\} \right)^2 \\ & + E\left[\Lambda V\left(z', m', B^{S'}, B^{L'}\right)\right] \Bigg\}\end{aligned}$$

Evolution of Customer Base $$m' = \rho m + (1-\rho)C = \rho m + (1-\rho)[(\frac{p}{P})^{-\eta} m^{\theta(1-\eta)} X]$$

Debt Pricings $$Q^S(m, B^S, B^L, z) = E\Lambda \int_z \left\{ (1-\mathbb{D}')(1+c) + \mathbb{D}' \times 0 \right\} d(z)$$

$$Q^L(m, B^S, B^L, z) = E\Lambda \int_z \left\{ (1-\mathbb{D}')(\gamma + c + (1-\gamma)Q^{L'}) + \mathbb{D}' \times 0 \right\} d(z)$$

Positive Cash-flow Constraint

$$\begin{aligned}& p\left[(\frac{p}{P})^{-\eta} m^{\theta(1-\eta)} X \right] - W(\frac{Y}{A})^{\frac{1}{\alpha}} - (c+1)B^S - (c+\gamma)B^L - \sigma z m \\ & + Q^S(B^{S'}) + Q^L(B^{L'} - (1-\gamma)B^L) \geq 0 \end{aligned} \tag{23}$$

Given the firm's policy function from the recursive problem, we can define the stationary distribution of the economy.

$$\mu\left(m', B^{S'}, B^{L'}, z'\right) = \int_m \int_{B^S} \int_{B^L} \int_z \mathscr{I}\left(m', b^{S'}, b^{L'}; m, b^S, b^L, z\right) [1 - \mathbb{D}(m, b^S, b^L, z)] \\ \times \pi[z'|z] \mu(m, b^S, b^L, z)\, dm\, dB^S\, dB^L\, dz + \mathscr{M}\left(m', B^{S'}, B^{L'}, z'\right) \tag{24}$$

in which the indicator function $\mathscr{I}\left(m', b^{S'}, b^{L'}; m, b^S, b^L, z\right) = 1$ when $m', B^{S'}, B^{L'}$ corresponds to the firm's optimal choice strategy $\phi(m, B^S, B^L, z) = \{m', B^{S'}, B^{L'}\}$. Also, there is endogenous default of firms when $\mathbb{D}(m, b^S, b^L, z) = 1$. The function $\mathscr{M}\left(m', B^{S'}, B^{L'}, z'\right)$ is entry of firms and we assume that the mass of entry of firms is equal to M at $m = m_{lowest}, B^S = 0, B^L = 0, z = z_{lowest}$. This means that the entry of firms have the lowest possible level of custoemr capital and cash-flow shock and they start from the zero amount of outstanding debts. In the stationary equilibrium the total mass of firms of the economy is fixed and the mass of entry M is constant.

Definition (Stationary Equilibrium) The stationary equilibrium of the economy is composed of (i) the values functions $V(m, B^S, B^L, z)$, $V_C(m, B^S, B^L, z)$, (ii) a policy vector $\phi(m, B^S, B^L, z) = \{p, m, B^S, B^L, \mathbb{D}\}$, (iii) pricing kernels for short-term debt and long-term debt $Q^S(m, B^S, B^L, z)$, $Q^L(m, B^S, B^L, z)$, (iv) household's aggregate consumption X, and labor supply L, (v) aggregate price levels P and W, (vi) the stationary distribution μ^* and equilibrium mass of entrants $\mathscr{M}^*$, such that:

1. The value functions $V(m, B^S, B^L, z)$, $V_C(m, B^S, B^L, z)$ and policy functions $\phi(m, B^S, B^L, z) = \{p, m, B^S, B^L, \mathbb{D}\}$ solves the firm's maximization problem (23).

2. The equilibrium price of short-term debt and long-term debt are determined in the financial markets as in (22).

3. The representative household chooses the optimal level of aggregate consumption X and labor supply L to maximize household's utility in (11) given the equilibrium wage W.

4. The labor market and final goods market clears. The market clearing condition and aggregate price is given by

$$L = \int_m \int_{B^S} \int_{B^L} \int_z l(m, B^S, B^L, z) dz\, dB^L dB^S dz, X = \left[\int_0^1 \left(\frac{Y_{it}}{m_{i,t}^{\theta}}\right)^{1-\frac{1}{\eta}} di\right]^{\frac{1}{1-\frac{1}{\eta}}} \tag{25}$$

6 Quantitative Analysis

6.1 Computation Methods

We employ global solution methods, where the objective functions are estimated using value function iteration techniques. Several challenges arise in computing the equilibrium of our model.

First, the associated objective function involves four state variables (m, B^S, B^L, z), and the computational burden increases significantly as the dimensionality of the state space expands. To address this, we implement collocation methods, where the objective functions are fully vectorized, and integrals are pre-computed to enhance computational efficiency.

Second, the model incorporates numerous nonlinearities and asymmetries, including firm default decisions and the issuance of defaultable short-term and long-term bonds, making the problem particularly challenging. Many studies addressing defaultable corporate bonds, such as Jungherr et al. (2022), Jungherr and Schott (2022), Jungherr and Schott (2021) tackle this issue by estimating the default threshold of shocks within the model. Rather than estimating the threshold at each period, we leverage the firm's policy function to directly determine the default probability for each state.

Third, the pricing kernel for long-term bonds exhibits forward-looking behavior. As indicated by Equation (22), the pricing kernel for long-term bonds is a function of future bond prices, which are in turn influenced by the firmâs future decisions. To address this, we employ a time-iteration procedure, solving the model backwards by first tackling the firmâs terminal problem in a finite horizon. We then iterate backwards over time until the value functions and pricing kernels converge. Such time-iteration techniques are widely used in the macro-finance and sovereign debt default literature (as in Hatchondo et al. (2010), Hatchondo et al. (2016)). An additional advantage of this approach is that it significantly reduces computation time by using a one-loop algorithm that iterates simultaneously on the value and bond price functions, rather than a two-loop algorithm, where the outer loop iterates on bond prices and the inner loop on value functions.

We now recast the firm's problem in collocation notations. first define vectors of state variables to vectorize the state variables in the model. We define $\mathbb{S} = [\vec{s_1}, \vec{s_2}, \vec{s_3}, \vec{s_4}]$ in which

$$\begin{aligned}
\vec{s_1} &= \mathbf{1}_{N_S \times N_L \times N_z} \otimes \vec{m} \\
\vec{s_2} &= \mathbf{1}_{N_L \times N_z} \otimes (\vec{B^S} \otimes \mathbf{1}_{N_m}) \\
\vec{s_3} &= \mathbf{1}_{N_z} \times (\vec{B^L} \otimes \mathbf{1}_{N_m \times N_S}) \\
\vec{s_4} &= \vec{z} \times \mathbf{1}_{N_m \times N_S \times N_L}
\end{aligned} \tag{26}$$

We express the value function of firms using collocation methods, note that $E[V(\mathbb{S})] = \Phi(\mathbb{S})\vec{c^e}$ and $V_C(\mathbb{S}) = \Phi(\mathbb{S})\vec{c}$, in which

$$\begin{aligned}
\Phi(\mathbb{S})\vec{c} = \max_{\vec{p}, \vec{B}^{S'}, \vec{B}^{L'}} & (\vec{p} - \frac{w}{A}) \left[(\frac{\vec{p}}{P})^{-\eta} X + \theta \vec{m} \right] - (1+c)\vec{B}^S - (c+\gamma)\vec{B}^L - \sigma \vec{m} \odot \vec{z} \\
& + \vec{Q}^S \odot \vec{B}^{S'} + \vec{Q}^L \odot (\vec{B}^{L'} - (1-\gamma)\vec{B}^L) - \zeta \left(\vec{B}^{S'} + \ max\{\vec{B}^{L'} - (1-\gamma)\vec{B}^L, 0\} \right)^2 \\
& + \Lambda \Phi([\vec{m}', \vec{B}^{S'}, \vec{B}^{L'}], \vec{z}) \vec{c^e}
\end{aligned}$$

$$\begin{aligned}
\Phi(\mathbb{S})\vec{c^e} &= (\mathbf{1}_{N_z} \otimes f') \otimes \mathbf{I}_{N_m \times N_s \times N_L} \max \{\vec{\mathbb{O}},\ \Phi(s)\vec{c}\} \\
&= (\mathbf{1}_{N_z} \otimes f') \otimes \mathbf{I}_{N_m \times N_s \times N_L} [\mathbf{I}(s) \odot \mathbb{O} + (\mathbf{1}_N - \mathbf{I}(s)) \odot \Phi(s)\vec{c}]
\end{aligned} \tag{27}$$

We solve for the steady-state equilibrium using value function iteration with collocation methods. I discretize the state space $\mathbb{S} = (\vec{m}, \vec{B}^S, \vec{B}^L, \vec{z})$ into $N_m \times N_{B^S} \times N_{B^L} \times N_z$ grid points. The details of the solution algorithm is outlined in the Appendix B.

6.2 Model Results with Short-term Debt

In this section, we present the results of our model. To explore the mechanism through which short-term debt and cash-flow shocks influence the firm's strategic product pricing behavior, we first simplify the model to highlight the role of short-term debt in shaping the firm's pricing decisions.

Figure (13) presents the estimated value functions from our model. Panels (a) and (b) compare the value functions under different cash-flow shocks. The value function drops to zero when the firm is unable to maintain positive shareholder value and opts for default. Firms tend to default, regardless of their accumulated customer capital or outstanding short-term debt, when exposed to sufficiently high cash-flow shocks.

Moreover, as illustrated in panel (c), the firm's default probability is influenced by both the level of customer capital it has accumulated and the outstanding short-term debt that must be repaid in the upcoming period.

The firm's default probability decreases with higher levels of customer capital but increases as the firm issues more short-term debt. The pricing kernel, determined by the break-even condition in financial markets, is illustrated in panel (d). In this panel, we observe that investors anticipate higher default risk when a firm issues large amounts of debt, leading to greater discounting of the debt price. However, if the firm has accumulated significant customer capital, the debt price is discounted less. Firms with more customer capital are better positioned to survive even with higher debt levels, resulting in a smaller discount on debt issuance prices for firms with greater customer capital.

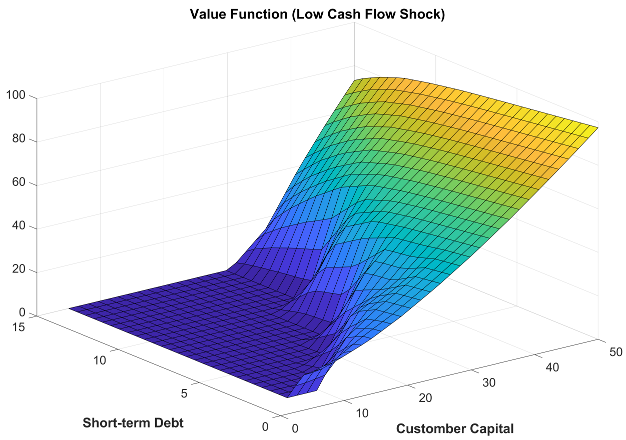
Next, Figure (**??**) illustrates the firm's policy rules for product pricing, markups, the price-to-maximum-price ratio, and decisions regarding customer capital. The lines in the graph, represented by different colors, correspond to firms exposed to varying levels of cash-flow shocks. We compare firms with the same amount of customer capital, so the variation in policy responses stems from differences in cash-flow shocks and the amount of outstanding debt that must be repaid immediately. The black line reflects the decisions of firms facing the highest level of cash-flow shock, while the green line represents firms exposed to a high level of cash-flow shock. The blue and red lines represent firms facing medium and low levels of cash-flow shock, respectively.

Panel (a) illustrates the product pricing decisions of firms. Notably, when the level of short-term debt is low, all firms charge similar prices, with the exception of those exposed to the highest level of cash-flow shock. Firms facing the most severe shock (black line) set higher prices compared to others. As the outstanding short-term debt gradually increases, we observe that the black line truncates at a certain threshold. This occurs because firms default, and no pricing decisions are made once a firm enters default.

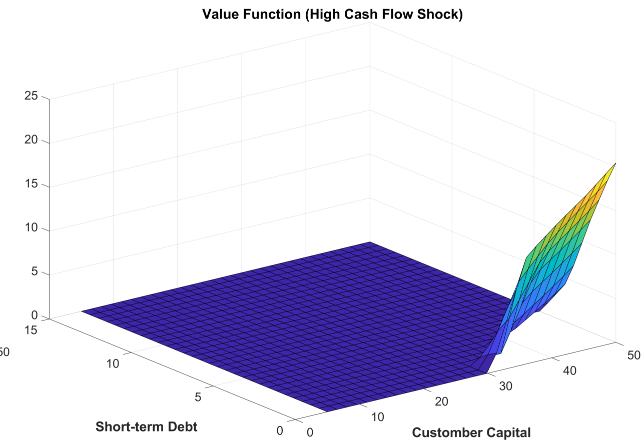
This indicates that the firm represented by the black line raises prices in an effort to survive. However, the firm is unable to sustain operations once its debt obligations exceed a certain threshold. After this threshold, around 4.5, firms represented by the green and blue lines begin to gradually increase their prices. This reflects their willingness to sacrifice customer capital to survive, as they face a higher level of short-term debt that

Figure 13: Estimated Value Functions and Pricing Kernel

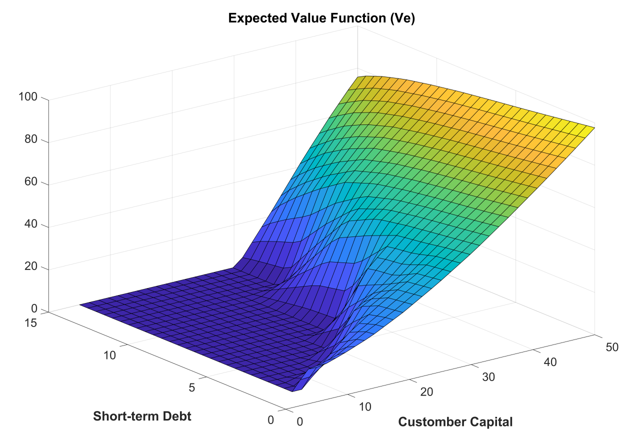
(a) Value Function (Low Cash Flow Shock)



(b) Value Function (High Cash Flow Shock)



(c) Expected Value Function (Ve)



(d) Short-term Debt Pricing Kernel

Notes: This figure displays the estimated variables in the model when firms are allowed to issue only short-term debt. The x-axis represents the level of outstanding short-term debt, while the y-axis represents the level of customer capital.

must be repaid immediately. The increase in product pricing allows these firms to generate more revenue in the current period to meet their debt obligations and continue operations. Additionally, the firm represented by the green line raises prices more sharply than the blue line, as it faces a more severe cash-flow shock and requires greater revenue to survive. In contrast, the firm in red does not raise prices despite the increased level of short-term debt, as it is exposed to the lowest level of cash-flow shock and can still operate without raising prices. However, as debt obligations continue to rise, surpassing a threshold around 12, the firm in red eventually increases its prices. This indicates that it too faces mounting debt pressure and must raise revenues through higher prices to meet its obligations.

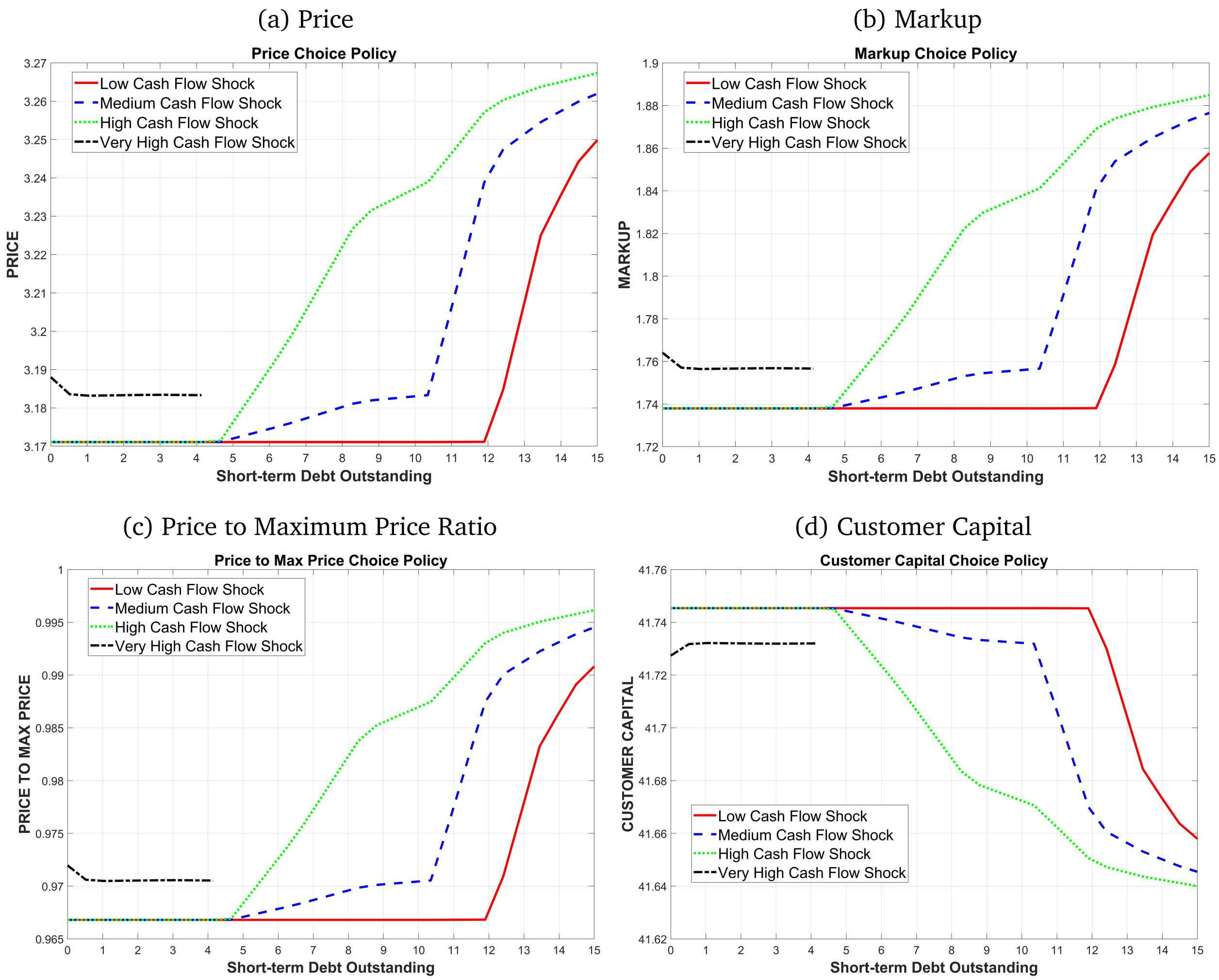
The pricing mechanism discussed in panel (a) is further evidenced in panel (b), which illustrates the relationship between firms' markup decisions and the outstanding short-term debt across varying levels of exposure to cash-flow shocks. Firms are generally reluctant to raise their markups as long as they can meet their debt obligations through current revenues, net of the cash-flow shock. However, as their debt burden increases, firms raise markups to generate higher revenues at the expense of future customer capital. Additionally, firms facing more severe cash-flow shocks exhibit less patience in restraining price increases, despite the negative impact on their customer capital, as the need to meet immediate debt obligations becomes more pressing.

In panel (c), the “maximum price" refers to the price at which firms can achieve their highest possible revenue. Charging this price implies that firms are fully leveraging their market power based on their accumulated customer capital. A price-to-maximum-price ratio below 1 indicates that firms are not fully utilizing their market power. As shown in panel (c), firms tend to reserve this ability when they face lower debt repayment obligations (i.e., lower levels of outstanding short-term debt) and less severe cash-flow shocks. However, as debt repayment obligations increase and cash-flow shocks worsen, firms become less patient and more inclined to fully exploit their market power in order to navigate the financial distress and mitigate default risk.

The graph in Panel (d) represents the counterpart to the dynamics observed in Panel (a). When firms choose to raise prices and markups to navigate the immediate challenges of repaying debt and surviving negative cash-flow shocks, this decision comes at the cost of eroding future customer capital. This trade-off is clearly illustrated in Panel (a), where short-term survival strategies reduce the firm's ability to sustain customer capital in the long run.

Figure (15) illustrates the policy rules of firms, holding their exposure to cash-flow shocks constant. The different colored lines represent firms with varying levels of existing customer capital. The firm represented by the black line possesses the largest amount of customer capital, followed by the firm in green, which has the second-largest amount. The firm in blue has a medium level of customer capital, while the firm in red has the lowest level.

Figure 14: Firm's Decision Rules



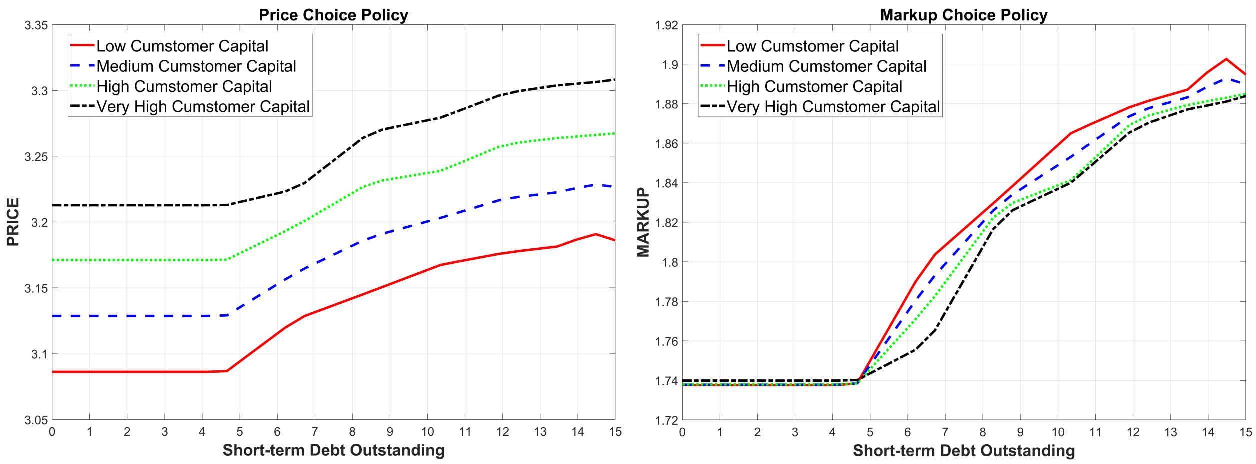
Notes: This figure illustrates the policy functions of firms when they are restricted to issuing only short-term debt. All firms share the same amount of customer capital but face varying levels of negative cash-flow shocks. The figure highlights the differing policy responses based on the level of outstanding short-term debt and the degree of exposure to negative cash-flow shocks.

6.3 Model Results with Short- and Long-term Debt

In this section, we present the complete model that incorporates both short-term and long-term debt. Firms in this model face a recurring need to issue debt, driven by negative cash-flow shocks that occur in every period. These shocks create liquidity challenges for firms, as they must simultaneously manage debt repayments, labor costs, and other financial obligations while ensuring a positive cash flow. The primary revenue

Figure 15: Firm's Decision Rules

(a) Price (b) Markup



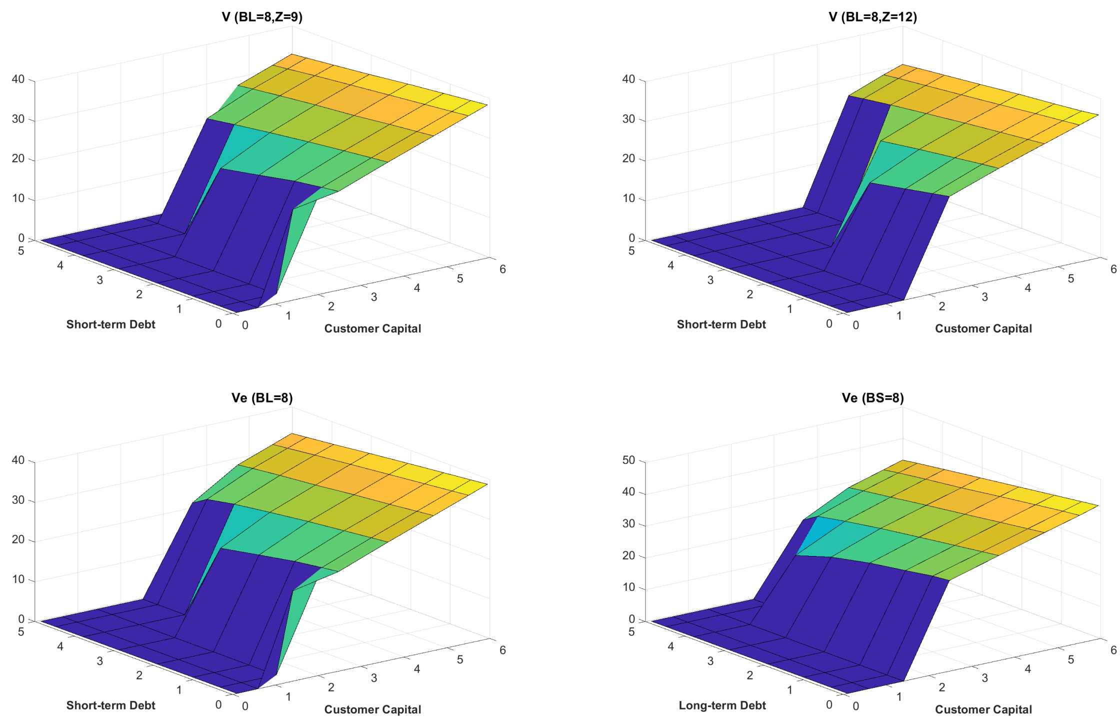
Notes: This figure illustrates the policy functions of firms limited to issuing only short-term debt, all of which are subject to the same level of negative cash-flow shock. The figure highlights varying policy responses based on the level of outstanding short-term debt and the accumulation of customer capital.

source is product sales, but when revenue falls short, firms turn to debt issuance to avoid default.

A key consideration in firms' financial strategy is the balance between maintaining liquidity and minimizing future losses in customer capital due to excessive price increases. Raising prices may provide immediate revenue but risks losing future customers. Hence, firms have incentives to issue debt as a means of smoothing cash flow and preserving their customer capital.

Firms also aim to optimize their capital structure by deciding how much short-term and long-term debt to issue. The advantage of long-term debt is that only a portion γ of the principal must be repaid each period, allowing firms to maintain a certain level of outstanding debt stock to reduce debt issuance costs, which are quadratic. However, an excessive reliance on long-term debt can result in debt overhang, increasing the risk of default. Investors, anticipating this risk, will heavily discount the price of long-term debt, making it more expensive to issue. Thus, firms face the challenge of finding the optimal mix of short-term and long-term debt. While long-term debt reduces the need for frequent refinancing, over-reliance can increase the cost of new debt. By carefully balancing the two types of debt, firms can efficiently manage their financing needs.

Figure 16: Firm's Value Functions (V & Ve)

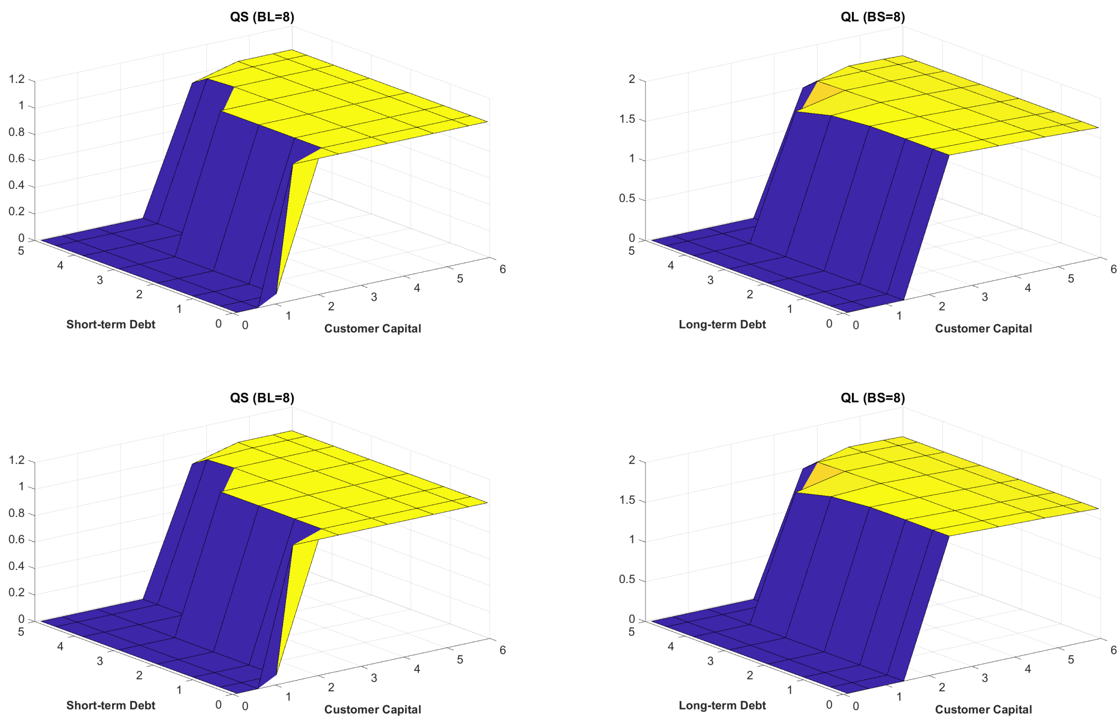


Notes: This figure presents the estimated value function and continuation value function for firms in the full model, which allows issuance of both short-term and long-term debt. It illustrates how the firm's value varies with different levels of outstanding short-term debt and accumulated customer capital, while holding outstanding long-term debt (or short-term debt) and exposure to cash-flow shocks constant.

Figure 16 and Figure 17 shows our estimated results of four main objects: 1) the value function $V(m, B^S, B^L, z)$, (2) continuation value function $V(m, B^S, B^L)$, (3) short-term debt pricing kernel $Q^S(m, B^S, B^L)$, and (4) long-term debt pricing kernel $Q^L(m, B^S, B^L)$. The value functions illustrate that firms derive greater value from accumulating customer capital, which enhances their capacity to generate future cash flows. However, an increase in both short-term and long-term debt obligations diminishes the firm's value due to the heightened default risk associated with these liabilities. Furthermore, the firm's value is adversely affected by more severe cash-flow shocks, highlighting the negative consequences of financial constraints on the firm's long-term viability.

The pricing kernels for short-term and long-term debt reveal that customer capital and the volume of debt issuance are key determinants of debt pricing. Firms with greater customer capital face a lower likelihood of default, which reduces their cost of financing.

Figure 17: Firm's pricing Kernels (QS & QL)

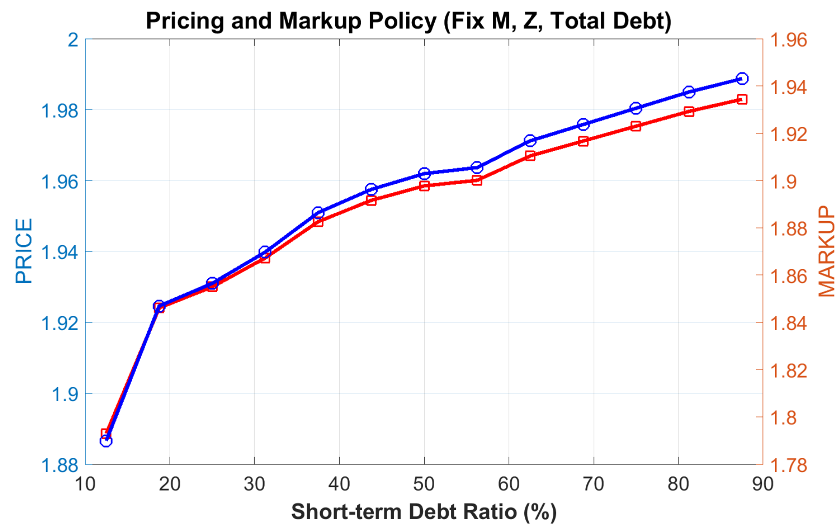


Notes: This figure presents the estimated short-term debt and long-term debt pricing kernels in the full model, which allows issuance of both short-term and long-term debt. It illustrates how the pricing kernel varies with different levels of outstanding short-term debt and accumulated customer capital, while holding outstanding long-term debt (or short-term debt) and exposure to cash-flow shocks constant.

However, when a firm issues excessive amounts of either short-term or long-term debt, investors anticipate a higher probability of future default. This increased risk is reflected in the discounted debt prices, raising the firm's overall cost of issuing additional debt.

After solving the model, we examine how firms adjust their product pricing and markup decisions in response to their debt repayment schedules. Figure 18 presents the product pricing strategies relative to the proportion of short-term debt in the firms' debt portfolios. To explore how debt composition influences pricing behavior, we compare firms that have the same level of accumulated customer capital and exposure to negative cash flow shocks. Importantly, we control for the total level of debt by holding it constant across firms, allowing us to isolate the impact of the short-term debt ratio. This approach enables us to assess whether, even when the total debt level is fixed, firms facing a higher proportion of short-term debt - hence greater pressure from imminent debt repayments - adjust their

Figure 18: Firm's Pricng & Markup Decisions



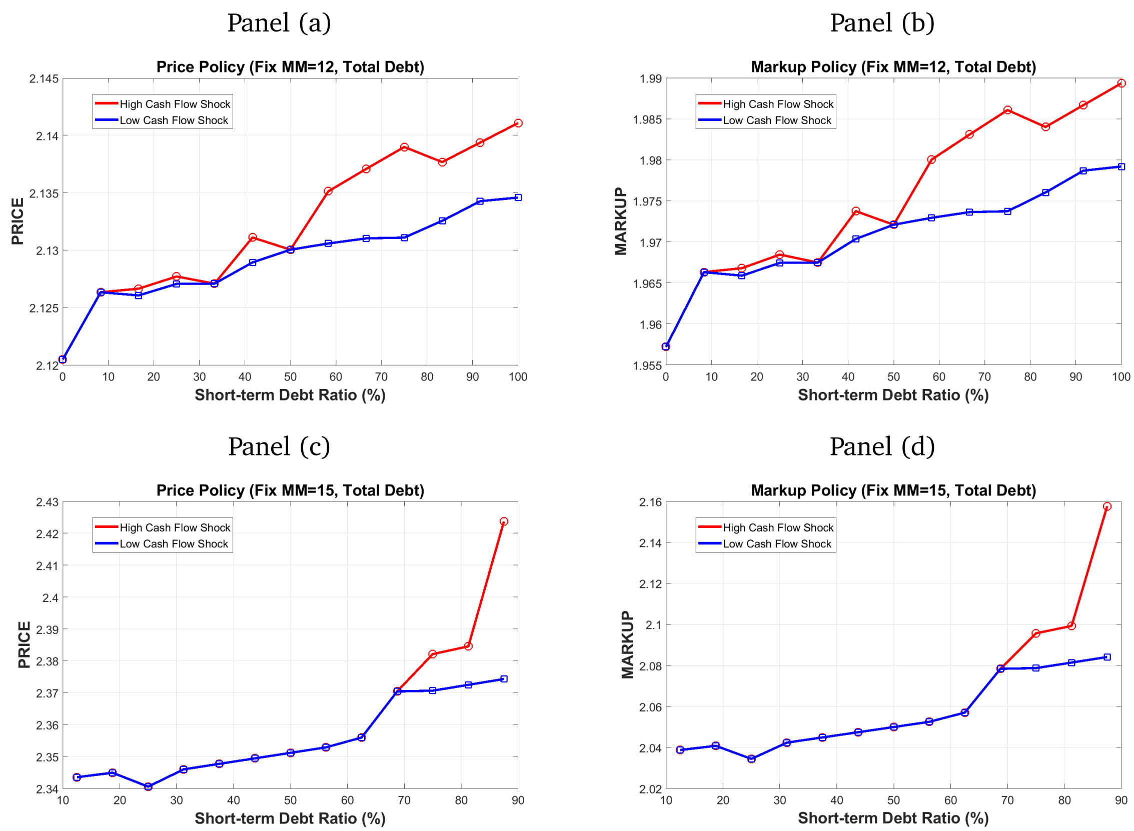
Notes: This figure presents the firm's optimal policies for price and markup in the full model, which allows issuance of both short-term and long-term debt. The left axis represents the price level, and the right axis represents the markup level. This figure illustrates the firmâs pricing strategy as the ratio of short-term debt to total debt varies, while holding total debt, customer capital, and cash-flow shock exposure constant.

pricing differently. The blue line in Figure 18 represents the firm's pricing decision, while the red line illustrates its markup strategy. Both pricing and markup decisions indicate that, despite a constant total debt level, firms with a higher proportion of short-term debt raise prices and markups more aggressively compared to firms with lower proportions of short-term debt, suggesting that the pressure of imminent repayments drives these decisions.

Figure 19 presents another set of results demonstrating that, although the total amount of outstanding debt remains the same, firms with higher short-term debt repayment obligations tend to raise their prices and markups more significantly than firms with fewer imminent repayment commitments. Additionally, when firms face a greater negative cash-flow shock, they become more impatient and more in need of immediate cash to avoid default. To illustrate this mechanism, each panel of Figure 19 compares firms exposed to a more severe cash-flow shock (red line) with those facing less exposure (blue line).

In Panels (a) and (b), firms have the same levels of customer capital and total debt outstanding. In Panels (c) and (d), firms also share the same level of customer capital and total debt outstanding, but they hold more customer capital than those in Panels (a) and

Figure 19: Firm's Pricng & Markup Decisions



Notes: This figure presents the firm's optimal policies for price and markup in the full model, which allows issuance of both short-term and long-term debt. It illustrates how the pricing and markup strategies change as the ratio of short-term debt to total debt increases, with total debt and accumulated customer capital held constant. Additionally, it compares the impact of different cash-flow shock exposure levels on the firmâs optimal pricing and markup decisions.

(b), resulting in higher markups and prices. The findings in Figure 19 reveal that, even with identical amounts of total debt, firms with larger short-term repayment obligations feel greater pressure, prompting them to increase prices and markups more than firms with less repayment pressure. Furthermore, the differing pricing behaviors between the red and blue lines indicate that firms more severely impacted by cash-flow shocks tend to raise prices more aggressively compared to those facing milder shocks. This suggests that, even when both the total debt and short-term debt ratios are fixed, firms with greater exposure to negative cash-flow shocks feel more pressure on default, leading them to raise prices and markups to secure higher revenues and cash flows to mitigate the default risk.

7 Conclusion

In this paper, we study the importance of debt maturity profiles in firms' price setting behaviors. We find that firms adjust their product pricing strategies differently based on their varying debt maturity structures. Specifically, firms with a high proportion of debt that is due within one or two years tend to increase their product prices as a means to increase their revenues. This finding implies that firms strategically adjust their product pricing to fulfill their debt obligations and mitigate rollover risk.

This is the first paper that investigates the relationship between a firm's product pricing and its debt maturity profile. The findings of this paper are particularly important, given that the average debt maturity is significantly shortened during periods of financial crisis.

Moreover, this finding holds substantial policy implications, illuminating the efficacy of the Federal Reserve's unconventional monetary policies, exemplified by the Maturity Extension Program (MEP), as a potent tool in relieving corporate debt roll-over risks. These findings underscore the instrumental role of such policies in advancing the Federal Reserve's objective of maintaining price stability within the U.S. economy.

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A Appendix

A.1 Steps in Cleaning S&P Capital IQ Data

(1) we drop observations with missing gvkey and period end date (the ending date of the financial reporting period). These two variables are important in merging Capital IQ data with Compustat data. One of the caveats in Capital IQ data is that a lot of observations have the period end date, which is not the actual ending date of the financial reporting period. In order to minimize the error of the recorded period end date in Capital IQ data, we modified the period end date in Capital IQ to the ending date of the financial reporting period in Compustat within ± 30 days of the window. For those variables that can not be matched within these windows, we use ± 15 days of the window to approximate the period end date and the nearest possible date of the financial reporting period.

(2) Since the Capital IQ data records outstanding amounts in the original currency, we also converted the amounts to USD dollars using IBES monthly exchange rate.

(3) The observations in Capital IQ data not only contain the actual amount of outstanding debt but also contain the maximum credit limit for each item that can be drawn by the borrower as illustrated in Appendix Table A3. To avoid duplicated loan amounts, we exclude item observations that recorded the maximum credit limit for each loan item.

(4) Given the presence of numerous duplicate entries in the Capital IQ dataset, we refine the data by leveraging details such as loan amounts, loan types, and maturity dates to address redundancy. For each firm, multiple records of the same loan may exist, differing only by the reporting date. To resolve these, we classify loans as identical if they have the same loan amount and type. In such instances, we retain only the record with the latest reporting date, ensuring that our dataset captures the most recent and accurate information while removing redundant entries.

(5) Despite the data refinement in step (4), a significant number of duplicate entries remain. To address this, we leverage the unique identifier (ID) information provided by S&P Capital IQ, which tags each company's specific debt obligation. For each unique identifier corresponding to a particular debt obligation, we retain only the record with the most recent reporting date. This approach ensures that our dataset is streamlined, capturing the most up-to-date information while eliminating redundant records.

(6) Even after completing the procedure in step (5), some redundant loan records remain for each company. This occurs because certain debt obligations are recorded as duplicates even with the same reporting date. To enhance the accuracy of our dataset, we cross-verify this information

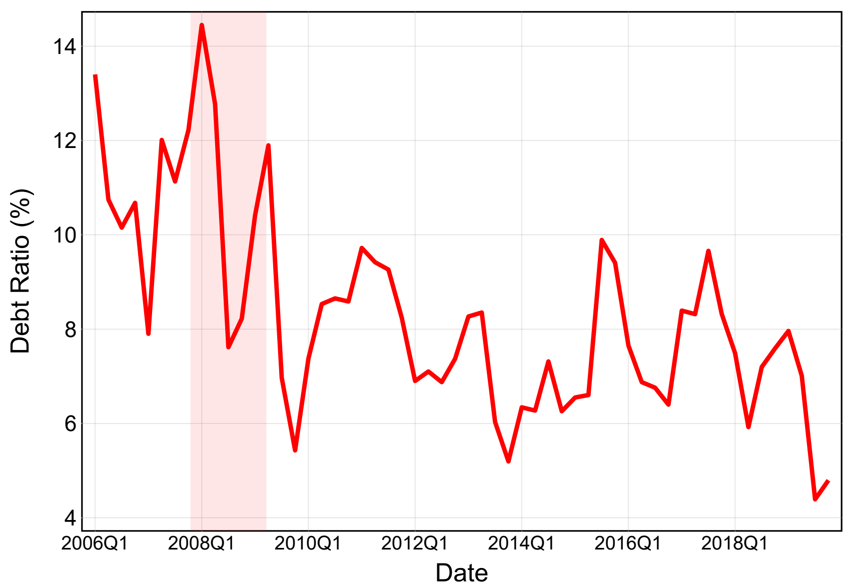
using the total debt outstanding data retrieved from Compustat. Ideally, a firm's total outstanding debt from Compustat should align with the aggregate outstanding debt computed from the Capital IQ data. We leverage the linked Capital IQ and Compustat datasets to compare these values and validate the debt information from Capital IQ. Specifically, we sum the total outstanding loan amounts derived from Capital IQ after applying steps (1) through (5) and compare this sum with the total debt obligations reported in Compustat. If we observe that the discrepancy between the Capital IQ and Compustat figures corresponds to the amount of debt duplicated due to identical reporting dates, we attribute this error to these duplicate loan entries. In such cases, we retain only one unique record per loan for each firm, ensuring consistency and accuracy in the data.

After completing the procedures from steps (1) through (6), we achieve a cleaned dataset in which the total debt obligations constructed from Capital IQ closely align with those reported in Compustat. This cross-verification with Compustat serves as a validation of the accuracy of our data cleaning process. The remaining discrepancy between the Capital IQ and Compustat totals is minimal, indicating that any residual differences are likely due to minor data reporting variations rather than substantive data quality issues. This alignment enhances the credibility and reliability of the debt data used in our analysis.

Figure A1: Example of Barcode Level Data

Notes: This figure provides an example of barcode-level data. Each unique product in the participating Nielsen store is assigned a distinct UPC code.

Figure A2: Trend in Firms' Share of Short- and Medium-Term Debt Ratio



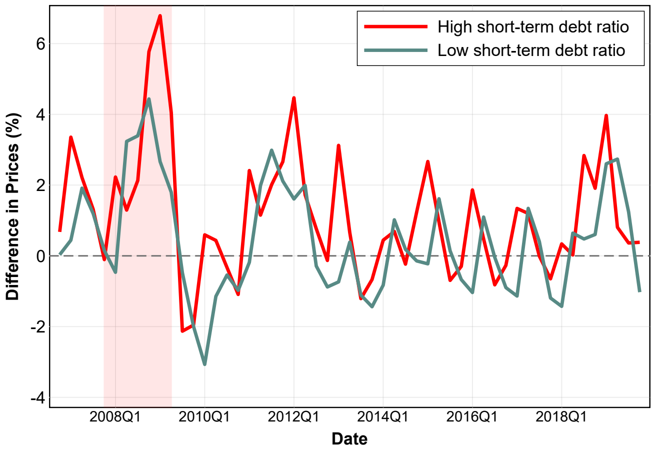
Notes: This figure shows the quarterly trends in the weighted average ratio of short-term debt (debt maturing within one year) to total debt. For each firm, we calculate the ratio of short-term debt to total debt and then compute the weighted average, using the firmâs total debt as the weighting factor. The data is derived from Capital IQ. The shaded area represents the period of recessions defined by NBER.

Table A1: Example of a Syndicated Loan

Administrative agent	citi		
Syndication agent	J.P.Morgan		
Documentation	Deutsche Bank; Royal Bank of Scotland; HSBC		
Participants	BofA SECURITIES; Morgan Stanley; GE Capital; Goldman Sachs		
Loan-level Information from Dealscan			
Borrower Name:	Procter & Gamble Co	**Lender Share (%)**	
Tracneh Active Date:	2007.Aug.17	Citi	16.76
Tranche Amount (million):	17,000	JP Morgan	11.76
Tranche Currency:	USD	Deutsche Bank AG	11.76
All In Spread Drawn (bps):	9.5	Royal Bank of Scotland Plc [RBS]	16.47
Base Reference Rate:	LIBOR	HSBC Banking Group	11.76
Deal Purpose:	General Purpose	BofA Securities	5.00
Tranche Maturity Date:	2008.Aug.15	Morgan Stanley	11.76
Seniority Type:	Senior	General Electric Capital Corp	6.76
Secured:	No	Goldman Sachs & Co	7.94

Figure A3: Price Change Difference With Different Maturity Group

(a) Price Change $(t-3)$, Threshold: 75



(b) Price Change $(t-3)$, Threshold: 90

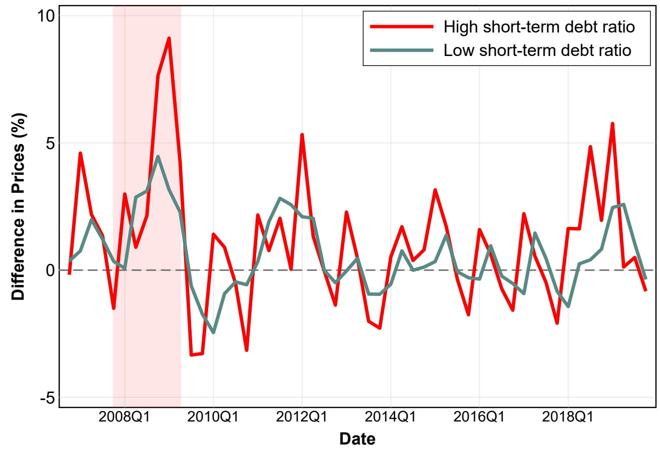
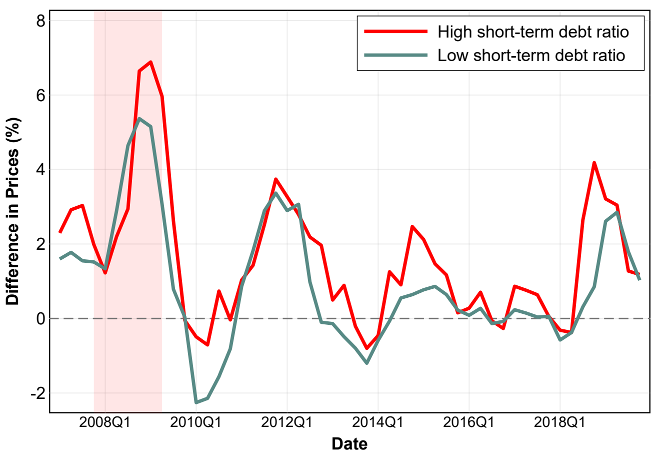


Figure A4: Price Change Difference With Different Maturity Group

(a) Year-over-Year Price Change, Threshold: 75



(b) Year-over-Year Price Change, Threshold: 90

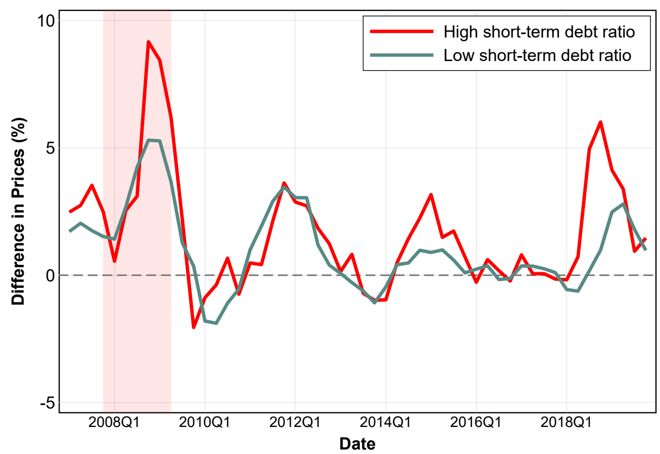
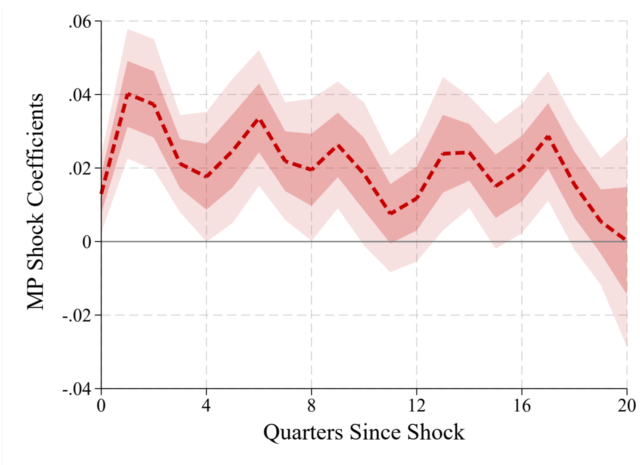
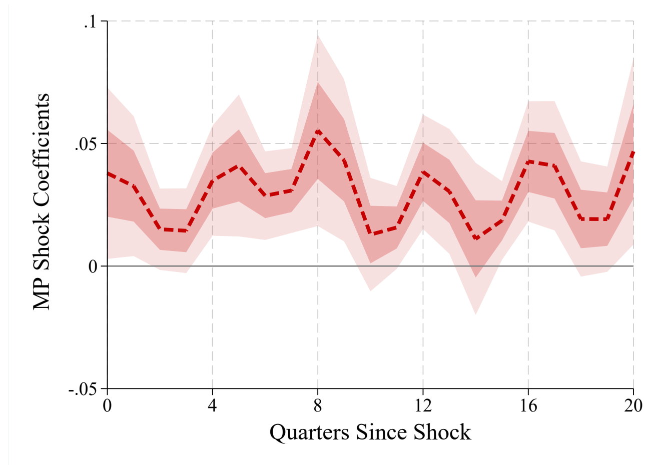


Figure A5: Price Change Impulse Response to Monetary Policy Shock

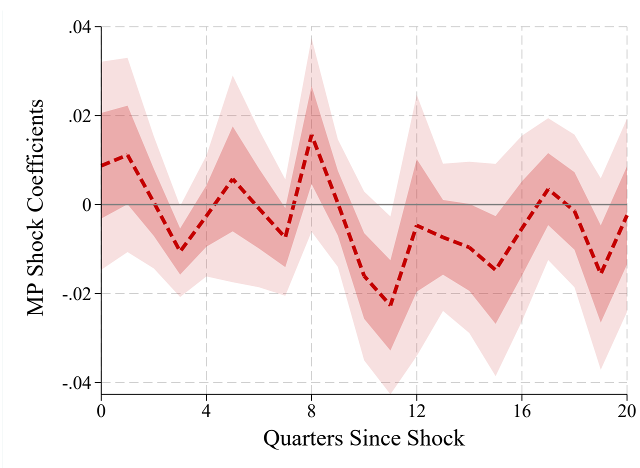
(a) Debt Due within 1 Year



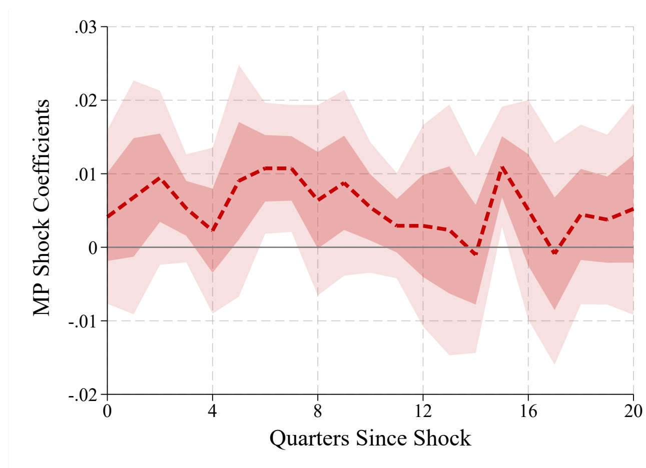
(b) Debt Due within 2 Years



(c) Debt Due within 3 Years



(d) Debt Due within 4 Years



(e) Debt Due within 5 Years

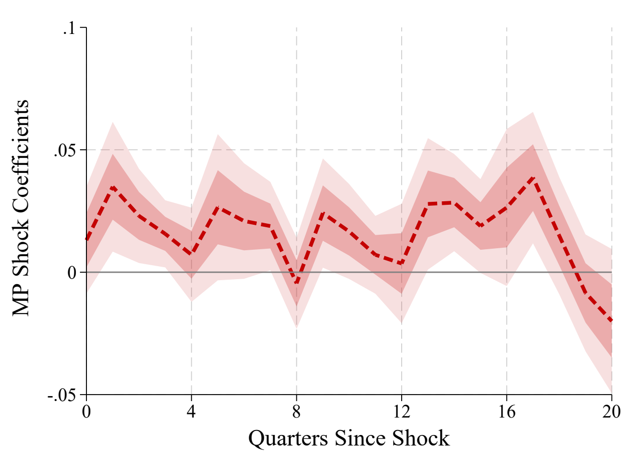
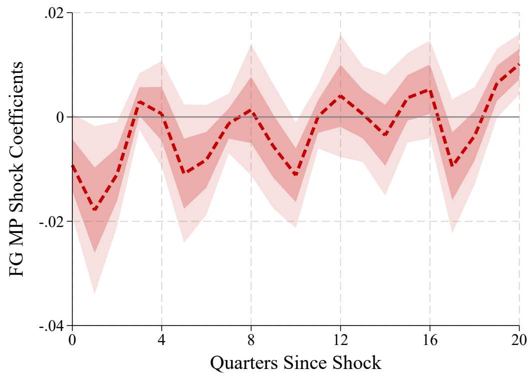
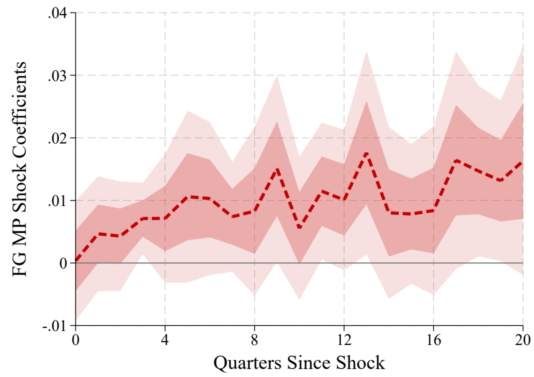


Figure A6: Price Change Impulse Response to Monetary Policy Shock

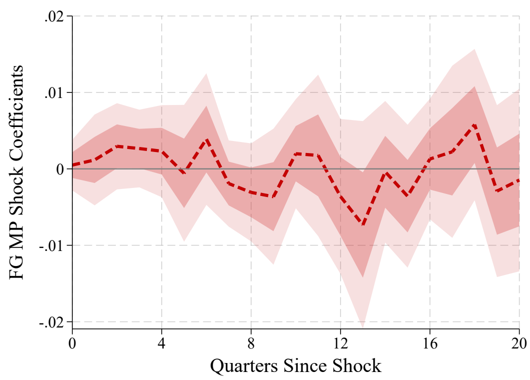
(a) Debt Due within 1 Year



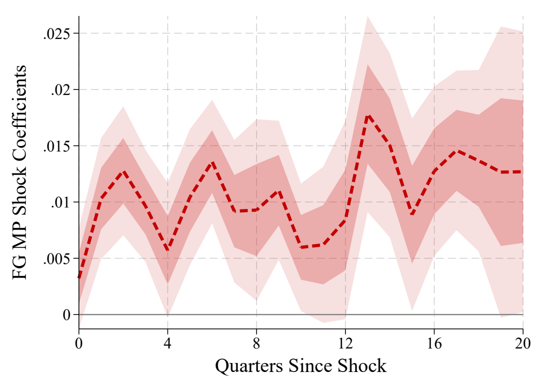
(b) Debt Due within 2 Years



(c) Debt Due within 3 Years



(d) Debt Due within 4 Years



(e) Debt Due within 5 Years

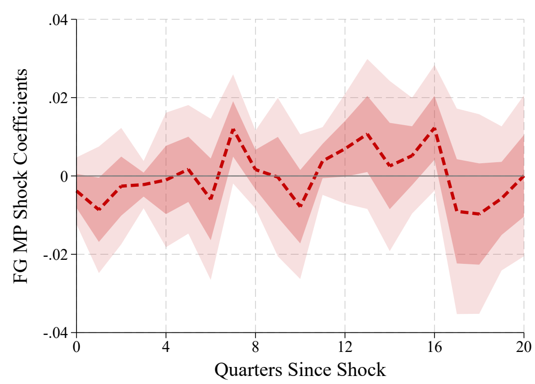


Table A2: Description of Main Variables

Variables	Construction	Source	Reference
Firm Size	$log(total\ assets_{i,t}) = log(ATQ_{i,t})$	Compustat	Alfaro et al. (2024)
Book Leverage	$\frac{total\ debt_{i,t}}{total\ debt_{i,t}+equity_{i,t}} = (\frac{DLCQ_{i,t}+DLTTQ_{i,t}}{DLCQ_{i,t}+DLTTQ_{i,t}+CEQQ_{i,t}}) \times 100$	Compustat	Alfaro et al. (2024)
Market Value	$shares\ outstanding_{i,t} \times stock\ price_{i,t} = CSHOQ_{i,t} \times PRCCQ_{i,t}$	Compustat	Alfaro et al. (2024)
Tobin's Q	$market\ value_{i,t} + total\ assets_{i,t} - equity_{i,t} = \frac{CSHOQ_{i,t} \times PRCCQ_{i,t}+ATQ_{i,t}-CEQQ_{i,t}}{ATQ_{i,t}}$	Compustat	Alfaro et al. (2024)
Cash Holding	$log(cash\ and\ short-term\ investments_{i,t}) = log(CHEQ_{i,t})$	Compustat	Alfaro et al. (2024)
Debt to Asset Ratio	$\frac{total\ debt_{i,t}}{total\ assets_{i,t}} = \frac{DLCQ_{i,t}+DLTTQ_{i,t}}{ATQ_{i,t}}$	Compustat	Alfaro et al. (2024)
Liquidity	$\frac{cash\ and\ short-term\ investments_{i,t}}{total\ assets_{i,t}} = \frac{CHEQ_{i,t}}{ATQ_{i,t}}$	Compustat	Gilchrist et al. (2017)
Inventory to Sales Ratio	$\frac{inventories_{i,t}}{sales_{i,t}} = \frac{INVTQ_{i,t}}{SALEQ_{i,t}}$	Compustat	Gilchrist et al. (2017)
Sales Growth	$log(\frac{sales_{i,t}}{sales_{i,t-4}}) = log(\frac{SALEQ_{i,t}}{SALEQ_{i,t-4}})$	Compustat	Gilchrist et al. (2017)
Cost of Goods Sold Growth	$log(\frac{cost\ of\ goods\ sold_{i,t}}{cost\ of\ goods\ sold_{i,t-4}}) = log(\frac{COGSQ_{i,t}}{COGSQ_{i,t-4}})$	Compustat	Gilchrist et al. (2017)
Debt Due in 1 Year	$\frac{firm\ level\ summation\ of\ debts\ due \leq 12\ months}{total\ debt}$	Capital IQ	Choi et al. (2018)
Debt Due in 1 to 2 Years	$\frac{firm\ level\ summation\ of\ debts\ due>12\ months\ \&\ \leq 24\ months}{total\ debt}$	Capital IQ	Choi et al. (2018)
Debt Due in 2 to 3 Years	$\frac{firm\ level\ summation\ of\ debts\ due>24\ months\ \&\ \leq 36\ months}{total\ debt}$	Capital IQ	Choi et al. (2018)
Debt Due in 3 to 4 Years	$\frac{firm\ level\ summation\ of\ debts\ due>36\ months\ \&\ \leq 48\ months}{total\ debt}$	Capital IQ	Choi et al. (2018)
Debt Due in 4 to 5 Years	$\frac{firm\ level\ summation\ of\ debts\ due>48\ months\ \&\ \leq 60\ months}{total\ debt}$	Capital IQ	Choi et al. (2018)
Debt Due in 2 Years	$\frac{firm\ level\ summation\ of\ debts\ due \leq 24\ months}{total\ debt}$	Capital IQ	Choi et al. (2018)
Debt Due in 3 Years	$\frac{firm\ level\ summation\ of\ debts\ due \leq 36\ months}{total\ debt}$	Capital IQ	Choi et al. (2018)
Debt Due in 4 Years	$\frac{firm\ level\ summation\ of\ debts\ due \leq 48\ months}{total\ debt}$	Capital IQ	Choi et al. (2018)
Debt Due in 5 Years	$\frac{firm\ level\ summation\ of\ debts\ due \leq 60\ months}{total\ debt}$	Capital IQ	Choi et al. (2018)

Notes: This table provides explanation on the main firm-level variables that are used in the main specifications.

Figure A7: Heterogeneous Effect of Credit Supply Shock

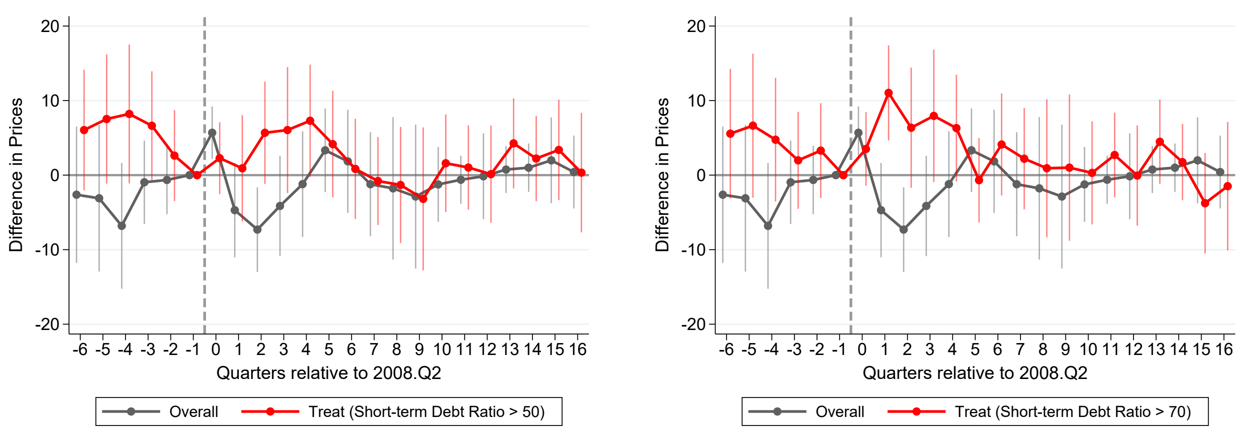


Table A3: Types of Observations in the Capital IQ Data

Outstanding Debt	Maximum Limit of Debt
Accrued Interest	N/A
Bank Loans	N/A
Bank Overdraft	Bank Overdraft
Bills Payable	Bills Payable
Bonds and Notes	N/A
Commercial Paper	Commercial Paper
Commercial Paper in RC Facility	N/A
Debentures	N/A
Debt Adjustments	N/A
Federal Funds Purchased	Federal Funds Purchased
Federal Home Loan Bank Borrowings	Federal Home Loan Bank Borrowings
Federal Reserve Bank Credit	Federal Reserve Bank Credit
General Borrowings	N/A
Lease Liabilities	N/A
Letters of Credit	Letters of Credit
Mortgage Bonds	N/A
Mortgage Loans	N/A
Mortgage Notes	N/A
Notes Payable	Notes Payable
Other Borrowings	N/A
Preferred Securities	N/A
Revolving Credit	Revolving Credit
Securities Loaned	N/A
Securities Sold Under Agreement to Repurchase	N/A
Securitization Facility	Securitization Facility
Term Loans	Term Loans
Unamortized Discount: Mortgage Notes	N/A

Notes: This table records all of the debt types in the Capital IQ data. Some debts have both of the outstanding amount and its maximum limit of credit lines. N/A refers to the maximum limit of credit line is not applicable in that case.

B Solution Algorithm

We use the global solution methods with time iteration procedures to solve the model. We utilize this technique since the long-term bond price is a forward looking object which depends on the firm's future optimal behaviors on default. To speed up the solution algorithm, we also make use of one-loop algorithm in which both of the pricing kernel and the firm's value functions are estimated simultaneously instead of two-loop algorithm.

Solutions in Period T

In the last period T, the firm needs to repay all of the existing debts including both of the short-term debt and long-term debt. A firm is subject to a cash-flow shock and it makes decision on whether to default based on the firm's value after debt repayment. The continuation value of a firm is dependent on the existing customer capital (m), outstanding stock of short-term debt (B^S), long-term debt (B^L), and exposure to cash-flow shock (z). We denote the endogenous states $(\vec{m}, \vec{B}^S, \vec{B}^L)$ as S and the combination of endogenous state and exogenous state $(\vec{m}, \vec{B}^S, \vec{B}^L, \vec{z})$ as $\mathcal{S}$. The value functions of a firms is given by:

$$
\begin{aligned}
V_T(\mathcal{S}) = V_T(\vec{m}, \vec{B}^S, \vec{B}^L, \vec{z}) &= \max_{\vec{\mathcal{D}}_T} \left[\vec{\mathcal{O}}, V_T^c(\vec{m}, \vec{B}^S, \vec{B}^L, \vec{z})\right] \\
&= \max_{\vec{\mathcal{D}}_T} \left[\vec{\mathcal{O}},\ \max_{\vec{P}_T}\ \vec{P}_T[(\vec{P}_T)^{-\eta}(\vec{m}_T)^{\theta(1-\eta)}X_T] - W(\frac{\vec{Y}_T}{A})^{\frac{1}{\alpha}} - (c+1)\vec{B}_T^L - (c+1)\vec{B}_T^S - \sigma\vec{z}_T\right]
\end{aligned}
$$

where $\quad \vec{Y}_T = (\vec{P}_T)^{-\eta}(\vec{m}_T)^{\theta(1-\eta)}X_T$

In the notation of collocation methods, we are able to find $\overrightarrow{c_T^c}$ from

$$
\begin{aligned}
V_T^c(\mathcal{S}) = V_T^c(\vec{m}, \vec{B}^S, \vec{B}^L, \vec{z}) &= \Phi(\mathcal{S})\overrightarrow{c_T^c} \\
&= \max_{\vec{P}_T}\ \vec{P}_T[(\vec{P}_T)^{-\eta}(\vec{m}_T)^{\theta(1-\eta)}X_T] - W(\frac{\vec{Y}_T}{A})^{\frac{1}{\alpha}} - (c+1)\vec{B}_T^L - (c+1)\vec{B}_T^S - \sigma\vec{z}_T
\end{aligned}
$$

Solutions in Period T-1

(1) Before we solve the firm's maximization problem, we first need to characterize the pricing kernels for short-term debt and long-term debt. The pricing kernel for short-term debt in period

T-1 can be expressed according to

$$\begin{aligned}\overrightarrow{Q}^{S}_{T-1}(\vec{m},\vec{B}^S,\vec{B}^L) &= \mathbb{E}_{z'}\left\{(c+1)\times\mathbb{I}\left[V^c_T(\vec{m},\vec{B}^S,\vec{B}^L,\vec{z}')\geq 0\right]\right\}\\ &=\sum_{z_i} f(z_i)(c+1)\times\mathbb{I}\left[V^c_T(\vec{m},\vec{B}^S,\vec{B}^L,\vec{z}')\geq 0\right]\end{aligned}$$

From the collocation notation, we can find the parameter vector $\overrightarrow{c^S_{T-1}}$ from

$$\Phi([\vec{m},\vec{B}^S,\vec{B}^L])\overrightarrow{c^S_{T-1}} = \left[w'\otimes I_{N_m\times N_{Bs}\times N_{Bl}}\right](c+1)\times\mathbb{I}\left[\Phi([\vec{m},\vec{B}^S,\vec{B}^L,\vec{z}])\overrightarrow{c^c_T}\geq 0\right]$$

(2) Since in the last period T, all of the outstanding amount of long-term debts should be repaid, the pricing kernel for long-term debt is similar to the short-term debt in period T-1. The pricing kernel of long-term debt can be expressed as

$$\begin{aligned}\overrightarrow{Q}^{L}_{T-1}(\vec{m},\vec{B}^S,\vec{B}^L) &= \mathbb{E}_{z'}\left\{(c+1)\times\mathbb{I}\left[V^c_T(\vec{m},\vec{B}^S,\vec{B}^L,\vec{z}')\geq 0\right]\right\}\\ &=\sum_{z_i} f(z_i)(c+1)\times\mathbb{I}\left[V^c_T(\vec{m},\vec{B}^S,\vec{B}^L,\vec{z}')\geq 0\right]\end{aligned}$$

From the collocation notation, we can find the parameter vector $\overrightarrow{c^L_{T-1}}$ from

$$\Phi([\vec{m},\vec{B}^S,\vec{B}^L])\overrightarrow{c^L_{T-1}} = \left[w'\otimes I_{N_m\times N_{Bs}\times N_{Bl}}\right](c+1)\times\mathbb{I}\left[\Phi([\vec{m},\vec{B}^S,\vec{B}^L,\vec{z}])\overrightarrow{c^c_T}\geq 0\right]$$

(3) Since we have found the parameters for both of the pricing kernels $\overrightarrow{c^S_{T-1}}$ and $\overrightarrow{c^L_{T-1}}$, we can solve the firm's maximization problem

$$\begin{aligned}V_{T-1}(\mathcal{S}) &= V_{T-1}(\vec{m},\vec{B}^S,\vec{B}^L,\vec{z}) = \max_{\vec{\mathcal{D}}_{T-1}}\left[\vec{\mathcal{O}},V^c_{T-1}(\vec{m},\vec{B}^S,\vec{B}^L,\vec{z})\right]\\ &=\max_{\vec{\mathcal{D}}_{T-1}}\Bigg\{\vec{\mathcal{O}},\max_{\vec{P}_{T-1},\vec{B}^S_T,\vec{B}^L_T}\ \vec{P}_{T-1}[(\vec{P}_{T-1})^{-\eta}(\vec{m}_{T-1})^{\theta(1-\eta)}X_{T-1}]-W(\frac{\vec{Y}_{T-1}}{A})^{\frac{1}{\alpha}}-(c+\gamma)\vec{B}^L_{T-1}\\ &-(c+1)\vec{B}^S_{T-1}-\sigma\vec{z}_{T-1}+\vec{B}^S_T\odot Q^S(\vec{m}_T,\vec{B}^S_T,\vec{B}^L_T)+(\vec{B}^L_T-(1-\gamma)\vec{B}^L_{T-1})\odot Q^L(\vec{m}_T,\vec{B}^S_T,\vec{B}^L_T)\\ &-\zeta\left[\vec{B}^S_T+\max\{\vec{B}^L_T-(1-\gamma)\vec{B}^L_{T-1},0\}\right]^2+\mathbb{E}_{z'}\left[\Lambda V_T(\vec{m}_T,\vec{B}^S_T,\vec{B}^L_T,z')\right]\Bigg\}\end{aligned}$$

subject to (i) **[Positive Cash Flow Constraint]**

$$\vec{P}_{T-1}[(\vec{P}_{T-1})^{-\eta}(\vec{m}_{T-1})^{\theta(1-\eta)}X_{T-1}] - W(\frac{\vec{Y}_{T-1}}{A})^{\frac{1}{\alpha}} - (c+\gamma)\vec{B}^L_{T-1} - (c+1)\vec{B}^S_{T-1} - \sigma\vec{z}_{T-1}$$
$$+ \vec{B}^S_T \odot Q^S(\vec{m}_T, \vec{B}^S_T, \vec{B}^L_T) + (\vec{B}^L_T - (1-\gamma)\vec{B}^L_{T-1}) \odot Q^L(\vec{m}_T, \vec{B}^S_T, \vec{B}^L_T) \geq 0$$

(ii) **[Evolution of Customer Base]**

$$\vec{m}_T = \rho\vec{m}_{T-1} + (1-\rho)\mathbb{C}(\vec{P}_{T-1}, \vec{m}_{T-1})$$

(iii) **[Cosumer Demand]**

$$\mathbb{C}(\vec{P}_{T-1}, \vec{m}_{T-1}) = (\vec{P}_T)^{-\eta}(\vec{m}_T)^{\theta(1-\eta)}X_T$$

(iv) **[Production Technology]**

$$\vec{Y}_T = (\vec{P}_T)^{-\eta}(\vec{m}_T)^{\theta(1-\eta)}X_T \ \ \& \ \ \vec{Y}_T \leq \mathbb{C}(\vec{P}_{T-1}, \vec{m}_{T-1})$$

In the notation of collocation methods, our objective is to find $\overrightarrow{c^c_{T-1}}$ from the equation below given $\overrightarrow{c^e_T}$, subject to the three constraints listed above.

$$\begin{aligned}
&\Phi([\vec{m}, \vec{B}^S, \vec{B}^L, \vec{z}])\overrightarrow{c^c_{T-1}} \\
&= \max_{\vec{P}_{T-1}, \vec{B}^S_T, \vec{B}^L_T} \vec{P}_{T-1}[(\vec{P}_{T-1})^{-\eta}(\vec{m}_{T-1})^{\theta(1-\eta)}X_{T-1}] - W(\frac{\vec{Y}_{T-1}}{A})^{\frac{1}{\alpha}} - (c+\gamma)\vec{B}^L_{T-1} \\
&- (c+1)\vec{B}^S_{T-1} - \sigma\vec{z}_{T-1} + \vec{B}^S_T \odot \Phi([\vec{m}, \vec{B}^S, \vec{B}^L])\overrightarrow{c^s_{T-1}} + (\vec{B}^L_T - (1-\gamma)\vec{B}^L_{T-1}) \odot \Phi([\vec{m}, \vec{B}^S, \vec{B}^L])\overrightarrow{c^L_{T-1}} \\
&- \zeta\left[\vec{B}^S_T + \max\{\vec{B}^L_T - (1-\gamma)\vec{B}^L_{T-1}, 0\}\right]^2 + \Lambda\Phi([\vec{m}, \vec{B}^S, \vec{B}^L])\overrightarrow{c^e_T}
\end{aligned}$$

(4) Once we have solved for $\overrightarrow{c^c_{T-1}}$, we can finally find $\overrightarrow{c^e_{T-1}}$ through the equation for the expectation.

$$\begin{aligned}
V^e_{T-1}(\vec{m}, \vec{B}^S, \vec{B}^L) &= \mathbb{E}_{z'}\left\{V_{T-1}(\vec{m}, \vec{B}^S, \vec{B}^L, z')\right\} \\
&= \sum_{z_i} f(z_i)V^c_{T-1}(\vec{m}, \vec{B}^S, \vec{B}^L, z_i) \times \mathbb{I}\left[V^c_{T-1}(\vec{m}, \vec{B}^S, \vec{B}^L, z_i) \geq 0\right]
\end{aligned}$$

We now can find the $\overrightarrow{c^e_{T-1}}$ through the collocation notation using $\overrightarrow{c^c_{T-1}}$ as we find in (3) through the equation

$$\Phi([\vec{m}, \vec{B}^S, \vec{B}^L])\overrightarrow{c^e_{T-1}} = \left[w' \otimes I_{N_m \times N_{Bs} \times N_{Bl}}\right] \times \Phi([\vec{m}, \vec{B}^S, \vec{B}^L, \vec{z}])\overrightarrow{c^c_{T-1}} \odot \mathbb{I}\left[\Phi([\vec{m}, \vec{B}^S, \vec{B}^L, \vec{z}])\overrightarrow{c^c_{T-1}} \geq 0\right]$$

Solutions in Period T-2

From periods T-2 we can proceed the iterative procedures as we discussed in period T-1 except the price kernels for long-term debt.

$$
\begin{aligned}
\overrightarrow{Q}^{L}_{T-2}(\vec{m},\vec{B}^S,\vec{B}^L) = \mathbb{E}_{z'}\Big\{&(c+1+\overrightarrow{Q}^{L}_{T-1}(\vec{m}_{T-1}(\vec{m},\vec{B}^S,\vec{B}^L,z^{'}),\vec{B}^S_{T-1}(\vec{m},\vec{B}^S,\vec{B}^L,z^{'}),\vec{B}^L_{T-1}(\vec{m},\vec{B}^S,\vec{B}^L,z^{'})))\\
&\times \mathbb{I}\left[V^c_{T-1}(\vec{m},\vec{B}^S,\vec{B}^L,z^{'})\geq 0\right]\Big\}\\
=&\sum_{z_i} f(z_i)(c+1+\overrightarrow{Q}^{L}_{T-1}(\vec{m}_{T-1}(\vec{m},\vec{B}^S,\vec{B}^L,z_i),\vec{B}^S_{T-1}(\vec{m},\vec{B}^S,\vec{B}^L,_i),\vec{B}^L_{T-1}(\vec{m},\vec{B}^S,\vec{B}^L,z_i)))\\
&\times \mathbb{I}\left[V^c_{T}(\vec{m},\vec{B}^S,\vec{B}^L,z_i)\geq 0\right]
\end{aligned}
$$

From the collocation notation, we can find the parameter vector $\overrightarrow{c^S_{T-1}}$ from

$$
\begin{aligned}
\Phi([\vec{m},\vec{B}^S,\vec{B}^L])\overrightarrow{c^L_{T-2}} = \left[w^{'}\otimes I_{N_m\times N_{Bs}\times N_{Bl}}\right]&\left(c+1+\Phi\Big([\vec{m}(\vec{m},\vec{B}^S,\vec{B}^L,\vec{z}),\vec{B}^S(\vec{m},\vec{B}^S,\vec{B}^L,\vec{z}),\vec{B}^L(\vec{m},\vec{B}^S,\vec{B}^L,\vec{z})]\Big)\overrightarrow{c^L_{T-1}}\right)\\
&\times \mathbb{I}\left[\Phi([\vec{m},\vec{B}^S,\vec{B}^L,\vec{z}])\overrightarrow{c^c_{T-1}}\geq 0\right]
\end{aligned}
$$