Online Appendix for Monetary Policy and Firm Heterogeneity: The Role of Leverage Since the Financial Crisis (Not for Publication)

Contents

A Empirical Appendix

A.1 Additional Details on Data Construction and Summary

Data Construction We construct the firm sample in three steps.

First, we create our investment variable using the following standard steps:

1. Flag the first date that a firm reports its gross capital stock, i.e., the level of the gross plant, property, and equipment (Compustat: ppegtq). This date must also have the necessary information to compute the change in the net capital stock: Compustat variable ppentq reported for quarter $t+1$ and either quarter t or $t-1$.
2. Interpolate any missing net investment values (ppentq) using the average of ppentq in quarters $t+1$ and $t-1$.
3. Create the capital stock beginning with the first reported gross capital stock from step #1. Then, update the following periods using the change in the net capital stock. If missing values of the net capital stock cannot be interpolated in step #2, then begin the process over with the next non-missing gross capital stock.
4. Create the quarterly intensive investment measure as the log change in the created capital stock series.
5. To remove the effect of outliers, we drop the top and bottom 0.5% of values.

Next, we define our control variables using the Compustat item names as follows:

- Ratio of current assets to total assets: $\frac{actq}{atq}$.
- Year-over-year real sales growth: log change in real $saleq$, relative to 4-quarter lagged real $saleq$. We use the quarterly price index from the BEA NIPA Table 1.3.4. Price Indexes for Gross Value Added by Sector (Non-Farm Business Index) to create all real variables.
- Firm size: log of real atq.
- Price-to-cost margin: $\frac{saleq-cogsq}{saleq}$.
- Receivables-minus-payables to sales: $\frac{rectq-apq}{saleq}$.
- Depreciation to assets: $\frac{dpq}{atq}$.
- Firm age: computed as the number of years since the firm first appeared in the Compustat database.
- Market capitalization: log of $cshoc$ multiplied by $prccd$.
- Fiscal quarter: $fqtr$.

Finally, the data is cleaned using the standard criteria:

- Keep only firms incorporated in the US ($FIC =$"USA").

- Drop firm-quarters with acquisitions greater than 5% of assets.
- Drop firm-quarters with assets or liabilities at or below zero or missing shareholder's equity ($SEQQ$).
- Drop firm-quarters that violate the accounting identity (Assets = Liabilities + Equity) by more than 10% of book value of assets.
- Winsorize leverage at 1% and 99% values and LT debt at 5% and 95% values.
- Drop firm-quarters with LT debt share greater than 1.

Summary Statistics Table A.1 provides the summary statistics of firm characteristics.

Table A.1: Summary Statistics of Firm Characteristics

	mean	std. dev.
Current to Total Assets Ratio	0.62	0.20
Log Year-Over-Year Real Sales Growth, %	3.74	21.45
Log of Real Total Assets	9.05	1.12
Price-to-Cost Margin	0.39	0.23
Receivables minus Payables to Sales	0.24	0.48
Depreciation to Assets	0.01	0.01
Firm Age	36.54	17.01
Log of Market Capitalization	15.98	1.32
Tobin's q	2.20	1.46
Observations	87,640	

Notes: The table shows summary statistics for the firm-level characteristics. All variables (excluding market capitalization) are measured quarterly at the firm level. Market capitalization is measured on the day prior to the FOMC meeting. The sample is non-financial firms in the S&P 500 between Jul-1991 and Jun-2019, excluding the financial crisis dates of Jul-2008 to Jul-2009.

A.2 Robustness Checks for the Main Results

A.2.1 Leverage in the Pre- and Post-crisis Samples

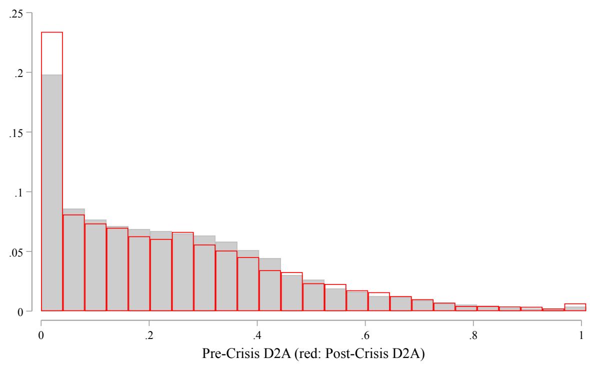
We first start by considering whether the firms that had high leverage in the pre-crisis also had high leverage in the post-crisis sample. This is potentially important because a systematic migration of less-sensitive firms toward lower leverage or more-sensitive firms toward higher leverage in the post-crisis period could, for instance, create an illusion of changed transmission mechanisms. However, we find that there is remarkable stability in the leverage distribution across the two periods, with only modest increases in average leverage post-crisis. We also demonstrate that our main findings are not driven by firms that substantially changed their leverage position. Figure A.1 below shows the distribution of leverage pre-crisis and post-crisis and how they correlate with credit ratings pre-crisis and post-crisis. We provide a discussion as follows.

First, from Table 1 in the main paper, we can see that leverage is, on average, only slightly higher in the post-crisis sample. For example, our baseline measure of leverage, debt-to-capital, has a mean of 0.42 in the post-crisis sample relative to a mean of 0.39 in the pre-crisis sample. Similarly the standard deviation of leverage is also roughly the same across the two samples. Figure A.1 shows the leverage distribution in the two samples where we have taken the firm-specific average for each sample. The grey shaded bars show the histogram for the pre-crisis sample, while the red transparent bars show the post-crisis histogram. While there is a little more mass toward the right in the post-crisis sample (and a little more toward the left in the pre-crisis sample), the distribution is quite similar in the two samples. In our baseline results presented in Section 3.1 we standardized our leverage measure by using the full sample mean and standard deviation of leverage. We have also tried using the pre-crisis mean and standard deviation to standardize our leverage measure (see Appendix Table A.3). As one would expect with the patterns from Table 1 and Figure A.1, we find these results are very similar to our baseline results.

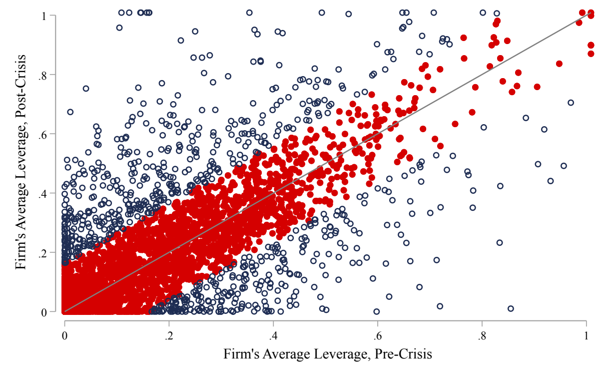
We further investigate whether firms have moved around in the leverage distribution in the two samples. Given the stability of the leverage distribution in the two samples, it is still possible that our results are driven by i) less-sensitive firms that had high leverage in the pre-crisis sample but switched to having lower leverage in the post-crisis sample and ii) more-sensitive firms with low leverage in the pre-crisis sample but switched to having higher leverage in the post-crisis sample. To this end, Figure A.1 displays a scatter plot of the firm-specific average leverage in the post-crisis sample versus the average in the pre-crisis sample. If firms' leverage across the two samples is similar, we should expect the points in the scatter plot to cluster around the 45-degree line. Figure A.1 does, in fact, show this pattern. We also investigate whether our results are driven by the firms that did change their leverage noticeably, i.e., those that are not close to the 45-degree line. In Appendix Table A.2, we present our baseline results excluding firms with more than one standard deviation away from the 45-degree line. The table confirms that our baseline stock market results are robust to excluding these outliers. This suggests that the movement of firms across the leverage distribution does not explain the difference in the transmission of monetary policy through firm leverage following the financial crisis.

Figure A.1

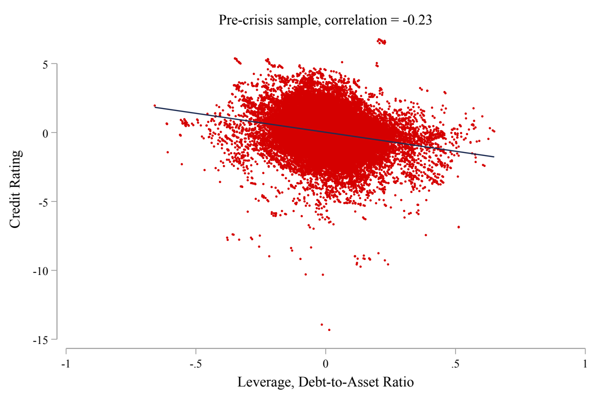
(a) Distribution of Firm Leverage



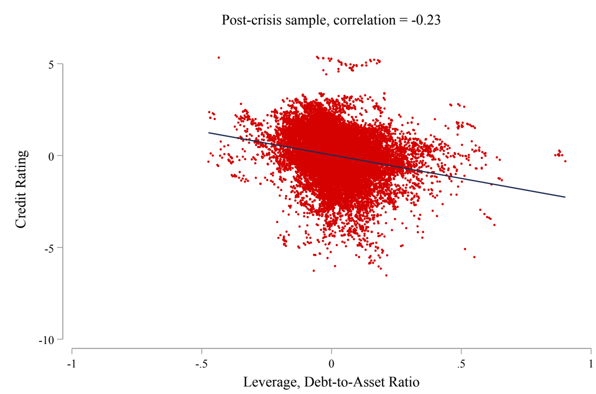
(b) Firm Leverage: Post vs. Pre



(c) Conditional Correlation of Credit Rating and Leverage: Pre-Crisis



(d) Conditional Correlation of Credit Rating and Leverage: Post-Crisis



Notes: Panel (a) plots the histogram of the quarterly firm leverage (measured as debt-to-assets), averaged across the pre-crisis (grey, shaded) and post-crisis (red, transparent) samples. Panel (b) plots the scatter plot of quarterly firm leverage (measured as debt-to-assets) averaged across the post-crisis versus the average in the pre-crisis sample. Firms below one standard deviation from the 45-degree line are shown in hollow circles. Panels (c) and (d) plot the residuals from regressing the firm's S&P long-term credit rating on our set of control variables against the residuals from regressing the firm's 4-quarter rolling leverage on a set of control variables. For all figures, pre-crisis is Jul-1991 to Jun-2008, post-crisis is Aug-2009 to Jun-2019, and the sample is non-financial firms in the S&P 500 on the date of FOMC announcement.

A.2.2 Excluding Outliers in Terms of Firm Leverage

We present our baseline results excluding firms that lie more than one standard deviation away from the 45-degree line of Figure A.1. The table confirms that our baseline stock market results are robust to excluding these outliers. This suggests that the movement of firms across the leverage distribution does not explain the difference in monetary policy transmission through firm leverage following the financial crisis. Table A.2 shows the results.

Table A.2: Robustness of baseline results to removing pre vs. post outliers

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage
Pre-Crisis	-1.98**	-0.85
	(0.870)	(0.647)
Post-Crisis	2.35**	0.70
	(1.023)	(0.710)
Difference	4.33***	1.56*
	(1.349)	(0.894)
Observations	49,330	35,004
R^2	0.266	0.788

Notes: Column (1) is the result from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right)[\alpha_i + \alpha_{s,t} + \beta l_{i,t-1}\epsilon_t^m + \delta l_{i,t-1} + \Gamma' Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock (FFR in the pre-crisis and LSAP in the post-crisis) and $Z_{i,t-1}$ is a vector of firm-level controls. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \left(1 + \zeta D_t^{post}\right)[\alpha_{s,t} + \delta l_{i,t-1} + \Gamma' Z_{i,t-1}] + e_{i,t}$. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Jun-2008, and post-crisis is Aug-2009 to Jun-2019. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement. We exclude 94 firms with a change in leverage from pre-crisis to post-crisis greater than one standard deviation. Two-way clustered (by firm and FOMC day) standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.2.3 Standardization of Firm Leverage Measure

In our baseline results, we standardized our leverage measure by using the full sample mean and standard deviation of leverage. We have also tried using the pre-crisis mean and standard deviation to standardize our leverage measure. As one would expect with the patterns from Figure A.1, we find these results shown in Table A.3 are very similar to our baseline results.

Table A.3: Robustness of baseline results with pre-crisis standardization of leverage

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage
Pre-Crisis	-2.44**	-1.36**
	(0.964)	(0.610)
Post-Crisis	2.18***	0.59
	(0.676)	(0.492)
Difference	4.61***	1.95***
	(1.176)	(0.631)
Observations	59,868	43,888
R^2	0.257	0.781

Notes: Column (1) is the result from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right)[\alpha_i + \alpha_{s,t} + \beta l_{i,t-1}\epsilon_t^m + \delta l_{i,t-1} + \Gamma' Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage normalized (using the pre-crisis period) to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock (FFR in the pre-crisis and LSAP in the post-crisis) and $Z_{i,t-1}$ is a vector of firm-level controls. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \left(1 + \zeta D_t^{post}\right)[\alpha_{s,t} + \delta l_{i,t-1} + \Gamma' Z_{i,t-1}] + e_{i,t}$. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Jun-2008, and post-crisis is Aug-2009 to Jun-2019. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.2.4 Alternative Leverage Measure: Debt-to-Capital

In our baseline results, we choose our leverage measure using the debt-to-asset measure, which is widely used among many papers, including Ottonello and Winberry (2020). We have also tried using another measure that is also quite commonly used, debt-to-capital ratio; we find these results shown in Table A.4 are very similar to our baseline results.

Table A.4: Robustness of baseline results to an alternative measure of leverage: Debt-to-Capital

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage
Pre-Crisis	-2.62***	-0.98*
	(0.877)	(0.542)
Post-Crisis	2.25***	0.81*
	(0.693)	(0.472)
Difference	4.86***	1.79***
	(1.110)	(0.590)
Observations	59,868	43,888
R^2	0.257	0.781

Notes: Column (1) is the result from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right)[\alpha_i + \alpha_{s,t} + \beta l_{i,t-1}\epsilon_t^m + \delta l_{i,t-1} + \Gamma' Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage (measured as debt-to-capital) normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock (FFR in the pre-crisis and LSAP in the post-crisis) and $Z_{i,t-1}$ is a vector of firm-level controls. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \left(1 + \zeta D_t^{post}\right)[\alpha_{s,t} + \delta l_{i,t-1} + \Gamma' Z_{i,t-1}] + e_{i,t}$. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Jun-2008, and post-crisis is Aug-2009 to Jun-2019. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement. Two-way clustered standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.2.5 Sample Composition Pre-Crisis and Post-Crisis

Third, we show that our stock market results are not driven by a change in the sample composition between the pre-crisis and post-crisis periods. We rerun our stock market specification, limiting the sample to only those firms that entered Compustat prior to 1993 and remained in the sample through at least 2017, and the results closely match our baseline results. In our baseline specification, we excluded the crisis period from July 2008 to July 2009. We show that our results are similar when we include the crisis dates in the post-crisis sample. Higher leverage firms are less responsive in the pre-crisis period and more responsive in the post-crisis period. This shows that our main results are not caused by certain firms entering or exiting the sample, e.g., firms that did not survive the financial crisis. Table A.5 shows the results.

Table A.5: Robustness of baseline results with consistent sample of firms

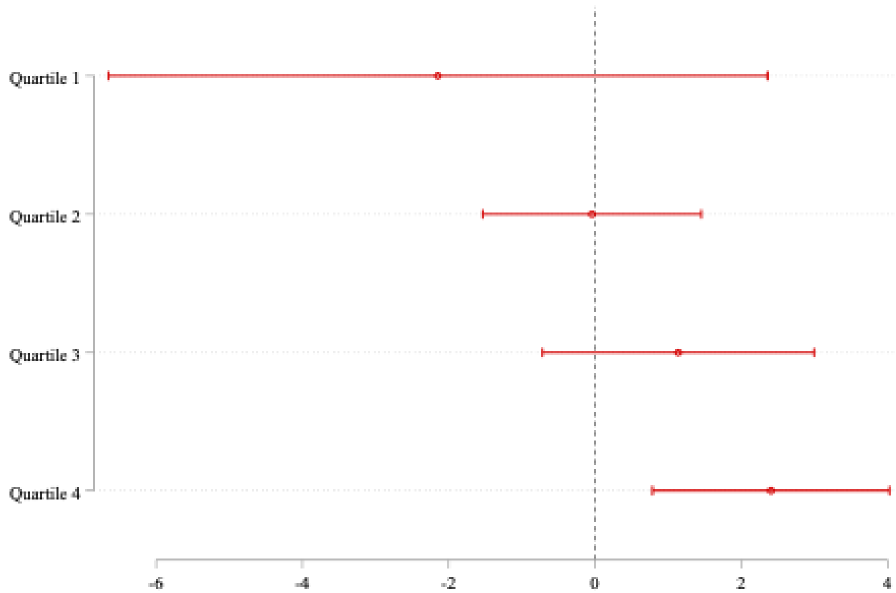
	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage
Pre-Crisis	-1.66**	-0.34
	(0.778)	(0.744)
Post-Crisis	2.04*	0.77
	(1.227)	(0.658)
Difference	3.70***	1.11*
	(1.358)	(0.668)
Observations	23,019	17,648
R^2	0.283	0.758

Notes: Column (1) is the result from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right)[\alpha_i + \alpha_{s,t} + \beta l_{i,t-1}\epsilon_t^m + \delta l_{i,t-1} + \Gamma' Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock (FFR in the pre-crisis and LSAP in the post-crisis) and $Z_{i,t-1}$ is a vector of firm-level controls. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \left(1 + \zeta D_t^{post}\right)[\alpha_{s,t} + \delta l_{i,t-1} + \Gamma' Z_{i,t-1}] + e_{i,t}$. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Jun-2008, and post-crisis is Aug-2009 to Jun-2019. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement that entered Compustat prior to 1993 and remained in the sample through at least 2017. Two-way clustered (by firm and FOMC day) standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.2.6 Non-S&P 500 Compustat Firms

We show that our main result qualitatively holds for non-S&P 500 firms and is statistically significant for those non-S&P 500 firms with the highest market capitalization. This is consistent with the evidence that stock prices incorporate news faster for bigger firms, which are tracked more closely by market analysts and traders. We chose to focus on the S&P 500 because it is an objective way to choose our sample. Figure A.2 shows the results.

Figure A.2: Stock response of non-S&P 500 Compustat firms by market capitalization



Notes: This figure plots the difference, by market capitalization quartile, between the pre-crisis and post-crisis interaction of leverage and the monetary policy shock, i.e. $\beta_{2,1}$, $\beta_{2,2}$, $\beta_{2,3}$ and $\beta_{2,4}$ from the following regression: $s_{i,t} = \alpha_t + I(q)_{i,t}(\alpha_{i,q} + \beta_{1,q} l_{i,t-1}\epsilon_t^m + \beta_{2,q} l_{i,t-1}\epsilon_t^m D_t^{post} + \gamma_{1,q} D_t^{post} + \gamma_{2,q}\epsilon_t^m + \gamma_{3,q}\epsilon_t^m D_t^{post} + \delta_{1,q} l_{i,t-1} + \delta_{2,q} l_{i,t-1} D_t^{post}) + \Gamma' Z_{i,t-1} + e_{i,t}$, where $I(q)_{i,t}$ is an indicator for the market capitalization quartile q to which firm i belongs to on FOMC day t, $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock (FFR in the pre-crisis and LSAP in the post-crisis) and $Z_{i,t-1}$ is a vector of firm-level controls. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield) and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Jun-2008 (153 obs.) and post-crisis is Aug-2009 to Jun-2019 (80 obs.). The sample is non-financial Compustat firms not listed in the S&P 500 on the date of the FOMC announcement. Two-way clustered standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.2.7 Including the Periods of Financial Crisis

In our baseline results, we consider a pre-crisis sample ranging from July 1991 to June 2008 and a post-crisis sample from August 2009 to June 2019. We are thus leaving out the crisis period as categorized by July 2008 to July 2009. In Table A.6 below, we present the results by including the crisis dates in the post-crisis sample. The coefficients show that including the financial crisis dates does not materially change the results.

Table A.6: Robustness of baseline results to including financial crisis period

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage
Pre-Crisis	-0.92**	-1.63***
	(0.440)	(0.588)
Post-Crisis	0.58	0.32
	(0.710)	(0.512)
Difference	1.50*	1.94***
	(0.834)	(0.568)
Observations	62,305	46,728
R^2	0.269	0.798

Notes: Column (1) is the result from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right)[\alpha_i + \alpha_{s,t} + \beta l_{i,t-1}\epsilon_t^m + \delta l_{i,t-1} + \Gamma' Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock (FFR prior to 2009 and LSAP beginning in 2009) and $Z_{i,t-1}$ is a vector of firm-level controls. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \left(1 + \zeta D_t^{post}\right)[\alpha_{s,t} + \delta l_{i,t-1} + \Gamma' Z_{i,t-1}] + e_{i,t}$. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Dec-2008, and post-crisis is Jan-2009 to Jun-2019. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement. Two-way clustered standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.2.8 Including Only Scheduled FOMC Meetings

Unscheduled FOMC meetings can affect financial markets differently from regularly scheduled meetings, as unscheduled meetings typically occur in times of economic turmoil. The unscheduled meetings are also instances in which the Federal Reserve is more likely to release information about economic fundamentals, for example, Lakdawala and Schaffer (2019). Thus, we want to ensure our results are not driven by these unscheduled meetings. This issue only arises in the pre-crisis sample, with 16 unscheduled meetings, while our post-crisis sample has none. Table A.7 shows the results. Excluding the unscheduled meetings gives results that are quite similar to the baseline case.

Table A.7: Robustness of baseline results with scheduled FOMC meetings only

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage
Pre-Crisis	0.17	-1.31**
	(0.721)	(0.621)
Post-Crisis	2.22***	0.63
	(0.671)	(0.494)
Difference	2.05**	1.94***
	(1.006)	(0.663)
Observations	56,568	42,067
R^2	0.230	0.779

Notes: Column (1) is the result from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right) [\alpha_i + \alpha_{s,t} + \beta l_{i,t-1}\epsilon_t^m + \delta l_{i,t-1} + \Gamma' Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock (FFR in the pre-crisis and LSAP in the post-crisis) and $Z_{i,t-1}$ is a vector of firm-level controls. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \left(1 + \zeta D_t^{post}\right) [\alpha_{s,t} + \delta l_{i,t-1} + \Gamma' Z_{i,t-1}] + e_{i,t}$. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Dec-2008, and post-crisis is Jan-2009 to Jun-2019. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement. Two-way clustered standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.2.9 Using Information Effect Robust Shocks in Lakdawala (2019)

There may still be a concern that even on regularly scheduled FOMC meetings, the high-frequency monetary policy shocks contain a substantial information component. To address this concern, we first use forecast data, following the approach in Lakdawala (2019), to cleanse the monetary policy shock of any information effect. Table A.8 shows the results. These results confirm that this issue does not drive our baseline results.

Table A.8: Robustness of stock return results to info-robust shocks

	(1a) Pre	(1b) Post	(1c) Diff
ϵ_t^m (FFR) x Leverage	-2.70**		
	(1.119)		
			4.72***
			(1.597)
ϵ_t^m (LSAP) x Leverage		2.02*	
		(1.141)	
Observations		55,189	
R^2		0.256	

Results from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right)[\alpha_i + \alpha_{s,t} + \beta l_{i,t-1}\epsilon_t^m + \delta l_{i,t-1} + \Gamma' Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock and $Z_{i,t-1}$ is a vector of firm-level controls. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock. The monetary policy shock is cleansed of information effects (as in Lakdawala (2019)). Pre-crisis is Jul-1991 to Jun-2008 and post-crisis is Aug-2009 to Dec-2017. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.2.10 Using Information Effect Robust Shocks in Bauer and Swanson (2023)

There may still be a concern that even on regularly scheduled FOMC meetings, the high-frequency monetary policy shocks contain a substantial information component. To address this concern, we then use the Bauer-Swanson orthogonal shocks, following the approach in Bauer and Swanson (2023), to cleanse the monetary policy shock of any information effect. Table A.9 shows the results. These results confirm that this issue does not drive our baseline results.

Table A.9: Response of firm-level stock returns to Bauer-Swanson monetary shocks

	(1a) Pre	(1b) Post	(1c) Diff
ϵ_t^m (Bauer-Swanson) x Leverage	-1.89*	1.00**	2.90**
	(1.061)	(0.466)	(1.126)
Observations		59,868	
R^2		0.250	

Notes: This table shows results from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right)[\alpha_i + \alpha_{s,t} + \beta l_{i,t-1}\epsilon_t^m + \delta l_{i,t-1} + \Gamma' Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock and $Z_{i,t-1}$ is a vector of firm-level controls. As in Bauer and Swanson (2023), the monetary policy shock is normalized to have a unit effect on ED4, and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Jun-2008, and post-crisis is Aug-2009 to Jun-2019. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.2.11 Controlling for the Fama-French Excess Returns

Our results also hold with Fama-French factors. In Table A.10 below, we show that our baseline specification while controlling for three factors: i) firm-specific beta, ii) size as captured by the firm's market capitalization on the day before the FOMC announcement, and iii)firm-level book to market.

Table A.10: Response of firm-level stock returns to monetary policy shocks: Controlling for Fama-French characteristics

	(1a) Pre	(1b) Post	(1c) Diff
ϵ_t^m (FFR) x Leverage	-1.64***		
	(0.519)		
ϵ_t^m (LSAP) x Leverage		2.45***	
		(0.907)	
Pre- vs. post-crisis			4.09***
			(1.126)
Observations		57,903	
R^2		0.275	

Notes: This table shows results from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right)[\alpha_i + \alpha_{s,t} + \beta l_{i,t-1}\epsilon_t^m + \delta l_{i,t-1} + \Gamma' Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock and $Z_{i,t-1}$ is a vector of firm-level controls (including book-to-market ratio and firm betas). The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Jun-2008, and post-crisis is Aug-2009 to Jun-2019. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.2.12 Alternative Measure of Stock Returns

Our results also hold with an alternative measure of stock returns using the open-to-close price differences. We show the results in Table A.11 below.

Table A.11: Response of firm-level stock returns (open-to-close) to monetary shocks

	(1a) Pre	(1b) Post	(1c) Diff
ϵ_t^m (FFR) x Leverage	-1.05		
	(0.647)		
ϵ_t^m (LSAP) x Leverage		2.14***	
		(0.597)	
Pre- vs. post-crisis			3.19***
			(0.801)
Observations		31,195	
R^2		0.430	

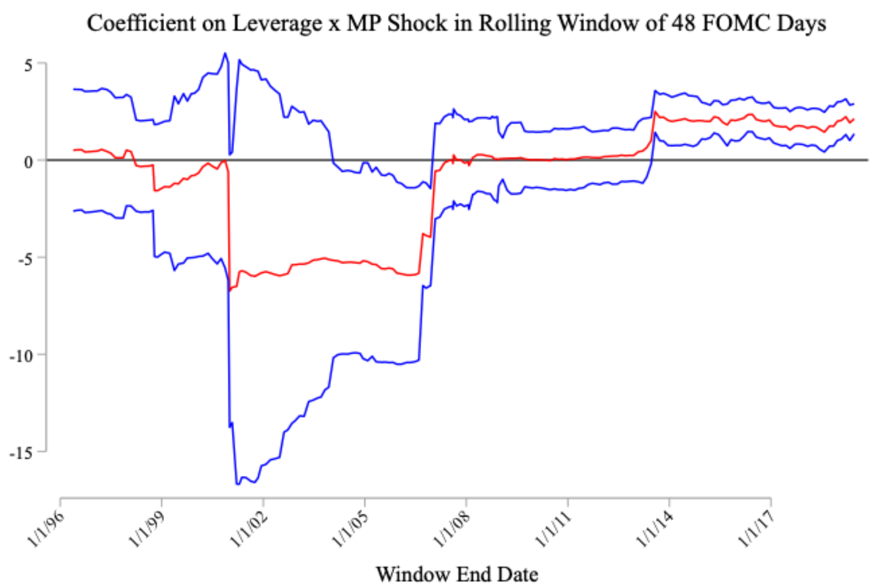
Notes: This table shows results from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right)[\alpha_i + \alpha_{s,t} + \beta l_{i,t-1}\epsilon_t^m + \delta l_{i,t-1} + \Gamma' Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return (measured from open-to-close), α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock and $Z_{i,t-1}$ is a vector of firm-level controls. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Jun-2008, and post-crisis is Aug-2009 to Jun-2019. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.3 Additional Empirical Results

A.3.1 Timing of the Change in Responsiveness

We answer whether the change in responsiveness could have occurred before or after the financial crisis. Using rolling window estimates, we show that the shift in responsiveness occurred sharply around early 2009, with the leverage-monetary policy interaction remaining consistently negative before and positive after this point. Figure A.3 shows the results.

Figure A.3: Interaction coefficient of leverage and monetary shock from rolling regression



Notes: This figure plots the coefficient β_1 estimated within a rolling window of 48 FOMC days using the specification: $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \delta_1 l_{i,t-1} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day $\times$ sector fixed-effect, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock (FFR in the pre-crisis and LSAP in the post-crisis) and $Z_{i,t-1}$ is a vector of firm-level controls. The sample is non-financial firms in S&P 500 on the FOMC announcement day. The date of the plotted coefficient refers to the final FOMC day within the window. 90% confidence intervals are plotted and calculated using the two-way clustered (by firm and FOMC day) standard errors. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock.

A.3.2 The Average Effects of Monetary Shocks

Since we use time fixed effects in the main regressions, we cannot estimate the stand-alone effect of the monetary policy shock on firm-level stock returns from this specification. Table A.12 shows the average effects of monetary shocks when we shut down the time fixed effects. First, we find our main results on the interaction between monetary policy shocks and leverage remain robust.

Table A.12: Robustness of stock return results without time fixed effects

	(1a) Pre	(1b) Post	(1c) Diff
ϵ_t^m (FFR)	5.17***		
	(1.625)		
ϵ_t^m (LSAP)		-2.39	
		(7.691)	
Pre- vs. post-crisis			-7.56
			(7.863)
ϵ_t^m (FFR) x Leverage	-3.35*		
	(1.717)		
ϵ_t^m (LSAP) x Leverage		4.21***	
		(1.275)	
Pre- vs. post-crisis			7.56***
			(2.148)
Observations		60,075	
R^2		0.043	

Results from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right)[\alpha_i + \alpha_s + \beta l_{i,t-1}\epsilon_t^m + \delta l_{i,t-1} + \Gamma' Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock and $Z_{i,t-1}$ is a vector of firm-level controls. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Jun-2008 and post-crisis is Aug-2009 to Dec-2017. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.3.3 Distinguishing Short-term and Long-term Leverage

In Table A.13, we show the results where we simultaneously include short-term and long-term leverage (and interaction with monetary policy) in our baseline specification. The results are consistent with our theory centralized around the essential role of long-term debt post-crisis. Before the financial crisis, both short-term and long-term leverage hindered firms' responses to monetary shocks because of debt overhang problems. After the financial crisis, the unconventional monetary policy moved the long-term rate much more than the short-term rate; therefore, debt dilution effects from the existing long-term debt dominated the debt overhang problems, and we have the reversal results. Short-term leverage has the same sign but is less/not significant because the short-term rates are moving much less or even not moving at all. We see these results as consistent with our main mechanism.

Table A.13: Response of firm-level stock returns to monetary shocks: LT vs. ST leverage

	(1a) Pre-Crisis	(1b) Post-Crisis
ϵ_t^m (FFR) x ST Leverage	-1.82***	
	(0.549)	
ϵ_t^m (FFR) x ST Leverage	-2.01***	
	(0.738)	
ϵ_t^m (LSAP) x ST Leverage		1.01
		(0.967)
ϵ_t^m (LSAP) x LT Leverage		2.05***
		(0.790)
Observations	59,868	
R^2	0.257	

Notes: Results from estimating $s_{i,t} = \left(1 + \zeta D_t^{post}\right)[\alpha_i + \alpha_{s,t} + \beta_1 l_{i,t-1}^{ST}\epsilon_t^m + \delta_1 l_{i,t-1}^{ST} + \beta_2 l_{i,t-1}^{LT}\epsilon_t^m + \delta_2 l_{i,t-1}^{LT} + \Gamma' Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1}] + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day x sector fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}^{ST}$ ($l_{i,t-1}^{LT}$) is four-quarter moving average short-term (long-term) leverage normalized to have mean 0 and variance 1, ϵ_t^m is the monetary policy shock and $Z_{i,t-1}$ is a vector of firm-level controls. The pre-crisis (post-crisis) monetary policy shock is normalized to have a unit effect on mp1 (the 10 year yield), and a positive value represents an expansionary shock. Pre-crisis is from Jul-1991 to Jun 2008, and post-crisis is from Aug 2009 to Dec-2017. The sample is non-financial firms in S&P 500 on the date of the FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

B Theoretical Appendix

B.1 Characterization of the Stylized Model in Section 4.2

B.1.1 Equilibrium Firm Policy

We recursively solve the equilibrium firm policy in the steady state and transition periods following unexpected monetary policy shocks. At the center of the policy is a Bellman equation of the continuation value function $V_t(b_t, z_{t+1})$, which is

$$V_{t-1}\left(b_{jt-1}, z_{jt}\right) = \max\left\{-\tilde{e}_{jt-1} + \frac{1}{1+r_s}\int_{\bar{\varepsilon}_{jt}}^{\infty}[n_{jt} + EV_t\left(b_{jt}, z_{jt+1}\right)]\varphi(\varepsilon)d\varepsilon\right\} \tag{14}$$

where $\tilde{e}_{jt-1} \equiv n_{jt-1} + e_{jt-1} \geq \underline{\tilde{e}}$ is defined as a choice variable and $\underline{\tilde{e}}$ is the redefined upper bound of equity issuance. In equilibrium, a firm maximizes shareholder value subject to creditors' bond prices and aggregate paths of real interest rates. The value $V_{t-1}\left(b_{jt-1}, z_{jt}\right)$ can be computed recursively. We omit all the j and t subscriptions, the firm chooses policies $\{\tilde{e_{-1}}, k, l, b_s, b_l\}$ to solve the following optimization problem

$$V(b_{-1}, z_t) = \max_{\left\{\begin{array}{c} k, l, \tilde{e_{-1}} \geq \underline{\tilde{e}} \\ b_s, b_l \end{array}\right\}} -\tilde{e_{-1}} + \frac{1}{1+r_s}\int_{\bar{\varepsilon}}^{\infty}\left[n + EV\left(b, z_{+1}\right)\right]\varphi(\varepsilon)d\varepsilon$$

$$\begin{aligned}
\text{s.t.: } & n = k - b_s - \lambda b_l + (1-\tau)\left[y + \varepsilon k - wl - \delta k - f - c\left(b_s + b_l\right)\right] \\
& y = zk^{\theta}l^{\nu} \\
& n(\bar{\varepsilon}) + (1-\kappa)EV\left(b, z_{+1}\right) = 0 \\
& k = \tilde{e} + b_s q_{s,-1} + \left(b_l - b\right)q_{l,-1} - \Theta(b_s, b_l, b) \\
& b = (1-\lambda)b_l \\
& q_{s,-1} = \frac{1}{1+r_s}[1-\Phi(\bar{\varepsilon})](1+c) \\
& q_{l,-1} = \frac{1}{1+r_l}[1-\Phi(\bar{\varepsilon})]\left[\gamma + c + (1-\gamma)Eg\left(b, z_{+1}\right)\right]
\end{aligned}$$

B.1.2 Derive the Variable Continuation Value V^*

In the firm's problem (14), the variable component of shareholder value at time $t-1$ to be maximized is $V(b_{t-1}, z_t)$ in terms of three choice variables: $\{k_t, b_{st}, b_{lt}\}$ which consequently determines the default cutoff $\bar{\varepsilon}_t$. Since the beginning of the period, net worth n_{t-1} is predetermined, and firms' optimal choices have no effect on it; we can focus only on $V(b_{t-1}, z_t)$. Combining the firm's problem (14) with its constraints (4), (5), (6), (7), and (8).

To derive the continuation stock value equation (9), we first combine the *ebita* equation and net worth equation and apply them to the definition of $\bar{\varepsilon}$ equation below

$$ebita_{jt} \equiv y_{jt} + \varepsilon_{jt}k_{jt} - wl_{jt} - \delta k_{jt} - f \tag{15}$$

$$n_{jt} = k_{jt} - b_{jst} - \lambda b_{jlt} + (1-\tau)\left[ebita_{jt} - c\left(b_{jst} + b_{jlt}\right)\right] \tag{16}$$

$$\bar{\varepsilon}_{\mathbf{jt}}: \quad n_{jt}(\bar{\varepsilon}_{jt}) + EV_t\left(b_{jt}, z_{jt+1}\right) = 0, \quad \text{default if } \varepsilon_{jt} < \bar{\varepsilon}_{jt} \tag{17}$$

to get the cutoff equation (18) below as

$$\begin{aligned}(1-\tau)\bar{\varepsilon}_{jt}k_{jt} = &- k_{jt} + b_{jst}(1+(1-\tau)c) + b_{jlt}(\lambda+(1-\tau)c) \\ &- (1-\tau)\left[y_{jt} - wl_{jt} - \delta k_{jt} - f\right] - EV_t\left(b_{jt}, z_{jt+1}\right)\end{aligned} \tag{18}$$

We then combine the reformulated equity equation with the capital equation below

$$\tilde{e}_{jt-1} \equiv n_{jt-1} + e_{jt-1} \geq \underset{\sim}{\tilde{e}} \tag{19}$$

$$k_{jt} = n_{jt-1} + e_{jt-1} + b_{jst}q_{jst-1} + \left(b_{jlt} - b_{jt-1}\right)q_{jlt-1} - \Theta_b \tag{20}$$

to get the reformulated equity equation (21)

$$\tilde{e}_{jt-1} = k_{jt} - b_{jst}q_{jst-1} - \left(b_{jlt} - b_{jt-1}\right)q_{jlt-1} + \Theta_b \tag{21}$$

Finally, apply equations (18) and (21) to equation (14) and omit all j, we have

$$V_{t-1}(b_{t-1}, z_t) = \underbrace{\left[q_{st-1}b_{st} + q_{lt-1}(b_{lt} - b_{t-1}) - \Theta_b\right]}_{\text{Net Debt Issuance Revenue}} + \underbrace{\left[\frac{1-\tau}{1+r_s}k_t\int_{\bar{\varepsilon}_t}^{\infty}(\varepsilon_t - \bar{\varepsilon}_t)\phi(\varepsilon_t)d\varepsilon_t - k_t\right]}_{\text{Net Capital Investment Revenue}}$$

B.2 Derive the First Order Conditions

Assuming $\Theta_b = \eta(b_s + b_l - b)^2$ and have $b_l - b > 0$, we would have the FOCs as below. In the paper, we shortcut to have $\Theta_b'(b_s)$ or $\Theta_b'(b_l)$ as the partial derivatives.

Debt FOCs The firm's first order condition on V^* with respect to b_s and b_l are

$$\frac{1-\Phi(\bar{\varepsilon})}{1+r_s}\tau c + \frac{\partial\bar{\varepsilon}}{\partial b_s}\left[b_s\frac{\partial q_s}{\partial\bar{\varepsilon}} + (b_l - b)\frac{\partial q_l}{\partial\bar{\varepsilon}}\right] - 2\theta_b\left(b_s + b_l - b\right) = 0$$

$$\begin{aligned}\frac{1-\Phi(\bar{\varepsilon})}{1+r_l}E\left[\tau c + (1-\gamma)\left(g\left(b', z'\right) + (b_l - b)\frac{\partial g\left(b', z'\right)}{\partial b_l}\right) + \frac{\partial V\left(b', z'\right)}{\partial b_l}\right] \\ + \frac{\partial\bar{\varepsilon}}{\partial b_l}\left[b_s\frac{\partial q_s}{\partial\bar{\varepsilon}} + (b_l - b)\frac{\partial q_l}{\partial\bar{\varepsilon}}\right] - 2\theta_b\left(b_s + b_l - b\right) = 0\end{aligned}$$

Given long-term debt choice b_l, we can rewrite the short-term debt FOC in terms of $\{r_s, r_l, b\}$ to analyze the effects of debt dilution and how it interacts with monetary policy:

$$\begin{aligned}-2\theta_b b_s + \frac{1}{1+r_s}&\left[(1-\Phi(\bar{\varepsilon}))\tau c - \frac{\partial\bar{\varepsilon}}{\partial b_s}\phi(\varepsilon)(1+c)b_s\right] \\ &+ \left[\frac{1}{1+r_l}\left[\frac{\partial\bar{\varepsilon}}{\partial b_s}\phi(\varepsilon)\left(1 + c + (1-\gamma)Eg\left(b', z'\right)\right)\right] + 2\theta_b\right](b - b_l) = 0\end{aligned} \tag{22}$$

Given short-term debt choice b_s, we can rewrite the long-term debt FOC in terms of $\{r_s, r_l, b\}$ to analyze the effects of debt dilution and how it interacts with monetary policy:

$$
\begin{aligned}
&-2\theta b_s - \frac{1}{1+r_s}\left[\frac{\partial\bar{\varepsilon}}{\partial b_l}\phi(\varepsilon)(1+c)b_s\right] + \frac{1}{1+r_l}E\left[(1-\Phi(\bar{\varepsilon}))\left(\tau c + (1-\gamma)g\left(b',z'\right) + \frac{\partial V\left(b',z'\right)}{\partial b_l}\right)\right] \\
&+\left[\frac{1}{1+r_l}E\left[\frac{\partial\bar{\varepsilon}}{\partial b_l}\phi(\varepsilon)\left(1+c+(1-\gamma)g\left(b',z'\right)\right) - (1-\Phi(\bar{\varepsilon}))(1-\gamma)\frac{\partial g\left(b',z'\right)}{\partial b_l}\right] + 2\theta_b\right](b-b_l) = 0
\end{aligned}
\tag{23}
$$

We then rearrange the above two FOCs to get the paper's equations (11) and (12).

Capital FOCs The firm's first order condition with respect to capital k is:

$$
\frac{\partial\bar{\varepsilon}}{\partial k}\left[b_s\frac{\partial q_s}{\partial\bar{\varepsilon}} + (b_l-b)\frac{\partial q_l}{\partial\bar{\varepsilon}} - \frac{1-\tau}{1+r_s}k[1-\Phi(\bar{\varepsilon})]\right] + \frac{1-\tau}{1+r_s}\int_{\bar{\varepsilon}}^{\infty}(\varepsilon-\bar{\varepsilon})\varphi(\varepsilon)d\varepsilon - 1 = 0
$$

where we can plug in the partial derivatives of bond prices $\partial q_s/\partial\bar{\varepsilon}$ and $\partial q_l/\partial\bar{\varepsilon}$ and rewrite the capital FOC as

$$
\begin{aligned}
&\frac{1}{1+r_s}\left[\left(-\frac{\partial\bar{\varepsilon}}{\partial k}\right)\phi(\varepsilon)(1+c)b_s + (1-\tau)\left[\left(-\frac{\partial\bar{\varepsilon}}{\partial k}\right)k[1-\Phi(\bar{\varepsilon})] + \int_{\bar{\varepsilon}}^{\infty}(\varepsilon-\bar{\varepsilon})\varphi(\varepsilon)d\varepsilon\right]\right] \\
&\qquad - \frac{1}{1+r_l}\left[\left(-\frac{\partial\bar{\varepsilon}}{\partial k}\right)\phi(\varepsilon)\left(1+c+(1-\gamma)\mathbb{E}g\left(b',z'\right)\right)\right](b-b_l) - 1 = 0
\end{aligned}
\tag{24}
$$

We then rearrange the above FOC to get the paper's equation (13).

B.3 Full-blown Quantitative Model

The stylized model has many abstractions to be analytically more intuitive. However, it quantitatively omits many important components, including productivity progress, exogenous exit risk, recovery value, details of the issuance costs, etc. In this appendix section, we lay down a full-blown model and quantify it using US data.

Firm's Production, Productivity Progress, and Entry/Exit Each firm j produces using capital k and labor l with decreasing returns to scale production function $y_{it} = z_{it}k_{it}^{\theta}l_{it}^{\nu}, \theta + \nu < 1$, where z_{it} is the persistent idiosyncratic productivity shock for firm i that follows distribution $p(z_{it}|z_{it-1})$. Earnings before interest and taxes are $ebita_{it} \equiv y_{jt} + \varepsilon_{jt}k_{jt} - wl_{it} - \delta k_{it} - f$ where ε_{it} is a firm-specific capital quality shock, δ is the depreciation rate, and f is a fixed cost of operation. There are three sources of idiosyncratic uncertainty. Productivity z_{it} is persistent and follows a Markov process. The capital quality shock ε_{it} is i.i.d. normal with mean zero and σ_{ϵ}. It is realized after production has taken place in period t. Finally, firms face exogenous exit risk κ. Exiting firms (both default and exogenous) are replaced by mass M free-entry firms with the initial lowest productivity z_e and zero starting debt. Productivity z_{it} is drawn from a ladder $Z = \{z_1 = z_e, z_2, ...z_J\}$ where the support of the natural logarithm of z_{it} is evenly spaced on the interval $[-\sigma_z, +\sigma_z]$. Surviving firms with last period productivity $z_{it-1} = z_j$ draws next period productivity $z_{it} = z_j$ with probability ρ_z and $z_{it} = \min(z_{j+1}, z_J)$ otherwise. We omit subscript i going forward to save notations.

Firm's Finance The firm can finance capital with equity and short-term and long-term debt at the end of the period $t-1$. Let b_{st} and b_{lt} denote the issuance of short-/long-term debt and b_{t-1} denote the stock of outstanding long-term debt at the end of period $t-1$. Short-term debt is a one-period contract. For long-term debt, we assume that a fraction λ of the long-term principal is paid back in every period while the remaining $(1-\lambda)$ remains outstanding. There are issuance costs for debt. These issuance costs are flotation fees for new debt issues and bank fees. The debt issuance cost is $\Theta_b = \theta_b \left(b_s + \max\{b_l - b, 0\}\right)^2$, where θ_b capture issuance cost. Coupon payments c are tax-deductible. The firm can also finance its capital stock by injecting equity. Let n_{t-1} be the net worth, and let e_{t-1} denote net equity issuance at the end of period $t-1$. A negative value of e_{t-1} indicates a net dividend payment from the firm to shareholders. Capital in period t is given by $k_t = n_{t-1} + e_{t-1} + b_{st}q_{st-1} + (b_{lt} - b_{t-1})\, q_{lt-1} - \Theta(b_{st}, b_{lt}, b_{t-1})$. Firm earnings are taxed at rate τ. The stock of net worth in period t after production and repayment of debt is $n_t = k_t - b_{st} - \lambda b_{lt} + (1-\tau)\left[ebita_t - c\,(b_{st} + b_{lt})\right]$. Shareholders are protected by limited liability, so they are free to default. A defaulting firm exits the economy. In addition to this, there is exogenous exit risk. With probability κ, a non-defaulting firm exogenously leaves the economy. We assume default and exogenous firms have zero value to show the mechanism more straightforwardly.

Firm's Recursive Problem Firms maximize shareholder value, the expected present value of net cash flows to shareholders. They discount cash flows at the short-term risk-free rate r_s. The shareholder value of a continuing firm at the end of period t can be written as the sum of net worth and a continuation value: $n_t + V_t\,(b_t, z_{t+1})$, where b_t is the remaining outstanding debt $b_t = (1-\lambda)b_{lt}$. Because there are no equity issuance costs, net worth n_{it} does not influence the optimal firm policy, and the continuation value $V_t\,(b_t, z_{t+1})$.

We describe the firm problem starting from the default decision at the end of period t. The idiosyncratic capital quality shock ε_t has been realized, but future firm productivity z_{t+1} is still uncertain. If the firm does not default, the expected shareholder value is $(1-\kappa)\left[n_t + \mathbb{E}V_t\,(b_t, z_{t+1})\right]$, where the expectation $\mathbb{E}$ is taken over future firm productivity z_{t+1} and κ is exogenous exit risk.

There exists a unique threshold realization $\bar{\varepsilon}_t$ which sets expected shareholder value to zero: $n_t(\bar{\varepsilon}_t) + (1-\kappa)\mathbb{E}V_t(b_t, z_{t+1}) = 0$. Firm default if $\varepsilon_t < \bar{\varepsilon}_t$.

At the end of the period of $t-1$, the firm chooses its corporate policies: current period finance and next period production $\{e_{t-1}, b_{st}, b_{lt}, k_t, l_t\}$. The firm anticipates that shareholder value will be positive if ε_t is higher than the threshold value $\bar{\varepsilon}_t$ and zero otherwise. Given a net worth n_{t-1}, existing debt b_{t-1}, and productivity z_t, a firm solves:

$$n_{t-1} + V_{t-1}(b_{t-1}, z_t) = \max\left\{-e_{t-1} + \frac{1}{1+r_s}\int_{\bar{\varepsilon}_t}^{\infty}[n_t + (1-\kappa)\mathbb{E}V_t(b_t, z_{t+1}) - \kappa b_t \mathbb{E}q_{lt}]\varphi(\varepsilon)d\varepsilon\right\} \quad (25)$$

Creditor's Problem Creditors are perfectly competitive and break even on expectations for both short- and long-term bonds $\{b_{st}, b_{lt}\}$ given the corresponding risk-free rates at different maturities $\{r_s, r_l\}$. At the steady state without monetary shocks, all interest rates and coupons are equal $(r^* = c = r_s = r_l)$. They buy firm bonds b_{st} and b_{lt} at the end of the period $t-1$. If the firm does not default in period t, short-term creditors receive $(1+c)b_{st}$, and long-term creditors are paid $(\gamma+c)b_{lt}$. In case of default, they receive $(1-\xi)\underline{n_t}$, where ξ is the proportional cost of a fire sale and $\underline{n_t} = k_t + (1-\tau)ebita_t$ is the firm's value without repaying. Short- and long-term debt have equal seniority. The break-even price of short-term debt is

$$q_{st-1} = \frac{1}{1+r_s}\left[[1-\Phi(\bar{\varepsilon}_t)](1+c) + \frac{1-\xi}{b_{st}+b_{lt}}\int_{-\infty}^{\bar{\varepsilon}_t}\underline{n_t}\phi(\varepsilon)d\varepsilon\right] \quad (26)$$

where $1-\Phi(\bar{\varepsilon}_t)$ is the probability that $\varepsilon_t > \bar{\varepsilon}_t$. The price of short-term debt depends on firm behavior at time t, in particular on the risk of default $\Phi(\bar{\varepsilon}_t)$. In contrast, the price of long-term debt also depends on the future market value of long-term debt $q_{lt+1} = g_{t+1}(b_t, z_{t+1})$:

$$q_{lt-1} = \frac{1}{1+r_l}\left[[1-\Phi(\bar{\varepsilon}_t)](\gamma + c + (1-\gamma)\mathbb{E}g_t(b_t, z_{t+1})) + \frac{1-\xi}{b_{st}+b_{lt}}\int_{-\infty}^{\bar{\varepsilon}_t}\underline{n_t}\phi(\varepsilon)d\varepsilon\right] \quad (27)$$

where if the firm does not default in period t, it repays a fraction γ of the outstanding debt plus the coupon c. A fraction $1-\gamma$ of the debt remains outstanding while the future price of long-term debt $q_{lt} = g_t(b_t, z_{t+1})$ depends on future firm behavior.

Equilibrium Firm Policy We recursively solve the equilibrium firm policy in the steady state and transition periods following unexpected monetary policy shocks. At the center of the policy is a Bellman equation of the continuation value function $V_t(b_t, z_{t+1})$. The key idea is to rewrite the firms' problem as

$$V_{t-1}(b_{t-1}, z_t) = \max\left\{-\tilde{e}_{t-1} + \frac{1}{1+r_s}\int_{\bar{\varepsilon}_t}^{\infty}[n_t + (1-\kappa)\mathbb{E}V_t(b_t, z_{t+1}) - \kappa b_t \mathbb{E}q_{lt}]\varphi(\varepsilon)d\varepsilon\right\} \quad (28)$$

where $\tilde{e}_{t-1} \equiv n_{t-1} + e_{t-1} \geq \underline{\tilde{e}}$ is defined as a choice variable and $\underline{\tilde{e}}$ is the redefined upper bound of equity issuance. The above bond prices, capital and net worth accumulation rules, and production technologies are the constraints.

Numerical Solution In terms of numerical solution, we solve the model in a partial equilibrium fashion, focusing on firms' decisions. More specifically, we follow the backward induction method in Hatchondo and Martinez (2009) and Jungherr and Schott (2020) to solve the continuation value function $V_t(b_t, z_{t+1})$, firm policies $\{e_{t-1}, b_{st}, b_{lt}, k_t, l_t\}$ and bond prices $\{q_{st-1}, q_{lt-1}\}$ recursively starting from a final date. We iterate backward for the steady-state equilibrium until all prices and quantities converge. Then, we use the first-period equilibrium allocation as the steady-state equilibrium of the infinite-horizon economy. We solve the equilibrium wage as if there is a representative household whose utility function is $ln(\sum(y_t - i_t)) - (\sum l_t)^3/3$. For the transition equilibrium, we take the wage as given and use a shooting method to solve backward the value and policy functions starting from the steady-state equilibrium and then simulate the steady-state distribution following the "MIT" monetary policy shocks in Ottonello and Winberry (2020). In both types of monetary expansions, we have $r_{st+1} = \rho_r r_{st} + \Delta r_s$ and $r_{lt+1} = \rho_r r_{lt} + \Delta r_l$, where ρ_r is the persistence of monetary policy shocks. Our modification is that given the same magnitude of changes in the short rate Δr_s, the difference between conventional monetary expansions and unconventional expansions is substantial, $|\Delta r_l^c| < |\Delta r_l^u|$.

B.4 Quantification of the Model Mechanism

We quantify the above full-blown model using U.S. firm-level data and responses of Treasury yields to monetary policy shocks. The model generates predictions that are consistent with our main empirical evidence and evidence on the mechanism channels.

B.4.1 Parameterization

The model is calibrated at a quarterly frequency. There are two groups of parameters for the stationary equilibrium and a third group for the transitional equilibrium. The first group is assigned, the second group is chosen jointly to match data moments in the stationary equilibrium, and the third group matches monetary policy shocks, which we will explain in the next subsection. Table A.14 below lists all parameters and moments.

Table A.14: Parameterization and Targeted Moments

Fixed Parameters	Notation	Value	Fixed Parameters	Notation	Value
Discount factor	$1/(1+r_s^*)$	0.99	Coupon rate	c	r_s^*
Capital coefficient	θ	0.250	Labor coefficient	ν	0.500
Exogenous exit rate	κ	0.017	Capital depreciation rate	δ	0.025
Corporate income tax rate	τ	0.400	Long-term debt repayment rate	λ	0.050
Monetary shock persistence	ρ_r	0.500	Productivity persistence	ρ_z	0.965
Fitted Parameters	**Notation**	**Value**	**Fitted Parameters**	**Notation**	**Value**
Capital quality shock volatility	σ_ε	0.627	Fixed cost of operation	f	0.303
Debt issuance cost	θ_b	0.004	Fire sale cost	ξ	0.900
Support of productivity shock	σ_z	0.290	CMP/UMP shock to short rate	Δr_s	-25bps/4
CMP shock to long rate	Δr_l^c	-4bps/4	UMP shock to long rate	Δr_l^u	-34bps/4
Targeted Moments	**Data**	**Model**	**Targeted Moments**	**Data**	**Model**
Leverage (%)	32.8	32.6	Long-term debt share (%)	66.9	66.4
Investment rate (%)	6.2%	6%	Default rate (%)	0.6	0.6
Long-term credit spread	2.5%	2.4%	Δ Short-term Treasury yield	-25bps	-25bps
Δ long-term Treasury yield (CMP)	-4bps	-4bps	Δ long-term Treasury yield (UMP)	-34bps	-34bps

In the first group, the steady state stochastic discount factor $1/(1 + r_s^*)$ is 0.99. Also, in the steady state, $c = r_s^* = r_l^*$ holds, so firms have no incentive to arbitrage from short- and long-term positions without considering monetary policy shocks. Following Gomes and Schmid (2010), we set the decreasing returns to scale parameter α to 0.65. The capital depreciation rate is set to 2.5%

per quarter. We set the long-term debt repayment rate to 0.05 to match the maturity of long-term debt of 5 years. The corporate income tax rate is 0.4 as in Gomes et al. (2016). We set the productivity parameters, exogenous firm exit rate, and monetary shock persistency following Ottonello and Winberry (2020). In the second group, we target an average investment rate of 6.2% and a mean quarterly default rate of 0.6%, as estimated in a survey of businesses by Dun and Bradstreet. We target a mean leverage ratio of about 33%, as reported in Crouzet and Mehrotra (2020). We target a mean long-term debt share of 67%, as in the data.

B.4.2 Monetary Expansions Move Long-term Rates More Post-Crisis

We first calibrate the monetary policy shocks roughly according to our empirical findings. Specifically, we first match the magnitude of the on-impact changes in the short-term real interest rate of Δr_s of $-25bps$ to changes in the short-term rates, regardless of conventional or unconventional monetary policy shocks, in the third group of parametrization. This is not exactly true because the short rate did not move after-crisis. However, we make this assumption since we want to demonstrate the difference only from the long-term rate. The shocks then last with the persistence of ρ_r. We then match the corresponding changes in the 10-year Treasury yield to the on-impact long-term real interest rate changes to the same shocks in the short-term rates as our empirical findings. A conventional expansion shock will change the long-term rate by $\Delta r_l^c = -0.15 * 25bps \simeq -4bps$, and an unconventional expansion shock will change the long-term rate by $\Delta r_l^c = -1.34 * 25bps \simeq -34bps$. We then rescale all the monetary policy shocks to quarterly frequency.

B.4.3 High-leverage Firms Hold More Long-term Debt

We then provide the quantitative model results that are consistent with the data that high-leverage firms hold more long-term debt. In the model simulated firm sample in the steady state, we find a high positive correlation between leverage and long-term debt share of about 0.71. This is consistent with the model mechanism such that high-leverage firms tend to rollover more long-term debt to reduce the debt issuance costs.

Table A.15: Untargeted Correlation between Leverage and Long Share

Data	Model
0.30	**0.71**

B.4.4 Regression Results in the Quantitative Model

Finally, we validate the main results and the mechanisms in Section 4.3 to show the changing role of leverage and the two channels of monetary policy shocks through leverage. We first simulate a firm sample under two scenarios. In the first scenario, 5000 firms (with entry and exit) stayed in the steady state by 50 quarters, were hit by a conventional monetary shock in the 51-quarter, and then converged back to their steady state in 50 quarters. In the second scenario, 5000 firms (with entry and exit) stayed in the steady state by 50 quarters, were hit by an unconventional monetary shock in the 51-quarter, and then converged back to their steady state in 50 quarters. We then pick 15 quarters pre-shock and 10 quarters post-shock. Therefore, we have a total of about 5000 firms for 25 quarters for both episodes. For half of the observations, there are no monetary policy shocks; for half of the observations, there are monetary policy shocks with decreasing effects departing from the on-hit quarters. We then run the following regression, which is the same as the main empirical regression:

$$y_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 D_t^{post} l_{i,t-1}\epsilon_t^m + \delta_1 l_{i,t-1} + \delta_2 D_t^{post} l_{i,t-1} + e_{i,t} \tag{29}$$

where $y_{i,t}$ is the dependent variable of firm i, α_i is a firm i fixed effect, α_t is the time fixed effect, D_t^{post} is a dummy that turns on for the post-crisis sample, $l_{i,t-1}$ is firm i's lagged leverage (measured as debt-to-capital), and ϵ_t^m is the monetary policy shock.

We run the regression for stock returns to show the main results and for debt borrowing and capital investment to show the two channels. As we did for the main empirical regressions, all three measures are in percentage changes. The results are in Table A.16 below; we do not show the significance level since it is model simulated regressions. The results are consistent with our empirical findings either with the triple interaction between D_t^{post}, ϵ_t^m, and other firm-level variables or without. The relative magnitudes are also consistent with our empirical findings: the coefficient for borrowing is the largest, the coefficient for investment is the smallest, and the coefficient for stock return lies in between.

Table A.16: Model Regression Results: Post-Crisis vs Pre-Crisis

	(1) Investment	(2) Investment	(3) Borrowing	(4) Borrowing	(5) Stock Return	(6) Stock Return
$D_t^{post} \times l_{i,t-1} \times \epsilon_t^m$	0.053	0.029	1.226	0.419	0.743	9.436
Interactions with Controls	No	Yes	No	Yes	No	Yes
N	72185	72185	72185	72185	72185	72185
adj. R^2	0.151	0.175	0.520	0.532	0.174	0.177