Monetary Policy and Firm Heterogeneity: The Role of Leverage Since the Financial Crisis*

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Abstract

We show that the role of leverage in explaining firm-level responses to monetary policy changed around the financial crisis of 2007-09. Stock prices of firms with high leverage were less responsive to monetary policy shocks in the pre-crisis period but have become more responsive since the crisis. Using expected volatility measures from firm-level options, we further document that financial markets have been aware of this change. The use of unconventional monetary policy tools by the Federal Reserve since the crisis played an important role in driving our results; but, we also find evidence for changing transmission of conventional tools.

Keywords: Monetary policy transmission, leverage, firm heterogeneity

JEL codes: E52, E44, E43, E22

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1 Introduction

Since the federal funds rate hit the zero lower bound at the beginning of the financial crisis, the Federal Reserve has relied more on unconventional policy tools like quantitative easing. In this paper we explore how the monetary transmission mechanism may have changed since the crisis, with a focus on the role of heterogeneity in firms' financing conditions. While the importance of the balance sheet of firms for the monetary transmission mechanism has long been established, recent work has highlighted the role of firm-level heterogeneity.[1] However, this literature on firm-level financial heterogeneity has typically focused on the pre-crisis period to study the transmission of conventional monetary policy actions. Our main contribution is to show that the role of financing conditions in explaining the firm-level response to monetary shocks has *reversed* in the post-crisis sample.

Our main empirical framework documents this pattern for non-financial firms in the S&P 500 index using stock price movements on FOMC announcement days. We complement this with two other approaches that use firm-level option prices and investment data. For all approaches, we construct monetary policy shocks using high frequency data from futures and Treasury bond markets. Our preferred measure of monetary policy shocks combines unexpected changes in the federal funds target with the change in the 10 year Treasury yield in a narrow window around FOMC announcements. This allows us to parsimoniously capture both conventional and unconventional monetary policy actions but we also show that our results are robust to using alternative measures of monetary shocks.

For our main approach, we combine firm-level characteristics with high frequency data on stock prices. Using leverage as the measure of the firm's financial position, we find that before the financial crisis of 2007-09, stock prices of firms with higher leverage respond *less* to monetary policy shocks on FOMC announcement days. However, this pattern is reversed

[1]For an early survey of the importance of the credit channel of monetary policy, see Bernanke and Gertler (1995). For recent work on firm-level heterogeneity see Ottonello and Winberry (2020), Jeenas (2019b) and Ozdagli (2018).

after the crisis: in the post-crisis sample firms with higher leverage respond *more* to monetary shocks. The panel data allows us to control for a variety of firm-level variables including a firm fixed effect to account for any permanent features at the firm level and a time fixed effect to control for any aggregate factors that could be changing over time. We also interact the monetary policy shock with various firm characteristics to show that our results are not explained by these other variables.

Our results hold across a variety of robustness checks, including using alternative measures of leverage, dropping unscheduled FOMC meetings, using time-by-sector fixed effects and accounting for the "information effect" in monetary shocks. A natural question is whether our results are driven by the changing behavior of leverage since the crisis. We document that average leverage has only slightly increased since the crisis and that the cross-sectional distribution of leverage is similar in the two samples. Moreover, we show that most firms have not moved around much in the leverage distribution since the crisis and more importantly that our results are not driven by firms that did move around a lot. Using a rolling regression framework we also check that the change in responsiveness that we highlight does indeed happen around the financial crisis and not considerably earlier or later.

Our baseline measure of monetary shocks combines short and long-term interest rates, motivated by the need to capture the increasing use of unconventional tools since the crisis. This raises the question of whether our results reflect a change in the conventional monetary transmission mechanism or simply that the Fed has used different tools since the crisis. To shed light on this, we use data from Swanson (2021) that creates three separate shocks: fed funds rate (FFR), forward guidance and large-scale asset purchases (LSAP). We find that firms with high leverage are less responsive to the FFR shock in the pre-crisis but more responsive to the LSAP shock in the post-crisis sample. This suggests that our results are entirely driven by the reliance on unconventional policy in the post-crisis sample. However, we offer two caveats to this interpretation which highlight the nuanced nature of this issue. First, we investigate the role of FOMC meetings when prominent LSAP announcements were made and find that the higher responsiveness tied to leverage is actually weaker on these dates. Second, we find evidence for the change in responsiveness even when we use single interest rate shocks, for example using the 2 year Treasury rate or 4 quarter Eurodollar futures rate. Thus, while our results appear to be driven by the increased reliance on unconventional tools in the post-crisis, we cannot rule out a change in transmission of conventional tools.

Since the monetary policy shocks are not predictable, our results have no implications for the *expected direction* of the movement in the stock price of firms with higher (or lower) leverage on FOMC announcement days. However, there is a direct implication for the *expected volatility* of the stock price. Specifically, we should expect that firms with high leverage will be less volatile on FOMC announcement days in the pre-crisis sample. Moreover, this relationship should flip with the crisis making high leverage firms more volatile on announcement days in the post-crisis sample. Our second approach involves testing this hypothesis by using high frequency firm-level options data. These options data allow for the construction of a measure of expected volatility for each firm. We analyze these firm-level expected volatility measures on the day before the FOMC announcement and confirm the reversal in the relationship between leverage and monetary policy announcements since the financial crisis. This also means that stock market participants were aware of this changing relationship and have updated their expectations of how volatile firms with high leverage will be on FOMC announcement days.

Our third approach involves using firm-level investment data. Since this measure of real activity is only available quarterly, we aggregate our monetary policy shock measure up to the quarterly level. At this frequency, there are several factors that could affect firm-level investment other than monetary policy. Nevertheless, these quarterly results confirm the pattern of increasing responsiveness of firms with higher leverage since the financial crisis.[2]

In the next part of the paper we shed light on the mechanism driving our empirical results.

[2]There is an ongoing discussion in the literature regarding the longer-run response of investment to monetary policy shocks, see Ottonello and Winberry (2020) and Jeenas (2019b). The relatively shorter sample of data since the crisis makes it difficult to do inference on comparing long-run responses in the pre- and post-crisis samples, so in this paper we focus on the contemporaneous response. Our findings for the contemporaneous response of investment in the pre-crisis sample are consistent with both these papers.

There is a growing literature on the transmission of monetary policy and heterogeneity in firm balance sheets. But, as mentioned above, this literature has focused on the pre-crisis period. We start by placing our pre-crisis results in the context of the leading heterogenous firm model of Ottonello and Winberry (2020) (OW), which builds on the work of Khan et al. (2016). Within this model, we then discuss potential channels that can rationalize our post-crisis results and provide supporting empirical evidence.

In the OW model there are competing forces affecting how high vs. low leverage firms respond to an expansionary monetary policy shock. The marginal cost curve of a high leverage firm is steeper making it less responsive to monetary policy induced shifts of the marginal benefit curve. However, the expansionary monetary policy shock flattens out the marginal cost curve more because of an increase in the value of collateral and cash flows, making high leverage firms more responsive. In a pre-crisis calibration, OW find that the former effect dominates, implying results that are consistent with our pre-crisis findings. We argue that to reverse this result in the post-crisis sample, an expansionary monetary policy shock must flatten the marginal cost curve more for high leverage firms.

To understand why this might happen, we consider extensions to a key feature of firm financing in the OW model, viz. firms rely solely on one period debt. In particular, we investigate the role of long-term debt share, liquidity and bank debt share. We find evidence suggesting long-term debt is an important feature in explaining our results, but not the other two. First, firms that have high leverage disproportionately rely on long-term debt. Moreover, we document that long-term interest rates have become more sensitive to monetary policy shocks in the post-crisis sample. Combining these two facts creates a natural explanation for why the marginal cost curve would flatten more for high leverage firms in the post-crisis sample. Consistent with this interpretation, we show that the increased responsiveness since the crisis is indeed driven by firms that have a larger share of long-term debt.

Related Literature: Our paper is related to three strands of the literature. The first one identifies firm-level characteristics, particularly financial constraints such as leverage, that are associated with a heterogenous stock market response to monetary policy shocks. Both Ehrmann and Fratzscher (2004) and Ottonello and Winberry (2020) find that financial constraints affect the strength of a firm's response to monetary policy. Consistent with our results, they find evidence that stock prices for firms with high leverage are relatively less responsive to monetary shocks in the pre-crisis period. Ozdagli (2018) finds that firms that have higher information frictions are less responsive while Ippolito et al. (2018),Chava and Hsu (2019) find that more financially constrained firms have a stronger response to monetary policy and Pollio (2022) investigates the relationship between information shocks and firm leverage. While most of the literature focuses on the period prior to the financial crisis, Wu (2018) analyses stock price responsiveness to monetary policy during the 2008-2012 period. Consistent with our results, he finds that firms with higher leverage were more responsive to monetary policy during this period. Gürkaynak et al. (2019) and Ippolito et al. (2018) show that the stock price of firms with more variable debt is more responsive to monetary policy shocks. We show that our leverage results are not driven by firms with high or low variable rate debt share. Other related work studies the role of the firm balance sheet in responding to ECB monetary shocks: Darmouni et al. (2020) and Holm-Hadulla and Thürwächter (2021) explore bond debt, while Auer et al. (2019) explore leverage.

Our paper closely relates to two recent papers. First, Anderson and Cesa-Bianchi (2020) use firm-level bond yields to show that credit spreads of higher leverage firms are more sensitive to monetary shocks. This is consistent with our post-crisis result.[3] Second, Palazzo and Yamarthy (2020) find that firm-level risk plays an important role in the response of credit default swap spreads to US monetary shocks. Specifically, firms with higher credit risk are more responsive. This is consistent with our post-crisis results as we show that firm leverage is correlated with measures of risk.

Our paper also adds to the growing literature on the heterogenous effects of unconventional

[3] Our pre-crisis results are somewhat different. This is likely due to differences in the sample (our sample of firms and pre-crisis dates are different) and empirical specification (we control for the interaction of firm characteristics with the monetary policy shock).

monetary policy since the crisis. Grosse-Rueschkamp et al. (2019) study the effect of the ECB's corporate sector purchase program on firm's capital structure, showing that firms with bonds eligible for the ECB's program chose to shift from bank loans to bond debt. Daetz et al. (2018) investigate the impact of the ECB's longer-term refinancing operations on corporate investment. They show that firms' investment choice was influenced by the riskiness of their lender. Foley-Fisher et al. (2016) find that firms that are more dependent on long-term debt responded more to the Federal Reserve's Maturity Extension Program implemented in 2011 and 2012. We find that this amplifying role of long-term debt holds more generally and is a pervasive feature of the post-crisis period.

Finally, our paper is related to the literature that explores heterogenous responses of real economic activity to changes in monetary policy. Gertler and Gilchrist (1994), an early influential paper in this literature, notes that sales at small manufacturing firms decrease disproportionately relative to larger manufacturing firms after Romer and Romer tight money dates.[4] They provide evidence that small firms are a proxy for financial constraints, as smaller firms seem to have more difficulty acquiring credit when monetary policy becomes contractionary. More recent papers explicitly attempt to control for financial constraints. Ottonello and Winberry (2020) find that investment spending at firms with higher leverage is less responsive to monetary policy shocks in the quarter of a monetary shock. Dedola and Lippi (2005) show that output of industries in the U.S. and four other OECD countries with higher leverage is less responsive between 4 and 12 quarters after a monetary policy shock. In contrast to those two papers, Jeenas (2019a) and Jeenas (2019b) find that sales and investment of higher leverage firms are more responsive to monetary policy shocks after approximately 8 quarters. We provide evidence that the contemporaneous effect on higher leverage firms has become larger following the financial crisis. A related line of work (e.g. Cloyne et al. (2018) and Casiraghi et al. (2021)) stress the importance of firm age for monetary transmission. In

[4] A related literature uses business cycle contractions as the type of shock under investigation rather than monetary shocks, e.g. Kudlyak and Sanchez (2017), Crouzet and Mehrotra (2020), Kalemli-Özcan et al. (2018) and Bustamante (2020).

our analysis we control for the interaction of monetary policy with firm age to confirm that age is not driving the changing relationship between leverage and monetary transmission.

The rest of the paper is organized as follows. In the next section we outline the data sources and data variables used in our empirical analysis. Section 3 presents the results from our three main empirical strategies using stock price, options and investment data. Next, in Section 4 we shed some light on the mechanism driving our results. Section 5 provides a variety of robustness checks and Section 6 concludes.

2 Data

This paper uses the daily share prices for firms in the S&P 500 index from the CRSP/Compustat Merged Security Daily dataset for July 1991 to June 2019 and firm characteristics from the 1991:Q3 to 2019:Q3 CRSP/Compustat Merged Fundamentals Quarterly dataset. We combine this firm-level data with measures of monetary policy shocks that occur on FOMC meeting days. Additionally, we merge this with a dataset of firm-level implied volatility from Option-Metrics. This section further describes these three data sources.

2.1 Monetary Policy Shocks

To construct our measure of monetary policy shocks, we combine data from fed funds futures and Treasury bond markets. In the high-frequency monetary policy literature, the most common method to construct shocks involves looking at the change in futures contracts around FOMC announcements, where the underlying asset is the fed funds rate. The early work of Kuttner (2001) and Bernanke and Kuttner (2005) used changes in the current month's futures contract. This measure captures any unexpected changes to the target for the fed funds rate. However, in more recent years, the Federal Reserve has been using alternative unconventional policy tools, including large scale asset purchases (quantitative easing) and forward guidance. FOMC announcements that provide information about these unconventional policy actions are not well captured by this measure. This issue has been especially relevant since the fed funds rate hit the zero lower bound in late 2008. Thus we also use the change in longer-term Treasury yields around FOMC announcements to supplement the Kuttner (2001) measure. Specifically, our monetary policy shock ϵ_t^m is defined as

$$\epsilon_t^m = P_{t+\delta_+} - P_{t-\delta_-} \tag{1}$$

where t is the time of the FOMC announcement, P_t is either the implied fed funds rate from the price of the current month's fed funds futures contract or on-the-run Treasury yields, $t+\delta_+$ and $t-\delta_-$ represent 20 minutes after the FOMC announcement and 10 minutes before the FOMC announcement, respectively. For our baseline measure (labeled MP Shock) we combine the change in the current month's futures contract[5] (labeled FFR Shock) and the 10 year Treasury yield by taking the first principal component of these two measures. The idea is to parsimoniously capture both conventional and unconventional monetary policy actions in one tool.[6] Since the scale of this shock is arbitrary, we rescale it to have a unit effect on the 2 year yield.

We also show our results with a variety of alternative measures. Appendix Table A.1 shows results when using just one rate to construct the monetary policy shock (4-quarter ahead Eurodollar futures contract, 2 year Treasury yield and 10 year yield as monetary policy shocks one at a time) and also simultaneously using the fed funds, forward guidance and LSAP shocks from Swanson (2021).

Table 1 shows the summary statistics for the monetary policy shock measures for a pre-crisis sample (July 1991 to June 2008) and a post-crisis sample (August 2009 to June 2019).

[5]Since fed funds futures contracts are based on the average rate for a month, the change in the implied rate needs to be adjusted by $\tau(t) = \frac{\tau_m^n(t)}{\tau_m^n(t)-\tau_m^d(t)}$ where $\tau_m^n(t)$ is the number of days in the month of the announcement and $\tau_m^d(t)$ is the day of the month the announcement occurred

[6]We perform this principal component analysis separately for the pre-crisis and post-crisis periods. The first principal component explains 84% of the variation in these two rates during the pre-crisis sample and 90% of the variation in these two rates during the post-crisis sample. Our results are robust to doing the principal component analysis for the full sample.

The effect of the zero lower bound is clearly apparent. The standard deviation of the FFR Shock measure falls substantially from 9 basis points in the pre-crisis sample to 1 basis point in the post-crisis sample. Even for the two year shock measure the standard deviation falls from 6.5 basis points to 3.5 basis points, reflecting the effective lower bound on Treasury yields starting in late 2011 as reported by Swanson and Williams (2014). However the standard deviation of the 10 year shock measure is roughly similar in the pre- and post-crisis samples, motivating our reliance on this measure to effectively capture monetary policy shocks.

Table 1: Summary Statistics

	Pre-Crisis		Post-Crisis	
	mean	std. dev.	mean	std. dev.
Stock return	0.23	3.03	0.08	1.92
Leverage (Debt-to-Capital)	0.39	0.22	0.42	0.24
Leverage (Debt-to-Assets)	0.26	0.15	0.28	0.17
LT debt share	0.79	0.23	0.87	0.16
Implied volatility, short maturity	44.36	26.42	32.25	15.30
Implied volatility, medium maturity	38.41	18.85	28.32	10.75
Implied volatility, long maturity	35.93	16.00	28.75	9.71
MP shock	0.01	0.04	0.00	0.02
FFR shock	0.02	0.09	0.00	0.01
10 year shock	0.00	0.04	0.00	0.03
2 year shock	0.01	0.06	0.01	0.04
ED4 shock	0.01	0.08	0.01	0.04
Firm observations	58,673		28,967	
FOMC observations	153		80	

The table shows summary statistics for stock returns, leverage measures, long-term debt share, implied volatility and monetary policy shocks. Stock returns and implied volatility are measured daily at the firm level. Leverage is measured quarterly at the firm level. The monetary policy shocks are measured within a 30-minute window around an FOMC announcement. Sample is non-financial firms in S&P 500 on date of FOMC announcement. Pre-crisis is Jul-1991 to Jun-2008 and post-crisis is Aug-2009 to Jun-2019.

2.2 Firm-Level Variables

We use the CRSP/Compustat Merged Fundamentals Quarterly sample beginning in 1991:Q3, as this is the first year where we have a complete record of our monetary policy shock measures.

We use the firms in the S&P 500 index and, as is common in the literature, we exclude financial firms (SIC 6000-6999). We focus on S&P 500 firms because our use of stock market data requires that news revealed in the FOMC announcements is accurately and quickly incorporated into stock prices. As discussed in Gorodnichenko and Weber (2016) there is evidence that stocks of smaller firms had no or few trades in the few hours after major macroeconomic news announcements, especially in the pre-crisis sample. On the other hand, there is evidence that stock prices of S&P 500 firms move very quickly to incorporate the information from FOMC announcements, see for example Zebedee et al. (2008). Moreover, in recent work Gürkaynak et al. (2019) show that for S&P 500 firms, investors do take into account firm balance sheet characteristics when responding to monetary policy surprises.[7]

Our primary measure of interest from Compustat is the firm's leverage ratio. The baseline results use the ratio of debt-to-capital, measured as the sum of debt in current liabilities (Compustat item: DLCQ) and long-term debt (DLTTQ) over the sum of debt in current liabilities, long-term debt and stockholder's equity (SEQQ). We also confirm our results below using an alternative measure of leverage: debt-to-assets (using the book value of assets (ATQ)). Table 1 displays the summary statistics for these definitions of leverage measured as the 4-quarter rolling average at the firm level. We also investigate the impact of monetary policy shocks on firms' quarterly investment. The construction of this investment variable is detailed in Appendix Section A.1.

We also use daily stock returns and implied volatility measures at the firm level. We use the daily return of a firm's share price on the day of an FOMC meeting, measured as the log difference between the closing share price on the day of the FOMC meeting and the closing share price on the day prior to the FOMC meeting. The implied volatility measures are computed using firm-level options data from OptionMetrics. The methodology used to do

[7] In Appendix Figure A.1, 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 choose to focus on the S&P 500 because it is an objective way to choose our sample.

this calculation closely follows the one used for implied volatility of the S&P 500 index, i.e. the VIX. This daily data is available from January 1996 to June 2019. The implied volatility measures for options set to expire in greater than 3 months have the highest liquidity. But we show that our results are very similar for shorter-term options, i.e. those set to expire in less than 1 month and those set to expire between 1 month and 3 months.

Additionally, we create several control variables using these quarterly data: year-over-year real sales growth, firm size as measured by the log of the book value of assets, price-to-cost margin, receivables-minus-payables to sales, depreciation to assets, firm age, the log of quarterly market capitalization, the ratio of current assets to total assets and an indicator for the firm's fiscal quarter. Including these controls are intended to capture important characteristics of the firm that could be correlated with both firm leverage and firm performance. Appendix Table A.3 displays summary statistics of these measures. The construction of these variables follows standard methods in the literature; however, we include these details in Appendix Section A.1.

3 Results

This section presents the main results illustrating how leverage explains the firm-level response to monetary shocks and how that relationship has changed since the financial crisis. First we document this changing effect using high frequency data on stock prices. Next, we use firm-level options data to show that financial market participants have been aware of this changing responsiveness. Finally, we use quarterly data on firm investment and show that a similar pattern emerges.

3.1 Evidence from firm-level stock returns

We first examine how leverage explains the stock price response to monetary policy shocks. In our baseline results we will 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. These dates are commonly used in the literature due to turbulence in the financial markets and the presence of some asset pricing anomalies, see for example Nakamura and Steinsson (2018).[8]

Our baseline regression takes the following general form:

$$s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 D_t^{post} l_{i,t-1}\epsilon_t^m + \delta_1 l_{i,t-1} + \delta_2 D_t^{post} l_{i,t-1} + \Gamma Z_{i,t-1} + \Upsilon \epsilon_t^m Z_{i,t-1} + e_{i,t} \quad (2)$$

where $s_{i,t}$ is the (daily) return on firm i's share price on FOMC meeting day t,[9] α_i is a firm i fixed effect, α_t is an FOMC meeting day t fixed effect (i.e. a dummy for each time period), D_t^{post} is a dummy that turns on for the post-crisis sample, $l_{i,t-1}$ is firm i's average leverage (measured as debt-to-capital) for the four quarters preceding the quarter of the FOMC announcement, ϵ_t^m is the monetary policy shock, and $Z_{i,t-1}$ is a vector of firm-level controls (lagged by a quarter). The monetary policy shock ϵ_t^m and post-crisis dummy (D_t^{post}) are not included separately as regressors because they are subsumed by the time fixed effect. $Z_{i,t-1}$ includes the following firm-level financial measures as controls: real sales growth, the log of the book value of assets, the price-to-cost margin, receivables-minus-payables to sales, depreciation to assets, firm age, the log of quarterly market capitalization and the ratio of current assets to total assets. Since the firm-level characteristics are measured at the quarterly level, the leverage ratio and the firm-level controls are lagged to ensure they are predetermined at the time of the FOMC announcement. We also include a dummy for the fiscal quarter, to account for differences across firms due to different positions in their fiscal year. The firm fixed effect accounts for permanent characteristics of the change in firm i's stock price that are not captured by our controls. The time fixed effect accounts for aggregate shocks common to all the firms on the day of the FOMC announcement. The standard errors reported in the parentheses are

[8] In Appendix Table A.4 we show that our results are robust to including the financial crisis dates in the "post-crisis" sample.

[9] $s_{i,t} = ln(p_{i,t}) - ln(p_{i,t-1})$ where the stock price p is measured at the end of the day.

calculated using two-way clustering along the time and firm dimensions.[10]

We multiply the monetary policy shock measure by negative one so that an increase in ϵ_t^m corresponds to an expansionary shock. β_1 captures how the share price response to a monetary policy shock depends on leverage, in the pre-crisis sample. β_2 captures how this responsiveness changed from the pre-crisis to the post-crisis period. We standardize leverage to be mean zero and unit variance, so these coefficients can be interpreted as the additional change in a firm's daily stock price in response to a unit expansionary monetary shock by moving from an average level of leverage to one standard deviation above the average leverage. In standardizing leverage we use the full sample mean and standard deviation of leverage across all firms.

The top panel of Table 2 presents the results for non-financial firms in the S&P 500 without the firm characteristics interacted with the monetary policy shock (i.e. setting Υ to zero in Equation 2). The interaction coefficient of the monetary shock and leverage in the pre-crisis sample (β_1) is *negative* and significant but in the post-crisis sample ($\beta_1 + \beta_2$) it is *positive* and significant. In particular, for firms that were one standard deviation above average leverage, their stock price rises by 8% *less* in the pre-crisis sample but rises by 2.6% *more* in the post-crisis sample. The third column shows that the difference between the pre- and post-crisis sample (β_2) is economically large and statistically significant. Since we use time fixed effects, we cannot estimate the stand-alone effect of the monetary policy shock on firm-level stock returns from this specification. We show in Appendix Table A.5 that without a time fixed effect a 100 basis point expansionary monetary policy shock leads to an 8.6% increase in stock prices.

In the bottom panel of Table 2 we add interactions of the monetary policy shock with firm characteristics listed above (i.e. we allow Υ to be non-zero in Equation 2).[11] Columns (1) - (7) show the results of individual interaction of the firm characteristics with the monetary

[10] Our results are robust to using Driscoll-Kraay standard errors instead of two-way clustering.

[11] In Appendix Table A.6 we also show that interacting the post-crisis dummy with firm characteristics and its interaction with the monetary policy shock gives very similar results.

Table 2: Response of firm-level stock returns to monetary shocks

Panel A:	(1a) Pre β_1	(1b) Post $\beta_1 + \beta_2$	(1c) Diff β_2
MP shock x Leverage	-7.95	2.55	10.51
	(4.121)	(0.729)	(4.218)
Observations		63,337	
R^2		0.216	

Panel B:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
D_t^{post} x MP x Leverage	10.23	10.50	10.32	10.17	10.49	10.42	10.13	9.96
	(4.038)	(4.212)	(4.065)	(3.959)	(4.196)	(4.168)	(3.909)	(3.693)
MP x Curr. Asset Ratio	-1.70							-2.50
	(1.576)							(1.908)
MP x Sales Growth		0.13						-0.22
		(1.760)						(1.495)
MP x Asset Value			-1.41					4.46
			(1.976)					(3.543)
MP x Price-Cost Marg.				31.74				29.30
				(23.841)				(18.792)
MP x Rec. - Pay.					1.09			-0.64
					(2.156)			(1.674)
MP x Deprec./Assets						1.73		1.75
						(1.185)		(1.333)
MP x Firm Age							-0.17	-0.15
							(0.124)	(0.110)
Observations	63,337	63,337	63,337	63,337	63,337	63,337	63,337	63,337
R^2	0.216	0.216	0.216	0.216	0.216	0.216	0.217	0.218

Panel A shows results from estimating
$s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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 monetary policy shock is normalized to have a unit effect on the 2 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.). Sample is non-financial firms in S&P 500 on date of FOMC announcement. Panel B includes interactions of each control variable with the MP shock. For space considerations, market capitalization and fiscal quarter are not displayed. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

shock, while in column (8) we interact all the characteristics with the monetary shock. The triple interaction coefficient measuring the difference between the pre- and post-crisis samples remains statistically significant and of roughly the same magnitude across all the specifications. Thus we can rule out the case that our leverage results are driven by these other firm characteristics.

Could the change in responsiveness have occurred before or after the financial crisis? To address this issue we estimate our baseline specification from Equation 2 (excluding the D_t^{post} interactions) with a rolling window of 48 FOMC days (typically corresponds to 6 years). We find similar results using slightly smaller or larger windows. Figure A.2 shows that β_1, the interaction coefficient of leverage and monetary policy shock, is negative for virtually the full pre-crisis period and turns positive around early 2009.

Is the result of higher responsiveness driven by changing transmission of conventional policy tools or is it a reflection of shifting balance between conventional and unconventional tools in the post-crisis sample? To shed light on this issue, we first rerun our regression using the three monetary policy shock measures from Swanson (2021) which extends the framework of Gürkaynak et al. (2005) to create a fed funds rate shock, forward guidance shock and LSAP shock. The top panel of Table A.1 shows that in the pre-crisis sample high leverage firms are less responsive to the fed funds shock but more responsive to the LSAP shock in the post-crisis sample. Prima facie, this is evidence for the interpretation that our baseline results are driven by changing tools used since the crisis. In other words, one interpretation is that for both conventional and unconventional policy tools the role of leverage in monetary transmission is constant over the pre- and post-period and the changing responsiveness in our results is driven by the fact that conventional policies were more dominantly used in the pre-crisis period and less so after that.

However, there are some subtleties worth pointing out. First, for both the FFR and LSAP shocks, the coefficient on interaction with leverage changes sign with the crisis, and the post-crisis coefficient is statistically significantly different from the pre-crisis one. Second, if LSAP shocks becoming more prominent in the post-crisis sample is the main story, then we might expect their effect to be more dominant on days with prominent LSAP announcements. In Table A.2 we show results for both our baseline shock and the Swanson (2021) shocks where we include a dummy for the prominent LSAP announcement dates in Fawley et al. (2013).[12] The results show that in fact the interaction with leverage is weaker on prominent LSAP dates relative to all other FOMC meeting dates, suggesting that the changing relationship with leverage is a pervasive feature of the post-crisis sample. Finally, in the bottom panel of Table A.1 we re-estimate our baseline regression using just one indicator of monetary shocks. Based on recent work in the literature (for example Hanson and Stein (2015) and Gertler and Karadi (2015)), we use the change in i)2 year Treasury rate, ii) four quarter ahead Eurodollar futures rate and ii) 10 year Treasury rate one at a time as the monetary policy shock. These results show that there is a flip in the sign of the leverage relationship for all three measures.

Overall, this analysis suggests that our results are likely driven by how the Fed's LSAP announcements transmit differently through firm leverage in the post-crisis sample but that perhaps the transmission of conventional actions changing after the crisis may have played some role as well.

We have also investigated if our effect holds for the Compustat firms not in the S&P 500. In Figure A.1 we plot the triple interaction coefficients from our baseline regression for all firms in Compustat and separate them into quartiles based on market capitalization. The sign of our main result of changing responsiveness since the crisis is consistent (i.e. implying more responsiveness since the crisis) for all 4 quartiles but is only statistically significant for the firms in the highest quartile. This is not surprising given that the literature has highlighted a discrepancy between the high frequency stock price movements of small and large firms in the aftermath of macroeconomic announcements, as we discussed above in Section 2.2. Accordingly we focus on the S&P 500 firms because it is an objective way to choose our

[12]We add the taper tantrum date of June 19, 2013 to this list. Also our results are similar if we just use the 10 dates with the biggest absolute changes in Swanson (2021) LSAP factor.

sample and guarantees that the inclusion of firms in the index means that market analysts and traders pay careful attention to high-frequency movements in their stock price.

In Section 5 below we conduct a battery of robustness checks. These include using a different leverage measure (debt-to-assets), including the crisis dates in the sample, excluding unscheduled FOMC meetings from the sample, using time-by-sector fixed effects, narrowing our panel to firms that consistently remain in the sample and including financial firms. Next we document some empirical patterns in our baseline leverage measure to show that our results are not being driven by any sudden change in the behavior of leverage since the crisis.

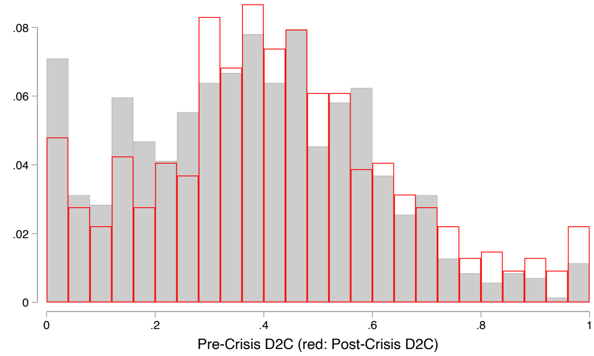
3.2 Leverage in the pre- and post-crisis samples

The results of differential responsiveness in the pre- versus post-crisis samples raise some natural questions about the behavior of leverage in the two samples. Has average leverage changed since the crisis? How does the cross-sectional distribution of leverage compare across the two samples? Has there been any "churning" of firms from low leverage in one sample to high-leverage in the other sample? Importantly, do these patterns play a role in driving the results? In this section we tackle these issues in order.

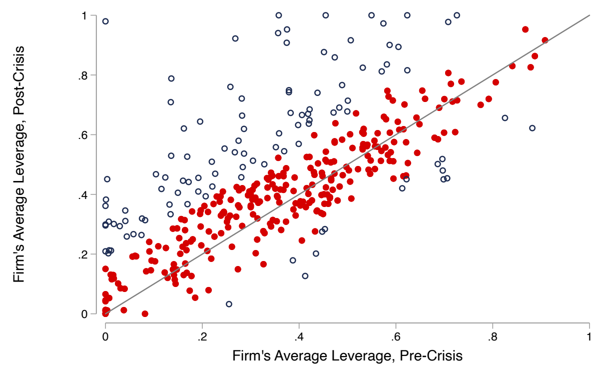
First, from Table 1 we can see that leverage is on average only slightly higher in the post-crisis sample. For example our baseline measure of leverage, debt-to-capital, has a mean of 0.42 in the post-crisis sample relative to a mean of 0.39 in the pre-crisis sample. Similarly the standard deviation of leverage is also roughly the same across the two samples. Figure 1 shows the distribution of leverage 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

Figure 1

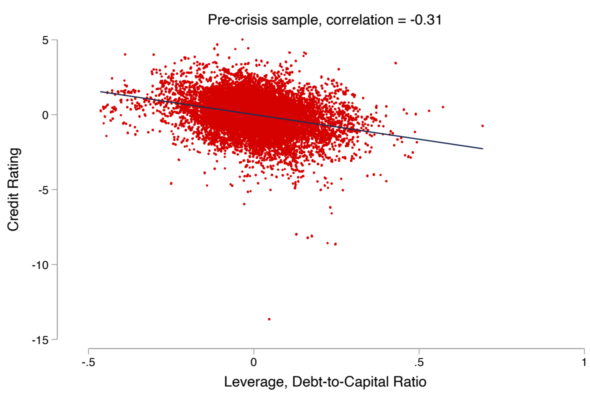
(a) Distribution of Firm Leverage



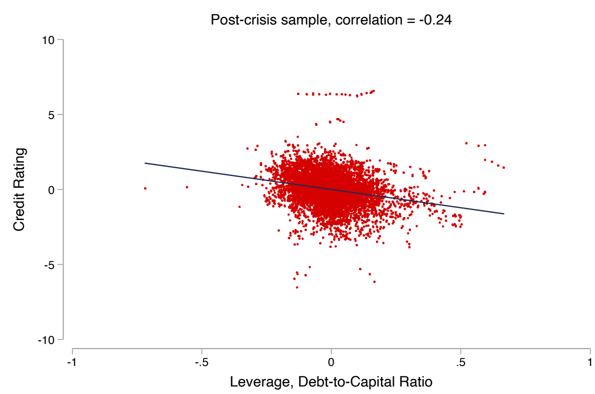
(b) Firm Leverage: Post vs. Pre



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



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



Panel (a) plots the histogram of the quarterly firm leverage (measured as debt-to-capital), 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-capital) averaged across the post-crisis versus the average in the pre-crisis sample. Firms further than one standard deviation from the 45-degree line are shown in hollow circles. Panels (c) and (d) plot the residuals from regressing firm's S&P long-term credit rating on our set of control variables against the residuals from regressing firm's 4-qtr 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 date of FOMC announcement.

our leverage measure (see Appendix Table A.7). As one would expect with the patterns from Table 1 and Figure 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 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 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. the ones that are not close to the 45 degree line. In Appendix Table A.8, we present our baseline results excluding firms which lie more than 1 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 movement of firms across the leverage distribution does not explain the difference in transmission of monetary policy through firm leverage following the financial crisis.

Next, we show this pattern of high leverage being related to less responsiveness before the financial crisis and more responsiveness afterwards is also evident using firm-level options data.

3.3 Evidence from firm-level options data

Given that monetary policy shocks are not predictable, our results from Section 3.1 have no implications for the *expected direction* of the movement in the stock price of firms with higher (or lower) leverage on FOMC announcement days. However, there is a direct implication for the *expected volatility* of the stock price of firms with higher (or lower) leverage. Specifically, we should expect that in the pre-crisis period high leverage firms should be less volatile on FOMC announcement days but more volatile in the post-crisis sample. In this section, using options data we indeed find evidence for this pattern.

We construct firm-level measures of expected volatility for non-financial S&P 500 firms using options data from the OptionMetrics dataset. The methodology used to do this calculation closely follows the one used for implied volatility of the S&P 500 index, i.e. the VIX. Specifically, for each firm we volume-weight the implied volatility of its associated options prices within three different maturity classifications. Short maturities are options expiring within 30 days; medium maturities are options expiring after 30 days, but within 90 days; and, long maturities are options expiring after 90 days. This gives us three measures of the implied volatility of the expected stock return.[13]

Table 3: Regression of firm-level implied volatility leading up to FOMC announcement

	(1) Short Maturity	(2) Medium Maturity	(3) Long Maturity
Pre-Crisis (δ_1)	-2.22	-1.96	-1.59
	(0.702)	(0.619)	(0.564)
Post-Crisis ($\delta_1 + \delta_2$)	1.17	1.42	1.26
	(0.522)	(0.481)	(0.452)
Difference (δ_2)	3.39	3.39	2.85
	(0.644)	(0.544)	(0.485)
Observations	39,586	44,475	45,225
R^2	0.590	0.726	0.741

Results from estimating $ivol_{i,t-1} = \alpha_i + \alpha_t + \delta_1 l_{i,t} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma Z_{i,t-1} + e_{i,t}$, where $ivol_{i,t-1}$ is firm-level implied volatility on the day before the FOMC announcement, α_i is a firm fixed-effect, α_t is an FOMC day fixed-effect, $l_{i,t-1}$ is four-quarter moving average leverage normalized to have mean 0 and variance 1, D_t^{post} is an indicator for the post-crisis period and $Z_{i,t-1}$ is the baseline vector of firm-level controls including firm-level stock price at close of prior trading day. Pre-crisis is Jan-1996 to Jun-2008 (108 obs.) and post-crisis is Aug-2009 to Jun-2019 (80 obs.). Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered standard errors in parentheses.

Using these implied volatility measures we explore whether the interrelation between firm-

[13] The long maturity options are more liquid than the other two classifications, i.e. there are fewer missing observations for the long maturities.

level expected volatility, leverage and FOMC announcements has changed in a way that is consistent with our earlier results. Specifically we run the following regression

$$ivol_{i,t-1} = \alpha_i + \alpha_t + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma Z_{i,t-1} + e_{i,t} \tag{3}$$

where for an FOMC meeting occurring on day t, $ivol_{i,t-1}$ is the level of implied volatility for firm i on the day before the FOMC meeting, $l_{i,t-1}$ is average leverage (debt-to-capital) for firm i for the four quarters preceding the quarter of the FOMC announcement, D_t^{post} is a dummy that is set to 1 for the post-crisis sample of August 2009 to June 2019, $Z_{i,t-1}$ contains a variety of firm-level controls,[14] α_i is a firm fixed effect and α_t is a time-fixed effect. The combination of the firm- and time-fixed effect allows us to control for factors that are firm specific (but fixed over time) and aggregate patterns that affect the level of the firm-specific implied volatility measure. Due to the data availability of options data, our sample runs from January 1996 to June 2019.

The estimates are presented in Table 3 with two-way clustered standard errors along the firm and time dimension. The three columns show the results for the three different maturities. For all columns, the coefficient on leverage (δ_1) is negative and significant. This means that in the pre-crisis sample firms with higher leverage had lower levels of expected volatility on the day before the FOMC announcement. But the coefficient on the interaction of leverage and the post-crisis dummy (δ_2) is positive and significant. Relative to the pre-crisis sample, leverage is more positively associated with implied volatility in the post-crisis sample. Moreover, the total effect in the post-crisis sample ($\delta_1 + \delta_2$) is positive and significant. This means that as measured on the day before the FOMC announcement, high leverage firms were expected to be *less* volatile in the pre-crisis sample but *more* volatile in the post-crisis sample. The results from Table 3 are robust to several tests, including using the alternative measure of leverage (debt-to-assets), putting in time-sector fixed effects, excluding unscheduled FOMC meetings

[14]The controls include the same as those in our baseline stock market regression, as well as the firm-level stock price on the trading day prior to the FOMC day.

from the sample, including the crisis dates in the post-crisis period or including financial firms in the sample. These results are discussed in Section 5.

These results also imply that financial market participants are aware of this changing relationship and have updated their expectations about how leverage is related to expected volatility due to FOMC announcements. In summary, we view this options-based result as supporting evidence for the main thesis in this paper that we confirm with stock market data and investment data.

3.4 Evidence from investment data

In this section we corroborate the evidence from the stock market using firm-level variables on economic activity from Compustat. Specifically we explore the response among S&P 500 firms of firm-level investment to monetary policy shocks. Our baseline empirical specification is the following:

$$\Delta ln(y_{it}) = \alpha_i + \alpha_t + \sum_{n\in N}\left(\beta_{1,n} l_{i,t-n-1}\epsilon^m_{t-n} + \beta_{2,n} l_{i,t-n-1}\epsilon^m_{t-n} D^{post}_{t-n}\right) + \Upsilon\epsilon^m_{t-1} Z_{i,t-1} + \Gamma Z_{i,t-1} + e_{it} \quad (4)$$

where y_{it} is firm i's capital stock in quarter t, α_i is a firm i fixed effect, α_t is a quarter t fixed effect, l_{it} is firm i's leverage ratio, ϵ^m_t is the sum of all high-frequency monetary policy shocks that occur in quarter t, D^{post}_t is an indicator for the post-crisis period, $Z_{i,t-1}$ is a vector of firm-level controls (lagged by one quarter), e_{it} is the residual and $N = [0, 4]$.[15] Since the prior quarter's monetary policy shocks could plausibly have an effect on the current quarter's investment (unlike securities prices that respond immediately), we include lagged values of the monetary policy shocks in this specification. The lagged values of leverage are also included

[15] $Z_{i,t-1}$ also contains each of the n lags of the firm's leverage ratio and the respective interactions with the lagged post-crisis dummy. As with the stock market specification, the monetary policy shock ϵ^m_t is subsumed by the time fixed effect. The same is true of the post-crisis dummy and its interaction with the monetary policy shock.

when interacting with the prior quarters' monetary policy shock, to be consistent with the timing of measurement for each.

The key parameters in the above specification are $\beta_{1,0}$ and $\beta_{2,0}$, which estimate how the responsiveness of investment to a contemporaneous quarterly monetary policy shock differs based on a firm's leverage ratio in the pre-crisis and post-crisis, respectively. Since we standardize l_{it} to be mean zero and unit variance, these parameters can be interpreted as the additional increase in a firm's investment in response to an expansionary monetary shock by moving from an average leverage ratio to one standard deviation above the average leverage ratio. As in the results discussed above, we multiply the monetary policy shock measure by negative one so that an increase in ϵ_t^m corresponds to an expansionary shock.

We control for factors in $Z_{i,t-1}$ that could potentially affect both a firm's leverage ratio and the quarterly growth in the firm's capital stock. $Z_{i,t-1}$ includes real sales growth, the log of the book value of assets, the price-to-cost margin, receivables-minus-payables to sales, depreciation to assets, firm age, the log of quarterly market capitalization and the ratio of current assets to total assets. Since the monetary policy shocks occur throughout the quarter and the firm-level variables are measured at the quarterly level, leverage and the controls are lagged to ensure they are predetermined at the time of the monetary policy shocks. We also include a dummy for the fiscal quarter in all specifications, to account for differences across firms due to different positions in their fiscal year. The standard errors reported in the parentheses are calculated using two-way clustering along the time and firm dimensions. Finally, to ensure that the firm fixed effect is not endogenous, we only keep firms in the sample that have at least 40 observations with non-missing investment data in both the pre- and post-crisis samples.

The top panel of Table 4 shows the contemporaneous response of investment without including the interaction of monetary shock with firm characteristics while the bottom panel includes the interactions. These results are consistent with the pattern emerging from the stock price and implied volatility results. In the pre-crisis sample, the interaction between the

Table 4: Contemporaneous response of firm-level investment to monetary shocks

Panel A: Baseline	(1a) Pre-Crisis β_1	(1b) Post-Crisis $\beta_1 + \beta_2$	(1c) Diff β_2
MP shock x Leverage	-2.82	2.56	5.38
	(1.904)	(1.990)	(2.592)
Observations		8,988	
R-squared		0.161	

Panel B: Including control interactions	(1a) Pre-Crisis β_1	(1b) Post-Crisis $\beta_1 + \beta_2$	(1c) Diff β_2
MP shock x Leverage	-1.52	2.80	4.32
	(1.511)	(2.175)	(2.285)
Observations		8,988	
R-squared		0.163	

Panel A shows results from estimating $\Delta ln(y_{it}) = \alpha_i + \alpha_t + \sum_{n \in N} \beta_{1n} l_{i,t-n-1} \epsilon^m_{t-n} + \beta_{2n} l_{i,t-n-1} \epsilon^m_{t-n} D^{post}_{t-n} + \Gamma' Z_{i,t-1} + e_{it}$, where y_{it} is value of firm i's capital stock in quarter t, α_i is a firm i fixed effect, α_t is a quarter t fixed effect, l_{it} is four-quarter moving average leverage normalized to have mean 0 and variance 1, ϵ^m_t is the sum of all high-frequency monetary policy shocks that occur in quarter t, D^{post}_t is an indicator for the post-crisis period, $N = [0, 4]$ and Z_{it-1} is a vector of firm-level controls. The monetary policy shock is normalized to have a unit effect on the 2 year yield and a positive value represents an expansionary shock. Sample is non-financial S&P 500 firms with at least 40 quarters of data in the pre-crisis and post-crisis sample for the dependent variable. Pre-crisis is 1991:Q3 to 2008:Q2 and post-crisis is 2009:Q3 to 2019:Q2. Panel B includes interactions of each control variable with the MP shock. Two-way clustered standard errors in parentheses.

monetary policy shock and leverage is negative, while the interaction is positive in the post-crisis sample. Importantly, the *difference* between the pre-crisis and post-crisis responsiveness is statistically significant. Our finding that investment is less responsive to a contemporaneous monetary policy shock in the pre-crisis period matches the main finding of Ottonello and Winberry (2020).[16] Specifically, during the pre-crisis period, a firm with leverage one standard deviation above average experiences an increase in investment 2.8% *less* than a firm with average leverage during the quarter in which an expansionary monetary policy shock occurs. In the post-crisis period, a high-leverage firm would experience an increase in investment 2.6% *more* than a firm with average leverage.

In section 5 below we discuss further robustness checks of these results, including using time-sector fixed effects, including the financial crisis period, using debt-to-assets to measure leverage and using a consistent sample of firms. Before detailing these tests, we now turn to a discussion of potential mechanisms behind the empirical findings we have presented up to this point.

4 Mechanism

In this section we shed some light on the mechanism underlying the change in the leverage relationship. We start with an organizing framework based on the theoretical heterogeneous firm model of Ottonello and Winberry (2020) (OW hereafter). We discuss the two competing mechanisms in their model: one that makes highly leveraged firms more responsive and the other one that makes it less responsive. To understand why the former effect dominates in the post-crisis sample we investigate potential empirical explanations based on three balance

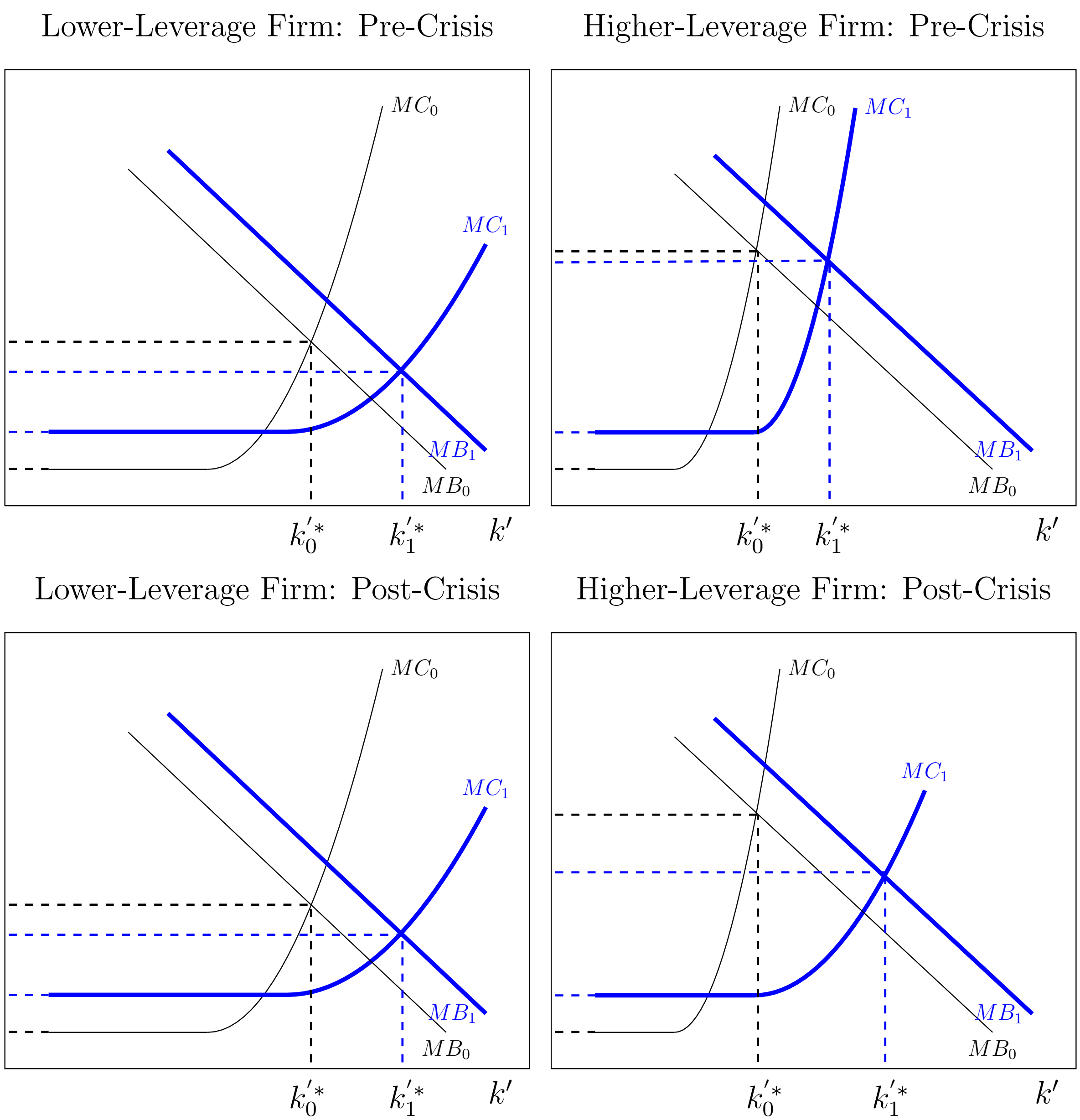
[16] Jeenas (2019b) finds that higher leverage firms become more responsive than lower leverage firms several quarters after a monetary policy shock in the pre-crisis period. In contrast, Ottonello and Winberry (2020) do not find a differential effect by leverage beyond the contemporaneous quarter. Ottonello and Winberry (2020) contains a lengthy discussion of the methodological differences between these two papers. Due to limited amount of data in the post-crisis sample, it is difficult to discern any statistically significant differences in the long-term response between the pre- and post-crisis samples. We find that the clearest change from the pre- to the post-crisis occurs in the contemporaneous sensitivity of investment due to differences in firm leverage. Thus we choose to focus on these results here.

sheet characteristics recently emphasized in the literature: liquidity, share of bank debt and share of long-term debt. We find some promising suggestive evidence for the role of long-term debt and document an increase in the responsiveness of long-term rates to monetary policy shocks in the post-crisis sample to help understand the mechanism.

In the literature, the theoretical predictions of how firm balance sheet characteristics affect monetary transmission are ambiguous. The canonical theoretical work is the financial accelerator model of Bernanke et al. (1999). Bernanke et al. (1999) did extend their baseline model to a heterogenous (two-firm) case. With their preferred calibration they find that firms that have a larger external finance premium respond more strongly to monetary policy shocks. Building on the work of Khan et al. (2016), OW extend the Bernanke et al. (1999) framework to allow for firm default and a richer structure of heterogeneity (including firm-specific productivity and capital quality shocks). They find that firms with higher leverage are less responsive to monetary policy and confirm their results using an empirical analysis for the pre-crisis sample. These OW results are consistent with our empirical results for the pre-crisis sample. If we start with the OW model as our baseline model for the pre-crisis sample, how do we explain our post-crisis results in this framework? To understand the relevant mechanism of monetary transmission in their model, we give the key intuition from the firm's optimization problem that equates marginal cost to marginal benefit, with details provided in Appendix Section A.2.

The marginal cost of capital for firms depends on two terms. First, an extra unit of investment is costly but it also adds to the firm's collateral and thus lowers the interest rate charged by lenders. Second, an increase in borrowing makes the firm riskier and thus makes lenders charge a higher premium. The marginal benefit schedule shows the standard diminishing returns to capital and is graphically represented by a downward sloping curve. Both marginal benefit and marginal cost curves are affected by a monetary policy shock. By lowering the risk-free rate, an expansionary shock lowers the discount rate and thus shifts the marginal benefit curve up and to the right. There are three effects on the marginal cost curve:

Figure 2: Effects of an expansionary monetary policy shock



i)shift up of the whole curve because an increase in the demand for investment leads to an increase in the price of capital, ii)extension of the flat part of the marginal cost curve because it increases the firm's cash on hand and decreases the amount the firm needs to borrow to finance a given amount of investment and iii)flattening of upward sloping part of the curve because the firm's collateral is worth more and thus reduces the loss to the lender in case of default.

How do firms with high and low leverage react differently to monetary policy shocks? There are two competing channels which make it theoretically ambiguous whether a high or low leverage firm will respond more. For a high-leverage firm, the upward sloping part of the marginal cost curve is steeper and thus this will make it less responsive to monetary policy induced shifts of the marginal benefit curve. On the other hand, a high leverage firm's marginal cost curve will flatten more in response to an expansionary monetary shock, making it more responsive. In the OW calibration they find that the former effect dominates and thus a high leverage firm is less responsive to monetary policy shocks. This case is highlighted in the top row of Figure 2. So how can we explain our results of higher sensitivity for high leverage firms in the post-crisis sample using this framework? While there are different combinations of changes to marginal cost and benefit curves that could theoretically give this result, we argue in the Appendix that the most reasonable way to extend the OW analysis would be to add a feature that increases the strength of the flattening of the marginal cost curve of high leverage firms more (relative to low leverage firms). In the OW model all firms finance with one period debt, which of course abstracts from various real-world aspects of firm financing. We explore the role of three features that have been highlighted in the recent literature on firm financing and monetary transmission: long-term debt share, bank debt share and liquidity.

We start with liquidity. Jeenas (2019a) argues that liquid asset holdings better predict the transmission of monetary policy at the firm level as compared to leverage, using cash and short-term investments to proxy for liquidity.[17] We investigate whether the firms with high

[17]Recall that our baseline set of controls includes the ratio of current assets to total assets. Specifically our

or low liquidity are driving the change in responsiveness. The top panel of Table 5 shows the quadruple interaction, i.e. the interaction of our baseline triple interaction ($lev_{i,t-1}$ x mp_t x D_t^{post}) with X_i^{hi} (a dummy for high liquidity categorized based on being higher than the median liquidity at the start of the sample). The coefficient on this quadruple interaction will tell us if our baseline effect is statistically (and economically) significantly different for low vs. high liquidity firms.[18] The table shows that there is not any discernible heterogeneity in our main effect based on the liquidity dimension.

Next, we investigate the role of composition of debt and whether that matters for monetary transmission. In recent work using US data, Ippolito et al. (2018) and Gürkaynak et al. (2019) document that firms that have a larger share of variable rate debt are more responsive to monetary policy shocks. For EU data, Darmouni et al. (2020) find that firms that have a higher share of bond debt are more responsive to monetary policy. But, as documented in Ippolito et al. (2018), the majority of the loans in the US from banks have a floating rate. Thus sorting firms by high share of bank debt is effectively also sorting by high share of floating rate debt. In Compustat, we cannot directly observe the share of bank debt on the firm's balance sheet. However, there is a way to create a reasonably accurate proxy for this. As in Lee (2017), we create our measure of bank debt as other long-term debt (Compustat item: DLTO) minus commercial paper (Compustat item: CMP).[19] Then bank debt share is calculated as $\frac{\text{Bank debt}}{\text{Total debt}}$.

Similar to liquidity, we create a dummy variable for firms that are above the median bank debt share and interact this dummy with our triple interaction. The results presented in Table 5 show that our baseline results are not driven by firms that have high or low share of bank

measure in Compustat includes cash and short-term investments but also includes "other assets, which in the next 12 months, expect to be realized in cash or used in the production of revenue" coming from inventories and receivables.

[18] Specifically, a positive quadruple interaction coefficient will imply that the increased responsiveness due to leverage since the crisis is larger for high liquid firms.

[19] Alternatively, Crouzet (2020) creates a bank debt proxy by summing both other long-term debt and notes payable (Compustat item: NP) and then subtracting commercial paper. Using this alternative measure produces similar results.

debt.

Finally we consider the role of long-term debt share. We create a measure of long-term (LT) debt share $= \frac{\text{LT debt}}{\text{Total debt}}$ where LT debt is defined as all debt maturing in more than one year (this is all the information available in Compustat at the quarterly level). Table 5 shows that the increase in leverage related responsiveness is substantially higher for firms that have a larger long-term debt share. Moreover, it is the case that firms with high leverage borrow more using long-term debt, as the correlation between them is 0.3 and statistically significant at the 1% level.

Table 5: Mechanism Tests: Interact dummy for "high" with main effect

	Liquidity	Bank Debt Share	Long-term Debt Share
	2.10	1.12	5.99
	(2.862)	(2.904)	(2.952)
Observations	65,729	55,974	63,074
R-squared	0.221	0.224	0.216

Results from estimating
$s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \beta_3 X_i^{hi} l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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, X_i^{hi} is an indicator for firm i's first observation for the column variable being classified as above the median value and $Z_{i,t-1}$ is a vector of firm-level controls. The monetary policy shock is normalized to have a unit effect on the 2 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.). Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered standard errors in parentheses.

An alternative approach to studying the importance of long-term debt is to focus on the long-term component of our overall leverage measure. Our baseline leverage measure (debt-to-capital) is defined as leverage $= \frac{\text{debt}}{\text{debt + equity}}$. We now define LT leverage $= \frac{\text{LT debt}}{\text{debt + equity}}$ with an analogous definition for ST leverage. We run our baseline regression separately replacing leverage with LT leverage and ST leverage.[20] The results are presented in Appendix Table A.9 and show that for the interaction of LT leverage with the monetary policy shock we get

[20]Specifically we estimate the baseline stock price specification from Equation 2, including the interactions of the monetary policy shock with our firm characteristics.

the same statistically significant flip in the sign as the baseline results, with a negative and significant coefficient in the pre-crisis sample but a positive and significant coefficient in the post-crisis sample. Whereas for ST leverage the coefficient is negative and significant in the pre-crisis sample but insignificant and close to zero in the post-crisis sample.

Why is long-term debt related to higher responsiveness *after* the crisis? We provide a potential explanation by showing that monetary policy shocks have had a bigger effect on long term interest rates since the crisis. In Table 6 we regress the (daily) change in the 10 year nominal yield, the 10 year real yield and the term premium of the 10 year nominal yield on monetary policy shocks. The nominal yields are from Gürkaynak et al. (2007), the real yields from Gürkaynak et al. (2010) and the term premium estimates are from Kim and Wright (2005). The table shows our baseline measure (MP shock) in Panel A, 2 year shock in Panel B and ED4 shock in Panel C. An expansionary shock (for all three shock measures) lowers the nominal yield, real yield and the term premium of the 10 year bond. Importantly, the fall is substantially larger in the post-crisis sample.[21] The difference in real yields and term premium between the pre- and post-crisis coefficients is statistically significant and economically meaningful.

These results suggest that monetary policy is having an outsize effect on long-term funding conditions in the post-crisis sample. This translates into a bigger effect on firms that are more reliant on long-term funding. In line with this interpretation, we provide further evidence that long-term debt issuance has responded more to monetary shocks since the crisis. These results are presented in Appendix Table A.10. These results are also consistent with the "gap-filling" framework outlined in Greenwood et al. (2010) and the estimates of Foley-Fisher et al. (2016) who find that the Federal Reserve's Maturity Extension Program (MEP) in 2011 and 2012 had disproportionate effects on firms with more long-term debt. We have run our results dropping the quarters containing the two MEP related FOMC meetings in 2011 and 2012 and find that they are essentially unchanged. Thus our results indicate that the phenomenon of monetary

[21] These results are consistent with the pattern documented in Hanson et al. (2021).

Table 6: Response of 10 year nominal yield, real yield and term premium to monetary shocks

Panel A:	10 year nominal		10 year real		10 year term premium	
	Pre-Crisis	Post-Crisis	Pre-Crisis	Post-Crisis	Pre-Crisis	Post-Crisis
MP shock	-0.19	-1.65	-0.40	-1.76	0.12	-1.36
	(0.228)	(0.297)	(0.157)	(0.387)	(0.168)	(0.301)
Observations	153	69	83	69	153	69
R^2	0.012	0.309	0.104	0.345	0.010	0.308
Null Hypothesis	p-value		p-value		p-value	
D_t^{post} x MP shock = 0	0.000		0.001		0.000	

Panel B:	10 year nominal		10 year real		10 year term premium	
	Pre-Crisis	Post-Crisis	Pre-Crisis	Post-Crisis	Pre-Crisis	Post-Crisis
2 yr shock	-0.78	-1.07	-0.61	-1.54	-0.38	-0.96
	(0.141)	(0.372)	(0.122)	(0.329)	(0.093)	(0.309)
Observations	153	69	83	69	153	69
R^2	0.205	0.120	0.226	0.244	0.103	0.142
Null Hypothesis	p-value		p-value		p-value	
D_t^{post} x 2 yr shock = 0	0.459		0.009		0.075	

Panel C:	10 year nominal		10 year real		10 year term premium	
	Pre-Crisis	Post-Crisis	Pre-Crisis	Post-Crisis	Pre-Crisis	Post-Crisis
ED4 shock	-0.69	-0.85	-0.40	-1.35	-0.32	-0.77
	(0.140)	(0.375)	(0.165)	(0.375)	(0.093)	(0.304)
Observations	153	69	83	69	153	69
R^2	0.163	0.076	0.116	0.189	0.070	0.092
Null Hypothesis	p-value		p-value		p-value	
D_t^{post} x ED4 shock = 0	0.700		0.023		0.153	

Results from estimating $\Delta y_t = \alpha_0 + \beta\epsilon_t^m + e_{it}$, where y_t is (daily) change in the 10 year nominal rate, 10-year real rate, or the Kim & Wright 10 year term premium estimate and ϵ_t^m is the monetary policy shock. The monetary policy shock is normalized so that a positive value represents an expansionary shock. The 2 year and ED4 shocks are standardized to match the standard deviation of the MP shock series in each sub-period. Pre-crisis is Jul-1991 to Jun-2008 (153 obs.) and post-crisis is Aug-2009 to Jan-2018 (69 obs.). The 10-year real rate is not available prior to 1999. The p-values for each panel are for a full sample estimation of the interaction coefficient $D_t^{post} * \epsilon_t^m$, where D_t^{post} is a dummy for the post-crisis period. Robust standard errors in parentheses.

policy having a bigger effect on firms that are more exposed to long-term debt has been true more generally of Federal Reserve policy since the crisis and not just specific to the MEP.

These results can be naturally mapped to the OW theoretical framework. In their original model all firms have only one period debt and thus the marginal cost curve flattens the same amount for each firm as a result of a monetary shock induced change in borrowing rate. A more general framework that has firms holding differential amount of long-term debt can explain the higher responsiveness since the crisis.[22] Combining the fact that high leverage firms borrow relatively more using long-term debt and the higher responsiveness of long rates since the crisis, this would result in the marginal cost curve of high leverage firms flattening more in the post-crisis sample, as depicted in the bottom panel of Figure 2.

5 Robustness Checks

We start by documenting the robustness of our three different empirical approaches to using an alternative definition of leverage: debt-to-assets. Debt-to-assets is widely used in the literature to measure firm leverage, e.g. Whited and Wu (2006) find that Compustat firms with a higher debt-to-assets ratio are more financially constrained. Appendix Table A.12 shows that these results using debt-to-assets confirm the baseline results. Our baseline results use the four-quarter moving average of debt-to-capital; however, one could be concerned that this smooths out meaningful, higher-frequency variations in leverage. In Appendix Table A.13, we show that our results are robust to using the one-quarter lagged version of our leverage measure.

Next, we tackle the concern that our results may be driven by different sectors being more or less responsive to monetary policy shocks. To account for this we include a sector by FOMC

[22] OW also hypothesize on the issue of a possible extension of their model, see footnote 13 on page 2489. They claim that long-term debt could create a situation where "*...the marginal cost curve may become more responsive to monetary shocks*". They suggest that the mechanism could be due to the channel outlined in Gomes et al. (2016), which works through monetary policy creating unexpected inflation and affecting the real burden of long-term debt more than short-term debt. In Appendix Table A.11, we find no increase in sensitivity of inflation expectations to monetary policy since the crisis (using 5 year break-even inflation from TIPS yields), which would be required for this channel to be driving our results.

day fixed effect, rather than just an FOMC day fixed effect. We also control for interaction of sector with the monetary policy shock. In Appendix Table A.14, we show that the significance and magnitude of our baseline results are not meaningfully affected.

The appendix contains several more robustness checks that we briefly mention here. First, we show that our post-crisis results are not just driven by the FOMC meetings with major announcements about lager scale asset purchases but are a pervasive feature of the post-crisis sample (Appendix Table A.2). Second, we present the results when we include the crisis dates in the post-crisis sample. The coefficients show that including the financial crisis dates does not materially change the results (Appendix Table A.4). Next, we show that our stock market results are not driven by a change in the composition of the sample between the pre-crisis and post-crisis periods. We rerun our baseline stock market specification, limiting the sample to only those firms that enter Compustat prior to 1994 and remain in the sample through at least 2017. Despite losing approximately 62% of our sample to this restriction, the results closely match our baseline results (Appendix Table A.15).

FOMC meetings that are unscheduled can have effects on financial markets that are different from regularly scheduled meetings as the 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, see for example Lakdawala and Schaffer (2019). Thus we want to make sure that our results are not driven by these unscheduled meetings.[23] Excluding the unscheduled meetings gives results that are quite similar to the baseline case (Appendix Table A.16). 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 use forecast data (following the approach in Lakdawala (2019)) to cleanse the monetary policy shock of any information effects. These results confirm that our baseline results are not driven by this issue (Appendix

[23]This issue only arises in the pre-crisis sample which has 16 unscheduled meetings, while our post-crisis sample has none.

Table A.17). Appendix Table A.18 shows that our results are similar when we follow Ottonello and Winberry (2020) and construct a within-firm leverage measure, i.e. we demean leverage at the firm level. Finally, we show that including financial firms in our sample does not affect our results (Appendix Table A.19).[24]

6 Conclusion

In this paper we add to the growing empirical literature on monetary policy and firm-level heterogeneity. Using both high frequency data from the stock market and lower frequency investment data we show that the role of leverage in explaining firm-level responses to monetary policy shocks has changed since the financial crisis. Before the financial crisis a firm with higher than average leverage was less responsive to monetary policy shocks. However, after the financial crisis this relationship has reversed so that firms with higher leverage are now more responsive to monetary policy shocks. We interpret our pre-crisis results through a structural model and provide suggestive evidence for a mechanism that can rationalize our post-crisis results. Since the crisis, long rates have become more sensitive to monetary policy shocks suggesting increased sensitivity of long-term funding conditions to monetary policy. Consistent with this story, we show that our baseline results of increased responsiveness since the crisis are stronger for firms whose leverage is more dependent on long-term debt. We also provide evidence suggesting that our results are related to the changing nature of tools used by the Federal Reserve since the crisis. Specifically, the higher responsiveness in the post-crisis sample is driven by the LSAP shocks of Swanson (2021). However, we also find some evidence of changing transmission of conventional monetary policy tools.

Our results have potentially important implications for the aggregate effects of monetary policy. Focusing on the pre-crisis sample, Ottonello and Winberry (2020) find that monetary policy is less effective in the aggregate when there is a bigger share of riskier firms in the

[24] When we include financial firms, the ratio of current assets to total assets can no longer be used as a control variable due to missing values.

economy. Our estimates from the post-crisis sample indicate that this relationship has reversed in the last decade. This suggests two important avenues for future research. First, developing general equilibrium models with firm heterogeneity that also allow a role for unconventional monetary policy will help us understand the aggregate transmission of monetary policy since the crisis. Second, we think that further exploring empirical strategies to tease out the state-dependent effects of monetary policy based on firm balance sheets is a promising area for future research.

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Appendix (Not intended for publication)

A.1 Additional Details on Data Construction

We create our investment variable using the following standard steps:

1. Flag the first date that a firm reports their gross capital stock, i.e. the level of 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 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.

- 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[25]
- 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 number of years since firm first appeared in Compustat database
- Market capitalization: log of real cshoq multiplied by prccq
- Fiscal quarter: fqtr

The data is cleaned using the standard criteria:

[25] 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.

- 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

A.2 Ottonello & Winberry channels of monetary transmission

In this section we layout in detail the monetary transmission channels of Ottonello and Winberry (2020) and use it to discuss the mechanism driving the changing responsiveness since the crisis.

The canonical theoretical framework to understand the transmission of monetary policy through firm balance sheets is the financial accelerator model of Bernanke et al. (1999). The essential feature of the models in this vein is the existence of some financial friction in the borrower-lender relationship. For our purposes, the key question is what this framework implies for the heterogenous firm response to monetary policy. In the literature, the theoretical predictions of how firm balance sheet characteristics affect monetary transmission are ambiguous. Bernanke et al. (1999) did extend their baseline model to a heterogenous (two-firm) case. With their preferred calibration they find that firms that have a larger external finance premium respond more strongly to monetary policy shocks. Building on the work of Khan et al. (2016), OW extend the Bernanke et al. (1999) framework to allow for a richer structure of heterogeneity (including firm-specific productivity and capital quality shocks) and firm default. Contrary to Bernanke et al. (1999), they find that firms with higher leverage are less responsive to monetary policy. Moreover, they confirm their results using an empirical analysis for the pre-crisis sample. These OW results are consistent with our empirical results shown above for the pre-crisis sample. If we start with the OW model as our baseline model for the pre-crisis sample, is it possible to explain our post-crisis results in this framework? Below we summarize their model in brief and layout the key mechanisms from their model to understand this issue.

The OW model has firms that can invest in capital by borrowing or using internal funds and generates default in equilibrium. They embed this heterogeneous firm setup into a standard New Keynesian sticky-price framework to study the effects of monetary policy. In the model firms can only borrow using one period debt. Relaxing this assumption will be important to understand our post-crisis results. However, to understand the relevant mechanism of monetary transmission, we first reproduce a key first-order condition from their model. For a given level of productivity (z), the first order condition for the optimal choice of a firm's investment (k') and borrowing (b') is given by[26]

$$\left(q_t - \varepsilon_{R,k'}\left(z,k',b'\right)\frac{b'}{k'}\right)\frac{R_t^{\mathrm{sp}}\left(z,k',b'\right)}{1-\varepsilon_{R,b'}\left(z,k',b'\right)} = \frac{1}{R_t}\mathbb{E}_t\left[\mathrm{MRPK}_{t+1}\left(z',k'\right)\right]$$

The left hand side represents the marginal cost of capital and is a product of two terms. The first one is the price of capital net of the elasticity of the lender's rate schedule with respect to investment ($\varepsilon_{R,k'}\left(z,k',b'\right)$). An extra unit of investment costs q_t but it adds to the firm's collateral and thus lowers the interest rate charged by lenders. The second term is how borrowing costs change with investment. $R_t^{sp}\left(z,k',b'\right)$ is the firm-specific rate $R_t(z,k',b')$ (relative to the risk-free rate R_t). This is scaled by one minus the elasticity of the debt price schedule $(1-\varepsilon_{R,b'}\left(z,k',b'\right))$ with respect to borrowing, which captures the idea that an increase in borrowing makes the firm riskier and thus makes lenders charge a higher premium. Graphically (as can be seen in Figure 2), the marginal cost schedule (as a function of capital accumulation) is flat for low levels of capital as the firm has enough cash on hand to not be perceived as risky. After a certain cutoff point, the marginal cost curve slopes upward as the higher level of borrowing required to fund the capital increases the riskiness of firms. The right hand side represents the marginal revenue product of capital discounted by the risk-free rate. Graphically, the marginal benefit schedule is represented by a standard downward sloping curve due to diminishing returns to capital.

What is the effect of an expansionary monetary policy shock in this framework? By lowering the risk-free rate, an expansionary shock lowers the discount rate and thus shifts the marginal benefit curve up and to the right.[27] An expansionary shock has three effects on the marginal cost curve. First, it shifts up the curve because an increase in the demand for investment leads to an increase in the price of capital. Next, this shock extends the flat part of the marginal cost curve because it increases the firm's cash on hand and decreases the amount the firm needs to borrow to finance a given amount of investment. Finally, it flattens the upward sloping part of the curve because the firm's collateral is worth more and thus reduces the loss to the lender in case of default. These can be seen in Figure 2.

How do firms with high and low leverage react differently to monetary policy shocks? In this framework there are competing channels which make it theoretically ambiguous whether a high or low leverage firm will respond more. For a high-leverage firm, the upward sloping part of the marginal cost curve is steeper and thus this will make it less responsive to monetary policy induced shifts of the marginal benefit curve. On the other hand, a high leverage firm's

[26]We have omitted two terms that capture the marginal benefit of investment from this first order condition. The first one is $\frac{1}{R_t}\frac{\mathrm{Cov}_t\left(\mathrm{MRPK}_{t+1}\left(z',k'\right),1+\lambda_{t+1}\left(z',k',b'\right)\right)}{\mathbb{E}_t\left[1+\lambda_{t+1}(z',k',b')\right]}$ which is the covariance between the return to capital and the firm's shadow value of resources. The second one is given by $\frac{1}{R_t}v_t^0\left(\underline{z}_{t+1}\left(k',b'\right)\right)g\left(\underline{z}\left(k',b'\right)\right)\left(\frac{\partial z_{t+1}\left(k',b'\right)}{\partial k'}-\frac{\partial z_{t+1}\left(k',b'\right)}{\partial b'}\right)$ and captures how more investment affects a firm's default probability. OW find that these two terms do not play a major role and we have thus omitted them for convenience.

[27]There are also general equilibrium effects due to changes in the price of output, capital and wages which in the OW calibration further shift out the marginal benefit curve.

marginal cost curve will flatten more in response to an expansionary monetary shock, making it more responsive. In the OW calibration they find that the former effect dominates and thus a high leverage firm is less responsive to monetary policy shocks. This case is highlighted in the top row of Figure 2. So how can we explain our results of higher sensitivity for high leverage firms in the post-crisis sample using this framework?

Theoretically, there are three possible ways in which this can happen. In the post-crisis sample we would need that i)the marginal benefit curve shifts more for high leverage firms in response to a monetary shock or ii)the slope of the marginal cost curve is more flat (on average, not in response to monetary shocks) for high leverage firms (relative to low leverage firms) or iii) the slope of the marginal cost curve flattens more in response to a monetary shock for high leverage firms and that this increased flattening is enough to outweigh the relative steepness of high leverage firms.

We argue that the first two explanations are less plausible and provide evidence that the third explanation is likely at play. Regarding the first explanation, the shift of the marginal benefit curve is driven by changes in the discount rate. It is unlikely that discount rates for high leverage firms respond differentially in the post-crisis samples.[28] The second explanation would require that in the post-crisis sample high leverage firms are perceived to be less risky than low-leverage firms. In other words, the credit spread charged by lenders (relative to the risk-free rate) to high leverage firms would increase less as these firms take on more borrowing. First, recall that in Figure 1 we have shown that a firm's leverage position is fairly stable across the two samples. Moreover, the figure also shows that the correlation of leverage with measures of firm riskiness are stable across the pre- and post-crisis samples.[29] This rules out the unlikely scenario that our results are being driven by the high leverage firms somehow becoming less risky in the post-crisis sample.

This leaves us with the third explanation. This requires that an expansionary monetary policy shock would flatten the marginal cost curve of high leverage firms more (relative to low leverage firms). Additionally this increased flattening would have to be large enough to overcome the relative steepness of the marginal cost curve for high leverage firms. From the first-order condition above, the marginal cost curve flattening more would imply that the credit spread charged by the lender (relative to the risk-free rate) to a high leverage firm falls more (relative to a low leverage firm) in response to an expansionary monetary shock. We can see this readily from the bottom row of Figure 2. This figure shows in the post-crisis sample that even though the slope of a high leverage firm is unconditionally steeper than a low leverage firm, it flattens more in response to an expansionary monetary shock to make the desired change in investment higher for high leverage firms.

This explanation provides a simple testable implication: the credit spread (relative to the risk-free rate) of high leverage firms should fall more in response to an expansionary monetary shock in the post-crisis sample. While we do not have access to high-frequency firm-level bond yields, we use bond indices that group together firms with similar risk profiles. Specifically, we

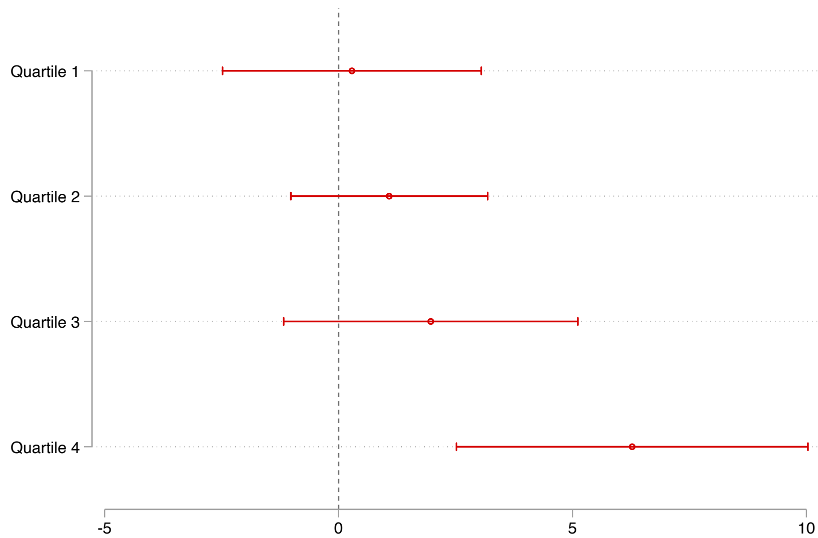
[28]There are also general equilibrium effects that work through the price of output goods, capital and wages but these are also unlikely to respond differentially for high leverage firms in the post-crisis sample.

[29]Note this is not at odds with our implied volatility results which showed that relationship between short-term volatility and leverage leading up to FOMC meetings has changed. While this correlation suggests that long-term correlation between leverage and risk has been stable.

use the Moody's bond yields index on firms rated AAA and those rated BAA. Our hypothesis then is that the spread between the BAA yield and risk free rate falls more in the post-crisis sample relative to the spread between the AAA yield and the risk-free rate. Or alternatively, the BAA-AAA yield spread should fall more in the post-crisis sample. The results presented in Table A.20 show that indeed this is the case.

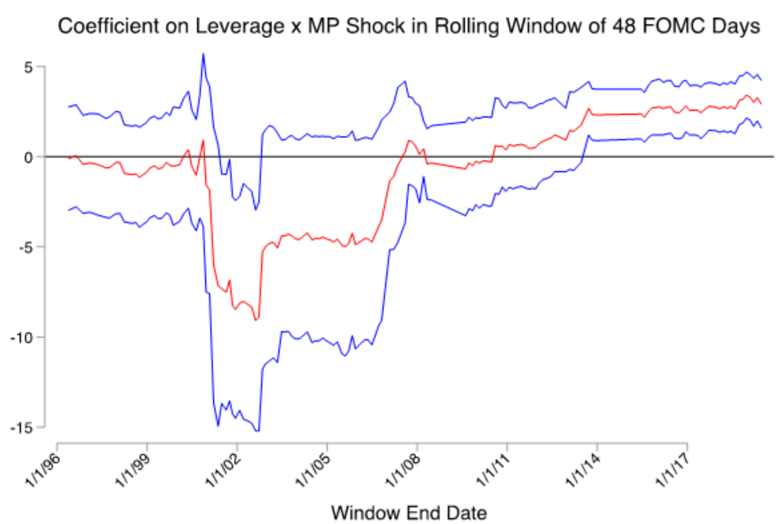
In Section 4 we discuss empirical evidence to motivate this shift. First, long-term debt share is higher for high leverage firms. Second, monetary shocks affect long-term rates more in the post-crisis sample. The combination of these two facts provides the explanation for the marginal cost curve flattening more for high leverage firms in the post-crisis sample.

Figure A.1: Stock response of non-S&P 500 Compustat firms, by market capitalization quartiles



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 and $Z_{i,t-1}$ is a vector of firm-level controls. The monetary policy shock is normalized to have a unit effect on the 2 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.). Sample is non-financial Compustat firms not listed in the S&P 500 on date of FOMC announcement. Two-way clustered standard errors in parentheses.

Figure A.2: Interaction coefficient of leverage and mp shock from rolling regression



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 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 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, calculated using the two-way clustered (by firm and FOMC day) standard errors. The monetary policy shock is normalized to have a unit effect on the 2 year yield and a positive value represents an expansionary shock.

Table A.1: Response of firm-level stock returns to monetary policy shocks: Alternative shocks

Panel A: Swanson (2021) shocks	(1) FFR shock x Lev.	(2) FG shock x Lev.	(3) LSAP shock x Lev.
Pre-crisis (β_1)	-6.47	1.00	-0.96
	(2.484)	(1.420)	(1.058)
Post-crisis($\beta_1 + \beta_2$)	1.70	1.07	2.66
	(1.154)	(0.774)	(0.836)
Difference (β_2)	8.18	0.07	3.62
	(3.295)	(1.904)	(1.409)
Observations		63,072	
R-squared		0.205	

Panel B: Individual shocks	(1) ED4 shock x Lev.	(2) 2 yr shock x Lev.	(3) 10yr shock x Lev.
Pre-crisis (β_1)	-3.25	-2.47	-0.31
	(1.592)	(1.618)	(1.119)
Post-crisis($\beta_1 + \beta_2$)	1.45	1.48	2.44
	(0.812)	(0.805)	(0.811)
Difference (β_2)	4.70	3.95	2.75
	(1.938)	(1.938)	(1.594)
Observations	63,337	63,337	63,337
R-squared	0.214	0.212	0.212

Results from estimating
$s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + \Upsilon' Z_{i,t-1}\epsilon_t^m + e_{i,t}$,
where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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 top panel uses the three shocks from Swanson (2021) all together, while the bottom panel has the following shocks one at a time: change in ED4 contract (column 1), change in 2-year yield (column 2) and change in 10-year yield (column 3). For all shocks a positive value represents an expansionary shock. All shocks are standardized to match the standard deviation of the MP shock series in each sub-period. Pre-crisis is Jul-1991 to Jun-2008 (153 obs.) and post-crisis is Aug-2009 to Jun-2019 (80 obs.). Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.2: Response of firm-level stock returns to monetary shocks with QE dummy

Panel A: MP shock	(1a) Pre-Crisis	(1b) Post-Crisis (non-QE)	(1c) Diff (1b - 1a)	(1d) Post-Crisis (QE)	(1e) Diff (1d - 1b)
MP shock x Leverage	-7.24	2.71	9.95	1.21	-1.50
	(3.370)	(1.048)	(3.900)	(0.950)	(0.956)
Observations			65,341		
R-squared			0.266		

Panel B: Swanson (2021) shocks	(1a) Pre-Crisis	(1b) Post-Crisis (non-QE)	(1c) Diff (1b - 1a)	(1d) Post-Crisis (QE)	(1e) Diff (1d - 1b)
FFR shock x Leverage	-6.94	1.51	8.45	0.40	-1.12
	(2.769)	(1.104)	(3.438)	(0.655)	(1.014)
FG shock x Leverage	0.67	0.55	-0.12	1.19	0.64
	(1.388)	(0.889)	(1.933)	(1.013)	(1.019)
LSAP shock x Leverage	-1.28	2.68	3.96	0.48	-2.19
	(1.184)	(0.972)	(1.584)	(0.703)	(1.053)
Observations			64,522		
R-squared			0.221		

Results from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \beta_3 l_{i,t-1}\epsilon_t^m D_t^{QE} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \delta_3 l_{i,t-1} D_t^{QE} + \Gamma' Z_{i,t-1} + \Upsilon' Z_{i,t-1}\epsilon_t^m + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day fixed-effect, D_t^{post} is an indicator for the post-crisis period, D_t^{QE} is an indicator for the Fawley et al. (2013) QE dates, $l_{i,t-1}$ 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 top panel uses our baseline monetary policy shock, normalized to have a unit effect on the 2 year yield. The bottom panel uses the three shocks from Swanson (2021) all together. For all shocks, a positive value represents an expansionary shock. All shocks are standardized to match the standard deviation of the MP shock series in each sub-period. Pre-crisis is Jul-1991 to Jun-2008 (153 obs.) and post-crisis is Nov-2008 to Jun-2019 (87 obs.). Sample is non-financial Compustat firms not listed in the S&P 500 on date of FOMC announcement. Two-way clustered standard errors in parentheses.

Table A.3: 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 Real Market Capitalization	9.12	1.13
Observations	87,634	

The table shows summary statistics for the firm-level characteristics. All variables are measured quarterly at the firm level. 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.

Table A.4: Robustness of baseline results to including financial crisis period

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage	(3) Investment MP shock x Leverage
Pre-Crisis	-7.96	-1.91	-2.78
	(4.133)	(0.576)	(1.958)
Post-Crisis	1.16	1.05	2.09
	(0.418)	(0.476)	(1.635)
Difference	9.11	2.96	4.87
	(4.155)	(0.499)	(2.404)
Observations	66,435	48,143	9,765
R^2	0.262	0.759	0.163

Column (1) is the result from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \alpha_t + \delta_1 l_{i,t} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma Z_{i,t-1} + e_{i,t}$. Column (3) is the result from estimating $\Delta ln(y_{it}) = \alpha_i + \alpha_t + \sum_{n\in N} \beta_{1n} l_{i,t-n-1}\epsilon_{t-n}^m + \beta_{2n} l_{i,t-n-1}\epsilon_{t-n}^m D_{t-n}^{post} + \Gamma' Z_{i,t-1} + e_{it}$, where y_{it} is the value of firm i's capital stock in quarter t. The monetary policy shock is normalized to have a unit effect on the 2 year yield and a positive value represents an expansionary shock. Pre-crisis is Jul-1991 to Jun-2008 and post-crisis is Jul-2008 to Jun-2019. Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered standard errors in parentheses.

Table A.5: Response of firm-level stock returns to monetary shocks: Without a time fixed effect

	(1a) Pre-Crisis	(1b) Post-Crisis	(1c) Diff	(1d) Full Sample
MP shock	9.44	3.63	-5.81	8.59
	(6.662)	(5.456)	(8.790)	(5.475)
MP shock x Leverage	-7.44	3.57	11.01	-5.18
	(4.166)	(1.048)	(4.279)	(3.552)
Observations		63,337		63,337
R^2		0.027		0.025

Results from estimating
$s_{i,t} = \alpha_i + \gamma_1 D_t^{post} + \gamma_2 \epsilon_t^m + \gamma_3 \epsilon_t^m D_t^{post} + \beta_1 l_{i,t-1} \epsilon_t^m + \beta_2 l_{i,t-1} \epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, 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 monetary policy shock is normalized to have a unit effect on the 2 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.). Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.6: Response of firm-level stock returns to monetary shocks: W/ Control triple interactions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
D_t^{post} x MP x Leverage	7.99	10.50	9.74	9.64	10.29	10.39	8.47	6.32
	(3.584)	(4.187)	(3.907)	(3.597)	(4.103)	(4.153)	(3.116)	(2.500)
D_t^{post} x MP x Curr. Asset Ratio	6.91							8.15
	(2.300)							(2.589)
D_t^{post} x MP x Sales Growth		0.00						0.97
		(3.593)						(3.367)
D_t^{post} x MP x Asset Value			5.33					-5.46
			(2.820)					(5.364)
D_t^{post} x MP x Price-Cost Marg.				-34.26				-17.54
				(34.235)				(27.995)
D_t^{post} x MP x Rec. - Pay.					-4.20			-1.63
					(3.354)			(2.977)
D_t^{post} x MP x Deprec./Assets						-1.94		-3.43
						(2.326)		(2.322)
D_t^{post} x MP x Firm Age							0.34	0.31
							(0.176)	(0.162)
Observations	63,337	63,337	63,337	63,337	63,337	63,337	63,337	63,337
R-squared	0.217	0.216	0.216	0.217	0.216	0.216	0.218	0.219

Results from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + \Upsilon' Z_{i,t-1}\epsilon_t^m + \Omega' Z_{i,t-1} D_t^{post} + \Pi' Z_{i,t-1}\epsilon_t^m D_t^{post} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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 monetary policy shock is normalized to have a unit effect on the 2 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.). Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.7: Robustness of baseline results with pre-crisis standardization of leverage

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage	(3) Investment MP shock x Leverage
Pre-Crisis	-7.76	-1.55	-2.75
	(4.020)	(0.550)	(1.857)
Post-Crisis	2.49	1.23	2.50
	(0.711)	(0.441)	(1.940)
Difference	10.25	2.78	5.25
	(4.115)	(0.473)	(2.529)
Observations	63,337	45,225	8,988
R^2	0.216	0.741	0.161

Column (1) is the result from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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 and $Z_{i,t-1}$ is a vector of firm-level controls. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \alpha_t + \delta_1 l_{i,t} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma Z_{i,t-1} + e_{i,t}$. Column (3) is the result from estimating $\Delta ln(y_{it}) = \alpha_i + \alpha_t + \sum_{n \in N} \beta_{1n} l_{i,t-n-1}\epsilon_{t-n}^m + \beta_{2n} l_{i,t-n-1}\epsilon_{t-n}^m D_{t-n}^{post} + \Gamma' Z_{i,t-1} + e_{it}$, where y_{it} is the value of firm i's capital stock in quarter t. The monetary policy shock is normalized to have a unit effect on the 2 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. Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered standard errors in parentheses.

Table A.8: Robustness of baseline results to removing pre vs. post outliers

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage	(3) Investment MP shock x Leverage
Pre-Crisis	-7.26	-0.03	-0.73
	(3.616)	(0.687)	(1.641)
Post-Crisis	4.07	2.58	3.27
	(0.992)	(0.658)	(2.735)
Difference	11.34	2.61	4.00
	(3.821)	(0.529)	(3.022)
Observations	50,614	34,670	6,467
R^2	0.219	0.754	0.123

Column (1) is the result from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \alpha_t + \delta_1 l_{i,t} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma Z_{i,t-1} + e_{i,t}$. Column (3) is the result from estimating $\Delta ln(y_{it}) = \alpha_i + \alpha_t + \sum_{n \in N} \beta_{1n} l_{i,t-n-1}\epsilon_{t-n}^m + \beta_{2n} l_{i,t-n-1}\epsilon_{t-n}^m D_{t-n}^{post} + \Gamma' Z_{i,t-1} + e_{it}$, where y_{it} is the value of firm i's capital stock in quarter t. The monetary policy shock is normalized to have a unit effect on the 2 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. Sample is non-financial firms in S&P 500 on date of FOMC announcement. We exclude 106 firms with a change in leverage from pre-crisis to post-crisis greater than 1 standard deviation. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.9: Response of firm-level stock returns to monetary shocks: LT vs. ST leverage

	(1a) Pre β_1	(1b) Post $\beta_1+\beta_2$	(1c) Diff β_2
MP shock x LT Leverage	-5.03	3.85	8.88
	(2.188)	(1.183)	(3.041)
Observations		63,337	
R^2		0.217	
MP shock x ST Leverage	-4.40	1.71	6.11
	(2.523)	(1.847)	(3.802)
Observations		63,337	
R^2		0.216	
MP shock x LT Leverage	-4.94	3.71	8.65
	(2.157)	(1.049)	(2.854)
MP shock x ST Leverage	-4.23	0.46	4.69
	(2.431)	(1.574)	(3.424)
Observations		63,337	
R^2		0.218	

This table shows results from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is four-quarter moving average of long-term leverage (top panel), short-term leverage (middle panel) or both short-term and long-term leverage (bottom panel) 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 the interactions of each control variable with the MP shock. The monetary policy shock is normalized to have a unit effect on the 2 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.). Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.10: Response of long-term debt issuance to MP shock, Post-crisis relative to pre-crisis

	LT Debt
Quarter t	879.97
	(509.005)
Quarter t+1	716.37
	(396.289)
Quarter t+2	338.45
	(456.594)
Quarter t+3	356.06
	(471.090)
Cumulative 4-qtr effect	2,290.84
	(931.827)
Observations	27,448
R^2	0.886

Results from estimating $\Delta y_{it} = \alpha_i + \alpha_t + \sum_{n \in N} \beta_{1n} l_{i,t-n-1} \epsilon^m_{t-n} + \beta_{2n} l_{i,t-n-1} \epsilon^m_{t-n} D^{post}_{t-n} + \Gamma' Z_{i,t-1} + e_{it}$, where y_{it} is value of firm i's long-term debt in quarter t, α_i is a firm fixed-effect, α_t is a quarter t fixed effect, D^{post}_t 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^m_t is the sum of all high-frequency monetary policy shocks that occur in quarter t, $Z_{i,t-1}$ is a vector of firm-level controls and $N = [0, 4]$. The monetary policy shock is normalized to have a unit effect on the 2 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.). Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered standard errors in parentheses.

Table A.11: Response of inflation expectations to monetary policy shock

	Pre-crisis	Post-crisis
MP shock	-0.26	-0.28
	(0.30)	(0.22)
Constant	0.00	0.01
	(0.01)	(0.00)
Observations	83	80
R^2	0.03	0.04

The table presents the results from regressing change in 5 year breakeven inflation expectations (measured from TIPS yields) on the monetary policy shock on FOMC meeting days. Due to data availability the pre-crisis sample runs from February 1999 to June 2008. The post-crisis sample runs from August 2009 to June 2019. Robust standard errors are reported in parentheses.

Table A.12: Robustness of baseline results to alternative measure of leverage: Debt-to-Assets

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage	(3) Investment MP shock x Leverage
Pre-Crisis	-7.62	-2.30	-3.48
	(4.375)	(0.635)	(2.389)
Post-Crisis	3.07	0.73	2.80
	(0.724)	(0.475)	(2.382)
Difference	10.69	3.03	6.28
	(4.474)	(0.522)	(3.150)
Observations	63,337	45,225	8,988
R^2	0.215	0.740	0.162

Column (1) is the result from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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-assets) 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. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \alpha_t + \delta_1 l_{i,t} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma Z_{i,t-1} + e_{i,t}$. Column (3) is the result from estimating $\Delta ln(y_{it}) = \alpha_i + \alpha_t + \sum_{n \in N} \beta_{1n} l_{i,t-n-1}\epsilon_{t-n}^m + \beta_{2n} l_{i,t-n-1}\epsilon_{t-n}^m D_{t-n}^{post} + \Gamma' Z_{i,t-1} + e_{it}$, where y_{it} is the value of firm i's capital stock in quarter t. The monetary policy shock is normalized to have a unit effect on the 2 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. Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.13: Robustness of baseline results to alternative measure of leverage: 1-quarter lagged debt-to-capital

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage	(3) Investment MP shock x Leverage
Pre-Crisis	-7.39	-1.31	-2.26
	(3.997)	(0.528)	(1.714)
Post-Crisis	2.23	1.36	2.27
	(0.748)	(0.425)	(1.916)
Difference	9.62	2.67	4.53
	(4.098)	(0.473)	(2.384)
Observations	69,381	49,806	9,504
R^2	0.201	0.738	0.157

Column (1) is the result from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day fixed-effect, D_t^{post} is an indicator for the post-crisis period, $l_{i,t-1}$ is one-quarter lagged 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. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \alpha_t + \delta_1 l_{i,t} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma Z_{i,t-1} + e_{i,t}$. Column (3) is the result from estimating $\Delta ln(y_{it}) = \alpha_i + \alpha_t + \sum_{n \in N} \beta_{1n} l_{i,t-n-1}\epsilon_{t-n}^m + \beta_{2n} l_{i,t-n-1}\epsilon_{t-n}^m D_{t-n}^{post} + \Gamma' Z_{i,t-1} + e_{it}$, where y_{it} is the value of firm i's capital stock in quarter t. The monetary policy shock is normalized to have a unit effect on the 2 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. Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.14: Robustness of baseline results: controlling for sector

Panel A: Time x Sector FE	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage	(3) Investment MP shock x Leverage
Pre-Crisis	-6.37	-1.32	-2.53
	(3.532)	(0.563)	(1.775)
Post-Crisis	1.70	1.49	1.76
	(0.675)	(0.453)	(1.752)
Difference	8.07	2.81	4.29
	(3.630)	(0.482)	(2.265)
Observations	63,068	45,059	8,887
R^2	0.264	0.762	0.235

Panel B: Control for MP x Sector	(1) Firm Share Price MP shock x Leverage	(2) Investment MP shock x Leverage
Pre-Crisis	-7.42	-2.59
	(3.805)	(1.729)
Post-Crisis	2.64	1.99
	(0.789)	(2.037)
Difference	10.05	4.57
	(3.923)	(2.425)
Observations	63,337	8,988
R^2	0.217	0.163

Column (1) of Panel A is the result from estimating $s_{i,t} = \alpha_i + \alpha_{jt} + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_{jt} is a sector j by 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 and $Z_{i,t-1}$ is a vector of firm-level controls. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \alpha_{jt} + \delta_1 l_{i,t} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma Z_{i,t-1} + e_{i,t}$. Column (3) is the result from estimating $\Delta ln(y_{it}) = \alpha_i + \alpha_{jt} + \sum_{n \in N} \beta_{1n} l_{i,t-n-1}\epsilon_{t-n}^m + \beta_{2n} l_{i,t-n-1}\epsilon_{t-n}^m D_{t-n}^{post} + \Gamma' Z_{i,t-1} + e_{it}$, where y_{it} is the value of firm i's capital stock in quarter t. The monetary policy shock is normalized to have a unit effect on the 2 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. Panel B follows the baseline specification with the addition of firm i's sector interacted with the monetary policy shock. Since the baseline implied volatility specification does not include MP shock, we exclude implied volatility from Panel B. Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered standard errors in parentheses.

Table A.15: Robustness of baseline results with consistent sample of firms

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage	(3) Investment MP shock x Leverage
Pre-Crisis	-5.32	-0.36	-0.73
	(3.176)	(0.648)	(1.583)
Post-Crisis	2.23	0.99	2.33
	(0.987)	(0.572)	(1.908)
Difference	7.55	1.35	3.05
	(3.392)	(0.594)	(2.512)
Observations	24,040	17,988	7,850
R^2	0.205	0.708	0.155

Column (1) is the result from estimating
$s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \alpha_t + \delta_1 l_{i,t} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma Z_{i,t-1} + e_{i,t}$. Column (3) is the result from estimating $\Delta ln(y_{it}) = \alpha_i + \alpha_t + \sum_{n \in N} \beta_{1n} l_{i,t-n-1}\epsilon_{t-n}^m + \beta_{2n} l_{i,t-n-1}\epsilon_{t-n}^m D_{t-n}^{post} + \Gamma' Z_{i,t-1} + e_{it}$, where y_{it} is the value of firm i's capital stock in quarter t. The monetary policy shock is normalized to have a unit effect on the 2 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. Sample is non-financial firms in S&P 500 on date of FOMC announcement that enter Compustat prior to 1994 and remain in the sample through at least 2017. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.16: Robustness of baseline results with scheduled FOMC meetings only

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage
Pre-Crisis	-1.92	-1.59
	(1.476)	(0.559)
Post-Crisis	2.52	1.23
	(0.727)	(0.446)
Difference	4.44	2.82
	(1.661)	(0.488)
Observations	59,526	43,338
R^2	0.182	0.739

Column (1) is the result from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \alpha_t + \delta_1 l_{i,t} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma Z_{i,t-1} + e_{i,t}$. The monetary policy shock is normalized to have a unit effect on the 2 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, excluding 16 unscheduled FOMC meeting dates in the pre-crisis period. Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.17: Robustness of stock return results to info-robust shocks

	(1a) Pre β_1	(1b) Post $\beta_1 + \beta_2$	(1c) Diff β_2
MP shock x Leverage	-6.21	4.29	10.50
	(2.823)	(1.386)	(3.786)
Observations		59,604	
R^2		0.217	

Results from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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 monetary policy shock is cleansed of information effects (as in Lakdawala (2019)), normalized to have a unit effect on the 2 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 Dec-2017 (68 obs.). Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.18: Robustness of baseline results to alternative measures of leverage: Within-firm variance

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage	(3) Investment MP shock x Leverage
Pre-Crisis	-10.03	-0.34	-4.41
	(4.592)	(0.703)	(2.659)
Post-Crisis	-1.49	-0.238	2.071
	(1.040)	(0.461)	(3.156)
Difference	8.54	0.10	6.48
	(4.631)	(0.775)	(3.768)
Observations	63,337	45,225	8,988
R^2	0.213	0.736	0.160

Results from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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. Leverage and all control variables are demeaned using the firm-specific sample mean. The monetary policy shock is normalized to have a unit effect on the 2 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.). Sample is non-financial firms in S&P 500 on date of FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.19: Robustness of baseline results including financial firms

	(1) Firm Share Price MP shock x Leverage	(2) Implied Volatility Leverage	(3) Investment MP shock x Leverage
Pre-Crisis	-5.21	-1.67	-1.68
	(2.827)	(0.554)	(0.241)
Post-Crisis	3.42	1.05	2.13
	(1.001)	(0.428)	(1.657)
Difference	8.64	2.72	3.80
	(3.340)	(0.469)	(0.037)
Observations	73,883	52,421	9,728
R^2	0.231	0.726	0.163

Column (1) is the result from estimating $s_{i,t} = \alpha_i + \alpha_t + \beta_1 l_{i,t-1}\epsilon_t^m + \beta_2 l_{i,t-1}\epsilon_t^m D_t^{post} + \delta_1 l_{i,t-1} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma' Z_{i,t-1} + e_{i,t}$, where $s_{i,t}$ is firm-level daily stock return, α_i is a firm fixed-effect, α_t is an FOMC day 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. Column (2) is the result from estimating $ivol_{i,t-1} = \alpha_i + \alpha_t + \delta_1 l_{i,t} + \delta_2 l_{i,t-1} D_t^{post} + \Gamma Z_{i,t-1} + e_{i,t}$. Column (3) is the result from estimating $\Delta ln(y_{it}) = \alpha_i + \alpha_t + \sum_{n \in N} \beta_{1n} l_{i,t-n-1}\epsilon_{t-n}^m + \beta_{2n} l_{i,t-n-1}\epsilon_{t-n}^m D_{t-n}^{post} + \Gamma' Z_{i,t-1} + e_{it}$, where y_{it} is the value of firm i's capital stock in quarter t. The monetary policy shock is normalized to have a unit effect on the 2 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. Sample is all firms in S&P 500 on date of FOMC announcement. Two-way clustered (by firm and FOMC day) standard errors in parentheses.

Table A.20: Response of Bond Yield Spread to Monetary Policy Shock

	BAA - AAA spread
MP Shock	1.034
	(4.447)
Post-Crisis x MP Shock	-20.414
	(12.211)
Observations	221
R^2	0.021

Results from estimating $\Delta ln(y_t) = \alpha_0 + \alpha_1 D_t^{post} + \delta\epsilon_t^m + \beta D_t^{post}\epsilon_t^m + e_{it}$, where y_{it} is BAA-AAA bond yield spread, D_t^{post} is a dummy for the post-crisis period and ϵ_t^m is the monetary policy shock. The monetary policy shock is normalized to have a unit effect on the 2 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 Dec-2017 (68 obs.). Robust standard errors in parentheses.