Monetary policy and volatility

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Abstract: This paper provides empirical evidence that the effectiveness of monetary policy transmission depends negatively on volatility and develops a general equilibrium model to quantify this relationship. In the cross section, firms with higher return volatility exhibit weaker responses to monetary policy shocks in equity prices, capital investment and employment. Similarly, in the time series, the stock market and aggregate investment are less responsive to monetary policy shocks when aggregate volatility is high. I develop a two-sector general equilibrium model with price rigidity and endogenous growth to quantify the relationship between volatility and the strength of monetary policy transmission.

Keywords: Monetary policy shocks, New Keynesian model, FOMC announcements, Asset pricing, Risk premia.

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1 Introduction

The most common policy instrument through which central banks pursue their macroeconomic objectives is the short-term interest rate. Changes in short-term nominal rates often propagate to the returns on other asset classes, such as long-term bond and stocks, then transmit to the rest of the economy.[1] A key step in the monetary policy transmission mechanism is that investors respond to shocks in asset returns by trading off expected returns against risk. This logic implies that the strength of monetary policy transmission should depend on the level of volatility. This paper provides both empirical evidence and a theoretical analysis of the impact of volatility on the effectiveness of monetary policy transmission.

Empirically, the paper shows that monetary policy transmits less effectively when volatility is high. The evidence comes in two parts. In the cross section, firms with more volatile returns respond less to the same policy surprise, and they do so on every margin the data allow us to measure. A one percentage point interest rate cut raises the announcement-day stock price of the average firm by about 4.7 percent; a firm with ten percentage points more annualized volatility gains about 0.77 percentage points less. On the same firms, a one percentage point cut raises the average firm's quarterly investment rate by about 0.54 percentage points, and ten percentage points more volatility costs about 0.34 percentage points of that. On the annual employment margin, the most volatile fifth of firms respond 10.4 percentage points less than the least volatile fifth, and the ordering is monotone across the five groups. In the aggregate time series, the same cut raises the market by 5.9 percent and aggregate investment by 1.7 percent, and both responses shrink when aggregate volatility is high: a ten percent rise in aggregate volatility removes about 1.2 percentage points of the market's response and about 0.7 of aggregate investment's. Monetary policy also moves aggregate volatility itself: an easing lowers it at every horizon after impact, and the effect grows for two years. The model developed in this paper not only accounts for the heterogeneous response to monetary policy shocks conditional on volatility, at the firm level and in the aggregate time series, but also predicts this last fact—a reallocation channel through which monetary policy shifts capital and labor across sectors and thereby changes aggregate volatility itself.

[1] It is well documented that monetary policy has a significant impact on both asset markets and real economic activity. For example, the classic paper by Bernanke and Kuttner (2005) shows that a 25 bp interest rate cut leads to a 100 bp increase in stock prices. More recently, Bauer and Swanson (2023) show that after a 25 bp interest rate cut, industrial production goes up by 1.4% within quarters and CPI by 0.5%.

There is a simple intuition to explain these new empirical facts about the heterogeneous effect of monetary policy shocks on the economy, and it goes back to the canonical portfolio choice model of Merton (1969). This model, later extended by Cox et al. (1985) to an exchange economy, essentially states that the wealth allocated to asset i is proportional to

$$\frac{\mu_i - r}{\gamma \sigma_i^2}$$

where γ is the parameter for constant relative risk aversion of the representative agent, μ_i the expected return of the asset, r the real interest rate, and σ_i the standard deviation of the asset's return. When there is an expansionary shock, the riskless rate declines and investment rises for all firms. However, for firms with higher return volatility, or higher σ_i, the increase in investment is smaller—the higher the volatility, the smaller the response, controlling for everything else. When aggregate volatility is high, high volatility firms comprise a larger share of the economy, which means a larger share of the economy is less responsive to monetary policy shocks and hence the economy as a whole responds less.

While it appears that the canonical portfolio allocation formula can intuitively rationalize how volatility affects monetary policy effectiveness across both cross-sectional and time-series dimensions, whether this holds in a production economy—where agents make optimal price-adjusting and investment decisions after a monetary policy shock, and where both returns and return volatility, whether cross-sectional or market level, are endogenously determined—unlike the vintage model, remains an open question.

To assess the importance of volatility's role in monetary policy shock transmission and to establish the canonical return-risk trade-off as the underlying mechanism for the negative correlation between volatility and monetary policy effectiveness, we enrich a standard New Keynesian model with Epstein and Zin (1991) preferences, endogenous growth from capital accumulation, and sectoral heterogeneity in productivity volatility. A representative household consumes, supplies labor, and delegates price setting to a continuum of monopolistically competitive firms subject to nominal rigidity, or price adjustment costs, à la Rotemberg (1982). The economy has two sectors responsible for investment and capital accumulation, and each sector is populated by a continuum of firms—the only distinction between firms in different sectors is the volatility of their stochastic productivity processes. Monetary policy follows a Taylor (1993) rule and the economy is subject to three aggregate AR(1) shocks—monetary policy shocks and two sectoral TFP shocks. Heterogeneity in productivity volatility generates heterogeneity in return volatility, and aggregate shocks affect the proportion of capital in the high volatility sector relative to aggregate capital, which gives rise to time-series variation in aggregate return volatility endogenously.

In a calibration matching key moments of the macroeconomy and asset pricing, the model quantitatively explains the observed role of volatility in monetary policy transmission. An expansionary shock decreases the nominal interest rate, generates a positive inflation surprise, lowers the real prices of consumption goods, and increases aggregate demand. At the same time, the real price of intermediate goods, the output of the two sectors with heterogeneity in volatility, rises, and this combined with higher demand increases their cash flow and leads firms to increase investment across firms with different levels of volatility. However, all else equal, firms increase investment more in the low volatility sector, according to the canonical return-risk trade-off mechanism. With aggregate productivity shocks continuously shifting the relative size of the high versus low volatility sector, the aggregate volatility of the economy is time-varying, and when aggregate volatility rises, the high volatility sector comprises a larger share of the economy. This in turn makes the economy as a whole less responsive to monetary policy shocks. Applying the same regression to the simulated data generated from the model as we did with the empirical data, the average stock price and investment response and the differences in increases attributed to cross-sectional and time-series volatility heterogeneity are highly comparable with the estimates from actual data, corroborating the quantitative importance of volatility in the transmission of monetary policy shocks.

A noteworthy feature of the model is that it contains an inherent portfolio choice problem between two sectors that are identical to each other at first-order approximation, which prevents the optimal allocations between the two sectors from being uniquely defined in nonstochastic steady states. As a result, there is no natural point around which to approximate, rendering the standard perturbation methods commonly used in DSGE models infeasible. Instead, we define and solve the recursive functional equilibrium globally, enabling a more accurate characterization of policy functions and facilitating the quantitative analysis of how the economy's dynamics in response to monetary policy shocks can vary with cross-sectional and time-series volatility.

Aside from quantitatively explaining the new empirical facts, this model also addresses why high-frequency identified monetary policy shocks have such substantial effects on stock prices. Monetary policy shocks differentially affect the stock valuation and investment of firms with heterogeneous volatility, altering the relative size of high versus low volatility sectors and thereby shifting aggregate volatility endogenously. With recursive utility featuring preference for early resolution of uncertainty, these movements in aggregate volatility translate into changes in the equity risk premium, generating significant effects on firm valuation and investment that match the magnitudes observed in the data.

Moreover, we closely mirror the empirical event study approach for measuring stock price responses to identified monetary policy shocks. While we observe the underlying AR(1) monetary shock process directly in the model, we deliberately use short-term nominal interest rate movements as our measure of monetary shocks in simulated regressions, mimicking how empiricists must identify shocks from yield curve movements. This approach is nontrivial in a New Keynesian model with capital accumulation. When agents can adjust savings over time through capital, exogenous monetary shocks and measured short-term nominal interest rate changes are not equivalent. Under some parameter configurations, an expansionary shock can trigger such a large investment response that endogenously determined real and nominal interest rates rise rather than fall, regardless of maturity. To replicate the empirical exercise rigorously and remain consistent with our emphasis on monetary policy transmission through asset prices—including both bonds and stocks—we calibrate the model to ensure that the nominal yield curve is upward sloping and that an expansionary shock always lowers endogenous real and nominal interest rates.

To further validate the model, we derive two additional implications and take both to the data. The first concerns the labor margin. The model's policy functions imply that the dampening role of volatility is not confined to investment and stock prices: following an expansionary shock, the labor input of high-volatility firms rises by less than that of low-volatility firms. On an annual panel of Compustat firms sorted into five volatility groups, the employment response of the most volatile fifth is 10.4 percentage points weaker than that of the least volatile fifth, and the gap is essentially unchanged over the following two years. The second concerns aggregate volatility. Consider an interest rate cut: investment rises in both sectors, but the low-volatility sector grows more, its share of aggregate capital rises, and aggregate volatility falls as a result. Measuring aggregate volatility as the value-weighted mean of firm asset volatility, we find that it declines after expansionary monetary shocks, and that the effect is robust and persistent over time.

Related literature This paper contributes to four strands of literature.

The first strand studies why small monetary policy shocks generate significant swings in asset prices. Nakamura and Steinsson (2018) show central banks can influence public beliefs about fundamentals to explain yield curve responses. Pflueger and Rinaldi (2022) and Kekre and Lenel (2022) generate time-varying risk aversion through habit formation and heterogeneous risk preferences, respectively. Lagos and Zhang (2020) use a search-liquidity framework where central banks affect the opportunity cost of holding nominal assets. This paper emphasizes a different mechanism: because firms with different volatility respond differently to monetary policy shocks, these shocks alter the relative size of high versus low volatility sectors, affecting aggregate volatility and hence the equity risk premium.

The second strand examines how monetary policy shocks differentially impact firms based on firm-specific characteristics. Prior studies examine how asset price responses vary with financial constraints (Ozdagli (2018);Chava and Hsu (2020)), cash holdings and payout policy (Pazarbasi (2026)), asset intangibility (Döttling and Ratnovski (2023)), leverage (Anderson and Cesa-Bianchi (2024)), and profitability (Ai et al. (2024)), or how real activity responses such as investment (Ottonello and Winberry (2020)) and debt composition adjustments (Chen (2025)) vary with leverage and financial constraints. This paper differs by studying firm-level volatility and establishing the return-risk tradeoff as the underlying mechanism for both asset prices and physical investment. Our empirical findings are robust to controlling for these other firm characteristics and do not contradict previous research; rather, we focus on a different dimension of the data. We contribute by showing that firm-level volatility generates heterogeneous responses to monetary policy shocks in both equity prices and investment, and that these cross-sectional differences aggregate to produce time-varying monetary policy effectiveness at the macroeconomic level. Moreover, while most existing models treat monetary policy shocks as MIT shocks, our framework incorporates them as part of aggregate uncertainty, allowing for richer quantitative analysis.

The third strand examines the role of volatility in macroeconomics and finance. From a macroeconomic perspective, Bloom (2009), Baker et al. (2016), and Bloom et al. (2018) study volatility shocks as an independent driver of business cycles alongside conventional TFP shocks. This paper differs in that volatility variation here is endogenous rather than exogenous: it emerges from first-moment shocks such as TFP and monetary policy shocks, rather than constituting an independent shock itself. On the asset pricing side, prior work studies idiosyncratic volatility and stock returns (Ang et al. (2006); Ai and Kiku (2016)), common factors in idiosyncratic volatility (Herskovic et al. (2016)), aggregate macroeconomic volatility (Bansal et al. (2014)), and volatility shocks in supply chains (Grigoris and Segal (2024)). This paper further differs by examining both firm-level and aggregate volatility and analyzing how they shape macroeconomic outcomes and stock prices through their interaction with monetary policy shocks.

The fourth strand studies the state dependence of monetary policy effectiveness. Koby and Wolf (2020) show that aggregate effects of monetary and fiscal stimulus can be sensitive to business-cycle conditions. Crouzet (2021) examines how debt intermediation patterns affect monetary policy transmission to corporate investment, while Di Giovanni and Hale (2022) study how global production linkages affect the spillover of monetary shocks to stock returns across countries. Two closely related papers are Vavra (2014) and Fang (2020), both of which study why monetary policy becomes less effective during periods of high volatility by applying the Ss model with real option channel generated by fixed adjustment costs from Caballero and Engel (2007), where the real option of waiting affects the extensive and intensive margins of economic behavior. Vavra (2014) finds that with fixed price adjustment costs, prices adjust with larger magnitude and higher frequency when volatility is high; Fang (2020) finds that with fixed capital adjustment costs, higher volatility increases the real option of waiting. This paper departs by introducing firm-level volatility heterogeneity and establishing the return-risk trade-off as the operative mechanism for state-dependent monetary policy effectiveness—a channel distinct from the adjustment cost and real option mechanisms in prior work. This mechanism operates both in the cross-section, with high-volatility firms responding less to monetary shocks, and in the time series, with the economy as a whole becoming less responsive when aggregate volatility rises as capital shifts toward high-volatility sectors.

Outline The paper is organized as follows. Section 2 provides empirical evidence that firm-level and aggregate responses to monetary policy shocks vary with volatility, on equity prices, investment and employment in the cross section and on the market return and aggregate investment in the time series, and shows that a monetary easing endogenously lowers aggregate volatility. Section 3 develops our two-sector volatility heterogeneity New Keynesian model with endogenous growth and long run risk to interpret these evidence. Section 4 discusses the solution and the policy function to study the monetary policy transmission mechanism of the model. Section 5 then calibrates the model and verifies that it is consistent with general macro-finance moments and can quantitatively reproduce the negative correlation between volatility and the strength of the transmission of monetary policy shocks both at cross-section and time series. Section 6 concludes.

2 Empirical Results

This section documents the empirical relationship between volatility and monetary policy effectiveness. In the cross section, firms with higher volatility respond less to a monetary policy surprise on three margins: equity prices, capital investment, and employment. In the aggregate time series, the stock market and aggregate investment respond less when aggregate volatility is elevated, and an easing lowers aggregate volatility at every horizon after impact—the compositional channel the model in Section 3 makes explicit.

2.1 Data and Measurement

The firm panel is built from Compustat quarterly fundamentals and merged to CRSP; the extract, the sample screens and their cost in firms and firm-quarters are set out in Appendix B.1.

Monetary policy shocks. The baseline surprise measure (MPS) is the first principal component of the changes in fed funds and eurodollar futures with maturities from one month to one year (MP1, FF4, ED2, ED3, ED4) over the 30-minute window around scheduled FOMC announcements, from Jarocinski and Karadi (2020), measured in percentage points, so a 50 basis point surprise is 0.50. Table 2 uses a single meeting's surprise; Table 3 uses the sum of the surprises within the quarter. The two carry the same name and are different variables: signs and ratios travel across the two tables, coefficient levels do not. A surprise orthogonalized to central bank information and the measure of Nakamura and Steinsson (2018) are used as robustness checks.[2]

Firm-level volatility. The volatility regressor is annualized *asset* volatility: the standard deviation of the residual from a four-factor regression of daily unlevered firm

[2]The orthogonalized measure addresses the concern that an FOMC announcement conveys two signals at once, the policy stance and the Fed's assessment of economic conditions. Isolating the policy component ensures that the estimated heterogeneity reflects differential sensitivity to policy rather than to information revelation.

returns over the quarter. Unlevered returns are daily equity returns divided by the ratio of the market value of assets to the market value of equity, where the market value of assets is total assets plus market equity less book equity less deferred taxes, and is defined only when all four inputs are reported. Equity volatility is the same object without the unlevering and is reported as a robustness check, as are gross return volatility, market-model residual volatility, and one- and three-factor residual volatility. Because the measure is annualized it is on the scale of the model's volatility, and a coefficient in Tables 2 and 3 may be multiplied by a standard deviation from Table 1 directly.

Sign and units. Throughout Section 2, coefficients are signed as the response to a monetary *easing* and multiplied by 100. A positive β_1 therefore means that prices, investment or employment rise when policy loosens, and a negative β_3 means that high-volatility firms respond less. Two standard errors are reported for every coefficient: clustered on firm, in parentheses, and clustered two-way on firm and on the time unit, in brackets.[3]

2.2 Cross-Sectional Evidence

2.2.1 Stock Price Responses

We regress firm stock returns on the FOMC announcement day on the surprise, firm volatility, and their interaction:

$$R_{i,\text{fomc}} = \alpha_i + \alpha_{sq} + \beta_1 MPS_{\text{fomc}} + \beta_2 \sigma^a_{i,\text{fomc}^-} + \beta_3 MPS_{\text{fomc}} \times \sigma^a_{i,\text{fomc}^-} + \text{Controls} + \epsilon_{i,\text{fomc}}$$

where $R_{i,\text{fomc}}$ is firm i's CRSP return on the announcement day, α_i a firm effect, α_{sq} an industry-by-quarter effect, and $\sigma^a_{i,\text{fomc}^-}$ the firm's asset volatility from the most recent completed fiscal quarter. Characteristics are lagged by the merge itself: they are joined to the meeting from the most recent completed fiscal quarter, three to six months earlier, and are therefore predetermined. Standard errors are clustered on firm and on announcement date. The estimation sample is 5,175 firms and 268 scheduled announcements from 1990 to 2023.

[3]The surprise takes one value per period shared by every firm, so the right-hand side carries as many independent draws as there are quarters or meetings, not as many as there are firm-periods, and the two-way standard error is the one to read for inference on β_1.

Table 1: Summary Statistics

	Obs	Mean	Std. Dev.	p25	Median	p75
Panel A: Firm characteristics (firm-quarter)						
Investment rate (CAPX/PP&E)	194,859	0.066	0.070	0.025	0.046	0.082
Cash flow/Assets	184,666	0.014	0.048	0.009	0.021	0.033
Asset volatility (FF4 residual)	194,859	0.284	0.200	0.142	0.226	0.368
Equity volatility (FF4 residual)	194,859	0.441	0.278	0.245	0.365	0.553
Profitability	194,034	0.013	0.039	0.004	0.019	0.032
Tangibility	194,859	0.551	0.398	0.238	0.448	0.795
Cash holdings	194,823	0.154	0.183	0.022	0.079	0.222
Book leverage	194,859	0.295	0.236	0.065	0.283	0.474
Book-to-market	194,511	0.617	0.512	0.300	0.489	0.774
Book equity, USD millions	194,859	939	2498	43	175	690
Tobin's Q	194,859	1.631	0.787	1.102	1.399	1.906
Size (log assets)	194,859	5.921	2.027	4.386	5.857	7.383
Age	194,859	19.58	17.06	7.00	15.00	27.00
Dividend payer (paid in quarter t)	194,581	0.381	0.486	0.000	0.000	1.000
Panel B: Stock returns (firm-meeting)						
Announcement-day return (%)	569,415	0.25	3.27	-1.30	0.00	1.64
Asset volatility (FF4 residual)	569,415	0.305	0.232	0.137	0.235	0.407
Panel C: Time series (quarterly)						
MP surprise, scheduled meetings	144	-0.012	0.069	-0.031	-0.002	0.019
MP surprise, OW timing weighted	135	-0.013	0.057	-0.032	-0.004	0.017
MP surprise, all meetings, weighted	135	-0.031	0.091	-0.052	-0.006	0.016
Aggregate investment rate, capital-weighted	143	0.0412	0.0082	0.0349	0.0410	0.0470
Aggregate asset volatility, capital-weighted	143	0.126	0.028	0.108	0.118	0.140

Notes: This table reports summary statistics for the variables used in the empirical analysis.
Panel A is the firm-quarter estimation sample of Table 3: 4,801 firms and 134 quarters from 1989q1 to 2023q4, 194,859 firm-quarter observations, with the Great Recession window 2008q1–2009q2 excluded as in investment specification. Panel B is the full firm-meeting event panel behind Table 2: 5,301 firms and 284 scheduled FOMC announcements from 1988 to 2023, 569,415 observations, one per firm per announcement; Panel C is the quarterly time series of aggregate variables. Both volatility measures are annualized. Table 2 uses a single meeting's surprise and Table 3 the sum within the quarter, which is what Panel C reports.

Table 2 presents the results, in the five columns used throughout. Column (1) is the baseline, which interacts the surprise with volatility, profitability, tangibility, the tangibility indicator, cash and the payout indicator. Column (2) interacts it with volatility alone, and column (3) with volatility, book leverage, book equity and Q. Columns (4) and (5) replace our design with Ottonello and Winberry's—firm, industry-by-quarter and fiscal-quarter effects, each characteristic entered alone, interacted with the surprise, and interacted with contemporaneous GDP growth—at the control sets of columns (3) and (1) respectively. Columns (3) and (4) therefore differ only in the design and columns (1) and (3) only in the control set, so the two are separately identified. Unlike Table 3, β_1 is identified in columns (4) and (5): the surprise is not constant within a industry-quarter cell here, because the quarter holds two meetings.

β_1 is positive and β_3 negative in every column, and both are identified here, which is what the model requires of this table. β_1 runs from 4.24 to 4.70 and β_3 from -4.21 to -7.74; every β_1 is significant on the two-way standard error and every β_3 is, except in column (5). Reading the baseline column (1): a one percentage point easing raises the announcement-day return of the average firm by about 4.7 percent, and a firm with ten percentage points more annualized asset volatility gains about 0.77 percentage points less.[4]

2.2.2 Investment Responses

The investment specification mirrors Table 2 column for column:

$$\frac{I_{i,q}}{K_{i,q-1}} = \alpha_i + \alpha_{sq} + \beta_1 MPS_q + \beta_2 \sigma^a_{i,q-1} + \beta_3 MPS_q \times \sigma^a_{i,q-1} + \text{Controls} + \epsilon_{i,q}$$

where the dependent variable is deflated capital expenditure over lagged deflated net property, plant and equipment on a panel of 4,801 firms and 134 quarters from 1989q1 to 2023q4, MPS_q is the sum of the surprises within quarter q, and every interacted characteristic enters lagged one quarter and demeaned on the column (1) sample, so that β_1 is the response of the average firm and is comparable across columns.

Table 3 presents the results and it is robust across designs and control sets. β_1 is

[4]The two-day window, which compounds the announcement day with the following session, is reported in the appendix as a reversal test. Its coefficients *exceed* the one-day coefficients—by a factor of 1.60 to 2.11 on β_1 and 1.51 to 1.71 on β_3—so the announcement-day estimate is a lower bound on the total effect rather than a transitory move that later reverses.

Table 2: Heterogeneous Response of Stock Prices to Monetary Policy

	(1) Baseline	(2) Volatility only	(3) OW controls	(4) *OW design*	(5) *OW, full*
Shock β_1	4.70	4.55	4.58	4.24	4.33
(firm)	(50.56)	(49.73)	(50.45)	(36.60)	(36.18)
[two-way]	[2.85]	[2.81]	[2.82]	[3.32]	[3.28]
Volatility $\times$ Shock β_3	-7.74	-5.85	-7.35	-4.46	-4.21
(firm)	(-12.73)	(-13.09)	(-13.24)	(-7.85)	(-6.70)
[two-way]	$[-2.54]$	$[-2.54]$	$[-2.58]$	$[-2.14]$	$[-1.93]$
Firm FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	—	—
Industry $\times$ time FE	—	—	—	Yes	Yes
Fiscal-quarter FE	—	—	—	Yes	Yes
Cyclical sensitivity	—	—	—	Yes	Yes
Observations	534,061	547,841	547,841	547,721	533,941

Notes: This table reports the response of firm stock returns to a monetary policy surprise and its interaction with firm volatility. The unit of observation is a firm-meeting: 5,175 firms and 268 scheduled FOMC announcements from 1990 to 2023, 534,061 firm-meeting observations in column (1); the Great Recession window is retained, since the quarter is not the unit of observation. The dependent variable is the firm's CRSP return on the day of the announcement, in percent. The monetary policy surprise is the high-frequency surprise around that single announcement, in percentage points. Volatility is the annualized standard deviation of the residual from a four-factor regression of daily unlevered firm returns. Characteristics are demeaned on the column (1) sample, so β_1 is the response of the average firm.[a]
The one-day window is the estimate reported; the two-day window is in the appendix as a reversal test. β_1 *is* identified in columns (4) and (5) despite the industry-by-quarter effects: the quarter holds two scheduled meetings, so the surprise is not constant within the cell. Coefficients are signed as the response to a one percentage point monetary *easing* and multiplied by 100. Figures in parentheses are t-statistics computed from standard errors clustered on firm; figures in brackets are t-statistics computed from standard errors clustered two-way on firm and announcement date.

[a]Two features of the design follow from the event structure. First, the time unit is a meeting, so standard errors cluster on firm and announcement date; with roughly two scheduled meetings per quarter, the industry-by-time effects in columns (4) and (5) are industry by *quarter*, which absorbs industry-level quarterly conditions while the difference between the two meetings inside the quarter survives. Industry-by-meeting effects would instead absorb the announcement itself, since on an event window nearly all systematic return *is* the response to the announcement. Second, because volatility is measured in the most recent completed fiscal quarter rather than immediately before the meeting, it is lagged by four to six months, which attenuates β_3; the estimate should be read as a lower bound.

positive: after a one percentage point easing the firm at average volatility raises its quarterly investment rate by about 0.54 percentage points in the baseline column (1). β_3 is the focus of this table. It is negative in all five columns, between -2.86 and -5.61, so a firm with ten percentage points more annualized volatility raises its investment rate by roughly 0.3 to 0.6 percentage points less.[5]

2.3 Time-Series Evidence

2.3.1 Aggregate Stock Market Responses

The aggregate part runs the same regression on one observation per FOMC meeting, with aggregate volatility built as the value-weighted mean of the very firm volatility from the panel regression,

$$R_{\text{fomc}} = \beta_0 + \beta_1 \,\text{MPS}_{\text{fomc}} + \beta_2 \,\log \text{Vol}_m + \beta_3 \,\text{MPS}_{\text{fomc}} \times \log \text{Vol}_m + \varepsilon_{\text{fomc}}$$

where R_{fomc} is the value-weighted market return on the announcement day. Market volatility enters in logs.[6]

Panel A of Table 4 reports the estimates on 268 meetings. $\beta_1 = 5.91$ with a t of 3.37: a one percentage point easing raises the value-weighted market return on the announcement day by 5.9 percent at the sample mean of volatility. $\beta_3 = -12.38$ with a t of -3.26: a one log point increase in aggregate volatility removes 12.4 points of that response, so at one standard deviation above the mean the market's response is about 3.0 percentage points smaller. The equal-weighted return gives 5.51 and -10.25.

[5] On the two-way standard error the impact estimates are imprecise—t between -1.01 and -1.88—and the local projection in Appendix Figure 8 shows why this is a power problem rather than an absent effect: the interaction is significant at every horizon under firm clustering and through $h = 5$ two-way, and the profile does not fade: the cumulative interaction through four quarters is -22.89 under the baseline column (1) and -29.33 under column (2), against impact estimates of -3.35 and -5.61. Reading $h = 0$ on its own understates what the panel identifies.

[6] The level distribution of aggregate market volatility is severely right-skewed, so the log is the natural scale. Aggregate β_3 is therefore per log point, while the cross-sectional β_3 of Tables 2 and 3 is per unit of the decimal.

Table 3: Heterogeneous Response of Investment to Monetary Policy

	(1) Baseline	(2) Volatility only	(3) OW controls	(4) *OW design*	(5) *OW, full*
Shock β_1	0.54	1.12	1.17	absorbed	absorbed
(firm)	(2.34)	(4.83)	(5.04)		
[two-way]	[0.47]	[0.81]	[0.99]		
Vol $\times$ Shock β_3	−3.35	−5.61	−3.46	−2.86	−4.38
(firm)	(−1.85)	(−3.62)	(−2.08)	(−1.74)	(−2.37)
[two-way]	[−1.01]	[−1.88]	[−1.34]	[−1.17]	[−1.69]
Firm FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	—	—
Industry $\times$ quarter FE	—	—	—	Yes	Yes
Fiscal-quarter FE	—	—	—	Yes	Yes
Aggregate controls	Yes	Yes	Yes	—	—
Cyclical sensitivity	—	—	—	Yes	Yes
Observations	194,859	196,812	196,812	236,520	233,032

Notes: This table reports the response of firm investment to a monetary policy surprise and its interaction with firm volatility, on a quarterly panel of U.S. non-financial, non-utility Compustat firms. The dependent variable is the investment rate, capital expenditure over lagged net PP&E. The surprise is the first principal component of high-frequency changes in fed funds and eurodollar futures around scheduled FOMC announcements, summed within the quarter and measured in percentage points. Volatility is the annualized standard deviation of the residual from a four-factor regression of daily unlevered firm returns over the quarter. Every interacted characteristic enters lagged one quarter and demeaned on the column (1) sample, so β_1 is the response of the average firm and is comparable across columns.
Column (2) interacts the surprise with volatility alone; (3) adds book leverage, book equity and Q; (1), the baseline, adds profitability, tangibility, the tangibility indicator, cash and the payout indicator; (4) and (5) replace the design with Ottonello and Winberry's, in which each characteristic enters three times—alone, interacted with the surprise, and interacted with contemporaneous real GDP growth—and the aggregate controls are dropped because they are collinear with the industry-by-quarter effects. Columns (3) and (4) therefore differ only in the design and (1) and (3) only in the control set.[a]

[a] β_1 is *not* identified in columns (4) and (5): the surprise takes one value per quarter and is absorbed by the industry-by-quarter effects, and those cells report "absorbed" rather than a number. The Great Recession window 2008q1–2009q2 is excluded throughout. Coefficients are signed as the response to a one percentage point easing and multiplied by 100. Figures in parentheses are t-statistics computed from standard errors clustered on firm; figures in brackets are t-statistics computed from standard errors clustered two-way on firm and quarter.

Table 4: Aggregate Market Returns, Investment, and Volatility

Panel A. Aggregate stock return on FOMC announcement days

	Value-weighted	Equal-weighted
Shock β_1	5.91	5.51
	(3.37)	(3.10)
logVol $\times$ Shock β_3	-12.38	-10.25
	(-3.26)	(-2.53)
Meetings	268	268

Panel B. Aggregate investment, local projections by horizon

Horizon h (quarters)	0	1	2	3	4	6	8
Shock $\beta_{1,h}$	1.73	2.29	1.56	0.46	1.50	0.12	-0.72
	(1.88)	(1.65)	(0.83)	(0.21)	(0.50)	(0.03)	(-0.12)
logVol $\times$ Shock $\beta_{3,h}$	-6.93	-16.43	-22.24	-27.40	-38.76	-46.30	-42.53
	(-1.40)	(-2.22)	(-2.40)	(-2.64)	(-2.61)	(-2.19)	(-1.50)
$\beta_{3,h}$ per quarter	-6.93	-8.21	-7.41	-6.85	-7.75	-6.61	-4.73

Notes: Both panels are estimated on the aggregate series: aggregate volatility is a cross-sectional mean of the same firm asset volatility that Tables 2 and 3 interact, value-weighted in Panel A and capital-weighted in Panel B. Volatility enters in logs throughout. Coefficients are signed as the response to a one percentage point easing and multiplied by 100. All figures in parentheses are t-statistics.

Panel A is one observation per scheduled FOMC announcement, 268 meetings. The dependent variable is the market return on the announcement day, value-weighted in the first column and equal-weighted in the second; the column labels refer to the weighting of the return, and the volatility regressor is value-weighted in both. Standard errors are heteroskedasticity- and autocorrelation-robust with a Newey-West correction.

Panel B is quarterly, 144 quarters. The dependent variable at horizon h is the cumulative change in log aggregate investment from quarter $q-1$ to quarter $q+h$, and both the investment aggregate and the volatility aggregate are capital-weighted. Standard errors are Newey-West with $h+1$ lags. The row $\beta_{3,h}$ *per quarter* divides the cumulative coefficient by $h+1$. Horizons 5 and 7 are estimated and omitted from the display only for width.

2.3.2 Aggregate Investment Responses

For aggregate investment we estimate local projections of the cumulative response to a quarterly surprise, with the same interaction:

$$\Delta_h \log I_{q+h} = \beta_{0,h} + \beta_{1,h}\,\mathrm{MPS}_q + \beta_{2,h}\,\log\mathrm{Vol}_{q-1} + \beta_{3,h}\,\mathrm{MPS}_q \times \log\mathrm{Vol}_{q-1} + \varepsilon_{h,q}$$

on 144 quarters, with both investment and the volatility capital-weighted. Panel B of Table 4 reports $\beta_{3,h}$. The interaction is negative throughout the horizon and significant from $h = 1$ onward: -6.93 at impact (t -1.40), -16.43 at $h = 1$, -27.40 at $h = 3$, -46.30 at $h = 6$. Expressed per quarter of accumulation the profile is flat, between -4.7 and -8.2. β_1 is 1.73 at impact with a t of 1.88 and decays into noise by $h = 3$, which is what a cumulative response to a single quarter's surprise should do.

These findings establish two facts. In the cross section, high-volatility firms respond less to monetary policy shocks in equity prices and investment. In the time series, the aggregate stock market and aggregate investment respond less when volatility is elevated. The following section develops a general equilibrium model that produces all three through a single channel: the return-risk trade-off of portfolio choice, operating in a production economy.

3 Model

To explain the negative correlation between volatility and monetary policy effectiveness documented in Section 2, I develop a two-sector New Keynesian model with recursive preferences and heterogeneity in productivity volatility. The model nests the standard three-equation New Keynesian framework but departs in two key ways.

First, I use recursive preferences (Epstein and Zin (1991); Bansal and Yaron (2004)) to account for long-run risk stemming from endogenous economic growth and time-varying endogenous volatility. Recursive preferences are essential for two reasons: they help explain observed asset market features through time-varying risk premia, and they allow the representative agent to price changes in aggregate volatility brought by monetary shocks out of preference for early resolution, thereby generating large stock price responses to measured monetary shocks.

Second, I introduce a two-sector structure for capital accumulation and intermediate goods production. Each sector contains a continuum of firms that are identical except for the volatility of their AR(1) productivity processes. Investors adjust aggregate capital accumulation and reallocate capital across sectors in response to business cycle fluctuations and monetary shocks. This structure generates both cross-sectional heterogeneity in firm-level volatility and time-series variation in aggregate volatility, providing the framework for studying how volatility affects monetary policy effectiveness.

The household. Time is discrete and infinite. The representative household has Epstein-Zin recursive preferences of the form:

$$U_t = \left\{ (1-\beta)\, u(C_t, n_t)^{1-\frac{1}{\psi}} + \beta \left(E_t \left[U_{t+1}^{1-\gamma} \right] \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}}.$$

where C_t denotes consumption and n_t denotes hours worked. This specification separates the coefficient of relative risk aversion γ from the elasticity of intertemporal substitution ψ, unlike standard CRRA preferences where these parameters are inverses of each other.

To ensure a balanced growth path, I adopt the KPR (King et al. (1988)) specification for period utility:

$$U_t = \left\{ (1-\beta) \left[C_t (1 - \theta n_t^{\chi+1}) \right]^{1-1/\psi} + \beta (E_t U_{t+1}^{1-\gamma})^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}}$$

The household's optimization problem yields the stochastic discount factor:

$$\Lambda_{t,t+1} = \beta \left(\frac{U_{t+1}}{E_t [U_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi}-\gamma} \left(\frac{C_{t+1}}{C_t} \right)^{-\frac{1}{\psi}} \left(\frac{1-\theta n_{t+1}^{\chi+1}}{1-\theta n_t^{\chi+1}} \right)^{1-\frac{1}{\psi}}$$

The household budget constraint in real terms is:

$$C_t + \frac{B_t}{P_t} = \frac{W_t}{P_t} n_t + \frac{\int D_{i,t} di}{P_t} + \frac{D_t^M}{P_t} + R_{t-1}^{nom} \frac{B_{t-1}}{P_t}$$

The household receives dividends from two types of firms: $D_{i,t}$ from monopolistically competitive firms producing consumption variety i (which face nominal rigidity), and D_t^M from intermediate goods producers that accumulate capital and hire labor. The household also owns final consumption goods firms, which earn zero profits in equilibrium and thus do not appear in the budget constraint. The household can save via nominal treasury bonds B_t earning gross nominal interest rate R_t^{nom}, and receives nominal wage W_t from intermediate goods sectors.

The firms

Final consumption goods producer. The final good market is perfectly competitive. A representative final goods producer aggregates a continuum of differentiated consumption varieties $i \in [0,1]$ using CES technology with elasticity of substitution ϵ:

$$Y_t = \left\{ \int_0^1 Y_{i,t}^{(\epsilon-1)/\epsilon} di \right\}^{\epsilon/(\epsilon-1)}$$

Cost minimization yields the demand function for each variety i:

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

where $P_{i,t}$ is the nominal price of variety i and P_t is the aggregate price level:

$$P_t = \left(\int_0^1 P_{i,t}^{1-\epsilon} \, di \right)^{\frac{1}{1-\epsilon}}$$

Consumption variety producers. A continuum $[0,1]$ of monopolistically competitive firms each produce a differentiated consumption variety i. Each firm uses intermediate goods $\tilde{Y}_{it}$ as its only input via a linear technology: $Y_{it} = \tilde{Y}_{it}$.

Firms face nominal rigidity in the form of quadratic price adjustment costs à la Rotemberg (1982). When changing prices from $P_{i,t}$ to $P_{i,t+1}$, firm i incurs a real cost of $\frac{\phi}{2}\left(\frac{P_{i,t+1}}{P_{i,t}} - 1\right)^2 Y_{t+1}$. Each firm chooses its price sequence to maximize the present value of real profits:

$$\max_{\{P_{i,t+s}\}_{s=0}^{\infty}} E_t \sum_{s=0}^{\infty} \Lambda_{t,t+s} \left\{ \left(\frac{P_{i,t+s}}{P_{t+s}} - \omega_{t+s} \right) Y_{i,t+s} - \frac{\phi}{2} \left(\frac{P_{i,t+s}}{P_{i,t+s-1}} - 1 \right)^2 Y_{t+s} \right\}$$

where ω_t is the real price of intermediate goods (determined in general equilibrium), and demand for each variety is given by:

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

I impose symmetry across all variety producers, so that in equilibrium $Y_{i,t} = Y_t$ for all i, and the aggregate demand for intermediate goods equals final output:

$$Y_t = \tilde{Y}_t$$

Intermediate goods producers. The intermediate goods sector consists of two heterogeneous sectors, indexed by $j \in \{h, l\}$. Each sector experiences an independent total factor productivity shock following an AR(1) process:

$$A_{j,t+1} = \rho_A A_{j,t} + \nu_{A_{j,t}}, \quad \nu_{A_{j,t}} \sim N(0, \sigma^2_{A,j})$$

The two sectors are identical in all respects except for the volatility of their productivity shocks. Sector h is the high-volatility sector with $\sigma^2_{A,h} > \sigma^2_{A,l}$, where sector l is the low-volatility sector. This volatility heterogeneity is the sole source of cross-sectional differences across sectors.

A representative firm in sector j chooses investment $I_{j,t}$, labor $n_{j,t}$, and capital $K_{j,t+1}$ to maximize the expected present value of dividends:

$$\max_{I_{j,t+s},\, n_{j,t+s},\, K_{j,t+s+1}} E_t \Bigg[\sum_{s=0}^{\infty} \Lambda_{t,t+s} \Big\{ \omega_{t+s} \Big[A_{j,t+s} K^{\alpha}_{j,t+s} \left(n_{j,t+s} K_{t+s} \right)^{1-\alpha} \Big] \\ - w_{t+s} n_{j,t+s} - \Big[I_{j,t+s} + G\left(I_{j,t+s}, K_{j,t+s}\right) \Big] \Big\} \Bigg]$$

subject to the capital accumulation equation:

$$K_{j,t+1} = (1-\delta) K_{j,t} + I_{j,t}$$

where δ is the depreciation rate. The function $G\left(I_{j,t}, K_{j,t}\right) = \frac{\Omega}{2}\left(\frac{I_{j,t}}{K_{j,t}} - \delta\right)^2 K_{j,t}$ represents quadratic capital adjustment costs.

The production function features a positive externality from aggregate capital $K_t = K_{h,t} + K_{l,t}$, which generates endogenous long-run growth. Firms sell their output to variety producers at the real price ω_t and hire labor at the real wage w_t, both determined in general equilibrium. Unlike capital, which is sector-specific, labor is perfectly mobile across sectors.

The firm's problem can be written recursively. The state variables are the productivities of both sectors, the capital stocks of both sectors, and the monetary policy shock (introduced below): $Z = \{A_h, A_l, K_h, K_l, e\}$. The value function for a firm in sector j is:

$$
\begin{aligned}
V_j(A_h, A_l, K_h, K_l, e) = \max_{I_j, n_j} \Big\{ &\omega(Z)\big[A_j K_j^{\alpha} (n_j(Z) K)^{1-\alpha}\big] - w(Z)\, n_j(Z) \\
&- I_j - G(I_j, K_j) + E[\Lambda(Z, Z')\, V_j(Z')] \Big\}
\end{aligned}
$$

where $Z' = \{A'_h, A'_l, K'_h, K'_l, e'\}$ denotes next period's state.

Monetary Authority The central bank sets the nominal risk-free interest rate R_t^{nom} according to a Taylor rule:

$$
\log R_t^{nom} = \ln R^* + \kappa_\pi \pi_t + e_t
$$

where κ_π is the policy response coefficient to inflation, R^* is the natural interest rate, and e_t is the monetary policy shock. The shock follows an AR(1) process:

$$
e_{t+1} = \rho_e e_t + \nu_{e,t+1}, \quad \nu_{e,t} \sim N(0, \sigma_e^2)
$$

I normalize the shock so that an increase in e_t represents an expansionary monetary policy shock (a reduction in the interest rate for a given level of inflation).

Market clearing

1. **Labor market.** The household's labor supply equals total labor demand from both intermediate goods sectors:

$$
n_t = \sum_{j=h,l} n_{j,t}
$$

2. **Intermediate goods market.** The supply of intermediate goods from both sectors equals the demand from consumption variety producers:

$$Y_t = \sum_{j=h,l} A_{j,t} K_{j,t}^{\alpha} \left(n_{j,t} K_t\right)^{1-\alpha}$$

3. **Final goods market.** Total consumption, investment, capital adjustment costs, and price adjustment costs sum to total output:

$$C_t + \sum_{j=h,l} \left[I_{j,t} + G\left(I_{j,t}, K_{j,t}\right)\right] + h\left(\pi_t\right) Y_t = Y_t$$

Definition of equilibrium An equilibrium consists of: (i) prices $\{P_t, \omega_t, w_t, R_t^{nom}\}$ for the aggregate price level, intermediate goods, wages, and the nominal interest rate; (ii) the stochastic discount factor $\Lambda_{t,t+1}$; (iii) value functions $V_{j,t}$ for firms in sectors $j \in \{h, l\}$; and (iv) allocations $\{C_t, n_t, I_{j,t}, n_{j,t}, Y_{i,t}\}$ for consumption, labor supply, sectoral investment, sectoral labor demand, and variety output, such that:

1. Given prices, the household optimizes by choosing consumption and labor supply.

2. Given prices, monopolistically competitive variety producers optimize by setting prices.

3. Given prices, intermediate goods firms optimize by choosing investment and labor demand.

4. All markets clear.

5. The nominal interest rate satisfies the Taylor rule.

Recursive Formulation A Markov equilibrium consists of equilibrium prices and quantities as functions of the state variable Z, along with the law of motion for Z, such that households maximize utility, consumption variety producers and intermediate goods firms maximize profits, and all markets clear.

Thanks to the assumption of positive externality from aggregate capital, equilibrium quantities and value functions are homogeneous of degree one in K or K_j ($j \in \{h, l\}$), while equilibrium prices do not depend on K. It is therefore convenient to normalize all quantities and prices by aggregate capital. I define:

$$c(Z) = \frac{C(Z)}{K}, \quad y(Z) = \frac{Y(Z)}{K}, \quad u(Z) = \frac{U(Z)}{K}$$

$$w(Z) = \frac{W(Z)}{K}, \quad i_j(Z) = \frac{I_j(Z)}{K}, \quad v_j(Z) = \frac{V_j(Z)}{K}$$

Rather than tracking both sectoral capital stocks $\{K_h, K_l\}$, I use the high-volatility sector's capital share $k_h = \frac{K_h}{K}$ as a state variable. The complete state vector is $Z = \{A_h, A_l, k_h, e\}$, where A_h and A_l are sectoral productivities and e is the monetary policy shock.

The law of motion for k_h is:

$$\begin{aligned} k_h' &= \frac{K_h'}{K_h' + K_l'} = \frac{\big[(1-\delta) + i_h\big] K_h}{\big[(1-\delta) + k_h i_h + (1-k_h) i_l\big](K_h + K_l)} \\ &= \frac{(1-\delta) + i_h}{(1-\delta) + k_h i_h + (1-k_h) i_l}\, k_h \end{aligned}$$

A recursive Markov equilibrium consists of policy functions for prices $\{\pi(Z), \omega(Z), w(Z), R^{nom}(Z), \Lambda(Z'|Z), v_j(Z)\}$ and quantities $\{i_j(Z), n_j(Z), n(Z), y_i(Z), y(Z), c(Z)\}$, with state variables $Z = \{A_h, A_l, k_h, e\}$, such that:

1. Given $\{c(Z), n(Z)\}$, the stochastic discount factor $\Lambda(Z'|Z)$ satisfies:

$$\begin{aligned} \Lambda(Z'|Z) = \beta &\left(\frac{u(Z')}{E[u(Z')^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi}-\gamma} \left(\frac{1-\theta n(Z')^{\chi+1}}{1-\theta n(Z)^{\chi+1}} \right)^{1-\frac{1}{\psi}} \\ &\times \left((1-\delta) + k_h i_h + (1-k_h) i_l\right)^{-1/\psi} \times \left(\frac{c(Z')}{c(Z)} \right)^{-\frac{1}{\psi}} \end{aligned} \tag{E.1}$$

2. Given $\{\Lambda(Z'|Z), \omega(Z), y(Z)\}$, the inflation rate $\pi(Z)$ satisfies the optimal pricing condition:

$$\begin{aligned} &1 - \epsilon(1-\omega(Z)) - \phi\pi(Z)\big(\pi(Z)-1\big) \\ +E&\Big[\Lambda(Z'|Z)\phi\pi(Z')(\pi(Z')-1)\frac{y(Z')}{y(Z)}\big((1-\delta) + k_h i_h + (1-k_h) i_l\big)\Big] = 0 \end{aligned} \tag{E.2}$$

3. Given $\omega(Z)$, sectoral investment and labor $\{i_j(Z), n_j(Z)\}$ satisfy the Euler equation:

$$\begin{aligned} 1 + G_I(i_j(Z)) = E\Big[&\Lambda(Z'|Z)\big\{\omega(Z')A_j'\alpha(k_j')^{\alpha-1}n_j(Z')^{1-\alpha} - G_K(i_j(Z')) \\ &+ (1-\delta)(1+G_I(i_j(Z')))\big\}\Big] \end{aligned} \tag{E.3}$$

and the labor demand condition:

$$\omega(Z)\big[A_j k_j^\alpha(1-\alpha)n_j(Z)^{-\alpha}\big] = w(Z) \tag{E.4}$$

4. The monetary authority follows the Taylor rule:

$$\log R^{nom}(Z) = \ln R^* + \kappa_\pi \pi(Z) + e \tag{E.5}$$

5. Markets clear. The resource constraint is:

$$\begin{aligned} c(Z) =& \Big[A_h k_h^\alpha n_h(Z)^{1-\alpha} + A_l(1-k_h)^{1-\alpha}n_l(Z)^{1-\alpha}\Big](1-h(\pi(Z))) \\ &- \Big(i_h(Z) + \frac{\Omega}{2}\big(i_h(Z)-\delta\big)^2\Big)k_h - \Big(i_l(Z) + \frac{\Omega}{2}\big(i_l(Z)-\delta\big)^2\Big)(1-k_h) \end{aligned} \tag{E.6}$$

Intermediate goods output is:

$$y(Z) = A_h k_h^\alpha n_h(Z)^{1-\alpha} + A_l(1-k_h)^{1-\alpha}n_l(Z)^{1-\alpha} \tag{E.7}$$

Labor market clearing requires:

$$n_h(Z) + n_l(Z) = n(Z) \tag{E.8}$$

6. The capital share evolves according to:

$$k_h' = \frac{(1-\delta) + i_h(Z)}{(1-\delta) + k_h i_h(Z) + (1-k_h)i_l(Z)}\, k_h \tag{E.9}$$

4 Model solution and policy function analysis

Model solution. I solve for the recursive Markov equilibrium using a policy function iteration algorithm. This global solution method fully characterizes the nonlinear equilibrium dynamics, including the transmission of monetary shocks across the economy. After normalizing all variables by aggregate capital (as described in Section 3), I implement the following iterative procedure.

Starting with initial guesses $\{i_h^0(Z), i_l^0(Z), \omega^0(Z), w^0(Z), u^0(Z), \pi^0(Z)\}$, the algorithm proceeds as follows:

1. **Update utility.** Iterate on the normalized recursive utility function:

$$u = \Bigg\{ (1-\beta)\Big[c(Z)(1-\theta n(Z)^{\chi+1})\Big]^{1-\frac{1}{\psi}} + \beta\big((1-\delta) + k_h i_h + (1-k_h) i_l\big)^{(1-1/\psi)} \Big(E\big[u(Z')^{1-\gamma}\big]\Big)^{\frac{1-1/\psi}{1-\gamma}} \Bigg\}^{\frac{1}{1-1/\psi}}$$

   until convergence. Use the updated $u^1(Z)$ to compute the stochastic discount factor $\Lambda^1(Z'|Z)$ via equation (E.1).

2. **Update investment and capital share.** Given the updated functions $\{\omega(Z), n_j(Z), w(Z)\}$, update sectoral investment $i_j^1(Z)$ for both sectors using the Euler equation (E.3). Update the law of motion for the high-volatility sector's capital share k_h using equation (E.9).

3. **Update inflation.** Given the updated functions $\{i_j^1(Z), \Lambda^1(Z'|Z)\}$, update the inflation function $\pi^1(Z)$ using the pricing equation (E.2).

4. **Update intermediate goods price.** Given the updated investment $i_j^1(Z)$ and inflation $\pi^1(Z)$, compute the intermediate goods price $\omega^1(Z)$ using equation (E.5).

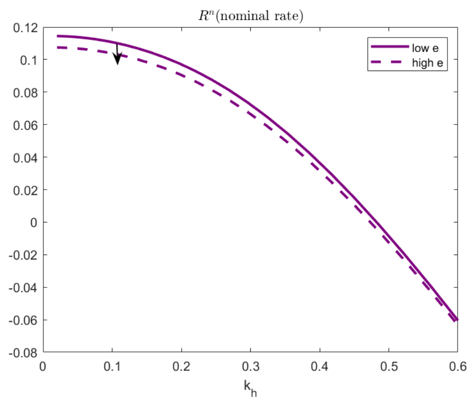
5. **Update wage and labor.** Given consumption $c^1(Z)$ and inflation $\pi^1(Z)$, compute the wage $w^1(Z)$ and labor $n^1(Z)$ using the labor demand condition (E.4) and the household's labor supply condition from the first-order condition.

6. **Iterate to convergence.** Return to step 2 and repeat until the policy functions converge (i.e., the maximum absolute difference between iterations falls below a specified tolerance).

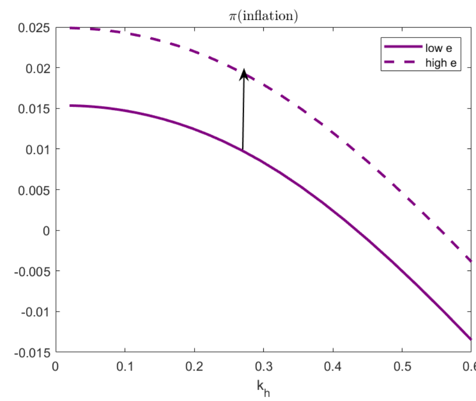
Policy function analysis. To understand the transmission of monetary policy shocks and the resulting heterogeneity in investment and stock price responses across both the cross-sectional and time-series dimensions, we analyze the policy functions while holding sectoral productivity shocks $\{A_{h,t}, A_{l,t}\}$ fixed at their steady-state values $\{A_h^*, A_l^*\}$. We vary the remaining state variables: aggregate volatility (captured by the share of high-volatility sector capital, $k_{h,t}$) and the monetary policy shock e_t. Variation in k_h generates time-series changes in aggregate volatility, while the two-sector structure creates cross-sectional heterogeneity in firm-level volatility. We impose $A_h^* = A_l^*$ so that the two sectors differ solely in productivity volatility, $\sigma_{A,j}$, isolating volatility as the key source of heterogeneity. In all policy function figures that follow, solid lines represent the economy before an expansionary monetary shock, while dashed lines represent the economy after the shock, with the vertical distance between them capturing the magnitude of the response to monetary policy.

Aggregate responses to monetary shocks. We begin by examining how monetary policy shocks transmit through interest rates and inflation. Figure 1 displays the initial transmission mechanism. Following an expansionary monetary shock (e_t rises), the nominal interest rate falls—panel (a) shows the dashed line lying below the solid line. Due to price rigidity, inflation increases as shown in panel (b), but less than proportionally to the nominal rate decline. As a result, the real interest rate falls in panel (c), stimulating real economic activity.In panel (d), the nominal yield curve drops from the solid line to the dashed line after the expansionary shock for maturities under 5 years, consistent with evidence documented in Hanson and Stein (2012). This long-run risk model generates an upward-sloping nominal yield curve because negative productivity shocks raise the marginal cost of consumption goods and hence inflation during bad times. This makes nominal Treasury bonds a poor hedge against adverse aggregate TFP shocks, rendering them risky assets that command higher yields at longer maturities.

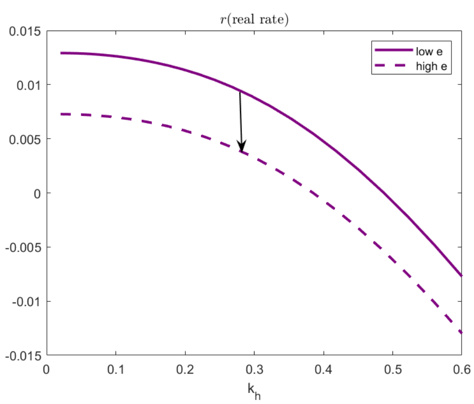
The interaction between the Taylor rule ($\kappa_\pi > 1$) and price rigidity is key to understanding this transmission. In a flexible-price equilibrium, an expansionary monetary shock cannot change the real rate; therefore, to satisfy the Taylor rule, inflation and the nominal rate would rise by the same amount, leaving the real rate unchanged. However, with sticky prices, inflation adjustment is costly. Consequently, the shock is absorbed through two channels: inflation rises partially and the real rate falls partially, with both adjustments working to maintain the Taylor rule balance. This incomplete inflation response allows monetary policy to affect real economic activity.



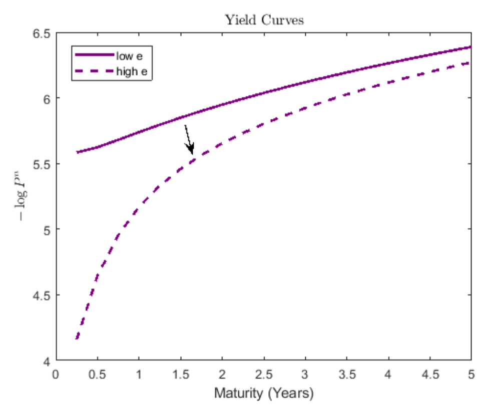
(a) Nominal interest rate



(b) Inflation



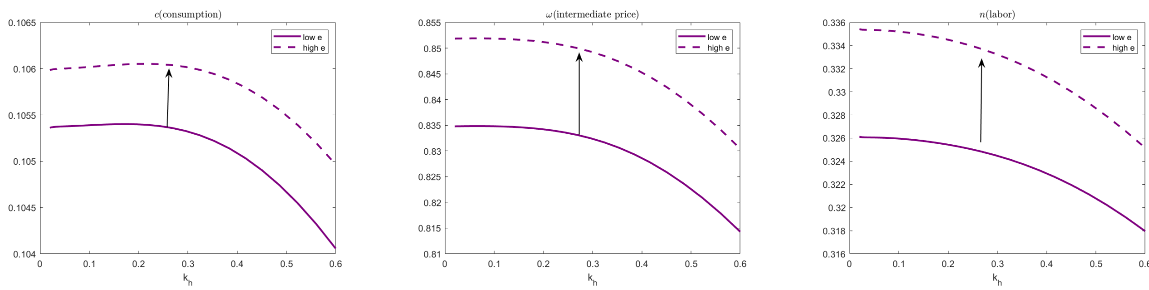
(c) Real interest rate



(d) Yield curves

Figure 1: Monetary policy transmission: Interest rates and inflation. Solid lines represent the economy before an expansionary monetary shock; dashed lines represent the economy after the shock.

Real economic responses. The decline in the real interest rate triggers responses across real economic variables, as shown in Figure 2. Consumption rises in panel (a), as inflation lowers the real price of final consumption goods. The real price of intermediate goods increases in panel (b)—the dashed line sits above the solid line. This price increase reflects a wedge between consumption and intermediate goods markets: consumption-variety firms face price adjustment costs and cannot fully pass through their cost increases, while intermediate-input producers adjust prices freely. With stronger demand and higher prices for their output, intermediate producers expand hiring, as shown by the increase in labor in panel (c). These responses set the stage for the investment and asset price dynamics we examine next.

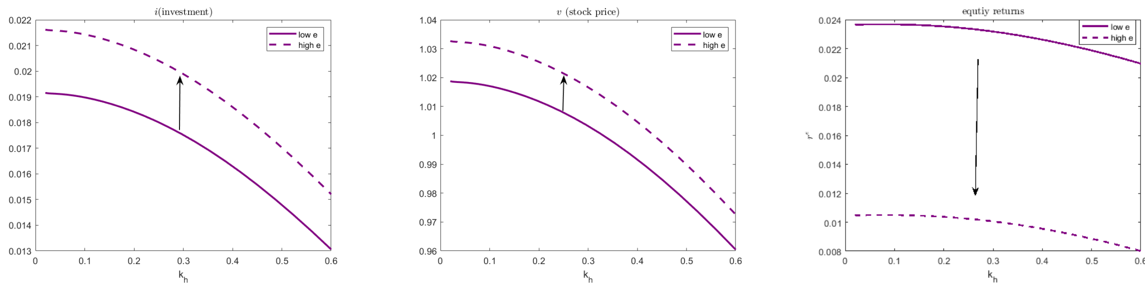


(a) Consumption (b) Intermediate price (c) Labor

Figure 2: Real economic variables response to an expansionary monetary policy shock. Solid lines are the economy before the shock, the "low e" case in the legend; dashed lines are after it, "high e"—recall that an increase in e is expansionary.

Investment and asset pricing responses. With higher intermediate goods prices and stronger demand, firms increase investment, as shown in Figure 3 panel (a)—the dashed line rises well above the solid line. This investment response reflects both improved profitability (higher output prices) and lower discount rates (the real interest rate decline from Figure 1). These same forces drive asset price dynamics. Panels (b) and (c) show that aggregate stock prices rise substantially while the expected equity returns falls following the expansionary shock. Stock prices increase because the present value of future cash flows rises through two channels: higher expected cash flows (from increased output prices and quantities) and lower discount rates, with the expected equity return declining accordingly.

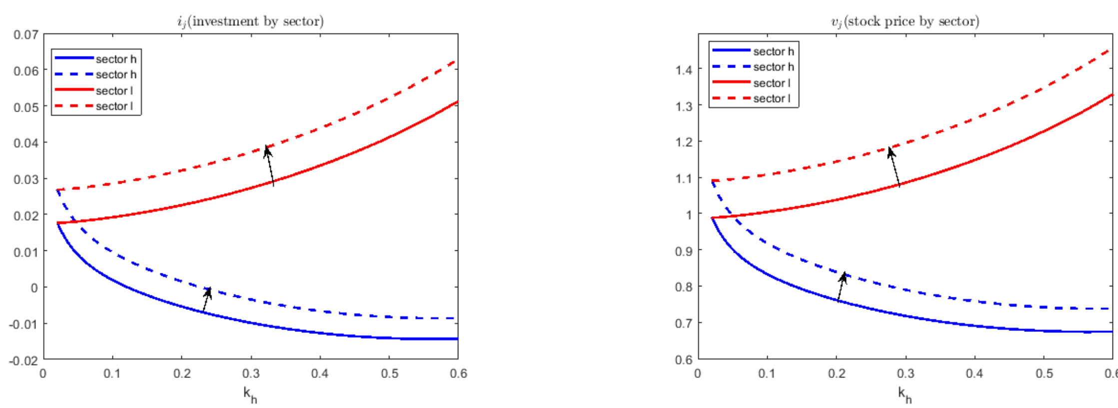
Time-varying monetary policy effectiveness. A key insight emerges from examining how responses vary with aggregate volatility. Returning to Figure 3, observe that the vertical distance between solid and dashed lines—measuring the response to mone-



(a) Aggregate investment (b) Stock price (c) Equity returns

Figure 3: Investment and asset pricing responses to an expansionary monetary policy shock. Solid lines are the economy before the shock, the "low e" case in the legend; dashed lines are after it, "high e"—recall that an increase in e is expansionary.

tary policy—narrows as we move rightward along the horizontal axis (as k_h increases). When aggregate volatility is high (k_h is large, meaning the high-volatility sector comprises a larger share of the economy), both investment and stock prices respond less to monetary policy shocks. This pattern directly matches our empirical findings: monetary policy becomes less effective during high-volatility periods. The mechanism underlying this time-varying effectiveness stems from the cross-sectional heterogeneity we examine next—when high-volatility firms, which are individually less responsive, constitute a larger share of the economy, aggregate responses naturally diminish.



(a) Investment by sector (b) Stock price by sector

Figure 4: Cross-sectional heterogeneity in the response to an expansionary monetary policy shock. Blue lines represent the high-volatility sector; red lines represent the low-volatility sector. Solid lines are the economy before the shock, the "low e" case in the legend; dashed lines are after it, "high e"—recall that an increase in e is expansionary.

Cross-sectional heterogeneity. Figure 4 reveals the differential responses across sectors that underlie the aggregate time-variation documented above. Blue lines represent the high-volatility sector and red lines represent the low-volatility sector. For each sector, the vertical gap between solid and dashed lines measures the response to the expansionary shock. Panel (a) shows that investment in the low-volatility sector (red) increases substantially more than in the high-volatility sector (blue)—the red gap is noticeably larger than the blue gap. Panel (b) displays the same pattern for stock prices: low-volatility firms experience larger price increases than high-volatility firms. These sectoral policy functions confirm that the intuition from Merton's canonical portfolio allocation model—presented in the introduction—holds in a full-fledged general equilibrium model with heterogeneous firms and nominal rigidity. This cross-sectional heterogeneity directly validates our empirical findings and explains the time-varying aggregate effectiveness. When the economy experiences high aggregate volatility, the composition shifts toward high-volatility firms (high k_h). Since these firms respond less to monetary shocks individually, the aggregate economy naturally becomes less responsive. The canonical return-risk trade-off drives this mechanism: for a given change in expected returns from monetary policy, high-volatility firms adjust their investment and valuations less because they must account for higher risk.

5 Quantitative Results

The policy function analysis in Section 4 established that the return-risk trade-off mechanism operates as predicted: high-volatility firms respond less to monetary policy shocks than low-volatility firms, and the aggregate economy becomes less responsive when high-volatility firms constitute a larger share of capital. This section assesses whether this mechanism is quantitatively important by calibrating the model to match key macroeconomic and asset market moments, then testing whether it can replicate the magnitudes of the empirical relationships documented in Section 2.

This quantitative exercise provides a nontrivial test of the model. While the qualitative patterns validate the mechanism's direction, matching the empirical magnitudes requires that the return-risk trade-off be the strong enough force driving heterogeneous responses to monetary policy, rather than other potential channels. Section 5.1 presents the calibration strategy and shows that the model matches standard macro-finance moments. Section 5.2 implements the identical regression specifications from Section 2 on simulated data, demonstrating that the model quantitatively replicates both the cross-sectional and time-series relationships between volatility and monetary policy effectiveness. Finally, Section 5.3 derives and tests a novel prediction: expansionary monetary shocks should endogenously reduce aggregate volatility, a pattern we confirm in the data.

5.1 Calibration

We calibrate the model in two steps to ensure transparency and minimize degrees of freedom. First, we fix a large subset of parameters at standard values from the literature, demonstrating that the model's quantitative success does not rely on parameter choices tailored to our specific empirical targets. Second, we calibrate the remaining parameters—primarily those governing volatility and preferences—to match key macro-finance moments.

Fixed parameters from the literature. Table 5 lists parameters fixed at quarterly frequency based on established studies. We follow Ottonello and Winberry (2020) for capital-related parameters: discount factor $\beta = 0.991$, depreciation rate $\delta = 0.025$, and capital adjustment cost $\Omega = 3.5$. From Kaltenbrunner and Lochstoer (2010), we adopt the elasticity of intertemporal substitution $\psi = 2$, capital share $\alpha = 0.36$, and TFP persistence $\rho_A = 0.94$ for both sectors.

For the New Keynesian block, we follow standard calibrations. The elasticity of substitution among consumption varieties $\epsilon = 5.2$ implies an average markup of 25%, consistent with Ascari and Rossi (2012) and Hazell et al. (2022). The price adjustment cost $\phi = 12.5$ generates a realistically flat Phillips curve, with firms reoptimizing prices approximately every 8 months on average. Following Gali(2008), the Taylor rule coefficient $\kappa_\pi = 1.5$ and the monetary shock persistence $\rho_e = 0.29$. The labor parameters—disutility $\theta = 0.7$ and inverse Frisch elasticity $\chi = 0.1$—are set to deliver a consumption-output ratio of 0.73 and ensure sufficiently elastic labor supply to avoid counterfactual increases in endogenous real interest rates following expansionary shocks.

Jointly calibrated parameters. The remaining parameters—risk aversion γ, sectoral TFP volatilities $\sigma_{A,h}$ and $\sigma_{A,l}$, and mean productivity levels μ_1 and μ_2—are chosen jointly to match *macroeconomic moments only*: consumption, output, and investment growth rates and volatilities, as well as inflation dynamics. Critically, we do not target any asset pricing moments. The mean productivity levels are set to ensure realistic consumption growth rates and to guarantee that the representative agent invests a non-trivial share of capital in the high-volatility sector in the stationary steady state. The risk aversion $\gamma = 27.5$ is higher than conventional choices in production-based asset pricing models (typically 10-20). This higher value is necessary because we allow the representative agent to invest in a sector with very low productivity volatility (0.5% vs. 4.1% in Kaltenbrunner and Lochstoer (2010)). Without sufficiently high risk aversion, the agent would allocate nearly all capital to the high-volatility sector, resulting in a degenerate allocation. This calibration ensures a meaningful capital allocation across both sectors while maintaining realistic macroeconomic dynamics.

Model fit. Table 6 compares simulated moments from the model with their empirical counterparts. The model successfully matches the targeted macroeconomic moments. Average consumption, output and investment growth rates closely align with the data. The standard deviations of consumption, output, and investment growth are realistic, with the correct ordering: consumption growth volatility is smaller than output growth volatility, which in turn is smaller than investment growth volatility, as observed in the data. The mean and standard deviation of inflation, as well as the mean and volatility of the risk-free real rate, are all reasonable.

Importantly, the model generates a sizable equity premium of 3.6%, against an empirical value of 7.6%. The model does understate equity return volatility (4.1% vs. 14.5% in the data), a well-known limitation of production-based asset pricing models. This tradeoff arises because generating realistic investment volatility requires moderate capital adjustment costs. Lower adjustment costs allow investment to respond strongly to shocks, matching the high volatility observed in aggregate investment data. However, these same moderate adjustment costs dampen the volatility of capital prices and hence equity returns.

5.2 Simulated Regressions

Having established that the model matches key macro-finance moments, we now assess whether it can quantitatively replicate the documented negative correlation between monetary policy effectiveness and volatility. We implement the identical regression specifications from Section 2 on simulated data, allowing for a direct comparison of coefficients.

Volatility measurement in simulated data. In the simulated regressions, we measure firm-level and aggregate volatility using the conditional expected return vari-

Table 5: Baseline Parameters (Quarterly)

Category / Parameter	Symbol	Value
Preference parameters		
Discount factor	β	0.991
Risk aversion	γ	27.5
Intertemporal elasticity of substitution	ψ	2.0
Labor disutility	θ	0.7
Inverse Frisch elasticity	χ	0.1
Natural interest rate	R^*	0.2%
Production/friction parameters		
Capital share	α	0.36
Depreciation rate of physical capital	δ	0.025
Adjustment cost of capital	Ω	3.5
Adjustment cost of price	ϕ	12.5
Elasticity of substitution of intermediate goods	ε	5.2
TFP and monetary shock parameters		
Persistence of TFP	ρ_A	0.94
Persistence of monetary shocks	ρ_e	0.29
Policy coefficient (Taylor π)	κ_π	1.50
Std. of monetary shocks	σ_e	0.5%
Std. of high-vol TFP shocks	$\sigma_{A,h}$	7.7%
Std. of low-vol TFP shocks	$\sigma_{A,l}$	0.5%
Expected TFP of sector 1	μ_1	0.21
Expected TFP of sector 2	μ_2	0.158

Table 6: Data and Simulated Moments

Moments	Description	Model	Data
Macroeconomy			
$E[\Delta \ln C]$	Mean consumption growth	2.14%	2.83%
$E[\Delta \ln Y]$	Mean output growth	2.14%	3.14%
$E[\Delta \ln I]$	Mean investment growth	2.60%	3.88%
$E[C/Y]$	Mean cons.-output ratio	0.69	0.85
$E[\pi]$	Mean inflation rate	1.51%	3.44%
$\sigma(\Delta \ln C)$	Std of consumption growth	3.31%	2.26%
$\sigma(\Delta \ln Y)$	Std of output growth	6.12%	4.66%
$\sigma(\Delta \ln I)$	Std of investment growth	15.91%	11.39%
$\sigma(\pi)$	Std of inflation	3.85%	2.67%
$\sigma(\Delta R^{nom})$	Std of monetary policy shocks	0.06%	0.07%
Asset Prices			
$E[r_f]$	Mean risk-free rate	0.08%	0.52%
$\sigma[r_f]$	Std of risk-free rate	2.90%	2.09%
$E[r_{ex}]$	Mean equity premium	3.61%	7.62%
$\sigma[r_{ex}]$	Std of equity premium	4.14%	14.51%

Notes: Model and data moments are constructed identically. The model is solved and simulated at a quarterly frequency; the simulated series are then aggregated to annual observations. Simulated moments use $T = 200{,}000$ quarters after a 2,000-quarter burn-in. The data moments are computed on annual U.S. series over 1929–2023. Growth rates, inflation, the risk-free rate and the equity premium are in percent; the consumption-output ratio is a ratio.

ance at time t, computed as:

$$E_t\left(\mathrm{Var}(R_{t+1})\right) = E_t R_{t+1}^2 - E_t^2 R_{t+1}$$

where R_t equals the sectoral return $R_{j,t} = \frac{V_{j,t+1}}{V_{j,t}-D_{j,t}}$ for cross-sectional regressions, and the aggregate market return $R_{M,t} = \frac{V_{h,t+1}+V_{l,t+1}}{V_{h,t}+V_{l,t}-D_{h,t}-D_{l,t}}$ for time-series regressions. This measure is more appropriate than realized volatility for our quarterly model, as realized volatility computed from a single quarter's returns would introduce substantial noise.

Cross-sectional regressions. For simulated firm data on stock prices and investment, we regress them on the monetary policy shocks measured from nominal interest rate shocks each period t, and include the interaction term between the firm return volatility and the monetary shocks in the regression as well.

$$R_{i,\text{fomc}} = \beta_0 + \beta_1 MPS_{\text{fomc}} + \beta_2 Vol_{i,-90,-1} + \beta_3 MPS_{\text{fomc}} \times Vol_{i,-90,-1} + \epsilon_{i,\text{fomc}}$$

$$\frac{I_{i,q}}{K_{i,q-1}} = \beta_0 + \beta_1 MPS_q + \beta_2 Vol_{i,q-1} + \beta_3 MPS_q \times Vol_{i,q-1} + \epsilon_{i,q}$$

The regression results based on simulated data from the model at firm level are listed next to their empirical counterparts in Table 7.

Table 7 compares the model's predictions with the data. Following a 1% expansionary monetary shock, stock prices in the model rise by 10.74% on average. For a firm with ten percentage points more return volatility, the increase is smaller at 9.66%, so β_3 dampens the response by 1.08 percentage points per ten percentage points of volatility. Similarly, investment rises by 1.91% on average and by 1.66% for a firm with ten percentage points more volatility. These magnitudes are quantitatively close to the empirical estimates, on the same perturbation: in the data the average firm's announcement-day return rises by 4.70% and a firm with ten percentage points more volatility gains 0.77 percentage points less. The model captures both the average responsiveness to monetary policy (β_1) and the moderating role of volatility (β_3) documented in Section 2.

The model slightly understates the moderating effect of volatility on investment responses, particularly for the interaction term. This likely reflects the two-sector structure: when interest rates fall, agents wish to allocate more capital to the low-volatility

Table 7: Data and Model Comparison: XS Heterogeneity of Responses to MPS

	Data		Model	
	β_1 (MPS)	β_3 (MPS×Vol)	β_1 (MPS)	β_3 (MPS×Vol)
$R_{i,\text{fomc}}$	4.70	−7.74	10.74	−10.80
$I_{i,q}/K_{i,q-1}$	0.54	−3.35	1.91	−2.52
control variables	yes		yes	
fixed effect	yes		yes	

Notes: This table compares the estimated response of firm stock returns and firm investment to a monetary policy surprise, and the interaction of that surprise with firm volatility, in the data and in model-simulated data. Both data columns are column (1), the baseline, of their own table: the one-day announcement return of Table 2 and the investment rate of Table 3. Both are signed as the response to a one percentage point easing and multiplied by 100, on the same convention as the model column, and volatility is annualized in both, so the two columns are on the same footing and the coefficients may be read against each other directly. β_1 is the response of the average firm; β_3 is the additional response per unit of annualized volatility, so a negative β_3 means high-volatility firms respond less. Both data and model regressions include control variables and firm fixed effects.

sector, but in a two-sector economy they quickly reach the point where further concentration becomes too risky from a portfolio perspective. This general equilibrium constraint binds more tightly than it would in an economy with many sectors spanning a continuum of volatilities. Consequently, the differential response between high- and low-volatility sectors is somewhat compressed, leading to a smaller interaction coefficient than in the data. Overall, the model successfully replicates the key qualitative and quantitative patterns.

Time-series regressions. We next examine aggregate responses and their time-variation with market volatility. For simulated time-series data on aggregate stock prices and investment, we implement the identical specifications from Section 2, including the interaction between aggregate market volatility and monetary policy shocks:

$$R_{\text{fomc}} = \beta_0 + \beta_1 MPS_{\text{fomc}} + \beta_2 Vol_{fomc-1} + \beta_3 MPS_{\text{fomc}} \times Vol_{fomc-1} + \epsilon_{fomc}$$

$$I_q/K_{q-1} = \beta_0 + \beta_1 MPS_q + \beta_2 Vol_{q-1} + \beta_3 MPS_q \times Vol_{q-1} + \epsilon_q$$

where Vol_{t-1} now denotes aggregate market volatility (the conditional expected return variance of the market portfolio).

Table 8 presents the regression results from simulated data alongside their empirical counterparts from Section 2.

Table 8: Data and Model Comparison: Time-Series Heterogeneity of Responses to MPS

	Data		Model	
	β_1 (MPS)	β_3 (MPS×Vol)	β_1 (MPS)	β_3 (MPS×Vol)
$R_{s,fomc}$	5.91	−12.38	10.92	−5.69
I_q/K_{q-1}	1.73	−6.93	2.64	−1.37

Notes: This table compares the estimated aggregate response to a monetary policy surprise, and its interaction with aggregate volatility, in the data and in model-simulated data. The data column is estimated on 268 scheduled FOMC meetings and 144 quarters. For the market return the dependent variable is $R_{s,fomc}$, the value-weighted market return on the announcement day; for investment it is the impact ($h = 0$) cumulative change in log aggregate investment from the local projections of Panel B of Table 4. Coefficients are signed as the response to a one percentage point easing and multiplied by 100.

Table 8 compares the model's time-series results with those from the data. Following a 1% expansionary monetary shock, the aggregate stock market rises by 10.92%. When the logged aggregate market volatility from the simulated data is one standard deviation (0.2) higher, the market response is smaller at 9.78%, demonstrating that monetary policy becomes less effective during high-volatility periods. Similarly, aggregate investment rises by 2.64% on average, but only 2.36% when market volatility is one standard deviation higher. As with the cross-sectional results, the model successfully replicates the empirical time-series patterns: both the average aggregate responsiveness (β_1) and the time-varying effectiveness through volatility (β_3) are close to their counterparts in the data.

5.3 Testable Implications from the Model

Having demonstrated that the model quantitatively replicates the documented relationships between volatility and monetary policy effectiveness, we now derive and test two predictions. First, the policy function of the model implies that just like investment and stock prices, the labor input of firms with high volatility responds less to monetary shocks. Second, the heterogeneous responses of firms imply that expansionary monetary shocks should endogenously reduce aggregate volatility, while contractionary shocks should increase it. The mechanism operates through compositional shifts: when an expansionary shock occurs, investment rises in both sectors, but the low-volatility sector experiences a larger increase (as documented in both the data and the model). Consequently, the low-volatility sector's capital share increases, mechanically reducing aggregate volatility. Conversely, contractionary shocks cause the high-volatility sector to shrink less than the low-volatility sector, raising aggregate volatility.

5.3.1 Employment Responses

Figure 5 illustrates the heterogeneous response of labor to monetary shocks. As above, blue lines represent the high-volatility sector and red lines represent the low-volatility sector. For each sector, the vertical gap between solid and dashed lines measures the response to the expansionary shock. The plot shows that labor in the low-volatility sector (red) increases substantially more than in the high-volatility sector (blue)—the red gap is noticeably larger than the blue gap.

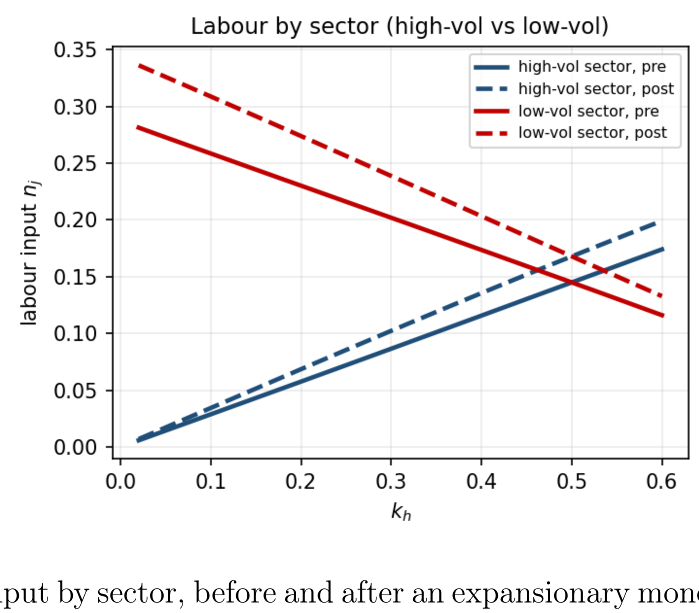


Figure 5: Labor input by sector, before and after an expansionary monetary policy shock. Blue lines represent the high-volatility sector; red lines represent the low-volatility sector. Solid lines are the economy before the shock, the "low e" case; dashed lines are after it, "high e". The horizontal axis is k_h, the share of aggregate capital held in the high-volatility sector.

Employment is reported only annually, so the regression runs at that frequency: the surprise is the sum of the quarterly surprises falling within each firm's own fiscal year, and firms are matched to it on the calendar quarter of their fiscal year end. The cost is that roughly three dozen fiscal years of independent surprise draws stand against 144 quarters on the investment part.

We report the response by volatility group rather than through a single interaction. Firms are sorted into five groups on lagged volatility, *ranked within each fiscal year* so that the group label is not partly a year label, and all five groups enter one regression with the least volatile as the base, so the top-minus-bottom difference is read directly off the top group's interaction with its own standard error. Table 9 reports that difference, at impact and cumulated over the following three years, with firm and year effects on 41,804 firm-years at impact.

The top-minus-bottom difference is -10.40 with a firm-clustered t of -4.10 and a two-way t of -3.10: after a one percentage point easing, employment growth at the most volatile fifth of firms rises 10.4 percentage points less than at the least volatile fifth. Replacing the year effects with industry effects and macroeconomic controls—a completely different design—gives -10.54. The difference is very robust over the following two years.

5.3.2 Monetary Policy and Aggregate Volatility

The compositional channel we have been discussing makes a further prediction that can be tested on data: if an easing shifts capital toward the low-volatility sector, it should lower aggregate volatility. Figure 6 illustrates this mechanism using the model's policy functions. Panel (a) shows that following an expansionary shock, investment rises in both sectors (the gap between dashed and solid lines), with the low-volatility sector (red) experiencing a larger increase than the high-volatility sector (blue). Panel (b) displays the consequence: the conditional volatility of the entire economy declines as the low-volatility sector grows to comprise a larger share of aggregate capital.

This prediction is borne out by the data. Table 10 reports the response of log aggregate volatility to the quarterly surprise.

From $h = 1$ onward the response is negative, significant and growing in magnitude: -46.28 (t -2.81) at one quarter, -47.30 at four quarters, and -81.90 (t -2.75) at eight. The equal-weighted measure gives the same profile with smaller magnitudes. An easing

Table 9: Employment Response to Monetary Policy Shocks: High- minus Low-Volatility Firms

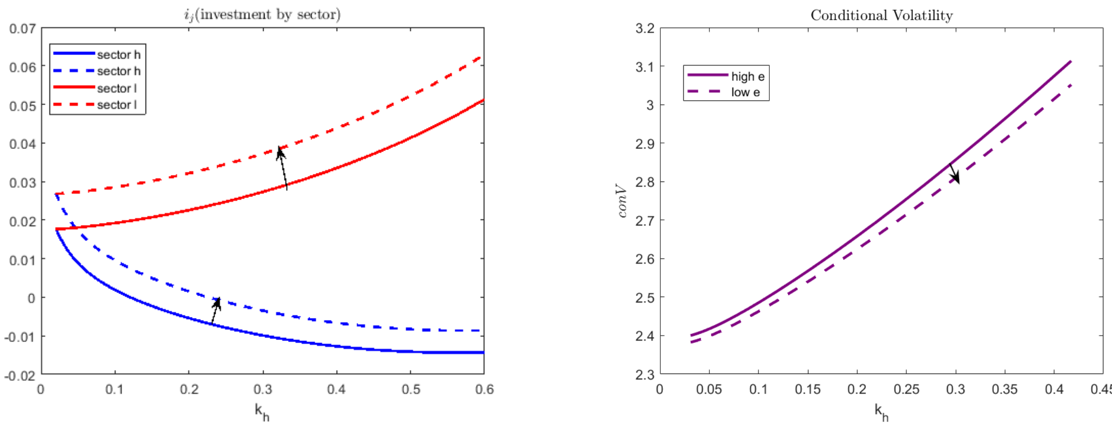
Horizon h (fiscal years)	0	1	2	3
Group 5 − group 1	−10.40	−10.48	−10.69	−8.76
(firm)	(−4.10)	(−2.61)	(−2.12)	(−1.48)
[two-way]	[−3.10]	[−1.63]	[−1.19]	[−0.89]
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm-years	41,804	34,061	28,093	23,265
Fiscal years	33	32	31	30

Notes: This table reports the difference between the employment response of the most volatile and the least volatile fifth of firms, at the year of the surprise and cumulated over the following three years. The sample is an annual panel of U.S. non-financial, non-utility Compustat firms, 41,804 firm-years over 33 years at $h = 0$; the sample shrinks with the horizon because a longer horizon requires more years of data per firm. The dependent variable at horizon h is the growth rate of the reported number of employees cumulated from the firm's fiscal year to h years later. The surprise is the sum of the quarterly high-frequency surprises falling within that firm's own fiscal year, in percentage points; firms are matched to it on the calendar quarter of their fiscal year end. Firms are sorted into five groups on annualized asset volatility at the end of the prior fiscal year, ranked within each fiscal year, and all five groups enter a single regression with group 1 as the omitted base, so the entry reported here is group 5's own coefficient read directly with its own standard error. Mean annualized asset volatility is 0.10 in group 1 and 0.57 in group 5, and is stated because a difference between the top and bottom groups is a difference across the volatility distribution these groups span. Coefficients are signed as the response to a one percentage point easing and multiplied by 100, so a negative entry means the most volatile firms respond less. Figures in parentheses are t-statistics computed from standard errors clustered on firm; figures in brackets are t-statistics computed from standard errors clustered two-way on firm and fiscal year.

Table 10: Response of Aggregate Volatility to Monetary Policy Shocks

Horizon h (quarters)	0	1	2	4	6	8
Value-weighted	−9.45	−46.28	−47.41	−47.30	−66.64	−81.90
	(−0.61)	(−2.81)	(−1.95)	(−1.65)	(−2.15)	(−2.75)
Equal-weighted	3.55	−27.35	−20.19	−28.12	−44.99	−51.55
	(0.24)	(−2.14)	(−1.17)	(−1.49)	(−2.55)	(−2.74)

Notes: This table reports the response of aggregate volatility to a monetary policy surprise, estimated on 144 quarters on the same aggregate series used throughout Section 2.3: aggregate volatility is a cross-sectional mean of firm asset volatility, value-weighted in the first row and equally weighted in the second. The dependent variable at horizon h is $\log \mathrm{Vol}_{q+h} - \log \mathrm{Vol}_{q-1}$, so the entries are changes in log points $\times 100$. Coefficients are signed as the response to a one percentage point easing, so a negative entry means that an easing reduces aggregate volatility. Figures in parentheses are t-statistics computed from Newey-West standard errors with $h + 1$ lags.



(a) Investment by sector

(b) Conditional volatility

Figure 6: Mechanism: an expansionary shock increases low-volatility sector investment more (panel a), reducing aggregate volatility (panel b). Solid lines are the economy before the shock, the "low e" case in the legend; dashed lines are after it, "high e"—recall that an increase in e is expansionary.

therefore reallocates resources toward the low-volatility sector, and aggregate volatility falls persistently over long horizons.

6 Conclusion

This paper documents that strength of the transmission of monetary shocks is negatively correlated with volatility, both across firms and over time. Firms with higher return volatility exhibit weaker responses to monetary policy shocks in both equity prices and investment. Similarly, the aggregate stock market and investment respond less to monetary policy when aggregate volatility is elevated. To explain these patterns, I develop a general equilibrium two-sector New Keynesian model with endogenous growth and heterogeneity in productivity volatility. The model quantitatively replicates both the cross-sectional and time-series negative relationships between volatility and monetary policy effectiveness.

The mechanism underlying these results is the canonical return–risk trade-off from portfolio choice theory. When monetary policy reduces interest rates, returns on all firms rise. However, investors respond less to these return increases for high-volatility firms because they must account for higher risk. This mechanism operates both in the cross-section—high-volatility firms respond less than low-volatility firms—and in the time series—the aggregate economy responds less when high-volatility firms constitute a larger share of capital. Importantly, this mechanism generates significant asset price responses to monetary shocks on average by moving the risk premium, helping explain why small monetary shocks produce large effects on stock prices.

This model has both positive and normative implications that merit further investigation. On the positive side, an econometrician who observes only inflation and the nominal interest rate in this economy could incorrectly infer that the Taylor-rule coefficient κ_π is time-varying if aggregate volatility is omitted. In particular, standard estimators would suggest that the central bank's response coefficient is negatively correlated with volatility even though the structural policy rule is constant in the model. Consistent with this mechanism, we also find that our aggregate volatility measure is negatively associated with time-series estimates of the policy coefficient based on survey data (Bauer et al. (2024)) . On the normative side, monetary authorities should consider volatility conditions when calibrating counterfactual spolicy responses, because the same shock can different effects across volatility states. In practice, implementing a Taylor rule with volatility-dependent coefficients can be welfare-improving.

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A Model Appendix

A.1 Model Derivation

Normalization Let's first consider the recursive formulation of the firm's problem. Let z denote the state variable of the Markov equilibrium. We conjecture that $z = (A_1, A_2, k, e)$, where $k = \frac{K_1}{K_1+K_2}$ is the capital ratio of firm 1. The firm 1 problem is [7]

$$V(A_1, A_2, K_1, K_2, e) = \max \Big\{ \omega(z) \left[A_1 K_1^{\alpha} (n_1(z)K)^{1-\alpha} \right] - I_1 - G(I_1, K_1) - W(z)n_1(z) + E\left[\Lambda V\left(A_1', A_2', K_1', K_2', e\right)\right] \Big\}$$

The Envelope theorem is

$$V_{K_1}(A_1, A_2, K_1, K_2, e) = \omega(z) A_1 \alpha K_1^{\alpha-1} (n_1(z)K)^{1-\alpha} - G_K(I_1, K_1) + (1-\delta) E\left[\Lambda V_{K_1}(A_1', A_2', K_1', K_2', e)\right]$$
$$= \omega(z) A_1 \alpha K_1^{\alpha-1} (n_1(z)K)^{1-\alpha} - G_K(I_1, K_1) + (1-\delta)(1 + G_{I_1}(I_1, K_1))$$

The FOC wrt I_1 is

$$1 + G_{I_1}(I_1, K_1) = E\left[\Lambda V_{K_1}(A_1', A_2', K_1', K_2', e)\right]$$

The FOC wrt N_1 is

$$\omega(z) \left[A_1 K_1^{\alpha} (1-\alpha) n_1(z)^{-\alpha} K^{1-\alpha} \right] = W(z)$$

Aanlogous Focs and Envelope theorem condtions hold, for firm 2.

We conjecture that $V(A_1, A_2, K_1, K_2, e) = v\left(A_1, A_2, \frac{K_1}{K_1+K_2}, e\right)(K_1 + K_2)$. In addition, we denote $i_1 = \frac{I_1}{K_1}$ and $i_2 = \frac{I_2}{K_2}$. We note that both $\bar{H}_K(I_1, K_1)$ and $\bar{H}_K(I_1, K_1)$ are functions of $\frac{I_1}{K_1}$.

[7] Note that $G(I_1, K_1) = \frac{\Omega}{2}\left(\frac{I_1}{K_1} - \delta_1\right)^2 K_1$

The above is written as:

$$v_k(A_1,A_2,k,e)(1-k)+v(A_1,A_2,k,e)=\omega(z)A_1\alpha k_1^{\alpha-1}n_1(z)^{1-\alpha}-G_K(i_1)+(1-\delta)(1+G_I(i_1)).$$

The analogy for firm 2 is

$$v(A_1,A_2,k,e)-v_k(A_1,A_2,k,e)k=\omega(z)A_2\alpha k_2^{\alpha-1}n_2^{1-\alpha}(z)-G_K(i_2)+(1-\delta)(1+G_I(i_2)).$$

That is, the optimal policy must satisfy:, for $j=1,2$,

$$1+G_I(i_j)=E\left[\Lambda\left\{\omega(z)A_j'\alpha(k_j')^{\alpha-1}n_1(z')^{1-\alpha}-G_K\left(i_j'\right)+(1-\delta)\left(1+G_I\left(i_j'\right)\right)\right\}\right].$$

And the FOC of N_i is

$$\omega(z)\left[A_jk_j^{\alpha}(1-\alpha)n_j(z)^{-\alpha}\right]=\frac{W(z)}{K}=w(z)$$

$$n_j=\left(\frac{\omega(z)}{w(z)}A_jk_j^{\alpha}(1-\alpha)\right)^{\frac{1}{\alpha}}$$

The law of motion of K becomes

$$\frac{K_1'+K_2'}{K_1+K_2}=(1-\delta)+\frac{I_1+I_2}{K_1+K_2}=(1-\delta)+ki_1+(1-k)i_2.$$

The law of motion of k is

$$k'=\frac{K_1'}{K_1'+K_2'}=\frac{[(1-\delta)+i_1]K_1}{[(1-\delta)+ki_1+(1-k)i_2](K_1+K_2)}=\frac{(1-\delta)+i_1}{(1-\delta)+ki_1+(1-k)i_2}k. \tag{1}$$

The resource constraint is:

$$C+I_1+G(I_1,K_1)+I_2+G(I_2,K_2)+h(\pi)\left[A_1K_1^{\alpha}N_1(z)^{1-\alpha}+A_2K_2^{\alpha}N_2(z)^{1-\alpha}\right]$$
$$=\left[A_1K_1^{\alpha}(n_1(z)K)^{1-\alpha}+A_2K_2^{\alpha}(n_2(z)K)^{1-\alpha}\right].$$

Let $C=cK$, we have:

$$c(z)=\left[A_1k^{\alpha}n_1(z)^{1-\alpha}+A_2(1-k)^{1-\alpha}n_2(z)^{1-\alpha}\right](1-h(\pi))-(i_1+\frac{\Omega}{2}(i_1-i^*)^2)k-(i_2+\frac{\Omega}{2}(i_2-i^*)^2)(1-k).$$

And the labor constraint will be

$$n_1(z) + n_2(z) = n(z)$$

For the household problem,

$$U_t = \left\{(1-\beta)\left[C_t(1-\theta n_t^{\chi+1})\right]^{1-1/\psi} + \beta(E_t U_{t+1}^{1-\gamma})^{\frac{1-1/\psi}{1-\gamma}}\right\}^{\frac{1}{1-1/\psi}}$$

Write $U = Ku$, then

$$Ku = \left\{(1-\beta)\left((c(z)K)(1-\theta n(z)^{\chi+1})\right)^{1-\frac{1}{\psi}} + \beta\left(E\left[(K'u')^{1-\gamma}\right]\right)^{\frac{1-1/\psi}{1-\gamma}}\right\}^{\frac{1}{1-1/\psi}}$$

$$u = \left\{(1-\beta)\left((c(z))(1-\theta n(z)^{\chi+1})\right)^{1-\frac{1}{\psi}} + \beta\left(E\left[((\frac{K'}{K})u')^{1-\gamma}\right]\right)^{\frac{1-1/\psi}{1-\gamma}}\right\}^{\frac{1}{1-1/\psi}}$$

Because we know K' at time t, the above can be written as

$$u = \left\{(1-\beta)\left((c(z))(1-\theta n(z)^{\chi+1})\right)^{1-\frac{1}{\psi}} + \beta(\frac{K'}{K})^{(1-1/\psi)}\left(E\left[(u')^{1-\gamma}\right]\right)^{\frac{1-1/\psi}{1-\gamma}}\right\}^{\frac{1}{1-1/\psi}}$$

$$u = \left\{(1-\beta)\left((c(z))(1-\theta n(z)^{\chi+1})\right)^{1-\frac{1}{\psi}} + \beta((1-\delta) + ki_1 + (1-k)\, i_2)^{(1-1/\psi)}\left(E\left[(u')^{1-\gamma}\right]\right)^{\frac{1-1/\psi}{1-\gamma}}\right\}^{\frac{1}{1-1/\psi}}$$

And the pricing kernel:

$$\Lambda_{t,t+1} = \beta\left(\frac{U_{t+1}}{E_t[U_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma}\left(\frac{C_{t+1}}{C_t}\right)^{-\frac{1}{\psi}}\left(\frac{1-\theta n_{t+1}^{\chi}}{1-\theta n_t^{\chi}}\right)^{1-\frac{1}{\psi}}$$

Write $U = Ku$, and $C = Kc$,

$$\Lambda_{t,t+1} = \beta \left(\frac{u_{t+1}}{E_t[u_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi}-\gamma} \left(\frac{c_{t+1}K_{t+1}}{c_t K_t} \right)^{-\frac{1}{\psi}} \left(\frac{1-\theta n_{t+1}^{\chi}}{1-\theta n_t^{\chi}} \right)^{1-\frac{1}{\psi}}$$

Simplify and we get

$$\Lambda_{t,t+1} = \beta \left(\frac{u_{t+1}}{E_t[u_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi}-\gamma} \left(\frac{1-\theta n_{t+1}^{\chi+1}}{1-\theta n_t^{\chi+1}} \right)^{1-\frac{1}{\psi}} ((1-\delta)+ki_1+(1-k)\, i_2)^{(-1/\psi)} \left(\frac{c_{t+1}}{c_t} \right)^{-\frac{1}{\psi}}$$

And the optimal choice for labor is

$$W_t U_c = -U_n$$

or

$$W_t(1-\theta n_t^{\chi+1}) = C_t \theta \left(\chi+1\right) n_t^{\chi}$$

Note that $W_t = w_t K_t$ and $C_t = c_t K_t$

$$w_t(1-\theta n_t^{\chi+1}) = c_t \theta \left(\chi+1\right) n_t^{\chi}$$

Policy function variables Aside from the variables that explicitly constitute the Markov equilibrium, we also need to compute asset pricing variables like real interest rate, stock returns and the yield curve.

Term structure of the nominal yields $n-$period bond:

$$P_t^n = E_t[M_{t+1} P_{t+1}^{n-1}]$$

where t denote time-t, and n denotes the maturing in n periods

Now that we already have one-period nominal rate policy rate function, and we can start from there to get two, there, four period and so on so forth.

$$P_t^2 = E_t[M_{t+1} P_{t+1}^1] = E_t[M_{t+1} \frac{1}{R_{t+1}^1}] = E_t[\frac{M_{t+1}}{R_{t+1}^1}]$$

Remember that nominal rate of one quarter is of the following expression

$$R_{f,t} = \frac{1}{E(\Lambda\left(z'|\, z\right)/\pi_{t+1})} = R^{*}\pi_t^{\kappa_\pi}\exp(e_t)$$

$$P_t^2(z) = E_t[\frac{M_{t+1}\left(z'|z\right)}{R_{t+1}^1(z'|z)}] = E_t[\frac{\Lambda\left(z'|\, z\right)/\pi_{t+1}}{E_{t+1}(\Lambda\left(z''|\, z'\right)/\pi_{t+2})}]$$

but we don't exactly need to use the last part of the above expression, we have the policy function for the numerator.

My question, I cannot apply law of iterated expectation for the last part of the two-period nominal yield expression, right?

$$\begin{aligned} P_t^2(z) = E_t\left[\frac{M_{t+1}\left(z'|z\right)}{R_{t+1}^1(z'|z)}\right] \\ = E_t\left[\frac{\beta\left(\frac{u(z')}{E_t[u(z')^{1-\gamma}]^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma}\left(\frac{1-\theta n(z')^{\chi+1}}{1-\theta n(z)^{\chi+1}}\right)^{1-\frac{1}{\psi}}}{R_{t+1}^1(z'|z)}\right. \\ \left. \times\frac{\left((1-\delta)+ki_1+(1-k)\,i_2\right)^{-\frac{1}{\psi}}\left(\frac{c(z')}{c(z)}\right)^{-\frac{1}{\psi}}}{\pi(z')}\right] \end{aligned}$$

$$= \frac{\beta\left((1-\delta)+ki_1+(1-k)\,i_2\right)^{-\frac{1}{\psi}}E_t\left[\left(u(z')\right)^{\frac{1}{\psi}-\gamma}\left(1-\theta n(z')^{\chi+1}\right)^{1-\frac{1}{\psi}}\left(c(z')\right)^{-\frac{1}{\psi}}/\left(\pi(z')R_{t+1}^1(z'|z)\right)\right]}{\left(E_t[u(z')^{1-\gamma}]\right)^{\frac{\frac{1}{\psi}-\gamma}{1-\gamma}}\left(1-\theta n(z)^{\chi+1}\right)^{1-\frac{1}{\psi}}\left(c(z)\right)^{-\frac{1}{\psi}}}$$

$$= \frac{\beta\left((1-\delta)+ki_1+(1-k)\,i_2\right)^{-\frac{1}{\psi}}E_t\left[\left(u(z')\right)^{\frac{1}{\psi}-\gamma}\left(1-\theta n(z')^{\chi+1}\right)^{1-\frac{1}{\psi}}\left(c(z')\right)^{-\frac{1}{\psi}}P_{t+1}^1(z'|z)/\left(\pi(z')\right)\right]}{\left(E_t[u(z')^{1-\gamma}]\right)^{\frac{\frac{1}{\psi}-\gamma}{1-\gamma}}\left(1-\theta n(z)^{\chi+1}\right)^{1-\frac{1}{\psi}}\left(c(z)\right)^{-\frac{1}{\psi}}}$$

when computing, pull out everything that's just a function of z, and compute the expectation of everything else as a function of z

Term Premium Computation The *n-period term premium* is defined as the difference between the actual n-period yield and the expected average of future short rates:

$$TP_t^n = y_t^n - \frac{1}{n}\sum_{j=0}^{n-1} E_t[y_{t+j}^1]$$

where y_t^n is the n-period yield and y_{t+j}^1 is the one-period yield at time $t+j$.

First, we convert bond prices to yields. The n-period yield is given by:

$$y_t^n = -\frac{1}{n}\log(P_t^n)$$

For the one-period rate, we have:

$$y_t^1 = \log(R_t^1)$$

Given the recursive bond pricing equation:

$$P_t^n = E_t[M_{t+1}P_{t+1}^{n-1}]$$

the n-period term premium can be computed as:

$$TP_t^n(z) = -\frac{1}{n}\log(P_t^n(z)) - \frac{1}{n}\sum_{j=0}^{n-1} E_t[\log(R_{t+j}^1)]$$

where $P_t^n(z)$ is computed recursively starting from $P_t^1(z) = \frac{1}{R_t^1(z)}$.

To compute the n-period term premium:

1. Compute the sequence of bond prices $\{P_t^1(z), P_t^2(z), \ldots, P_t^n(z)\}$ recursively:

$$P_t^k(z) = E_t\left[\frac{M_{t+1}(z'|z)}{R_{t+1}^{k-1}(z')}\right] \quad \text{for } k = 2, 3, \ldots, n$$

2. Convert bond prices to yields:

$$y_t^k(z) = -\frac{1}{k}\log(P_t^k(z)) \quad \text{for } k = 1, 2, \ldots, n$$

3. Compute the expected path of short rates:

$$E_t[y^1_{t+j}] = E_t[\log(R^1_{t+j})] \quad \text{for } j = 0, 1, \ldots, n-1$$

4. Calculate the term premium:

$$TP^n_t(z) = y^n_t(z) - \frac{1}{n}\sum_{j=0}^{n-1} E_t[\log(R^1_{t+j})]$$

For a 2-period bond, the term premium is:

$$TP^2_t(z) = y^2_t(z) - \frac{1}{2}(y^1_t(z) + E_t[y^1_{t+1}(z')])$$

$$= -\frac{1}{2}\log(P^2_t(z)) - \frac{1}{2}\log(R^1_t(z)) - \frac{1}{2}E_t[\log(R^1_{t+1}(z'))]$$

Given the policy rate function $R^1_t(z) = R^*\pi_t^{\kappa_\pi}\exp(e_t)$, we have:

$$E_t[\log(R^1_{t+1}(z'))] = \log(R^*) + \kappa_\pi E_t[\log(\pi_{t+1})] + E_t[e_{t+1}]$$

Stock returns and volatility The market expected return would be:

$$\begin{aligned}
R^M &= \frac{E[V_1' + V_2']}{V_1 + V_2 - D_1 - D_2} = \frac{E[v_1'K_1' + v_2'K_2']}{v_1K_1 + v_2K_2 - d_1K_1 - d_2K_2} = \frac{E[v_1'K_1' + v_2'K_2']}{v_1K_1 + v_2K_2 - d_1K_1 - d_2K_2} \\
&= \frac{E[v_1'k_1' + v_2'k_2']K'}{(v_1k_1 + v_2k_2 - d_1k_1 - d_2k_2)\,K} = \frac{E[v_1'k_1' + v_2'k_2']}{(v_1k_1 + v_2k_2 - d_1k_1 - d_2k_2)}\left((1-\delta) + ki_1 + (1-k)\,i_2\right)
\end{aligned}$$

$$\begin{aligned}
&= \frac{E[v_1'k_1' + v_2'k_2']}{(v_1 - d_1)\,k_1 + (v_2 - d_2)\,(1-k)}\left((1-\delta) + ki_1 + (1-k)\,i_2\right) \\
&\qquad = \frac{E[v_1'k_1' + v_2'k_2']\left((1-\delta) + ki_1 + (1-k)\,i_2\right)}{\left(v_1(z) - \left(\omega\,(z)\,A_1k_1^{\alpha-1}n_1(z)^{(1-\alpha)} - i_1\,(z) - g(i_1\,(z)) - wn_1k^{-1}\right)\right)k_1} \\
&\qquad + \qquad \frac{1}{\left(v_2(z) - \left(\omega\,(z)\,A_2k_2^{\alpha-1}n_2(z)^{(1-\alpha)} - i_2\,(z) - g(i_2\,(z)) - wn_2k_2^{-1}\right)\right)(1-k)}
\end{aligned}$$

To compute the volatility for the simulated regression result, compute the expected volatility for the next period. $E_{t-1}\left(Var(R_t)\right) = E_{t-1}(E_t R^2 - E_t^2 R) = E_{t-1}R(z)^2 - E_{t-1}^2 R$, regress on log variance (to make it more comparable with variation in VIX).

$$ER^2(z') = E\left(\frac{V_1' + V_2'}{V_1 + V_2 - D_1 - D_2}\right)^2 = E\left(\frac{[v_1' k_1' + v_2' k_2']}{(v_1 k_1 + v_2 k_2 - d_1 k_1 - d_2 k_2)}\left((1-\delta) + k i_1 + (1-k)\, i_2\right)\right)^2$$

$$= E\left(\frac{[v_1' k_1' + v_2' k_2']\left((1-\delta) + k i_1 + (1-k)\, i_2\right)}{\mathcal{D}}\right)^2$$

where

$$\begin{aligned}\mathcal{D} = &\left(v_1(z) - \left(\omega\left(z\right) A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - w n_1 k^{-1}\right)\right) k_1 \\ &+ \left(v_2(z) - \left(\omega\left(z\right) A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2\left(z\right) - g(i_2\left(z\right)) - w n_2 k_2^{-1}\right)\right)(1-k)\end{aligned}$$

while for $E^2 R(z)$, we have the following

$$E^2 R(z') = E^2\left(\frac{[v_1' k_1' + v_2' k_2']\left((1-\delta) + k i_1 + (1-k)\, i_2\right)}{\mathcal{D}}\right)$$

where

$$\begin{aligned}\mathcal{D} = &\left(v_1(z) - \left(\omega\left(z\right) A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - w n_1 k^{-1}\right)\right) k_1 \\ &+ \left(v_2(z) - \left(\omega\left(z\right) A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2\left(z\right) - g(i_2\left(z\right)) - w n_2 k_2^{-1}\right)\right)(1-k)\end{aligned}$$

1. compute for the real interest rate:

$$\begin{aligned}R_t &= \frac{1}{E_t\left[\Lambda_{t,t+1}\right]} \\ &= \frac{1}{E_t\left[\beta \cdot M_1 \cdot M_2 \cdot M_3 \cdot M_4\right]}\end{aligned}$$

where

$$M_1 = \left(\frac{u(z')}{E_t\left[u(z')^{1-\gamma}\right]^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma}, \quad M_2 = \left(\frac{1-\theta n(z')^{\chi+1}}{1-\theta n(z)^{\chi+1}}\right)^{1-\frac{1}{\psi}},$$

$$M_3 = \left((1-\delta) + k i_1 + (1-k)\, i_2\right)^{-\frac{1}{\psi}}, \quad M_4 = \left(\frac{c(z')}{c(z)}\right)^{-\frac{1}{\psi}}$$

$$R_t = \frac{\left(E_t[u(z')^{1-\gamma}]\right)^{\frac{\frac{1}{\psi}-\gamma}{1-\gamma}} \left(1-\theta n(z)^{\chi+1}\right)^{\left(1-\frac{1}{\psi}\right)} \left((1-\delta)+ki_1+(1-k)\,i_2\right)^{\frac{1}{\psi}} \left(c(z)\right)^{-\frac{1}{\psi}}}{\beta E_t\left[\left(u(z')\right)^{\frac{1}{\psi}-\gamma}\left(1-\theta n(z')^{\chi+1}\right)^{1-\frac{1}{\psi}}\left(c(z')\right)^{-\frac{1}{\psi}}\right]}$$

2. Compute for stock price , stock returns for sector 1:

$$V_1 = \omega A_1 K_1^{\alpha}\left(n_1(z)K\right)^{1-\alpha} - \frac{I_1}{K_1}K_1 - g(\frac{I_1}{K_1})K_1 - Wn_1 + E[\Lambda' V_1']$$

write $V_1 = \nu_1 K_1$and divding by K_1

$$\nu_1\left(z\right)K_1 = \omega\left(z\right)A_1 k_1^{\alpha} n_1(z)^{(1-\alpha)}K - \frac{I_1}{K_1}K_1 - g(\frac{I_1}{K_1})K_1 - wKn_1 + E[\Lambda'\nu_1\left(z'\right)K_1']$$

$$\nu_1\left(z\right) = \omega\left(z\right)A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - wk^{-1}n_1 + E[\Lambda(z'|z)\nu_1\left(z'\right)K_1'/K_1]$$

$$= \omega\left(z\right)A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - wk^{-1}n_1 + E\left[\Lambda'\nu_1\left(z'\right)\frac{k'}{k}\frac{K'}{K}\right]$$

$$= \omega\left(z\right)A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - wk^{-1}n_1 + E[\Lambda(z'|z)\nu_1\left(z'\right)\left(1-\delta+i_1\right)]$$

$$= \omega\left(z\right)A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - wn_1k^{-1} + E\Bigg[\beta\left(\frac{u_{t+1}}{E_t[u_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma}\left(\frac{1-\theta n_{t+1}^{\chi+1}}{1-\theta n_t^{\chi+1}}\right)^{1-}$$
$$\times\left((1-\delta)+ki_1+(1-k)\,i_2\right)^{-1/\psi}\left(\frac{c_{t+1}}{c_t}\right)^{-\frac{1}{\psi}} \times \nu_1(z')\left((1-\delta)+i_1(z)\right)\Bigg]$$

The recursion is:

$$\begin{aligned} v_1\left(z\right) &= \omega\left(z\right)A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - wn_1k^{-1} \\ &\quad +\left((1-\delta)+ki_1+(1-k)\,i_2\right)^{(-1/\psi)}\left((1-\delta)+i_1\left(z\right)\right)\times \\ &\quad E\left[\beta\left(\frac{u(z')}{E_t[u(z')^{1-\gamma}]^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma}\left(\frac{1-\theta n_{t+1}^{\chi+1}}{1-\theta n_t^{\chi+1}}\right)^{1-\frac{1}{\psi}}\left(\frac{c_{t+1}}{c_t}\right)^{-\frac{1}{\psi}}\nu_1(z')\right], \end{aligned}$$

where $z = (A_1, A_2, k, e)$, and $k' = \frac{(1-\delta)+i_1(z)}{(1-\delta)+ki_1(z)+(1-k)i_2(z)}k$.

And the expected return of sector 1 will be

$$ER_1 = \frac{E[V_1(z')]}{V_1(z) - D_1(z)} = \frac{E[v_1(z')K_1']}{(v_1(z) - d_1(z))K_1} = \frac{E[v_1(z')]}{(v_1(z) - d_1(z))}\frac{K_1'}{K_1} = \frac{E[v_1(z')]}{(v_1(z) - d_1(z))}\frac{K'}{K}\frac{k'}{k}$$

$$= \frac{E\left(v_1(z')\right)}{v_1(z) - \left(\omega\left(z\right) A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - wn_1 k^{-1}\right)} \times \left((1-\delta) + ki_1 + (1-k)\, i_2\right) \frac{(1-\delta) + i_1}{(1-\delta) + ki_1 + (1-k)\, i_2}$$

$$= \frac{E\left(v_1(z')\right)}{v_1(z) - \left(\omega\left(z\right) A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - wn_1 k^{-1}\right)} \left((1-\delta) + i_1\right)$$

For the realized returns, it should be

$$RE_1 = \frac{v_1(z')}{v_1(z) - \left(\omega\left(z\right) A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - wn_1 k^{-1}\right)} \left((1-\delta) + i_1\right)$$

Conditional variance as follows:

$$ER_1^2 == \frac{E\left(v_1^2(z')\right)}{\left(v_1(z) - \left(\omega\left(z\right) A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - wn_1 k^{-1}\right)\right)^2} \left((1-\delta) + i_1\right)^2$$

1. Compute for stock price and stock returns:

$$PD_1 = \frac{V_1}{D_1} = \frac{v_1}{d_1} = \frac{v_1}{\omega\left(z\right) A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - wn_1 k^{-1}}$$

For sector 2, the value function will be

1. Dividing by K and write $V_2 = \nu_2 K_2$

$$\begin{aligned}\nu_2(z) &= \omega\left(z\right) A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2\left(z\right) - g(i_2\left(z\right)) - wn_2 k_2^{-1} \quad + E\left[\Lambda' \nu_2' \frac{K_2'/K'}{K_2/K}\frac{K'}{K}\right] \\ &= \omega\left(z\right) A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2\left(z\right) - g(i_2\left(z\right)) - wn_2(1-k)^{-1} + E\left[\Lambda' \nu_2' \left(1-\delta+i_2\right)\right]\end{aligned}$$

$$
\begin{aligned}
&= \omega(z)\, A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2(z) - g(i_2(z)) - w n_2 k_2^{-1} + E[\Lambda' \nu_2^{'} (1-\delta+i_2)] \\
&= \omega(z)\, A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2(z) - g(i_2(z)) - w n_2 k_2^{-1} + E\left[\Lambda' \nu_2^{'} \frac{1-k'}{1-k}\left(1-\delta+ki_1+(1-k)\, i_2\right)\right]
\end{aligned}
$$

$$
\begin{aligned}
&= \omega(z)\, A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2(z) - g(i_2(z)) - w n_2 k_2^{-1} + E\Bigg[\beta\left(\frac{u_{t+1}}{E_t[u_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma}\left(\frac{1-\theta n_{t+1}^{\chi+1}}{1-\theta n_t^{\chi+1}}\right)^{1-} \\
&\quad \times \left((1-\delta)+ki_1+(1-k)\, i_2\right)^{-1/\psi}\left(\frac{c_{t+1}}{c_t}\right)^{-\frac{1}{\psi}} \nu_2^{'} (1-\delta+i_2)\Bigg]
\end{aligned}
$$

$$
\begin{aligned}
&= \omega(z)\, A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2(z) - g(i_2(z)) - w n_2 k_2^{-1} + \left((1-\delta)+ki_1+(1-k)\, i_2\right)^{-1/\psi}(1-\delta+i \\
&\quad \times E\left[\beta\left(\frac{u_{t+1}}{E_t[u_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma}\left(\frac{1-\theta n_{t+1}^{\chi+1}}{1-\theta n_t^{\chi+1}}\right)^{1-\frac{1}{\psi}} \times \left(\frac{c_{t+1}}{c_t}\right)^{-\frac{1}{\psi}} \nu_2^{'}\right]
\end{aligned}
$$

The recursion is:

$$
\begin{aligned}
v_2(z) &= \omega(z)\, A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2(z) - g(i_2(z)) - w n_2 k_2^{-1} \\
&\quad + \left((1-\delta)+ki_1+(1-k)\, i_2\right)^{(-1/\psi)}\left((1-\delta)+i_2(z)\right) \times \\
&\quad E\left[\beta\left(\frac{u(z')}{E_t[u(z')^{1-\gamma}]^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma}\left(\frac{1-\theta n_{t+1}^{\chi+1}}{1-\theta n_t^{\chi+1}}\right)^{1-\frac{1}{\psi}}\left(\frac{c_{t+1}}{c_t}\right)^{-\frac{1}{\psi}} \nu_2(z')\right],
\end{aligned}
$$

where $z = (A_1, A_2, k, e)$, and $k' = \frac{(1-\delta)+i_1(z)}{(1-\delta)+ki_1(z)+(1-k)i_2(z)}k$.

2. Compute the expected returns as

$$
ER_2 = \frac{E[V_2(z')]}{V_2(z)-D_2(z)} = \frac{E[v_2(z')K_2']}{(v_2(z)-d_2(z))K_2} = \frac{E[v_2(z')]}{(v_2(z)-d_2(z))}\frac{K_2'}{K_2} = \frac{E[v_2(z')]}{(v_2(z)-d_2(z))}\frac{K'}{K}\frac{(1-k')}{(1-k)}
$$

$$= \frac{E[v_2(z')]}{v_2(z) - \left(\omega\left(z\right) A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2\left(z\right) - g(i_2\left(z\right)) - w n_2 k_2^{-1}\right)} \frac{K'}{K} \frac{(1-k')}{(1-k)}$$
$$= \frac{E[v_2(z')] \frac{(1-k')}{(1-k)} \left((1-\delta) + k i_1 + (1-k)\, i_2\right)}{v_2(z) - \left(\omega\left(z\right) A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2\left(z\right) - g(i_2\left(z\right)) - w n_2 k_2^{-1}\right)}$$

$$= \frac{E\left(v_2(z')\right)}{v_2(z) - \left(\omega\left(z\right) A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2\left(z\right) - g(i_2\left(z\right)) - w n_2 k_2^{-1}\right)} \times \frac{(1-k')}{(1-k)} \left((1-\delta) + k i_1 + (1-k)\, i_2\right)$$
$$= \frac{E\left(v_2(z')\right)\left((1-\delta) + i_2\right)}{v_2(z) - \left(\omega\left(z\right) A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2\left(z\right) - g(i_2\left(z\right)) - w n_2 k_2^{-1}\right)}$$

3. For the realized returns

$$RE_2 = \frac{v_2(z')}{\left(v_2(z) - \left(\omega\left(z\right) A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2\left(z\right) - g(i_2\left(z\right)) - w n_2 k_2^{-1}\right)\right)} \left((1-\delta) + i_2\right)$$

compute for aggregate expected returns and PD ratio

$$ER = \frac{E[V_1(z')k' + V_2(z')(1-k')]}{\left(V_1(z) - D_1(z)\right) k + \left(V_2(z) - D_2(z)\right)(1-k)}$$

$$= \frac{E[v_1(z')k'^2 + v_2(z')(1-k')^2]\left((1-\delta) + k i_1 + (1-k)\, i_2\right)}{\left(v_1(z) - d_1(z)\right) k^2 + \left(v_2(z) - d_2(z)\right)(1-k)^2}$$
$$= \frac{E[v_1(z')k'^2 + v_2(z')(1-k')^2]\left((1-\delta) + k i_1 + (1-k)\, i_2\right)}{\left(v_1(z) - d_1(z)\right) k^2 + \left(v_2(z) - d_2(z)\right)(1-k)^2}$$

$$ER = \frac{E[v_1(z')k'^2 + v_2(z')(1-k')^2]\left((1-\delta) + k i_1 + (1-k)\, i_2\right)}{\begin{array}{l}\left(v_1(z) - \left(\omega\left(z\right) A_1 k_1^{\alpha-1} n_1(z)^{(1-\alpha)} - i_1\left(z\right) - g(i_1\left(z\right)) - w n_1 k^{-1}\right)\right) k^2 \\ + \left(v_2(z) - \left(\omega\left(z\right) A_2 k_2^{\alpha-1} n_2(z)^{(1-\alpha)} - i_2\left(z\right) - g(i_2\left(z\right)) - w n_2 k_2^{-1}\right)\right)(1-k)^2\end{array}} \tag{2}$$

A.2 Stationary Distribution of k_h

We choose an interval for k_h when solving the model; for the calibration it is [0.02, 0.6]. In the calibrated simulation (Figure 7), the simulated k_h remains above 0.02 and well below 0.6 after 20,000 quarters, discarding the first 2,000 as burn-in. Therefore, when we run the same regression on the simulated data as on the empirical data, the economy always features two sectors.

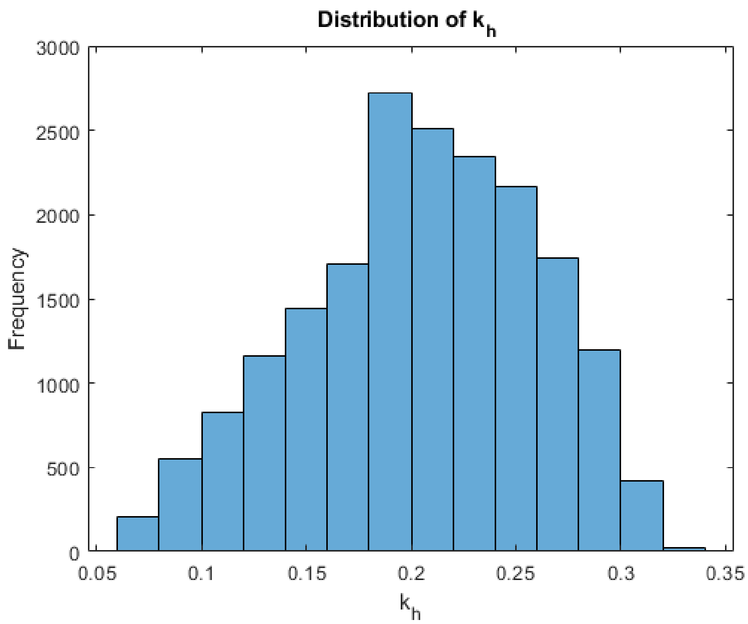

Figure 7: Distribution of Capital Share

B Empirical Appendix

B.1 Sample construction

The firm panel is built from Compustat quarterly fundamentals, restricted to industrial-format consolidated statements for firms incorporated in the United States with non-missing income before extraordinary items, from 1988 onward. No upper date bound is imposed; the sample ends where the extract ends. Five Compustat items—capital expenditure, sale of property, stock issuance, stock repurchase and dividends—are reported year to date within the fiscal year and are differenced to quarterly flows at the *fiscal* reset, before any filter is applied and before the panel grid is built, so that a deleted row or a grid gap cannot cause a later observation to be differenced against a non-adjacent quarter. The flow is left missing, rather than imputed, at a firm's first observation, at any reporting gap, and at any change of fiscal year end.[8]

Table 11 reports the sample construction. Four screens do essentially all of the work, and the two largest are worth stating rather than leaving in a replication file.

Fiscal quarters are required to align with calendar quarters, that is fiscal year ends in March, June, September or December. This screen costs 11.9 percent of firms. It is not a convention here but a requirement of the merge: every accounting record is stamped to the last calendar day of its quarter, so a January-year-end firm's books, closed on 31 January, would be dated 31 March. That two-month error would propagate into the accounting-to-announcement lag on the stock part and into the assignment of quarterly surprises on the investment part. It would also not be classical measurement error. Firms with off-calendar year ends are concentrated in retail and business services, so the error would be correlated with season, with industry, and with the timing of the treatment—which can move a coefficient in either direction rather than attenuating it.

Firms are required to be observed for at least 40 quarters. This is the single largest screen: it removes 12,630 of 21,101 firms, roughly 85 percent of the total reduction. The requirement is there because the investment specification is estimated within firm, with lagged characteristics and firm fixed effects, and needs a long series per

[8] Through an earlier version of this paper the differencing was performed on the calendar quarter, which coincides with the fiscal reset only for firms with a December fiscal year end. For firms with March, June or September year ends it differenced across the reset in one quarter of each year and failed to difference at all in another. Roughly twelve percent of the investment outcome was affected. The estimates reported here use the fiscal-quarter rule.

firm. Two things about it should be said out loud rather than discovered by a reader. First, the count is of observed quarters over the whole sample span and is applied globally, so it is an entry criterion as much as a data requirement: forty quarters ending in 2024 means entry by 2014 at the latest, and no firm that first appears in Compustat after 2014 is in the panel. Second, the resulting decline in firms per meeting late in the sample—about 36 percent between 2015 and 2023—is this screen and not attrition, since the panel admits no new firms over that period by construction. The late-sample estimates are therefore identified on an ageing cohort of incumbents. This is a selection statement, not a data limitation, and it applies with more force to the stock part than to the investment part, where nothing in the announcement specification requires a long firm history.

The remaining screens are conventional and cheap. Utilities, financial firms and public administration are excluded, which costs a further 2,145 firms. Total assets and net property, plant and equipment are required to be present and strictly positive and debt to be present and non-negative; these remove ten firms but 39,221 firm-quarters, because they delete rows rather than firms. Where Compustat reports more than one record for a firm in a calendar quarter, the record with the largest total assets is retained; this arises in 286 firm-quarters.

Firms are matched to CRSP through the link history, restricted to primary researched links with the fiscal period end inside the link's validity window. The link is then reduced to one identifier per firm for its entire history, so time variation in the link is discarded; coverage is 96.9 percent of firm-years and decays only from 100 to 94.5 percent across the sample, so this cannot account for the thinning of the panel. Because the reduction is not one-to-one in the other direction, a single CRSP identifier can attach to two firms, which is why the volatility merge *gains* firms in Table 11; a subsequent de-duplication on identifier and quarter then removes 467 firms. Those firms lose a tie rather than failing a stated criterion, and the final panel has equal firm and identifier counts by construction.

Volatility is estimated over the 90 calendar days ending at each quarter end, requiring at least 30 observations to enter the estimation, and is placed on a quarterly basis by $\sqrt{63}$ and then annualized. It is the sample standard deviation of the abnormal return series, not the regression root mean squared error, so no degrees-of-freedom correction for the number of factors is applied.

The event panel keeps only regularly scheduled announcements, and the window is the announcement day together with the preceding and following weekday. A firm-event is retained only if all three days are present in CRSP, so a market holiday beside a meeting removes the firm-event rather than one day.[9] Accounting data are joined to each announcement from a completed fiscal quarter ending three to six months earlier, which guarantees the data were public at the announcement; where more than one quarter qualifies the implementation retains the earlier, so the effective lag sits at the longer end of that range. Because volatility is measured in the fiscal quarter the join supplies rather than immediately before the meeting, it is lagged, and β_3 on the stock part should be read as a lower bound.

Nominal series are deflated by a quarterly consumer price index with the first quarter of the sample as the base. Outcome and control variables are trimmed at the 0.5th and 99.5th percentiles, pooled over the panel rather than by year or industry, and the trim sets out-of-range values to missing rather than replacing them with the cutoff. This is why the dispersion of Tobin's Q here is lower than in studies that winsorize at 1 and 99. The Great Recession window 2008q1–2009q2 is excluded from every investment specification and retained on the event panel, where the quarter is not the unit of observation; Table 18 reports both parts with the Great Financial Crisis and the COVID period excluded. On the annual employment panel the window cannot be applied as written, since a fiscal year cannot be cut in half, and fiscal years 2008 and 2009 are dropped in full; the estimates are reported both ways in Section 5.3.1.

B.2 Firm-level local projections

The impact estimates of Table 3 are imprecise on the two-way standard error. Figure 8 traces the same interaction across horizons, on the baseline specification, to show that the effect is present and persistent rather than absent.

[9] One further feature of the event panel should be recorded. CRSP reports a negative price when there was no closing trade and the price is a bid–ask midpoint. Using the absolute value and flagging the observation, 10.5 percent of firm-events have at least one of the three window days built on a midpoint rather than a trade, concentrated in small illiquid firms. The announcement-day return is unaffected in the baseline, which uses the CRSP return rather than the price change, but the three-day price change is not, and a specification that uses it should exclude these events.

Table 11: Sample Construction

	Firms	Δ Firms	Firm-quarters
U.S. Compustat quarterly, non-missing income, 1988–	23,944		1,024,533
+ fiscal year ending Mar, Jun, Sep or Dec	21,101	−2,843	902,749
+ observed in at least 40 quarters	8,471	−12,630	662,849
+ excluding utilities, financials, public admin.	6,326	−2,145	495,809
+ assets, capital and debt reported	6,325	−1	465,907
+ assets and capital positive, debt non-negative	6,316	−9	456,588
+ matched to a CRSP identifier	5,686	−630	444,269
+ with an estimated volatility	5,765	+79	364,406
+ one firm per identifier and quarter	5,298	−467	

Notes: This table reports the number of firms and firm-quarters surviving each sample screen, in the order the screens are applied. *Firms* is the count of distinct Compustat identifiers; Δ *Firms* is the change from the row above; *Firm-quarters* is the count of firm-quarter records. They are counts, not percentages. The four data-quality screens delete rows rather than firms, which is why they cost ten firms but roughly 39,000 firm-quarters. The volatility row *gains* firms because the CRSP link is not one-to-one: a single CRSP identifier can attach to more than one Compustat identifier, and each volatility observation for that identifier is then duplicated. The final row removes those duplicates on identifier and quarter, so the firms it drops lose a tie rather than fail a stated criterion. The estimation samples are smaller again, because the regressions require lagged characteristics and a monetary policy surprise in the same quarter: the event panel of Table 2 has 547,841 firm-meetings in column (2) and the investment panel of Table 3 194,859 firm-quarters in column (1). The employment panel of Table 9 is built separately from annual data and is not on this funnel.

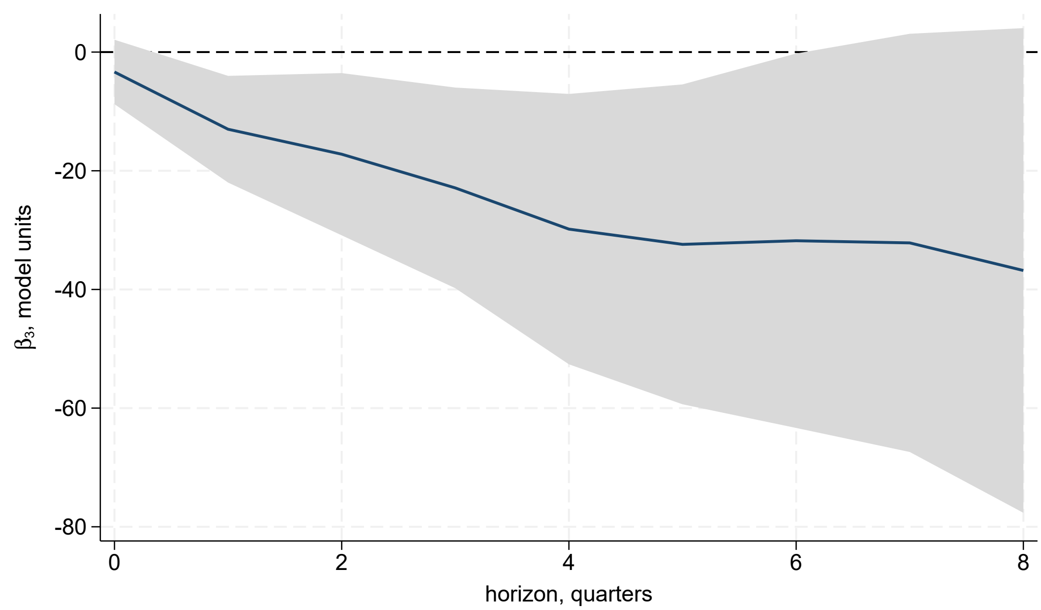

Figure 8: The Investment Interaction across Horizons

Notes: The line plots β_3, the coefficient on the interaction of the quarterly monetary policy surprise with lagged firm volatility, from local projections at horizons $h = 0$ to $h = 8$ quarters. The dependent variable at horizon h is the investment rate cumulated from quarter q to quarter $q+h$; the specification is otherwise the baseline, column (1) of Table 3, and at $h = 0$ the estimate reproduces that column exactly. Coefficients are signed as the response to a one percentage point easing and multiplied by 100, and volatility is annualized, so β_3 is per one unit of annualized asset volatility and the vertical axis is on the same scale as Table 3. The shaded area is a 90 percent confidence band, computed as 1.645 times the standard error clustered two-way on firm and quarter. The estimation sample shrinks with the horizon, from 194,859 firm-quarters at $h = 0$ to 128,230 at $h = 8$, because a longer horizon requires more quarters of data per firm.

B.3 Robustness check: two-day returns

Table 12: Heterogenous Response of Two-day Stock Prices to Monetary Policy

	(1)	(2)	(3)	(4)
MPS	−9.58	−10.15		
	(1.84)	(2.58)		
MPS_median			−9.36	−10.63
			(1.94)	(2.64)
Vol×MPS	10.94	10.71		
	(2.95)	(2.83)		
Vol×MPS_median			9.28	8.99
			(3.29)	(3.14)
leverage×MPS		−0.44		
		(0.25)		
leverage×MPS_median				−0.47
				(0.38)
BM×MPS		0.12		
		(0.64)		
BM×MPS_median				0.14
				(0.01)
Observations	547,428	547,428	547,428	547,428
R^2	0.09	0.09	0.09	0.07
Firm Controls	Yes	Yes	Yes	Yes
Industry × time FE	Yes	Yes	Yes	Yes
Firm&Time clustering	Yes	Yes	Yes	Yes

Notes: This table reports estimates from regressing firm-level two-day stock returns on FOMC days and the day after the meeting on monetary policy shocks and their interactions with firm volatility. The dependent variable is the two-day cumulative stock return on and after FOMC announcement days. MPS is the monetary policy shock from Jarociński and Karadi (2020) and MPS_median uses the shocks orthogonalized to central bank information as a robustness check. Vol denotes equity volatility measured over the 90 days prior to the announcement. Leverage and BM are book leverage and book-to-market ratios. All specifications include firm fixed effects and industry-by-quarter fixed effects. Standard errors (in parentheses) are clustered at both the firm and FOMC date levels.

B.4 Robustness check: different volatility measures

Table 13: Heterogenous Response of Stock and Investment to Monetary Policy

	Stock Price			Investment		
	(1)	(2)	(3)	(1)	(2)	(3)
MPS	−5.66	−5.43	−5.34	−2.47	−1.72	−3.02
	(1.83)	(1.61)	(1.74)	(0.79)	(0.73)	(1.34)
Vol_3×MPS	6.05			6.31		
	(3.06)			(1.71)		
Vol3_a×MPS		7.69			7.67	
		(3.24)			(2.66)	
Vol_asset×MPS			2.37			3.66
			(1.44)			(1.07)
Observations	547,428	547,428	486,513	202,021	202,021	140,800
R^2	0.07	0.07	0.07	0.17	0.17	0.18
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry × time FE	Yes	Yes	Yes	No	No	No
Firm&Time clustering	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports estimates from regressing firm-level stock returns (columns 1-3) and investment rates (columns 4-6) on monetary policy shocks and their interactions with different volatility measures. For stock returns, the dependent variable is the one-day return on FOMC announcement days. For investment, the dependent variable is the quarterly investment rate (capital expenditure scaled by lagged capital stock). MPS is the monetary policy shock from Jarociński and Karadi (2020). Vol_3 denotes idiosyncratic equity return volatility,adjusted by Carhart 4 factors , Vol3_a denotes the return volatility unlevered equity return adjusted by Carhart 4 factors, and Vol_asset denotes asset volatility generated iteratively by the method of Bharath and Shumway(2008). All specifications include firm controls, firm fixed effects, and industry-by-quarter fixed effects. Standard errors (in parentheses) are clustered at both the firm and time (FOMC date or quarter) levels.

B.5 Robustness check: different MPS measures

Table 14: Heterogenous Response of Stock and Investment to MPS: Different Shocks

	Stock Prices		Investment		
	(1)	(2)	(3)	(4)	(5)
NS	−0.31	−0.32		−0.09	
	(0.09)	(0.12)		(0.04)	
MPS_w			−1.45		
			(0.66)		
Vol×NS	0.34	0.34		0.51	0.25
	(0.16)	(0.16)		(0.15)	(0.12)
Vol×MPS_w			1.97		
			(1.19)		
leverage×NS		0.01			−0.43
		(0.08)			(0.28)
BM×NS		0.01			
		(0.02)			
q×NS					−0.03
					(0.03)
size×NS		7.0e-7			6.28e-7
		(9.0e-7)			(1.39e-6)
Observations	464,571	464,571	186,905	166,528	166,020
R^2	0.07	0.07	0.16	0.18	0.18
Firm Controls	Yes	Yes	Yes	Yes	Yes
Industry × time FE	Yes	Yes	No	No	Yes
Firm&Time clustering	Yes	Yes	Yes	Yes	Yes

Notes: This table reports estimates from regressing firm-level stock returns on FOMC announcement days on alternative monetary policy shocks and their interactions with firm volatility. The dependent variable is the one-day stock return on FOMC announcement days. NS is the Nakamura-Steinsson monetary policy shock (from 01feb1995 to 27jul2022), and MPS_w is the benchmark monetary shocks aggregated over each quarter following the method of Ottonello and Winberry (2020). Vol denotes equity volatility measured over the 90 days prior to the announcement. Leverage, BM (book-to-market), q (Tobin's Q), and size are firm-level control variables. All specifications include firm fixed effects. Columns (1)-(2) and (5) include industry-by-quarter fixed effects. Standard errors (in parentheses) are clustered at both the firm and FOMC date levels.

B.6 Correlation of firm volatility with other firm characteristics

Table 15: Correlation Matrix of Firm Characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) vol3_at	1.00									
(2) atq	−0.27*	1.00								
(3) debt_atq	−0.41*	0.17*	1.00							
(4) btom	−0.14*	−0.04*	0.04*	1.00						
(5) mveq	−0.17*	0.76*	0.07*	−0.14*	1.00					
(6) cashratio	0.47*	−0.17*	−0.43*	−0.20*	−0.07*	1.00				
(7) Age	−0.39*	0.37*	0.11*	0.06*	0.27*	−0.26*	1.00			
(8) tangibility	−0.24*	0.11*	0.25*	0.13*	0.01*	−0.38*	0.21*	1.00		
(9) profitability	−0.41*	0.11*	0.08*	−0.01*	0.13*	−0.42*	0.18*	0.09*	1.00	
(10) payout_dummy	−0.37*	0.28*	0.15*	−0.05*	0.22*	−0.29*	0.39*	0.21*	0.24*	1.00

Notes: This table presents pairwise correlations between firm characteristics. (1) vol3_at is firm volatility, (2) atq is total assets, (3) debt_atq is the debt-to-assets ratio, (4) btom is book-to-market ratio, (5) mveq is market value of equity, (6) cashratio is cash holdings ratio, (7) Age is firm age, (8) tangibility is asset tangibility, (9) profitability is profitability ratio, and (10) payout_dummy is a dividend payout indicator. * indicates statistical significance at the 5% level.

B.7 Robustness check: different controls

Table 16: Heterogenous Response of Stock Prices to MPS: Additional Controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
MPS	−5.44	−5.69	−5.79	−5.97	−5.93	−5.7	−5.68
	(2.03)	(1.78)	(1.94)	(1.8)	(1.76)	(2.1)	(1.85)
Vol×MPS	5.6	6.18	6.26	6.6	6.26	6.32	5.79
	(2.84)	(2.79)	(3.03)	(2.87)	(3)	(2.96)	(2.91)
leverage×MPS	−0.01						
	(1.79)						
BM×MPS	0.06						
	(0.41)						
profit×MPS	−4.74						−4.64
	(3.99)						(3.85)
tangibility×MPS	−0.19					−0.28	
	(0.56)					(0.66)	
cash×MPS	−0.04				0.53		
	(1.15)				(1.28)		
payout_dummy×MPS	−0.06		−0.15				
	(0.35)		(0.4)				
size×MPS	2.2e-5			1.62e-4			
	(1.7e-5)			(1.96e-4)			
Age×MPS	−0.0087	−0.008					
	(0.02)	(0.017)					
Observations	531,532	531,532	531,532	531,532	531,532	531,532	531,532
R^2	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm&Time clustering	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports estimates from regressing firm-level stock returns on FOMC announcement days on monetary policy shocks and their interactions with firm volatility and additional firm characteristics. The dependent variable is the one-day stock return on FOMC announcement days. MPS is the monetary policy shock from Jarociński and Karadi (2020). Vol denotes equity volatility measured over the 90 days prior to the announcement. Additional controls include leverage, book-to-market ratio (BM), profitability (profit), asset tangibility, cash holdings, payout dummy, firm size, and firm age. All specifications include firm fixed effects and industry-by-quarter fixed effects. Standard errors (in parentheses) are clustered at both the firm and FOMC date levels.

Table 17: Heterogenous Response of Investment to MPS: Additional Controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Vol×MPS	8.33	4.66	7.3	6.47	9.61	8.17	8.23	6.84
	(3.95)	(2.21)	(3.71)	(2.43)	(4.45)	(3.44)	(3.55)	(3.24)
leverage×MPS	−14.08							
	(2.31)							
q×MPS	−0.47							
	(0.82)							
profit×MPS	13.25				13.29			
	(15.87)				(13.36)			
tangibility×MPS	−2.56						−2.68	
	(1.2)						(1.44)	
cash×MPS	−2.57					0.66		
	(4.12)					(3.55)		
payout_dummy×MPS	−0.24		0.77					
	(1.17)		(1.19)					
size×MPS	−2.84e-5			−2.23				
	(3.37e-5)			(2.28)				
Age×MPS	−0.037							−0.05
	(0.034)							(0.03)
SA_index×MPS		0.53						
		(0.67)						
Observations	211,644	211,644	211,644	211,644	211,644	211,644	211,644	211,644
R^2	0.23	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm&Time clustering	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports estimates from regressing firm-level investment rates on quarterly aggregated monetary policy shocks and their interactions with firm volatility and additional firm characteristics. The dependent variable is the investment rate (capital expenditure scaled by lagged capital stock). MPS is the quarterly aggregate of monetary policy shocks from Jarociński and Karadi (2020). Vol denotes equity volatility measured in the previous quarter. Additional controls include leverage, Tobin's Q (q), profitability (profit), asset tangibility, cash holdings, payout dummy, firm size, firm age, and the SA index for financial constraints. All specifications include firm fixed effects and industry-by-quarter fixed effects. Standard errors (in parentheses) are clustered at both the firm and quarter levels.

Table 18: Heterogeneous Response of Stock Prices and Investment to Monetary Policy

	Stock Prices		Investment		
	(1)	(2)	(3)	(4)	(5)
MPS	−6.94	−7.74	−2.03		
	1.5	1.95	1.02		
Vol*MPS	7.68	7.6	6.91	4.51	4.41
	2.5	2.51	1.87	1.61	1.61
leverage*MPS		0.86			−11.99
		1.84			6.95
BM*MPS		0.43			
		0.41			
q*MPS					−1.29
					0.76
size*MPS		1.46E-05			4.11E-05
		2.10E-05			3.77E-05
Observations	518,482	518,482	186,934	186,332	186,332
R^2	0.06	0.06	0.17	0.17	0.17
Firm Controls	Yes	Yes	Yes	Yes	Yes
Industry × time FE	Yes	Yes	No	Yes	Yes
Firm×Time clustering	Yes	Yes	Yes	Yes	Yes

Note: This table presents the baseline specification of stock price and investment responses to monetary policy shocks, excluding the Great Financial Crisis and COVID-19 periods. Columns (1) and (2) report results from regressions of stock price changes on monetary policy shocks. Columns (3), (4), and (5) report results from investment regressions. Standard errors are reported below coefficients.

B.8 Interaction term of macro controls

Table 19: Heterogeneous Response of Stock Prices and Investment to Monetary Policy

	Stock Prices		Investment		
	(1)	(2)	(3)	(4)	(5)
MPS			−2.24		
			0.87		
MPS_ORTH	−7.15	−7.2			
	1.67	2.13			
Vol*MPS			4.79	3.41	3.37
			1.53	1.31	1.3
Vol*MPS_ORTH	6.4	6.15			
	2.92	2.82			
leverage*MPS_ORTH(MPS)		0.15			−7.72
		1.54			4.96
BM*MPS_ORTH		0.12			
		0.54			
q*MPS_ORTH(MPS)					−0.93
					0.59
size*MPS_ORTH(MPS)	1.84e-5				1.44e-5
	1.91e-5				2.89e-5
Vol#dlog_GDP			0.28	−0.27	−0.32
			0.27	0.22	0.20
Vol#dlog_CPI			0.27	0.15	0.12
			0.28	0.19	0.18
Vol#UR			0.0033	−0.0015	−0.0028
			0.003	0.0024	0.0021
Observations	527,950	527,950	200,919	200,249	199,829
R^2	0.06	0.06	0.16	0.16	0.18
Firm Controls	Yes	Yes	Yes	Yes	Yes
Industry × time FE	Yes	Yes	No	Yes	Yes
Macro×Vol			Yes	Yes	Yes
Firm×Time clustering	Yes	Yes	Yes	Yes	Yes

Note: Columns (1) and (2) report results from regressions of stock price changes on monetary policy shocks. This specification uses the Bauer and Swanson (2023) filtered monetary policy surprise measure, 253 FOMC meetings in total, from May 22, 1988 to December 16, 2019, which removes the predictable component such that the interaction term between MPS and volatility does not capture differences in business cycle sensitivities across firms. Columns (3), (4), and (5) report results from investment regressions. The specifications include interactions between firm volatility and four macroeconomic indicators: GDP growth, inflation (CPI), and unemployment rate, to control for differential cyclical sensitivities across firms. The interaction terms with lagged macro variables beyond one quarter are omitted for brevity.