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Abstract

Monetary policy is usually evaluated through aggregate output and inflation, with less attention to how it reallocates innovative investment across firms. Existing evidence shows that higher rates reduce innovation, but the firms driving this response remain unclear. Combining Norway's research and development (R&D) survey with administrative data and narrative monetary shocks for 2001–18, we estimate heterogeneous firm responses. Contractionary policy reduces R&D most in high-growth firms with recent equity issuance, consistent with the asset-price channel of monetary transmission. Standard debt-based measures explain little heterogeneity. Monetary policy therefore has long-run real effects primarily by reducing R&D in high-growth innovative firms.

Key words: Monetary policy, innovation, productivity, research and development.

JEL classification: E52, O31.

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1 Introduction

Monetary policy is typically assessed through its effects on inflation, output, employment, and investment at the aggregate level. This perspective is informative, but incomplete. When interest rates change, firms do not adjust all expenditures symmetrically, and they do not adjust them equally across the firm distribution. If tighter monetary policy disproportionately reduces innovative investment in firms with the strongest growth potential, then the consequences of monetary transmission depend not only on the aggregate fall in spending, but also on its composition across firms and activities.

This paper studies the composition of monetary transmission through firm-level R&D spending. Using comprehensive Norwegian data, we show that contractionary monetary policy reduces R&D on average, but the average effect masks sharp heterogeneity. The strongest responses come from firms that are both high-growth and recently reliant on external equity finance. These firms cut R&D substantially more than other innovators, while standard debt-based measures such as leverage, liquidity, and interest burdens explain little of the cross-sectional variation.

The paper's central claim is therefore not merely that monetary policy affects innovation. It is that the composition of monetary transmission matters because it falls disproportionately on innovation-intensive growth firms. Moreover, this compositional pattern is economically important. A large body of literature on firm dynamics shows that high-growth firms account for a disproportionate share of job creation, output growth, and productivity growth (Haltiwanger, Jarmin, Kulick, and Miranda, 2016; Acemoglu, Akcigit, Alp, Bloom, and Kerr, 2018; Sterk, Sedláček, and Pugsley, 2021). If tighter monetary policy pushes precisely these firms to reduce R&D, then the long-run real effects of disinflation may be larger than aggregate averages alone suggest.

Our contribution. We combine Statistics Norway's annual R&D survey with administrative data on firms' balance sheets and income statements, and a narrative monetary policy shock series from Holm, Paul, and Tischbirek (2021). This dataset allows us to study how monetary policy affects R&D across a broad set of firms, including many firms outside the listed sector. Relative to prior work focused on aggregate innovation or public firms, our contribution is to identify which firms account for the response and to connect this heterogeneity to a simple asset-price mechanism.

We establish three main results. First, a 100-basis-point increase in interest rates reduces internal R&D spending by roughly 0.5% of value added. The decline occurs quickly, is driven primarily by R&D-related wage expenditures, and is partly due to an extensive-margin adjustment whereby some firms temporarily exit R&D altogether. Productivity declines later, consistent with lower innovation feeding through to firm performance with a lag.

Second, the average effect masks substantial heterogeneity. Firms with recent equity issuance and high prior growth reduce R&D significantly more than other firms. By contrast, standard debt-related measures do not systematically explain the cross-section of responses. The interaction between growth and equity dependence is especially important: the sharpest decline in R&D occurs among firms that combine both characteristics.

Third, these heterogeneous responses imply that monetary policy alters the allocation of innovation across firms. The firms most affected are not peripheral innovators. In the firm life-cycle literature, firms characterized by high growth and reliance on external equity are typically classified as being in the introduction (Dickinson, 2011) or capital infusion (DeAngelo, DeAngelo, and Stulz, 2006) stage, which is an important stage for firms to reach maturity. Moreover, being "high-growth" tends to be a persistent characteristic of firms (Sterk, Sedláček, and Pugsley, 2021), often referred to as transformative entrepreneurs (Schoar, 2010) that may be disproportionately important for aggregate productivity and output growth (Haltiwanger, Jarmin, Kulick, and Miranda, 2016). In that sense, monetary policy does not simply lower aggregate innovative spending; it shifts the burden of adjustment toward firms whose innovative activity is likely to matter most for future productivity growth.

Related literature. This paper engages three interconnected literatures.

Monetary policy and long-run growth. A growing literature challenges the conventional neutrality view by showing that monetary policy affects innovation and productivity. Döttling and Ratnovski (2023) and Ma (2023) show that U.S. firms reduce intangible investment after monetary tightening; Jordà, Singh, and Taylor (2024) and Guérin (2023) document persistent productivity effects in U.S. and international data; and Elfsbacka-Schmöller, Goldfayn-Frank, and Schmidt (2024) provide similar evidence for Europe. We contribute to this literature by shifting attention from average effects to the composition of those effects across firms. Our results show that aggregate responses conceal important heterogeneity and that the firms driving the decline in R&D are concentrated in a particularly dynamic part of the firm distribution.

The asset-price channel of monetary transmission. Conventional analyses emphasize debt-based transmission through borrowing costs, collateral, and bank balance sheets. That logic is less directly suited to R&D, which is intangible, risky, and difficult to collateralize (Hall, 1992; Himmelberg and Petersen, 1994; Brown, Fazzari, and Petersen, 2009; Cincera, Ravet, and Veugelers, 2016). Recent theoretical work instead emphasizes how higher discount rates lower firm valuations and thereby increase the effective cost of equity-financed investment. Jeenas and Lagos (2024) formalize this mechanism, and Almeida, Johnson, Oliveira, and Zhou (2024) show that equity-constrained U.S. firms cut innovation more after monetary tightening. Our findings are strongly consistent with this view, but we highlight a compositional implication that has received less attention: the firms that grow more, and thus have more back-loaded cash flows, are most exposed to the asset-price channel because their valuations are especially sensitive to discount rates.

Firm heterogeneity and aggregate dynamics. A central insight of the firm dynamics literature is that firms are not interchangeable. A relatively small group of high-growth firms accounts for an outsized share of job creation, output growth, and productivity growth (Haltiwanger, Jarmin, Kulick, and Miranda, 2016; Acemoglu, Akcigit, Alp, Bloom, and Kerr, 2018; Schoar, 2010). High growth also tends to persist rather than fully revert to the mean (Sterk, Sedláček, and Pugsley, 2021). We connect this insight to monetary economics. If the burden of tighter policy falls disproportionately on innovation-intensive growth firms, then the allocation of monetary transmission across firms becomes central for understanding its aggregate and longer-run real effects.

Roadmap. The rest of the paper proceeds as follows. Section 2 presents a simple framework that motivates why monetary policy should affect R&D most strongly in firms that are both equity-dependent and high-growth. Section 3 describes the data. Section 4 documents aggregate and average firm-level responses. Section 5 shows that these average effects are driven disproportionately by innovation-intensive growth firms. Section 6 concludes.

2 A model of q-monetary transmission to R&D spending

In this section, we present an illustrative framework to explain how monetary transmission to R&D firms operates through an asset-price channel. The model is a simplified version of Jeenas and Lagos (2024). Its purpose is not to offer a complete theory of firm financing, but to motivate a central empirical prediction of the paper: monetary tightening should have its strongest effect on R&D in firms that are both dependent on external equity and characterized by high growth prospects.

Environment. Consider a firm that chooses R&D spending x at date 0. This investment generates intangible capital that produces a stream of future cash flows. Cash flow in period t from the investment in intangible capital at date 0 is

$$A(1+g)^t x^\alpha, \tag{1}$$

where $A > 0$ is initial productivity, $g \geq 0$ captures growth in future cash flows, and $\alpha \in (0, 1)$ governs decreasing returns. One unit of R&D costs one unit of output, and the firm has internal funds ω.

The entrepreneur discounts future cash flows at an internal rate $r_e > g$, while outside investors discount them at the market rate $\rho > r_e$. The wedge may reflect risk premia, information asymmetry, or the non-collateralizable nature of R&D. Monetary policy affects the market discount rate according to

$$\rho = \bar{\rho} + \varepsilon, \tag{2}$$

where $\bar{\rho}$ is the steady-state market rate and ε is an i.i.d. monetary shock with mean zero. We assume the monetary shock is permanent for simplicity in this section, because it allows us to derive closed-form expressions. The qualitative predictions in Proposition 1 do not rely on permanent shocks. We assume $\bar{\rho} + \varepsilon > r_e > g$ so that valuations remain finite.

R&D decision. An unconstrained firm with sufficient internal funds, $\omega \geq x_e^*$, chooses R&D to maximize

$$\max_x \frac{(1+g)}{r_e - g} A x^\alpha - x, \tag{3}$$

which yields optimal R&D spending

$$x_e^*(g) = \left(\frac{\alpha A(1+g)}{r_e - g} \right)^{\frac{1}{1-\alpha}}. \tag{4}$$

A firm with insufficient internal funds, $\omega < x_s^*$, must issue equity to outside investors. Its marginal valuation of R&D is therefore market-based:

$$\max_x \frac{(1+g)}{\bar{\rho} + \varepsilon - g} A x^\alpha - x, \tag{5}$$

which yields

$$x_s^*(g, \varepsilon) = \left(\frac{\alpha A(1+g)}{\bar{\rho} + \varepsilon - g} \right)^{\frac{1}{1-\alpha}}. \tag{6}$$

Since $\bar{\rho} > r_e$, we have $x_s^* < x_e^*$: equity-dependent firms underinvest in R&D relative to the entrepreneur's preferred level.

Proposition 1. *Consider a contractionary monetary shock $\varepsilon > 0$.*

(i) Equity-dependent firms ($\omega < x_s^*$) reduce R&D in response to monetary shocks:

$$\frac{\partial \log x_s^*}{\partial \varepsilon} = -\frac{1}{1-\alpha} \cdot \frac{1}{\bar{\rho} + \varepsilon - g} < 0. \tag{7}$$

(ii) Among equity-dependent firms, high-growth firms have larger R&D responses:

$$\frac{\partial^2 \log x_s^*}{\partial \varepsilon \, \partial g} = -\frac{1}{1-\alpha} \cdot \frac{1}{(\bar{\rho} + \varepsilon - g)^2} < 0. \tag{8}$$

The model yields two predictions. First, there is a *financing channel*: when monetary policy raises the market discount rate, external valuations fall, making equity finance more dilutive and lowering R&D among firms that depend on outside investors. Second, there is a *growth-sensitivity channel*: among externally financed firms, those with more back-loaded cash flows respond more because their valuations are especially sensitive to discount rates.

The paper's key empirical implication follows immediately. Monetary tightening should not reduce R&D uniformly across firms. Instead, the strongest responses should come from firms that combine external equity dependence with high growth prospects. This is a prediction about the composition of monetary transmission across firms, which we test in the data.

3 Data

We combine three data sources: Statistics Norway's annual R&D survey, administrative records on firm financials, and a narrative monetary policy shock series. Together, these data allow us to study both the average effect of monetary policy on R&D and the firm characteristics that account for heterogeneous responses.

3.1 R&D survey

Our primary data come from Statistics Norway's annual R&D survey, conducted from 2001 to 2018, following the OECD Frascati Manual guidelines. The survey covers all Norwegian firms with more than 50 employees, providing near-universal coverage of medium and large enterprises. Activity qualifies as R&D if it "contains something new, is creative, has uncertainty related to the results, is systematic, and can be transferred and/or reproduced."

The survey distinguishes internal from external R&D. Internal R&D—our primary focus—comprises wage expenses for R&D personnel (62% of spending), other current expenses (33%), and capital expenditures (5%). External R&D captures purchased research services. We focus on internal R&D because it most directly measures innovative activity carried out within the firm.

We link the survey to administrative tax records containing audited income statements and balance sheets using firm identifiers. These records provide information on value added, assets, debt, equity, wages, and other firm characteristics needed for the analysis of heterogeneous responses.

3.2 Institutional setting

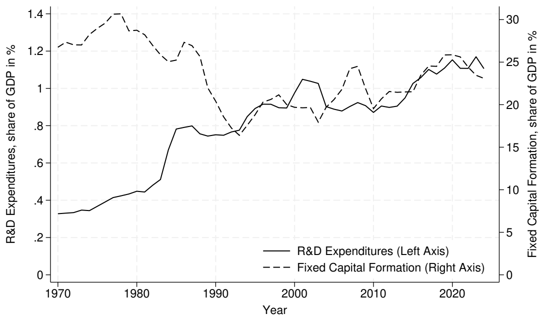
Since 2002, the Norwegian government has subsidized R&D activity. At first, the subsidy scheme was available only to small and medium-sized enterprises (less than 250 employees and a maximum of €50 million in operating expenses), and allowed firms to deduct 20 per cent of their R&D spending up to NOK 4 million per year. The scheme was extended to all firms in 2003, with a lower deduction for large firms (18 percent). In 2009 and 2014, the maximum deduction was extended to NOK 5.5 million and NOK 8 million, respectively.

3.3 Aggregate trends

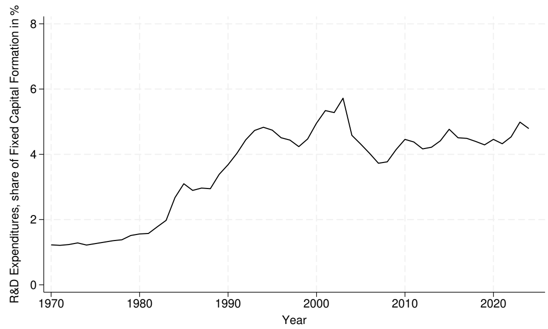
Figure 1 places Norwegian R&D in context. Panel (a) shows that private R&D spending rose gradually from around 0.8% of GDP in 1990 to more than 1% by 2020. The large increase around 2002 and increase during the early 2010s are associated with the use of the R&D subsidy scheme Benedictow, Bjøru, Nordberg-Schulz, and Røtnes (2018, Figure 2.2). Panel (b) shows that R&D remained roughly 4% of fixed capital formation over the period. Relative to the OECD average and the United States, Norwegian R&D intensity is somewhat lower, though cross-country comparisons are partly affected by the outsized role of the petroleum sector in Norway.

3.4 Variable definitions

R&D spending. Our main outcome is internal R&D spending scaled by lagged value added, defined as EBIT plus the wage bill. This normalization serves two purposes. First,



(a) R&D Spending and Fixed Capital Formation.



(b) R&D Spending as a Share of Fixed Capital.

Notes: Aggregate data on GDP, fixed capital formation, and R&D expenditures are obtained from Statistics Norway (SSB). GDP and fixed capital formation refer to mainland Norway. R&D expenditures refers to private-sector R&D spending for total Norway (including the petroleum sector).

Figure 1: Aggregate R&D spending and fixed capital formation.

many firm-years record zero R&D, making log specifications unattractive. Second, scaling by value added allows direct comparisons between R&D and other input categories.

Productivity. We estimate total factor productivity following Levinsohn and Petrin (2003), using intermediate inputs to proxy for unobserved productivity shocks. This approach addresses the standard simultaneity problem in production function estimation. Results are similar if we use the Olley and Pakes (1996) investment-based alternative. We also study return on assets, defined as EBIT divided by total assets, as a directly observed performance measure.

Other outcomes. We additionally examine changes in total wages and net fixed capital investment, also scaled by value added, to assess whether R&D behaves differently from other firm expenditures under monetary tightening.

Firm characteristics. To analyze composition, we focus on two characteristics central to the model: growth and external equity dependence. Growth is measured using lagged value-added growth and, in robustness exercises, lagged TFP growth. External equity dependence is proxied by an indicator equal to one if the firm reports a positive change in paid-in capital at least once during the preceding three years. We also include debt relative to fixed assets, interest costs relative to EBIT, and the size (log assets). All level variables are deflated by the GDP deflator.

3.5 Sample construction

R&D sample. Our main analysis uses firms reporting positive R&D expenditures between 2001 and 2019. We impose three initial restrictions: (i) the firm should not be very small (fixed capital should exceed USD 50,000 and we remove the bottom 5% of the value-added distribution); (ii) the firm should persist for some time (at least 10 years of operation in our sample); and (iii) the firm should have sufficient activity (positive values for sales, total assets, value added, and capital, and non-negative values for equity).

We further impose some additional restrictions to remove implausible observations. First, we exclude the top and bottom 1 % of each distribution for the cumulative R&D spending growth up to 5 years. Second, we remove the top and bottom 1% of the distribution for other firm-level variables (sales growth, interest costs relative to earnings, the debt-to-fixed-assets ratio, and size). The final R&D sample contains 12,149 firm-year observations covering the period 2001–2019. About 63% of the sample of firms are in the manufacturing sector, while the rest are distributed across other sectors. After trimming, we standardize each independent variable using its cross-sectional mean and standard deviation (see Table 1 for the values).

Full sample. For the productivity comparison between innovators and non-innovators, we use the universe of Norwegian limited liability companies, applying the same restrictions except those based on R&D spending. This yields 173,921 firm-year observations.

Descriptive statistics. Table 1 reports descriptive statistics. Three features are particularly relevant. First, R&D is lumpy: only 47% of firm-years record positive R&D in a given year. Second, most internal R&D spending is wage-related, indicating that innovative activity is labor-intensive. Third, equity issuance is common enough to be economically meaningful: 29% of firms issued equity at least once in the preceding three years. These features make the data well suited to studying how monetary policy changes the composition of innovative activity across firms.

3.6 Monetary policy shocks

We use the narrative shock series from Holm, Paul, and Tischbirek (2021), constructed following Romer and Romer (2004). The idea is to isolate policy-rate changes orthogonal to Norges Bank's own forecasts of output and inflation. Meeting-level shocks are summed to annual frequency to match the firm panel.

Variables	Mean	S.D.
Panel A: Overview (USD 1,000)		
Total internal R&D spending	884	5,736
Wage-related R&D spending	558	3,426
Building & equipment R&D spending	45	464
Other R&D spending	282	2,764
Wage bill	15,616	39,051
Fixed capital	11,506	51,486
Total assets	50,141	132,377
Equity	17,570	50,092
Debt	32,810	93,386
Value added	20,785	48,075
Panel B: Other		
Share of firms with non-zero R&D spending	0.47	0.50
Equity issuance	0.15	0.35
Panel C: Left-hand side variables (percent of value added)		
Δ Total internal R&D spending	0.39	4.88
Δ Wage-related R&D spending	0.28	3.32
Δ Building & equipment R&D spending	0.04	1.70
Δ Other R&D spending	0.08	2.01
Δ Fixed investments	1.28	19.76
Δ Wage spending	3.07	13.59
Panel D: Performance measures		
Δ Return on assets (percentage points)	-0.32	9.20
Δ Productivity (percent)	-0.34	18.07
Panel E: Heterogeneity variables		
Interest costs to earnings	0.10	0.40
Debt to fixed capital	12.15	24.89
Equity issuance	0.29	0.45
Δ Value-added (percent)	3.33	17.90

Table 1: Descriptive statistics.

Figure A.1 plots the series. The identifying variation includes the well-known contractionary shocks in 2002 and expansionary shocks in 2003, which were also criticized by Norges Bank Watch at the time (Bjørnland, Ekeli, Geraats, and Leitemo, 2004). Norway is particularly well suited to this analysis because conventional monetary policy remained operative throughout the sample and was not constrained by the effective lower bound.

4 Aggregate and average R&D responses

We begin by documenting the average effect of monetary policy on R&D. These results establish that R&D is an economically meaningful adjustment margin under monetary tightening. They also motivate the paper's central question: whether the average decline conceals an important reallocation of innovative activity across firms.

4.1 Aggregate R&D responses

We estimate aggregate responses using local projection instrumental variables. In the first stage, we regress changes in the Norwegian policy rate on the narrative monetary policy shocks:

$$\Delta r_t = \alpha + \beta \varepsilon_t^m + \delta' \mathbf{X}_{t-1} + \varepsilon_t, \tag{9}$$

where ε_t^m are the shocks from Holm, Paul, and Tischbirek (2021) and $\mathbf{X}_{t-1}$ contains three lags of the monetary policy shocks. In the second stage, we estimate

$$\frac{y_{t+h} - y_{t-1}}{gdp_{t-1}} = \alpha_h + \beta_h \widehat{\Delta r_t} + \delta_h' \mathbf{X}_{t-1} + u_{t+h}, \tag{10}$$

where y is aggregate output, fixed capital formation, or R&D spending. We estimate the interest rate response as

$$r_{t+h} - r_{t-1} = \alpha_h + \beta_h \widehat{\Delta r_t} + \delta_h' \mathbf{X}_{t-1} + u_{t+h}. \tag{11}$$

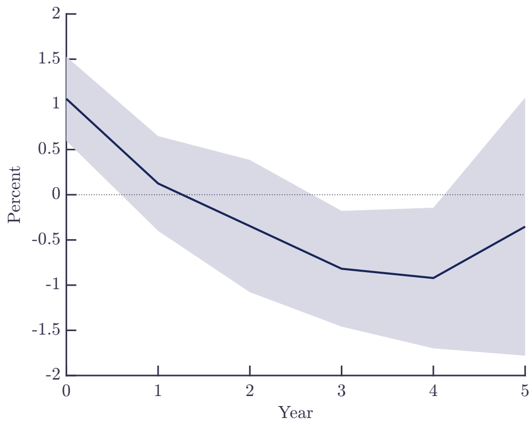
Figure 2 shows that the Norwegian economy responds to monetary tightening in familiar ways: the policy rate rises, output falls, and fixed investment contracts. Aggregate R&D spending also eventually declines. Relative to its average share in GDP, this decline is economically large. Although R&D only makes up about 1% of output, it accounts for almost 10% of the output response to monetary policy in year 4.

This result establishes that innovation is not insulated from conventional monetary policy. At the aggregate level, however, it remains unclear whether the fall in R&D reflects broad-based reductions across firms or sharp cuts concentrated among a narrower group. Since those two possibilities have different implications for future productivity, we turn to firm-level data.

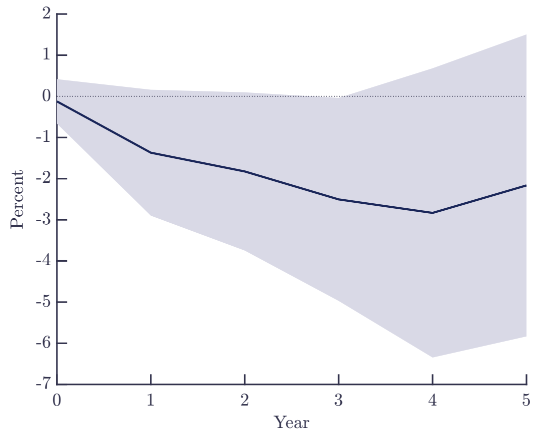
4.2 Firm-level R&D responses

We estimate firm-level responses using local projections with firm fixed effects:

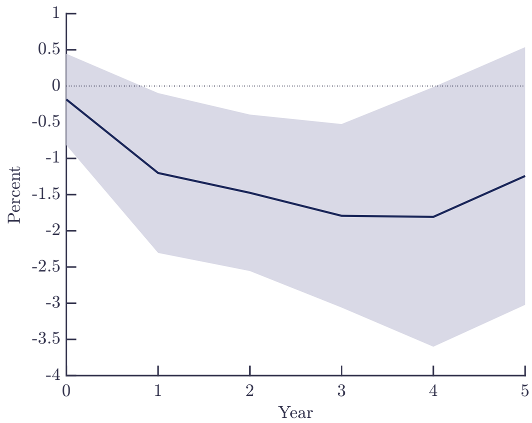
$$\frac{R\&D_{i,t+h} - R\&D_{i,t-1}}{VA_{i,t-1}} = \alpha_{i,h} + \beta_h \widehat{\Delta r_t} + \delta_h' \mathbf{X}_{t-1} + \gamma_h' \mathbf{Z}_{i,t-1} + \varepsilon_{i,t+h}, \tag{12}$$



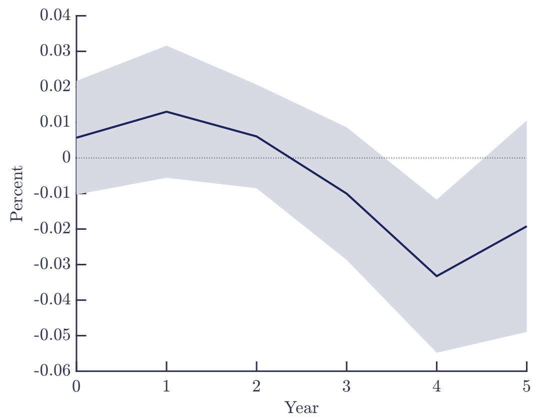
(a) Interest rate.



(b) Real output.



(c) Fixed capital formation.



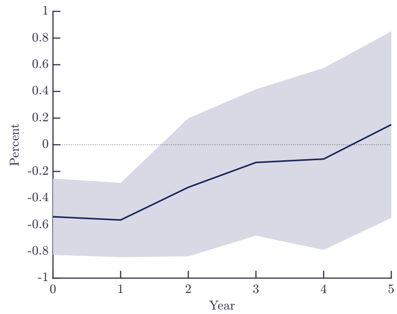
(d) R&D spending.

Notes: The figure displays the response of the key policy rate, aggregate output, aggregate fixed capital formation, and aggregate R&D spending to a 100 basis point interest rate increase, estimated using equation (10) or (9). The shaded areas indicate the 95% confidence interval based on the standard errors of Driscoll and Kraay (1998).

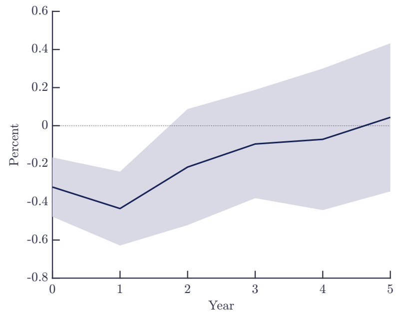
Figure 2: Aggregate responses to higher interest rates.

where $h = \{0, 1, \dots, 5\}$, $\mathbf{X}_{t-1}$ contains macroeconomic controls (inflation, GDP growth, and three lags of the monetary policy shocks), and $\mathbf{Z}_{i,t-1}$ contains lagged firm controls (leverage, liquidity, sales growth, interest costs to earnings, debt to fixed assets, firm age, firm size, and one lag of the dependent variable). Inference uses Driscoll and Kraay (1998) standard errors.

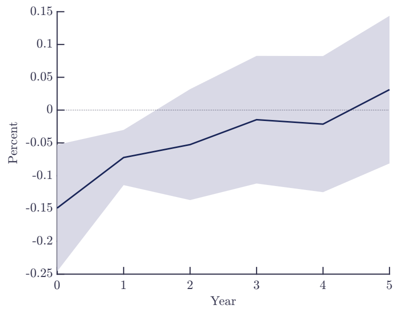
Figure 3 shows that internal R&D spending falls quickly after a contractionary monetary shock. A 100-basis-point increase in interest rates reduces internal R&D by about 0.5% of value added, with the response peaking early and remaining negative for several years. This timing is consistent with previous evidence for the United States and Europe (Ma, 2023; Döttling and Ratnovski, 2023), but it is also informative in its own right: firms



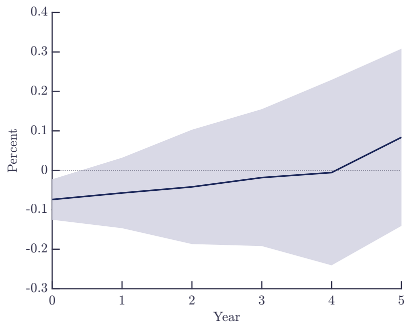
(a) Internal R&D spending.



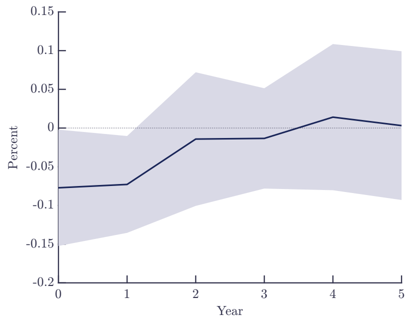
(b) Wage R&D spending.



(c) Capital R&D spending.



(d) Other R&D spending.



(e) External R&D spending.

Notes: The figures display the responses of total internal R&D spending, wage R&D spending, capital R&D spending, other R&D spending, and external R&D spending as shares of value added to a 100 basis point monetary policy shock, estimated using equation (12). The shaded areas indicate the 95% confidence interval based on the standard errors of Driscoll and Kraay (1998).

Figure 3: R&D spending responses to higher interest rates.

appear to use R&D as an early adjustment margin when financing conditions tighten.

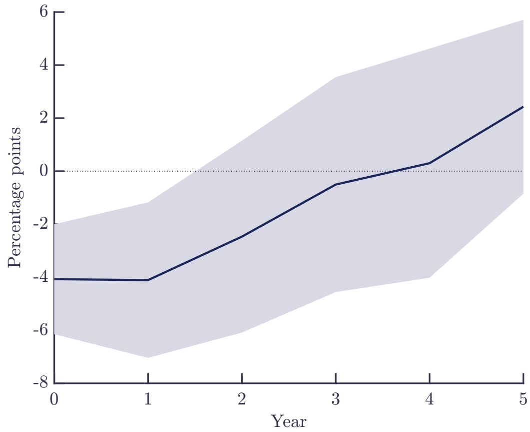
The composition of the decline is equally informative. Most of the response comes from lower R&D-related wage expenditures, while R&D capital expenditures and other R&D expenses decline by less. External R&D purchases also fall. Taken together, these patterns suggest that tighter monetary policy reduces underlying innovative effort rather than merely postponing ancillary expenditures.

Extensive-margin adjustment. The average decline in R&D could reflect either smaller innovation budgets among continuing R&D firms or some firms exiting R&D activity. To distinguish between these channels, we estimate

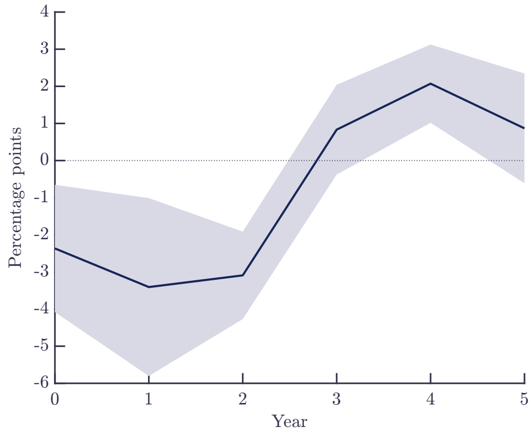
$$\mathbb{1}_{\{\chi_{i,t+h}\neq 0\}} = \alpha_{i,h} + \beta_h \widehat{\Delta r}_t + \delta_h' \mathbf{X}_{t-1} + \gamma_h' \mathbf{Z}_{i,t-1} + \varepsilon_{i,t,t+h}, \tag{13}$$

where the indicator equals 1 if the firm has non-zero R&D spending or issues stock.

Figure 4a shows a clear extensive-margin response. The share of firms with positive



(a) Share of firms with R&D spending.



(b) Share of firms issuing stocks.

Notes: The figures display the response of a dummy equal to one if firms have non-zero R&D spending or issues stocks to a 100 basis point monetary policy shock, estimated using equation (13). The shaded areas indicate the 95% confidence interval based on the standard errors of Driscoll and Kraay (1998).

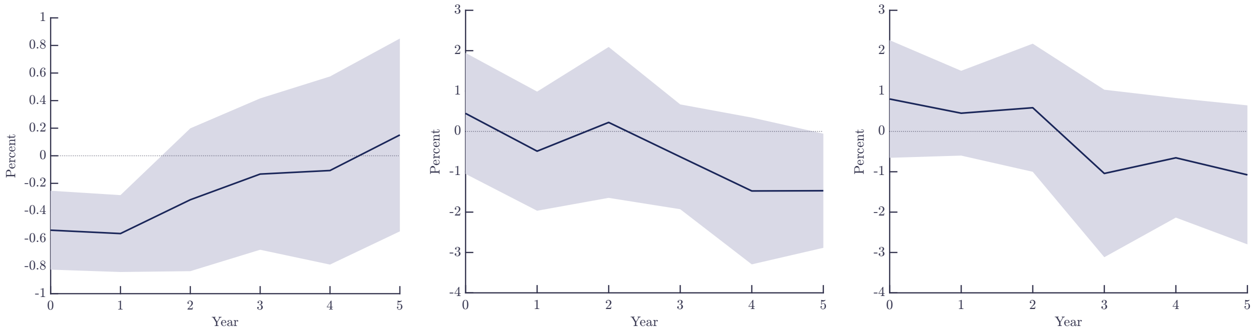
Figure 4: Extensive margin responses to higher interest rates.

R&D falls by roughly 4 percentage points after a 100-basis-point tightening. Since only 47% of firms undertake R&D in a typical year, this implies that around 8% of firms that would otherwise have innovated stop doing so after the shock. Monetary policy therefore affects both the intensity of innovation and participation in innovation.

Figure 4b shows that firms also respond to an interest rate increase by reducing stock issuance activity. About 15% of firms in our sample issue stocks in any given year (see Table 1). Hence, the estimated 3-percentage-point reduction in stock issuance activity is about 20%. The stock issuance response closely aligns with the interest rate movement in Figure 2a, consistent with monetary policy being an important factor in the external financing market.

R&D relative to labor and fixed capital. To assess whether R&D behaves differently from other input margins, we compare its response to those of total wages and fixed capital formation.

Figure 5 shows a striking difference in timing. R&D falls almost immediately, whereas broader wage adjustment and fixed-capital adjustment occur later. This suggests that firms treat R&D as a relatively flexible expenditure margin. In that sense, monetary transmission does not fall evenly across firms' activities: it falls early on expenditures that are potentially tied to future growth.



(a) Internal R&D spending. **(b)** Total wages. **(c)** Fixed capital formation.

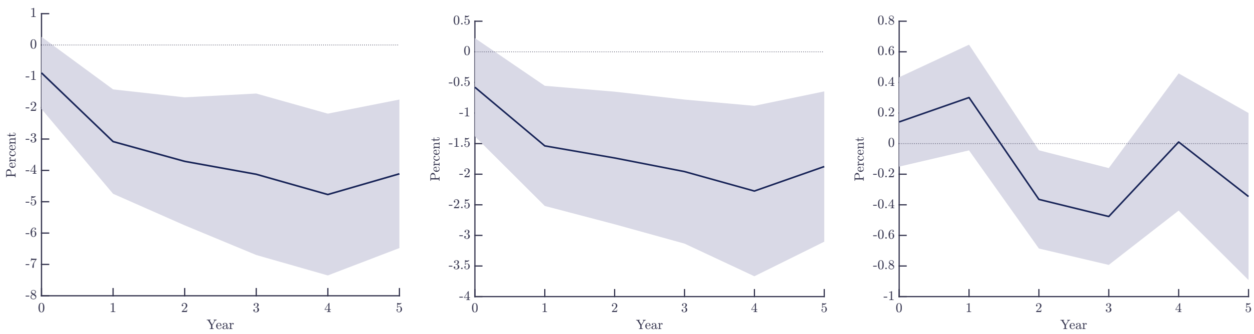
Notes: The figure displays the response of total internal R&D spending and fixed capital as a share of value added to a 100 basis point monetary policy shock, estimated using equation (12). The shaded areas indicate the 95% confidence interval based on the standard errors of Driscoll and Kraay (1998).

Figure 5: R&D spending, labor, and fixed capital responses to higher interest rates.

Productivity effects. To examine whether lower R&D translates into lower firm performance, we estimate

$$y_{i,t+h} - y_{i,t-1} = \alpha_{i,h} + \beta_h \widehat{\Delta r}_t + \delta_h' \mathbf{X}_{t-1} + \gamma_h' \mathbf{Z}_{i,t-1} + \varepsilon_{i,t,t+h}, \tag{14}$$

where $y_{i,t}$ is measured (log) productivity or return on assets, and the controls are the same as above.



(a) TFPR response. **(b)** Return on assets. **(c)** TFPR response. R&D vs. non-R&D firms.

Notes: The figures displays the responses of productivity estimated using Levinsohn and Petrin (2003) and return on assets (profits divided by total assets) to a 100 basis point monetary policy shock, estimated using equation (12). The shaded areas indicate the 95% confidence interval based on the standard errors of Driscoll and Kraay (1998).

Figure 6: Productivity responses to higher interest rates.

Figures 6a and 6b show that both productivity and return on assets decline after monetary tightening, with a delay relative to the R&D response. This timing is consistent with lower innovation affecting firm performance only gradually.

At face value, the productivity response is large. But measured productivity may also reflect changes in demand, markups, and sales. To isolate the component more plausibly linked to innovation, we compare the productivity response of R&D firms with that of non-R&D firms in Figure 6c. To estimate this, we use the full sample including non-R&D firms and estimate Equation (14) with an interaction term equal to one if the firm is in the R&D sample. The relative response is much smaller than the baseline estimate, suggesting that standard productivity measures likely overstate the R&D-specific channel when used in isolation. Still, R&D firms experience a larger productivity decline than non-R&D firms, consistent with lower innovation contributing to lower future performance.

The average evidence therefore makes two points. First, R&D is a meaningful and early margin of adjustment to monetary tightening. Second, the timing of productivity declines is consistent with R&D being one channel through which monetary policy affects future firm performance. The next section shows that these average effects are driven disproportionately by a particular set of firms.

5 Heterogeneous R&D responses

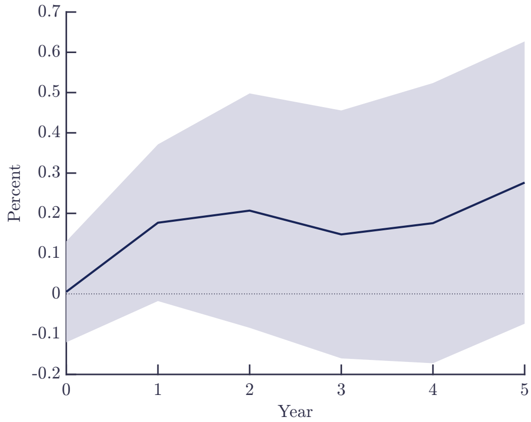
Average responses conceal substantial heterogeneity. The central question in this section is not whether monetary policy reduces R&D on average, but whether it does so uniformly across firms or whether it shifts the burden of adjustment toward firms whose innovative activity is especially important for future growth. Guided by the model in Section 2, we ask whether the strongest responses come from firms that are both externally equity-dependent and high-growth.

Linear interaction evidence. We begin with a linear interaction framework:

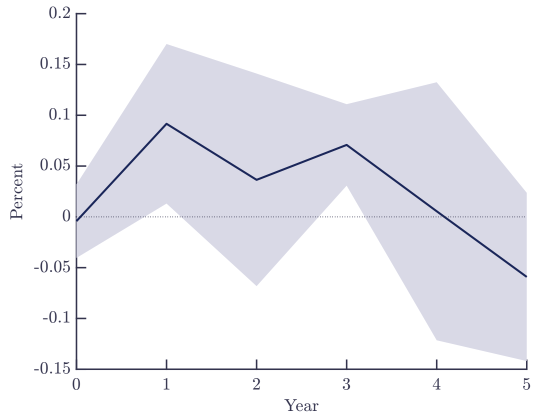
$$\frac{R\&D_{i,t+h} - R\&D_{i,t-1}}{VA_{i,t-1}} = \alpha_{i,h} + \delta_{t,h} + \beta_h \widehat{\Delta r_t \cdot z_{i,t-1}} + \delta_h' \mathbf{X}_{t-1} + \gamma_h' \mathbf{Z}_{i,t-1} + \varepsilon_{i,t,t+h}, \tag{15}$$

$$\Delta r_t \cdot z_{i,t-1} = \alpha_t + \beta \varepsilon_t^m \cdot z_{i,t-1} + \delta' \mathbf{X}_{t-1} + \gamma' \mathbf{Z}_{i,t-1} + \varepsilon_t. \tag{16}$$

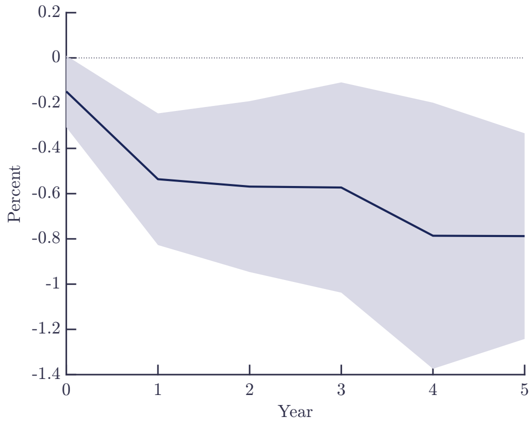
where $z_{i,t-1}$ is a firm variable that we interact with monetary policy. The controls are the same as in the specifications in Section 4, except that we always include the interaction variable $z_{i,t-1}$ as one of the firm-specific controls in $\mathbf{Z}_{i,t-1}$. The coefficient of interest is β_h,



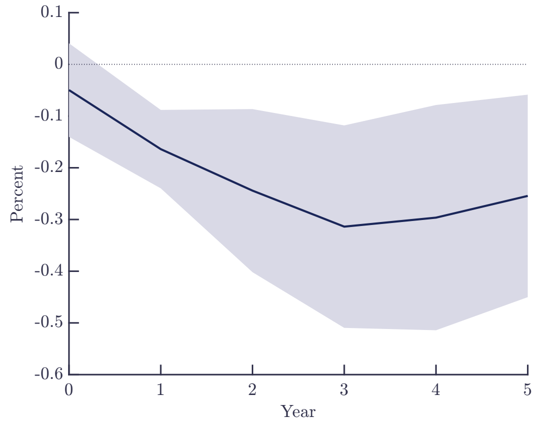
(a) Debt-to-capital.



(b) Interest-to-income.



(c) Recent equity issuer.



(d) Value-added growth.

Notes: The figures show the estimated interaction coefficients β_h for a selected set of variables, estimated using Equations (15) and (16). The shaded areas indicate the 95% confidence interval based on the standard errors of Driscoll and Kraay (1998).

Figure 7: The association between selected observables and the R&D response to an interest rate increase.

which estimates the marginal association between $z_{i,t-1}$ and the R&D response to monetary policy.

Figure 7 delivers a sharp result. Among the characteristics we consider, recent equity issuance and prior growth are the only robust predictor of a stronger R&D response to higher interest rates. The associations are consistent across time and statistically significant from year one to five. Firms that recently issued equity or with faster value-added growth reduce R&D more after monetary tightening. By contrast, measures of debt constraints, such as debt relative to fixed assets and the interest burden (Lian and Ma, 2021) are not systematically associated with the monetary policy responses.

The pattern observed in Figure 7. If conventional debt-based channels were the main source of heterogeneity, one would expect proxies for debt constraints to matter, such as debt-to-capital or interest-to-income. Our evidence does not suggest they matter much. Instead, what matters is external equity issuance and growth—precisely the dimension that should amplify valuation sensitivity in the model in Section 2. The same conclusion holds when growth is measured using TFP rather than value added (Figure B.2 in Appendix B) and when we control for all interactions at the same time in Figure B.1 in Appendix B.

Non-linear evidence. To make this interaction explicit, we estimate a specification that splits firms into four groups: low-growth non-issuers, low-growth issuers, high-growth non-issuers, and high-growth issuers:

$$\begin{aligned}\frac{R\&D_{i,t+h} - R\&D_{i,t-1}}{VA_{i,t-1}} = \alpha_{i,h} &+ \beta_1^h \widehat{\Delta r}_t \mathbb{1}_{\Delta VA_{i,t-1} < \text{ median \& not stock issuer}} + \beta_2^h \widehat{\Delta r}_t \mathbb{1}_{\Delta VA_{i,t-1} < \text{ median \& stock issuer}} \\ &+ \beta_3^h \widehat{\Delta r}_t \mathbb{1}_{\Delta VA_{i,t-1} \geq \text{ median \& not stock issuer}} + \beta_4^h \widehat{\Delta r}_t \mathbb{1}_{\Delta VA_{i,t-1} \geq \text{ median \& stock issuer}} \\ &+ \delta_h' \mathbf{X}_{t-1} + \gamma_h' \mathbf{Z}_{i,t-1} + \varepsilon_{i,t,t+h}.\end{aligned} \tag{17}$$

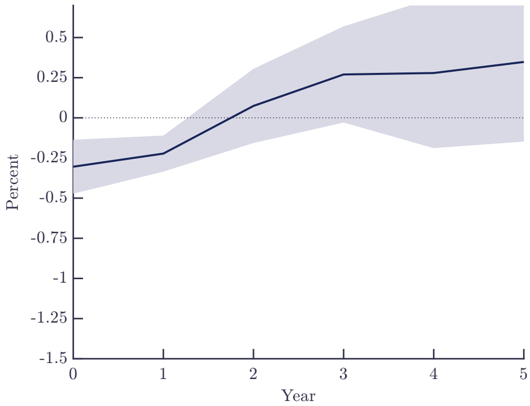
The coefficients β_h^j measure the average R&D spending response to an interest rate increase within each group. The estimation of Equation (17) requires four instruments in the first stage, in which the monetary policy shocks are interacted with the group dummies.

Figure 8 shows that the strongest response comes from firms that are both high-growth and recent equity issuers. These firms reduce R&D by the most after a contractionary shock. Firms with only one of the two characteristics also respond more than firms with neither trait. Low-growth firms without recent equity issuance exhibit comparatively little response.

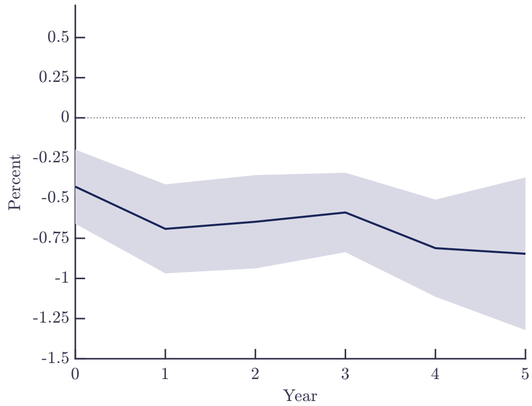
This is the central empirical result of the paper. Monetary policy does not affect innovative firms uniformly. Instead, it reallocates the burden of adjustment toward firms whose innovative activity is both externally valuation-sensitive and closely tied to future growth.

Interpretation. The economic logic is straightforward. For internally financed firms, the relevant valuation of innovative investment is largely private. For firms that must access external equity markets, the relevant valuation is the market valuation assigned by outside investors. When interest rates rise, those valuations fall, making external finance more dilutive and increasing the effective cost of R&D. This is the financing channel.

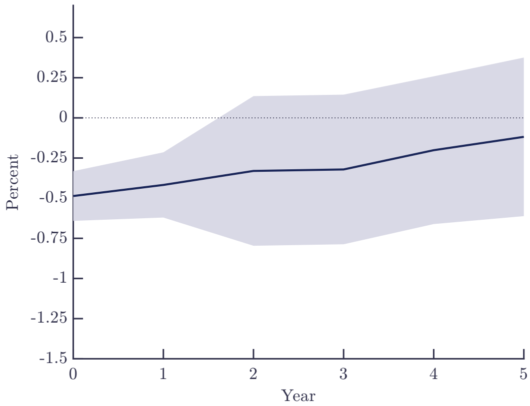
High-growth firms are even more exposed because their value depends disproportionately on distant future cash flows. A rise in discount rates therefore reduces valuations more sharply for them than for low-growth firms. This is the growth-sensitivity channel.



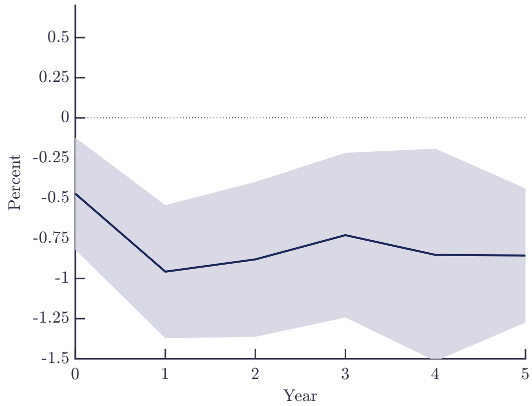
(a) Low value-added growth & not equity issuer.



(b) Low value-added growth & equity issuer.



(c) High value-added growth & not equity issuer.



(d) High value-added growth & equity issuer.

Notes: The figures show the R&D responses to a 100-basis-point interest rate increase with four groups, estimated using Equation (17). The shaded areas indicate the 95% confidence interval based on the standard errors of Driscoll and Kraay (1998).

Figure 8: R&D responses to an interest rate increase by value-added growth and recent equity issuer groups.

Our evidence provides little comparable support for conventional debt-based transmission to R&D. Proxies for debt-based borrowing constraints do not explain which firms cut innovation the most. We therefore interpret the cross-sectional evidence as pointing more strongly toward an asset-price channel than toward standard debt-based alternatives.

Broader implications. The aggregate significance of these results comes from the type of firms that respond. High-growth firms contribute disproportionately to job creation, output growth, and productivity growth (Haltiwanger, Jarmin, Kulick, and Miranda, 2016; Acemoglu, Akcigit, Alp, Bloom, and Kerr, 2018; Sterk, Sedláček, and Pugsley, 2021), and recent equity issuance is characteristic of firms in expansionary phases of their lifecycle (DeAngelo, DeAngelo, and Stulz, 2006; Dickinson, 2011). If monetary tightening causes these firms to reduce R&D more than others, then the same aggregate decline in innovative spending may have larger long-run consequences than a representative-firm perspective would imply.

6 Conclusion

This paper studies monetary transmission through the composition of firm-level R&D adjustment. We show that contractionary monetary policy reduces R&D spending on average, induces some firms to exit R&D altogether, and is followed by lower productivity. But the paper's main contribution is not the average effect itself. It is to show that the decline in R&D is concentrated in firms with high growth and recent equity issuance.

This compositional pattern changes how the real effects of monetary policy should be interpreted. Tighter policy does not fall uniformly across firms. Instead, it disproportionately curtails innovation in firms whose future growth appears especially dependent on external valuations and continued innovative investment. Since these firms are likely to be unusually important for aggregate dynamism, the allocation of monetary transmission across firms matters alongside its aggregate size.

Our evidence is consistent with an asset-price channel of monetary transmission, in which higher interest rates depress external valuations and thereby raise the effective cost of equity-financed R&D. More broadly, the paper suggests that monetary policy changes not only the level of spending in the economy, but also its composition across firms and activities. The relevant question is therefore not only how much spending falls today, but also which firms scale back the investments that shape future productivity growth.

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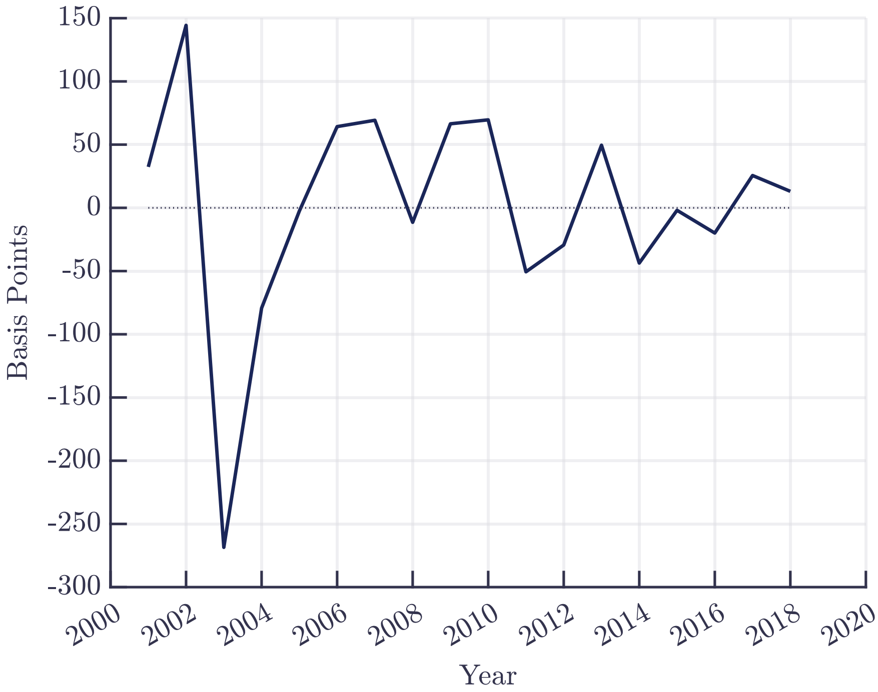
Online Appendix to
"Monetary Transmission to Firm-level R&D"

Ruslana Datsenko   Martin B. Holm

A Monetary shocks from Holm, Paul, and Tischbirek (2021)

Central banks adjust interest rates mostly in response to current or expected economic conditions. To estimate the effect of monetary policy, it is important to isolate the component of interest-rate changes that is orthogonal to those policy responses. We therefore use the monetary policy shock series from Holm, Paul, and Tischbirek (2021), which follows the logic of Romer and Romer (2004).



Notes: The figure displays the monetary policy shocks from Holm, Paul, and Tischbirek (2021).

Figure A.1: Monetary policy shock series.

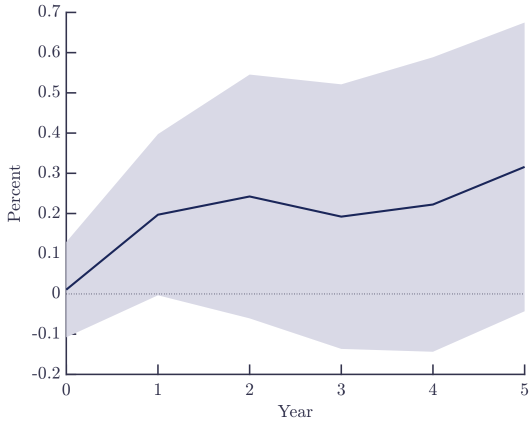
Holm, Paul, and Tischbirek (2021) estimate the following regression at the policy-meeting frequency:

$$\delta i_m = \alpha_1 + \alpha_2 i_{m,-1} + \sum_{k=0}^{I} \beta_k^{\pi} \pi_{m,t+k} + \sum_{k=0}^{I} \beta_k^{\delta\pi} \Delta\pi_{m,t+k} + \sum_{k=0}^{I} \beta_k^{y} y_{m,t+k} + \sum_{k=0}^{I} \beta_k^{\delta y} \Delta y_{m,t+k} + \gamma_1 ex_{m,-1} + \gamma_2 I_m^{IT} \cdot ex_{m,-1} + \varepsilon_m^{MP}. \tag{A.1}$$

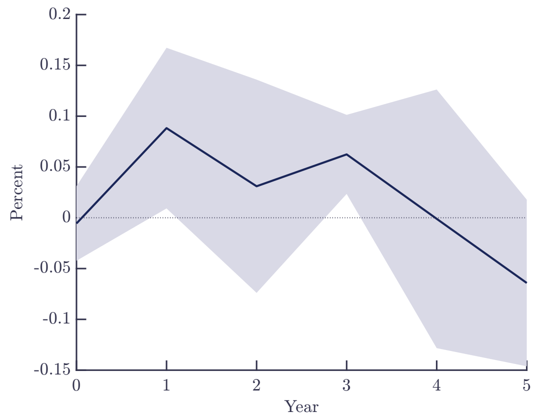
The residual ε_m^{MP} is the monetary policy shock. Holm, Paul, and Tischbirek (2021) aggregate these meeting-level shocks to annual frequency by summing all shocks within a year.

Figure A.1 displays the resulting series. As discussed in Holm, Paul, and Tischbirek (2021), the large shock in 2003 corresponds to policy decisions that were also criticized by external observers in Norges Bank Watch (Bjørnland, Ekeli, Geraats, and Leitemo, 2004).

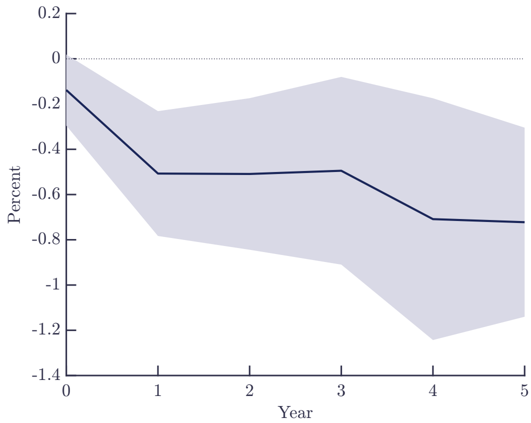
B Extra figures



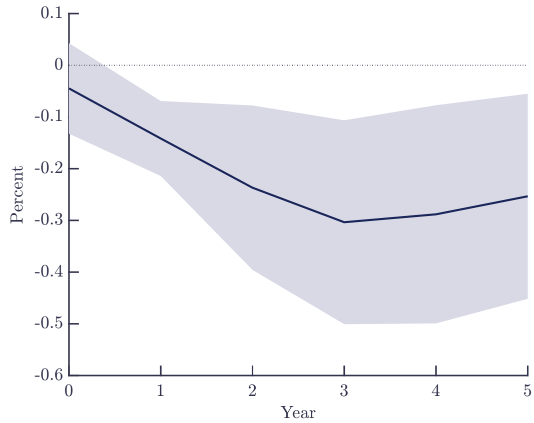
(a) Debt-to-capital.



(b) Interest-to-income.



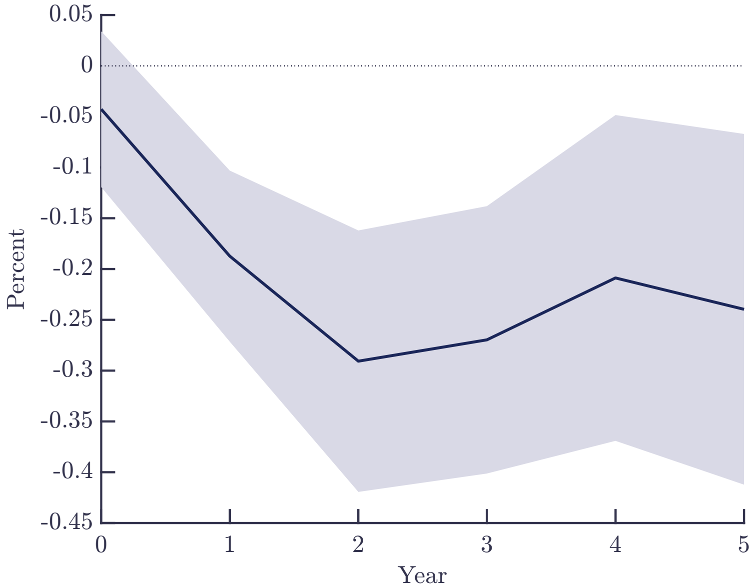
(c) Recent equity issuer.



(d) Value-added growth.

Notes: The figures show the estimated interaction coefficients β_h for a selected set of variables, estimated using Equations (15) and (16) when we include all interaction effects simultaneously. The shaded areas indicate the 95% confidence interval based on the standard errors of Driscoll and Kraay (1998).

Figure B.1: The association between selected observables and the R&D response to an interest rate increase.



Notes: The figures show the estimated interaction coefficients β_h for past tfpr growth, estimated using Equations (15) and (16). The shaded areas indicate the 95% confidence interval based on the standard errors of Driscoll and Kraay (1998).

Figure B.2: Robustness: TFPR growth instead of value-added growth.