Journal of Monetary Economics 134 (2023) 53–72

Contents lists available at ScienceDirect

Journal of Monetary Economics

journal homepage: www.elsevier.com/locate/jmoneco

Monetary policy and intangible investment☆

Robin Döttling[a,*], Lev Ratnovski[b]

[a] Erasmus University Rotterdam, Burgemeester Oudlaan 50, 3062 PA Rotterdam, the Netherlands
[b] International Monetary Fund, 700 19th St. NW, Washington DC 20431, United States

ARTICLE INFO

Article history:
Received 29 December 2021
Revised 31 October 2022
Accepted 1 November 2022
Available online 3 November 2022

JEL classification:
E22
E52
G31
G32

Keywords:
Intangible investment
Monetary policy
Credit channel
Stock returns
Heterogeneity

ABSTRACT

The investment and stock prices of firms with relatively more intangible assets respond less to monetary policy. Similarly, intangible investment responds less to monetary policy compared to tangible investment. These effects are most pronounced among financially constrained firms, indicating that corporate intangible capital weakens the credit channel of monetary policy transmission. The evidence that higher depreciation rates or higher adjustment costs of intangible assets explain these effects is mixed, suggesting a smaller role for these channels.

1. Introduction

Technological progress and the transition to a service economy have increased the importance of corporate intangible assets, such as the knowledge derived from R&D, intellectual property, organizational structure, business strategy, and brand equity. Intangible investment was under half of tangible investment in the 1970s, and now exceeds tangible investment (Corrado and Hulten, 2010). This technological transition is associated with changes in corporate financing and investment patterns. The literature documents that firms with relatively more intangible assets use less debt and invest mostly from internal funds, due to the lower collateral value of intangible assets (Bates et al., 2009; Brown et al., 2009; Falato et al., 2020). On the asset side, intangible investment responds less than tangible investment to changes in corporate valuation

☆ We are grateful to Dalida Kadyrzhanova and Camelia Minoiu for substantial contribution in the early stages of this project. We thank for helpful comments and suggestions an anonymous referee, Urban Jermann (the editor), Stijn Claessens, Romain Duval, Michael Ehrmann, Peter Hoffmann, Albert-Jan Hummel, Marek Jarocinski, Peter Karadi, Luc Laeven, Alberto Martin, Roberto Steri, Felix Ward, Ryan Peters, Andreas Neuhierl, Martina Jasova, Petros Migiakis, as well as seminar participants at the 2022 EFA Annual Meeting, the 2021 FIRS Conference, MoFiR Virtual Seminar Series, European Central Bank, the Bank of Portugal, Erasmus University Rotterdam, Tinbergen Institute Macro Research Day, the 6th IWH FIN-FIRE Workshop, the 2020 EEA Virtual Congress, the 8th workshop of the MPC Task Force on Banking Analysis for Monetary Policy, and De Nederlandsche Bank. Francesca Caucci and Anna Stelzer provided excellent research assistance. Much work on this paper took place when Lev Ratnovski was at the European Central Bank. The views expressed in this paper are those of the authors and do not represent those of the ECB, the IMF, nor of their executive boards or management.

* Corresponding author.
E-mail address: doettling@rsm.nl (R. Döttling).

https://doi.org/10.1016/j.jmoneco.2022.11.001
0304-3932/

(Crouzet and Eberly, 2021; Peters and Taylor, 2017), and intangible assets depreciate faster than physical capital (Ewens et al., 2019). These corporate financing and investment patterns raise the question of how corporate intangible capital affects monetary policy transmission. While the relation between the rise of intangible capital and monetary policy transmission has been recognized in the academic and policy debate, comprehensive empirical evidence investigating this link is lacking.

We analyze the relationship between intangible capital and monetary policy transmission among publicly-listed U.S. firms using two empirical approaches. The first approach examines the heterogeneity in firm stock price responses to monetary policy announcements to elicit the market's perception of how monetary policy affects firms depending on their intangible capital stock. The second approach uses instrumental variable local projections to directly estimate the slow-moving adjustment of firm investment in response to monetary policy over horizons of multiple quarters (Jordà, 2005). The two approaches are complementary in their identification strategy. The stock price analysis identifies monetary policy shocks from changes in Fed Funds futures prices in a narrow time window around FOMC announcements (as in Bernanke and Kuttner, 2005), thus offering a tight high-frequency specification. The investment response analysis, in turn, uses these high-frequency shocks to instrument the monetary policy stance (following Gertler and Karadi, 2015), thus mirroring the stock market results in a low-frequency dynamic environment.

These two empirical approaches yield consistent results documenting that the stock prices and investment of firms with relatively more intangible capital respond less to monetary policy. Similarly, intangible investment responds less to monetary policy compared to tangible investment. These findings are present across alternative measures of intangible capital and monetary policy shocks, and robust to controlling for a rich set of time-varying firm characteristics, the interactions of firm characteristics with the monetary policy stance and with GDP growth, firm fixed effects, and granular time-by-industry fixed effects. These controls ensure that the results are not driven by differences in cyclicality or other observable differences between tangible and intangible firms, time-invariant unobservable firm characteristics, nor by economy-wide or industry-specific trends.

The effects of intangible capital on monetary policy transmission are statistically and economically significant. Whereas tangible investment declines by 3% to 6% after 12 quarters in response to a 25bps monetary tightening, intangible investment declines by less than 1%. In the cross-section of firms, a one standard deviation increase in the intangible-to-total capital ratio is associated with a one-tenth smaller stock price decline and one-seventh smaller investment decline in response to monetary tightening.

We test three economic channels that may explain why intangible assets mute monetary policy transmission. The first channel is a weaker credit channel of monetary policy. Monetary policy affects firm investment not only through the cost of capital, but also through the collateral value of firm assets and therefore firm financial constraints. However, intangible assets are not a good source of collateral, and consequently firms with relatively more intangible assets use less debt to begin with (Brown et al., 2009; Falato et al., 2020). Therefore, the marginal effect of monetary policy on collateral-based borrowing is smaller for firms with relatively more intangible assets. A testable prediction of the credit channel is that intangible assets weaken the transmission of monetary policy particularly among firms that are more reliant on collateral for their marginal borrowing and investment. Consistent with this prediction, the difference in the investment and stock price responses between tangible and intangible firms is more pronounced among more financially constrained firms, as proxied by young age and small size, high cash holdings, or tighter constraints according to the textual analyis-based *Delaycon* measure of Hoberg and Maksimovic (2015). Corroborating evidence also shows the net debt issuance in firms with relatively more intangible assets responds less to monetary policy, especially among more constrained firms.

The second economic channel relates to the fact that intangible assets have higher depreciation rates.[1] When the depreciation rate is higher, the elasticity of the user cost of capital (i.e., the sum of the interest rate and the depreciation rate) to interest rates is smaller (Crouzet and Eberly, 2019). Therefore, investment may respond less to changes in interest rates when depreciation rates are higher. Consistent with this channel, the weaker stock price and investment responses to monetary policy in firms with relatively more intangible assets are more pronounced among firms with a wider gap between tangible and intangible asset depreciation rates. However, some of these results have modest statistical and economic significance, indicating that the depreciation channel appears to play a smaller role in explaining our headline findings compared to the credit channel.

In the third economic channel, intangible investment may respond less to monetary policy due to higher adjustment costs. Higher adjustment costs may be driven by the fact that firm-specific intangible assets need to be built over a period of time and are not easily redeployable across firms. Moreover, the creation of intangible assets requires skilled human capital that is costly to hire and fire (Eisfeldt and Papanikolaou, 2013). However, using different adjustment cost proxies, we find that tangible and intangible investment by firms with higher adjustment costs respond *more* to monetary policy.[2] The extrapolation of this finding to the comparison of tangible and intangible investment suggests that higher adjustment costs unlikely contribute to the weaker response of intangible investment to monetary policy.

Our empirical strategy hinges on resolving a number of methodological challenges. The first challenge is measuring intangible capital. Firm financial statements report tangible investment and capital stock. By contrast, most intangible investment

[1] For example, the BEA and Ewens et al. (2019) estimate intangible asset depreciation rates of between 10%–46%, while most tangible asset depreciation rates are below 10% (Li, 2012).

[2] A possible mechanism behind this result is that interest rates are positively associated with uncertainty (Bekaert et al., 2013), and uncertainty discourages investment with high adjustment costs (Bloom, 2009).

is expensed, and most intangible capital is not recorded on a firm's balance sheet. Following Peters and Taylor (2017), in firm-level Compustat data we define intangible investment as expenditures on R&D and organizational capital. These expenditures are capitalized and supplemented with on-balance sheet intangible assets (externally acquired patents, software, and post-merger goodwill) to obtain an estimate of a firm's intangible capital stock. The results are robust to using alternative measures of firm-level intangible capital from Ewens et al. (2019), and to using the perpetual inventory method to measure the tangible capital stock as well. We also confirm that the weaker response of intangible investment to monetary policy holds in aggregate data sourced from the U.S. Bureau of Economic Analysis (BEA). This is reassuring given the BEA data cover all U.S. establishments rather than just public firms, and uses a different definition of intangible investment based on expenses on R&D, software, and artistic originals.

The second methodological challenge is to identify the effects of monetary policy on stock prices and investment. We identify monetary policy shocks from the change in the 3-months ahead Fed Funds futures prices in the 30 min around an Federal Open Markets Committee (FOMC) announcement, following Bernanke and Kuttner (2005) and Gurkaynak et al. (2005). We use these monetary policy shocks to directly estimate the high-frequency stock price response and also show that the results are robust to separating out central bank information shocks (Jarocinski and Karadi, 2020). The investment response analysis captures the monetary policy stance by the 1-year Treasury rate level (as in Cloyne et al., 2018), which is instrumented using the cumulative high-frequency monetary policy shocks (similar to Bu et al., 2021). This paper brings together two growing strands of literature. The first strand is the literature on the heterogeneity in firm investment and stock price response to monetary policy, usually related to firm financial constraints. The literature employs various proxies of financial constraints, including firm size (Gertler and Gilchrist, 1994; Kashyap et al., 1994), age (Cloyne et al., 2018; Jasova et al., 2021), cash and leverage (Jeenas, 2018), distance to default (Ottonello and Winberry, 2020), or composite indexes (Chava and Hsu, 2020; Ozdagli, 2018). We contribute to this literature by comprehensively documenting a novel source of heterogeneity in monetary policy transmission, namely that between firms with relatively more tangible and relatively more intangible assets, and between tangible and intangible investment. Crucially, our analysis controls for other firm balance sheet characteristics, including traditional proxies of financial constraints, and for the interaction of those characteristics with monetary policy. This ensures that the effect of intangible capital on monetary policy transmission is distinct from the effects of financial constraints on monetary policy transmission.

The second strand of related literature focuses on the secular rise of corporate intangible capital (Corrado et al., 2018; Corrado and Hulten, 2010) and its implications for firm productivity, financing, and investment (Bianchi et al., 2019; Brown et al., 2009; Crouzet and Eberly, 2019; Falato et al., 2020). Our analysis documents how these established features of intangible capital affect monetary policy transmission. (Caggese and Pérez-Orive, 2022) develop a model in which lower interest rates reduce the income on corporate savings, disadvantaging firms with intangible assets that invest primarily from internal funds. This dynamic effect can further weaken the effect of monetary policy on intangible firms.

This paper proceeds as follows. Section 2 describes the data, Section 3 documents the main results, Section 4 presents evidence on the economic channels, and Section 5 concludes.

2. Data

Firm-level asset and investment data are sourced from quarterly financial statements of public firms in Compustat. Tangible investment and capital stock are reported in firm financial statements as capital expenditure (CAPX) and net property, plant, and equipment (PPENT), respectively.[3] Measuring intangible investment and capital is more challenging. Most intangible investment is expensed, so most of intangible capital is not on a firm's balance sheet. We follow Peters and Taylor (2017) and define intangible investment as the sum of research and development (R&D) expense and 30% of selling, general and administrative (SG&A) expense. R&D expense captures investment in knowledge capital, whereas a share of SG&A expense reflects investment in brand and organizational capital.[4] We also consider R&D and SG&A investments separately to verify the results are not driven by the pro rata share of SG&A expenditure, which cannot isolate intangible spending from other expenditures in SG&A when using intangible investment as dependent variable.

A firm's intangible capital stock is measured by capitalizing intangible investment using depreciation rate estimates from Li (2012) and adding on-balance sheet intangibles (mostly goodwill). We take this annual measure directly from Peters and Taylor (2017) through Wharton Research Data Services (WRDS), and interpolate it to obtain a quarterly measure.

Following sampling procedures standard in the corporate finance literature, we exclude financial firms (SIC 4900–4999), utilities (SIC 6000–6999), and government (SIC 9000 and above). We also exclude firms with missing or negative assets or sales, negative CAPX, R&D, or SG&A expenditure, and very small firms with physical capital under $5 million. The final sample contains 9863 unique firms and 327,431 firm-quarter observations between 1991 and 2016. We deflate all data using

[3] In U.S. GAAP, net property, plant, and equipment is defined as "the cost, less accumulated depreciation, of tangible fixed property used in the production of revenue". Therefore, the tangible capital stock measure is similar to our intangible capital stock measure in that it is derived from applying the perpetual inventory method on tangible fixed investment (using accounting-based depreciation rates).

[4] The share of SG&A expenditure attributed to organizational capital varies in the literature from 20% to 30% (see Falato et al., 2020). Ewens et al. (2019) estimate an average share of 28%. Compustat often adds R&D expenditure to SG&A expenditure. Therefore, we follow the procedure of Peters and Taylor (2017), Appendix B, and subtract R&D investment from SG&A expenditure whenever reported SG&A expenditure exceeds reported R&D investment.

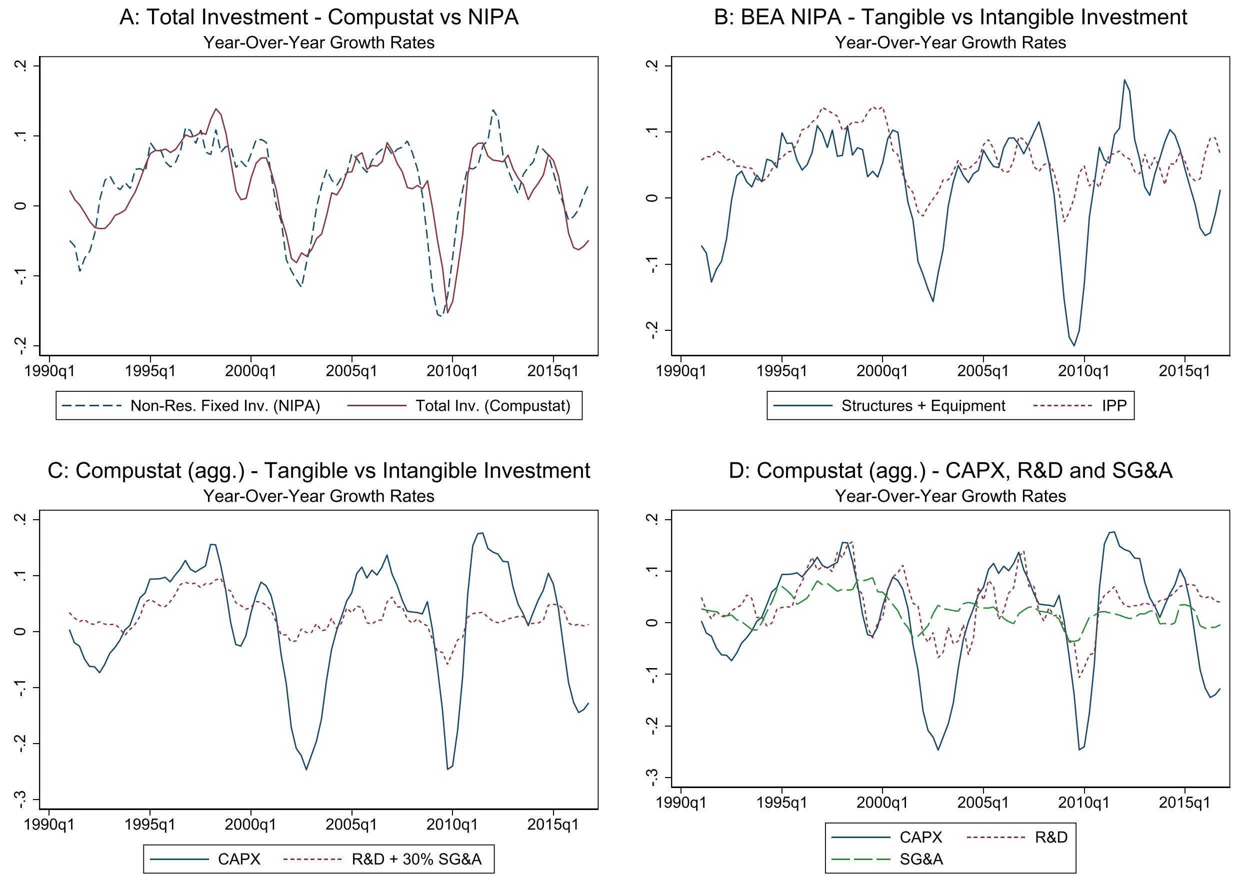

Fig. 1. Decomposing Investment Growth. This figure plots the growth rates of investment ratios in Compustat and BEA data. The aggregated Compustat data is based on public firms and defines intangible investment as investment in research and development (R&D) and organizational capital (measured as a portion of SG&A expenditures). The BEA data is based on all establishments and defines intangible investment as that in intellectual property products (IPP).

the CPI into real 1990 U.S. dollars, and map firm fiscal quarters to calendar quarters using information on a firm's fiscal year end (see Online Appendix Section AI.3).

Next to firm-level data, we source aggregate corporate asset and investment data from the BEA's National Income and Product Accounts (NIPA) at quarterly frequency. Total investment is defined as total non-residential fixed investment. This can be split into tangible investment in structures and equipment, and intangible investment in intellectual property products (IPP) that include R&D, software, and artistic originals.[5] We use NIPA data in robustness exercises and to illustrate the aggregate dynamics of tangible and intangible investment in different data sources.

2.1. Dynamics of tangible and intangible investment

Figure 1 depicts aggregate investment growth rates. Panel A documents a strong similarity in the growth rates of total investment (tangible + intangible) in Compustat and BEA data. Panels B and C decompose BEA and Compustat investment into their tangible and intangible components. In both datasets, intangible investment is procyclical but less volatile than physical investment (see Aghion et al., 2012; Barlevy, 2007; Fatas, 2000, for a discussion of the cyclicality of R&D investment). The lower cyclicality of intangible investment is consistent with the notion that it may respond less to monetary policy, a hypothesis that we explore rigorously in the remainder of the paper. The similarity between the firm-level and aggregate intangible investment series is reassuring, given the difficulty in measuring intangible investment. Panel D further decomposes Compustat intangible investment into its R&D and SG&A components. Although R&D investment appears somewhat more volatile, it is still substantially less cyclical than physical investment.

[5] NIPA Table 5.3.3 - Real Private Fixed Investment by Type. Compared to the firm-level Compustat-based measure, the BEA employs a narrower definition of intangible investment that excludes organizational capital. At the same time, BEA data cover all U.S. establishments, while Compustat only covers public firms. We show in the Online Appendix that the firm-level and aggregate data exhibit a similar upward trend in intangible investment and capital stock.

Table 1
Summary Statistics of Compustat Variables. Summary statistics are reported for all firms, and for intangible and tangible firms separately. Intangible firms are defined as those with an above-median intangible ratio (intangible-to-total capital ratio) in a given quarter. Tangible firms are below the median. The sample runs from 1991–2016 and includes all firms in the matched CRSP-Compustat sample excluding financial firms, utilities and government, and firms with missing or negative assets or sales, negative CAPX, R&D, or SG&A expenditure, very small firms with physical capital under $5 million. The *Intangible Ratio* is a firm's intangible-to-total capital, *total Q* is a firm's market value of total assets divided by the book value of total assets, *cash* is cash divided by book assets, *leverage* is long-term and short-term debt divided by book assets, *age* is measured as quarters since the first observation in Compustat, *book assets* are all assets reported on a firm's balance sheet, *total assets* are book assets plus off-balance sheet intangible capital, *Delaycon* is a textual analysis-based financial constraints measure taken from Hoberg and Maksimovic (2015), *dividend paid* is a dummy whether a firm paid a dividend in a given fiscal year, *debt growth* is the change in long-term and short-term debt relative to its lagged level, *equity growth* is the change in book equity relative to its lagged level, the *tangible investment rate* is CAPX divided by lagged property, plant and equipment, the *intangible investment rate* is intangible investment defined as R&D expenditures and 30% of SG&A expenditures divided by lagged intangible capital, and the *total investment rate* is the sum of tangible and intangible investment divided by lagged total capital. For more details on how the variables are constructed, see Table A1 in the Online Appendix.

	All			Intangible Firms			Tangible Firms		
	mean	p50	sd	mean	p50	sd	mean	p50	sd
Intangible Ratio	0.577	0.653	0.290	0.815	0.824	0.0964	0.347	0.359	0.217
Total Q	1.621	1.357	0.845	1.680	1.406	0.872	1.557	1.315	0.798
Cash	0.130	0.0596	0.163	0.171	0.0948	0.186	0.0961	0.0476	0.122
Leverage	0.288	0.248	0.252	0.219	0.181	0.215	0.300	0.275	0.230
Age	63.00	50	48.27	69.63	57	48.57	67.55	54	49.43
Book Assets	1.903	0.280	8.197	1.772	0.298	6.436	2.297	0.322	9.534
Total Assets	2.558	0.415	10.42	2.488	0.454	8.827	2.673	0.381	11.01
Delaycon	-0.0147	-0.0211	0.0886	-0.0208	-0.0270	0.0888	-0.0115	-0.0167	0.0873
Dividend Paid	0.429	0	0.495	0.399	0	0.490	0.483	0	0.500
Debt Growth	0.0650	-0.00908	0.549	0.0686	-0.0114	0.606	0.0682	-0.00766	0.513
Equity Growth	0.0172	0.0114	0.279	0.0186	0.0132	0.252	0.0207	0.0118	0.276
Total Inv. Rate	0.0550	0.0448	0.0405	0.0551	0.0470	0.0357	0.0552	0.0427	0.0443
Tangible Inv. Rate	0.0664	0.0462	0.0668	0.0763	0.0564	0.0676	0.0581	0.0397	0.0618
Intan Inv. Rate	0.0554	0.0476	0.0379	0.0525	0.0458	0.0345	0.0585	0.0500	0.0400
CAPX / Intan Inv.	2.432	0.504	6.192	0.411	0.256	0.758	4.625	1.462	8.419
CAPX / R&D	1.741	0.539	4.008	0.785	0.385	1.758	4.232	1.857	6.346
Observations	327431			125775			125825		

2.2. Other variables

Firm-level control variables are sourced from Compustat and include firm age, Tobin's Q, leverage, cash holdings, cash-flow, firm size, and a dummy for whether a firm pays a dividend (see Online Appendix Tables A1 and A2 for variable definitions). Daily stock returns data from CRSP are merged with Compustat using the linking table from WRDS. Variables are winsorized at the 1% level to avoid outliers. Table 1 presents summary statistics for all firms and separately for firms with above- and below-median intangible-to-total capital ratios. Consistent with the literature, firms with relatively more intangible assets have more cash, lower leverage, and are less likely to pay a dividend (see Falato et al., 2020). Unsurprisingly, firms with relatively more intangible assets have relatively higher intangible investment. The ratio of tangible over intangible investment is 0.411 for the average intangible firm and 4.652 for the average tangible firm. Otherwise, the two groups are comparable in terms of firm age, total assets, and profitability.

The macroeconomic variables 1-year Treasury rate, consumer price index (CPI), industrial production, real GDP growth, and the employment ratio are sourced from the Federal Reserve Economic Data, and the excess bond premium is taken from Gilchrist and Zakrajšek (2012) to control for financial conditions.

3. Main results

This section consists of two parts. The first part examines how the stock prices of firms with relatively more intangible assets respond to monetary policy shocks. The second part considers how intangible investment responds to monetary policy compared to tangible investment, and how the total investment in firms with relatively more intangible assets responds to monetary policy.

3.1. Stock price response to monetary policy shocks

The Federal Reserve communicates changes to its monetary policy stance through Federal Open Market Committee (FOMC) announcements. We identify monetary policy shocks using high-frequency movements in Fed Funds futures prices in the 30 min window around an FOMC announcement, following Bernanke and Kuttner (2005) and Gurkaynak et al. (2005). The identifying assumption is that this narrow window contains no other news that affect interest rate expectations. The data cover all FOMC meetings from 1991 to 2016.[6] We assess a firms' stock price response to monetary policy shocks using the regression specification:

$$RET_{it} = \beta_1 \cdot IR_{it} + \beta_2 \cdot \Delta FF4_t \times IR_{it} + \gamma_1' \cdot X_{it}^f + \gamma_2' \cdot \Delta FF4_t \times X_{it}^f + \eta_{jt} + \mu_i + \psi_{fq} + \varepsilon_{it}, \tag{1}$$

where RET_{it} is the stock return of firm i on the day of the FOMC meeting, and $\Delta FF4_t$ is the change in the 3-month ahead Fed Funds futures rate in the 30 min around the FOMC announcement on event-date t. IR_{it} is a firm's *intangible ratio*, defined as the ratio of intangible-to-total capital at the end of the previous quarter. The key coefficient of interest β_2 captures whether the stock prices of firms with relatively more intangible assets react differently to monetary policy surprises. The vector X_{it}^f contains time-varying firm-level controls Tobin's Q, age, cash holdings, leverage, size, cashflows, and a dummy for whether the firm pays a dividend. We control for the level of these firm characteristics and for their interaction with the FF4 shock, to ensure that any differences in the stock price response between tangible and intangible firms is not driven by other observable firm characteristics. Firm size is measured as book assets (which include tangible capital) plus off-balance sheet intangible capital, following Peters and Taylor (2017). The regressions thus include both the intangible-to-total capital ratio (as the main variable of interest), and the control variable for firm *total* assets, and therefore capture the *size* and the *composition* of a firm's capital stock.

The model is saturated with 4-digit NAICS industry × event-date fixed effects η_{jt} that absorb any differences across narrowly-defined industries on each announcement date. Furthermore, we report results with and without firm fixed effects μ_i that absorb all time-invariant, unobserved firm heterogeneity. Firm fixed effects offer a within-estimation of the effects of intangible capital on monetary policy response, which uses solely the time variation of the variables within each firm (equivalent to a de-meaning of all variables). All regression include fiscal-quarter fixed effects ψ_{fq} to control for seasonality (fiscal quarters may differ from calendar quarters, see Online Appendix Section AI.3). Standard errors are clustered at the industry and event-date levels.

In measuring stock returns RET_{it} we consider both raw and abnormal returns. Abnormal returns are estimated from a basic capital asset pricing model over 100 days prior to the FOMC meeting, using the CRSP value-weighted index as market benchmark. Abnormal returns control for a firm's beta, which captures the volatility of a stock and its exposure to systematic risk.

3.1.1. Results

Table 2 documents the headline results. Column 1 reports an average stock price response of −4.35% to a 1% unexpected increase in the Fed Funds rate (in line with −4.68% in Bernanke and Kuttner, 2005). Columns 2 to 5 add the interactions of ΔFF4 with firm characteristics under different stock return measures and fixed effect combinations. The main explanatory variable of interest is the interaction between ΔFF4 and a firm's intangible ratio. The coefficient estimate for this interaction term is stable at between 1.25 and 1.33 across the specifications and consistently significant at the 5% level. This implies that a one standard deviation increase in the intangible-to-total capital ratio (by 0.29) is associated with a 36bps–38bps smaller stock price decline in response to a 1% unexpected increase in the Fed Funds rate.

These results demonstrate that the market value of firms with relatively more intangible assets responds less to monetary policy shocks. This finding is robust in specifications that use abnormal stock price returns (columns 4 and 5), which verifies that the weaker response of intangible firms to monetary policy is not driven by their differential co-movement with the broader market and, by extension, by their exposure to systematic risk factors such as the macroeconomic cycle.[7] Online Appendix Table A4 further verifies that these results are driven by monetary policy shocks rather than communication of the central bank's views about the state of the economy (Jarocinski and Karadi, 2020), and that the results are robust to using an alternative measure of firm intangible capital from Ewens et al. (2019), an alternative firm-level tangible capital measure based on applying the perpetual inventory method to capital expenditures, and a within-firm de-meaned intangible ratio.

3.2. Investment response

This section analyzes the tangible, intangible, and total (tangible plus intangible) investment response to monetary policy in quarterly firm-level data.

3.2.1. Empirical strategy

The FF4 monetary policy shocks are appropriate for measuring their high-frequency impact on stock prices. However, the adjustment of investment is slow-moving, with long and uncertain lags, and measured at quarterly frequency. Therefore,

[6] As common in the literature, we exclude the FOMC meeting on September 17, 2001, which coincided with the market opening following the September 11, terrorist attacks. We thank Peter Karadi for kindly sharing the data.

[7] For example, a potential concern may be that intangible firms' stock returns react more to any unanticipated shock to the aggregate economy because they have riskier business models. Interestingly, in specifications with abnormal returns the coefficients on the interactions between the monetary policy shock and all firm characteristics except the intangible ratio become statistically insignificant or only marginally significant. Such weak significance appears consistent, for example, with the fact that some papers establish an amplifying and others a dampening effect of firm financial constraint measures on stock price response to monetary policy (Chava and Hsu, 2020; Ozdagli, 2018).

Table 2
Stock Returns Around FOMC Meetings. This table presents coefficient estimates from estimating Eq. (1). The dependent variable is a firm's stock return on FOMC announcement days. Columns 1–3 consider raw returns, and columns 4 and 5 consider abnormal returns, with betas estimated over a 100-day window before the event date using the CRSP value-weighted index as market benchmark. ΔFF4 is the change in the 3-months ahead Fed Funds futures rate in the 30 min around the FOMC announcement. *Intangible Ratio* is a firm's intangible-to-total capital ratio. Other control variables are defined in Online Appendix Table A1. The sample includes all FOMC meetings over 1991–2016, except the meeting on September 17, 2001, and covers all firms in the matched CRSP-Compustat sample excluding financial firms, utilities and government. Industry fixed effects are based on 4-digit NAICS codes. Standard errors in parentheses are clustered by event date and industry. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)
	Raw Return	Raw Return	Raw Return	Abnormal Return	Abnormal Return
ΔFF4	-4.35**				
	(1.74)				
ΔFF4 × Intangible Ratio		1.31**	1.29**	1.33**	1.25**
		(0.62)	(0.64)	(0.57)	(0.59)
ΔFF4 × Log Age		0.75***	0.76***	0.13	0.14
		(0.26)	(0.26)	(0.26)	(0.26)
ΔFF4 × Total Q		-0.42	-0.43	0.050	0.043
		(0.48)	(0.47)	(0.31)	(0.31)
ΔFF4 × Cash		-4.01*	-4.33*	-0.052	-0.18
		(2.24)	(2.22)	(1.06)	(1.07)
ΔFF4 × Leverage		-0.16	-0.18	-0.91	-0.97
		(1.15)	(1.12)	(1.00)	(0.97)
ΔFF4 × Cashflows		3.73	3.86	-3.54	-3.84
		(8.15)	(8.63)	(4.56)	(4.87)
ΔFF4 × Log Size		-0.63**	-0.66**	-0.064	-0.076
		(0.28)	(0.27)	(0.11)	(0.11)
ΔFF4 × Dividend Paid		0.33	0.27	-0.23	-0.29
		(0.35)	(0.36)	(0.21)	(0.23)
Observations	463,130	454,678	454,599	454,678	454,599
R-squared	0.030	0.239	0.258	0.140	0.160
Industry × Event-Date FE	No	Yes	Yes	Yes	Yes
Firm FE	Yes	No	Yes	No	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes
Firm-Level Controls	Yes	Yes	Yes	Yes	Yes

as common in the literature, we estimate the dynamic response of investment to monetary policy instrumented by the high-frequency FF4 shocks (similar to Bu et al., 2021; Cloyne et al., 2018).

We measure the monetary policy stance as the 1-year Treasury rate. Compared to the Fed Funds rate, the 1-year Treasury rate better captures interest rate variation in the unconventional monetary policy environment during the later part of our time sample. Because monetary policy is endogenous to macroeconomic conditions, we instrument the Treasury rate using cumulative FF4 shocks as a *level* measure of monetary policy surprises (as in Bu et al., 2021; Coibion, 2012; Romer and Romer, 2004), while controlling for key lagged macroeconomic variables.[8] The Online Appendix (Section AII) verifies that this approach yields the monetary policy responses of key macroeconomic variables consistent with the extant literature, and that the cumulative FF4 shocks are a strong instrument for the 1-year Treasury rate.

To trace out the dynamic impact of monetary policy on firm investment, we use instrumental-variable local projections (Jordà, 2005). That is, for each horizon h, we estimate the regression specification:

$$y_{it+h} - y_{it-1} = \beta_1^h \cdot \hat{R}_t + \gamma_1^{h\prime} \cdot X_{t-1}^m + \gamma_2^{h\prime} \cdot X_{it-1}^f + \mu_i + \psi_{fq} + \varepsilon_{it}, \tag{2}$$

where the outcome variable y_{it} is a measure of investment, and $\hat{R}_t$ is the instrumented 1-year Treasury rate. X_{t-1}^m contains lagged macroeconomic control variables (log CPI, log industrial production, the excess bond premium, real GDP growth, and the employment ratio). When estimating local projections on firm-level data, we include firm fixed effects μ_i, fiscal-quarter fixed effects ψ_{fq}, and the same firm-level controls X_{it-1}^f as in the stock returns regression, including a firm's intangible-to-total capital ratio. Note that we cannot include time fixed effects in Eq. (2), because they would absorb all time-series variation that identifies the coefficient of interest β_1^h. However, can include time fixed effects in further specifications that examine the interaction between monetary policy and firm characteristics (see Eq. (3) below), and confirm there that including time fixed effects does not affect the results.

[8] We follow Gertler and Karadi (2015), Footnote 11, and construct cumulative FF4 shocks by first creating a monthly series that accounts for the timing of FOMC announcements within a month. We then cumulate this monthly series to obtain a level measure, which is a strong instrument for the 1-year Treasury rate as compared to contemporaneous FF4 shocks, which have little explanatory power.

3.2.2. Results from local projections

The investment analysis considers as outcome variables the log of tangible, intangible, and total investment rates, defined as the respective investment divided by the lagged capital stock.[9] Figure 2, Panel A, documents an average decline of the firm total investment rate by almost 3% after 8 − 12 quarters in response to a 25bps monetary tightening in the full sample of firms. Panel B splits the sample and documents that the response of total investment is substantially weaker among firms with relatively more intangible capital. In response to a 25bps higher Treasury rate, firms with a below-median intangible ratio reduce their total investment by almost 5% after 10–12 quarters. By contrast, firms with an above-median intangible ratio reduce their total investment by around 1%. This pattern is consistent with the high-frequency results showing a weaker stock price response to monetary policy shocks in intangible firms (see Table 2).

Panels C and D decompose the total investment response by comparing the effects of monetary policy on a firm's tangible and intangible investment. The vast majority of the total investment response comes from tangible investment, which declines by about 5–6% after 12 quarters in response to a 25bps higher Treasury rate. By contrast, intangible investment declines by less than 1%.

To test whether the difference in the response of tangible and intangible investment is statistically significant, panel E plots the response of the log ratio of a firm's tangible over intangible investment, that is, the percentage point difference between the response of tangible and intangible investment. This ratio's decline by up to 4% is statistically different from zero. Panel F repeats this exercise using the log ratio of tangible investment to R&D. This narrower measure of intangible investment omits SG&A expenditure, and verifies that the weaker response of intangible investment is not driven by its SG&A component.[10]

3.2.3. Results from interaction term estimates

To ensure that the weaker total investment response in firms with relatively more intangible assets, documented in panel B of Fig. 2, is not driven by other observable differences between tangible and intangible firms (for example, in leverage or cash holdings, see the summary statistics in Table 1), we enrich Specification (2) with interaction terms between the 1-year Treasury rate and firm characteristics:

$$y_{it+h} - y_{it-1} = \beta_1^h \cdot IR_{it-1} + \beta_2^h \cdot \hat{R}_t \times IR_{it-1} + \beta_3^h \cdot \Delta Y_{t-1} \times IR_{it-1} + \gamma_1^{h\prime} \cdot X_{it-1}^f + \gamma_2^{h\prime} \cdot \hat{R}_t \times X_{it-1}^f + \mu_i + \eta_t + \psi_{fq} + \varepsilon_{it}. \tag{3}$$

This specification mirrors the stock returns Specification (1). The coefficient β_2^h captures whether firms with a higher intangible-to-total capital ratio respond differently to monetary policy, while controlling for the interaction of monetary policy with other firm characteristics X_{t-1}^f. Additionally, Specification (3) controls for the interaction of a firm's intangible ratio and GDP growth, $\Delta Y_{t-1} \times IR_{it-1}$, to ensure that the heterogenous effects of monetary policy on investment are not driven by differences in the cyclicality of the investment by tangible and intangible firms (for example, due to heterogeneity in firm financing patterns over the business cycle, see Covas and Den Haan, 2011). Since the main coefficient of interest is the interaction term coefficient β_2^h, we can include time fixed effects η_t, or industry-by-time fixed effects η_{jt}, to control for time-varying unobserved macroeconomic conditions that influence all firms, or all firms within a given industry, respectively. These fixed effects also ensure that the results are not driven by long-run economy-wide or industry-specific trends.[11]

Table 3 documents the results from estimating Eq. (3) for horizons of $h = 8$ and $h = 12$ quarters (at which the impulse response functions of Fig. 2 demonstrate the strongest investment response). The interaction term between the intangible ratio and the 1-year Treasury rate is positive and statistically significant (columns 2 and 5), also when including industry-by-time fixed effects (columns 3 and 6). A one standard deviation increase in the intangible-to-total capital ratio reduces a firm's total investment response to a 25bps increase in the 1-year Treasury rate by between 36bps and 44bps, corresponding to around one-seventh of the average investment response of 3%. This strong attenuating effect is consistent with the previous results from the sample splits in Fig. 2, panel B, and confirms that the weaker investment response by intangible firms is not driven by other firm characteristics.[12]

Robustness The Online Appendix (Section AIII) verifies that the results are robust to using monetary policy shocks separated from central bank information shocks from (Jarocinski and Karadi, 2020) as the instrument (see Online Appendix Figure A4). The results in Table 3 are also robust to using the alternative firm-level intangible capital estimate from

[9] See the Online Appendix Section AI for detailed variable definitions. These quarterly investment rates are winsorized at the 1% level, and their summary statistics are in line with the annual investment rates in Peters and Taylor (2017) (see Table 1).

[10] Figure A5 in the Online Appendix compares the response of the knowledge and organizational components of intangible investment to monetary policy. R&D and SG&A expenditures respond similarly to monetary policy and the total investment of firms with above-median knowledge or organizational capital respond less to monetary policy than those of firms below the medians. This verifies that our results are not driven by the fact that the investment in organizational capital is measured based on a pro rata 30% share of SG&A expenditure (consistent with the literature), which implies that changes in organizational investment cannot be isolated from other expenditures recorded in SG&A.

[11] In a robustness test (not reported) we confirm that the main results from estimating Specification (3) are very similar with and without time fixed effects. This indicates that unobserved time-varying macroeconomic conditions have a limited effect on our results and offers credibility to the results from estimating Specification (2) that cannot include time fixed effects.

[12] Note that the results on the weaker total investment response in firms with relatively more intangible assets and on the weaker intangible investment compared to tangible investment response mirror each other, as firms with relatively more intangible capital do more of intangible investment. The pooled correlation between firms' tangible-to-total capital and tangible-to-total investment ratios is 76.25%.

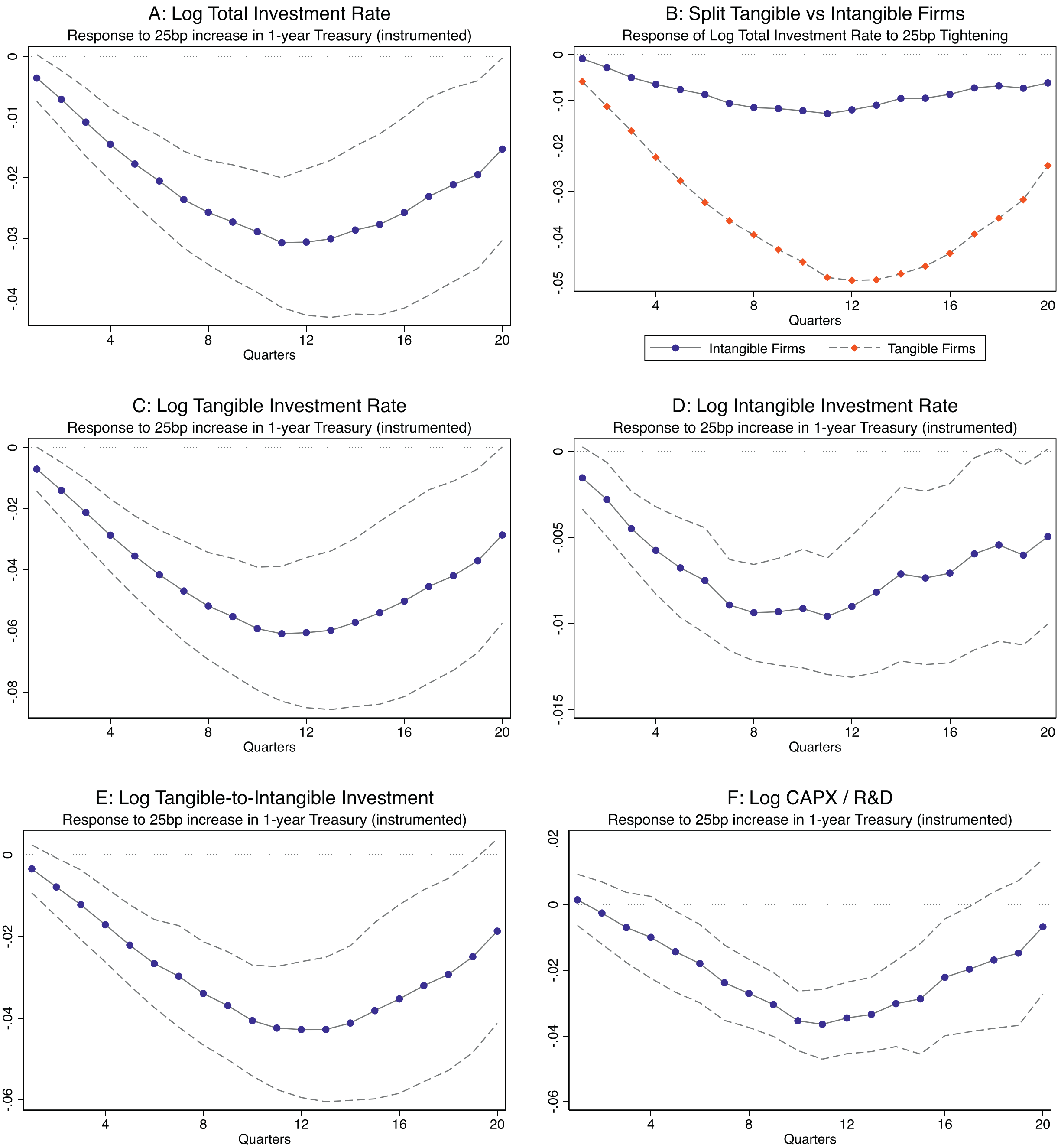

Fig. 2. Firm-level Investment Response. This figure plots the dynamic response of investment to a 25bps higher 1-year Treasury rate, estimated using Eq. (2). The 1-year Treasury rate is instrumented by cumulative high-frequency monetary policy shocks measured as changes in the 3-month ahead Fed Funds futures rate in the 30 min window around FOMC announcements. The sample covers all firms in the matched CRSP-Compustat sample excluding financial firms, utilities and government from 1991–2016. Each point represents the point estimate of the coefficient of instrumented the 1-year Treasury rate (β_1^h in Eq. (2)). All regressions include firm and macro controls, as well as firm and fiscal quarter fixed effects. The dashed line represents 95% confidence intervals using heteroscedasticity and autocorrelation robust Driscoll-Kraay standard errors. Intangible firms (tangible firms) are firms with an above-median (below-median) intangible-to-total capital ratio in a given quarter.

Table 3
Investment Response. This table presents coefficient estimates from estimating Eq. (3). The dependent variable is the h-quarter change in the log total investment rate. $\hat{R}$ is the 1-year Treasury rate, instrumented by cumulative high-frequency monetary policy shocks measured as changes in the 3-month ahead Fed Funds futures rate in the 30 min window around FOMC announcements. *Intangible Ratio* is a firm's intangible-to-total capital ratio. Other control variables are defined in Online Appendix Table A1. The sample covers all firms in the matched CRSP-Compustat sample excluding financial firms, utilities and government from 1991–2016. In parentheses we report Driscoll-Kraay heteroscedasticity and autocorrelation robust standard errors standard errors. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively. Non-interacted coefficients are omitted for brevity.

	$h = 8$			$h = 12$		
	ΔI_t^{tot}	ΔI_t^{tot}	ΔI_t^{tot}	ΔI_t^{tot}	ΔI_t^{tot}	ΔI_t^{tot}
$\hat{R}$	-0.10***			-0.12***		
	(0.017)			(0.024)		
$\hat{R}$ × Intangible Ratio		0.055**	0.049***		0.060**	0.059***
		(0.021)	(0.014)		(0.025)	(0.017)
ΔGDP × Intangible Ratio		-0.072	-0.057*		-0.041	-0.052*
		(0.044)	(0.032)		(0.038)	(0.027)
$\hat{R}$ × Log Age		0.0095***	0.0099***		0.0063*	0.0095***
		(0.0033)	(0.0022)		(0.0036)	(0.0023)
$\hat{R}$ × Total Q		-0.0073***	-0.0022		-0.0052**	-0.00018
		(0.0026)	(0.0023)		(0.0026)	(0.0023)
$\hat{R}$ × Cash		0.020**	0.0050		0.018**	0.0014
		(0.0080)	(0.0068)		(0.0074)	(0.0075)
$\hat{R}$ × Leverage		-0.00018	-0.0046		-0.016**	-0.016*
		(0.0060)	(0.0073)		(0.0072)	(0.0080)
$\hat{R}$ × Cashflows		0.017	-0.053		0.016	-0.083+
		(0.044)	(0.038)		(0.056)	(0.053)
$\hat{R}$ × Log Size		0.00027	-0.00060		0.0019**	0.00087
		(0.00088)	(0.00070)		(0.00095)	(0.00076)
$\hat{R}$ × Dividend Paid		0.0013	0.00015		-0.0019	-0.0022
		(0.0031)	(0.0030)		(0.0035)	(0.0039)
Observations	160,437	159,789	154,437	142,792	142,123	137,119
R-squared	0.077	0.049	0.039	0.101	0.067	0.055
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	No	Yes	No
Industry × Time FE	No	No	Yes	No	No	Yes
Fiscal Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Macro Controls	Yes	No	No	Yes	No	No

(Ewens et al., 2019), and an alternative firm-level tangible capital measure based on applying the perpetual inventory method to capital expenditures (see Online Appendix Table A5). The results are also robust to de-meaning the intangible ratio within firms, which indicates that the results are not confounded by unobserved, time-invariant, and proportionate to the average intangible-to-total capital ratio differences in firm monetary policy response (see Ottonello and Winberry, 2020, Online Appendix A.1). Another robustness exercise complements the firm-level analysis based on public firms with an analysis based on national accounts data from the BEA that cover all establishments. The BEA also employs a different definition of intangible investment based on intellectual property products (IPP), which include R&D, software, and artistic originals, but exclude organizational capital.

Synthesis The investment results based on firm-level and aggregate data consistently document that intangible investment responds less to monetary policy compared to tangible investment, and that the total investment in firms with relatively more intangible assets responds less to monetary policy. These results are consistent with those obtained in the tightly-identified high-frequency stock price analysis that documents a weaker response of the market value of firms with relatively more intangible capital to monetary policy shocks (see Section 3.1). This is reassuring given the complexity of accounting for the endogeneity of monetary policy when estimating the dynamic response of investment (Nakamura and Steinsson, 2018). Overall, we therefor document a set of consistent findings based on different methodologies and data sources that all confirm that intangible capital attenuates the effectiveness of monetary policy transmission. The remainder of the paper explores several economic channels that may explain these findings.

4. Economic channels

This section discusses and tests three economic mechanisms that may explain why intangible capital weakens monetary policy transmission to firm stock prices and investment.

4.1. Credit channel

The credit channel of monetary policy is an amplification mechanism by which interest rates affect not only the price but also the quantity of credit available to firms, through their effect on the collateral value (or pledgeable value) of firm assets and thus on firm financial constraints (Kiyotaki and Moore, 1997).[13] However, intangible assets have lower collateral value compared to tangible assets, so firms with relatively more intangible assets use less debt to begin with.[14]

Formally, consider a profit-maximizing firm that chooses its investment at date t. The firm has an initial capital stock K_t and internal funds (cash) A_t. It decides how much debt D_t to raise in order to make an investment $I_t = A_t + D_t$, resulting in a capital stock $K_{t+1} = K_t + I_t$ at $t+1$. Capital produces $F(K_{t+1})$, where $F'(K) \geq 0$ and $F''(K) \leq 0$. The firm's cost of borrowing (and the value of internal funds in alternative use) is the interest rate r_t. Importantly, the firm is subject to a collateral constraint:

$$D_t \leq (1-\mu)Q_t(r_t)K_t, \tag{4}$$

where $Q_t(r_t)$ is the collateral value of capital, which declines in the interest rate r_t, i.e., $Q_t'(r_t) \leq 0$. The parameter μ captures the share of the capital stock that is intangible and thus cannot be pledged as collateral. The empirical counterpart of μ in our analysis is the intangible-to-total capital ratio.

The Online Appendix (Section AIV) shows that solving this optimization problem gives rise to two solution regions, depending on whether the collateral constraint (4) binds. An *unconstrained firm* matches the marginal product of capital to its opportunity cost r_t and chooses investment I_t such that $F'(K_{t+1}) = r_t$. Investment declines in the interest rate because $F''(K_{t+1}) \leq 0$, representing the effect of monetary policy on the hurdle rate of investment. The share of intangible assets, μ, does not affect investment because collateral values are irrelevant in a financially unconstrained firm.

By contrast, the investment of a *constrained firm* is given by $I_t = (1-\mu)Q_t(r_t)K_t + A_t$, with

$$\frac{dI_t}{dr_t} = (1-\mu)Q_t'(r_t)K_t. \tag{5}$$

Here, investment is limited by the collateral value of firm assets, which declines in the interest rate since $Q_t'(r_t) \leq 0$. Importantly, the investment of firms with a higher share of intangible assets μ declines *less* when interest rates increase because such firms use less debt funding. Intuitively, fluctuations in asset values have little effect on financial constraints if a firm cannot pledge these assets anyway.

This stylized model thus yields the following testable prediction: *(1) firms with a higher intangible-to-total capital ratio adjust their investment less in response to monetary policy, (2) but only to the extent that such firms are financially constrained.* Accordingly, whereas our baseline results confirm that firms with relatively more intangible assets indeed respond less to monetary policy, the goal of this section is to analyze whether this muted reaction is driven primarily by firms that rely on collateral for their marginal borrowing. If collateral constraints were measured perfectly and explained 100% of the weaker monetary policy response by intangible firms, then we should expect a large difference in the monetary policy response between financially constrained tangible and financially constrained intangible firms, but no difference in the monetary policy response between financially unconstrained tangible and financially unconstrained intangible firms.

It is useful to contrast our posited economic channel with the existing literature. Much of the literature compares financially constrained to unconstrained firms and finds that financial constraints may either amplify or weaken monetary policy transmission (Chava and Hsu, 2020; Cloyne et al., 2018; Ottonello and Winberry, 2020; Ozdagli, 2018). By contrast, we posit an *interactive* effect of financial constraints and intangible capital, where the difference in the monetary policy response between tangible and intangible firms is sharper for financially constrained firms.[15]

4.1.1. Measuring financial constraints

The literature uses several approaches to measure financial constraints based on firm characteristics. For example, young and small firms may face frictions in obtaining external financing because they have less well-established financial market relationships, are subject to greater asymmetric information, and have more uncertain returns. Therefore, young firm age (e.g., Cloyne et al., 2018; Hadlock and Pierce, 2010) and small firm size (e.g., Gertler and Gilchrist, 1994; Kashyap et al., 1994)

[13] The literature often uses the term "collateral constraints" without distinguishing between secured and unsecured debt. Whereas much corporate debt is de-jure unsecured (Lian and Ma, 2021; Rampini and Viswanathan, 2022) articulate the importance of pledgeable value even for unsecured debt, which is implicitly backed by unencumbered collateral in case of default. In this paper, we use the term "collateral" to refer not only to de-jure collateral behind secured debt, but also to the liquidation value of firm assets that serves as implicit collateral for most unsecured debt.

[14] The reason is that intangible assets are often firm-specific and harder to value and liquidate than tangible assets. For example, the value of a partially-developed technology is often linked to the human capital of the researchers who work on it, making it difficult to transfer ownership of such an asset without a substantial loss of value. Another reason for the low collateral value of intangible assets is that the structure of a debt contract is not well-suited for R&D-intensive firms due to uncertain and volatile returns, adverse selection problems, and the ease of risk-shifting (see Brown et al., 2009, p. 157). Accordingly, empirical studies confirm that firms finance intangible assets primarily through equity or internal funds (Bates et al., 2009; Brown et al., 2009; 2013; Falato et al., 2020; Hall and Lerner, 2010). Consistent with this, the median leverage of intangible firms is 18.1%, but 27.5% for tangible firms. While some intangible assets, notably patents, can be used as collateral (Mann, 2018), patents do not fully ameliorate external finance frictions caused by the low collateral value of intangible assets (Dell'Ariccia et al., 2021).

[15] To fully understand the mechanism behind our hypothesis, note that both tangible and intangible firms *may or may not* be financially constrained. For example, Table 1 documents that the correlation between the intangible ratio and the measures of financial constraints is far away from one. Although relatively more intangible firms have more cash and lower leverage, these firms have similar age and appear, if anything, less constrained according to the *Delaycon* measure of Hoberg and Maksimovic (2015). Consequently, we do not consider asset intangibility and financial constraints as interchangeable categories. Rather, we measure both characteristics separately, and compare the effect of intangible assets on firms' monetary policy response between constrained and unconstrained firms.

are common proxies of financial constraints. Another approach uses firm characteristics that may be induced by financial constraints. For example, Cunha and Pollet (2019) document that financially constrained firms accumulate more cash, likely for precautionary reasons. Yet another approach identifies financial constraints from the textual analysis of firm financial statements, by assessing the frequency of language that indicates investment delays due to a lack of financing capacity, as in the *Delaycon* measure of Hoberg and Maksimovic (2015).[16] Either approach is potentially imperfect (Farre-Mensa and Ljungqvist, 2016). Therefore, we document the results using all the above approaches to measuring financial constraints and obtain consistent results.

4.1.2. Stock price and investment response

To assess whether the weaker stock price and investment responses to monetary policy in firms with relatively more intangible assets are more pronounced among financially constrained firms, we re-run the baseline regressions as in Tables 2 and 3, while splitting the sample into more and less financially constrained firms. All regressions include the same controls and fixed effects as in the baseline.

Columns 1–4 in Table 4 re-estimate the coefficient on the interaction term ΔFF4 $\times$ Intangible Ratio in the stock price analysis (i.e., β_2 in Specification 1). Columns 5–8 document the coefficient estimates on the interaction term $\hat{R}$ $\times$ Intangible Ratio in the investment analysis at $h = 8$ and $h = 12$ quarter horizons (i.e., β_2^h in Specification 3).[17]

Panel A splits the sample into young firms (columns 1–2 and 5–6), defined as those with below-median age in a given quarter, and old firms with above-median age (columns 3–4 and 7–8). For young firms, the coefficient estimates are higher than the full-sample estimates (cf. Tables 2 and 3), and about twice the magnitude of the estimates for old firms. A potential shortcoming of using age as proxy of financial constraints is that some young firms may grow quickly and not be financially constrained. We address this in panel B by comparing estimates among firms of below-median age *and* size to firms of above-median age *and* size. In the stock return regressions, the coefficient estimates among firms that are young and small range between 1.93 and 2.46, while estimates among old and large firms are close to zero and statistically insignificant. The coefficient estimates for young and small firms imply that a one standard deviation increase in the intangible-to-total capital ratio leads to a 56bps–0.71bps smaller stock price decline in response to a 1% unanticipated increase in the Fed Funds rate, compared to a 36bps smaller decline in the full sample.

Similarly, for firm investment the coefficient estimates on the interaction between the instrumented 1 year Treasury rate and the intangible ratio range from 0.091 to 0.10 for firms that are young and small, while estimates among old and large firms are economically small and only marginally statistically significant. The coefficient estimates for young and small firms imply that a one standard deviation increase in the intangible-to-total capital ratio is associated with a 66bps–73bps smaller decrease of total investment in response to a 25bps monetary policy tightening for these firms, compared to a 36bps–44bps smaller decrease in the full sample.

Panel C splits the sample into firms with high and low cash holdings, defined as, respectively, firms in the top tercile and bottom two terciles of the cash-to-assets ratio distribution in a given quarter.[18] Panel D splits the sample by the median for the textual analysis-based *Delaycon* measure of Hoberg and Maksimovic (2015) in each quarter. The results consistently reveal that the coefficient estimates on the interaction of the intangible ratio with the FF4 shocks or the instrumented 1-year Treasury rate are larger for constrained firms compared to unconstrained firms, and that coefficient estimates for unconstrained tangible and intangible firms are economically smaller and have lower to no statistical significance.

Overall, the results based on multiple measures of firm financial constraints confirm that the weaker stock price and investment response to monetary policy in firms with relatively more intangible assets is more pronounced among financially constrained firms, consistent with the credit channel predictions. As the credit channel might not explain 100% of the weaker monetary policy response by intangible firms, and given that all proxies of financial constraints remain imperfect, we observe some effects of a weaker monetary policy response by more intangible firms also among financially unconstrained firms – although the differences are smaller in magnitude and often not statistically significant.

4.1.3. Borrowing response

The results from the previous subsection document a weaker credit channel of monetary policy for intangible firms based on differences in firm investment responses. Yet the credit channel is fundamentally a liability-side mechanism. If the credit channel is at work, one should expect that firms with relatively more intangible assets adjust not only their investment, but also their borrowing less in response to monetary policy. Accordingly, we extend our analysis and document how firms adjust their borrowing in response to monetary policy.

[16] Hoberg and Maksimovic (2015) identify a set of constrained firms that discuss investment delays due to liquidity constraints in their annual reports. They then construct a continuous *delaycon* measure by scoring how proximate a firm's wording in the liquidity and capitalization section is to these constrained firms.

[17] Figure A9 in the Online Appendix plots the estimates of the interaction term of the 1-year Treasury rate and the intangible ratio for the different sub-samples for all quarterly horizons $h = 1$ to $h = 20$.

[18] We pool the two lower cash holding terciles because the relation between cash and financial constraints is potentially not monotonic. While high cash holdings indicate precautionary cash hoarding in response to financial constraints, intermediate cash holdings are unlikely indicative of tighter financial constraints compared to low cash holdings. In fact, very low cash holdings may stem from a firm's poor performance, which tightens financial constraints, see Denis and Sibilkov (2010).

Table 4
Sample Splits Credit Channel. For different sub-samples of firms, this table replicates the stock returns regressions from Table 2 in columns 1–4, and the investment regressions from Table 3 in columns 5–8. Age and size splits compare below-median to above-median firms in the respective distribution. High cash firms are those in the top tercile of the cash-to-asset ratio distribution in a given quarter, and low cash are those in the bottom two terciles. In panel D, more (less) constrained firms have an above-median (below-median) textual analysis-based *delaycon* financial constraints measure of Hoberg and Maksimovic (2015). Columns 1–4 report estimates from firm-event date level regressions. The dependent variables are raw or abnormal stock returns on FOMC announcement days, and the reported coefficient estimates are β_2 in Eq. (1), i.e., the interaction term between ΔFF4 (the change in the 3-month ahead Fed Futures rate in the 30 min around the FOMC announcement), and a firm's *Intangible Ratio* (intangible-to-total capital). All regressions in columns 1–4 include firm fixed effects, fiscal quarter fixed effects, and industry × event-date fixed effects based on 4-digit NAICS codes, as well as the same control variables and interaction terms as in the baseline regression reported in Table 2. Standard errors in parentheses are clustered by event date and industry. Columns 5–8 report estimates from firm-quarter level regressions. The dependent variable is the h-quarter change in the log total investment rate, and the reported coefficient estimates are β_2^h in Eq. (3), i.e., the interaction term between $\hat{R}$ (the 1-year Treasury rate, instrumented by cumulative high-frequency monetary policy shocks), and a firm's *Intangible Ratio*. All regressions in columns 5–8 include firm fixed effects, fiscal quarter fixed effects and time fixed effects, as well as the same control variables and interaction terms as in the baseline regressions reported in Table 3. In parentheses we report Driscoll-Kraay heteroscedasticity and autocorrelation robust standard errors. The sample includes all FOMC meetings over 1991–2016, except the meeting on September 17, 2001, and covers all firms in the matched CRSP-Compustat sample excluding financial firms, utilities and government. ***, **, *, indicate significance levels of 1%, 5%, 10%, respectively.

	Stock Returns				Investment			
	(1) Raw	(2) Abn.	(3) Raw	(4) Abn.	(5) $h = 8$	(6) $h = 12$	(7) $h = 8$	(8) $h = 12$
Panel A: Split by Age								
	Young		Old		Young		Old	
MP × Intangible Ratio	1.87*	1.56*	0.94	0.92	0.087***	0.092***	0.045**	0.051*
	(1.02)	(0.79)	(0.86)	(0.82)	(0.021)	(0.023)	(0.022)	(0.027)
Observations	228,751	228,751	209,537	209,537	76,848	67,242	79,341	71,606
Panel B: Split by Age & Size								
	Young & Small		Old & Large		Young & Small		Old & Large	
MP × Intangible Ratio	2.46***	1.93***	0.15	-0.027	0.10***	0.091***	0.036	0.045*
	(0.92)	(0.67)	(1.03)	(1.12)	(0.029)	(0.027)	(0.022)	(0.025)
Observations	128,994	128,994	127,151	127,151	43,072	37,088	51,570	47,354
Panel C: Split by Cash Holdings								
	High Cash		Low Cash		High Cash		Low Cash	
MP × Intangible Ratio	2.90**	2.64***	0.30	0.47	0.100***	0.096***	0.041*	0.049*
	(1.19)	(0.96)	(0.92)	(0.95)	(0.018)	(0.024)	(0.023)	(0.025)
Observations	144,799	144,799	295,785	295,785	50,614	44,805	105,124	93,637
Panel D: Split by Delaycon								
	More Constrained		Less Constrained		More Constrained		Less Constrained	
MP × Intangible Ratio	2.69*	2.69**	1.43	0.15	0.093***	0.098***	0.047**	0.043*
	(1.54)	(1.25)	(1.75)	(1.40)	(0.024)	(0.028)	(0.023)	(0.023)
Observations	123,909	123,909	127,779	127,779	48,268	42,761	50,684	45,206

Figure 3 documents that firms with relatively more intangible capital reduce their debt growth by less in response to monetary policy, consistent with a weaker credit channel.[19] Panel A documents that debt growth declines by 0.5–0.7 percentage points 8–12 quarters after a 25bps monetary policy tightening in the full sample (compared to the mean debt growth of 6.5%). Panel B shows that the decline in debt growth is smaller at around 0.3–0.5 percentage points for firms with above-median intangible-to-total capital ratio and larger at more than 0.8 percentage points for firms with a below-median intangible ratio.

Table 5 tabulates the coefficient estimates of an interaction term of the intangible ratio with the instrumented 1-year Treasury rate across the sample splits by firm financial constraints (analogous to the investment analysis in Table 4). In panel A, the full-sample estimates imply that a one standard deviation higher intangible ratio is associated with a 7bps weaker response in debt growth. Consistent with the credit channel predictions, these coefficient estimates are larger among young and small firms (panels B and C), and among firms with an above-median *Delaycon* financial constraints measure (panel D).[20] For example, the estimates in panel C imply that, among young and small firms, a one standard deviation increase in the intangible-to-total capital ratio is associated with a 22bps smaller reduction in debt growth 8 quarters after a

[19] Debt growth is defined as the growth in total debt (the sum of short term debt and long term debt), scaled by lagged total debt outstanding. Thus, debt growth measures the net issuance of total debt relative to outstanding debt.

[20] We do not report the results for sample splits by cash holdings because cash holdings affect the need for external financing (and therefore adjustments to debt) also directly, and not only as a proxy for firm financial constraints.

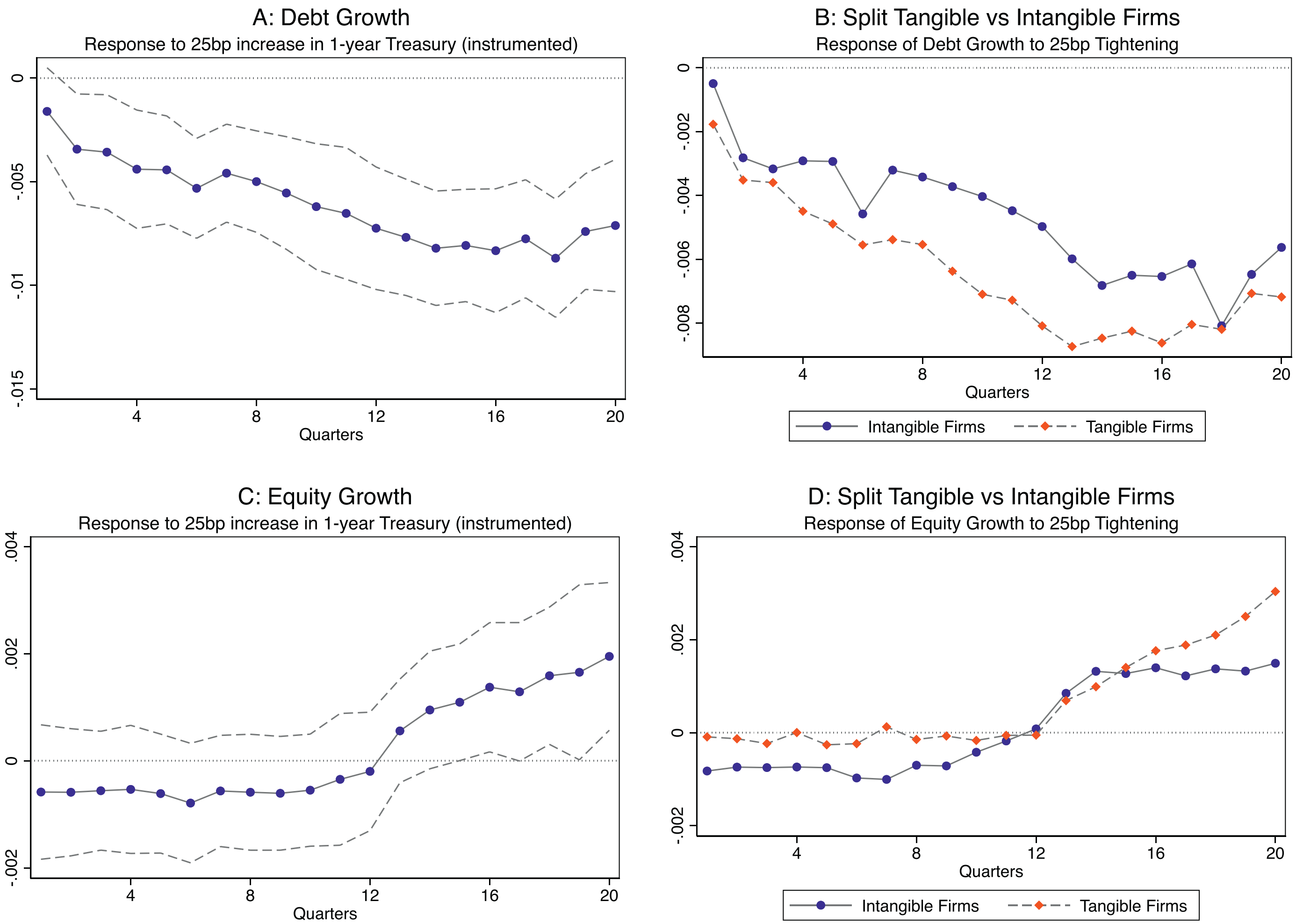

Fig. 3. Firm-level Borrowing Response. This figure plots the dynamic response of borrowing to a 25bps higher 1-year Treasury rate, estimated using Eq. (2). Debt growth is defined as the growth rate of short-term and long-term debt (i.e., net debt issuance). Equity growth is defined as the growth rate of book equity (i.e., net increase in shareholder capital). The 1-year Treasury rate is instrumented by cumulative high-frequency monetary policy shocks measured as changes in the 3-month ahead Fed Funds futures rate in the 30 min window around FOMC announcements. The sample covers all firms in the matched CRSP-Compustat sample excluding financial firms, utilities and government from 1991–2016. Each point represents the point estimate of the coefficient of instrumented the 1-year Treasury rate (β_1^h in Eq. (2)). All regressions include firm and macro controls, as well as firm and fiscal quarter fixed effects. The dashed line represents 95% confidence intervals using heteroscedasticity and autocorrelation robust Driscoll-Kraay standard errors. Intangible firms (tangible firms) are firms with an above-median (below-median) intangible-to-total capital ratio in a given quarter.

Table 5
Debt Growth - Sample Splits Credit Channel. This table presents estimates of the firm borrowing response to monetary policy. The dependent variable is the h-quarter change in debt growth, defined as the growth rate of short-term and long-term debt. Age and size splits compare below-median to above-median firms in the respective distribution. In panel C, more (less) constrained firms have an above-median (below-median) textual analysis-based *delaycon* financial constraints measure of Hoberg and Maksimovic (2015). $\hat{R}$ is the 1-year Treasury rate, instrumented by cumulative high-frequency monetary policy shocks measured as changes in the 3-month ahead Fed Funds futures rate in the 30 min window around FOMC announcements. *Intangible Ratio* is the firm's intangible-to-total capital ratio. The sample covers all firms in the matched CRSP-Compustat sample excluding financial firms, utilities and government from 1991–2016. All regressions include firm fixed effects, fiscal quarter fixed effects and time fixed effects, as well as the same control variables and interaction terms as in the baseline investment regressions (Table 3). In parentheses we report Driscoll-Kraay heteroscedasticity and autocorrelation robust standard errors. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

	(1) Δ Debt Growth $h = 8$	(2) Δ Debt Growth $h = 12$	(3) Δ Debt Growth $h = 8$	(4) Δ Debt Growth $h = 12$
Panel A: Full Sample				
$\hat{R}$ × Intangible Ratio	0.0086	0.0095*		
	(0.0059)	(0.0052)		
Observations	155,945	138,003		
Panel B: Split by Age				
	Young		Old	
$\hat{R}$ × Intangible Ratio	0.015*	0.013*	0.0094	0.0095
	(0.0075)	(0.0075)	(0.0079)	(0.0072)
Observations	72,507	62,832	78,914	71,104
Panel C: Split by Age & Size				
	Young & Small		Old & Large	
$\hat{R}$ × Intangible Ratio	0.030***	0.030**	0.0015	0.002
	(0.011)	(0.014)	(0.007)	(0.0073)
Observations	38,909	33,070	53,801	49,415
Panel D: Split by Delaycon				
	More Constrained		Less Constrained	
$\hat{R}$ × Intangible Ratio	0.031***	0.028***	0.016**	0.008
	(0.0078)	(0.0067)	(0.0072)	(0.0076)
Observations	45,295	39,811	46,922	41,491

25bps monetary policy tightening. By contrast, coefficient estimates are not statistically different from zero and economically smaller than in the full sample among old and large firms.

Firms might also respond to monetary policy shocks by issuing equity. This effect, if present, might be more pronounced for intangible firms because their investment relies on equity financing and responds to equity financing shocks (Brown et al., 2009; Hall and Lerner, 2010). To test for this effect, we consider how monetary policy affects the growth of firm book equity, which captures net changes in equity stemming from new issuance, payouts, and retained earnings.[21] Figure 3 documents in panels C and D that book equity growth does not respond to monetary policy, neither in more tangible nor in more intangible firms. This lack of response is consistent with frictions and costs in public equity issuance, and with the fact that accumulating internal equity from retained earnings takes time.

4.2. Depreciation channel

Intangible assets depreciate faster than tangible assets. The BEA reports R&D capital depreciation rates of 10–40% depending on the industry (Li, 2012), and Ewens et al. (2019) estimate an R&D capital depreciation rate between of 30% and 46%. This contrasts with an average tangible capital depreciation rate of under 10% in the BEA data.

Crouzet and Eberly (2019) argue that higher depreciation rates make intangible investment less interest rate sensitive. To see this, consider a standard neoclassical production model. Firms scale up investment until the marginal product of

[21] Book equity growth is defined as the growth in book equity scaled by lagged book equity stock, analogous to our definition of debt growth. Online Appendix, Figure A10, furthermore confirms that gross equity issuance does not respond to monetary policy. At the same time, payouts to shareholders (dividends and share repurchases) decrease in response to monetary tightening, leading to a somewhat counter-intuitive *increase* in net equity issuance in response to monetary tightening. Furthermore, cash flows decline (not reported), explaining the altogether flat response of book equity growth in Fig. 3.

Table 6
Sample Splits by Depreciation Gap. This table replicates the baseline investment and stock price results for firms with an above- and below-median *depreciation gap*, defined as the difference between a firm's intangible and tangible asset depreciation rates in a given quarter. Panel A replicates the stock returns regressions from Table 2 and the dependent variables are raw or abnormal stock returns on FOMC announcement days. $\Delta FF4$ is the change in the 3-month ahead Fed Futures rate in the 30 min around the FOMC announcement. Panel B replicates the investment regressions from Table 3 and the dependent variable is the h-quarter change in the log total investment rate. $\hat{R}$ is the 1-year Treasury rate, instrumented by cumulative high-frequency monetary policy shocks measured as changes in the 3-month ahead Fed Funds futures rate in the 30 min window around FOMC announcements. *Intangible Ratio* is the firm's intangible-to-total capital ratio. The sample includes all FOMC meetings over 1991–2016, except the meeting on September 17, 2001, and covers all firms in the matched CRSP-Compustat sample excluding financial firms, utilities and government. All regressions include the same fixed effects and control variables as in the baseline regressions from Tables 2 and 3. Standard errors are in parentheses. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

Panel A: Stock Returns				
	High Depreciation Gap		Low Depreciation Gap	
	(1)	(2)	(3)	(4)
	Raw Return	Abnormal Return	Raw Return	Abnormal Return
ΔFF4 × Intangible Ratio	2.59***	2.46***	-0.45	-0.47
	(0.83)	(0.69)	(1.30)	(1.27)
Observations	112,472	112,472	106,197	106,197
Panel B: Investment				
	High Depreciation Gap		Low Depreciation Gap	
	ΔI_t^{tot}	ΔI_t^{tot}	ΔI_t^{tot}	ΔI_t^{tot}
	$h = 8$	$h = 12$	$h = 8$	$h = 12$
$\hat{R}$ × Intangible Ratio	0.042**	0.049**	0.023	0.042
	(0.021)	(0.026)	(0.024)	(0.027)
Observations	39,579	35,162	41,627	37,339

capital equals the user cost of capital, defined as the sum of the interest rate r and the depreciation rate δ: $F'(K_t) = r_t + \delta$. When depreciation rates are high, the elasticity of the user cost of capital with respect to the interest rate is lower. Online Appendix Section AIV.3 verifies that higher depreciation rates make investment less interest rate-sensitive whenever the marginal product of capital is decreasing and convex. This condition holds for a range of production functions, including Cobb-Douglas.[22]

The depreciation channel predicts that *investment in assets with higher depreciation rates responds less to monetary policy*. A corollary is that *firms with relatively more intangible assets adjust their investment less in response to monetary policy particularly when the gap between tangible and intangible asset depreciation rates is wider.* We test these predictions in turn, using depreciation rate estimates for tangible assets at the industry level from the BEA Fixed Assets Tables 3.3 and 3.6, and for intangible assets from Ewens et al. (2019).[23]

We first consider the effect of depreciation rates on the response of investment to monetary policy. Figure 4, panel A, plots the response of intangible investment to a 25bps monetary tightening in firms with high (above-median) and low (below-median) intangible asset depreciation rates. Consistent with the depreciation channel predictions, intangible investment of firms with high depreciation rates initially responds less for firms with low depreciation rates, although this difference disappears after 8 quarters. Panel B documents that tangible investment with high depreciation rates also responds less to monetary policy compared to that with low depreciation rates, but the difference between the two is relatively small.

We then proceed to test whether depreciation rates can explain the weaker monetary policy response in firms with relatively more intangible assets. To do so, we calculate for each firm the difference between its intangible and tangible asset depreciation rates, which we call a firm's "depreciation gap". Table 6 documents the impact of the depreciation gap on the difference in monetary policy response between tangible and intangible firms by splitting the sample into firms with above- and below-median depreciation gap in a given quarter. Panel A reports the stock price response to monetary policy (as in Table 2) on the respective subsamples. The coefficient estimates for the interaction term between ΔFF4 and the firm's intangible ratio are between 2.46 and 2.59 (almost twice the full-sample estimates) for high depreciation gap firms and statistically insignificant for low depreciation gap firms. Panel B documents the total investment response to monetary policy at 8 and 12 quarters horizons (as in Table 3) on the respective subsamples. The coefficient estimates for the interaction between the instrumented 1-year Treasury rate and the firm's intangible ratio are larger for firms with a

[22] Online Appendix Section AIV.3 verifies that higher depreciation rates also make firm profits – and hence firm value – less sensitive to interest rates. This prediction underlies our analysis of the effects of monetary policy on stock prices depending on asset depreciation rates.

[23] Ewens et al. (2019) assume a fixed depreciation rate of 20%, so that there is no variation in intangible depreciation estimates among firms that have only organizational but no knowledge capital. For that reason, we exclude firms with zero or missing knowledge capital in sample splits based on intangible depreciation rates.

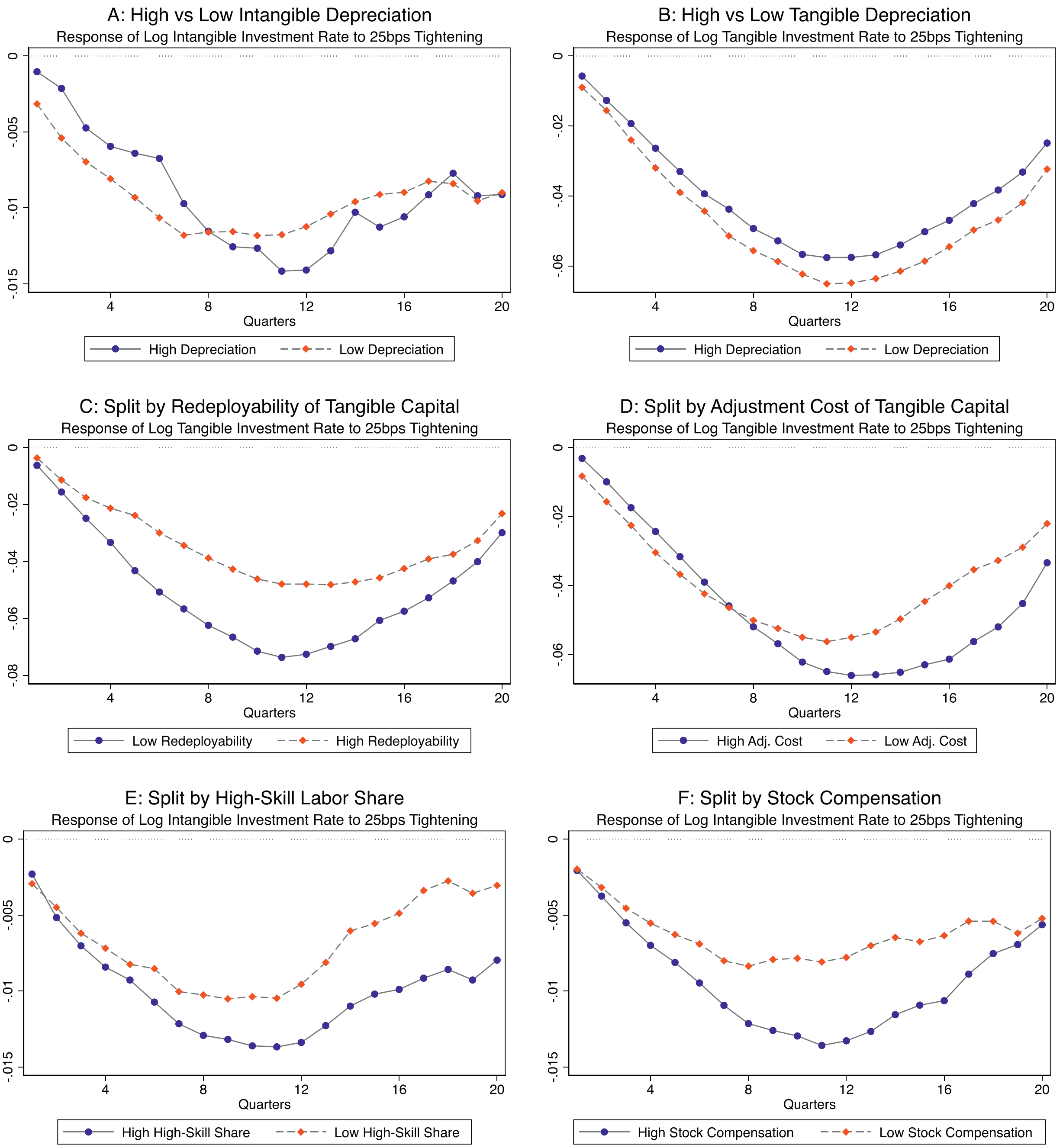

Fig. 4. Investment Response - Sample Splits by Depreciation Rates and Adjustment Costs. This figure plots the dynamic response of firm investment rates to a 25bps higher 1-year Treasury rate on different sub-samples on different sub-samples. High vs low splits split firms above- vs below-median based on depreciation rates, redeployability estimates from Kim and Kung (2017), adjustment cost estimates from Hall (2004), income share of non-production labor according to the NBER-CES Manufacturing Industry Database, or employee stock compensation according to Compustat. The 1-year Treasury rate is instrumented by cumulative high-frequency monetary policy shocks measured as changes in the 3-month ahead Fed Funds futures rate in the 30 min window around FOMC announcements. The sample covers all firms in the matched CRSP-Compustat sample excluding financial firms, utilities and government from 1991–2016. Each point represents the point estimate of the coefficient of instrumented the 1-year Treasury rate (β_1^h in Eq. 2). All regressions include firm and macro controls, as well as firm and fiscal quarter fixed effects.

high depreciation gap compared to low depreciation gap firms, but they remain close to the the full-sample estimates (cf. Table 3).

Overall, the evidence on the role of the depreciation channel in explaining the weaker response of intangible investment to monetary policy is thus mixed. Depreciation rates help explain the weaker stock price response for firms with relatively more intangible assets. Yet the depreciation channel offers statistically less significant and short-lived results in explaining the heterogeneous response of tangible and intangible investment to monetary policy, and the weaker total investment response for firms with more intangible-to-total assets. This mixed evidence suggests that, compared to the credit channel, the depreciation channel plays a smaller role in explaining the muted response of intangible investment to monetary policy.

4.3. Channels related to adjustment costs

Another potential reason for a weaker response of intangible investment to monetary policy may be that intangible investment is harder to scale up and down. We refer to a range of economic mechanisms behind this channel as higher adjustment costs. Creating tangible and intangible capital takes planning and production time. This makes investment a forward-looking, not easily reversible, multi-period decision (Bernanke, 1983). Several features of intangible capital may contribute to its higher adjustment costs. First, intangible assets often have to be built rather than purchased, and liquidated rather than sold, because intangible assets are firm-specific and therefore not easily redeployable across firms. Second, intangible investment relies on highly skilled human capital as a key production factor (Döttling et al., 2020; Eisfeldt and Papanikolaou, 2013), and hiring and firing talent is costly and takes time. Consistent with these arguments, Peters and Taylor (2017) document that "compared with physical capital, intangible capital adjusts more slowly to changes in investment opportunities."[24]

Existing data does not permit comparing adjustment costs between tangible and intangible assets. Therefore, we analyze the effect of adjustment costs on the tangible and intangible investment response separately, and extrapolate our findings to the comparison between tangible and intangible investment.[25] To capture the effect of adjustment costs on the tangible investment response to monetary policy, we use two proxies of adjustment costs. The first proxy is the (Hall, 2004) measure of capital adjustment costs, obtained from a structural model of investment estimated on industry-level data. The second proxy is the (Kim and Kung, 2017) firm-level measure of asset redeployability. The intuition is that redeployable assets can be purchased and sold more easily, and consequently have lower capital adjustment costs. Figure 4 documents that firms with higher tangible adjustment costs, as captured by below-median asset redeployability (panel C) or above-median (Hall, 2004) capital adjustment costs (panel D), respond, if anything, *more* to monetary policy. A potential explanation for this finding is that investment with high adjustment costs responds negatively to uncertainty (because uncertainty increases the risk that irreversible investment will not pay off, see Bloom, 2009), and uncertainty responds positively to interest rate shocks (Bekaert et al., 2013). The results also mirror findings in Kim and Kung (2017) that firms with less redeployable assets respond more to uncertainty shocks.

We similarly consider the effect of adjustment costs on the response of intangible investment to monetary policy. To do so, we consider the high-skill labor share in a firm, which we interpret as leading to higher adjustment costs because skilled labor is costly to hire and fire. We measure a firm's reliance on high-skill labor using data on the high-skill labor share of income from the NBER-CES Manufacturing Industry Database. These data report value added, total payroll, and the production workers' payroll for manufacturing industries at the 6-digit NAICS industry level. Following Pierce and Schott (2016), we compute the income share of high-skill labor as the total payroll net of production workers' wages, scaled by value added. As an alternative measure of a firm's reliance on high-skill human capital, we use the amount of employee stock compensation paid by a firm, motivated by the fact that many high-skill employees are rewarded with stock compensation (Eisfeldt et al., 2022).[26] Consistent with the earlier findings for tangible capital adjustment costs, in Fig. 4 firms with above-median high-skill labor share and above-median stock compensation, which face higher intangible capital adjustment costs, respond more to monetary policy (panels E and F).

Extrapolating these results to a comparison between tangible and intangible investment suggests that high adjustment costs should make intangible investment respond *more* to monetary policy, which is counterfactual. Taken at face value, this indirect inference does not support the notion that higher adjustment costs contribute to the weaker response of intangible investment to monetary policy.

5. Conclusion

Technological progress and the transition to a service economy increase the importance of corporate intangible assets. This paper sheds light on the implications of this transition for monetary policy. The key result is that monetary policy

[24] For example, Eisfeldt and Papanikolaou (2013) document that organizationally complex firms often list the loss of talent as a risk in their annual reports. Also see further discussions on high adjustment costs of intangible investment in Brown et al. (2009), p. 160.

[25] Higher adjustment costs may affect the stock price response to monetary policy differently from how they affect the investment response. For example, the market value of a firm with a more inflexible production schedule may respond more negatively to any shock. For this reason, we focus this analysis on the effect of monetary policy on investment only.

[26] Stock compensation is measured as stock compensation expense (Compustat variable STKCO) scaled by a firm's market value. This measure is averaged over 2006–2016, as this is the period over which data is consistently available.

impacts investment less when more of corporate capital is intangible. The stock prices and investment of firms with relatively more intangible assets respond less to monetary policy, and intangible investment responds less to monetary policy compared to tangible investment. In the cross-section, the attenuating effect of intangible assets is most pronounced among firms that rely most on collateral, consistent with intangible capital muting the credit channel of monetary policy. We also find somewhat weaker evidence that higher intangible capital depreciation rates contribute to these effects. Lastly, indirect evidence is not consistent with higher adjustment costs explaining the weaker responsiveness of intangible investment.

These findings have important economic policy implications. The result that the rise of intangible capital makes corporate investment less responsive to monetary policy helps shed light on why investment has responded only tepidly to substantial monetary easing during the last decade. Technological progress is likely to keep elevating the role of intangible capital, further weakening the investment channel of monetary policy in the future. Given these frictions in the transmission of monetary policy, intangible investment may best be encouraged not by traditional monetary policy, but by other means. These can include fiscal policies and structural reforms that support innovation and equity markets, and possibly expanding unconventional monetary policy tools to support equity financing of firms.

Data Availability

Data will be made available on request.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jmoneco.2022.11.001.

References

Aghion, P., Askenazy, P., Berman, N., Cette, G., Eymard, L., 2012. Credit constraints and the cyclicality of R&D investment: evidence from France. J. Eur. Econ. Assoc. 10 (5), 1001–1024.
Barlevy, G., 2007. On the cyclicality of research and development. Am. Econ. Rev. 97 (4), 1131–1164.
Bates, T.W., Kahle, K.M., Stulz, R.M., 2009. Why do us firms hold so much more cash than they used to? J. Finance 64 (5), 1985–2021.
Bekaert, G., Hoerova, M., Duca, M.L., 2013. Risk, uncertainty and monetary policy. J. Monet. Econ. 60 (7), 771–788.
Bernanke, B.S., 1983. Irreversibility, uncertainty, and cyclical investment. Q. J. Econ. 98 (1), 85–106.
Bernanke, B.S., Kuttner, K.N., 2005. What explains the stock market's reaction to federal reserve policy? J. Finance 60 (3), 1221–1257.
Bianchi, F., Kung, H., Morales, G., 2019. Growth, slowdowns, and recoveries. J. Monet. Econ. 101, 47–63.
Bloom, N., 2009. The impact of uncertainty shocks. Econometrica 77 (3), 623–685.
Brown, J.R., Fazzari, S.M., Petersen, B.C., 2009. Financing innovation and growth: cash flow, external equity, and the 1990s R&D boom. J. Finance 64 (1), 151–185.
Brown, J.R., Martinsson, G., Petersen, B.C., 2013. Law, stock markets, and innovation. J. Finance 68 (4), 1517–1549.
Bu, C., Rogers, J., Wu, W., 2021. A unified measure of fed monetary policy shocks. J. Monet. Econ. 118, 331–349.
Caggese, A., Pérez-Orive, A., 2022. How stimulative are low real interest rates for intangible capital? Eur. Econ. Rev. 142, 103987.
Chava, S., Hsu, A., 2020. Financial constraints, monetary policy shocks, and the cross-section of equity returns. Rev. Financ. Stud. 33 (9), 4367–4402.
Cloyne, J., Ferreira, C., Froemel, M., Surico, P., 2018. Monetary Policy, Corporate Finance and Investment. NBER Working Paper 25366.
Coibion, O., 2012. Are the effects of monetary policy shocks big or small? Am. Econ. J. Macroecon. 4 (2), 1–32.
Corrado, C., Haskel, J., Jona-Lasinio, C., Iommi, M., 2018. Intangible investment in the EU and US before and since the great recession and its contribution to productivity growth. J. Infrastruct. Policy Dev. 2 (1), 11–36.
Corrado, C.A., Hulten, C.R., 2010. How do you measure a "technological revolution"? Am. Econ. Rev. 100 (2), 99–104.
Covas, F., Den Haan, W.J., 2011. The cyclical behavior of debt and equity finance. Am. Econ. Rev. 101 (2), 877–899.
Crouzet, N., Eberly, J.C., 2019. Understanding Weak Capital Investment: The Role of Market Concentration and Intangibles. NBER Working Paper 25869.
Crouzet, N., Eberly, J.C., 2021. Rents and Intangible Capital: A Q+ Framework. Technical Report. Forthcoming, Journal of Finance.
Cunha, I., Pollet, J., 2019. Why do firms hold cash? Evidence from demographic demand shifts. Rev. Financ. Stud. 33 (9), 4102–4138.
Dell'Ariccia, G., Kadyrzhanova, D., Minoiu, C., Ratnovski, L., 2021. Bank lending in the knowledge economy. Rev. Financ. Stud. 34 (10), 5036–5076.
Denis, D.J., Sibilkov, V., 2010. Financial constraints, investment, and the value of cash holdings. Rev. Financ. Stud. 23 (1), 247–269.
Döttling, R., Ladika, T., Perotti, E.C., 2020. Creating Intangible Capital. Working paper.
Eisfeldt, A.L., Falato, A., Xiaolan, M.Z., 2022. Human capitalists. NBER Macroecon. Annu. 2022 37.
Eisfeldt, A.L., Papanikolaou, D., 2013. Organization capital and the cross-section of expected returns. J. Finance 68 (4), 1365–1406.
Ewens, M., Peters, R., Wang, S., 2019. Measuring Intangible Capital with Market Prices. NBER Working Paper 25960.
Falato, A., Kadyrzhanova, D., Sim, J., Steri, R., 2020. Rising intangible capital, shrinking debt capacity, and the us corporate savings glut. J. Finance.
Farre-Mensa, J., Ljungqvist, A., 2016. Do measures of financial constraints measure financial constraints? Rev. Financ. Stud. 29 (2), 271–308.
Fatas, A., 2000. Do business cycles cast long shadows? Short-run persistence and economic growth. J. Econ. Growth 5 (2), 147–162.
Gertler, M., Gilchrist, S., 1994. Monetary policy, business cycles, and the behavior of small manufacturing firms. Q. J. Econ. 109 (2), 309–340.
Gertler, M., Karadi, P., 2015. Monetary policy surprises, credit costs, and economic activity. Am. Econ. J. Macroecon. 7 (1), 44–76.
Gilchrist, S., Zakrajšek, E., 2012. Credit spreads and business cycle fluctuations. Am. Econ. Rev. 102 (4), 1692–1720.
Gurkaynak, R.S., Sack, B.P., Swanson, E.T., 2005. Do actions speak louder than words? The response of asset prices to monetary policy actions and statements. Int. J. Cent. Bank. 1 (1), 55–93.
Hadlock, C.J., Pierce, J.R., 2010. New evidence on measuring financial constraints: moving beyond the kz index. Rev. Financ. Stud. 23 (5), 1909–1940.
Hall, B.H., Lerner, J., 2010. The financing of R&D and innovation. In: Handbook of the Economics of Innovation, Vol. 1. Elsevier, pp. 609–639.
Hall, R.E., 2004. Measuring factor adjustment costs. Q. J. Econ. 119 (3), 899–927.
Hoberg, G., Maksimovic, V., 2015. Redefining financial constraints: a text-based analysis. Rev. Financ. Stud. 28 (5), 1312–1352.
Jarocinski, M., Karadi, P., 2020. Deconstructing monetary policy surprises: the role of information shocks. Am. Econ. J. Macroecon. 12 (2), 1–43.
Jasova, M., Mendicino, C., Panetti, E., Peydró, J.-L., Supera, D., 2021. Monetary Policy, Labor Income Redistribution and the Credit Channel: Evidence from Matched Employer-Employee and Credit Registers. CEPR Discussion Paper No. DP16549.
Jeenas, P., 2018. Monetary Policy Shocks, Financial Structure, and Firm Activity: A Panel Approach. Working Paper.

Jordà, Ò., 2005. Estimation and inference of impulse responses by local projections. Am. Econ. Rev. 95 (1), 161–182.
Kashyap, A.K., Lamont, O.A., Stein, J.C., 1994. Credit conditions and the cyclical behavior of inventories. Q. J. Econ. 109 (3), 565–592.
Kim, H., Kung, H., 2017. The asset redeployability channel: how uncertainty affects corporate investment. Rev. Financ. Stud. 30 (1), 245–280.
Kiyotaki, N., Moore, J., 1997. Credit cycles. J. Polit. Economy 105 (2), 211–248.
Li, W.C., 2012. Depreciation of business R&D capital. In: Bureau of Economic Analysis/National Science Foundation R&D Satellite Account Paper.
Lian, C., Ma, Y., 2021. Anatomy of corporate borrowing constraints. Q. J. Econ. 136 (1), 229–291.
Mann, W., 2018. Creditor rights and innovation: evidence from patent collateral. J. Financ. Econ. 130 (1), 25–47.
Nakamura, E., Steinsson, J., 2018. Identification in macroeconomics. J. Econ. Perspect. 32 (3), 59–86.
Ottonello, P., Winberry, T., 2020. Financial heterogeneity and the investment channel of monetary policy. Econometrica 88 (6), 2473–2502.
Ozdagli, A.K., 2018. Financial frictions and the stock price reaction to monetary policy. Rev. Financ. Stud. 31 (10), 3895–3936.
Peters, R.H., Taylor, L.A., 2017. Intangible capital and the investment-q relation. J. Financ. Econ. 123 (2), 251–272.
Pierce, J.R., Schott, P.K., 2016. The surprisingly swift decline of us manufacturing employment. Am. Econ. Rev. 106 (7), 1632–1662.
Rampini, A.A., Viswanathan, S., 2022. Collateral and Secured Debt. Working paper.
Romer, C.D., Romer, D.H., 2004. A new measure of monetary shocks: derivation and implications. Am. Econ. Rev. 94 (4), 1055–1084.