Inattentiveness and the Investment Channel of Monetary Policy*

Abolfazl Rezghi[†]
This Draft: August 3, 2024
Most Recent Draft: [Link]

Abstract

How does rational inattention interact with financial frictions? I provide new empirical evidence from survey data that suggests that the answer to this question likely plays an important role in understanding macroeconomic dynamics. In a simple model, I show that financially constrained firms will generally choose to be more attentive to economic conditions, consistent with my empirical evidence. Embedding this mechanism into a DSGE model, I show that the aggregate response of investment to a monetary policy shock hinges on this interaction. The model also predicts that credit-constrained firms ultimately reduce their investment after an expansionary shock, a prediction that I confirm empirically.

JEL Classification: D22, D83, D25, E22, E52

Keywords: Monetary policy, Rational inattention, Financial frictions, Investment

*I would like to thank Saroj Bhattarai, Olivier Coibion, and Stefano Eusepi for their guidance and support. I also want to thank Hassan Afrouzi, Chris Boehm, Andres Drenik, Cooper Howes, Andreas Mueller, Aysegul Sahin, Kei-Mu Yi, and all the participants in UT Austin's Macro workshop and Texas Macro Job Candidate Conference for their suggestions and comments. All remaining errors are my own.

[†]Department of Economics, University of Texas at Austin. Contact: Rezghi@utexas.edu

1 Introduction

In the last twenty years, macroeconomists have thought extensively about the role of two different frictions in affecting firm decisions: financial frictions and information frictions. Under the former, models incorporate the fact that some firms face limited access to credit markets or that collateral constraints may limit their ability to borrow (e.g., Kiyotaki and Moore 1997, Bernanke, Gertler and Gilchrist 1999, Jermann and Quadrini 2012). Under the latter, firms are assumed to face limits to their ability to process information about their environment, leading to expectations that deviate from full information rational expectations (e.g., Mankiw and Reis 2002, Sims 2003, Woodford 2001). In this paper, I take a first step in bringing these two literatures together.

Why think that financial and information frictions might be related? A puzzle from recent survey data of firms provides one motivation. I find that smaller firms in New Zealand tend to be better informed about aggregate economic conditions such as inflation or unemployment than larger firms, even after controlling for a wide range of firm and manager observables. These smaller firms also report that they value macroeconomic information more highly than do larger firms. Because firm size is a commonly used proxy for financial constraints (Gertler and Gilchrist 1994), this result suggests that there might be a link between the financial constraints faced by firms and their economic attentiveness.

As a first step to understanding how these two frictions might be related, I study a simple two-period model with financial frictions in a partial equilibrium setting to illustrate the determinants of attentiveness. Theoretically, I show that financial frictions can increase a firm's incentive to acquire information through different channels. First, sub-optimal actions reduce firms' profit and internal funds, increasing their need to access external sources to finance their production. Financial friction increases the cost of external finance and, thus, the curvature of the profit function around the full information optimal action. As a result, any decision that deviates from the optimal action leads to a higher loss of profit and creates a motive for firms to avoid such non-optimal decisions. Second, financial friction can affect the pass-through of shocks to investment under full information by affecting the marginal cost of investment. Since any deviation from the full information decision is sub-optimal, firms that are more sensitive to shock need to be more attentive to follow the full information action as closely as possible. Unlike the curvature of the profit function, pass-through depends on the parameters of the model and can increase or decrease with the degree of financial friction. Moreover, this pass-through will be determined in relation to other firms' actions in the economy and thus requires a general equilibrium model with proper calibration.

I, therefore, build a dynamic general equilibrium model based on the intuition provided in the simple two-period model to study the cross-sectional and aggregate implications of financial friction and rational inattention in the economy. The model consists of a continuum of two types of firms: financially constrained and unconstrained ones. Constrained firms use equity and debt to finance their production and investment plans. Consistent with the empirical evidence provided in Lian and Ma (2021), I assume that these firms face an earning-based borrowing constraint, meaning that the amount of debt they can borrow is limited by their earnings in each period. Therefore, the borrowing constraint would be affected by the monetary policy shock. In order to have financial friction in the model, equity issuance is also subject to an adjustment cost similar to Jermann and Quadrini (2012). Unconstrained firms on the other hand can finance their needs freely, either through risk-free debt or equity. Both types of firms have a prior belief about the monetary policy shock in each period. They need to collect information, process it, and form a posterior belief about the shock.

Processing information is costly; therefore, firms might not find it optimal to have perfect information about the shock. Constrained firms have a higher incentive to collect more precise information, as in the two-period model. That means they adjust their prices faster relative to the unconstrained firms following the shock. Therefore, the difference in attentiveness generates a novel form of cross-sectional heterogeneity in the model, in addition to the heterogeneity caused directly by the financial friction.

This heterogeneity matters for aggregate dynamics. An expansionary monetary shock increases nominal demand in the economy. On the supply side and due to inattentiveness, firms will not increase their price to fully offset the rise in the nominal demand. That means they encounter a higher level of real demand in the economy and, as a result, need to hire more employees to increase their production. Higher wages due to elevated demand for labor and the decreasing marginal product of labor give firms an incentive to purchase more capital for the next period. This is where financial constraints make constrained firms behave differently than unconstrained ones: unconstrained firms find it optimal to increase their investment since they have access to cheap funds whereas constrained firms have a tighter borrowing constraint because of the fall in their profit resulting from higher wages in the economy. Financing through equity is also costlier for them than for unconstrained firms because of the equity adjustment cost. As a result, constrained firms choose to decrease their investment after an expansionary monetary policy shock. Rational inattention incorporated in the model is the reason that monetary policy is not neutral and, when coupled with financial friction, creates this differential behavior of investment for constrained and unconstrained firms in the economy.

I then test this stark prediction using firm-level data from Compustat. In order to identify firms that are affected by financial friction, I use S&P's long-term issuer credit rating. The low-credit quality or junk-rated firms are grouped as constrained, and high-credit quality or investment-grade firms are labeled unconstrained. Following an expansionary Romer and Romer (2004) monetary shock, high-credit quality firms expand their fixed capital while low-credit quality firms shrink their capital stock, precisely as predicted in the model.

The model makes another testable prediction about the effect of aggregate inattentiveness in the economy. An increase in inattentiveness in the economy dampens the aggregate investment response to shock for initial quarters. However, since aggregate inattentiveness is higher in the economy, the aggregate price level does not respond to shocks as quickly as before, which results in higher aggregate demand. Consequently, firms accumulate more capital to meet the demand. The dampening effect of the rise in inattentiveness and the sluggish response of the firm's investment to shock can also be found in the firm-level data. Using the measure of information rigidity estimated in Coibion and Gorodnichenko (2015), I find that a one standard deviation increase in information rigidity lowers the effect of one standard deviation expansionary monetary policy shock on aggregate fixed capital by about half a percent.

Finally, I can run a counterfactual to investigate the aggregate implications of the financial heterogeneity and attentiveness for monetary policy. In this counterfactual, I increase the weight of constrained firms in the economy. In this case, the model predicts that an expansionary monetary shock has a more significant impact on unconstrained firms than the baseline model and leads to a greater expansion in their investment. However, the constrained firms respond to the shock by almost as much as in the baseline model. The aggregate investment response will be dampened since there are more constrained firms in the economy that contract in response to the shock. In addition, since more attentive firms are operating in the economy, aggregate prices will become more flexible, which mitigates the real effect of monetary shock. Therefore, the mechanism could provide a new explanation for why monetary policy becomes less effective during recessions, as shown in Tenreyro and Thwaites (2016).

The rest of the paper is organized as follows: section (2) describes how this paper relates to the literature. Section (3) presents a simple two-period model to show how financial friction can affect a firm's attentiveness. Section (4) presents some empirical evidence using a survey of firms' expectations in New Zealand and the United States. Section (5) studies a fully dynamic general equilibrium model to analyze the implications of the interaction between financial friction and attentiveness for the investment channel of monetary policy. Section (6) presents empirical evidence using firm-level investment data to test the implications of the GE model. Finally, section (7) concludes.

2 Related Literature

This paper is related to the rational inattention literature pioneered by Sims (2003). Using communication theories, he introduced a deviation from rational expectation in macroeconomic models. In models with rational inattention, economic agents have a limited capacity to process information and, therefore, cannot have full information about economic fundamentals. Empirical studies such as Coibion, Gorodnichenko and Kumar (2018) also provide evidence for this behavior among New Zealand firms. Within the literature, several papers study the determining factors of firms' attentiveness to economic conditions. Two recent ones that emphasize the role of firm and industry characteristics are Afrouzi (2016) and Yang (2020). They explore the effect of competition and product scope on firms' attentiveness, respectively. In another closely related paper to mine, Wang (2022) connects financial friction and a firm's attentiveness to aggregate conditions by providing evidence using New Zealand's survey. In this project, and by using firm size as a proxy for financial friction, I provide more supporting evidence on the relationship between financial friction and the degree of attentiveness to aggregate conditions. I use firms' willingness to pay for professional forecasts and errors on forecast and nowcast of aggregate variables such as inflation, unemployment rate, GDP growth rate, and interest rate as a proxy for attentiveness. Moreover, I examine how the interaction between financial friction and attentiveness can affect firms' investment decisions, which is not addressed in Wang (2022).

The other set of papers studies the attentiveness of firms to aggregate and sectoral shocks. For example, Maćkowiak and Wiederholt (2009) shows how firms allocate their limited attention toward sector-specific shocks rather than aggregate ones and analyze their effects on firms' pricing decisions. Our empirical results also show that larger firms are more attentive to industry inflation than smaller firms.

The other strand of the literature studies firms' investment response to shocks with different origins. Investment decisions are always accompanied by financing decisions and are affected by the firm's financial conditions. Therefore, financial friction has been a crucial element in analyzing firms' investments. For instance, Bernanke, Gertler and Gilchrist (1999) introduces a financial accelerator mechanism based on the role of a firm's net worth in determining the external finance premium to explain how monetary policy can have a sizeable real effect. Another recent paper that studies the investment channel of monetary policy is the Ottonello and Winberry (2018), showing how financial friction can force more constrained firms to be less responsive to monetary shocks. While both of these works analyze the investment channel of monetary policy, they assume that firms have full information about monetary shocks. That is an assumption I will relax on in this paper. In addition, our model tries to match the response of constrained and unconstrained firms' investments to monetary shock.

Some studies examine firms' investment decisions in an environment with imperfect information. For instance, Zorn (2020) studies firms' investment under rational inattention and explains why investment has a hump-shaped response to aggregate shocks and a monotonic one to sectoral ones. While he incorporates investment adjustment cost in his model, the model does not explicitly include financial frictions. In another study, Charoenwong et al. (2021) propose an investment model with capital budgeting and partially flexible investment plans. They show that high-productivity firms are more incentivized to learn about firm-specific fundamentals, which reduces capital misallocation. The current paper differs from these studies by focusing on monetary policy as a source of aggregate variation in the economy.

Finally, this paper studies how the heterogeneity in attentiveness as a function of a firm's financial condition would affect the aggregate monetary policy outcome. In that regard, it aligns with two strands of the literature studying state dependence in attentiveness and aggregate transmission. For the papers that document the state dependence of attentiveness, I can mention Flynn and Sastry (2021), where they find a counter-cyclical behavior in firms' information acquisition. As a result of this attention cycle, they find a significant asymmetric and state-dependent shock propagation. Coibion and Gorodnichenko (2015) also provides empirical evidence on the reduction of information rigidity in the economy during recessions using a survey of professional forecasters. For the papers that study the state dependence of aggregate transmission, I can name Vavra (2014) and Mckay and Wieland (2021) in addition to Tenreyro and Thwaites (2016). According to Vavra (2014) and Mckay and Wieland (2021), monetary policy is less effective during recessions due to changes in the distribution of price adjustments and durable expenditures, respectively. In this project, I show how changes in the financial condition of firms can affect their investment response directly by affecting their marginal benefit and the marginal cost of investment and indirectly through shaping their attentiveness to the aggregate conditions and, thus, their pricing decisions.

3 A Two-Period Model

3.1 Full Information

This section analyzes a two-period partial equilibrium investment model with exogenous aggregate demand shocks. The firm maximizes the sum of two periods' dividends while discounting the second period's dividend by a risk-free interest rate r: $d_0 + \frac{1}{1+r}d_1$. k and b are the next period's capital and debt which the firm decides in period 0. k_0 and b_0 are at the steady state level and firm takes them as given.

The firm has a DRS production function with a constant productivity level normalized to one. Firm's net worth in period zero is $n_0 = pk_0^\theta + q(1-\delta)k_0 - b_0$, and in the next period is given by $n_1 = pk^\theta + q(1-\delta)k - b$, where $\theta < 1$. p and q are the relative prices of output and capital for both periods with steady state levels $\bar{p} = \bar{q} = 1$. Both p and q change exogenously following the aggregate shocks in period 0. I assume that q changes one-to-one with the aggregate shock. p, however, has an elasticity equal to ξ with respect to the aggregate shock. Because of this assumption, I treat q as an exogenous shock while the price of output p reacts to changes in q. Firm takes q and p as given when it makes decision at $t = 0$, following the realization of the shock.

Firms use both internal and external funds to finance their investment. If a firm encounters financial constraints, its borrowing capacity is restricted, i.e., $b \leq \tilde{b}(q)$. I assume that the borrowing limit depends on aggregate shock. As a result, an aggregate shock can affect firms investment decision through borrowing limit as well. In order to have the borrowing constraint to bind in equilibrium, I assume that debt is subsidized and has a rate equal to $R < 1 + r$. Consequently, debt is preferred to equity and is used to its full capacity before firm decides to issue equity. Following Jermann and Quadrini (2012), I add another source of friction by assuming that firms have a target for their equity payout at

$t = 0$, denoted by $\bar{d}$, making equity issuance also costly.

I can write the constrained firm's maximization problem under full information as follows:

$$\max_k \pi(k, q) = d_0 + \frac{1}{1+r} d_1$$

subject to

$$d_0 + \frac{\phi_d}{2}(d_0 - \bar{d})^2 = n_0 - qk + \frac{1}{R}\tilde{b}(q), \quad d_1 = n_1$$

Where $\frac{\phi_d}{2}(d_0 - \bar{d})^2$ is the cost of deviation from equity payout target. ϕ_d governs the degree of financial friction in the model. Higher values of ϕ_d means costlier equity issuance or share repurchases for the firm.

If a firm is not financially constrained, the Modigliani-Miller theorem holds, meaning that there is no difference between financing the investment through equity or debt. In this case, unconstrained firm maximizes its sum of discounted profits subject to $d_0 = n_0 - qk$ and $d_1 = n_1$.

Let us define $\hat{\pi}(\hat{k}, \hat{q}) = \pi(\bar{k}e^{\hat{k}}, \bar{q}e^{\hat{q}})$ where $\hat{k}, \hat{q}$ are the log-deviation of k and q from their steady states. The second-order Taylor expansion of $\hat{\pi}$ will be as follows

$$\hat{\pi}(\hat{k}, \hat{q}) = \hat{\pi}(0, 0) + \hat{\pi}_1 \hat{k} + \frac{\hat{\pi}_{11}}{2}\hat{k}^2 + \hat{\pi}_{12}\hat{k}\hat{q} + \text{terms independent of } \hat{k}$$

Taking the derivative with respect to $\hat{k}$ from this equation gives us the log-linearized solution of the firm's problem under full information:

$$\hat{k}^{\diamond} = \frac{\hat{\pi}_{12}}{|\hat{\pi}_{11}|}\hat{q}$$

Where $\hat{\pi}_{11} = \pi_{11}\bar{k}^2$ and $\hat{\pi}_{12} = \pi_{12}\bar{k}\bar{q}$. $\frac{\hat{\pi}_{12}}{|\hat{\pi}_{11}|}$ is the pass-through of shock $\hat{q}$ to the optimal capital level under full information $\hat{k}^{\diamond}$.

3.2 Rational Inattention

Now I proceed to add inattentiveness to the model. I assume that shock realizes at the beginning of period 0 while the firm does not fully observe it. Firm decides how much to invest based on its belief about the economy's fundamentals. The firm is allowed to form its posterior belief by choosing signal **s** that carries information about the fundamental shock. This process of updating belief, however, is costly. To quantify the information carried by signal **s** and the cost of processing information, I use the mutual information function $\mathcal{I}(q;\mathbf{s})$ following the literature on rational inattention. This function measures the reduction in uncertainty (*entropy*) about fundamental shocks by using signal $\mathbf{s}$.[1]

After deciding on the next period's capital, the firm needs to finance it. Similar to the perfect information case, firms can use equity and debt. Debt is subsidized but constrained, and I assume that the borrowing constraint binds even in the imperfect information case. Financing through equity is also subject to adjustment costs which introduce financing friction in the model. The optimization problem of an inattentive firm will be as follows:

$$\max_{\mathbf{s}\in\Gamma} \mathbb{E}\left(\pi(k^*,q) - \mu\mathcal{I}(q;\mathbf{s})|\mathbf{s}^{-1}\right) \tag{1}$$

where k^* is the firm's optimal decision condition on its information set

$$k^* = \arg\max_{k} \mathbb{E}\left[\pi(k,q)|\mathbf{s}\right]$$

μ is the marginal cost of information, and Γ is the set of all signals from which the firm can choose. I can use the second-order Taylor expansion of $\pi(k,q)$ to find the log deviation of k^* from the steady state:

$$\hat{k}^* = \mathbb{E}(\hat{k}^\diamond|\mathbf{s}) = \frac{\hat{\pi}_{12}}{|\hat{\pi}_{11}|}\mathbb{E}(\hat{q}|\mathbf{s}) \tag{2}$$

where $\hat{k}^\diamond$ is the firm's optimal decision under full information, $\frac{\hat{\pi}_{12}}{|\hat{\pi}_{11}|}$ is the pass-through of shocks to investment decision under full information, and $\hat{q}$ is the log deviation of q from its steady states.

I impose some restrictions on Γ to have an analytical solution. Similar to Maćkowiak and Wiederholt (2009), I assume following properties for the signals in Γ: 1) log-deviation of signals from the steady states are of the form of "true state plus white noise error": $\hat{s} = \hat{q} + \epsilon$. 2) $\hat{q} \sim N(0,\sigma_q^2)$, $\epsilon \sim N(0,\sigma_\epsilon^2)$, and are independent from each other.

Let us transform the maximization problem denoted in (1) to an equivalent minimization problem where the firm minimizes the total cost of processing information plus the profit loss due to deviation of its decision under rational inattention from the optimal full information :

$$\min_{\mathbf{s}\in\Gamma} \mathbb{E}\left(\pi(k^\diamond,q) - \pi(k^*,q) + \mu\mathcal{I}(q;\mathbf{s})|\mathbf{s}^{-1}\right) \tag{3}$$

Using second-order Taylor expansion and the fact that the q and the noise are Gaussian and independent, I can have the equivalent problem where firm chooses the information

[1] A more detailed explanation of the mutual information function is provided in appendix C.

capacity to minimize its profit loss:

$$\min_{\kappa} \mathbb{E}\left[\underbrace{\frac{|\hat{\pi_{11}}|}{2}\left(\hat{k}^{*}-\hat{k}^{\diamond}\right)^{2}}_{\substack{\text{Loss from}\\ \text{suboptimal capital}}} + \underbrace{\mu\kappa}_{\substack{\text{Cost of}\\ \text{info. processing}}} \middle| \mathbf{s}^{-1} \right] \tag{4}$$

where κ is the information flow that equals $I(q;\mathbf{s})$ and gives us the following signal-to-noise ratios:

$$\frac{\sigma_q^2}{\sigma_\epsilon^2} = 2^{2\kappa} - 1 \tag{5}$$

I can also rewrite equation 2:

$$\hat{k}^{*} = \frac{\hat{\pi}_{12}}{|\hat{\pi}_{11}|}\frac{\sigma_q^2}{\sigma_q^2 + \sigma_\epsilon^2}\hat{s} \tag{6}$$

Plugging equation (5) and (6) in equation (4) gives the minimization problem to solve for optimal κ:

$$\min_{\kappa} \frac{|\hat{\pi_{11}}|}{2}\left(\frac{\hat{\pi}_{12}}{|\hat{\pi}_{11}|}\right)^{2} 2^{-2\kappa}\sigma_q^2 + \mu\kappa \tag{7}$$

This problem shows the trade-off that firm faces when it decides to process information prior to making any decisions. The first term is the cost of inattentiveness to the shock and the second is the cost of information acquisition. Firm can reduce the profit loss due to inattentiveness by increasing κ. However, it has to pay more for information acquisition. First order condition gives us the optimal level of information κ^*:

$$\kappa^{*} = \frac{1}{2}\log\left(\underbrace{\frac{\sigma_q^2}{\mu/\log 2}}_{\text{Volatility per unit cost}} \underbrace{|\hat{\pi_{11}}|}_{\text{Curvature}} \underbrace{\left(\frac{\hat{\pi}_{12}}{|\hat{\pi}_{11}|}\right)^{2}}_{\text{Pass-through}} \right) \tag{8}$$

Higher volatility of the shock and lower cost of information increases the firm's optimal information level. The curvature of the profit function and the pass-through of the shock also affect firm's incentive to acquire information, both of which depend on financial condition of the firm among other parameters.

The curvature of the profit function is

$$|\hat{\pi}_{11}| = \phi_d \bar{k}^2 + \frac{1}{1+r}\theta(1-\theta)\bar{k}^{\theta}.$$

When comparing constrained firms ($\phi_d > 0$) to unconstrained ones ($\phi_d = 0$) and considering that the steady-state level of capital $\bar{k}$ is equal for both types of firms, defined as $\bar{k} = \left(\frac{\theta}{r+\delta}\right)^{\frac{1}{1-\theta}}$, it becomes evident that constrained firms exhibit a higher level of curvature in their profit function around the steady state. As a result the profit loss due to imperfect actions is higher, giving firms more incentive to be attentive to economic conditions. On the other hand, the overall effect of financial friction on pass-through is mixed. Financial friction can either amplify firms' sensitivity to shocks or dampen their effects. For financially constrained firms we have

$$\frac{\hat{\pi}_{12}}{|\hat{\pi}_{11}|} = \frac{\phi_d \left(\xi\bar{k}^{\theta} - \delta\bar{k} + \frac{1}{R}\frac{\partial\tilde{b}}{\partial q}\right) - 1 + \frac{1}{1+r}\left(\theta\xi\bar{k}^{\theta-1} + 1 - \delta\right)}{\phi_d\bar{k} + \frac{1}{1+r}\theta(1-\theta)\bar{k}^{\theta-1}} \tag{9}$$

For unconstrained firms ($\phi_d = 0$), the pass-through is given by $\frac{\hat{\pi}12}{|\hat{\pi}11|} = \frac{\xi-1}{1-\theta}$. Assuming $\xi > 1$, unconstrained firms will always increase their level of capital following an expansionary shock. However, this may not hold true for constrained firms in the model.

As equation (9) suggests, the new level of optimal capital under full information depends on how much the marginal cost and marginal benefits of investment moves after the shock hits. For both types of firms, the marginal benefit of investing one more unit of capital increases following an expansionary shock. However, the shifts in marginal costs for constrained firms may exhibit different signs compared to unconstrained ones, depending on how the borrowing constraint would respond to the aggregate shocks. If an expansionary shock tightens the borrowing constraint ($\frac{\partial\tilde{b}}{\partial q} < 0$) and the increase in internal funds due to higher sales prices at $t = 0$ is insufficient, then $\left(\xi\bar{k}^{\theta} - \delta\bar{k} + \frac{1}{R}\frac{\partial\tilde{b}}{\partial q}\right) < 0$. In such a scenario, the upward shift in marginal costs of investment may offset the increase in marginal benefit, potentially resulting in a negative overall pass-through.[2]

While the sign of pass-through has important implications for the model, it does not matter for the optimal level of information acquisition, as shown in equation (8). In fact, κ^* is higher if $|\hat{\pi_{11}}|\left(\frac{\hat{\pi}_{12}}{|\hat{\pi}_{11}|}\right)^2$, which depends on the financial condition of the firm, increases. Given that the curvature is always increasing in ϕ_d, the value of optimal information level κ^* will be larger for constrained firms compared to unconstrained ones if the absolute value of pass-through is also greater for them. In scenarios where the absolute value of pass-through is smaller and the curvature of the profit function for constrained

[2]In section (6), I provide empirical evidence suggesting that this pass-through is indeed negative for the constrained firms and positive for unconstrained ones.

firms is not sufficiently high, unconstrained firms may have a greater incentive to acquire information due to their heightened sensitivity to shocks. In general, however, if a firm is constrained enough, then it has the incentive to be more attentive relative to unconstrained firms. The following proposition outlines the conditions under which this holds.

Proposition 1. *Financially constrained firms with $\phi_d > \bar{\phi}_d$ exhibit higher attentiveness compared to unconstrained firms. The threshold $\bar{\phi}_d$ depends on the net change of firm's access to funds $(\xi \bar{k}^{\theta} - \delta \bar{k} + \frac{1}{R}\frac{\partial \bar{b}}{\partial q})$ following a shock.*

Proof. Appendix E.1. □

The variation in the sum of a constrained firm's internal funds and external borrowing plays a crucial role in determining its response to shocks, whether it involves increasing or cutting investment. A substantial decrease or increase in funds requires a bigger response to shocks and a higher level of pass-through. That means constrained firms need to exercise greater attentiveness in order to make informed investment decisions and not deviate too much from the optimal full information path. Even in scenarios where financial friction acts as a dampening mechanism, constrained firms continue to demonstrate higher attentiveness compared to unconstrained ones when the level of friction is sufficiently high. This is primarily due to the dominance of the effect arising from the curvature of the profit function for constrained firms over the effect resulting from a smaller absolute value of the pass-through.

This section examined the role of financial friction, assuming that ξ is exogenous and given. However, this assumption may not be reasonable, given that sales for constrained and unconstrained firms could react differently to shocks. In section (5), I aim to relax some of the simplifying assumptions of this basic model to explore the interplay between financial friction, attentiveness, and monetary policy in a more dynamic context. I extend the two-period model to a fully dynamic general equilibrium framework while largely retaining the financial friction and rational inattention components of the toy model. This extended framework allows firms to set prices, hire employees, and adjust their borrowing constraints based on performance. Before delving into the general equilibrium dynamic model, I will leverage surveys of firms' expectations in New Zealand and the United States to provide supporting evidence on how financial conditions could influence firms' incentives to acquire information.

Table 1: Summary Statistics for Firm Characteristics

	Mean	Median	SD	10%	90%
Total Employment	22.0	12	28.32	6	54
age (years)	10.9	6	16.3	3	23
No. of competitors	17.8	15	12.1	5	38
Foreign trade share (%)	2.3	0.0	9.0	0	0
Labor cost share (%)	47.0	45.1	9.6	35	60
Average profit margin (%)	29.2	30	10.5	15	45

Notes: Total No. of observations is 3144. Sample weights are applied. Foreign trade share is the percentage of the firm's revenues in the last 12 months coming from sales outside of New Zealand. Profit margin is the percentage amount that sales prices exceed operating costs

4 Survey Evidence

In this section I provide supporting evidence on the relationship between financial condition of a firm and its attentiveness to aggregate conditions. Since I do not have a direct measure of financial friction, I use firm size as a proxy for financial constraint.[3] I mainly use survey of firm's expectations in New Zealand provided in Coibion, Gorodnichenko and Kumar (2018). The survey is conducted in 6 waves, with the first wave being in 2013Q4. The survey covers 3,144 firms in New Zealand with firms as small as having only 6 employees to firms with 698 employees. As table (1) shows, the overwhelming majority of firms in the sample have less than 54 employees. Since firms in the New Zealand survey are much smaller compared to firms in the United States, it is ambiguous whether our empirical results also hold for the United States. Therefore I will use the Survey of Firms' Inflation Expectations (SoFIE) run by the Federal Reserve Bank of Cleveland as a robustness check.[4] However, this survey contains more limited information on firm's characteristics relative to New Zealand's survey.

Table (2) compares firms' nowcast of aggregate variables such as inflation, unemployment rate, and GDP growth rate to the actual value of these variables. The average of firms' nowcast of inflation rate was 3.9 % which is significantly different from the actual value, which equals 0.8% at the time of the survey. This observation points to the fact that firms do not have accurate information about macroeconomic conditions. In section (4.2), I show that inattentiveness could be the primary driver of a firm's nowcast error.

Table (3) presents the residualized correlation between firm size and other firm charac-

[3]Firm size has been used as a proxy for financial constraint with smaller firms being more constrained in several papers including Gertler and Gilchrist (1994), Whited and Wu (n.d.), Hadlock and Pierce (2010), and Duygan-Bump, Levkov and Montoriol-Garriga (2015).

[4]For more information on SoFIE refer to http://firm-expectations.org.

Table 2: Actual Value and Nowcast of Firms

	Actual	Mean	Median	SD	10%	90%
Inflation rate (%)	0.8	3.9	4	2.4	1	7
Unemployment rate (%)	5.5	6.1	6	1.2	5	8
GDP growth rate (%)	4.3	3.7	3.5	1.2	3	5

Notes: The actual values are the rates for 2014Q4 reported by central bank of New Zealand. Sample weights are applied.

Table 3: Residualized Correlation

	log(age)	log(#compet.)	Foreign trade share	Labor cost share	Average profit margin
log(Employment)	0.45	-0.43	0.16	0.03	0.20
P-value	0.00	0.00	0.00	0.31	0.00

Notes: Correlation between log(employment) and the variable denoted in each column, along side the P-value, after controlling for other variables and industry fixed effects. Sample weights are applied.

teristics. As expected, larger firms are older, have a higher profit margin, and have higher foreign trade shares. I also find that larger firms have a lower number of competitors. Since all of these characteristics can affect a firm's attentiveness, I will control for them in the following regression models.

4.1 Firm's Size and Nowcast Error

Figure (1) illustrates the unconditional correlation between firms' size and the nowcast error of aggregate variables, suggesting a positive relationship between firms' size and their nowcast error. Table (4) presents the regression result showing how firm size correlates with nowcast error of inflation, unemployment rate, and GDP growth rate from Wave #4 of the survey. Nowcast error is measured as the absolute value of the difference between the actual value of a variable and the firm's belief about it. I use the number of employees and total production as proxies for firm size. As mentioned earlier, since the firm size is correlated with other firm characteristics such as age, the number of competitors, labor cost share, trade share, and average margin that might affect firms' attentiveness, I control for them in the specification using wave #1 of the survey. In addition, as the survey questions are asked from the managers of the firms and their characteristics such as education, tenure, and income also might affect how they allocate attention to economic variables, I control for them as well using Wave #3 of the survey. In order to deal with outliers, I will use the Huber robust regression method as in Coibion, Gorodnichenko and Kumar

(2018). Also, to account for the difference between firms across industries, I control for the two-digit industry (SIC2) fixed effect. As table (4) suggests, larger firms tend to make a larger error on all the aggregate variables.

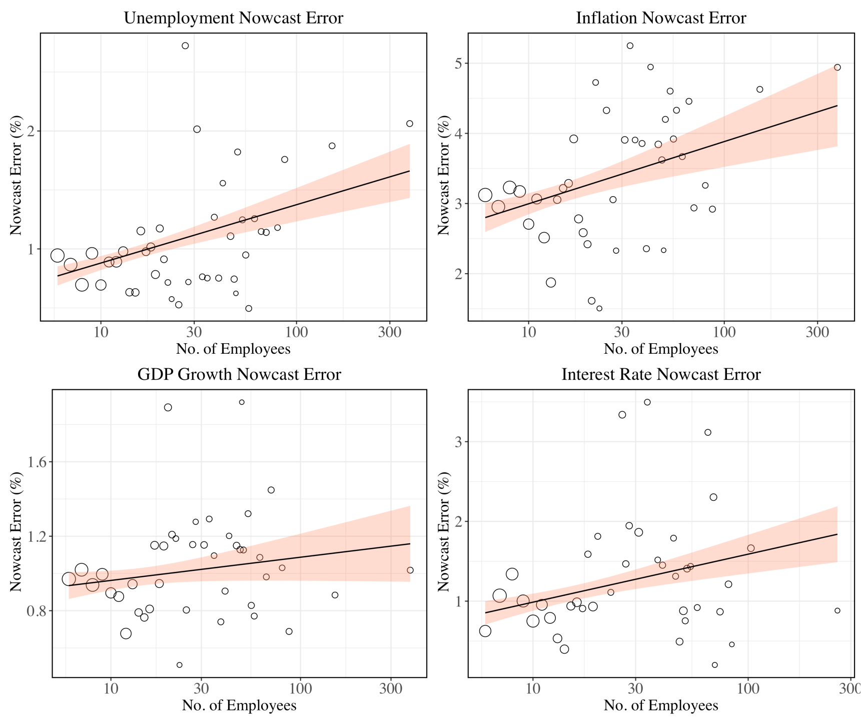

Figure 1: Unconditional correlation between number of employees and nowcast error of unemployment, inflation, GDP growth, and interest rate.

Notes: Size of the circles shows the weight of each sample. The shaded area is the 95 % confidence interval.

4.2 Tracking a Variable and the Nowcast Error

The table (4) suggests that larger firms are probably less attentive to aggregate conditions than smaller ones. I can provide more direct supporting evidence of this claim by using another question in the survey. In wave #4, managers were asked "*Which macroeconomic variables do you keep track of?*," and they could choose between the following options: " *a. Unemployment rate b. GDP c. Inflation d. None*." Based on this question, I can add a dummy variable called *track dummy*, which equals one if the firm tracks the dependent variable of the regression and zero otherwise. As tracking a variable is almost equivalent to being attentive to that specific variable, I expect firms to make smaller nowcast errors of that variable when they track it. That is what columns 4-6 of the table (5) depict. The

Table 4: Firm Size and Nowcast Error of Aggregate Variables

	(1) π_t	(2) ue_t	(3) $GDPg_t$	(4) π_t	(5) ue_t	(6) $GDPg_t$
log(employment)	0.276***	0.078***	0.016			
	(0.072)	(0.024)	(0.026)			
log(production)				0.321***	0.088***	0.050**
				(0.069)	(0.024)	(0.025)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Manager Controls	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1080	1042	1099	1080	1041	1100
R^2	0.625	0.118	0.164	0.627	0.121	0.166

Notes: The table reports results for the Huber robust regression. Dependent variable are the absolute value of firm errors about past 12-month inflation, unemployment rate and GDP growth rate from wave 4 survey. Sample weights are applied to all specifications. Robust standard errors (clustered at the 3-digit ANZ SIC level) are reported in parentheses. Firm controls are log(age), log(#competitors), labor cost share, trade share, and average margin. Manager characteristics are tenure, education, and income. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively.

tracking dummy's coefficients are statistically and economically significant for all three aggregate variables. Moreover, after I control for the tracking dummy, the coefficients on firm size become smaller and less significant, suggesting that larger firms choose to track the aggregate variables less than smaller firms do.

4.3 Firm's Size and Willingness to Pay for Professional Forecasts

Another supportive evidence for the relationship between size and attentiveness comes from analyzing firms' willingness to pay for professional forecasts. The survey asks managers of the firms how much they are willing to pay ($/year) for the professional forecasts of inflation, unemployment rate, and GDP. If a firm is willing to pay more for the professional forecast of a variable, it can be an indicator of the importance and relevance of that variable in its decision-making. Also, the more important a variable is, the higher the incentive to be attentive to that variable, resulting in smaller nowcast errors. However, this might not always be the case. A firm might consider a variable important when making its business decisions. However, it might not track that variable closely because of all the costs associated with being attentive. Thus, the relationship between willingness to pay for a professional forecast and nowcast error is ambiguous. In other words, smaller firms might be willing to pay less than large firms for the professional forecasts of aggregate variables. One possible explanation is that firms in different size groups care about spe-

Table 5: Tracking a Variable and its Nowcast Error

	(1) π_t	(2) ue_t	(3) $GDPg_t$	(4) π_t	(5) ue_t	(6) $GDPg_t$
log(employment)	0.276***	0.078***	0.016	0.085*	0.015	0.013
	(0.072)	(0.024)	(0.026)	(0.049)	(0.010)	(0.026)
Track dummy				−3.067***	−1.003***	−0.084*
				(0.058)	(0.025)	(0.046)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Manager Controls	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1080	1042	1099	1065	1034	1099
R^2	0.625	0.118	0.164	0.859	0.800	0.172

Notes: The table reports results for the Huber robust regression. Dependent variable are the absolute value of firm errors about past 12-month inflation, unemployment rate and GDP growth rate from wave 4 survey. Firm controls are log(age), log(#competitors), labor cost share, trade share, and average margin. Manager characteristics are tenure, education, and income. Track dummy is the answer to the following question in the survey: "*Which macroeconomic variables do you keep track of? a. Unemployment rate b. GDP c. Inflation d. None.*" Sample weights are applied to all specifications. Robust standard errors (clustered at the 3-digit ANZ SIC level) are reported in parentheses.***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively.

cific aggregate variables. For instance, it might be possible that smaller firms find GDP growth more critical for them. In contrast, firms with more employees see labor market conditions as crucial for their profitability. In addition, larger firms can benefit from the economy of scale; therefore, paying a fixed cost for accurate information could be more justifiable. Columns 1-3 of table (6) show the relationship between firm size and willingness to pay after controlling for the same variables as in the baseline model of table (4). I find a negative coefficient for unemployment, a positive coefficient for the GDP, and an insignificant one for the inflation rate.

In columns 4-6, I also control for importance dummies constructed from answers to the following question: "*Which macroeconomic variables are most important to you in making your business decisions (rank them)? a. Unemployment rate b. GDP c. Inflation d. None*". I can construct this ranking using three dummy variables which turn one if a variable is ranked higher than the other and zero otherwise. Controlling for these importance dummies helps us to make sure I compare willingness to pay for the professional forecast of a variable between firms with different sizes and the same importance ranking. The coefficients for these specifications are all negative and significant, suggesting that smaller firms are more willing to pay for a professional forecast. Signs of the coefficients on im-

Table 6: Firms Size and Willingness to Pay for Professional Forecast

	(1) π	(2) ue	(3) GDP	(4) π	(5) ue	(6) GDP
log(employment)	-0.000	-0.029^{**}	0.035^{***}	-0.017^{*}	-0.026^{**}	-0.021^{**}
	(0.019)	(0.013)	(0.011)	(0.010)	(0.010)	(0.010)
$\mathbb{1}(\pi > ue)$				0.383^{***}	-0.114^{***}	-0.056^{**}
$\mathbb{1}(\pi > gdp)$				0.417^{***}	0.000	-0.359^{***}
$\mathbb{1}(ue > gdp)$				-0.065^{***}	0.228^{***}	-0.084^{***}
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Manager Controls	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1082	1112	1094	1108	1111	1105
R^2	0.578	0.101	0.110	0.850	0.429	0.575

Notes: The table reports results for the Huber robust regression. Dependent variables are log of the willingness to pay ($/year) for a professional forecast for variable X. Firm controls are log(age), log(#competitors), labor cost share, trade share, and average margin. Manager characteristics are tenure, education, and income. The importance dummies are constructed based on the answer to the following question in the survey: "*Which macroeconomic variables are most important to you in making your business decisions (rank them)? a. Unemployment rate b. GDP c. Inflation d. None*". Sample weights are applied to all specifications. Robust standard errors (clustered at the 3-digit ANZ SIC level) are reported in parentheses. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively.

portance dummy variables are all consistent with what I would predict: If a firm finds a variable more important in making its business decision, then it should be willing to pay more for that variable.[5]

4.4 The United States Survey

I will provide evidence for the relationship between firm size and the nowcast error of inflation using the the Survey of Firms' Inflation Expectations (SoFIE) run by the Federal Reserve Bank of Cleveland. Since I will be using investment data from the United States in section (6), it is essential to make sure that the relationship I found for firms in New Zealand also holds for firms in the United States. Another reason for running this extra exercise is that firms in New Zealand are generally small relative to firms in the United States, which might make us doubt whether the relationship would still hold. However, the information available in this new survey is limited relative to the New Zealand survey. I only observe firms' size group (small, medium, large) and their operating sector. The

[5]This can be an indicator of the quality of the survey and the accuracy of the answers provided by the managers. Coibion, Gorodnichenko and Kumar (2018) discuss the validity of their survey in detail.

Table 7: Firm Size and Inflation Nowcast Error in US

	2018Q3	2019Q3	2020Q3	Pool (1)	Pool (2)
Constant	0.729^{***}	0.234^{***}	1.023^{***}	0.936^{***}	0.746^{***}
	(0.129)	(0.021)	(0.092)	(0.069)	(0.055)
Medium	-0.036	-0.007	-0.018	-0.202^{**}	-0.169^{**}
	(0.144)	(0.026)	(0.374)	(0.092)	(0.059)
Small	-0.182	0.002	-0.296^{***}	-0.342^{***}	-0.262^{***}
	(0.130)	(0.021)	(0.077)	(0.069)	(0.051)
Time fixed effect					Yes
Sector fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	182	142	329	684	671
R^2	0.413	0.030	0.308	0.215	0.651

Notes: The table reports results for the Huber robust regression. Dependent variables are the nowcast error of inflation. The base group in the model is the large firm group. Medium and small are dummies that turn one if firm belongs to that group. Sector fixed effects include dummies for 7 sector. Sample weights are applied to all specifications. Robust standard errors (clustered at 21 sub-sector level) are reported in parentheses. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively.

survey is conducted quarterly starting from 2018Q2. The Nowcast error of inflation in the last 12 months is our dependent variable. Table (7) shows that larger firms (denoted by constant in the table) make larger inflation nowcast error relative to firms in medium and small size groups. The last two columns of the table are the results for when I pool the data from all three survey rounds, without and with time-fixed effects in the model.

4.5 Additional Survey Evidence

All empirical results indicate a relationship between firm size and their attentiveness to aggregate conditions. If I accept that smaller firms are more financially constrained than larger ones, I can claim that financial friction increases a firm's attentiveness. In appendix A, I provide additional evidence regarding the role of firm size in their attentiveness. First, by using industry inflation as the only industry variable in the survey, I show that larger firms make a smaller error on the nowcast of industry inflation. This can rule out the idea that larger firms make bigger nowcast errors on all kinds of economic variables, maybe because the managers in larger firms have more limited time available to them to allocate toward tracking economic conditions. Second, I add importance dummies to the specifications in table (4) to ensure that the relationship between firm size and nowcast error still holds among firms with the same importance ranking. Third, I control for the number of products as an important firm characteristic correlated with a firm size that can potentially affect their attentiveness. Fourth, I also use the nowcast error of interest rate and exchange rates as dependent variables of the baseline specification in table (4). Fifth, I look into the role of age in determining a firm's nowcast error, as it is another proxy variable for financial friction used in the literature. Finally, I use the forecast error of aggregate variables as dependent variables to examine if the same relationship still holds between firm size and forecast error.

5 Dynamic General Equilibrium Model

In this section, I extend the simple investment model discussed in section (3) to a dynamic general equilibrium framework. Within this framework, firms engage in various activities such as processing information, setting prices, hiring workers, and making investment and finance decisions. Monetary policy plays a crucial role, as it targets aggregate nominal demand in the economy, and the persistence of monetary policy shocks influences a firm's level of attentiveness. Additionally, in general equilibrium, firms' decisions are interdependent, meaning that the actions of other firms also affect each individual firm's level of attentiveness.

5.1 Full Information

Similar to the simple model, I begin by describing the model in a full information environment. Then I proceed to add rational inattention. The model is populated by a continuum of two types of firms: constrained firms with weight ω and unconstrained ones with weight $1-\omega$.

5.1.1 Final Good Producers

The final good producer buys intermediate goods y_{it}^c from constrained firms and y_{it}^u from unconstrained firms at prices p_{it}^c and p_{it}^u respectively, aggregates them in a CES fashion, and sells the final good y_t to the households at a competitive price P_t. The maximization problem of the final good producer is as follows:

$$\max_{y_{it}^c, y_{it}^u, y_t} P_t y_t - \int_0^{\alpha_s} p_{it}^c y_{it}^c di - \int_{\alpha_s}^1 p_{it}^u y_{it}^u di$$

Subject to:

$$y_t = \left(\int_0^{\alpha_s} y_{it}^{c\,\frac{\epsilon-1}{\epsilon}} di + \int_{\alpha_s}^1 y_{it}^{u\,\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \tag{10}$$

The first order conditions with respect to y_{it}^c and y_{it}^u give rise to the demand functions for the constrained and unconstrained firms: $y_{it}^x = (\frac{p_{it}^x}{P_t})^{-\epsilon} y_t$, where $x \in \{c, u\}$. Substituting the demand function in equation (10) gives the aggregate price:

$$P_t = \left(\alpha_s p_t^{c\,1-\epsilon} + (1-\alpha_s) p_t^{u\,1-\epsilon} \right)^{\frac{1}{1-\epsilon}} \tag{11}$$

Where $p_t^c = p_{it}^c, \forall i \in [0, \alpha_s)$ and $p_t^u = p_{it}^u, \forall i \in [\alpha_s, 1]$.

5.1.2 Intermediate Good Producers: Constrained Firms

At the beginning of each period and following the realization of the shock, firms decide what price to set, how much labor to hire to meet the realized demands, and how much to invest for the next period's capital. They have two sources of funds to finance their production process: internal and external. The firm's revenue in each period makes up its internal funds, and it can use debt or equity as sources of its external funds. Following Drechsel (2022), constrained firms face earning-based borrowing constraints. This type of borrowing constraint is supported by empirical evidence in Lian and Ma (2021), where they find that for U.S. nonfinancial firms, 20% of debt by value is asset-based, whereas 80% is based predominantly on cash flows from firms' operations.[6,7]

As mentioned earlier, after the realization of the shock at the beginning of each period, firms set price p_{it}[8], receive demand orders and hire labor l_{it} by paying wage W_t, and produce intermediate goods y_{it}. Firms have a Cobb-Douglas production function that takes both labor l_{it} and capital k_{it} as inputs: $y_{it} = k_{it}^{\theta} l_{it}^{1-\theta}$. I assume that both types of firms have a constant productivity level normalized to 1. The firm's capital at period t is determined at $t-1$; therefore, changes in labor are the only margin that can affect the firm's production in the current period. For production in the next periods, firms can increase or decrease their capital by trading capital goods in the economy. As in the two-period model, firms finance their production cost through debt b_{it} and equity

[6]Similar evidence is provided in Kermani and Ma (2021), Drechsel (2022), and Caglio, Darst and Kalemli-Özcan (2021).

[7]In addition, as Drechsel (2022) shows in a macro model, firms with earning-based financial constraints are able to borrow more in response to positive investment shocks consistent with the data, while firms with asset-based constraints borrow less.

[8]To simplify the notation, I will drop superscript c and u from decision variables of constrained and unconstrained firms.

d_{it}. Following Hennessy and Whited (2005), debt is subsidized ($R_t = 1 + (1-\tau)r_t$) and therefore preferred to equity. However, borrowing is subject to an earning constraint, meaning that firms can only borrow up to a multiplication of their profit in each period. Even though a firm's borrowing capacity is constrained, it still can use its equity freely. Therefore, in order to have financial friction in the model, I assume firm's equity payout to be subject to a quadratic adjustment cost $\frac{\phi_d}{2}(d_{it} - \bar{d})^2$ similar to Jermann and Quadrini (2012). This friction means that firms have an equity payout target and deviation from this target is costly. As Jermann and Quadrini (2012) explain, the adjustment cost of equity payouts should not necessarily be viewed as pecuniary costs. It can represent the speed at which firms can change their funding sources when financial conditions change. This quadratic adjustment cost can also incorporate the possible costs associated with share repurchases and equity issuance.

Firm's objective is to maximize sum of stream of dividends discounted by a stochastic discount factor $\Lambda_t = \beta^t \left(\frac{C_t}{C_0}\right)^{-1}$ coming from the household side of the economy:

$$\max_{d_{it}, p_{it}, l_{it}, k_{it+1}, b_{it+1}} \mathbb{E} \sum_{t=0}^{\infty} \Lambda_t d_{it}$$

This maximization problem is subject to budget and borrowing constraints. The budget constraint is:

$$d_{it} + \frac{\phi_d}{2}(d_{it} - \bar{d})^2 + q_t I_{it} + b_{it} = \frac{p_{it}}{P_t} y_{it} - \frac{W_t}{P_t} l_{it} + \frac{b_{it+1}}{R_t} \tag{12}$$

where capital good $I_{it} = k_{it+1} - (1-\delta)k_{it}$ and q_t is its price. I assume that firms borrow real debt b_{it}, to abstract from debt deflation channel that might arise following monetary shocks. The borrowing constraint is an earning-based financial constraint:

$$\frac{b_{it+1}}{1 + r_t} \leq \theta_\pi \Pi_{it} \tag{13}$$

where $\Pi_{it} = \frac{p_{it}}{P_t} y_{it} - \frac{W_t}{P_t} l_{it}$. Since $1 + r_t > R_t$, the borrowing constraint binds and I can substitute for b_{it+1} in the budget constraint:

$$d_{it} + \frac{\phi_d}{2}(d_{it} - \bar{d})^2 + q_t I_{it} + = (1 + \frac{1 + r_t}{R_t}\theta_\pi)\Pi_{it} - (1 + r_{t-1})\theta_\pi \Pi_{it-1} \tag{14}$$

5.1.3 Intermediate Good Producers: Unconstrained Firms

Unconstrained firm's problem is similar to their counterpart except for the fact the they do not face a borrowing constraint or equity adjustment cost:[9]

$$\max_{d_{it}, p_{it}, l_{it}, k_{it+1}, b_{it+1}} \mathbb{E} \sum_{t=0}^{\infty} \Lambda_t d_{it}$$

subject to:

$$d_{it} + q_t I_{it} + b_{it} = \frac{p_{it}}{P_t} y_{it} - \frac{W_t}{P_t} l_{it} + \frac{b_{it+1}}{1 + r_t} \tag{15}$$

Since I assumed firms hold real debt and there is no other friction in the model, money will be neutral in this economy. I add inattentiveness to both firm's problem in next section which makes monetary policy non-neutral, and I will proceed to study the heterogeneous response of firms to monetary shocks.

5.2 Rational Inattention

I follow Maćkowiak and Wiederholt (2015) to incorporate rational inattention into the full information model. Firms face information friction that makes paying attention to economic conditions costly. I can think of the cost of attentiveness as the time and energy that managers need to allocate to analyze the economy. First, let us define function g as follows:

$$g(X_{-1}, X_0, Z_0, X_1, Z_1, X_2, Z_2, ...) = \sum_{t=0}^{\infty} \Lambda_t d_{it}$$

where X_t is the vector of variables that the firm can control at time t, which affects the value of the firm's profit $\Lambda_t d_{it}$. On the other hand, Z_t is the vector of variables that firms take as given when making their decisions. Using equations (14) and (15), x_t and z_t are:

$$X_t^{'} = (p_{it}, k_{it+1})$$

$$Z_t^{'} = (P_t, W_t, Y_t, q_t, C_t, r_t)$$

There is one variable that appears in the firm's profit at period t and is not present in either X_t or Z_t: The predetermined capital level k_{it}. Defining $X_{-1}^{'} = (k_{i0}, 0)$ results in k_{it}

[9] In this model, debt is indeterminate since the real interest rate that unconstrained firms pay on non-contingent debt is assumed to be r_t. Therefore, I will rewrite the model by not incorporating debt explicitly as follows: $\max_{p_{it}, l_{it}, k_{it+1}} \mathbb{E} \sum_{t=0}^{\infty} \Lambda_t (\frac{p_{it}}{P_t} y_{it} - \frac{W_t}{P_t} l_{it} - q_t I_{it})$.

being an element of X_{it-1} for all $t \geq 0$. Using the definition of g, I show in appendix D that the firm's problem can be written as the following minimization problem:

$$\min_{\kappa,\sigma_\nu} \Bigg\{ -\sum_{t=0}^{\infty} \beta^t \mathbb{E}_{i,-1} \Big[\frac{1}{2} \left(x_t^* - x_t\right)' H_{x,0} \left(x_t^* - x_t\right) + \left(x_t^* - x_t\right)' H_{x,1} \left(x_{t+1}^* - x_{t+1}\right) + \left(x_t^* - x_t\right)' H_{x,2} \left(x_{t+2}^* - x_{t+2}\right) \Big] + \frac{\mu}{1-\beta}\kappa \Bigg\} \tag{16}$$

subject to the law of motion for optimal action under full information

$$x_t^* = \begin{pmatrix} \hat{p}_{it}^* \\ \hat{k}_{it+1}^* \end{pmatrix} = \begin{pmatrix} A(L) \\ B(L) \end{pmatrix} \varepsilon_t^m, \tag{17}$$

the law of motion for actual action under rational inattention

$$x_t = E\left[x_t^* | \mathcal{F}_{i0}, s_{i1}, s_{i2}, ..., s_{it}\right], \tag{18}$$

and the information flow constraint

$$\mathcal{I}(\{\hat{p}_{it}^*\}; \{s_{it}\}) \leq \kappa. \tag{19}$$

$A(L)$ and $B(L)$ are infinite order lag polynomials. $\beta^t H_{x,\tau}$ is the matrix of second order derivatives of g with respect to x_t and $x_{t+\tau}$ evaluated at the non-stochastic steady state. I assume that the signal that the firm acquires in each period is in the form of full information optimal action plus a white noise:

$$s_{it} = \hat{p}_{it}^* + \nu_{it}$$

where $\nu_{it} \sim N(0, \sigma_\nu^2)$ are i.i.d. across firms and over time and independent from monetary shocks.

Following the literature on rational inattention, I evaluate the cost and benefit of paying attention by writing down the firm's problem in terms of the deviation of their profit under rational inattention from the full information profit. The minimization problem (16) states that at period -1 firm decides the standard deviation of the rational inattention error σ_ν, which determines how much information it will acquire in each period. Based on this decision and given the full information action, it then finds the optimal action x_t, which minimizes its expected profit loss condition on its information set at period t.[10] The objective function (16) shows that the more attentive firms get, they can follow the optimal action under full information more accurately, and thus, prevent losing profit due to inattentiveness.

5.3 Closing The Model

5.3.1 Households

The model is populated with a standard representative household. Households consume final good c_t and supply labor l_t to firms. They live forever and maximize their expected lifetime utility from consuming final goods and leisure

$$\max_{C_t, b_{t+1}, l_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \big(ln(C_t) + \psi \, ln(1 - l_t) \big)$$

Where β is the discount factor and ψ governs the disutility of labor supply. Firms hold non-contingent real bonds b_{t+1} issued by constrained firms and pay a lump sum tax T_t to finance the debt subsidy. Households own all the firms in the economy; therefore, they receive profits Π_t in each period. The Household's budget constraint is as follows:

$$C_t + \frac{b_{t+1}}{1 + r_t} + T_t \leq \frac{W_t}{P_t} l_t + b_t + \Pi_t \tag{20}$$

r_t is the real interest rate, P_t is the price of the final good, and W_t is the nominal wage paid to the worker.

5.3.2 Government and Monetary Policy

Government tax households to finance the debt subsidy:

$$T_t = \frac{b_{t+1}}{1 + (1 - \tau) r_t} - \frac{b_{t+1}}{1 + r_t}$$

and controls money supply that directly affects household nominal demand: $M_t = P_t C_t$.[11] Money supply growth follows an AR(1) process:

[10] Taking FOC from equation with respect to x_t (16) and using the law of iterated expectation results in optimal rational inattention action denoted in (18).

[11] This is a standard approach and has been used in several papers such as Mankiw and Reis (2002), Nakamura and Steinsson (2010), Golosov and Lucas Jr. (2007), and Afrouzi (2016) among others.

$$\Delta \log(M_t) = \rho_m \Delta \log(M_{t-1}) + \varepsilon_t^m$$

where ε_t^m is a shock to money supply growth, and ρ_m controls the persistence of the shock in the model. Using the Euler equation from the household's problem, I can show how the money supply will be related to the interest rate in the economy:

$$\frac{1}{1+r_t} = \beta \mathbb{E}\left(\frac{P_{t+1}}{P_t}\frac{M_t}{M_{t+1}}\right)$$

5.3.3 Capital Good Producer

Following Bernanke, Gertler and Gilchrist (1999) and Ottonello and Winberry (2020), there is a representative capital good producer in the model which purchases final good I_t from the CES aggregator and produces aggregate capital K_t using a production technology $\Phi(\frac{I_t}{K_t})K_t$. $K_t = \int k_{it} di$ is the aggregate capital and evolves according to

$$K_{t+1} = (1-\delta)K_t + \Phi(\frac{I_t}{K_t})K_t$$

where $\Phi(\frac{I_t}{K_t}) = \frac{\delta^{1/\phi}}{1-1/\phi}\left(\frac{I_t}{K_t}\right)^{1-1/\phi} - \frac{\delta}{\phi-1}$, with δ being the steady-state investment rate. Firm's maximization problem is:

$$\max_{I_t} q_t K_{t+1} - I_t$$

The FOC determines the relative price of capital good in the economy: $q_t = \left[\Phi'(\frac{I_t}{K_t})\right]^{-1}$

5.4 Parameterization

There are two groups of parameters in the model. The first one is parameters that I borrow from other studies. The Cobb-Douglas parameter in the production function is set to $\theta = 0.36$, the quarterly depreciation rate $\delta = 0.025$, the elasticity of substitution between intermediate goods is set $\epsilon = 8.3$ resulting in steady state price markups of 13.7%. The equity adjustment cost parameter is set to $\phi_d = 0.4$, and the tax advantage $\tau = 0.35$. The aggregate capital adjustment cost parameter is set to $\phi = 4$ following the literature. θ_π, which governs the tightness of earning-based constraint, is set 18.4 following Drechsel (2022). The discount factor is set to $\beta = 0.995$ resulting in a 2% annual real interest rate. The parameter that determines the disutility of labor is set to $\psi = 1.35$ to have a steady

Table 8: Parametrization

Parameter	Description	value	Source
θ	Share of Capital	0.36	Jermann and Quadrini (2012)
δ	Depreciation rate	0.025	Jermann and Quadrini (2012)
ϵ	Demand Elasticity	8.3	Jermann and Quadrini (2012)
ϕ_d	Equity adjustment cost	0.4	Jermann and Quadrini (2012)
τ	Tax advantage	0.35	Jermann and Quadrini (2012)
ϕ	Aggregate capital AC	4	Bernanke, Gertler and Gilchrist (1999)
θ_π	debt constraint	18.4	Drechsel (2022)
Calibrated:			
β	Discount factor	0.995	2% annual real rate
ψ	Utility parameter	1.35	L = 0.3
ω	Share of constrained firms	0.26	$\frac{\omega k^{JR}}{(1-\omega)k^{IG}} = \frac{1}{T}\sum_t(\frac{\sum_i k_{i,t}^{JR}}{\sum_i k_{i,t}^{IG}})$
μ	Info. processing cost	0.0095	Targeting empirical IRFs.
ρ_m	Shock persistence	0.9	$\Delta(pce_t) = \rho_m \Delta(pce_{t-1}) + \epsilon_m$
σ_m	s.d. of shock	0.006	$s.d(\epsilon_m)$

state value of labor equal to 0.3. The share of constrained firms ω is the share of junk-rated firms in the dataset and is set to 0.26 using observation between $1990-2008$ from Compustat and solving $\frac{\omega k^{const.}}{(1-\omega)k^{uncons.}} = \frac{1}{T}\sum_t(\frac{\sum_i k_{i,t}^{JR}}{\sum_i k_{i,t}^{IG}})$, where t is time and i denotes a firm.

The parameter determining the level of inattentiveness in the model is the per-period marginal cost of attention μ. To calibrate this parameter, I follow Christiano, Eichenbaum and Evans (2005) and minimize the distance of model IRFs from the empirical IRFs of capital for both constrained and unconstrained firms estimated in equation (22):

$$\min_{\boldsymbol{\mu}}[\hat{\boldsymbol{\Psi}} - \boldsymbol{\Psi}(\boldsymbol{\mu})]'\boldsymbol{V}^{-1}[\hat{\boldsymbol{\Psi}} - \boldsymbol{\Psi}(\boldsymbol{\mu})] \tag{21}$$

where $\boldsymbol{\Psi}(\boldsymbol{\mu})$ denotes the mapping from $\boldsymbol{\mu}$ to model IRF, $\hat{\boldsymbol{\Psi}}$ is the empirical IRF, and $\boldsymbol{V}$ is the diagonal matrix with variances of the empirical IRFs on its diagonals. I also calibrate the monetary policy using the nominal personal expenditure data from 1990-2008 and running the following regression: $\Delta(pce_t) = \rho_m \Delta(pce_{t-1}) + \epsilon_m$. ρ_m is the persistence of the shock, and the standard deviation of the residuals will be the standard deviation of the monetary shock σ_m. Table (8) summarizes the parameters.

5.5 Impulse Response Functions

I follow Maćkowiak and Wiederholt (2015) to solve the rational inattention model. First, I need to guess the optimal full information actions. It means that I need to guess $A(L)$ and $B(L)$ for the law of motion for optimal actions in equation (17). $A(L)$ and $B(L)$ are infinite-order lag polynomials that must be truncated for the numerical solution. Second, I solve the firm's attention problem denoted in (16) and find the firm's actual action. Third, I aggregate firms' actions to obtain aggregate variables. Fourth, and based on these aggregate variables and the firm's FOCs, I come up with the new guess on full information optimal action. Finally, I iterate the procedure until the initial and final guesses are close enough.

Figure (2) presents the impulse response functions of a firm's output price and capital to one standard deviation expansionary monetary policy shock. As firms are inattentive, their output price does not follow the full information output price paths. An inattentive firm's decision is slow and sluggish and lags behind the full information optimal price. As a result, the real nominal demand in the economy rises, and firms hire more employees to meet the demand. This puts upward pressure on wages, increasing the firm's production cost and lowering its per-period profit. As firms hire more employees, the marginal product of labor falls, giving an incentive for firms to invest in capital. However, figure (2) shows that constrained and unconstrained firms behave differently in the model. Unconstrained firms increase their capital as they have access to cheap funds. Unconstrained firms' higher demand for capital in the economy raises capital's price and makes investment less profitable. More expensive capital will affect constrained firms more as they can only access costly funds. Constrained firms cannot borrow more since their revenue has already fallen, and their borrowing constraint is tighter than before the shock. Raising funds through equity is also costly as they have to pay for financial costs. As a result, it is an optimal decision for constrained firms to contract.

The optimal information capacity κ^* equals 1.1 for constrained firms and 0.97 for unconstrained ones, showing that constrained firms acquire more information than unconstrained ones. Firm's nowcast error of inflation in the model measured by $\mathbb{E}|\pi_t - B^i(\pi_t)|$ is equal 0.60% for constrained firms and equals 0.77% for unconstrained ones. Therefore, the model predicts that financial friction reduces nowcast error by 0.17%. Column fifth of the table (7) shows that the difference between the nowcast error of large and small firms is about 0.26%, suggesting that model estimates of the difference between nowcast errors and the evidence from data are comparable.

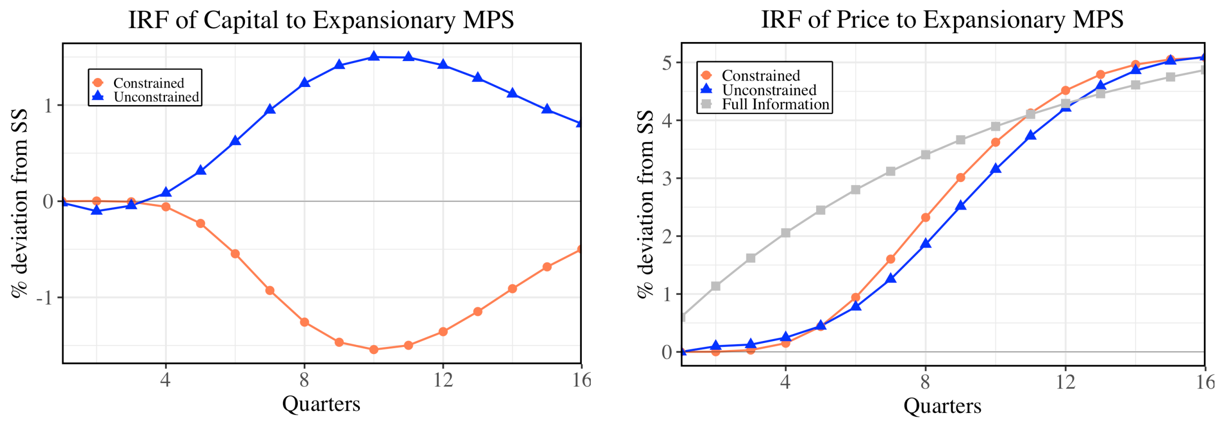

Figure 2: Impulse response functions of capital (left) and output price (right) of both constrained and unconstrained firms to one s.d. expansionary monetary policy shocks.

5.6 Financial Frictions and Aggregate Attentiveness

Now I run two counterfactuals to examine how inattentiveness and financial frictions impact the outcome of monetary policy shock through investment. Inattentiveness has two channels to shape a firm's investment response. It can have a direct effect through the dampening factor and an indirect one through general equilibrium. Figure (3) presents the effect of a higher cost of information (Increasing μ from 0.0095 to 0.019) on firm-level and aggregate investment response to expansionary monetary policy shocks. Higher inattentiveness makes firms' responses more sluggish and dampened for the first ten quarters in this counterfactual. However, as prices become less flexible, aggregate demand peaks higher eventually, demanding greater investment. In other words, for longer horizons, as firms accumulate enough information about the shock that hit the economy at period zero, the direct effect of inattentiveness vanishes away, and the indirect effect dominates.

The next counterfactual studies the effect of higher financial frictions in the economy as shown in figure (4). More constrained firms in the economy mean more firms contract following an expansionary shock. This allows unconstrained firms in the economy to invest more as they find aggregate demand for capital lower in the counterfactual. However, the response of aggregate investment is dampened in the case with a bigger weight on constrained firms. Two forces dampen the aggregate response. First, there are more constrained firms that are contracting in the economy. Second, attentiveness is higher in the economy due to higher financial frictions. That means investment responds faster to the shock for the initial periods, but it peaks lower as aggregate demand will be lower in this case following the shock.

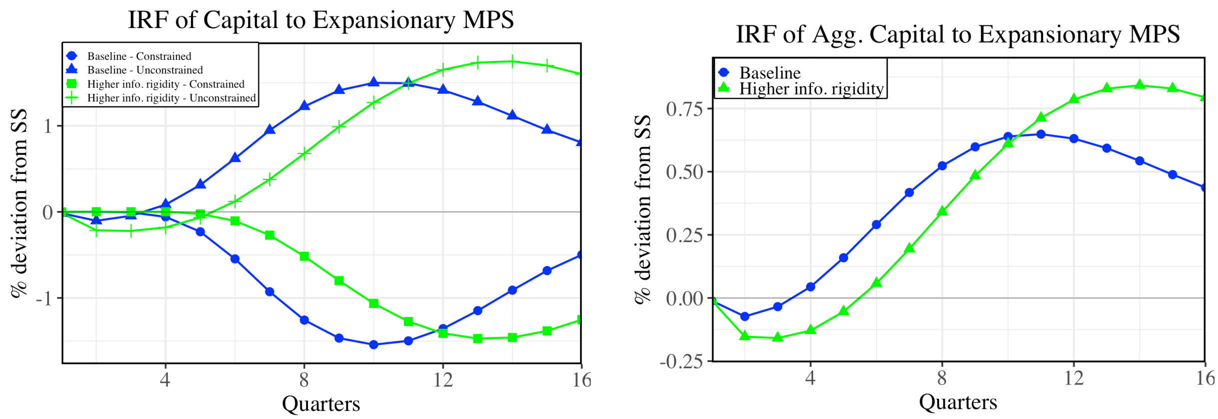

Figure 3: Impulse response functions of capital for constrained and unconstrained firms (left) and aggregate capital (right) to one s.d. expansionary monetary policy shocks. Baseline results are for the case where cost of each unit of information $\mu = 0.0095$ and high information rigidity is when $\mu = 0.019$.

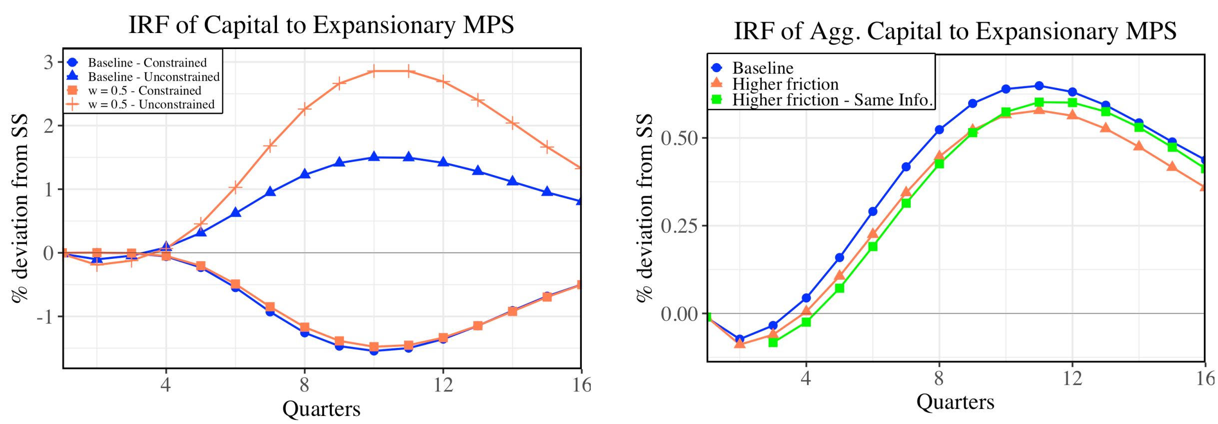

Figure 4: Impulse response functions of capital for constrained and unconstrained firms (left) and aggregate capital (right) to one s.d. expansionary monetary policy shocks. Baseline results are for the case where share of constrained firms $\omega = 0.26$ and the counterfactual is when $\omega = 0.5$.

6 Empirical Evidence from Firm-level Investment Data

6.1 Data

The firm-level data used in the empirical analysis comes from Compustat, which provides detailed quarterly balance sheet data for public firms. The rich set of variables from the firm's balance sheet allows us to control for factors that might affect the estimations. The main variable of interest in this paper is capital investment. Instead of directly using lumpy measures of investment available in the Compustat, I follow the literature and use the change in the book value of a firm's tangible capital stock as its investment.

Since this section aims to study how constrained and unconstrained firms respond to monetary shocks, I need to identify financial constraints. Unlike most of the literature, I use S&P's long-term issuer credit rating to identify financially constrained firms. High credit quality firms, with A- rating or higher, are grouped as firms that are unaffected by financial frictions. On the other hand, the low credit quality firms with BB+ ratings or lower are grouped as financially constrained. As Rezghi (2020) shows, the behavior of firms grouped based on this criteria is consistent with how a financially constrained firm would behave following a monetary shock: unconstrained firms can raise funds through issuing new equity, while constrained firms cannot. In Rezghi (2020), I discuss in more detail the merit of using credit rating in identifying financial frictions and the robustness of our empirical evidence using alternative proxies like distance to default. In appendix B, I explain how the sample is constructed.

An aggregate measure of information rigidity is required to estimate the effect of inattentiveness on a firm's investment response to monetary policy shocks. I use the measure of information rigidity estimated in Coibion and Gorodnichenko (2015) using the survey of professional forecasters. The implicit assumption in using this measure as an aggregate information rigidity and examining its effect on firm-level investment decisions is that professional forecasters are the most informed agents in the economy. Thus, when they become less attentive to aggregate conditions, I expect other agents in the economy also to be less attentive.

Another variable crucial for conducting the analysis is the monetary shock. I use the monetary shocks series constructed by Romer and Romer (2004) and extended by Coibion and Gorodnichenko (2012) to cover the period until 2008. Romer and Romer (2004) identify monetary policy shocks as changes to the intended federal funds rate that is not predictable by the economic information in the Federal Reserve's Greenbook forecasts. To transform the monthly series to a quarterly one, I simply sum over shocks within each quarter.[12]

6.2 Regression Model: Constrained vs Unconstrained Firms

I estimate the following panel regression model in the spirit of Jordà (2005) local projection to determine how constrained and unconstrained firms respond to expansionary monetary shocks.

$$\begin{aligned} \Delta_h \log\left(k_{i,t+h}\right) = f_{i,h} + q_{t+h} + \mathit{Trend} + \Theta_h' W_{i,t-1} + \sum_{j=1}^{4} \Omega_{h,j}' Y_{t-j} \\ + \left(\beta_h + \tilde{\gamma}_h \varepsilon_t^m\right) \times \mathbb{1}_{i \notin \mathcal{I}_{t-1}} + \left(\beta_h' + \gamma_h' \varepsilon_t^m\right) \times \mathbb{1}_{i \in \mathcal{I}_{t-1}} + u_{i,h,t+h} \end{aligned} \tag{22}$$

This local projection model estimates the cumulated effect of monetary shock on fixed capital $k_{i,t}$ after h period. The dependent variable is the change in the logarithm of $k_{i,t}$ between period $t-1$ and $t+h$. On the right hand side, I control for firm-level fixed effect $f_{i,h}$, quarterly dummies q_{t+h} to take out seasonal effects, and a linear *Trend*. $W_{i,t}$ denotes a vector of firm-level variables that contains log(size), sales growth, Tobin's q, cash flow, capital share, leverage, and liquid asset ratio. I also control for lags of aggregate variables Y_t, which includes inflation, GDP growth, unemployment rate, and excess bond premium for four quarters. $\mathcal{I}_t$ is the set of unconstrained firms at time t. $\mathbb{1}_{i \in \mathcal{I}_{t-1}}$ is an indicator that equals one when firm i is an unconstrained firm at time $t-1$ and equals zero otherwise. Firm-level and aggregate control variables are measured at least one period before the shock to ensure that those variables are exogenous to the shock.

The monetary policy shock ε_t^m is normalized so that one standard deviation expansionary shock (27 basis points change in federal fund rate (APR)) equals 1. Some empirical findings suggest that the effects of monetary shock during tightening and easing periods are not symmetric. In Rezghi (2020), I relax the assumption of having a symmetric response. The results are qualitatively the same for positive and negative shocks; however, the difference between the investment response of constrained and unconstrained firms is starker for expansionary shocks.

The parameters of interest are the coefficients of monetary shocks, which estimate the average effect of shock across two groups of firms. γ_h and $\tilde{\gamma}_h$ compare the level response of unconstrained and constrained firms to an expansionary shock respectively. Figure 5

[12] In Rezghi (2020), I provide robustness checks for using high-frequency identified monetary shocks.

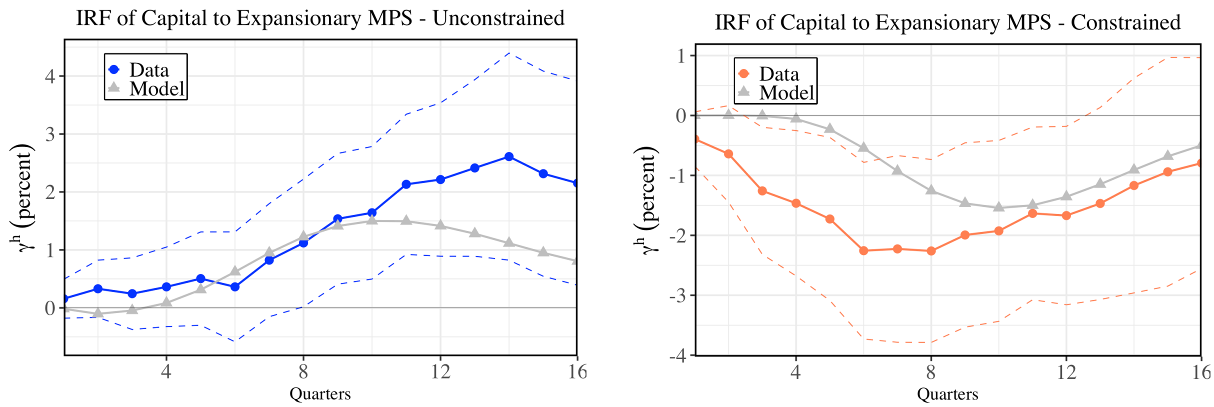

Figure 5: The effect of one s.d. expansionary monetary shock on fixed capital of high and low credit quality firms, along side the model IRFs.

Notes: The point estimates and the 95% confidence interval for γ_h by estimating specification (22). Standard deviations are two-way clustered across both firms and time dimensions.

shows the effect of monetary shocks on firms' investment across the groups along with the model results.

6.3 Regression Model: Information Rigidity and Aggregate Investment Response

This section estimates how inattentiveness to macroeconomic conditions shapes aggregate investment response to monetary policy shocks. Similar to the previous section, I run the following local projection:

$$\Delta_h \log\left(k_{i,t+h}\right) = f_{i,h} + q_{t+h} + Trend + \left(\Theta_h' + \Gamma_h' \varepsilon_t^m\right) W_{i,t-1} + \sum_{j=1}^{4} \left(\Omega_{h,j}' + \Lambda_t' \varepsilon_t^m\right) Y_{t-j} + \left(\alpha_h + \beta_h \lambda_t\right) \varepsilon_t^m + u_{i,h,t+h} \tag{23}$$

The only new variable in this regression relative to the specification in equation (22) is λ_t which is a normalized measure of information rigidity estimated in Coibion and Gorodnichenko (2015). A higher level of λ_t corresponds to a higher level of information rigidity and inattentiveness in the economy. The coefficient on the interaction between monetary shock and the measure of inattentiveness will reveal how much a one standard deviation increase in λ_t changes the average capital response to one standard deviation expansionary monetary shocks. According to the estimation presented in figure (6), one standard deviation higher information rigidity dampens the investment response to expansionary monetary shocks by about 0.5%.

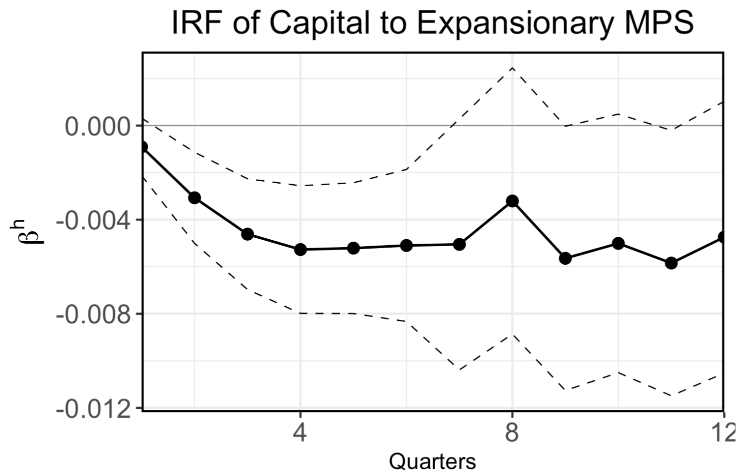

Figure 6: The effect of one s.d. expansionary monetary shock on fixed capital when inattentiveness level is also increased by one s.d..

Notes: The point estimates and the 95% confidence interval for β_h by estimating specification (23). Standard deviations are two-way clustered across both firms and time dimensions.

7 Conclusion

This paper studied the investment channel of monetary policy in an environment with financial frictions and rational inattention. I showed that, theoretically, firms' attentiveness could be a function of their financial conditions. I also provided empirical evidence using firms' expectations surveys to support this prediction. Then I studied the implications of this interaction between attentiveness and financial conditions for the investment channel of monetary policy. First, I showed that higher inattentiveness makes the investment response sluggish and dampened for initial periods. However, the aggregate fixed capital in the economy rises to higher levels due to higher demand levels. Empirical evidence also supports the dampening effect of inattentiveness on firms' investment. Finally, by changing the weight of constrained firms in the economy, I showed that the outcome of monetary policy could depend on both the financial condition and attentiveness of the firms in the economy.

The results of this paper could be of interest to policymakers. As monetary policy becomes predictable and the standard deviation of monetary shock decreases in the economy, economic agents become less attentive to it. The model predicts that in such an environment, where the level of inattentiveness to monetary policy is higher, the investment response to the shock is more sluggish and thus delays the real effect of nominal shocks.

References

Afrouzi, Hassan. 2016. "Strategic Inattention, Inflation Dynamics, and the Non-Neutrality of Money."

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist. 1999. "The financial accelerator in a quantitative business cycle framework."

Caglio, Cecilia, Matthew Darst, and Sebnem Kalemli-Özcan. 2021. "Risk-Taking and Monetary Policy Transmission: Evidence from Loans to Smes and Large Firms." *SSRN Electronic Journal*.

Charoenwong, Ben, Yosuke Kimura, Alan Kwan, and Eugene Tan. 2021. "Capital Budgeting, Uncertainty, and Misallocation." *Working Paper*, 1–45.

Christiano, Lawrence J, Martin Eichenbaum, and Charles L Evans. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Source: Journal of Political Economy*, 113(1): 1–45.

Clementi, Gian Luca, and Berardino Palazzo. 2019. "Investment and the Cross-Section of Equity Returns." *Journal of Finance*, 74(1): 281–321.

Coibion, Olivier, and Yuriy Gorodnichenko. 2012. "What Can Survey Forecasts Tell Us about Information Rigidities?" *Source: Journal of Political Economy*, 120(1): 116–159.

Coibion, Olivier, and Yuriy Gorodnichenko. 2015. "Information rigidity and the expectations formation process: A simple framework and new facts." *American Economic Review*, 105(8): 2644–2678.

Coibion, Olivier, Yuriy Gorodnichenko, and Saten Kumar. 2018. "How do firms form their expectations? New survey evidence." *American Economic Review*, 108(9): 2671–2713.

Cover, Thomas M., and Joy A. Thomas. 2006. *Information Theory Elements of.*

Drechsel, Thomas. 2022. "Earnings-Based Borrowing Constraints and Macroeconomic Fluctuations."

Duygan-Bump, Burcu, Alexey Levkov, and Judit Montoriol-Garriga. 2015. "Financing constraints and unemployment: Evidence from the Great Recession." *Journal of Monetary Economics*, 75: 89–105.

Flynn, Joel P., and Karthik A. Sastry. 2021. "Attention Cycles."

Gertler, Mark, and Simon Gilchrist. 1994. "Monetary Policy, Business Cycles, and the Behavior of Small Manufacturing Firms." 2.

Golosov, Mikhail, and Robert E. Lucas Jr. 2007. "Menu Costs and Phillips Curves." *Journal of Political Economy*.

Hadlock, Charles J, and Joshua R Pierce. 2010. "New evidence on measuring financial constraints: Moving beyond the KZ index." *Review of Financial Studies*, 23(5): 1909–1940.

Hennessy, Christopher A., and Toni M. Whited. 2005. "Debt Dynamics." *The Journal of Finance*, 60(3): 1129–1165.

Jeenas, Priit. 2018. "Monetary Policy Shocks, Financial Structure, and Firm Activity: A Panel Approach."

Jermann, Urban, and Vincenzo Quadrini. 2012. "Macroeconomic effects of financial shocks."

Jordà, Òscar. 2005. "Estimation and inference of impulse responses by local projections." *American Economic Review*, 95(1): 161–182.

Kermani, Amir, and Yueran Ma. 2021. "Two Tales of Debt." *SSRN Electronic Journal*.

Kiyotaki, Nobuhiro, and John Moore. 1997. "Credit Cycles." 2, The University of Chicago Press.

Lian, Chen, and Yueran Ma. 2021. "Anatomy of Corporate Borrowing Constraints." *Quarterly Journal of Economics*, 136(1): 229–291.

Maćkowiak, Bartosz, and Mirko Wiederholt. 2009. "Optimal sticky prices under rational inattention." *American Economic Review*, 99(3): 769–803.

Maćkowiak, Bartosz, and Mirko Wiederholt. 2015. "Real Business Cycle Dynamics under Rational Inattention." 1(14089).

Mankiw, N. Gregory, and Ricardo Reis. 2002. "Sticky information versus sticky prices: A proposal to replace the new Keynesian Phillips curve." *Quarterly Journal of Economics*, 117(4): 1295–1328.

Mckay, Alisdair, and Johannes F Wieland. 2021. "Lumpy Durable Consumption Demand and the Limited Ammunition of Monetary Policy."

Nakamura, Emi, and Jón Steinsson. 2010. "Monetary non-neutrality in a multisector menu cost model." *Quarterly Journal of Economics*, 125(3): 961–1013.

Ottonello, Pablo, and Thomas Winberry. 2018. "Financial Heterogeneity and the Investment Channel of Monetary Policy." 1–72.

Ottonello, Pablo, and Thomas Winberry. 2020. "Financial Heterogeneity and the Investment Channel of Monetary Policy." *Econometrica*, 88(6): 2473–2502.

Rezghi, Abolfazl. 2020. "Monetary Policy Shocks, Financial Frictions, and Investment."

Romer, Christina D, and David H Romer. 2004. "A New Measure of Monetary Shocks: Derivation and Implications." *American Economic Review*, 94(4): 1055–1084.

Sims, Christopher A. 2003. "Implications of rational inattention." *Journal of Monetary Economics*, 50(3): 665–690.

Tenreyro, Silvana, and Gregory Thwaites. 2016. "Pushing on a string: Us monetary policy is less powerful in recessions." *American Economic Journal: Macroeconomics*, 8(4): 43–74.

Vavra, Joseph. 2014. "Inflation Dynamics and Time-Varying Uncertainty." *The Quarterly Journal of Economics*, 129(No. 1 (February 2014)): 215–258.

Wang, Zijian. 2022. "Rational Inattention , Financial Heterogeneity and Effectiveness of Monetary Policy."

Whited, Toni M, and Guojun Wu. n.d.. "Financial Constraints Risk."

Woodford, Michael. 2001. "Imperfect Common Knowledge and the Effects of Monetary Policy." *NBER Working Paper Series*.

Yang, Choongryul. 2020. "Rational Inattention, Menu Costs, and Multi-Product Firms: Micro Evidence and Aggregate Implications."

Zorn, Peter. 2020. "Investment under Rational Inattention : Evidence from US Sectoral Data."

Appendix

A Additional Survey Evidence

A.1 Nowcast Error of Industry Inflation

Table 9: Firm Size and Nowcast Error of Industry Inflation

	(1)	(2)	(3)	(4)
	π_t	π_t^{ind}	π_t	π_t^{ind}
log(employment)	0.276^{***}	-0.044^{**}	0.085^{*}	-0.048^{**}
	(0.072)	(0.018)	(0.049)	(0.019)
Track dummy			-3.067^{***}	-0.034^{**}
			(0.058)	(0.015)
Firm Controls	Yes	Yes	Yes	Yes
Manager Controls	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes
Observations	1080	958	1065	961
R^2	0.625	0.931	0.859	0.928

Notes: The table reports results for the Huber robust regression. Dependent variable are the absolute value of firm errors about past 12-month headline and industry inflation from wave 4 survey. Sample weights are applied to all specifications. Robust standard errors (clustered at the 3-digit ANZ SIC level) are reported in parentheses. Track dummy is equal to one if manager tracks the headline inflation and zero otherwise. Firm controls are log(age), log(#competitors), labor cost share, trade share, and average margin. Manager characteristics are tenure, education, and income. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively.

A.2 Number of products and Nowcast Error

Table 10: Number of Products and Nowcast Error of Aggregate Variables

	(1) π_t	(2) ue_t	(3) $GDPg_t$
log(employment)	0.237*	0.132**	0.068
	(0.123)	(0.058)	(0.051)
log(#products)	0.047	0.007	−0.061***
	(0.067)	(0.022)	(0.020)
Firm Controls	Yes	Yes	Yes
Manager Controls	Yes	Yes	
Sector FE	Yes	Yes	Yes
Observations	383	372	387
R^2	0.624	0.370	0.336

Notes: The table reports results for the Huber robust regression. Dependent variable are the absolute value of firm errors about past 12-month inflation, unemployment rate and GDP growth rate from wave 4 survey. Number of products comes from wave 2 survey. Sample weights are applied to all specifications. Robust standard errors (clustered at the 3-digit ANZ SIC level) are reported in parentheses. Firm controls are log(age), log(#competitors), labor cost share, trade share, and average margin. Manager characteristics are tenure, education, and income. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively.

A.3 Importance of An Aggregate Variable

Table 11: Importance of An Aggregate Variable and Nowcast Error

	(1) π_t	(2) ue_t	(3) $GDPg_t$	(4) π_t	(5) ue_t	(6) $GDPg_t$
log(employment)	0.276***	0.078***	0.016	0.127**	0.053**	0.032
	(0.072)	(0.024)	(0.026)	(0.050)	(0.024)	(0.026)
$\mathbb{1}(\pi > ue)$				−1.069***	1.013***	0.004
$\mathbb{1}(\pi > gdp)$				−2.004***	−0.866***	0.213***
$\mathbb{1}(ue > gdp)$				0.025	−0.235***	0.104**
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Manager Controls	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1080	1042	1099	1082	1060	1095
R^2	0.625	0.118	0.164	0.836	0.222	0.484

Notes: The table reports results for the Huber robust regression. Dependent variable are the absolute value of firm errors about past 12-month inflation, unemployment rate and GDP growth rate from wave 4 survey. The importance dummies are constructed based on the answer to the following question in the survey: "*Which macroeconomic variables are most important to you in making your business decisions (rank them)? a. Unemployment rate b. GDP c. Inflation d. None*" Sample weights are applied to all specifications. Robust standard errors (clustered at the 3-digit ANZ SIC level) are reported in parentheses. Firm controls are log(age), log(#competitors), labor cost share, trade share, and average margin. Manager characteristics are tenure, education, and income. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively.

A.4 Nowcast Error of Interest Rate and Exchange Rate

Table 12: Firm Size and Forecast Error of Aggregate Variables

	(1) Interest rate	(2) Output gap	(3) Exchange rate
log(employment)	0.198***	0.383	0.005**
	(0.058)	(0.429)	(0.002)
log(age)	−0.182***	0.030	−0.002
	(0.053)	(0.323)	(0.002)
Firm Controls	Yes	Yes	Yes
Manager Controls	Yes	Yes	
Sector FE	Yes	Yes	Yes
Observations	1075	1076	1094
R^2	0.444	0.122	0.130

Notes: The table reports results for the Huber robust regression. Dependent variable are the absolute value of firms' nowcast errors about interest rate, output gap, and exchange rate. Interest rate and output gap are from wave 2 and the exchange rate is from wave 4. Sample weights are applied to all specifications. Robust standard errors (clustered at the 3-digit ANZ SIC level) are reported in parentheses. Firm controls are log(age), log(#competitors), labor cost share, trade share, and average margin. Manager characteristics are tenure, education, and income. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively.

A.5 Firm Age and Nowcast Error

Table 13: Firm Size and Nowcast Error of Aggregate Variables

	(1) π_t	(2) ue_t	(3) $GDPg_t$	(4) π_t	(5) ue_t	(6) $GDPg_t$
log(employment)	0.276***	0.078***	0.016			
	(0.072)	(0.024)	(0.026)			
log(age)	0.256***	−0.009	−0.038	0.350***	0.015	−0.031
	0.070	0.020	0.024	(0.064)	(0.019)	(0.024)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Manager Controls	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1080	1042	1099	1082	1040	1099
R^2	0.625	0.118	0.164	0.623	0.105	0.166

Notes: The table reports results for the Huber robust regression. Dependent variable are the absolute value of firm nowcast errors of past 12-month inflation, unemployment rate and GDP growth rate from wave 4 survey. Sample weights are applied to all specifications. Robust standard errors (clustered at the 3-digit ANZ SIC level) are reported in parentheses. Firm controls are log(age), log(#competitors), labor cost share, trade share, and average margin. Manager characteristics are tenure, education, and income. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively.

A.6 Forecast Error and Firm's Size

Table 14: Firm Size and Forecast Error of Aggregate Variables

	(1) π_t	(2) ue_t	(3) $GDPg_t$
log(employment)	0.206**	0.040	−0.041*
	(0.094)	(0.028)	(0.024)
log(age)	0.340***	−0.033	0.030
	(0.087)	(0.026)	(0.026)
Firm Controls	Yes	Yes	Yes
Manager Controls	Yes	Yes	
Sector FE	Yes	Yes	Yes
Observations	1075	1076	1094
R^2	0.444	0.122	0.130

Notes: The table reports results for the Huber robust regression. Dependent variable are the absolute value of firms' forecast errors about inflation, unemployment rate and GDP growth rate in the next 12 months from wave 4 survey. Professional forecasters' forecast is used as a reference point. Sample weights are applied to all specifications. Robust standard errors (clustered at the 3-digit ANZ SIC level) are reported in parentheses. Firm controls are log(age), log(#competitors), labor cost share, trade share, and average margin. Manager characteristics are tenure, education, and income. ***, **, * denotes statistical significance at 1%, 5%, and 10% levels respectively.

B Sample Construction for Panel Local Projections

B.1 Firm Level Data

Firm-level data comes from Compustat and CRSP. Following recent papers on the heterogeneous effect of monetary shocks on firms' investment like Jeenas (2018) and Ottonello and Winberry (2018), I focus on the period between 1990Q1 and 2007Q4. The observations during the financial crisis are omitted since I am interested in the effects of the conventional monetary policy. Excluding the data before 1990 also allows me to check the robustness of the results to high frequency identified monetary shocks that are available from 1990. The baseline result is broadly robust to including observations from 1985-1990. I exclude the following firms from my sample:

1. Firms that are incorporated outside US.
2. Firms in utilities (SIC codes 4900–4999), finance, insurance, and real estate (SIC codes 6000–6999), and public administration sector (SIC codes 9100–9999).
3. Observations with non-positive values for $ATQ_{i,t}$, $PPENTQ_{i,t}$, $PPEGTQ_{i,t}$, $SALEQ_{i,t}$, $INVTQ_{i,t}$, $PRCCQ_{i,t}$, and $CSHOQ_{i,t}$.
4. Observations with negative values for $DLCQ_{i,t}$, $DLTTQ_{i,t}$, and $CHEQ_{i,t}$.
5. Firms that have less than 40 observations in the sample, unless otherwise stated.

Also, When I run the regression model 22, I drop 1 percent of outlier observations at both tails of distribution for dependent variable $\Delta_h log(y_{i,t+h})$.

B.1.1 Dependent Variables:

1. *Fixed Capital:* I use the perpetual inventory method to construct the time series of fixed capital. This method is common in the literature and used in many papers such as Jeenas (2018), Ottonello and Winberry (2018), and Clementi and Palazzo (2019). The first observation for the fixed capital $k_{i,0}$ will be set as the earliest available value for the $PPEGTQ_{i,t}$ (Property, Plant and Equipment (Gross)) in the dataset. Fixed capital for the following periods would be iteratively constructed from this equation:

$$k_{i,t} = k_{i,t-1} + PPENTQ_{i,t} - PPENTQ_{i,t-1}$$

where $k_{i,t}$ is the firm i's capital at the end of period t and $PPENTQ_{i,t}$ is the net value of Property, Plant and Equipment on firm's balance sheet. Before applying the perpetual inventory method, I deflate $PPENTQ_{i,t}$ and $PPEGTQ_{i,t}$ using the implied price index of gross value added in the U.S. non-farm business sector (BEA-NIPA Table 1.3.4 Line 3).

2. *Debt, Inventory, and Sale:* Total debt is the sum of short and long term debt ($DLCQ_{i,t} + DLTTQ_{i,t}$). The inventory is $INVTQ_{i,t}$ in Compustat and sale is $SALEQ_{i,t}$.

B.1.2 Control Variables:

In the baseline regressions, I include following firm-level variables as controls:

1. *Size*: measured as firm's total assets ($ATQ_{i,t}$).

2. *Sales growth*: log difference of deflated value of sale ($SALEQ_{i,t}$) between period t and $t-4$.

3. *Cash flow ratio*: measured as the sum of Income Before Extraordinary Items ($IBQ_{i,t}$) and Total Depreciation and Amortization ($DPQ_{i,t}$) divided by firm's size $(\frac{IBQ_{i,t}+DPQ_{i,t}}{ATQ_{i,t}})$.

4. *Leverage:* measured as sum of Debt in Current Liabilities ($DLCQ_{i,t}$) and Long-Term Debt ($DLTTQ_{i,t}$) divided by firm's size $(\frac{DLCQ_{i,t}+DLTTQ_{i,t}}{ATQ_{i,t}})$. Outliers are dropped at 99% cutoff for each quarter.

5. *Liquid asset ratio:* measured as the ratio of Cash and Short-Term Investments ($CHEQ_{i,t}$) to firm's size $(\frac{CHEQ_{i,t}}{ATQ_{i,t}})$. Outliers are dropped at 99% cutoff for each quarter.

6. *Capital share*: measured as the ratio of firm's fixed capital to its size.

7. *Tobin's q*: measured as the ratio of market to book value of assets. I follow Ottonello and Winberry (2018) and define the market value of asset as the book value ($ATQ_{i,t}$), plus the market value of common stock ($PRCCQ_{i,t} \times CSHOQ_{i,t}$), minus the book value of common stock ($CEQQ_{i,t}$), plus deferred taxes and investment tax credit ($TXDITCQ_{i,t}$) $(\frac{ATQ_{i,t}+PRCCQ_{i,t}CSHOQ_{i,t}-CEQQ_{i,t}+TXDITCQ_{i,t}}{ATQ_{i,t}})$. The observations will be winsorized at 1% of each tail of the distribution.

B.2 S&P's Long-Term Issuer Credit Rating

These ratings are available at a monthly frequency. I define *Junk-Rated* firm as a firm with a rating equal to BB+ or lower for at least a month in a given quarter. The *Investment-Grade* firm, on the other hand, will be defined as a firm with an A- or above rating condition on not having BB+ or lower rating in the same quarter. I exclude firms with only BBB rating in a quarter from my sample, which are also known as investment-grade firms. It helps to have two sets of firms which are significantly different in terms of their credit ratings. The Baseline result is robust to also including BBB firms as investment-grades in the sample.

According to S&P's manuals, Prior to September 1, 1998, the rating is an "assessment of the creditworthiness of an obligor with respect to a senior or subordinated debt obligation". While After September 1, 1998, it is an "opinion of an issuer's overall creditworthiness" and not a specific type of debt. This issue might make the ratings not perfectly comparable before and after that time. However, in my analysis, I am interested in a set of rating categories (i.e., Junk Rated vs. Investment-Grade) and not a specific rating, and thus, this issue might be alleviated. In addition, excluding the firms with BBB ratings from the grouping procedures lowers the chance of misclassifying firms due to this change in definition.

C Quantifying Information

In this section, I define the mutual information function $\mathcal{I}$ used in equation (3).[13] Following Sims (2003) and the literature on rational inattention, I quantify information as the reduction in uncertainty about a random variable that firms experience by choosing a signal. The uncertainty of a random variable is measure by *entropy*. The entropy of a vector of normally distributed random variables $X = (X_1, ..., X_N)$ is

$$H(X) = \frac{1}{2}\log_2\left[(2\pi e)^N \det \Omega_X\right]$$

where Ω_X is the covariance matrix of X. I also need to define entropy of a random variable X condition on Y. This would allow us to compare the uncertainty of a random variable X with and without knowing Y, and the difference will be used as the quantity of information carried by Y about X:

$$X(X|Y) = \frac{1}{2}\left[(2\pi e)^N \det \Omega_{X|Y}\right]$$

where $\Omega_{X|Y}$ is the covariance matrix of X condition on Y. The mutual information function $\mathcal{I}(X;Y)$ which quantifies the amount of information the two random variables X and Y reveal about each other equals

$$\mathcal{I}(X;Y) = H(X) - H(X|Y)$$

and it is easy to show that $\mathcal{I}(X;Y) = \mathcal{I}(Y;X)$. For a series of random variables like $\{X_t\}_{t=0}^{\infty}$ and $\{Y_t\}_{t=0}^{\infty}$, I can define the mutual information function similar to Maćkowiak and Wiederholt (2015) as follows

$$\mathcal{I}(\{X_t\};\{Y_t\}) = \lim_{T\to\infty}\frac{1}{T}\left[H(X_0, ..., X_{T-1}) - H(X_0, ..., X_{T-1}|Y_0, ..., Y_{T-1})\right]$$

which is the average per period quantity of information that the first T elements of a random process contains about another random process. For a stationary Gaussian random process $\{X_t, Y_t\}_{t=0}^{\infty}$ I have

$$\mathcal{I}\left(\{X_t\};\{Y_t\}\right) = \lim_{T\to\infty}\frac{1}{T}\left[\frac{1}{2}\log_2\left(\frac{\det\Omega_X}{\det\Omega_{X|Y}}\right)\right].$$

I use this definition for equation (19) of the paper where $X_t = p^*_{it}$ and $Y_t = s_{it}$.

[13] Refer to Cover and Thomas (2006) for a more thorough review of information theory.

D Derivation of the Firm's Objective

This appendix derives the firm's objective function under rational inattention presented in equation (16). The derivation follows Appendix D of Maćkowiak and Wiederholt (2015) closely. I assume that firm's manager in period -1 values the real dividend at period t using the following stochastic discount factor:

$$\Lambda_t = \beta^t \left(\frac{C_t}{C_0} \right)^{-1}$$

Let g denote the discounted sum of dividends from zero to infinity using Λ_t. Let $\hat{g}$ denote the discounted sum of dividends in terms of log-deviations and Let $\tilde{g}$ denote the second-order Taylor approximation to $\hat{g}$ around the non-stochastic steady state. Let $\mathbb{E}_{i,-1}$ be the expectation operator conditioned on firm's information set at $t = -1$. Let us define the following vectors:

$$x_t^{'} = (\hat{p}_{it}, \hat{k}_{it+1})$$

$$z_t^{'} = (\hat{P}_t, \hat{W}_t, \hat{Y}_t, \hat{q}_t, \hat{C}_t, \hat{r}_t)$$

x_t is the vector of variables that firm can choose which affects its dividend payout. z_t on the other hand is the vector of aggregate variables that firm does not have any control over and take as given. Knowing x_t and z_t for all $t \geq 0$ plus $\hat{k}_{i0}$ is sufficient to calculate $\tilde{g}$. So, to simplify the notation, I introduce $x'_{-1} = (0, \hat{k_{i0}})$. Now we derive a log-quadratic approximation to the expected stochastic discounted sum of dividends around the non-stochastic steady state:

$$\begin{aligned}
&E_{i,-1} \left[\tilde{g} \left(x_{-1}, x_0, z_0, x_1, z_1, x_2, z_2, \ldots \right) \right] \\
&= E_{i,-1} \left[\begin{array}{c}
\hat{g}(0,0,0,0,0,0,0,0,\ldots) \\
+\beta^{-1} \left(\begin{array}{c} h'_{-1} x_{-1} + \frac{1}{2} x'_{-1} H_{-1} x_{-1} + \frac{1}{2} x'_{-1} H_{x,1} x_0 \\ + \frac{1}{2} x'_{-1} H_{x,2} x_1 + \frac{1}{2} x'_{-1} H_{xz,1} z_0 \end{array} \right) \\
+ \sum_{t=0}^{\infty} \beta^t \left(\begin{array}{c}
h'_x x_t + h'_z z_t \\
+\frac{1}{2} x'_t H_{x,-2} x_{t-2} + \frac{1}{2} x'_t H_{x,-1} x_{t-1} + \frac{1}{2} x'_t H_{x,0} x_t \\
+\frac{1}{2} x'_t H_{x,1} x_{t+1} + \frac{1}{2} x'_t H_{x,2} x_{t+2} \\
+\frac{1}{2} x'_t H_{xz,0} z_t + \frac{1}{2} x'_t H_{xz,1} z_{t+1} + \frac{1}{2} x'_t H_{xz,2} z_{t+2} \\
+\frac{1}{2} z'_t H_{z,0} z_t + \frac{1}{2} z'_t H_{zx,-2} x_{t-2} + \frac{1}{2} z'_t H_{zx,-1} x_{t-1} + \frac{1}{2} z'_t H_{zx,0} x_t
\end{array} \right)
\end{array} \right]
\end{aligned} \tag{24}$$

Where $\beta^t h_x$ and $\beta^t h_z$ are the first derivative of $\hat{g}$ with respect to x_t and z_t respectively calculated at steady state. $\beta^t H_{x,\tau}$ ($\beta^t H_{z,\tau}$) is the matrix of second derivative of $\hat{g}$ with respect to x_t (z_t) and $x_{t+\tau}$ ($z_{t+\tau}$) evaluated at steady state. $\beta^t H_{xz,\tau}$ ($\beta^t H_{zx,\tau}$) is the matrix of second derivative of $\hat{g}$ with respect to x_t (z_t) and $z_{t+\tau}$ ($x_{t+\tau}$) at steady state. Finally, $\beta^{-1}h_{-1}$ is the first derivative of $\hat{g}$ with respect to x_{-1} and $\beta^{-1}H_{-1}$ is the matrix of second order derivatives of $\hat{g}$ with respect to x_{-1}. Note that we are able to use the sum operator, since we are evaluating the derivatives at non-stochastic steady state, and these derivatives depends on t only through the multiplicative term β^t.

In order to simplify equation (24), let us define $v_t' = \left(x_t', z_t', 1\right)$ for all $t \geq 0$ and v_{-1} as an eight dimensional column vector where $\hat{k}_{i0}$ is its second element and all the other elements are equal zero. Now, I assume the following regularity conditions that will allow us move the expectation operator inside the summation operator:

$$E_{i,-1}\left[\hat{k}_{j,-1}^2\right] < \infty \tag{25}$$

$$E_{i,-1}\left|\hat{k}_{j,-1}v_{n,0}\right| < \infty; \text{ For all } n \tag{26}$$

where $v_{i,t}$ denotes the ith element of v_t. Also suppose that there are two constant $\delta < \frac{1}{\beta}$ and $A \in \mathbb{R}$ such that the following inequality holds for all m and n, for $t \geq 0$, and $\tau = 0, 1, 2$:

$$E_{i,-1}\left|v_{m,t}v_{n,t+\tau}\right| < \delta^t A \tag{27}$$

Based on these assumptions and given that $H_{xz,0} = H_{zx,0}'$, $H_{xz,1} = \beta H_{zx,-1}'$, $H_{x,1} = \beta H_{x,-1}'$, $H_{x,2} = \beta^2 H_{x,-2}'$ and $H_{xz,2} = \beta^2 H_{zx,-2}'$, one can rewrite equation (24) as follows:

$$\begin{aligned}
&E_{j,-1}\left[\tilde{g}\left(x_{-1}, x_0, z_0, x_1, z_1, x_2, z_2, \ldots\right)\right] = g(0,0,0,0,0,0,0,\ldots) \\
&+ \beta^{-1}E_{i,-1}\left[h_{-1}'x_{-1} + \frac{1}{2}x_{-1}'H_{-1}x_{-1} + x_{-1}'H_{x,1}x_0 + x_{-1}'H_{x,2}x_1 + x_{-1}'H_{xz,1}z_0\right] \\
&+ \sum_{t=0}^{\infty}\beta^t E_{i,-1}\left[h_x'x_t\right] + \sum_{t=0}^{\infty}\beta^t E_{i,-1}\left[h_z'z_t\right] \\
&+ \sum_{t=0}^{\infty}\beta^t E_{i,-1}\left[\frac{1}{2}x_t'H_{x,0}x_t\right] + \sum_{t=0}^{\infty}\beta^t E_{i,-1}\left[x_t'H_{x,1}x_{t+1}\right] + \sum_{t=0}^{\infty}\beta^t E_{i,-1}\left[x_t'H_{x,2}x_{t+2}\right] \\
&+ \sum_{t=0}^{\infty}\beta^t E_{i,-1}\left[x_t'H_{xz,0}z_t\right] + \sum_{t=0}^{\infty}\beta^t E_{i,-1}\left[x_t'H_{xz,1}z_{t+1}\right] + \sum_{t=0}^{\infty}\beta^t E_{i,-1}\left[x_t'H_{xz,2}z_{t+2}\right] \\
&+ \sum_{t=0}^{\infty}\beta^t E_{i,-1}\left[\frac{1}{2}z_t'H_{z,0}z_t\right].
\end{aligned} \tag{28}$$

Now, let us define the process $\{x_t^*\}_{-1}^{\infty}$,where $x_{-1}^* = (0, \hat{k}_{i,-1})'$ and x_t^* holds in the following equation for all $t \geq 0$:

$$E_t \left[\begin{array}{c} h_x + H_{x,-2}x_{t-2}^* + H_{x,-1}x_{t-1}^* + H_{x,0}x_t^* + H_{x,1}x_{t+1}^* + H_{x,2}x_{t+2}^* \\ +H_{xz,0}z_t + H_{xz,1}z_{t+1} + H_{xz,2}z_{t+2} \end{array} \right] = 0, \tag{29}$$

where E_t denote the expectation operator condition on the entire history of the shocks up to and including period t. We can multiply the last equation by $(x_t - x_t^*)'$ and use the law of iterated expectation to get the following equation which will be used later:

$$\begin{aligned} &E_{j,-1}\left[(x_t - x_t^*)' \left(H_{x,-2}x_{t-2}^* + H_{x,-1}x_{t-1}^* + H_{x,0}x_t^* + H_{x,1}x_{t+1}^* + H_{x,2}x_{t+2}^*\right)\right] \\ &= -E_{j,-1}\left[(x_t - x_t^*)' \left(h_x + H_{xz,0}z_t + H_{xz,1}z_{t+1} + H_{xz,2}z_{t+2}\right)\right]. \end{aligned} \tag{30}$$

In order to derive equation (16), I write down the expected sum of losses in dividend payout that firms incur under rational inattention for not having full information:

$$\begin{aligned} &E_{j,-1}\left[\tilde{g}\left(x_{-1}, x_0, z_0, x_1, z_1, x_2, z_2, \ldots\right)\right] - E_{j,-1}\left[\tilde{g}\left(x_{-1}^*, x_0^*, z_0, x_1^*, z_1, x_2^*, z_2, \ldots\right)\right] \\ &= \sum_{t=0}^{\infty} \beta^t E_{j,-1}\left[\frac{1}{2}x_t' H_{x,0}x_t + x_t' H_{x,1}x_{t+1} + x_t' H_{x,2}x_{t+2} - \frac{1}{2}x_t^{*\prime} H_{x,0}x_t^* - x_t^{*\prime} H_{x,1}x_{t+1}^* - x_t^{*\prime} H_{x,2}x_{t+2}^*\right] \\ &+ \sum_{t=0}^{\infty} \beta^t E_{j,-1}\left[(x_t - x_t^*)' \left(h_x + H_{xz,0}z_t + H_{xz,1}z_{t+1} + H_{xz,2}z_{t+2}\right)\right] \\ &+ \beta^{-1} E_{j,-1}\left[h_{-1}' x_{-1} + \frac{1}{2}x_{-1}' H_{-1}x_{-1} + x_{-1}' H_{x,1}x_0 + x_{-1}' H_{x,2}x_1 + x_{-1}' H_{xz,1}z_0\right] \\ &- \beta^{-1} E_{j,-1}\left[h_{-1}' x_{-1}^* + \frac{1}{2}x_{-1}^{*\prime} H_{-1}x_{-1}^* + x_{-1}^{*\prime} H_{x,1}x_0^* + x_{-1}^{*\prime} H_{x,2}x_1^* + x_{-1}^{*\prime} H_{xz,1}z_0\right]. \end{aligned} \tag{31}$$

In the next step, assuming $x_{-1} = x_{-1}^{*\prime}$ and using equation (30) , we can come up with the following equation:

$$\begin{aligned} &E_{j,-1}\left[\tilde{g}\left(x_{-1}, x_0, z_0, x_1, z_1, x_2, z_2, \ldots\right)\right] - E_{j,-1}\left[\tilde{g}\left(x_{-1}^*, x_0^*, z_0, x_1^*, z_1, x_2^*, z_2, \ldots\right)\right] \\ &= \sum_{t=0}^{\infty} \beta^t E_{j,-1}\left[\frac{1}{2}x_t' H_{x,0}x_t + x_t' H_{x,1}x_{t+1} + x_t' H_{x,2}x_{t+2} - \frac{1}{2}x_t^{*\prime} H_{x,0}x_t^* - x_t^{*\prime} H_{x,1}x_{t+1}^* - x_t^{*\prime} H_{x,2}x_{t+2}^*\right] \\ &- \sum_{t=0}^{\infty} \beta^t E_{j,-1}\left[(x_t - x_t^*)' \left(H_{x,-2}x_{t-2}^* + H_{x,-1}x_{t-1}^* + H_{x,0}x_t^* + H_{x,1}x_{t+1}^* + H_{x,2}x_{t+2}^*\right)\right] \\ &+ \beta^{-1} E_{j,-1}\left[x_{-1}' H_{x,1}(x_0 - x_0^*) + x_{-1}' H_{x,2}(x_1 - x_1^*)\right] \end{aligned} \tag{32}$$

Finally, using the conditions in equations (25 - 27), the fact that $H_{x,1} = \beta H_{x,-1}, H_{x,2} = \beta^2 H_{x,-2}$, and $x_{-1} = x_{-1}^*,\ x_{-2} = x_{-2}^*$, we can simplify the last equations to:

$$
\begin{aligned}
&E_{j,-1}\left[\tilde{g}\left(x_{-1},x_0,z_0,x_1,z_1,x_2,z_2,\ldots\right)\right]-E_{j,-1}\left[\tilde{g}\left(x^*_{-1},x^*_0,z_0,x^*_1,z_1,x^*_2,z_2,\ldots\right)\right]\\
=&\sum_{t=0}^{\infty}\beta^t E_{j,-1}\Bigg[\frac{1}{2}\left(x_t-x^*_t\right)' H_{x,0}\left(x_t-x^*_t\right)+\left(x_t-x^*_t\right)' H_{x,1}\left(x_{t+1}-x^*_{t+1}\right)\\
&+\left(x_t-x^*_t\right)' H_{x,2}\left(x_{t+2}-x^*_{t+2}\right)\Bigg].
\end{aligned}
\tag{33}
$$

In the last step, I need to calculate the second order derivative matrices denoted by $H_{x,0}, H_{x,1},$ and $H_{x,2}$ in the final equation. For that purpose, I need to calculate following derivatives at non-stochastic steady states:

$$
H_{x,0}=\begin{bmatrix}\frac{\partial^2\hat{g}}{\partial p^2_{it}} & \frac{\partial^2\hat{g}}{\partial p_{it}\partial k_{it+1}}\\ \frac{\partial^2\hat{g}}{\partial k_{it+1}\partial p_{it}} & \frac{\partial^2\hat{g}}{\partial k^2_{it+1}}\end{bmatrix},
\tag{34}
$$

$$
H_{x,1}=\begin{bmatrix}\frac{\partial^2\hat{g}}{\partial p_{it}\partial p_{it+1}} & \frac{\partial^2\hat{g}}{\partial p_{it}\partial k_{it+2}}\\ \frac{\partial^2\hat{g}}{\partial k_{it+1}\partial p_{it+1}} & \frac{\partial^2\hat{g}}{\partial k_{it+1}\partial k_{it+2}}\end{bmatrix},
\tag{35}
$$

$$
H_{x,2}=\begin{bmatrix}\frac{\partial^2\hat{g}}{\partial p_{it}\partial p_{it+2}} & \frac{\partial^2\hat{g}}{\partial p_{it}\partial k_{it+3}}\\ \frac{\partial^2\hat{g}}{\partial k_{it+1}\partial p_{it+2}} & \frac{\partial^2\hat{g}}{\partial k_{it+1}\partial k_{it+3}}\end{bmatrix}.
\tag{36}
$$

Doing some algebra results in:

$$
H_{x,0}=\begin{bmatrix}\left((1+\frac{1+r}{R})\theta_\pi\frac{\partial^2\Pi_{it}}{\partial p^2_{it}}-\beta\frac{\partial^2 b_{it}}{\partial p^2_{it}}\right)\bar{p}^2_i & 0\\ 0 & \begin{gathered}\Bigg(\phi_d\frac{\partial d_{it}}{\partial k_{it+1}}\bar{q}+\beta\Bigg(-\phi_d(\frac{\partial d_{it+1}}{\partial k_{it+1}})^2\\ +\frac{\partial^2\Pi_{it+1}}{\partial k^2_{it+1}}+\frac{\partial^2 b_{it+1}}{\partial k^2_{it+1}}\frac{1}{R}\Bigg)\\ +\beta^2\left(-\frac{\partial^2 b_{it+1}}{\partial k^2_{it+1}}-\phi_d\left(\frac{\partial d_{it+2}}{\partial k_{it+1}}\right)^2\right)\Bigg)\bar{k_i}^2\end{gathered}\end{bmatrix}
\tag{37}
$$

$$
H_{x,1}=\begin{bmatrix}0 & 0\\ \begin{gathered}\Bigg(\beta\left(\frac{\partial^2\Pi_{it+1}}{\partial p_{it+1}\partial k_{it+1}}+\frac{\partial^2 b_{it+1}}{\partial p_{it+1}\partial k_{it+1}}\frac{1}{R}\right)\\ +\beta^2\left(-\phi_d\frac{\partial d_{it+1}}{\partial p_{it}}\frac{\partial d_{it+2}}{\partial k_{it+1}}-(1+r)\theta_\pi\frac{\partial^2\Pi_{it+1}}{\partial p_{it+1}\partial k_{it+1}}\right)\Bigg)\bar{k}_i\bar{p}_i\end{gathered} & \begin{gathered}\Bigg(\beta\left(-\phi_d\frac{\partial d_{it}}{\partial k_{it+1}}\frac{\partial d_{it+1}}{\partial k_{it+1}}\right)\\ +\beta^2\left(-\phi_d\frac{\partial d_{it+1}}{\partial k_{it+1}}\frac{\partial d_{it+2}}{\partial k_{it+1}}\right)\Bigg)\bar{k}^2_i\end{gathered}\end{bmatrix},
\tag{38}
$$

$$H_{x,2} = \begin{bmatrix} 0 & 0 \\ 0 & \beta^2 \phi_d \frac{\partial d^2_{it+2}}{\partial k_{it+1} \partial k_{it+3}} \bar{k}^2 \end{bmatrix}. \tag{39}$$

Where $\Pi_{it} = \frac{p_{it}}{P_t} y_{it} - \frac{W_t}{P_t} l_{it}$ and $b_{it} = (1 + r_t)\theta_\pi \Pi_{it}$. Evaluating theses derivatives at steady state provide the second-order derivative matrices for constrained firms. Likewise, one can calculate these matrices for unconstrained firms.

E Proof of Propositions

E.1 Proof of Proposition (1)

Proof. Since higher $\frac{\hat{\pi}^2_{12}}{|\hat{\pi}_{11}|}$ means higher level of attentiveness, we only need to compare this ratio for constrained and unconstrained firms. Let us define $X = \xi \bar{k}^\theta - \delta \bar{k} + \frac{1}{R} \frac{\partial \tilde{b}}{\partial q}$, $A = -1 + \frac{1}{1+r}(\theta \xi \bar{k}^{\theta-1} + 1 - \delta)$, and $B = \frac{1}{1+r} \theta (1 - \theta) \bar{k}^{\theta-2}$. Using the new definitions, the constrained firm is more attentive iff

$$\frac{(\phi_d X + A)^2}{\phi_d + B} > \frac{A^2}{B}$$

where the left hand side is $\frac{\hat{\pi}^2_{12}}{|\hat{\pi}_{11}|}$ for the constrained firms and the right hand side for the unconstrained ones. Simplifying this inequality gives us

$$\phi_d > \frac{A}{X} \left(\frac{A}{XB} - 2 \right)$$

Given A and B are both positive, if $X < 0$ then the right hand side is positive and therefore $\bar{\phi}_d = \frac{A}{X} \left(\frac{A}{XB} - 2 \right)$. If $X > 0$ then

$$A - 2XB = \frac{2\theta(1-\theta)\bar{k}^{\theta-1}}{1+r} \left[\frac{\xi - 1}{2(1-\theta)} - \left(\underbrace{\xi \frac{r+\delta}{\theta} - \delta + \frac{\bar{1}}{\bar{k}} \frac{1}{R} \frac{\partial \tilde{b}}{\partial q}}_{\frac{X}{\bar{k}}} \right) \right]$$

$A - 2XB$ (and equivalently $\frac{A}{XB} - 2$) is positive if $\frac{\xi-1}{2(1-\theta)} - \frac{X}{\bar{k}} > 0$ and negative otherwise. Therefore, if $0 < X < \bar{k} \frac{\xi-1}{2(1-\theta)}$, then $\bar{\phi}_d = \frac{A}{X} \left(\frac{A}{XB} - 2 \right)$. For $X > \bar{k} \frac{\xi-1}{2(1-\theta)}$, $\bar{\phi}_d = 0$. Thus we can define the threshold as follows: $\bar{\phi}_d = \max\{ \frac{A}{X} \left(\frac{A}{XB} - 2 \right), 0 \}$.

□