# Disentangling Uncertainty: Risk Type Shocks and Firm Investment in Innovation and Capital

Preliminary

Franziska Bender

August 2025

**Abstract**

The theoretical and empirical literature provides mixed evidence on the effect of uncertainty on R&D investment. We hypothesize that this ambiguity arises because the effect depends on the type of uncertainty a firm faces. This paper, therefore, investigates how different types of risk shocks affect R&D and capital investment. To do so, we introduce a novel methodology that exploits a specific feature of SEC disclosure regulation: the requirement that firms report "material changes" to their risk factors in quarterly 10-Q filings. Using textual analysis, we leverage this rule to create a new dataset of firm-specific, time-varying shocks to distinct risk categories. Our analysis yields two main findings. First, the effect of risk shocks on R&D is highly heterogeneous: shocks related to regulatory risk decrease R&D, while shocks related to financial and technological risk increase it. Second, the set of risks that matter for R&D is almost entirely different from the set that matters for capital investment. Our results suggest that to better understand the effect of uncertainty on firm decisions, it is important to move beyond a monolithic view and consider the heterogeneous impacts of its different sources.

**Keywords:** R&D, Capital Investment, Uncertainty, Risk Shocks, Textual Analysis, Corporate Disclosure

**JEL Codes:** G31, O31, D81.

## 1 Introduction

Technological innovation is widely recognized as the primary driver of long-term economic growth, and corporate research and development (R&D) is a key input to this process. Understanding the factors that encourage or inhibit R&D investment is therefore of first-order importance. A central factor, yet one with a notoriously complex relationship to R&D, is uncertainty.

For traditional capital investment, the relationship is well-established. An extensive body of literature demonstrates that rising uncertainty typically leads firms to delay or forgo projects due to "wait-and-see" dynamics. This behavior is a rational response to irreversible costs in a volatile environment, as there is an option value to waiting for uncertainty to resolve before committing capital.

In contrast, the relationship between uncertainty and R&D investment is theoretically ambiguous and empirically contested. On one hand, the same wait-and-see logic may apply, causing firms to reduce R&D expenditures. On the other hand, uncertainty can create valuable "growth options". A successful R&D project undertaken in a volatile market environment could allow a firm to gain a significant competitive advantage, which can make immediate R&D investment an attractive strategy. This theoretical tension is reflected in the empirical evidence, where studies have found the effect of uncertainty on R&D to be positive, negative, or insignificant.

We argue that these mixed findings may be reconciled by recognizing that "uncertainty" is not a monolithic concept. The empirical literature employs a variety of different measures—such as economic policy uncertainty, stock market volatility, or exposure to oil price or exchange rate volatility. We argue that these proxies, while valid in their respective contexts, capture fundamentally distinct types of uncertainty. It is therefore a natural consequence that studies employing these different measures find divergent effects. This suggests that a firm's investment response is contingent on the specific nature of the uncertainty it faces.

To address the question of how different types of uncertainty affect firms, this paper introduces a novel methodology that leverages mandatory risk factor disclosures. Following the Securities Offering Reform of 2005, firms are required to disclose a comprehensive set of risk factors in their annual 10-K filings. Our approach, however, exploits a specific feature of quarterly disclosure regulation: the SEC requirement that firms must report only if there has been a "material change" to their previously disclosed risks. We use this rule to identify the timing of discrete risk shocks at the firm level. This contrasts with prior literature that has utilized the narrative disclosures in annual reports. To the best of our knowledge, our study is the first to exploit this feature of quarterly filings to identify such shocks.

We employ text analysis first to identify firms that report such a material change, and second, to classify the nature of the underlying shock. By applying a dictionary-based method to the narrative of the disclosure, we categorize different types of risk shocks, such as risks relating to regulatory, competitive, macroeconomic, or technological risks, among others. This classification is our key contribution, as it allows us to move beyond studying the effect of a single, aggregate shock and instead estimate how firm-level capital and R&D investment react distinctly to shocks from various sources.

While our approach does not directly measure different types of uncertainty, it addresses the core issue of heterogeneity, which we argue is a crucial but underexplored dimension of the broader uncertainty literature. By focusing on how firms' investment decisions respond to shocks originating from different, identifiable sources of risk, our analysis provides new evidence on the complex relationship between a firm's environment and its strategic investments.

Our empirical analysis yields two main findings. First, and central to our motivation, the effect of risk shocks on R&D investment is highly heterogeneous. We find that shocks related to regulatory risk lead to a significant decrease in R&D, consistent with "wait-and-see" dynamics. In contrast, shocks related to financing and technology risk are associated with a significant increase in R&D. While this finding may be consistent with "growth options" theory, we also consider alternative explanations for this positive response. Second, we show that the set of risks that significantly affect R&D is almost entirely different from the set that affects capital investment, underscoring the fundamental differences in how firms approach these two types of investment under uncertainty.

This paper contributes to two key strands of literature. The first is the empirical literature on the effects of uncertainty on R&D. Several papers have estimated the effect of uncertainty on R&D investment using different measures of uncertainty (Stein and Stone, 2013; Czarnitzki and Toole, 2013; Vo and Le, 2017; Cui et al., 2021; Atanassov et al., 2024). The collective evidence from this literature is mixed, with studies finding the effect of uncertainty on R&D to be positive, negative, or insignificant. We contribute to this literature by directly testing the hypothesis that these mixed findings are driven by the type of uncertainty. Our approach is novel in that, unlike prior studies that typically rely on a single measure of uncertainty[1], we simultaneously estimate the effect of shocks from several distinct risk categories. This allows us to systematically investigate the heterogeneity of these effects and provide direct evidence on which specific sources of risk stifle versus stimulate R&D investment.

Second, we contribute to the growing literature that uses textual analysis to construct novel measures from corporate disclosures and other sources. This field has provided new ways of using text data to

[1] Or if they use different measures of uncertainty in robustness tests they typically are proxies for the same type of uncertainty.

measure different economic concepts, such as new industry classifications (Hoberg and Phillips, 2016), the degree of firms' financial constraints (Buehlmaier and Whited, 2018) or the diffusion of new technologies across firms and states (Bloom et al., 2021). Within this literature, a number of studies have specifically utilized the risk factor disclosures that are central to our analysis. This work has used text-data from the risk factor section of SEC filings to measure whether specific threats like inflation risk are disclosed appropriately Konchitchki and Xie (2023), to study whether the disclosures have an effect on the market (Filzen et al., 2023; Lyle et al., 2023), or to assess their informativeness by showing how they capture major macroeconomic events like the financial crisis or the COVID-19 pandemic (Choi et al., 2024; Cao and Ren, 2022; Beatty et al., 2019; Zhu et al., 2024). Our contribution to this literature is a novel methodology for identifying firm-level shocks to different types of risk. While prior work has also classified risk types from disclosures (e.g. Bao and Datta, 2014; Zhu et al., 2024), a central challenge is to quantify changes[2]. We address this challenge by leveraging a key, but previously unexploited, feature of SEC disclosure regulation: the requirement that firms report only "material changes" to their risk factors in their quarterly 10-Q filings. This rule provides a unique identification strategy, allowing us to quantify a *change* not as a continuous shift in language or the volume of text, but as a discrete shock that management has itself deemed material. To the best of our knowledge, this is the first paper to leverage this regulatory feature, which provides an alternative way to measure changes in risk types, notably at a quarterly frequency unavailable in traditional annual report analyses.

The remainder of the paper is structured as follows. Section 2 reviews the relevant theoretical and empirical literature. Section 3 describes our data, the methodology for constructing the risk shock measures, and presents descriptive statistics. Section 4 outlines our empirical strategy, and Section 5 presents the main results as well as several robustness tests. Section 6 concludes.

# 2 Literature Review and Hypothesis Development

## 2.1 Uncertainty and Capital Investment: The "Wait-and-See" Principle

The relationship between uncertainty and traditional capital investment is well-established in the theoretical and empirical literature. Real options theory posits that when investments are irreversible and future payoffs are uncertain, there is a significant value to waiting for more information (Stokey, 2016; Bachmann et al., 2013). This "option value of waiting" increases with uncertainty, creating a powerful incentive for firms to delay or forgo capital expenditures. This phenomenon, often termed "wait-and-see" dynamics, implies a negative relationship between uncertainty and capital investment. A vast body of empirical work supports this prediction, showing that firms reduce capital spending in response to heightened uncertainty. This negative effect is consistently found in studies for different measures of firm-specific as well as aggregate uncertainty such as subjective macroeconomic uncertainty elicited from survey responses (Kumar et al., 2023), economic policy uncertainty index (Baker et al., 2016; Gulen and Ion, 2016) or proxies derived from stock return volatility (Panousi and Papanikolaou, 2012; Alfaro et al., 2024) to mention just a few.

Whether wait-and-see dynamics are the primary channel through which uncertainty exerts a negative effect on investment is debated. Gilchrist et al. (2014), for example, highlight the importance of financial frictions, arguing that higher uncertainty tightens credit markets and raises the cost of external capital,

[2]Prior work has classified different types of risk using topic models (such as LDA), primarily from annual 10-K filings. This approach has some advantages, in particular when the objective is to describe a complete set of risk types or to discover the emergence of new types of risk. However, quantifying changes in risk can be challenging. A change in a topic's prevalence or language in an annual report may reflect shifts in disclosure strategy rather than a genuine change in the firm's underlying risk profile.

thereby depressing investment. A more integrated view is offered by Alfaro et al. (2024), who suggest that real options and financial frictions are not mutually exclusive; rather, financial constraints amplify the initial negative investment response driven by the wait-and-see effect. Thus, while the academic literature continues to explore the precise theoretical channels and their relative importance, the empirical consensus strongly suggests a significant, negative overall effect of uncertainty on capital investment.

## 2.2 The Ambiguous Effect of Uncertainty on R&D Investment

In stark contrast to capital investment, the relationship between uncertainty and research and development (R&D) is theoretically ambiguous and empirically contested. While the same "wait-and-see" logic could apply, several unique characteristics of R&D investment complicate the prediction.

### 2.2.1 Theoretical Ambiguity

The theoretical literature offers competing views on how uncertainty should affect R&D. The standard real options framework can be applied directly to R&D. Given that a large portion of R&D expenditure is on intangible assets like researcher salaries, it is highly irreversible and cannot be recouped if a project fails (Czarnitzki and Toole, 2011). This high degree of irreversibility suggests that the "wait-and-see" principle should hold, leading to a negative relationship between uncertainty and R&D.

However, a competing perspective within the literature that views investment through an option-pricing lens is to frame R&D as a "growth option". In this view, the initial R&D outlay is not the final investment, but rather the cost of acquiring an option to make a larger capital investment in the future (e.g., to commercialize a patented technology). The downside risk is limited, as the firm can choose to abandon the project if market conditions are unfavorable. The potential upside, however, increases with uncertainty. This creates an opportunity cost of waiting, rather than a value of waiting, predicting a positive relationship between uncertainty and R&D investment.

Furthermore, introducing strategic interactions between firms adds another layer of complexity. In a competitive "winner-takes-all" environment, such as a patent race, uncertainty can alter the incentives to pre-empt rivals. While the effect is generally ambiguous, some models show that higher uncertainty can accelerate R&D investment as firms race to innovate first (Mason and Weeds, 2010).

Crucially, some theoretical models suggest that the ambiguity can be resolved by disaggregating the concept of uncertainty itself. Pindyck (1993), for instance, distinguishes between technical uncertainty (uncertainty about the cost or difficulty of completing a project) and input cost uncertainty (uncertainty about the cost of production after innovation). He shows that these two types of uncertainty have opposing effects: higher technical uncertainty can encourage investment as it is resolved by the act of investing, while higher input cost uncertainty encourages waiting. This suggests that without being specific about the type of uncertainty, theory provides no clear-cut prediction for its impact on R&D.

### 2.2.2 Mixed Empirical Evidence

The theoretical ambiguity is mirrored in the empirical literature, which reports mixed and often conflicting findings. A key challenge in this literature is the measurement of uncertainty, and different studies adopt different proxies, which can broadly be divided into two types.

The first approach uses volatility-based measures. Some studies use the idiosyncratic volatility of a firm's stock returns as a proxy for firm-specific uncertainty and find a negative effect on R&D (e.g., Vo and Le (2017)). Stein and Stone (2013) use a forward-looking measure based on options-implied volatility and also find a negative relationship. In a more nuanced study, Czarnitzki and Toole (2011, 2013) use sales volatility from new products versus established products to distinguish between "innovation-related" and "general market" uncertainty. They find that the innovation-specific uncertainty negatively impacts R&D, while general market uncertainty has no significant effect.

The second approach uses text-based indices. The most prominent is the Economic Policy Uncertainty (EPU) index of Baker et al. (2016). Studies using the EPU index to explain R&D investment have also produced conflicting results, with some finding a negative effect (Xu, 2020; Cui et al., 2021) and others finding a positive effect (De La Horra et al., 2022).

### 2.3 The Role of Uncertainty Type: A Path to Reconciliation?

The lack of consensus in both theoretical and empirical work suggests that treating "uncertainty" as a monolithic concept may be a key reason for these divergent findings.. The empirical studies that most carefully address identification challenges—for example, by using instrumental variables or quasi-experimental designs—often do so by focusing on a very specific source of uncertainty, such as exposure to energy price volatility (Stein and Stone, 2013) or political uncertainty from close elections (Atanassov et al., 2024).

This observation raises a crucial question: can the mixed findings be reconciled if we recognize that these different studies are, in effect, measuring fundamentally different types of uncertainty? A firm's reaction to uncertainty about future tax policy is likely very different from its reaction to uncertainty about a competitor's next move. This paper builds on this premise. We argue that to understand the true relationship between uncertainty and R&D, we must first disaggregate the concept and investigate how investment responds to shocks originating from different sources of risk.

## 3 Data and Methodology

### 3.1 Measuring Risk Shocks from SEC Filings

To measure firm-level risk shocks, we use text data from the risk factor disclosure section of quarterly 10-Q filings submitted to the SEC. Our methodology leverages a key institutional detail of this disclosure requirement. Following the Securities Offering Reform of 2005, firms must disclose a comprehensive set of risk factors in their annual 10-K filings. In subsequent quarterly 10-Q filings, however, they are only required to provide an update if there has been a "material change" to the previously reported risks. We exploit this feature to identify the arrival of discrete, firm-level risk shocks. A detailed discussion of the assumptions and limitations inherent in this approach is provided in Section 3.1.3.

Our initial sample consists of the risk factor section from all 10-Q filings available from 2006 to 2024, comprising 487,554 firm-quarter observations for 20,171 unique firms. Following standard practice, we exclude smaller reporting companies[3], which are not subject to the same disclosure requirements.

#### 3.1.1 Identification of Firm-Level Risk Shocks

Our first methodological step is to isolate the firm-quarters in which a material risk shock occurred. The process begins with our initial sample of 487,554 firm-quarter observations and applies a series of filters to identify a final set of shock events. The complete breakdown of this sample construction is summarized in Figure 1.

First, we identify the filings that clearly indicate the absence of a risk factor shock, which will serve as our control group. These fall into two categories: filings where the risk factor section is left empty (143,065 observations, or 29% of the sample) and filings where the company explicitly states that no

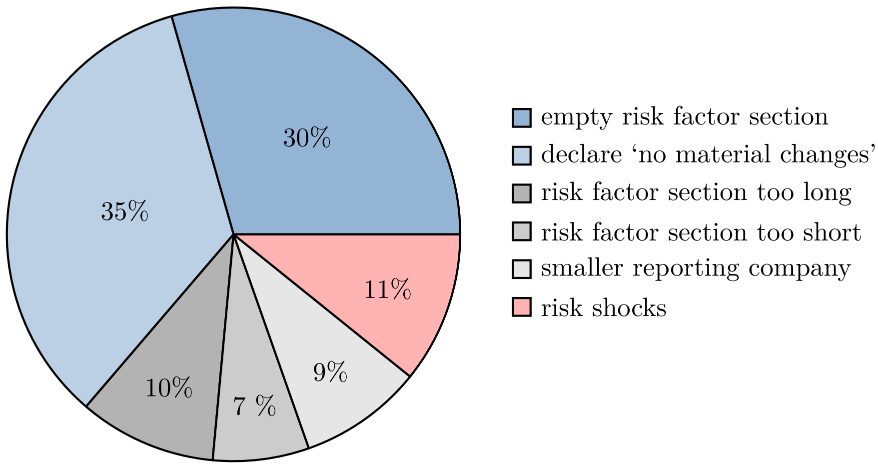
[3]Smaller reporting companies are identified by specific phrases they use.

material changes have occurred since the last report (168,666 observations, or 35%). We identify this second category using a comprehensive list of phrases such as "not been any material changes" (see Appendix Table 9 for the full list of phrases used).

The remaining filings must be filtered further to ensure they represent genuine, discrete changes in risk factors. We apply two exclusion criteria. First to filter out broad restatements, we exclude filings where the length of the quarterly risk section exceeds 20% of the firm's average annual risk factor section length. These instances likely represent a restatement of many or all annual risks rather than a specific, material change (48,856 observations, 11%). As an additional check to filter out broad restatements we exclude filings that simultaneously report more than three distinct types of risk shocks, after classification (described in section 3.1.2). This helps ensure our sample consists of specific events rather than comprehensive overhauls of a firm's risk reporting. Second, to filter out uninformative disclosures, we exclude filings with fewer than 25 terms (34,261 observations, 9%). These brief texts typically do not represent a substantive disclosure and are often alternative ways of stating "no material change" that are not captured in our dictionary.

After applying these filters, we are left with a final sample of 53,802 firm-quarter observations, or 11% of the initial sample, which we classify as risk shocks[4]. The observations where the risk factor section is empty or where firms explicitly declare no changes constitute our 'no shock' control group.

Figure 1: Categorization of risk factor disclosures.




### 3.1.2 Classification of Risk Types

Having identified the firm-quarters that contain a potential risk shock, we now turn to the central component of our empirical strategy: classifying the type of risk described in these filings. This step is crucial, as our primary research question is whether investment decisions respond differently to shocks originating from distinct sources of risk. To do this, we analyze the narrative content of each disclosure identified as a potential shock.

We define eight primary risk categories that are substantively important and frequently discussed in corporate disclosures: regulatory & legislative change risk, tax risk, macroeconomic & geopolitical risk, financial & liquidity risk, legal & litigation risk, technological & innovation, governance & shareholder risk, and competitive risk. These categories, detailed in table 1, are grounded in prior research and capture a broad range of uncertainties that can materially affect firm performance.

[4] This is the basis for the dummy variables $RiskShock_{i,t}$ that is used in section 5.1.

Table 1: Overview of Risk Types and Descriptions

| **Risk Type** | **Description** |
|---|---|
| Regulatory & Legislative Change Risk | Risks from potential future regulations or changes in laws that could impact business operations. |
| Tax Risk | Risk from changes in tax rates or from current tax positions. |
| Macroeconomic and Geopolitical Risk | Risks arising from economic downturns, inflation, political instability, or trade restrictions. |
| Financial & Liquidity Risk | Risks related to financial instability, debt, liquidity, or market conditions. |
| Legal & Litigation Risk | Risks from current lawsuits, intellectual property disputes, and contractual obligations. |
| Technological and Innovation Risk | Risks related to technological advancements, innovation failure, R&D investment, obsolescence, and disruptive technologies. |
| Governance & Shareholder Risk | Risks affecting corporate leadership, board decisions, and shareholder value. |
| Competitive Risk | Risk from existing or new competitors, strategic interactions. |

To classify the shocks, we employ a dictionary-based method. We manually constructed a unique dictionary of keywords and multi-word phrases for each of the eight risk categories based on conceptual relevance and iterative inspection of sample filings (see Appendix A.2 for the complete keyword lists). For each filing in our "potential risk shock" sample, we code a specific risk type as present if any of its associated keywords appear at least once in the disclosure text[5].

Of the 53,802 potential risk shocks, our classification method identifies at least one specific risk type in approximately 92% of cases. The remaining observations either had no match to our dictionaries or were reclassified for having more than three simultaneous risk types. The distribution of the identified shocks across our categories is shown in figure 2. These type-specific risk shocks constitute the primary treatment variables for our empirical analysis.

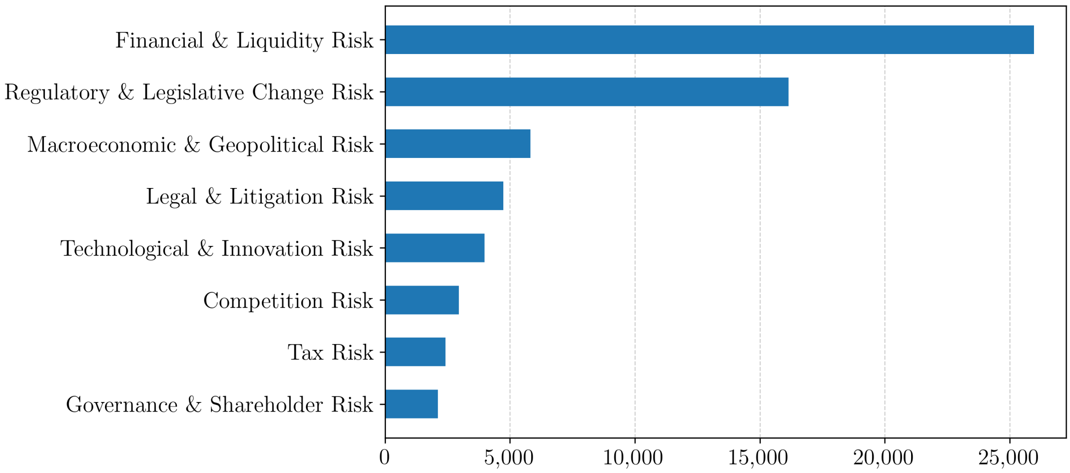
#### 3.1.3 Methodological Discussion

Before proceeding to the empirical analysis, it is important to discuss several considerations regarding our measurement strategy.

- **Subjectivity of "Materiality":** What management deems "material" is inherently subjective. Firms with greater aversion to risk or a greater fear of litigation might have a lower disclosure threshold. This could introduce a selection bias if the propensity to disclose is correlated with the investment response to a shock. However, this also means our measure captures shocks that are salient to management, events that have cleared an internal threshold of importance, making them more likely to be drivers of corporate decisions. We are therefore measuring a *perceived* shock, which is arguably what matters for decision-making.

[5]Since the filings are short it is not necessary to require the number of keywords to surpass a certain threshold. Although this could easily be implemented as an additional robustness test.

Figure 2: Number of Identified Shocks to Different Types of Risk




- **Endogeneity of Disclosure:** A key challenge for our identification strategy is that the decision to disclose a risk is not an exogenous event, but a strategic choice by the firm. This raises concerns about endogeneity, particularly reverse causality. For instance, management might have already decided to reduce capital expenditures due to shifting priorities or poor performance and then use a risk disclosure to publicly justify that pre-determined decision. In this case, the disclosure is a consequence, not a cause, of the investment cut. Conversely, a disclosure could be the direct result of a new investment, such as the entry into a new market, which necessitates reporting new risks. If such endogeneity is present, our estimates would not capture the true causal effect of risk shocks on investment.

- **Conceptual Interpretation of the Shock Measure:** Our measure likely conflates first-moment shocks (e.g., "bad news") and second-moment shocks (i.e., pure uncertainty). It is plausible that negative information is more likely to be deemed "material". This is a common challenge for most empirical uncertainty proxies; the Economic Policy Uncertainty (EPU) index, for example, spikes during recessions and crises, periods characterized by both negative first-moment shocks and high volatility (Baker et al., 2016). While this means we are not measuring pure uncertainty shocks, our methodology allows us to address our central research question about heterogeneity. The key insight is that even if all shocks contain a mix of first and second-moment effects, the source of the shock provides a meaningful dimension of variation. A shock originating from a new competitor generates a different type of strategic problem—and thus a different form of uncertainty—than a shock originating from new legislation. By estimating the differential investment responses across these distinct risk categories, we can indirectly learn how firms react to different types of uncertainty. Our approach, therefore, uses the source of the risk shock as a proxy to unpack the monolithic concept of uncertainty and test whether its effects are indeed heterogeneous.

- **Informativeness and Vagueness of Disclosure:** A significant concern is whether risk factor disclosures are genuinely informative. Critics argue that since firms are not required to quantify the probability or financial impact of a disclosed risk, the disclosures can become a boilerplate exercise where managers list every conceivable risk to avoid liability. While this concern remains valid, a significant body of research finds that these disclosures are not merely cheap talk. For instance, Campbell et al. (2014) show that the content of disclosures is systematically related to firms' pre-existing risk profiles and that investors revise their risk estimates and reduce information asymmetry after filings are released. This suggests the market finds them credible. Our methodology further mitigates the boilerplate concern by exploiting the "material change" rule in quarterly filings. The explicit decision to report a change, as opposed to the routine requirement of listing all risks annually, creates a higher threshold for disclosure and naturally filters for information that is new and significant.

- **Measurement Error in Classification:** Our classification of risk types relies on a dictionary-based method, which has known limitations. It can miss nuanced discussions of risk (false negatives) or misclassify text based on ambiguous keywords (false positives). The large portion (37%) of potential shocks that do not match any of our predefined categories could be due to such false negatives or the disclosure of risk types that fall outside our classification scheme. Furthermore, our decision to exclude filings with more than three types is a heuristic based on the assumption that a specific shock is unlikely to span many distinct risk domains. However, a major systemic event, like the 2008 financial crisis or the COVID-19 pandemic, could legitimately trigger material changes across multiple dimensions simultaneously. These limitations likely bias our results against finding a significant effect (attenuation bias). While this lends credibility to any significant findings, it requires a careful interpretation of null results. As our research question is focused on distinguishing between risk types that do and do not affect investment, a finding of no effect is an important outcome. We therefore interpret null results cautiously, acknowledging that while they may reflect a true lack of response, they could also be a consequence of measurement error.

- **Evolving Disclosure Rules:** A final concern is that the rules and guidelines governing risk factor disclosures are not static. Over time, the SEC may issue new guidance that alters the content, language, and frequency of reporting on specific topics. A prominent example is the SEC's 2010 interpretive guidance on climate-change-related disclosures, which likely prompted an increase in reporting on environmental and regulatory risks across many firms. Such regulatory shifts could create spurious time-series trends in our measured risk types that are driven by changes in reporting standards rather than changes in firms' underlying risk environments. Our empirical design directly addresses this issue through the inclusion of time-fixed effects in our regression models. These fixed effects absorb the average change in disclosure patterns across all firms in any given period, including any market-wide shifts prompted by new SEC guidance. By controlling for these common time trends, our analysis ensures that the estimated effects are identified from a firm's idiosyncratic deviation from the average reporting behavior in a given quarter, thus alleviating concerns that our results are driven by evolving disclosure rules.

## 3.2 Firm Characteristics and Investment Data

We obtain firm-level financial data from the Compustat North America Fundamentals Quarterly database. From this data, we construct our dependent variables and a standard set of control variables motivated by the corporate investment literature (e.g. Atanassov et al. (2024)). Detailed definitions for all variables are provided in Appendix Table 8.

Our two main dependent variables are R&D Intensity, measured as the ratio of firm's research and development expenses to its total assets, and Capital Intensity, defined as the ratio of firm's capital expenditure to its total assets.

The control variables include Tobin's Q, defined as the market value of assets divided by the book value of assets, to proxy for investment opportunities. We measure Cash Flow as income before extraordinary items plus depreciation and amortization, divided by total assets. To control for firm size we use the natural logarithm of one plus net sales as a proxy. Additionally we control for firm age (natural logarithm of one plus the number of years the firm is listed on Compustat), Tangibility (net property, plant, and equipment scaled by assets), Leverage (book value of debt scaled by assets), and industry competition using the Herfindahl-Hirschman Index (HHI) based on three-digit SIC industry sales.

### 3.3 Final Sample and Descriptive Statistics

We merge the firm–quarter-level risk shock data constructed from quarterly SEC filings with quarterly financial data from Compustat. The matching is performed using firm identifiers and dates. Specifically, we link each SEC filing observation to Compustat using the company's Central Index Key (CIK) matched to Compustat's Global Company Key (GVKEY), and align observations based on the fiscal quarter end date. This ensures that, for each firm and quarter, the SEC-based measures are paired with the corresponding Compustat financial variables.

We require firms to have data available from both the SEC filings and Compustat, drop observations with total assets of less than $1 million, and require non-missing values for our dependent variables as well as all control variables. This process yields a baseline sample of 162,928 firm-quarter observations for 8,974 unique firms over the period 2007-2023[6]. Further sample restrictions may be applied for specific analyses later in the paper.

Table 2 presents summary statistics for our sample. Panel A shows that the mean R&D intensity (1.3%) and its median (0%), indicating that R&D spending is highly skewed and concentrated among a subset of high-investment firms. Capital expenditure intensity is less skewed. Panel B details the control variables. The average firm in our sample has a Tobin's Q of 2.35, is moderately levered, and has been listed for approximately 4.5 years. The statistics are consistent with those reported in the corporate investment literature.

Table 2: Summary statistics

A. Dependent Variables

| | Mean | Median | Std Dev |
|---|---|---|---|
| R& Intensity | 0.013 | 0.000 | 0.035 |
| Capital Intensity | 0.009 | 0.004 | 0.014 |

B. Control Variables

| | Mean | Median | Std Dev |
|---|---|---|---|
| Tobins Q | 2.353 | 1.422 | 3.001 |
| Cash Flow | -0.020 | 0.011 | 0.118 |
| Sales | 863 | 69 | 4,205 |
| Firm Age | 4.591 | 3.688 | 3.749 |
| Tangibility | 0.222 | 0.118 | 0.250 |
| Leverage | 0.264 | 0.191 | 0.294 |
| HHI | 0.166 | 0.102 | 0.168 |

## 4 Empirical Strategy

To test how different types of risk shocks affect corporate investment, we estimate a fixed-effects regression model. Our primary goal is to investigate whether R&D investment responds heterogeneously to different

[6]The Securities Offering Reform was implemented for annual 10-K filings for fiscal years ending on or after December 1, 2005. The requirement to disclose material changes in quarterly 10-Q filings applies only after a firm has filed its first 10-K under this reform. We begin our sample in 2007 to ensure all firms are subject to the same disclosure regime.

types of risk shocks. The literature on uncertainty suggests a theoretically ambiguous relationship for R&D, and we hypothesize that the type of risk is a key factor in explaining the mixed empirical evidence. As a point of comparison, and to provide a more complete picture of corporate investment responses, we also analyze the effect of these shocks on capital expenditures, where the literature has more consistently found negative effects consistent with "wait-and-see" dynamics.

Our analysis proceeds in two stages. First, to establish a baseline, we estimate the average effect of any disclosed risk shock on investment, independent of its type. This allows us to understand the overall impact of a 'general' risk shock. Second, to test our main hypothesis, we disaggregate this general shock into its constituent types to examine whether the average effect masks significant heterogeneity.

Our main specification is as follows:

$$Y_{i,t} = \alpha_i + \delta_t + \sum_{j=1}^{J} \beta_j \, RiskType(j)_{i,t-1} + \gamma' \mathbf{X}_{i,t-1} + \epsilon_{i,t}, \tag{1}$$

where the dependent variable $Y_{i,t}$ represents one of two investment measures for firm $i$ at time $t$: R&D investment (measured as R&D expenditures scaled by total assets) or capital investment (measured as capital expenditures scaled by total assets). The key independent variables are the dummy variables, $\mathit{RiskType}(j)_{i,t-1}$, which take a value of one if firm $i$ disclosed a material change related to risk type $j$ in the previous quarter $(t-1)$, and zero otherwise[7]. In our initial baseline regression, we replace the set of type-specific dummies with a single dummy variable, $\mathit{RiskShock}_{i,t-1}$, which equals one if a firm disclosed a material change of any type in the previous quarter. We lag the shock variables by one quarter to allow time for the new information to be incorporated into corporate planning and to mitigate concerns about immediate reverse causality.

The model includes firm fixed effects $(\alpha_i)$ to control for all time-invariant firm characteristics, such as corporate culture or industry effects, and time fixed effects $(\delta_t)$ to control for aggregate macroeconomic conditions and market-wide trends that affect all firms in a given quarter. Following the corporate investment literature (Atanassov, 2013; Atanassov et al., 2024) we include a vector of standard firm-level control variables, $\mathbf{X}_{i,t-1}$[8]. This vector includes Tobin's Q to control for investment opportunities, cash flow to control for the availability of internal funds, firm size (ln(Sales)) and age (ln(Age)) to control for scale and life-cycle effects, tangibility to control for asset structure, and leverage to control for financial constraints. Standard errors are clustered at the firm level to account for potential serial correlation within firms over time.

# 5 Results

This section presents our main empirical findings. We first establish a baseline by examining the average effect of a general risk shock on R&D and capital investment. We then proceed to our main analysis, where we estimate the effect of different types of risk to investigate the heterogeneous effects that this average may be masking.

[7] Note that all observations where the risk factor section is ambiguous (see section **??**) are dropped, i.e. $\mathit{RiskType}(j)$ is *False* when the firm had 'no material change' to their risk factors, or when the firm had a material change that is not associated to type $j$

[8] We use lagged values for these control variables to mitigate simultaneity and reverse causality concerns. With contemporaneous we face the problem that we can't be sure if, for example, cash flow is affecting investment, or if investment is affecting cash flow. The main argument for using contemporaneous controls is that they arguably better reflect the information set available to managers when they make their decisions. In section 5.3.1 we test the robustness of our results with respect to this choice.

## 5.1 Effect of a General Risk Shock Investment

We first establish a baseline effect of risk disclosures on firm investment. Table 3 presents the results from our baseline regression, where we estimate the effect of any disclosed "material change", irrespective of its specific type. To facilitate interpretation, the coefficient of our main variable, *RiskShock*, is scaled by the sample mean of the respective dependent variable; it can thus be read as the average percentage change in investment relative to its mean.

We find opposing effects of a risk shock for the two forms of investment. Following the disclosure of a 'material change' in risk, R&D intensity shows a statistically significant increase of approximately 5.8% relative to its sample mean. In contrast, capital intensity experiences a statistically significant decrease of 3.5% relative to its mean. The negative effect on capital investment aligns with wait-and-see dynamics, where firms delay irreversible investment amid heightened uncertainty. This is consistent with a large body of prior literature (e.g. Panousi and Papanikolaou, 2012; Gulen and Ion, 2016; Kim and Kung, 2017) and provides some validation for our text-based risk shock measure. The positive effect of a risk shock on R&D would seem to offer support for the "growth options" perspective. We contend, however, that this average effect is misleading. To investigate whether this result is driven by specific sources of risk, we now move beyond this general effect to examine how different risk types uniquely influence investment decisions.

Table 3: Effect of General Risk Shocks on Investment

| | (1)<br>R&D Intensity | (2)<br>Capital Intensity |
|---|---|---|
| *RiskShock* | 0.05775** | -0.03498** |
| Tobins Q | 0.001*** | 0.000*** |
| cash flow | -0.049*** | 0.003*** |
| ln(sale) | -0.001** | 0.001*** |
| ln(age) | 0.001** | -0.002*** |
| tangibility | 0.005** | 0.005*** |
| leverage | -0.000 | -0.005*** |
| HHI | 0.001 | 0.001 |
| Observations | 160,798 | 159,593 |
| R-squared (within) | 0.060 | 0.026 |
| R-squared (between) | 0.258 | 0.008 |
| Firm FE | Yes | Yes |
| Time FE | Yes | Yes |

*Notes*: This table presents the results of a panel regression with firm and time fixed effects. The dependent variable in Column (1) is R&D Intensity (R&D expenditures scaled by total assets) and in Column (2) is Capital Intensity (capital expenditures scaled by total assets). The coefficients of the key independent variable *RiskShock* (see section 3.1.1) have been scaled by the sample mean of the respective dependent variable. Standard errors are clustered at the firm level. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

## 5.2 Heterogeneous Effect of Risk Types

While the baseline analysis in Section 5.1 shows a positive average effect of firm-specific risk shocks on R&D and a negative one on capital investment, it treats all risks as homogenous. Our core hypothesis, however, is that the *type* of uncertainty matters. This section investigates whether these aggregate results mask important heterogeneity.

Table 4 presents the results from our main specification (equation 1) using disaggregated risk types. To facilitate the interpretation of economic magnitude, the coefficients for the risk types have been scaled by the sample mean of the respective dependent variable. Each coefficient can therefore be interpreted as the average percentage change in the investment variable relative to its mean following a risk shock of a given type.

Table 4: Types of Risk and Investment Decisions

| | (1) R&D Intensity | (2) Capital Intensity |
|---|---|---|
| *Regulatory* | -0.04923** | 0.00838 |
| *Tax* | 0.00573 | -0.05753** |
| *Macro* | -0.01991 | -0.02276 |
| *Financial* | 0.07601** | -0.03806 |
| *Technological* | 0.10993** | 0.00467 |
| *Legal* | 0.03934 | 0.03152 |
| *Governance* | 0.01811 | 0.00928 |
| *Competition* | -0.01234 | -0.05520* |
| Tobins Q | 0.001*** | 0.000*** |
| cash flow | -0.049*** | 0.003*** |
| ln(sale) | -0.001** | 0.001*** |
| ln(age) | 0.001** | -0.002*** |
| tangibility | 0.005** | 0.005*** |
| leverage | -0.000 | -0.005*** |
| HHI | 0.001 | 0.001 |
| Observations | 160,798 | 159,593 |
| R-squared (within) | 0.060 | 0.026 |
| R-squared (between) | 0.259 | 0.008 |
| Firm FE | Yes | Yes |
| Time FE | Yes | Yes |

*Notes*: This table presents the results of a panel regression with firm and time fixed effects. The coefficients for the risk type variables (see section 3.1.2) have been scaled by the sample mean of the respective dependent variable. Standard errors are clustered at the firm level. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

The central finding, immediately apparent from Table 4, is the evidence of heterogeneity along two dimensions. First, within each investment category, the results show that different types of risk shocks have different effects; for R&D, some shocks are associated with a decrease in investment, some with an increase, and many have no significant effect at all. Second, and crucially, the types of risks that matter for R&D are distinct from those that matter for capital expenditures.

We first discuss the results for R&D intensity (column 1), which are central to our paper's contribution. The findings provide evidence consistent with our hypothesis that the mixed results in the prior literature may be driven by the type of underlying risk. The results indicate that the effect of a risk shock on R&D is not uniform, but depends critically on its source.

Consistent with "wait-and-see" dynamics, we find that a regulatory risk shock leads to a statistically significant decrease in R&D intensity of approximately 4.9% relative to the sample mean. This suggests that when faced with risk or uncertainty about new or changing regulations, firms pause their innovation-related investments to await clarity. This finding, at first glance, appears to contrast with Atanassov et al. (2024), who find a positive effect of political uncertainty on R&D using close gubernatorial elections as their proxy. We argue that these results are not contradictory, but instead highlight the central thesis of our paper: the type of uncertainty matters. Atanassov et al. (2024) measure broad, temporary electoral uncertainty about the general direction of policy. In contrast, our measure captures a firm's own disclosure of a specific, material regulatory issue. It is plausible that while broad electoral uncertainty may spur "growth option" investments to prepare for multiple potential outcomes, uncertainties tied to specific regulatory matters affecting the firm's operations induce a more cautious "wait-and-see" approach until the regulatory path becomes clearer[9].[10]

In contrast, and consistent with a "growth options" perspective, we find that shocks related to financial risk and technological risk lead to a significant increase in R&D investment. A financing-related shock is associated with a 7.6% increase in R&D intensity, while a technology-related shock is associated with a 10.9% increase. These results suggest that when faced with financing uncertainty or a new technological threat, firms do not wait and see, but instead accelerate their R&D spending, likely to create valuable new growth options or to innovate in response to a disruptive technological shift.

Completing the picture of heterogeneity, it is important to note that several other risk types, including those related to taxes, the macroeconomic, and the competitive environment, have no statistically significant effect on R&D investment. The null result for macroeconomic risk, in particular, may seem counterintuitive but is a likely consequence of our empirical design. Our model includes time fixed effects, which absorb the impact of aggregate, market-wide economic conditions that affect all firms in a given quarter. The insignificant coefficient therefore suggests that a firm's idiosyncratic disclosure of a macroeconomic risk does not have an additional effect on its investment beyond the aggregate trends that are already accounted for. This highlights that only a specific subset of firm-level risks appears to drive R&D decisions.

For the technological risk result in particular, an alternative interpretation involving reverse causality warrants consideration. It is plausible that a firm's decision to initiate a major new R&D project could itself trigger the disclosure of a new material risk related to that technology. While our use of a lagged shock variable ($t-1$) helps mitigate this concern from a timing perspective, we acknowledge that the interpretation of this specific coefficient should be made with this potential endogeneity in mind.

An important alternative explanation for the positive financial risk result is a substitution mechanism. It is well-documented that firms often respond to uncertainty by cutting back on capital expenditures (e.g., Julio and Yook, 2012; Jens, 2017) and increasing cash holdings. Given that financing R&D is often more difficult than financing physical capital and relies heavily on internally generated funds (Brown et al., 2009), it is plausible that the increase in R&D we observe is not driven by its option-like properties, but rather from firms reallocating cash saved from reduced capital expenditures. Our results do not provide strong evidence to support this as the primary channel. The corresponding coefficient for capital intensity is not statistically significant, which would be a necessary condition for this type of direct substitution. However it is negative and in some alternative specifications that we estimate to test the robustness of our results we do find a significant negative effect of financial risk on capital investment (see section 5.3.1), therefore no clear conclusion can be drawn regarding this substitution mechanism and it remains a valid alternative explanation.

Turning to capital investment (Column 2), the findings show a distinct pattern from R&D. Where significant, the coefficients on the risk shocks are negative, a finding that is broadly consistent with the

[9] Future work could refine the "Regulatory & Legislative Change Risk" category by distinguishing between innovation-specific policies that likely affect cost and returns to R&D directly and other general policies. This would allow for a direct test of whether the negative effect on R&D is driven primarily by uncertainty about policies that directly target the innovation process itself.

[10] Furthermore, the negative coefficient should be interpreted with caution, as our measure likely captures both a pure uncertainty effect and a first-moment ("bad news") effect. If firms are more likely to disclose regulatory matters when they anticipate costly new compliance, the reduction in investment could be a direct response to these expected costs, not just to the uncertainty itself.

established "wait-and-see" literature. Specifically, we find that shocks related to tax risk and competition risk have a negative and statistically significant effect on capital expenditures. Following a tax-related risk shock, capital investment decreases by an economically significant 5.7% relative to the sample mean. Similarly, a competitive risk shock is associated with a 5.5% decrease. These results suggest that when faced with tax-related uncertainty or a shifting competitive landscape, firms delay irreversible capital projects.

In summary, our analysis provides two key findings. First, and central to our motivation, the effect of risk shocks on R&D investment is highly heterogeneous: some risk types (regulatory) are associated with a significant decrease in R&D, while others (financial, technological) are associated with a significant increase. This finding, which shows that both "wait-and-see" and "growth options" or other dynamics may be at play, depending on the type of risk, helps to explain the mixed evidence in the prior literature. Second, the set of risks that significantly affect R&D is almost entirely different from the set that affects capital investment. This underscores the fundamental differences in how firms approach innovation versus more traditional investment when faced with uncertainty.

## 5.3 Robustness Tests

We conduct a series of tests to assess the robustness of our main findings. We examine whether our results are sensitive to alternative specifications and sample compositions. Specifically, we test the stability of our estimates with respect to the timing of our control variables, the inclusion of more stringent industry-by-quarter fixed effects to control for unobserved industry-level shocks, and by analyzing high-tech and non-high-tech firms separately to account for heterogeneity in firm investment strategies.

### 5.3.1 Contemporaneous Controls

In our main specification (equation 1), we use lagged values for all firm-characteristic control variables $\mathbf{X}_{i,t-1}$. The primary reason for this choice is to mitigate concerns about simultaneity and reverse causality. For example, a large investment expenditure in the current period could mechanically affect a firm's contemporaneous cash flow or leverage. Using pre-determined, lagged controls helps to address this issue by modeling the investment decision based on information from the prior period. However, one could argue that using contemporaneous controls ($\mathbf{X}_{i,t}$) is theoretically better specified, as investment decisions are based on the firm's current financial state. To ensure our results are not sensitive to this alternative specification, we re-estimate our model using contemporaneous control variables.

The results, presented in table 5, are largely consistent with our main findings for R&D investment; the coefficients for financing and technology risk remain positive and significant, while the coefficient for regulation risk remains negative and significant.

The results for capital investment, however, are not fully consistent. Notably, the coefficient for financial risk, which was insignificant in our main specification, is now negative and statistically significant. This finding is important because it has direct implications for the interpretation of our R&D results. One possible explanation for the positive association between financial risk and R&D is a substitution effect, where firms facing higher financial or liquidity risk reduce their more rigid capital investments and reallocate those resources toward more flexible R&D projects. While our main results did not provide strong evidence for this channel, this robustness test shows that we cannot exclude this explanation. The emergence of a significant negative relationship between financing risk and capital investment in this alternative specification suggests that this substitution mechanism may indeed be at play, representing an important alternative to the "growth options" interpretation.

Table 5: Effect of Risk Types with Contemporaneous Control Variables

| | (1) R&D Intensity | (2) Capital Intensity |
|---|---|---|
| *Regulatory* | -0.0404* | 0.0111 |
| *Tax* | 0.0016 | -0.0360 |
| *Macro* | -0.0174 | -0.0228 |
| *Financial* | 0.0715** | -0.0428* |
| *Technological* | 0.1156** | 0.0079 |
| *Legal* | 0.0388 | 0.0169 |
| *Governance* | 0.0181 | 0.0088 |
| *Competition* | -0.0005 | -0.0478* |
| Observations | 164,390 | 163,203 |
| R-squared (within) | 0.132 | 0.042 |
| Firm FE | Yes | Yes |
| Time FE | Yes | Yes |

*Notes*: This table presents the results of a panel regression with firm and time fixed effects, using contemporaneous instead of lagged control variables. All specifications include the full set of control variables; coefficients are omitted for brevity. Standard errors are clustered at the firm level. Significance levels: * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

### 5.3.2 Industry-Time Fixed Effects

Our main specification includes firm and time fixed effects to control for time-invariant firm characteristics and economy-wide shocks. However, some shocks may be common to all firms within a specific industry at a particular point in time. In such cases, a firm's risk disclosure could be correlated with an unobserved industry-level shock, potentially biasing our estimates.

To address this, we conduct a more stringent robustness test by replacing the time fixed effects with a full set of industry-by-quarter fixed effects. This specification absorbs any unobserved, time-varying shocks at the industry level, ensuring that the coefficients on our risk variables capture a firm's idiosyncratic response over and above any concurrent industry trends.

The results of this test, presented in Table 6, largely reinforce our central conclusions for R&D investment. The coefficients for regulation, financing, and technology risk remain statistically significant and retain their original signs. This demonstrates that even after controlling for all common industry-level dynamics, these firm-specific risk disclosures have a significant impact on R&D investment. The coefficients for regulatory risk and technological risk are slightly smaller and their significance has dropped from the 5% to the 10% level. This is expected, as the new fixed effects correctly absorb the portion of the response attributable to industry-wide shocks. The persistence of a significant coefficient, albeit at the 10% level for regulation and technology risk, suggests that a genuine firm-specific component drives the investment response.

The analysis for capital expenditures, however, reveals the importance of accounting for these industry-level dynamics. While our baseline model showed that tax and competition shocks were correlated with lower investment, these effects become insignificant in the stricter specification, suggesting they are largely industry-wide phenomena. More importantly, this specification reveals a significant negative relationship between firm-specific disclosures of macroeconomic risk and capital investment. This suggests that when managers perceive their firm to be uniquely vulnerable to the business cycle, relative to their industry peers, they are significantly more likely to delay irreversible capital projects.

Table 6: Effect of Risk Types with Industry-by-Quarter Fixed Effects

| | (1) R&D Intensity | (2) Capital Intensity |
|---|---|---|
| *Regulatory* | -0.0387* | 0.0090 |
| *Tax* | -0.0066 | -0.0265 |
| *Macro* | -0.0206 | -0.0407* |
| *Financial* | 0.0742** | -0.0275 |
| *Technological* | 0.0886* | 0.0017 |
| *Legal* | 0.0327 | 0.0328 |
| *Governance* | 0.0118 | -0.0166 |
| *Competition* | -0.0050 | -0.0469 |
| Observations | 160,798 | 159,593 |
| R-squared (within) | 0.085 | 0.082 |
| Firm FE | Yes | Yes |
| Industry x Time FE | Yes | Yes |

*Notes*: This table presents the results of a panel regression with firm and industry-by-quarter fixed effects. All specifications include the full set of control variables as in our main specification; coefficients are omitted for brevity. Standard errors are clustered at the firm level. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

### 5.3.3 High-Tech versus Non-High-Tech Industries

To investigate whether our main findings are driven by specific types of firms, we conduct a robustness check by splitting our sample into high-tech and non-high-tech industries[11]. The results, presented in Table 7, suggest that the investment strategies of these two groups may differ fundamentally, indicating that our full-sample results are an aggregation of distinct underlying behaviors.

For the high-tech subsample, the R&D investment response is somewhat consistent with our main results. We continue to find that financing and technology-related risk shocks are associated with a significant increase in R&D intensity. However, the effect of regulatory risk, while still negative in sign, is no longer statistically significant. For capital investment among high-tech firms, none of the risk shock coefficients are statistically significant, suggesting that R&D is the primary margin of adjustment for these firms.

Turning to the non-high-tech subsample, the results diverge more sharply. For R&D investment, all risk types become insignificant. This is likely due to the generally lower propensity of these more traditional firms to engage in R&D, meaning it is not a primary strategic lever for responding to uncertainty or risk. For capital expenditures, the negative effect of competition risk remains significant, consistent with "wait-and-see" behavior. However, the effect of tax risk, which was significant in the full sample, is no longer significant for this group.

### 5.3.4 Summary of Robustness and Implications

Taken together, our series of robustness tests provides further support for the central hypothesis of this paper: the type of risk a firm faces is a crucial determinant of its investment decisions for both R&D and capital expenditures. This general finding remains consistent across alternative specifications and subsamples.

However, the tests also highlight important nuances and indicate that the effects of specific risk types are not uniformly stable. A key objective of our analysis is to determine not only which risk types matter

[11] High-Tech industries are identified by NAICS industry codes in line with the classification proposed by Goldschlag and Miranda (2020).

Table 7: Effect of Risk Types on Investment: High-Tech vs. Non-High-Tech Firms

| | High-Tech Firms | | Non-High-Tech Firms | |
|---|---|---|---|---|
| | (1) R&D Intensity | (2) Capital Intensity | (3) R&D Intensity | (4) Capital Intensity |
| *Regulatory* | -0.0258 | 0.0143 | -0.0497 | 0.0077 |
| *Tax* | -0.0227 | -0.0063 | 0.0992 | -0.0371 |
| *Macro* | -0.0205 | 0.0532 | -0.0279 | -0.0329 |
| *Financial* | 0.1058** | -0.0656 | 0.0017 | -0.0301 |
| *Technological* | 0.0774* | 0.0039 | 0.1321 | 0.0051 |
| *Legal* | -0.0033 | -0.0084 | 0.0319 | 0.0220 |
| *Governance* | -0.0326 | -0.0608 | 0.1167 | 0.0327 |
| *Competition* | -0.0445 | 0.0150 | 0.0650 | -0.0646* |
| Observations | 40,479 | 40,354 | 123,911 | 122,849 |
| R-squared (within) | 0.093 | 0.058 | 0.032 | 0.047 |
| Firm FE | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |

*Notes*: This table presents the results of a panel regression with firm and industry fixed effects. Columns (1) and (2) restrict the sample to high-tech firms, while columns (3) and (4) use the sample of non-high-tech firms. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

for investment, but also which do not. In our main results, we find significance primarily at the 5% level, which, given our large sample size, suggests the effects are not overwhelmingly strong. The subsequent robustness tests confirm this fragility; the statistical significance of specific drivers of R&D and capital investment can change when we alter the model specification or analyze specific subsamples.

This partial robustness suggests that while the type of risk clearly matters, the precise nature of the relationship is complex, cautioning against drawing definitive conclusions about specific risk types too soon. We suspect that measurement error related to our classification of risk types may be partially responsible for both the modest significance levels in our main results and the inconsistencies across tests. A significant concern is that the degree of measurement error may differ between risk types. This makes it difficult to interpret a significant coefficient versus an insignificant one: the difference could mean one type matters while the other does not, or it could simply mean that one type is measured with more precision than the other.

Therefore, before more definitive conclusions can be drawn about the specific types of risk that drive investment, in future work we focus on refining the risk classification to obtain more precise measures. Revisiting this analysis with an improved measurement methodology will be crucial to more clearly disentangle the distinct effects of each risk category on corporate investment.

# 6 Conclusion

The existing literature reveals a stark contrast in how uncertainty affects different types of corporate investment. For capital expenditures, the literature predominantly finds a negative "wait-and-see" effect. For R&D, however, the evidence is mixed, with studies finding positive, negative, and insignificant effects. This paper was motivated by the idea that these divergent findings are not necessarily contradictory, but may instead reflect the fact that different studies, using different proxies, are capturing different types of uncertainty. Our central research question was therefore to examine whether R&D investment responds heterogeneously to shocks originating from different sources of risk, and how these responses compare to those of capital investment.

To address this question, we introduce a novel methodology that uses the textual content of firms' quarterly SEC filings. By exploiting the regulatory requirement that firms must disclose any "material changes" to their risk factors, we identify the timing of discrete, firm-level shocks and classify their type.

Our analysis provides strong support for our central hypothesis that the response of investment to a risk shock depends critically on the type of risk. For R&D investment, we find that different risk types elicit investment responses of opposite signs: shocks related to financial and technological risk are associated with a significant increase in investment, while regulatory risk is associated with a significant decrease. This finding of opposing effects helps to explain the mixed evidence in the prior literature. Furthermore, we find that the set of risks that significantly affect R&D is almost entirely different from the set that affects capital investment, underscoring the fundamental differences in how firms approach innovation versus more traditional investment when faced with uncertainty. However, we urge caution in drawing definitive conclusions about the specific risk types, as our robustness tests indicate that the statistical significance of individual coefficients can be sensitive to model specification and sample composition.

The heterogeneous responses we document have several important implications. For theory, they suggest that the various channels through which uncertainty can affect R&D investment – some predicting a decrease in investment, others an increase – should not be viewed as mutually exclusive. Rather, our results indicate that these different theoretical dynamics may be activated by distinct types of uncertainty. For empirical research, our paper suggests that the interpretation of results based on single, aggregate uncertainty proxies can be enriched by considering which specific types of risk they most likely represent. Our findings, which show distinct patterns of investment responses to different risk shocks, make a strong case for disaggregating the concept of uncertainty into its constituent sources. Finally, our results offer an important consideration for policymakers. Our main analysis finds that regulatory risk is associated with a significant decrease in R&D investment. To the extent that our measure of regulatory risk captures heightened uncertainty about the regulatory environment, this suggests that regulatory ambiguity may have 'hidden costs' by potentially dampening the innovation that is essential for long-term economic growth.

It is important to consider our findings in the context of several caveats stemming from our data and measurement strategy. In addition to potential endogeneity of the disclosure decision and the constraints of a dictionary-based classification method, a key consideration is that our measure likely does not isolate pure second-moment uncertainty shocks. It is plausible that the "material changes" we identify often represent a mix of "bad news" (a negative first-moment shock) and an increase in variance (a second-moment shock). This is a common challenge for many empirical risk and uncertainty proxies, and as such, our results should be interpreted with these caveats in mind.

Our work suggests promising avenues for both empirical and theoretical future research. On the empirical side, a particularly promising avenue lies in using the first step of our methodology – the identification of "material change" disclosures – as a starting point for discovering new emergent risk categories. This sample of shock events could be analyzed with unsupervised machine learning methods, such as topic modeling, to allow for a data-driven classification of risks. Such an approach could identify emergent categories of risk not captured by our predefined dictionaries, such as those related to cybersecurity, or ESG issues; a key advantage of this approach is its ability to discover risks that researchers may not anticipate a priori. On the theoretical side, our results could provide a valuable empirical starting point for macroeconomic models of endogenous growth. While these models often incorporate uncertainty as a key factor, they typically feature only one type (that can be interpreted as technological or market uncertainty). Our firm-level evidence helps to identify which of the many potential sources of risk are empirically most relevant for the R&D decisions that ultimately drive growth. Future theoretical work could therefore leverage our findings to refine these models by incorporating the specific risk channels that are empirically important.

## References


Alfaro, I., Bloom, N., and Lin, X. (2024). The Finance Uncertainty Multiplier. *Journal of Political Economy*, 132(2):577–615.

Atanassov, J. (2013). Do Hostile Takeovers Stifle Innovation? Evidence from Antitakeover Legislation and Corporate Patenting. *The Journal of Finance*, 68(3):1097–1131.

Atanassov, J., Julio, B., and Leng, T. (2024). The Bright Side of Political Uncertainty: The Case of R&D. *The Review of Financial Studies*, 37(10):2937–2970.

Bachmann, R., Elstner, S., and Sims, E. R. (2013). Uncertainty and Economic Activity: Evidence from Business Survey Data. *American Economic Journal: Macroeconomics*, 5(2):217–249.

Baker, S. R., Bloom, N., and Davis, S. J. (2016). Measuring Economic Policy Uncertainty. *The Quarterly Journal of Economics*, 131(4):1593–1636.

Bao, Y. and Datta, A. (2014). Simultaneously Discovering and Quantifying Risk Types from Textual Risk Disclosures. *Management Science*, 60(6):1371–1391.

Beatty, A., Cheng, L., and Zhang, H. (2019). Are Risk Factor Disclosures Still Relevant? Evidence from Market Reactions to Risk Factor Disclosures Before and After the Financial Crisis. *Contemporary Accounting Research*, 36(2):805–838.

Bloom, N., Hassan, T. A., Kalyani, A., Lerner, J., and Tahoun, A. (2021). The Diffusion of Disruptive Technologies.

Brown, J. R., Fazzari, S. M., and Petersen, B. C. (2009). Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom. *The Journal of Finance*, 64(1):151–185.

Buehlmaier, M. M. M. and Whited, T. M. (2018). Are Financial Constraints Priced? Evidence from Textual Analysis. *The Review of Financial Studies*, 31(7):2693–2728.

Campbell, J. L., Chen, H., Dhaliwal, D. S., Lu, H.-m., and Steele, L. B. (2014). The information content of mandatory risk factor disclosures in corporate filings. *Review of Accounting Studies*, 19(1):396–455.

Cao, L. and Ren, J. (2022). Machine learning shows that the Covid-19 pandemic is impacting U.S. public companies unequally by changing risk structures. *PLOS ONE*, 17(6):e0269582.

Choi, S. J., Gulati, M., Liu, X., and Pritchard, A. C. (2024). COVID-19 Risk Factors and Boilerplate Disclosure.

Cui, X., Wang, C., Liao, J., Fang, Z., and Cheng, F. (2021). Economic policy uncertainty exposure and corporate innovation investment: Evidence from China. *Pacific-Basin Finance Journal*, 67:101533.

Czarnitzki, D. and Toole, A. A. (2011). Patent Protection, Market Uncertainty and R&D Investment. *The Review of Economics and Statistics*, 93(1):147–159.

Czarnitzki, D. and Toole, A. A. (2013). The R&D Investment–Uncertainty Relationship: Do Strategic Rivalry and Firm Size Matter? *Managerial and Decision Economics*, 34(1):15–28.

De La Horra, L. P., Perote, J., and De La Fuente, G. (2022). The impact of economic policy uncertainty and monetary policy on R&D investment: An option pricing approach. *Economics Letters*, 214:110413.

Filzen, J. J., McBrayer, G. A., and Shannon, K. S. (2023). Risk Factor Disclosures: Do Managers and Markets Speak the Same Language? *Accounting Horizons*, 37(2):67–83.

Gilchrist, S., Sim, J. W., and Zakrajsek, E. (2014). Uncertainty, Financial Frictions and Investment Dynamics.

Goldschlag, N. and Miranda, J. (2020). Business dynamics statistics of High Tech industries. *Journal of Economics & Management Strategy*, 29(1):3–30.

Gulen, H. and Ion, M. (2016). Policy Uncertainty and Corporate Investment. *Review of Financial Studies*, page hhv050.

Hoberg, G. and Phillips, G. (2016). Text-Based Network Industries and Endogenous Product Differentiation. *Journal of Political Economy*, 124(5).

Jens, C. E. (2017). Political uncertainty and investment: Causal evidence from U.S. gubernatorial elections. *Journal of Financial Economics*, 124(3):563–579.

Julio, B. and Yook, Y. (2012). Political Uncertainty and Corporate Investment Cycles. *The Journal of Finance*, 67(1):45–83.

Kim, H. and Kung, H. (2017). The Asset Redeployability Channel: How Uncertainty Affects Corporate Investment. *Review of Financial Studies*, 30(1):245–280.

Konchitchki, Y. and Xie, J. (2023). Undisclosed material inflation risk. *Journal of Monetary Economics*, 140:S82–S100.

Kumar, S., Gorodnichenko, Y., and Coibion, O. (2023). The Effect of Macroeconomic Uncertainty on Firm Decisions. *Econometrica*, 91(4):1297–1332.

Lyle, M. R., Riedl, E. J., and Siano, F. (2023). Changes in Risk Factor Disclosures and the Variance Risk Premium. *The Accounting Review*, 98(6):327–352.

Mason, R. and Weeds, H. (2010). Investment, uncertainty and pre-emption. *International Journal of Industrial Organization*, 28(3):278–287.

Panousi, V. and Papanikolaou, D. (2012). Investment, Idiosyncratic Risk, and Ownership. *The Journal of Finance*, 67(3):1113–1148.

Pindyck, R. S. (1993). Investments of uncertain cost. *Journal of Financial Economics*, 34(1):53–76.

Stein, L. C. D. and Stone, E. C. (2013). The Effect of Uncertainty on Investment, Hiring, and R&D.

Stokey, N. L. (2016). Wait-and-see: Investment options under policy uncertainty. *Review of Economic Dynamics*, 21:246–265.

Vo, L. V. and Le, H. T. T. (2017). Strategic growth option, uncertainty, and R&D investment. *International Review of Financial Analysis*, 51:16–24.

Xu, Z. (2020). Economic policy uncertainty, cost of capital, and corporate innovation. *Journal of Banking & Finance*, 111:105698.

Zhu, X., Li, J., and Wang, Y. (2024). Are risk disclosures in financial reports informative? A text mining-based perspective. *Humanities and Social Sciences Communications*, 11(1):1653.

# A Appendix

## A.1 Tables

Table 8: Definition of Variables

| Variable | Definition | Source |
|---|---|---|
| R&D Intensity | Calculated as firms' research and development expenditure (XRDQ) divided by book value of assets (ATQ), measured at the end of fiscal quarter $t$ | Compustat |
| Capital Intensity | Calculated as firms' capital expenditure (CAPEXQ) divided by book value of assets (ATQ), measured at the end of fiscal quarter $t$ | Compustat |
| Tobin's q | Defined as [the market value of equity (PRCC_Q × CSHOQ from Compustat) plus book value of assets (ATQ) minus book value of equity (CEQQ from Compustat)] divided by book value of assets (ATQ), measured at the end of fiscal quarter $t$ | Compustat |
| Cash flow | Firm's cash flows. It is defined as income before extraordinary items (IBQ from Compustat) plus depreciation and amortization (DPQ from Compustat) divided by book value of total assets (ATQ), measured at the end of fiscal quarter $t$ | Compustat |
| ln(Age) | Defined as natural logarithm of one plus the number of years the firm is listed with a nonmissing stock price on Compustat | Compustat |
| ln(Sales) | Defined as natural logarithm of one plus the net sales/turnover (SALEQ from Compustat) measured at the end of fiscal quarter $t$ | Compustat |
| Tangibility | Defined as total net property, plant and equipment (PPENTQ from Compustat) divided by book value of total assets (ATQ), measured at the end of fiscal quarter $t$ | Compustat |
| Leverage | Firm's leverage ratio. It is defined as book value of debt (DLTTQ + DLCQ) divided by book value of total assets (ATQ) measured at the end of fiscal year $t$ | Compustat |
| HHI | We compute the HHI as a measure of industry concentration based on firm-level sales data. For each three-digit SIC industry $g$ in year $t$, the HHI is defined as: $$HHI_{gt} = \sum_{i=1}^{N_g} S_{igt}^2,$$ where $S_{igt}$ is the market share of firm $i$ in industry $g$ and year $t$, calculated as the firm's sales divided by total industry sales. The summation is taken over all $N_g$ firms in that industry-year. A higher HHI indicates greater market concentration and lower competition. All Compustat firms are included, regardless of whether they report R&D. | Compustat |

## A.2 Dictionaries

Table 9: Phrases used to indicate no material change in risk factors

| No Material Change | |
|---|---|
| no material changes | no other material changes |
| no material change | no significant changes |
| not changed materially | not materially changed |
| not been any material changes | no changes to our risk factors |
| risk factors have not changed | no changes in any risk factors |
| no material updates or changes | no material updates |
| none of which have materially changed | has not been any material change |
| no significant material changes | no substantial changes relative to the risk factors |
| not aware of any material changes | no changes that constitute a material changes |
| no additions or material changes | have not been material changes to our risk |
| no change in risk factors | does not believe there have been any material changes |
| does not have any updates to its risk factors | no changes that constitute material changes |

## A.3 Securities Offering Reform of 2005

In the 2005 Securities Offering Reform (Release No. 33-8591), the Commission added a "Risk Factors" requirement to Exchange Act reports. Form 10-K now includes new Item 1A in Part I directing registrants, "where appropriate", to present the risk factors described in Item 503(c) of Regulation S-K and to write the discussion in plain English under Securities Act Rule 421(d) (see Form 10-K text at pp. 462–63). Form 10 was amended in the same manner, likewise requiring plain-English risk-factor disclosure keyed to Item 503(c). SEC Form 10-Q was amended to add Part II, Item 1A, which requires issuers to disclose "any material changes from risk factors as previously disclosed in the registrant's Form 10-K" rather than restating the full section (p. 462); the adopting release further "discourage[s] unnecessary restatement or repetition of risk factors in quarterly reports".

The adopting release clarifies scope and alignment. The Commission "adopt[ed] substantially as proposed" the new risk-factor item for annual reports on Form 10-K and Exchange Act registration statements on Form 10, but did not extend the requirement to the small-business forms (10-KSB/10-SB). It also excluded asset-backed issuers from the Form 10-K risk-factor requirement, noting the different disclosure framework under Regulation AB and the structure of ABS transactions; it observed that Form 20-F already required risk factors (pp. 257–58). The Commission emphasized that these changes align the Exchange Act standard with the Securities Act standard in Item 503(c) and that, while risk factors in Exchange Act reports can be incorporated by reference into a Securities Act registration statement, offering-specific risks may still need to be added for a particular deal (pp. 257–59).

The amendments (including the new Risk Factors items) became effective December 1, 2005. The Risk Factors section is required for fiscal years ending on or after December 1, 2005. The new Item 1A update appears only after the issuer's first Form 10-K that is required to include Risk Factors—i.e., in subsequent 10-Qs following that first 10-K.