Firm-level EPU exposure and R&D investments

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Abstract

This study investigates the heterogeneous effects of firm-level Economic Policy Uncertainty (EPU) exposure on innovation investment activities. Utilising the EPU index of Baker et al. (2016), the common risk factors, and a comprehensive US sample, we estimate time-series EPU exposure for each firm in the sample over the period 1988-2021. Consistent with the real option theory, our analysis provides robust evidence that 1% increase in EPU exposure is associated with 15% lower R&D investment. Firm-level EPU exposure shows superior explanatory power to R&D investment compared to that of the EPU index. Our results also show that different industries' R&D investments react to the change in EPU exposure heterogeneously. More interestingly, firms with more growth opportunity are more affected by EPU exposure. This study contributes to the literature by providing novel insights and strong evidence on how alternative measure to the EPU index, EPU exposure, affects firms' R&D investment in the country with the largest innovation investment and continuously introduces economic policy reform.

JEL classification: O31, G38

Keywords: Economic Policy Uncertainty, EPU exposure, EPU, R&D investment, corporate innovation investment

1. Introduction

Uncertainty refers to a scenario in which individuals involved in the economy possess only limited information, making it challenging for them to confidently evaluate the current situation and predict future outcomes (Knight Frank 1921). The effect of uncertainty on investments can be either positive or negative. Based on the real option theory, a negative relationship between uncertainty and investment is expected as firms postpone investments when uncertainty increases to avoid sunk costs of irreversible investments. Hence, the value of the future investment option will increase further if firms wait longer to invest. Consistent with the real option theory, Tian et al. (2022) and Zhou et al. (2023) find a negative relationship between EPU and innovation investments in China suggesting that firms tend to defer or postpone their innovation investments, proxied by Research & Development (hereafter R&D) investments, to avoid sunk costs because R&D investments are a long-term commitment and associated with high risk (Gulen & Ion 2016; Jens 2017; Julio & Yook 2012; Pindyck 1990; Xu 2020). In contrast to real option theory, growth option theory suggests that uncertainty promotes investment, particularly R&D investment, as R&D investment can help firms to capitalise on growth opportunities to gain competitive advantage which works as an option on growth opportunities (Kulatilaka & Perotti 1998; Weeds 2002).

R&D investments generally have a long-time span and are costly to adjust once the investment is made. The adjustment costs associated with R&D investment differ from those associated with general fixed investment, resulting in different effects of uncertainty on R&D investments compared to fixed investments (Bloom et al. 2007). When it comes to innovation, the primary expenses include funding R&D activities, compensating R&D personnel, and sunk costs. The significant adjustment costs in innovation investment stem from the persistence of labour costs, the unrecoverable costs of recruitment, the expenses associated with hiring and laying off employees, and the costs of training highly skilled personnel (Brown & Petersen 2015; König et al. 2014; Xu et al. 2020). In contrast, the adjustment costs of fixed investment are comparatively lower (Cooper & Haltiwanger 2006), although they do involve high sunk costs. Hence, the effect of uncertainty on R&D tends to be more intense than on other types of investment.

In the literature, various effects of uncertainty on investments have been tested using different uncertainty proxies. Among the proxies for uncertainty, Economic Policy Uncertainty (hereafter EPU), which measures economic policy-related uncertainty, has attracted a lot of attention since the last decade, especially the EPU index of Baker et al. (2016) (hereafter BBD's EPU index). The application of EPU index in explaining R&D investment has been accelerating in recent years. For example, it has been studied in China (Tian et al. 2022; Zhou et al. 2023), the UK (Nguyen and Trinh (2023); Nguyen and Kim (2023)), and internationally (William and Fengrong (2022) and Tajaddini and Gholipour (2021)). Some studies found a positive relationship between EPU index and R&D investment (Guan et al. (2021); Kong et al. (2022); Liu et al. (2022); Xie et al. (2022)), which is supported by the growth option theory, proposed by (Oi 1961) and further developed by Bloom (Bloom 2009; Bloom et al. 2007). On the other hand, others found a negative relationship (Gulen & Ion 2016; Jens 2017; Julio & Yook 2012; Nguyen & Trinh 2023; Nguyen & Kim 2023; Pindyck 1990; Xu 2020), which are aligned with the real option theory developed by Bernanke (1983) and Abel and Eberly (1996). The findings on the relationship between the EPU index and R&D are also mixed in the US studies. For example, Xu (2020) is the first one to look at the effects of EPU on innovation, proxied by patent-based metrics developed by (Hall & Ziedonis 2001). Xu (2020) found that EPU exacerbates firm's cost of capital and thus leads to a drop in their R&D investments suggesting a negative relationship between EPU and R&D over the period of 1985 to 2007; Horra et al. (2022) examined the relationship using a sample of US public firms over the period of 2000 to 2019 and found a positive relationship between R&D and EPU. Up to date, there is a lack of empirical evidence on the robustness of this relationship in the US as sample periods of the existing US studies are relatively short compared to that of BBD's EPU data.

More importantly, recent research attention on the application of EPU index has started shifting from this macro-level uncertainty measure to firm-level EPU exposure measure. EPU exposure is defined as the beta of the EPU variable obtained from the asset pricing models, such as the signal factor model and Fama and French factor models (Fama & French 1993, 2015). The Efficient Market Hypothesis suggests that investors incorporate new information into security prices through trading. By constructions, EPU index reflects the news that were released to the market, which were also observed and processed by the investors. Hence, investors incorporate effective EPU changes, which are expected to affect the firm's future earnings, into the firm's stock price via trading. EPU beta, commonly referred to as EPU exposure in the literature, measures the sensitivity of firm's stock return to changes in EPU. Unlike these above-mentioned studies who adopt a macro-level EPU index to investigate individual firms' decision-making at micro-level, we are motivated to investigate whether individual firms experience heterogeneous exposure to EPU given their own characteristics, and thus firm's R&D investment decision may vary significantly as a result of the heterogeneous exposure. We are interested in effect of EPU of exposure on R&D investment because EPU exposure is considered as a refined alternative to the EPU index as it contains more information regarding the extent to which individual firms are affected by EPU (Xu, 2020). In other words, EPU exposure contains firm-level information in relation to firm's stock price response to EPU, and it is expected to have robust explaining power on firm-level activities compared to the macro-level EPU index. This argument is supported by the recent EPU exposure studies. For example, EPU exposure is found to have strong effects on stock returns (Bali et al. 2017; Brogaard & Detzel 2015; Pástor & Veronesi 2013), stock price bubbles (Cheng et al. 2021), firm value (Yang et al. 2019), earnings management (Cui, Yao, et al. 2021), innovation (Cui, Wang, et al. 2021), leverage (Francis et al. 2014), and hedging (Nguyen et al. 2018). Among the above-mentioned studies, there is only one attempt from Cui, Wang, et al. (2021) that investigated the relationship between EPU exposure and corporate innovation investment using a sample of listed companies in China. However, according to our best knowledge, the role of EPU exposure in explaining firm innovation investments has not been examined in the US, where the most significant innovation investments were made in the world (Córdova & Guile 2022; Griffith 2000; Stam & Wennberg 2009). For example, the US has always been a leading country worldwide in terms of R&D (Griffith et al. 2004); invested more than 679 billion US dollars in R&D in 2022 (Dyvik 2022).

In this study, we investigate the effect of EPU exposure on corporate R&D investment in the US while revisiting the relationship between the EPU index and R&D using the longest possible BBD's EPU sample to shed light on the effect of BBD's EPU on R&D investments over a longer sample period compared to the existing US studies. We are motivated to perform this study in the US because it is not clear whether firm-level EPU exposure plays a more important role or not than BBD's EPU index in explaining R&D investments by the US firms. Although Cui et al. (2021) have examined the relationship between EPU exposure and R&D investments using a sample of Chinese firms, their results are biased toward firms with negative exposures as they excluded firms with positive EPU exposure in their sample. However, individual firm's EPU exposure/beta does not always have a stable sign as it may change from negative to positive or vice-versa over time. The practical implication is that it would be costly for managers to adjust their hedging strategies on economic policy uncertainty if EPU exposure changes, e.g., firm's EPU exposure changes from positive to negative over short to medium term, as firms are expected to have contractual obligations after implementing hedging strategies and sudden changes in EPU exposure will reduce effectiveness of the implemented hedging strategies. Moreover, both negative and positive EPU exposures drive up stock return volatility, so managers have incentives to hedge both types of EPU Exposures because excessive stock return volatility is not preferred (Keshavarz & Raei 2017; Lansing et al. 2022; LeRoy 2006). Our research design differentiates this study from Cui et al. (2021) not only by sample. More importantly, we include both positive and negative EPU exposures in the analysis to provide more insightful and robust results on the relationship between EPU exposure and R&D investment. We also aim to provide new evidence regarding whether firm-level EPU exposure is superior to the macro-level EPU index in explaining firm-level R&D investment as there is no comparison between EPU and EPU exposure in Cui et al. (2021). Moreover, revisiting the relationship between EPU and R&D investment in the US complements the US R&D literature as the existing US studies on EPU and R&D have shorter sample periods, and the results are mixed.

This study makes several important contributions to the literature. First, we estimate firm-level EPU exposure and examine how this firm-level alternative to the EPU index affects corporate innovation investments using a comprehensive US sample. According to our best knowledge, this study is the first to investigate the effect of EPU exposure on R&D investments in the US where the most significant innovation investments have been made. Second, our analysis further investigates the effect of EPU exposure on R&D investment across different industries to provide new insights on whether the effect of EPU exposure varies across industries. Third, we revisit the long-term relationship between EPU and innovation investments in the US since BBD's EPU index became available. Although this relationship has been barely examined in the literature, such as Horra et al. (2022) who found a positive relationship in the US from 2000-2019 in conjunction with monetary policy, our sample covers all the US firms with R&D data over the period of 1988-2021. Therefore, our analysis further checks the robustness of the existing findings by revisiting the relationship between EPU and innovation investment over the longest possible sample period of BBD's EPU index. Fourth, using both BBD's EPU index and firm-level EPU exposure in the regressions allows a comparison between the macro-level EPU index and firm-level EPU exposure in the current research setting. The results provide novel insights on which measure is superior in explaining firm-level innovation investments which broadens the literature on the application of EPU in finance research.

Following Bali et al. (2017), we define firm-level EPU exposure as the regression coefficient of BBD's EPU index obtained in the presence of a signal market risk factor and the Fama and French five factors. Using a comprehensive US panel sample from 1988 to 2022, our results show that (1) BBD's EPU index does not explain R&D investment in the US over the sample period of 1988 to 2021, but our EPU exposure measure, namely Time Series Exposure (TSE), is significantly and negatively associated with R&D expenditures and R&D intensity. The finding is consistent with the real option theory as the results show that higher TSE is associated with lower R&D investment. More importantly, the results show that firm-level EPU exposure is superior to the EPU index in explaining firm-level innovation investments lending further support to the importance of broader EPU application in finance research; (2) the industry-level analyses show that the effect of TSE varies across different industries. A stronger effect of TSE is found in research-intensive industries such as Healthcare, Technology, and Consumer cyclicals; (3) the adverse effect of TSE on R&D is exacerbated for firms who insignificantly exposed to EPU and/or have higher growth opportunity, implying that the effect of firm-level EPU exposure on innovation investment is stronger for firms with higher growth prospect; (5) the relationship between TSE and R&D investment remains robust while controlling for different model specifications.

Our study provides novel insights that firms' level of R&D investment is exacerbated by heightened TSE. In terms of practical implications, our results collectively point out that it is critical for managers and stakeholders to understand the difference between EPU and EPU exposure as applications of the two measures need to be carefully considered, especially since the two measures can affect firm-level decisions differently. The existing knowledge on EPU is not sufficient to understand the effect of economic policy uncertainty on firm decisions as to which can be shaped by their individual exposures to EPU.

2. Literature review and hypotheses development

2.1. Uncertainty and R&D Investments

The relationship between uncertainty and innovation investments has been widely studied in the literature. Most recent studies concern EPU and enterprise investment, but mixed results have been documented. There are two main theories that explain this nexus, real option theory and growth option theory which suggest completely opposite relationship. The growth option theory, or Oi–Hartman–Abel effects (Abel 1983; Hartman 1972; Oi 1961), suggests that uncertainty increases the expected profit margin and potential prize of the project, resulting in an increase in investment. It is enriched by Bloom (2014), who believed that companies prefer to increase innovation investments if uncertainty is expected to increase. Uncertainty creates a growth option which allows firms to increase their competitive advantage and create new opportunities to expand in the future. It suggests that R&D investment opportunities can be seized by other enterprises, thus hindering competitiveness and future profitability. In addition, during an economic downturn that involves a higher level of uncertainty, firm experiences lower price adjustments and a greater chance to exit (Bloom 2014), thus it is advisable to conduct costly experiments (Moscoso Boedo & D'Erasmo 2011; Pástor & Veronesi 2013). In other words, unsuccessful R&D investments result in the enterprise incurring sunk costs, which can be minimized through timely exit. Therefore, during times of high uncertainty, firms are motivated to invest in R&D. This theory has been supported by several recent empirical studies. For example, a positive relationship between EPU and R&D investment is reported for Chinese firms by Liu et al. (2022), Guan et al. (2021), German firms by Ross et al. (2018) internationally by Alam et al. (2019), Tajaddini and Gholipour (2021), and US firms by Horra et al. (2022) and Van Vo and Le (2017).

One of the well-cited papers in this strand of literature is Van Vo and Le (2017), who used idiosyncratic volatility as a proxy for uncertainty, which was found to be positively related to R&D investment, implying that firms tend to invest more in R&D when they operate in more uncertain market conditions. The interaction between strategic growth options and uncertainty strengthens the positive relationship, and firms with more strategic growth options are more responsive to increased uncertainty. Ross et al. (2018) examined how a firm's ability to learn from its past experiences and adapt to uncertainty influences its R&D investment decisions. The study suggests that firms with good learning conditions tend to invest earlier in R&D projects when there is uncertainty. This is because they can learn from early investments and adapt their strategies as new information becomes available. Tajaddini and Gholipour (2021) investigated how economic policy uncertainty influences a firm's R&D investments. The study found a positive relationship between economic policy uncertainty and R&D expenditures. In other words, higher levels of economic policy uncertainty are associated with increased investments in R&D by firms. Guan et al. (2021) investigated how fluctuations in economic policy uncertainty affect a firm's innovation activities. The study reported evidence of a positive relationship between economic policy uncertainty and corporate innovation in China. When firms face greater economic policy uncertainty, they may view R&D investment as a means to adapt to changing conditions and regulations. This investment in innovation can help firms navigate uncertain economic environments and enhance their competitiveness. Liu et al. (2022) found a positive relationship between EPU and enterprise investment decisions in China suggesting that when facing greater uncertainty, enterprises tend to view investments as a means to adapt to changing conditions, seize opportunities, or respond to evolving policy dynamics. In the US, Horra et al. (2022) this suggests that higher EPU and contractionary monetary policy encourage corporate investment in

R&D, although this effect is partially offset when both EPU and monetary policy rates increase simultaneously.

On the other hand, the real option theory (Abel & Eberly 1996; Dixit et al. 1994) suggests a negative relationship between uncertainty and R&D investments. According to this theory, firms' option to wait becomes more valuable when uncertainty is high because innovation is costly and irreversible. Under high adjustment costs, postponement allows firms to uphold their option awaiting better opportunities and avoiding costly mistakes (Dixit et al. 1994). As the cost of investment is irreversible, the value of option to wait becomes higher, and firms will be less likely to rush investing into R&D in an environment where uncertainty presents. Consequently, uncertainty can lead firms to postpone their investments until more information becomes available and the uncertainty diminishes. Thus, elevated uncertainty discourages investments while low uncertainty motivates those activities. This theory is well supported by a number of studies, including Bernanke (1983), Brennan and Schwartz (1985), (Dixit 1992), and McDonald and Siegel (1986). Bloom et al. (2007) posits that uncertainty affects R&D differently compared to traditional investments because of the contrasting adjustment costs associated with capital and knowledge stocks. In line with this, Barrero et al. (2017) present empirical evidence that long-term uncertainty has a more pronounced negative effect on R&D activity than on employment. This is attributed to lower depreciation rates and higher adjustment costs associated with R&D, which make it more sensitive to fluctuations in long-run uncertainty.

Empirically, Gulen and Ion (2016) developed a conceptual framework that distinguishes between the effect of policy uncertainty on the extensive margin (the decision to invest) and the intensive margin (the amount of investment), which are different channels through which policy uncertainty can influence corporate investment. They found that policy uncertainty has a negative impact on corporate investment. The negative effect of policy uncertainty on investment is more pronounced for firms that are more exposed to government policies and regulations, such as those in highly regulated industries. Xu (2020) explores how economic policy uncertainty influences a firm's cost of capital and consequently investment in innovation. The study suggests that higher economic policy uncertainty tends to increase a firm's cost of capital. Thus, firms facing greater uncertainty may need to offer higher returns to attract capital, which results in an elevated cost of capital, which is ultimately associated with reduced corporate innovation as they are less willing or able to invest in innovation.

In recent years, the application of EPU in explaining R&D investment has further advanced. Cui et al.2021) estimated individual firm's EPU exposure and investigated the effect of firm-level EPU exposure on innovation investment in China over the period of 2007 to 2017. Their results show that there is a statistically significant impact of EPU exposure on corporate innovation investment. In other words, higher EPU exposure is associated with reduced R&D investment. However, Cui et al. (2021) excluded positive EPU exposures from their sample as they argue that positive EPU exposure represents a good hedge which is out of their focus on the adverse effect of EPU. According to our observation, a firm's EPU exposure sign can fluctuate significantly over time as it can change from negative to positive and vice-versa. Excluding positive EPU exposures from the sample results in a bias toward negative EPU. Therefore, Cui et al. (2021) conclusion is inconclusive as their results do not provide full insights into the effect of both positive and negative EPU exposure on R&D.

Based on the discussions above, uncertainty can either have a positive or negative effect on R&D investment as firms with higher EPU exposure may invest more in R&D to enhance their competitive advantage according to the growth option theory or they may make less R&D investments to wait for a better investment opportunity according to the real option theory. However, the effect of firm-level EPU exposure has been rarely examined in the literature except for Cui et al. (2021) who investigated the effect using a sample of Chinese firms, even though R&D in the US is worth investigating as R&D has been justified as a key component of economic growth in the US (Merrifield 1989). Therefore, we are motivated to propose the following hypothesis with a non-directional relationship between EPU exposure and R&D investment:

Hypothesis 1: There is a significant relationship between EPU exposure and R&D investment.

2.2. Effect of EPU exposure in different industries

The effect of EPU on R&D varies across industries as some industries are more affected by policy uncertainty, while others exhibit more resilience. For example, prior research shows that the effect of

EPU on firms' innovation is more pronounced in more competitive industries in the US (Van Vo & Le 2017) and political-sensitive industries in an international sample (Nguyen & Kim 2023). Xie et al. (2022) suggest that higher EPU inhibits the R&D innovation of companies in strategic emerging industries, which may vary across different strategic emerging industries. Nguyen and Trinh (2023) found that EPU has a negative effect on the innovation investment of firms in consumer goods, consumer services, healthcare, and technology, while such a relationship is not observed in basic materials, oils and gas, and industrials. The majority of studies on the relationshipship between EPU and firm innovation investment cover general industries and omit their distinctive characteristics. To date, there has not been any attempt to examine the effect of EPU exposure across different industries. We propose the following hypothesis to examine whether the effect of EPU exposure on R&D varies across industries:

Hypothesis 2: EPU exposure has different effects on R&D investments across industries.

2.3. Moderating effect

Previous research has established that firms achieve growth opportunities by engaging in R&D projects (Kulatilaka & Perotti, 1998). That growth is due to the creation of new products or more efficient production processes, as a result of R&D, or from the new market penetration, reduction in production costs, etc, which eventually leads to an increase in market share and profits. As evidenced by Kang et al (2014), government policy uncertainty weakens the link between a firm's investment and its sales growth. Considering that R&D investments create potential avenues for growth, we hypothesize that, in the presence of economic policy uncertainty, firms with greater growth prospects will be more motivated to invest in R&D. This strategic move aims to prolong or enhance their competitiveness over rivals. To measure firms' growth opportunities, we utilised two proxies: the ratio of a firm's market value to the book value of its common equity, Tobin's Q (Atanassov et al. 2015), and the market-to-book value ratio provided by Refinitiv.

H3: Firm's growth opportunity moderates the effect of EPU exposure on R&D investments.

3. Research design

3.1. Sample

Our initial sample consists of all firms listed on the NYSE and NASDAQ from 1986 to 2021, including listed and delisted firms. Our sample period begins in 1986 because BBD's EPU index data for the US starts in 1986. We drop the firms without R&D data and data for other firm-level variables. Firm-level data is gathered from Refinitiv. Market return, Fama-French five factors and risk-free rate are downloaded from the Fama-French online data library[1]. The EPU index is obtained from BBD's website[2]. Macro level uncertainty variables, VIXX and GDP Growth rate, are collected from the website of the Federal Reserve Bank of St. Louis[3]. Our final sample consists of 23,319 firm-year observations after matching the initial sample with the R&D data and the data for other firm variables.

3.2. Variables

In line with Balli et al. (2017); Cheng et al. (2021); Cui, Wang, et al. (2021); Yang et al. (2019), we define EPU exposure, denoted as TSE, as the coefficient of EPU obtained from the following rolling regression over rolling windows of 36 months and 60 months:

$$R_{i,t} - r_{f,t} = \alpha + \beta_{i,t}^{EPU} EPU_t + \beta_{i,t}^{mkt} R_{mt} + \beta_{i,t}^{SMB} SMB_t + \beta_{i,t}^{HML} HML_{mt} + \beta_{i,t}^{CMA} CMA_t + \beta_{i,t}^{RMW} RMW_t + \delta_{it} \qquad (1)$$

Where $R_{i,t}$ is the monthly return of stock i, $r_{f,t}$ is the risk-free rate in the US, EPU_t is the monthly BBD's EPU index, R_{mt}, SMB_t, HML_t , CMA_t ,and RMW_t are the Fama and French five factors and δ_t is a random error term. Our EPU exposure measures, TSEFF30 and TSEFF60, are the values of $\beta_{i,t}^{EPU}$obtained from equation (1) above, using a 36- (60-) month rolling window. Annual TSE is calculated by averaging of the monthly TSE in a year. We also estimate alternative measures of TSE over rolling window of 36 months and 60 months, namely TSE36, and TSE60 respectively, using a single market risk factor and the EPU index as the explanatory variables[4]. The purpose of estimating

[1] https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html
[2] https://www.policyuncertainty.com
[3] https://fred.stlouisfed.org
[4] TSE36 and TSE60 are the products of the following regression model over 36-month rolling window and 60-month rolling window, respectively:

alternative TSE36 and TSE60 using a different model is to confirm whether the information contained in EPU is captured by the common Fama and French risk factors. If information contained in EPU is also captured by the common risk factors, then the EPU exposure estimated using the Fama and French five-factor model should have a different effect on R&D investment compared to that of the EPU exposure estimated using the market risk factor.

We employ the R&D expenditure and R&D intensity as proxies for R&D investment. In line with the recent R&D studies (Cui, Wang, et al. 2021; Nguyen & Trinh 2023; Nguyen & Kim 2023), R&D intensity is calculated as R&D expenditure divided by total sales. To address the economic magnitude across covariates, we applied logarithm on market value, R&D expenditure, and R&D intensity. According to Schumpeterian endogenous growth theory, the effectiveness of R&D decreases as more products become available (Cai & Saadaoui 2022). To be consistent with empirical data, innovative activities and product variety ratio, also known as R&D intensity must be stationary and free from autocorrelation. We performed the Wooldridge test as well as the Augmented Dicky-Fuller test and detected both issues. Thus, we apply logarithm on R&D intensity to resolve the issues of non-stationary (Ang & Madsen 2011) and skewness (Falk 2012), as the ratio of R&D expenditure to total sales is highly positively skewed.

We include market value (SIZE), return on total asset (ROA), debt to equity ratio (LEV), cash holdings to total asset (CASH), fixed asset ratio (FA), and current ratio (CUR) as control variables in the regression to control for their effects on R&D. For robustness check, we include historic volatility of firm's stock (VOL), GDP growth rate (GDP GROW RATE) and CBOE Volatility Index (VIXX) in the regressions while testing the effect EPU exposure on R&D.

3.3. Baseline model

We employ the following models, along with robustness check and modification to test the proposed hypotheses:

$$R_{i,t} - r_{f,t} = \alpha + \beta_{i,t}^{EPU} EPU_t + \beta_{i,t}^{mkt} R_{mt} + \delta_{it}$$

$$Innovation_{i,t} = \beta_0 + \beta_1 TSE_{i,t} + \sum_{k=0}^{n} \beta_k Controls_{k,i,t} + \varepsilon_{i,t} \quad (2)$$

$$Innovation_{i,t} = \beta_0 + \beta_1 TSE_{i,t} + \beta_{EPU} EPU_t + \sum_{k=0}^{n} \beta_k Controls_{k,i,t} + \varepsilon_{i,t} \quad (3)$$

Where $Innovation_{i,t}$ is proxied by R&D expenditure and R&D intensity. $TSE_{i,t}$ is the individual firm's EPU exposure which is proxied by TSEFF36, TSEFF60, TSE36, and TSE60[5]. Control variables consist of the firm's market value (SIZE), return on asset (ROA), firm financial leverage (LEV), cash holdings (CASH), fixed asset ratio (FA), and operating capital ratio (CUR). Year fixed effect and industry fixed effect are included in all models performed except for the industry analysis. Autocorrelation up to one lag is detected in the model using the Wooldridge test. In order to address the potential consequence of autocorrelation and heteroskedasticity on statistical inference, Petersen (2009) proposes the standard errors to be double clustered to improve the robustness of the results. Thus, we included double clustering at firm and year level in the regressions.

4. Empirical results

4.1. Summary statistics

[Insert table 1 here]

We present descriptive statistics[6] of the variables in Table 1. As shown in Table 1, the mean values of R&D expenditure and R&D intensity are $256,268 and 3.361% respectively. Consistent with Bali et al. (2017), mean values and distributions of TSE estimated using different models and over different timeframes are very similar. Mean values of the control variables reveal some key characteristics of the firms invested in R&D. For example, the average size of the firms with R&D investment is $8 million; the average and median ROA of the firms over the sample period are -0.04 and -0.03 respectively indicating they had negative earnings on average during the sample period; mean value

[5] TSEFF30 and TSEFF60 are the firm-level EPU exposure estimated using the Fama and French five factors and the EPU index over rolling window of 36 months and 60 months respectively. TSE36 and TSE60 are the firm-level EPU exposure estimated using a market factor and the EPU index over rolling window of 36 months and 60 months respectively.

[6] The summary statistics for each industry and year are provided in Appendix 2, 3 and 4.

of LEV is 0.22 indicating that the US firms on average have the debt to total asset of 22%. Those figures are highly consistent with the US data summary report by Xu (2020).

Table 2 shows the correlation coefficients between the variables. As expected, TSE36 is highly correlated with TSEFF36 at 0.905 and TSE60 is highly correlated with TSEFF60 at 0.876. The high correlations between TSE variables estimated using different models provide an important implication that they contain very similar information regarding how a firm's stock return reacts to EPU while controlling for different risk factors suggesting that EPU contains different information compared to other common risk factors. Interestingly, the correlation between TSEFF36 and TSEFF60 is 0.6 suggesting that the effect of EPU on stock return varies over different timeframes. In the analysis, we run regressions using TSE36, TSE60, TSEFF36, and TSEFF60, but the results obtained using TSE36 and TSE60 are not tabulated due to high similarity to those obtained using TSEFF36 and TSEFF60. The un-tabulated results will be available upon request.

[Insert table 2 here]

4.2. Baseline results

[Insert table 3 here]

The baseline regression results are reported in Table 3. In Table 3, the coefficients of TSEFF36 and TSEFF60 remain significant and negative across different models. The significant relationships between TSE and the R&D variables are consistent with Hypothesis 1 and the negative signs on TSE lends support to the real option theory as it suggests that firms with high EPU exposure postpone R&D investments to avoid sunk costs of irreversible investments. Interestingly, EPU does not have any significant explanatory power on the R&D variables implying that the firm-level EPU exposure variable, TSE, has superior explanatory power on individual firms' innovation investments compared to that of the macro-level EPU index. The coefficients of the control variables are consistent with the related R&D studies. For example, cash holdings are positively related to R&D (Baldi & Bodmer 2018); higher tangible asset ratio diminishes the incentive to invest (Lai et al. 2015); Big firms invest more than small firms (Link & Rees 1990). In summary, Table 3 provides strong evidence that TSE has a negative effect on R&D investment. Although this negative relationship is consistent with Cui et al. (2021), our findings contribute to the EPU exposure literature as well as the US R&D literature by providing more robust results and complete insight on the relationship using a comprehensive TSE sample which includes both positive and negative TSE. On the other hand, EPU shows no effect on R&D investment in the US over the sample period lending support to the argument that TSE is superior to EPU in explaining firm-level decisions. This finding opposes that of Horra et al. (2022) who found that R&D investment positively associated with EPU over the period of 2000 to 2019. To test this opposition, we conducted a sub-sample analysis for this sample period. The un-tabulated sub-sample analysis results are identical qualitatively compared to those of Horra et al. (2022) using the same method. Overall, the results obtained using the EPU index suggest that the effect of EPU on R&D investment may become insignificant when stricter model specifications are controlled for, while the effect of EPU exposure remains significant.

4.3. Industry Analysis

[Insert table 4 here]

To test hypothesis 2, we split the whole sample into industries using the Refinitiv Business Classifications[7]. This study employs first-level industry classification that includes ten sectors: Healthcare, Consumer Non-cyclical, Basic materials, Technology, Financial services, Industrials, Utilities, Energy, Real estate, and Consumer Cyclicals. We exclude the Real Estate industry due to an insufficient number of observations and a lack of R&D investments in that industry. Financial Services are also excluded due to the differences in the assets and liabilities between the financial firms and firms operating in other industries.

Table 4 reports the effect of TSE on R&D investment in eight industries. Consistent with hypothesis 2, the effect of TSE on R&D investment varies across industries. For example, TSE shows a consistent negative effect on R&D investment in Healthcare, Technology, and Consumer Cyclicals, a positive effect on R&D investment in Basic Materials, and no effect or weak effect in Industrials and

[7] Available at: https://www.refinitiv.com/en/financial-data/indices/trbc-business-classification

Utilities. TSE negatively impacts Healthcare, Technology, and Consumer Cyclicals because these service-oriented industries offer intangible products and services, potentially necessitating R&D investment (Nguyen & Trinh 2023). The effect of TSE is stronger and more persistent in the long run, as R&D investment is more sensitive to TSEFF60 than to TSEFF36. More interestingly, the consistent positive effect of TSE is observed in Basic Materials. This positive effect is consistent with the growth option theory that suggests this market is strongly efficient, and firms are induced to undertake R&D projects under uncertainty as a tool for potential future growth and to outrun their competitors. TSE has weak or no effect on R&D investment in Industrials, Utilities, and Energy because R&D investment doesn't form a significant part of total investment in these industries, so their R&D investments are not expected to be notably influenced by uncertainties in economic policies. This is the first empirical study that examines the effects of EPU exposure on R&D investments at the industry level to the best of our knowledge. The results also support our second hypothesis that the effect of TSE, or EPU exposure, on innovation investment varies across industries.

Our results are consistent with prior studies which explored varying levels of capital and labour adjustment costs. For example, Czarnitzki and Hottenrott (2011) emphasized the substantial sunk costs associated with R&D programs and the difficulty in adjusting R&D spending. This finding resonates with real options theory, suggesting that uncertainty might lead managers to delay investment, opting to wait and observe rather than engage in partially irreversible activities that could later prove to be disadvantageous. In line with Dibiasi et al. (2021), the consumer services sector appears to face higher capital and labour adjustment costs compared to firms investing in intangible assets. Our finding implies that the impact of macroeconomic uncertainty shocks is likely to vary across industries.

4.5. Robustness check and endogeneity tests

[Insert table 5 here]

To test the robustness of the relationship between TSE and R&D investments, we include other macro uncertainty proxies, such as VIXX (market volatility index), GDP growth rate as well as firms' historic volatility (VOL), in the regressions. Table 5 shows the effect of TSE on the RD variables remains robust and consistent in the presence of the additional macro and firm-level uncertainty proxies.

[Insert table 6 here]

As shown above in Table 6, the effect of TSE on R&D investment is highly consistent with that observed in Table 3 as the coefficients are significant and negative except for those of TSEFF60 in model (2) and model (4) suggesting that the effect of TSE becomes weaker if it is estimated over a longer period.

It is our concern that TSE may correlate with unobservable factors that may also affect R&D investment. For example, firms with better borrowing capacity and/or lower cost of capital have stronger investment capacity and are simultaneously less exposed to EPU (Xu 2020). Thus, the coefficients may be biased due to endogeneity. To address this potential issue, we applied the GMM method developed by Arellano and Bond (1991) to estimate the following model:

$$Innovation_{i,t} = \beta_0 + \beta_1 TSE_{i,t} + \beta_{innovation} Innovation_{i,t-1} + \sum_{k=0}^{n} Controls_{k,i,t} + \varepsilon_{i,t} \quad (4)$$

In line with Aivazian et al. (2005); Elnahass et al. (2020); Nguyen and Trinh (2023) and Trinh et al. (2020), the lagged R&D variable is presented in the model to capture the dynamic impacts of investment. This addition is crucial because companies base their innovation investment decisions for upcoming years on their previous year's R&D investments. When R&D investments yield economic benefits like scaling up production output, firms may expedite their innovation process in the subsequent period to secure enough capital to meet escalating demands. This, in turn, creates an acceleration effect in innovation investment. GMM, as noted by Bond and Windmeijer (2002), offers a significant advantage of not necessitating a new instrumental variable and allowing for the use of longer lags of regressors as instruments. Additionally, GMM is adept at handling dynamic panel models where lagged dependent variables (for example $RD_{i,t}$) are correlated with individual effects, $\varepsilon_{i,t}$. We also included in this section the Arellano test of second-order autocorrelation as well as the Hansen test for overidentification. In Table 7, both of these p-values show (1) the model is appropriate and (2) there is no overidentification detected. The GMM estimation results are consistent wtih our baseline result that TSE proposes a significant and negative impact on innovation investment, which holds robustness even in the existence of endogeneity.

[Insert Table 7 here]

4.6. Moderating effect

[Insert Table 8 here]

Nguyen and Kim (2023) suggested that growth opportunity is one channel of effect from EPU to R&D investment, thus in this section, we employ the market-to-book value ratio and Tobin's Q as a proxy for the firm's growth prospect. Using this model, we examine whether firms with more growth opportunities invest less in R&D as TSE increases. In Table 8, the market-to-book value ratio and Tobin's Q, as well as their interaction with TSEFF36 and TSEFF60 were added to the baseline regression model. The estimated coefficient of the interaction is found to be negative and significant, except for the MTB-RDS pair. This result suggests that the effect of TSEFF36 (TSEFF60) on RD and RDS is stronger for firms with higher growth prospects. It is also consistent with the conclusion of Nguyen and Kim (2023) those who studied EPU's effect on R&D investment.

5. Conclusion

In this study, we examined the relationship between EPU exposure (TSE) and corporate innovation investment, focusing on the US market that includes firms listed on the NYSE and NASDAQ from 1988 to 2021. We construct several TSE measurements following Yang et al. (2019), controlling for market risk premium; Cheng et al. (2021); Cui, Wang, et al. (2021), controlling for Fama-French 3 factors, and Bali et at (2017), controlling for Fama-French 5 factors. TSE is found to have a consistent and significant negative effect on firm's innovation activities measured by R&D expenditure and R&D intensity. These results hold strong given the control of double clustering at year and industry level, in the presence of other macro-economic variables, as well as robustness tests. Interestingly, the effect of TSE outruns the effect of the EPU index by Baker et al. (2016) in explaining the innovation investment at the firm level. It implies that TSE is a better predictor of innovation investment than

EPU at firm-level and a higher degree of TSE is associated with lower R&D investment in the US. We further find the negative and significant impact of TSE on corporate R&D in Healthcare, Consumer Cyclicals, and Technology, while this relationship is negative in Basic Materials. Innovation investment in Consumer Non-Cyclicals, Industrials, Utilities, and Energy are shown to have either weak or no effect from TSE. Finally, we found that the negative impact of TSE on R&D activities is less pronounced for firms with higher growth opportunities and/or in the long run.

Our study has important contributions to the literature and policy implications. First of all, our results emphasise that managers and stakeholders to understand the difference between EPU and EPU exposure as applications of the two measures need to be carefully considered, especially since the two measures can heterogeneously affect firm-level decisions. The existing knowledge and literature on EPU, especially in the US, is clearly not adequate to comprehend the effect of uncertainty on firm decisions as which can be shaped by their exposure to EPU. Further, different industries may have unconventional reactions to EPU exposure, as evidenced above, and this divergence must be taken into account when making investment or management decisions. Second, as Gulen and Ion (2016) pointed out, policy and the uncertainty surrounding policy change can be as damaging as making the wrong decisions. As the negative impact of EPU exposure is found, it is recommended that policymakers should be mindful that their fast and significant economic policy change can hamper a firm's investment activities, and potentially exacerbate future profit, growth opportunity, firm value, and ultimately the development and performance of the economy. As such, R&D activities and/or innovation promotion efforts might be hindered by the uncertainty caused by those policies.

Table 1: Summary statistic

Statistics	N	Mean	St. Dev.	Min	Q1	Median	Q3	Max
R&D expenditure	23319	256268	1290329	1	7000	28500	105940	56100000
R&D intensity	23319	3.361	109.746	0.000	0.020	0.068	0.169	12991
RD	23319	10.23	2.13	10.23	8.85	8.85	11.57	17.84
RDS	23319	-2.73	1.86	-2.73	-3.91	-3.91	-1.78	9.47
TSE36	23319	-0.0006	0.0012	-0.0134	-0.0011	-0.0011	0.0000	0.0103
TSE60	23319	-0.0005	0.0009	-0.0115	-0.0008	-0.0008	-0.0001	0.0048
TSEFF36	23319	-0.0005	0.0013	-0.0178	-0.0010	-0.0010	0.0001	0.0118
TSEFF60	23319	-0.0005	0.0009	-0.0113	-0.0008	-0.0008	0.0000	0.0053
EPU	23319	120.22	39.57	120.22	88.13	88.13	143.95	242.99
SIZE	23319	6.65	2.27	6.65	5.09	5.09	8.18	14.35
ROA	23319	-0.04	0.88	-0.04	-0.03	-0.03	0.10	3.95
LEV	23319	0.22	1.39	0.22	0.00	0.00	0.30	180.50
CASH	23319	0.22	0.22	0.22	0.06	0.06	0.31	0.99
FA	23319	17.97	15.65	17.97	6.74	6.74	24.65	386.99
CUR	23319	3.38	3.94	3.38	1.57	1.57	3.86	166.01

Table 2: Pairwise correlation

	RD	RDS	TSE36	TSE60	TSEFF36	TSEFF60	EPU	SIZE	ROA	LEV	CASH	FA	CUR
RD	1												
RDS	0.218[a]	1											
TSE36	0.038[a]	-0.044[a]	1										
TSE60	0.056[a]	-0.059[a]	0.689[a]	1									
TSEFF36	0.039[a]	-0.024[a]	0.905[a]	0.609[a]	1								
TSEFF60	0.059[a]	-0.047[a]	0.570[a]	0.876[a]	0.571[a]	1							
EPU	0.067	0.067[c]	0.011[a]	0.126[a]	-0.067[a]	0.026[a]	1						
SIZE	0.391[a]	-0.040[a]	0.044[a]	0.048[a]	0.039[a]	0.039[a]	0.038[a]	1					
ROA	0.110[a]	-0.216[a]	0.035[a]	0.027[a]	0.025[a]	0.014[a]	-0.036[a]	0.036[a]	1				
LEV	-0.015[a]	0.019[a]	-0.021[a]	-0.018[a]	-0.009[a]	-0.008[a]	0.009[a]	0.003[a]	-0.567[a]	1			
CASH	-0.031[b]	0.575[b]	-0.013[a]	-0.010[a]	-0.004[a]	-0.016[b]	0.137[c]	-0.037[a]	-0.121[a]	-0.016[a]	1		
FA	-0.049[a]	-0.406[b]	-0.036[a]	-0.025[a]	-0.037[a]	-0.019[b]	-0.074[a]	0.051[a]	0.045[a]	0.019[a]	-0.375[b]	1	
CUR	-0.145[a]	0.305[a]	-0.017[a]	-0.035[a]	-0.014[a]	-0.043[a]	0.024[a]	-0.079[a]	0.004[a]	-0.049[a]	0.391[a]	-0.19[a]	1

[a] *indicates 1% level of significance*
[b] *indicates 5% level of significance*
[c] *indicates 10% level of significance*

Table 3: Baseline model

	RD	RD	RD	RD	RD	RD	RDS	RDS	RDS	RDS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TSEFF36	-0.15***			-0.15***		-0.15***			-0.15***	
	(-4.46)			(-4.46)		(-3.51)			(-3.51)	
TSEFF60		-0.16***			-0.16***		-0.29***			-0.29***
		(-3.20)			(-3.20)		(-4.63)			(-4.63)
EPU			0.004	0.00	0.00			0.003	0.00	0.00
			(0.63)	(0.66)	(0.64)			(0.34)	(0.36)	(0.35)
SIZE	0.50***	0.50***	0.50***	0.50***	0.50***	-0.03***	-0.03***	-0.03***	-0.03***	-0.03***
	(105.23)	(105.17)	(105.14)	(105.23)	(105.17)	(-4.99)	(-4.88)	(-5.12)	(-4.99)	(-4.88)
ROA	-0.02***	-0.02***	-0.03***	-0.02***	-0.02***	-0.15***	-0.15***	-0.17***	-0.15***	-0.15***
	(-3.85)	(-3.89)	(-4.61)	(-3.85)	(-3.89)	(-24.21)	(-24.24)	(-22.86)	(-24.21)	(-24.24)
LEV	0.00	0.00	-0.01**	0.00	0.00	0.00	0.00	-0.02***	0.00	0.00
	(-0.54)	(-0.54)	(-2.43)	(-0.54)	(-0.54)	(-1.02)	(-1.02)	(-4.55)	(-1.02)	(-1.02)
CASH	-0.25***	-0.25***	-0.25***	-0.25***	-0.25***	0.74***	0.74***	0.74***	0.74***	0.74***
	(-7.85)	(-7.84)	(-7.93)	(-7.85)	(-7.84)	(18.93)	(18.98)	(18.97)	(18.93)	(18.98)
FA	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	(6.68)	(6.74)	(6.72)	(6.68)	(6.74)	(2.71)	(2.76)	(2.65)	(2.71)	(2.76)
CUR	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***	0.02***	0.01***	0.02***	0.02***	0.01***
	(-11.62)	(-11.64)	(-11.48)	(-11.62)	(-11.64)	(9.66)	(9.55)	(9.82)	(9.66)	(9.55)
Constant	6.10***	6.11***	5.640***	5.59***	5.62***	-1.29***	-1.28***	-1.60	-1.65	-1.63
	(56.54)	(56.76)	(7.11)	(7.05)	(7.09)	(-9.71)	(-9.67)	(-1.61)	(-1.63)	(-1.62)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs	23319	23319	23319	23319	23319	23319	23319	23319	23319	23319
Adjusted R2	0.69	0.75	0.69	0.75	0.75	0.53	0.53	0.42	0.53	0.53

Note: This table presents the regression result of:

$Innovation_{i,t} = \beta_0 + \beta_1 TSE_{i,t} + \beta_{EPU} EPU_t + \sum_{k=0}^{n} \beta_{control} Controls_{k,i,t} + \varepsilon_{i,t}$, *while controlling for industry and year fixed effects, double clustered.*

*Where $Innovation_{i,t}$ are proxies for corporate investment of firm i in year t, measured as RD and RDS. $TSE_{i,t}$ is the EPU exposure, including TSEFF36 and TSEFF60. Control variables consist of the firm's market value (SIZE), return on asset (ROA), firm financial leverage (LEV), cash holdings (CASH), fixed asset ratio (FA), and operating capital ratio (CUR). The detailed variable description is provided in Appendix 1 *, **, and *** indicate significance at 10%, 5% and 1% levels respectively. T-stats are in parentheses.*

Table 4: Industry analysis

Panel A: RD	Healthcare		Consumer Non-Cyclicals		Basic Materials		Technology		Industrials		Utilities		Energy		Consumer Cyclicals	
TSEFF36	-0.29***		-0.15		0.5***		-0.07		-0.1		0.34		-0.33		-0.18***	
	(-4.47)		(-0.66)		(3.01)		(-1.53)		(-1.11)		(0.35)		(-1.21)		(-1.31)	
TSEFF60		-0.40***		1.01***		1.35***		-0.12**		-0.04		-1.63		-0.04		-0.57***
		(-3.96)		(2.94)		(5.44)		(-1.69)		(-0.28)		(-1.1)		(-0.07)		(-0.60)
Constant	5.78***	5.81***	5.94***	6.11***	7.22***	7.24***	6.73***	6.73***	6.16***	6.18***	4.76***	4.18***	4.11	6.31***	5.62***	5.60***
	(57.73)	(48.05)	(22.70)	(23.42)	(34.16)	(34.93)	(75.54)	(76.05)	(51.85)	(52.51)	(3.93)	(3.42)	(1.10)	(18.58)	(30.63)	(30.73)
Controls variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs	5639	5639	1257	1257	1542	1542	7924	7924	4096	4096	112	112	581	581	1988	1988
Adjusted R2	0.76	0.76	0.71	0.71	0.51	0.51	0.74	0.74	0.68	0.68	0.78	0.78	0.70	0.70	0.57	0.57
Panel B: RDS	**Healthcare**		**Consumer Non-Cyclicals**		**Basic Materials**		**Technology**		**Industrials**		**Utilities**		**Energy**		**Consumer Cyclicals**	
TSEFF36	-0.3***		-0.47**		0.71***		-0.07		0.09		0.09		-0.10***		-0.34*	
	(-2.76)		(-2.12)		(4.45)		(-1.62)		(1.01)		(0.09)		(-0.31)		(-2.49)	
TSEFF60		-0.56***		1.12		1.66***		-0.24***		0.02		-3.09**		0.55*		-0.66
		(-3.38)		(3.40)		(6.93)		(-3.94)		(0.16)		(-2.05)		(1.16)		(-3.06)
Constant	-1.75***	-1.74***	-4.61***	-4.36***	-3.61***	-3.61***	-2.35***	-2.36***	-3.50***	-3.52***	-4.17***	-5.06***	-3.81***	-3.74***	-4.21***	-4.21***
	(-8.66)	(-8.61)	(-18.06)	(-17.16)	(-17.54)	(-17.99)	(-27.55)	(-27.79)	(-28.19)	(-28.56)	(-3.32)	(-4.09)	(-9.58)	(-9.40)	(-24.01)	(-24.14)
Controls variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs	5639	5639	1257	1257	1542	1542	7924	7924	4096	4096	112	112	581	581	1988	1988
Adjusted R2	0.35	0.35	0.04	0.03	0.11	0.12	0.05	0.05	0.15	0.15	0.59	0.61	0.55	0.53	0.25	0.25

Note: This table presents the regression result of:

$Innovation_{i,t} = \beta_0 + \beta_1 TSE_{i,t} + \beta_{EPU} EPU_t + \sum_{k=0}^{n} \beta_k Controls_{k,i,t} + \varepsilon_{i,t}$, *while controlling for year-fixed effects.*

Where $Innovation_{i,t}$ *are proxies for corporate investment of firm i in year t, measured as RD and RDS.* $TSE_{i,t}$ *is EPU exposure, including TSEFF36 and TSEFF60. Control variables consist of the firm's market value (SIZE), return on asset (ROA), firm financial leverage (LEV), cash holdings (CASH), fixed asset ratio (FA), and operating capital ratio (CUR). The detailed variable description is provided in Appendix 1 *, **, and *** indicate significance at 10%, 5% and 1% levels respectively. T-stats are in parentheses.*

Table 5: Robustness tests: controlling for macro-level uncertainties

Panel A:	RD	RD	RD	RD	RD	RD	RD	RD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TSEFF36	-0.17***	-0.15***	-0.15***				-0.17***	
	(-5.17)	(-4.46)	(-4.46)				(-5.17)	
TSEFF60				-0.26***	-0.16***	-0.16***		-0.26***
				(-5.15)	(-3.20)	(-3.20)		(-5.15)
VOL	-0.32***			-0.33***			-0.32***	-0.34***
	(-12.26)			(-12.65)			(-12.26)	(-12.65)
VIXX		-0.07			-0.07		-0.03	-0.02***
		(-1.12)			(-1.09)		(-0.22)	(-0.19)
GDP GROWTH			0.02			0.02	-0.06	-0.06***
			(0.14)			(0.12)	(-0.67)	(-0.65)
Constant	6.37****	7.85***	6.04***	6.40***	7.83***	6.07***	7.18**	7.01***
	(58.04)	(5.03)	(14.97)	(58.34)	(5.02)	(15.04)	(2.25)	(2.23)
Controls variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs	23319	23319	23319	23319	23319	23319	23319	23319
Adjusted R2	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69

Panel B:	RDS	RDS	RDS	RDS	RDS	RDS	RDS	RDS
TSEFF36	-0.12***	-0.14***	-0.14***				-0.12***	
	(-3.01)	(-3.51)	(-3.51)				(-3.01)	
TSEFF60				-0.21***	-0.29***	-0.29***		-0.21***
				(-3.27)	(-4.63)	(-4.63)		(-3.27)
VOL	0.29***			0.27***			0.29***	0.27***
	(8.79)			(8.36)			(8.79)	(8.36)
VIXX		-0.05			-0.04		-0.03	-0.03
		(-0.63)			(-0.61)		(-0.21)	(-0.19)

GDP GROWTH			-0.04***			-0.05	-0.08	-0.08
			(-0.17)			(-0.19)	(-0.72)	(-1.71)
Constant	-1.54***	-0.05	-1.21**	-1.51***	-0.07	-1.19**	-0.56	-0.61
	(-11.34)	(-0.02)	(-2.36)	(-11.21)	(-0.04)	(-2.33)	(-0.14)	(-0.15)
Controls variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs	23319	23319	23319	23319	23319	23319	23320	23321
Adjusted R2	0.43	0.42	0.42	0.43	0.42	0.43	0.43	0.43

Note: This table presents the regression result of:
$Innovation_{i,t} = \beta_0+\beta_1 TSE_{i,t} + \beta_{Macro} Macro_{i,t} + \sum_{k=1}^{n} \beta_k Controls_{k,i,t} + \varepsilon_{i,t}$, while controlling for industry fixed effect and year fixed effect; univariate and multivariate, as individually indicated.
*Where $Innovation_{i,t}$ are proxies for corporate investment of firm i in year t, measured as RD and RDS. $TSE_{i,t}$ is EPU exposure, including TSEFF36 and TSEFF60. $Macro_{i,t}$ are macroeconomic proxies, containing VIXX and GDP Growth rate. Control variables consist of the firm's market value (SIZE), return on asset (ROA), firm financial leverage (LEV), cash holdings (CASH), fixed asset ratio (FA), and operating capital ratio (CUR). The detailed variable description is provided in Appendix 1 *, **, and *** indicate significance at 10%, 5% and 1% levels respectively. T-stats are in parentheses.*

Table 6: Robustness tests_Lagged TSE

	RD	RD	RD	RD	RDS	RDS	RDS	RDS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TSEFF36 (-1)	-0.091***		-0.091***		-0.11***		-0.11***	
	(-2.71)		(-2.71)		(-2.67)		(-2.67)	
TSEFF60 (-1)		-0.081		-0.081		-0.11***		-0.31***
		(-1.54)		(-1.54)		(-2.67)		(-4.97)
EPU (-1)			0.00	0.00			0.00	0.00
			(-0.09)	(-0.11)			(-0.03)	(-0.03)
SIZE (-1)	0.51***	0.51***	0.51***	0.51***	-0.01*	-0.01*	-0.01*	-0.01*
	(101.30)	(101.23)	(101.30)	(101.23)	(-1.86)	(-1.86)	(-1.86)	(-1.76)
ROA (-1)	-0.01**	-0.01**	-0.01**	-0.01**	-0.10***	-0.10***	-0.10***	-0.10***
	(-2.20)	(-2.23)	(-2.20)	(-2.23)	(-14.09)	(-14.09)	(-14.09)	(-14.07)
LEV (-1)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(-0.63)	(-0.64)	(-0.63)	(-0.64)	(0.38)	(0.38)	(0.38)	(0.42)
CASH (-1)	-0.15***	-0.15***	-0.15***	-0.15***	0.62***	0.62***	0.62***	0.62***
	(-4.33)	(-4.33)	(-4.33)	(-4.33)	(15.34)	(15.34)	(15.34)	(15.41)
FA (-1)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00*
	(0.78)	(0.81)	(0.78)	(0.81)	(1.59)	(1.59)	(1.59)	(1.64)
CUR (-1)	-0.02***	-0.02***	-0.02***	-0.02***	0.03***	0.03***	0.03***	0.03***
	(-8.89)	(-8.88)	(-8.89)	(-8.88)	(16.58)	(16.58)	(16.58)	(16.44)
Constant	6.22***	6.23***	6.29***	6.31***	-1.53***	-1.53***	-1.50	-1.50
	(57.21)	(57.40)	(8.01)	(8.04)	(-11.87)	(-11.89)	(-1.56)	(-1.56)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs	20347	20347	20347	20347	20347	20347	20347	20347
Adjusted R2	0.713	0.713	0.713	0.713	0.430	0.430	0.431	0.431

Note: This table presents the regression result of:

$Innovation_{i,t} = \beta_0 + \beta_1 TSE_{i,t-1} + \beta_{EPU} EPU_{t-1} + \sum_{k=1}^{n} \beta_k Controls_{k,i,t-1} + \varepsilon_{i,t}$, while controlling for industry fixed effect and year fixed effect, double clustered.

*Where $Innovation_{i,t}$ are proxies for corporate investment of firm i in year t, measured as RD and RDS. $TSE_{i,t}$ EPU exposure, including TSE and TSE60. Control variables consist of the firm's market value (SIZE), return on asset (ROA), firm financial leverage (LEV), cash holdings (CASH), fixed asset ratio (FA), and operating capital ratio (CUR). The detailed variable description is provided in Appendix 1 *, **, and *** indicate significance at 10%, 5% and 1% levels respectively. T-stats are in parentheses.*

Table 7: GMM analysis

	RD	RD	RDS	RDS
	(1)	(2)	(3)	(4)
RD (-1)	0.86***	0.86***		
	(1123.27)	(921.65)		
RDS (-1)			0.88***	0.88***
			(889.05)	(883.03)
TSEFF36	-0.10***		-0.14***	
	(-38.34)		(-33.95)	
TSEFF60		-0.05***		-12.25***
		(-11.32)		(-26.34)
Constant	0.70***	0.73***	-0.43***	-0.43***
	(114.34)	(104.84)	(-78.28)	(-93.79)
Control variables	Yes	Yes	Yes	Yes
No. of Obs	20347	20347	20347	20347
Chi-squared	4.68E+09	2.50E+09	2.57E+08	9.89E+08
AR(1) p-value	0	0	0	0
AR(2) p-value	0.33	0.33	0.89	0.88
Hansen test p-value	0.28	0.24	0.19	0.29

Note: This table presents the regression result of:
$Innovation_{i,t} = \beta_0 + \beta_1 TSE_{i,t-1} + \beta_{Innovation} Innovation_{t-1} + \sum_{k=1}^{n} \beta_k Controls_{k,i,t-1} + \varepsilon_{i,t}$, *using GMM. Where* $Innovation_{i,t}$ *are proxies for corporate investment of firm i in year t, measured as RD and RDS.* $TSE_{i,t}$ *includes TSEFF36 and TSEFF60. Control variables consist of the firm's market value (SIZE), return on asset (ROA), firm financial leverage (LEV), cash holdings (CASH), fixed asset ratio (FA), and operating capital ratio (CUR). The detailed variable description is provided in Appendix 1 *, **, and *** indicate significance at 10%, 5% and 1% levels respectively. T-stats are in parentheses.*

Table 8: The moderating effect

Panel A: Market to book ratio as a mediator				
	RD	**RD**	**RDS**	**RDS**
TSEFF36	-0.18***		-0.13***	
	(-5.48)		(-3.10)	
TSEFF60		-0.18***		-0.25***
		(-3.48)		(-3.90)
MTB	-0.0008***	-0.0006***	0.00002	0.0001
	(-4.65)	(-3.51)	(0.09)	(0.82)
MTB*TSEFF36	0.007***		0.002	
	(4.24)		(1.08)	
MTB*TSEFF60		0.59***		-0.28
		(2.92)		(-1.14)
Constant	6.08***	6.10***	-1.31***	-1.31***
	(56.59)	(56.84)	(-9.93)	(-9.89)
Controls variables	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes
No. of Obs	22844	22844	22844	22844
Adjusted R2	0.70	0.70	0.43	0.43

Panel B: Tobin's Q as a mediator				
	RD	**RD**	**RDS**	**RDS**
TSE	-0.20***		-0.15***	
	(-6.88)		(-3.79)	
TSE60		-0.22***		-0.29***
		(-4.35)		(-4.65)
TOBIN	-0.008***	-0.01***	-0.006***	-0.007***
	(-12.70)	(-15.06)	(-7.66)	(-6.93)
TOBIN*TSEFF36	0.02***		0.008***	

	(12.18)		(4.80)	
TOBIN*TSEFF60		0.03***		0.01***
		(15.15)		(4.65)
Constant	6.07***	6.1***	-1.31***	-1.29***
	(56.59)	(56.96)	(-9.85)	(-9.76)
Controls variables	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes
No. of Obs	23319	23319	23319	23319
Adjusted R2	0.70	0.70	0.42	0.42

Note: This table presents the regression result of:
$Innovation_{i,t} = \beta_0 + \beta_1 TSE_{i,t} + Moderator_{i,t} + Moderator_{i,t} * TSE_{i,t} + \sum_{k=1}^{n} \beta_k Controls_{k,i,t} + \varepsilon_{i,t}$, while controlling for industry fixed effect and year fixed effect.
*Where $Innovation_{i,t}$ are proxies for corporate investment of firm i in year t, measured as RD and RDS. $TSE_{i,t}$ is the EPU exposure, including TSEFF36 and TSEFF60. Meditor is market to book ratio (MTB) and/or Tobins' Q (TOBIN). Control variables consist of the firm's market value (SIZE), return on asset (ROA), firm financial leverage (LEV), cash holdings (CASH), fixed asset ratio (FA), and operating capital ratio (CUR). The detailed variable description is provided in Appendix 1 *, **, and *** indicate significance at 10%, 5% and 1% levels respectively. T-stats are in parentheses.*

Appendix

Appendix 1: List of variables

Variable	Definitions
RD	R&D investment is calculated as Ln(R&D Expenditure).
RDS	R&D investment is calculated as Ln(R&D Expenditure To Total Sales).
TSEFF36	36-Month Rolling EPU Exposure. This variable is measured by the $\beta_{i,t}^{EPU}$ from equation (1), which is obtained by regressing excess stock returns on the EPU index controlling for the Fama-French five factors using a 36-month rolling window (τ-36, τ-1). Annual TSEFF36 is the average monthly TSEFF36 from January to December of that year. See section 3 for details.
TSEFF60	60-Month Rolling EPU Exposure. This variable is measured by the $\beta_{i,t}^{EPU}$ from equation (1), which is obtained by regressing excess stock returns on the EPU index controlling for the Fama-French five factors using a 36-month rolling window (τ-36, τ-1). Annual TSEFF36 is the average monthly TSEFF36 from January to December of that year. See section 3 for details.
EPU	EPU Index by Baker et al (2016), available at https://www.policyuncertainty.com/.
SIZE	The firm's size is calculated as Ln(Market Value).
ROA	Return on Asset is calculated as net profit divided by the total assets.
LEV	Firm financial leverage is calculated as the total debt divided by the total assets.
CASH	Cash ratio is calculated as cash holdings to total asset.
FA	Tangible ratio is calculated by the book value of the fixed assets to the total asset.
CUR	Operating ratio is calculated by the ratio of current assets to current liabilities.
TOBIN	Tobin's Q is calculated by the market value of equity divided by the book value of the total assets.

MTB	Market-to-book value is calculated as a firm's market value divided by book value.
Vol	Stock return historic volatility, obtained from Refinitiv
VIXX	Volatility Index by CBOE
GDP Growth	US Annual GDP Growth rate

Appendix 2: Sample distribution by industry

Industry	**No of Obs**	**Percentage**	**Cumm. Percentage**
Healthcare	5639	0.24182	0.24182
Consumer Non-Cyclicals	1257	0.053905	0.295725
Financial services	85	0.003645	0.29937
Basic Materials	1542	0.066126	0.365496
Technology	7924	0.339809	0.705305
Industrials	4096	0.175651	0.880955
Utilities	112	0.004803	0.885758
Energy	581	0.024915	0.910674
Real Estate	68	0.002916	0.91359
Consumer Cyclicals	1988	0.085252	0.998842
NA	27	0.001158	1
Total	23319		

Appendix 3: Sample distribution by year

Year	No of Obs	Percentage	Cumm. Percentage
1986	0	0	0
1987	0	0	0
1988	0	0	0
1989	0	0	0
1990	238	0.010206	0.010206
1991	256	0.010978	0.021184
1992	274	0.01175	0.032935
1993	283	0.012136	0.045071
1994	299	0.012822	0.057893
1995	340	0.01458	0.072473
1996	376	0.016124	0.088597
1997	408	0.017496	0.106094
1998	438	0.018783	0.124877
1999	479	0.020541	0.145418
2000	539	0.023114	0.168532
2001	607	0.02603	0.194562
2002	647	0.027746	0.222308
2003	699	0.029976	0.252284
2004	831	0.035636	0.28792
2005	903	0.038724	0.326644

2006	913	0.039153	0.365796
2007	911	0.039067	0.404863
2008	917	0.039324	0.444187
2009	918	0.039367	0.483554
2010	946	0.040568	0.524122
2011	980	0.042026	0.566148
2012	1040	0.044599	0.610747
2013	1049	0.044985	0.655731
2014	1040	0.044599	0.70033
2015	1016	0.04357	0.7439
2016	974	0.041769	0.785668
2017	950	0.040739	0.826408
2018	961	0.041211	0.867619
2019	1034	0.044342	0.91196
2020	1080	0.046314	0.958274
2021	973	0.041726	1
Total	23319		

Appendix 4: Summary statistics by industry

	STATS	RD	RDS	TSE36	TSE60	TCI	SIZE	ROA	DTE	CA	TANG	OPERA
Healthcare	**No. of Obs**	5639	5639	5639	5639	5639	5639	5639	5639	5639	5639	5639
	Mean	10.15	-1.37	-0.06	-0.05	122.97	6.24	-0.17	0.07	0.34	13.15	4.89
	St. Dev.	2.25	2.11	0.14	0.09	41.41	2.40	0.88	2.97	0.28	12.28	5.19
	Median	10.23	-1.90	-0.05	-0.03	115.40	6.08	0.00	0.00	0.26	9.96	3.39
Consumer Non-Cyclicals	**No. of Obs**	1257	1257	1257	1257	1257	1257	1257	1257	1257	1257	1257
	Mean	10.27	-4.49	-0.04	-0.03	119.51	8.08	0.01	0.02	0.11	25.68	1.84
	St. Dev.	2.38	1.36	0.08	0.05	38.96	2.39	1.17	1.41	0.12	14.34	1.24
	Median	10.59	-4.43	-0.03	-0.02	111.45	8.42	0.09	0.01	0.06	23.42	1.57
Financial services	**No. of Obs**	85	85	85	85	85	85	85	85	85	85	85
	Mean	8.91	-2.74	-0.03	-0.02	119.29	5.90	0.01	0.17	0.38	9.33	4.54
	St. Dev.	1.83	1.90	0.12	0.09	39.66	1.69	0.22	0.93	0.33	9.39	15.09
	Median	9.22	-2.46	-0.03	-0.01	115.40	5.78	0.02	0.00	0.29	6.51	2.38
Basic Materials	**No. of Obs**	1542	1542	1542	1542	1542	1542	1542	1542	1542	1542	1542
	Mean	10.14	-4.32	-0.07	-0.05	118.00	7.45	0.05	0.48	0.07	34.94	2.17
	St. Dev.	1.53	1.16	0.10	0.07	37.73	1.63	0.14	9.95	0.08	14.75	2.07
	Median	10.17	-4.23	-0.06	-0.04	111.45	7.54	0.06	0.01	0.04	33.89	1.90
Technology	**No. of Obs**	7924	7924	7924	7924	7924	7924	7924	7924	7924	7924	7924
	Mean	10.65	-2.18	-0.07	-0.06	119.71	6.54	-0.03	0.17	0.26	12.90	3.34
	St. Dev.	2.05	1.06	0.13	0.10	39.31	2.27	0.88	6.49	0.19	11.82	3.41
	Median	10.68	-2.02	-0.06	-0.04	111.45	6.51	0.04	0.00	0.22	9.31	2.52
Industrials	**No. of Obs**	4096	4096	4096	4096	4096	4096	4096	4096	4096	4096	4096

	Mean	9.77	-3.68	-0.08	-0.06	118.22	6.50	-0.01	0.16	0.13	19.30	2.75
	St. Dev.	2.02	1.25	0.11	0.08	38.02	2.10	1.18	4.88	0.14	13.82	3.05
	Median	9.79	-3.68	-0.07	-0.05	111.45	6.59	0.06	0.01	0.08	16.43	2.16
Utilities	**No. of Obs**	112	112	112	112	112	112	112	112	112	112	112
	Mean	8.68	-5.50	-0.02	-0.02	112.51	7.53	0.04	0.10	0.06	62.53	1.69
	St. Dev.	1.48	1.13	0.10	0.08	37.87	1.82	0.03	0.46	0.09	24.64	1.76
	Median	8.97	-5.57	0.00	0.00	108.67	7.92	0.05	0.01	0.02	72.63	1.05
Energy	**No. of Obs**	581	581	581	581	581	581	581	581	581	581	581
	Mean	10.38	-4.07	-0.08	-0.07	121.49	7.82	-0.01	0.07	0.14	39.59	2.73
	St. Dev.	2.18	1.82	0.12	0.09	40.43	2.57	0.17	0.48	0.17	24.84	3.24
	Median	10.47	-4.10	-0.07	-0.05	111.45	7.85	0.04	0.00	0.08	31.10	1.77
Real Estate	**No. of Obs**	68	68	68	68	68	68	68	68	68	68	68
	Mean	9.74	-4.29	-0.06	-0.04	111.11	7.66	0.02	0.05	0.13	46.70	2.94
	St. Dev.	1.85	1.90	0.09	0.07	35.67	2.01	0.11	0.18	0.19	30.71	5.72
	Median	10.22	-5.09	-0.05	-0.03	110.13	7.95	0.04	0.01	0.05	58.72	1.54
Consumer Cyclicals	**No. of Obs**	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988
	Mean	9.86	-3.91	-0.07	-0.05	121.09	6.70	0.04	-0.06	0.15	21.74	2.76
	St. Dev.	2.21	1.38	0.11	0.08	39.63	1.93	0.19	7.35	0.14	14.81	3.29
	Median	9.80	-3.88	-0.06	-0.04	111.45	6.67	0.06	0.00	0.11	19.61	2.00
NA	**No. of Obs**	27	27	27	27	27	27	27	27	27	27	27
	Mean	8.75	-3.26	-0.09	-0.07	121.04	5.21	-0.09	0.25	0.20	12.19	2.47
	St. Dev.	0.83	2.54	0.11	0.10	43.53	1.04	0.22	0.69	0.10	9.77	1.36
	Median	8.61	-4.14	-0.07	-0.03	113.44	5.14	0.00	0.00	0.19	10.14	1.83

Appendix 5:

	RD	RDS
EPU	0.003***	-0.0046***
	(17.11)	(-2.01)
Constant	6.587***	6.23216***
	(75.54)	(57.4)
Control variables	Yes	Yes
Firm fixed effect	Yes	Yes
Year fixed effect	No	No
Industry fixed effect	No	No
No. of Obs	17875	17875
Adjusted R2	0.65	0.3

Note: This table presents the regression result of:
$Innovation_{i,t} = \beta_0 + \beta_1 EPU_t + \sum_{k=0}^{n} \beta_{control} Controls_{k,i,t} + \varepsilon_{i,t}$*, while controlling for firm fixed effects, from 2000-2019, as Horra et al. (2022).*
Where $Innovation_{i,t}$ *are proxies for corporate investment of firm i in year t, measured as RD and RDS. Control variables consist of firm's market value (SIZE), return on asset (ROA), firm financial leverage (LEV), cash holdings (CASH), fixed asset ratio (FA), and operating capital ratio (CUR). *, **, and *** indicate significance at 10%, 5% and 1% levels respectively. T-stats are in parentheses.*

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