Reward-Timing Uncertainty, Languages and R&D Investment*

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Abstract

One of the key features of research and development (R&D) is that the timing of investment reward is uncertain - you do not know when the reward will be materialized. Because of the convexity of time preferences, higher *reward-timing uncertainty* raises R&D investment. To capture this effect, we measure people's perceived reward-timing uncertainty using a special structure of languages, so-called *future-time reference* (FTR), proposed by Chen (AER, 2013), which refers to when and how languages mark the timing of events. Weak-FTR language speakers hold less precise beliefs on the timing of future events and hence perceive higher timing uncertainty. International evidence strongly supports the positive effect of reward-timing uncertainty on R&D both at the country level and at the firm level. On average, aggregate R&D of the business sector as a percentage of GDP and firm-level R&D-to-Assets ratios for weak-FTR countries are respectively 0.18 and 0.6 percentage points higher than those for strong-FTR countries. Within-country analysis based on Belgium, in which both weak- and strong-FTR languages are used, and Difference-in-Differences tests based on Hong Kong, in which a weak-FTR language relative to a strong-FTR language became increasingly important after 1997, further confirm our cross-country results.

Keywords: R&D, Timing Uncertainty, Language, Future Time Reference
JEL Classification:

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1 Introduction

Uncertainty as the essential core of research and development (R&D) affects R&D investment, for example, through creating value of waiting-to-invest (e.g., Dixit and Pindyck, 1994; Oriani and Sobrero, 2008), increasing entrepreneurial risk (e.g., Caggese, 2012), or inducing agency problems (e.g., Block, 2012). Generally speaking, uncertainty in R&D reward has two dimensions: one is how much the reward will be; the other is when the reward will be materialized. However, the literature has almost never distinguished these two dimensions. When reward uncertainty is mentioned, it largely mixes the two dimensions or only refers to the first dimension, represented by the distribution of investment reward at a specific future time. In this paper, we instead focus on the second dimension of uncertainty, henceforth called *reward-timing uncertainty*, and demonstrate a surprisingly positive effect of uncertainty on R&D investment.

A simple example illustrates our idea. Consider two R&D projects to invest today. The reward of project 1 has no timing uncertainty and will be materialized at a specific time, say $t = 2$. The reward of project 2 will be materialized at either $t = 1$ or $t = 3$ with equal probabilities. The two projects hence have the same expected reward time - two periods from now. Let β ($0 < \beta < 1$) be the one-period discount factor. It follows that future rewards of the two projects are discounted respectively by $d_1 = \beta^2$ and $d_2 = \beta(1 + \beta^2)/2$. Because $2\beta < 1 + \beta^2$, we have $d_1 < d_2$. Namely, one unit of future reward of project 2 has a higher present value than that of project 1, due to the convexity of the time preference. If the two projects have the same investment-return combinations, intuitively firms are willing to invest more in project 2. That is, reward-timing uncertainty raises R&D investments.

In order to test this positive effect, we need an appropriate measure of reward-timing uncertainty. It is difficult to obtain a direct measure, because any project, firm or industry characteristic that reflects R&D reward uncertainty can be a mixture of the two dimensions of uncertainty. Yet, as the decision of corporate R&D investment is made by firm managers, managers' perceived uncertainty is the key driver in making the decision. This encourages us to test the model prediction by examining how managers' perceived reward-timing uncertainty affects firm R&D investment. In particular, based on Chen (2013), we measure managers' perceived reward-timing uncertainty using a special structure of languages, so-called *future-time reference* (FTR), which refers to when and how languages mark the timing of events.

The principle of *linguistic relativity* (Whorf, 1956) argues that languages can influence the way speakers think and their cognitive processes. Languages differ in whether or not they require speakers to grammatically mark future events. For example, in the sentence, *It will be cloudy tomorrow*, English marks the future using "will" and it is grammatically wrong to use the present tense, "is", to talk about the weather tomorrow. However, in Chinese there is no tense. Chinese speakers can simply replace *jintian* (today) with *mingtian* (tomorrow) without changing any other part of the sentence. This difference in language structures is captured by FTR. English is a language with strong FTR, while Chinese is with weak FTR. According to Chen (2013), strong FTR speakers pay more attention to time and/or encode the markers in memory, so they hold more precise beliefs on the timing of future rewards and hence perceive lower timing uncertainty. As language FTR does not directly affect managers' beliefs on how much the reward will be, it captures solely reward-timing uncertainty.

Based on this measure, we provide strong evidence supporting the positive effect of reward-timing uncertainty on R&D investment both at the country level and at the firm level. To conduct country level analyses, we obtain data on national R&D expenditures for the 1996-2013 period from the UNESCO Institute of Statistics. Among the 56 countries in the sample, 16 are classified as weak-FTR language speaking countries. After controlling for a large set of economic, legal, culture and religious variables and continent fixed effects, weak-FTR countries have significantly higher national R&D expenditures both as a percentage of GDP and at a per capita basis. In particular, aggregate R&D of the business sector as a percentage of GDP for weak-FTR countries are on average 0.18 percentage points higher than that for strong-FTR countries. This difference is around 20% of the average business R&D to GDP ratios of all countries in our sample (0.91%).

At the firm level, we obtain R&D data of the 1985-2013 period from the Worldscope database. Our sample consists of 32,470 non-financial and non-utility firms (222,820 firm-year observations) of 40 countries. Among these firms, 10,677 (79,552 firm-year observations) are located in 15 weak-FTR countries. Besides the set of country-level variables, we further control for firm characteristics, such as firm size, cash flow, leverage, market-to-book ratio, etc. Our results show that firms located in weak-FTR countries invest significantly more in R&D, measured by the ratio of firm R&D to book assets, sales or long-term investments (R&D plus capital expenditure). Specifically, the R&D-to-assets ratio of firms in weak-FTR countries is 0.6 percentage points higher than firms in strong-FTR countries. This difference is about 26% of the average firm R&D-to-assets ratio in our sample (2.3%).

We also use two continuous measures of language FTR, *Verb Ratio* and *Sentence Ratio*, developed by Chen (2013). They are respectively defined as the frequency of verbs and sentences that are grammatically future-marked in weather forecasts. Both higher *Verb Ratio* and higher *Sentence Ratio* indicate stronger language FTR. Results using these two measures confirm the positive effect of reward-timing uncertainty on R&D investment.

All our measures of language FTR are time-invariant at the country level, so our tests cannot include country fixed effects. This raises the concern of omitted variable biases. It could be some omitted country characteristics that drive firm R&D investment and are also closely related to languages, resulting in the significant association between languages and R&D. To alleviate this endogeneity concern, we control for a large set of country characteristics as well as continent fixed effects in the cross-country tests. Furthermore, we conduct within-country tests. First, in Belgium, both weak-FTR (Dutch) and strong-FTR language (French) are used in different regions. We show that R&D investment is significantly higher for firms in weak-FTR regions. Within country analysis excludes time-invariant factors. Second, after the handover of Hong Kong from U.K. to China in 1997, a weak-FTR language (Chinese) relative a strong-FTR language (English) became increasingly important in the country's business domain (Chen, Cronqvist, Ni, and Zhang, 2015). This offers a nice setting for us to test the effect of language FTR on corporate R&D. Using a difference-in-differences (DiD) approach, we show that firms located in Hong Kong, compared to a control group consisting of either the Asian Tigers or Asian countries that suffered heavily from the 1997 Asian Finance Crisis, have significantly increased R&D after the handover. Overall, these analyses mitigate potential endogeneity concerns and further confirm our cross-country results.

Our study contributes to the broad literature on how uncertainty affects corporate R&D investment. Uncertainty has a dark side - higher uncertainty depresses R&D investment, for example, through raising the option value of wait-to-invest (e.g., Oriani and Sobrero, 2008), increasing entrepreneurial risk (e.g., Caggese, 2012), or inducing agency problems (e.g., Block, 2012). In the literature, uncertainty is widely measured by the realized volatility of firm performance such as the profit-to-assets ratio (Caggese, 2012) and stock prices implied by equity options (Stein and Stone, 2014), or of macroeconomics variables such as interest rates (e.g., Huizinga, 1993; Fernández-Villaverde, Guerrón-Quintana, Rubio-Ramírez, and Uribe, 2011) and exchange rates (e.g., Goldberg, 1993). These measures implicitly assume that the investment reward is independently and identically distributed across time, and hence cannot capture timing uncertainty. Instead, we focus on the impact of timing uncertainty. Using language FTR to measure speakers' perceived timing uncertainty, we demonstrate a bright side of uncertainty on R&D investment. The positive effect of reward-timing uncertainty contrasts the negative effects of uncertainty found in the literature, indicating that the effect of the first dimension of uncertainty could be underestimated in the literature.

More generally, we contribute to the increasing literature that identifies various determinants of corporate R&D, such as firm cash flow and external equity (e.g., Brown, Fazzari, and Petersen, 2009). Our work is in particular related to the international studies in this literature that study the link between R&D investment and tax environment (e.g., Bhagat and Welch, 1995), culture (e.g., Li, Griffin, Yue, and Zhao, 2013; Shao, Kwok, and Zhang, 2013), product market competition (e.g., Griffith, Harrison, and Simpson, 2010), and financial development (Maskus, Neumann, and Seidel, 2012).

We also complement the literature on how manager personal traits and beliefs impact corporate policies (e.g., Bertrand and Schoar, 2003; Cronqvist, Makhija, and Yonker, 2012). Barker and Mueller (2002) document that several CEO characteristics including age and career experience are important determinants of firm R&D investment. Galasso and Simcoe (2011) and Hirshleifer, Low, and Teoh (2012) examine the effect of CEO overconfidence on firm innovation and find that firms with overconfident CEOs have significantly higher R&D expenditure. Our study is particularly related to the studies on the relation between managerial beliefs and R&D investment, while our focus is on a different type of managerial belief, namely perceived reward-timing uncertainty associated with languages.

Finally, our study adds to the recent literature on how languages affect individual and corporate decisions (e.g., Chen, 2013; Sutter, Angerer, Rützler, and Lergetporer, 2015).

Chen (2013) is the first to study the link between languages and individual intertemporal choice and finds that weak-FTR language speakers save more and retire with more wealth. Chen, Cronqvist, Ni, and Zhang (2015) examine whether languages affect corporate saving behaviour and document that weak-FTR languages are associated with higher corporate cash holding. While individual savings today will be used for consumption in the future, what is the purpose of corporate cash holdings? If languages have effect on corporate cash holdings, smoothing R&D investment could be one of the key drivers (e.g., Brown and Petersen, 2011; Qiu and Wan, 2015). Therefore, our results are consistent with both above studies, and further point to the underlying reasons for increased cash holdings in Chen, Cronqvist, Ni, and Zhang (2015). In another study, Liang, Marquis, Renneboog, and Sun (2014) show that firms with strong-FTR languages perform worse in future-oriented strategies such as corporate social responsibility.

The remainder of the paper is organized as follows. In Section 2, we develop the main hypothesis and the empirical strategy to test the hypothesis. Section 3 and 4 provide cross-country evidence based on country-level and firm-level R&D data respectively to support the hypothesis. Section 5 presents supporting within-country evidence. Finally, Section 6 concludes.

2 Model, Hypothesis and Empirical Strategy

2.1 Hypothesis Development

We use the following simple model to develop our hypothesis concerning how reward-timing uncertainty affects firms' investment decision in R&D. Consider a firm with an R&D project. By investing x today, the firm will be rewarded $R(x)$ at time t. We assume that the reward function R is increasing and concave in x, i.e., $R'(x) > 0$ and $R''(x) < 0$, reflecting the diminishing return to scale. As one of the key features of R&D investment, the reward time, t, is uncertain.[1] Let t follow a distribution $F(t)$, defined in interval $[0, +\infty]$ with mean T. Our main interest is to examine how $F(t)$ affects the R&D investment decision x.

[1] Another key feature of R&D is that the level of reward is uncertain. For simplicity, we consider only deterministic reward. Randomizing R does not change the conclusion of the model.

The firm maximizes its net expected profit:

$$\max_x \; P(x) = -x + \int_0^{+\infty} e^{-\delta t} \, R(x) \; dF(t) \tag{1}$$

where δ is the discount rate of the economy. The first-order condition for this problem is

$$R'(x^*) \cdot \int_0^{+\infty} e^{-\delta t} \; dF(t) = 1 \tag{2}$$

From Equation (2), we can solve for the optimal R&D investment, x^*. This optimal investment is determined by $F(t)$. To see the effect of $F(t)$, consider two different distributions of t, $F_1(t)$ and $F_2(t)$. Assume $F_2(t)$ exhibits more uncertainty than $F_1(t)$ in the sense that $F_2(t)$ is a mean-preserving spread (MPS) of $F_1(t)$ (Rothschild and Stiglitz, 1970). Because $-e^{-\delta t}$ is a strictly concave function of t, appealing to one important property of the MPS,[2] we have

$$\int_0^{+\infty} -e^{-\delta t} \; dF_1(t) > \int_0^{+\infty} -e^{-\delta t} \; dF_2(t) \tag{3}$$

or equivalently

$$\int_0^{+\infty} e^{-\delta t} \; dF_1(t) < \int_0^{+\infty} e^{-\delta t} \; dF_2(t) \tag{4}$$

Combining (4) and (2), we have

$$R'(x_1^*) > R'(x_2^*)$$
$$x_1^* < x_2^*$$

Namely, a higher reward-timing uncertainty increases the optimal R&D investment.

A simple example similar to the one in the Introduction shows the idea. Suppose that $F_1(t)$ has only one value, T, while $F_2(t)$ has two values, $T - \epsilon$ and $T + \epsilon$, with equal probabilities. ϵ is a positive constant and $\epsilon < T$. Applying Equation (2) for both distributions, we have

$$(e^{\delta\epsilon} + e^{-\delta\epsilon}) \cdot R'(x_2^*) = 2 \cdot R'(x_1^*) \tag{5}$$

It follows $x_1^* < x_2^*$, because

$$e^{\delta\epsilon} + e^{-\delta\epsilon} = 2 + \left(\sqrt{e^{\delta\epsilon}} - \sqrt{e^{-\delta\epsilon}}\,\right)^2 > 2.$$

[2] MPS has the following property. Suppose that $F_1(t)$ and $F_2(t)$ are two distribution functions and $F_2(t)$ is a MPS of $F_1(t)$. For any concave function u, $\int_0^{+\infty} u(t) \; dF_1(t) > \int_0^{+\infty} u(t) \; dF_2(t)$. The proof can be seen in Rothschild and Stiglitz (1970).

To sum up, the prediction here is that due to the convexity of the time preference, higher reward-timing uncertainty raises the optimal R&D investment. Note in our setting, the firm is risk-neutral and the reward of R&D is deterministic, so the risk-seeking response to reward-timing uncertainty is different from people's risk attitude towards uncertain rewarding payoffs in the traditional sense. The conclusion seems to be counterintuitive, as in general reward risk has a negative effect on R&D in the literature. Although hardly studied in the finance literature, this risk-seeking response to timing uncertainty was found by Redelmeier and Heller (1993) and is commonly observed in animal studies (e.g. Kacelnik and Bateson, 1996).

To test the model prediction, we need an appropriate measure of reward-timing uncertainty. It is difficult to obtain a direct measure, because any project, firm or industry characteristic that reflects R&D reward uncertainty can be a mixture of the two dimensions of uncertainty. We thus resort to indirect measures. As the decision of R&D investment is made by firm managers, managers' perceived reward-timing uncertainty is the key driver in making the decision. Different managers may have different beliefs on the reward time even for the same R&D project. This encourages us to test the model prediction by examining how managers' perceived reward-timing uncertainty affects R&D investment. We thus form the following hypothesis.

Hypothesis I: *A higher perceived reward-timing uncertainty of managers raises firm's R&D investment.*

2.2 Measuring Perceived Timing Uncertainty

What determine people's perception on the timing of a future reward? In the linguistics and psychology literature, the principle of *linguistic relativity*, also known as Sapir-Whorf Hypothesis (SWH) (Whorf, 1956), argues that languages can influence the way speakers think and their cognitive processes. For example, languages differ in the way that colors are described, directly influencing the precision of the speakers' color beliefs. Winawer, Witthoft, Frank, Wu, Wade, and Boroditsky (2007) find that Russian speakers are better at discriminating light blue (goluboy) and dark blue (siniy). This phenomenon is attributed to the linguistic difference that Russian obligatorily assigns different names to these two colors while in English a generic word, blue, is often used. The study suggests that linguistic difference can influence the precision of color beliefs and thus the performance in color discrimination.

Based on the linguistic studies, Chen (2013) examines how a language structure, so-called *future-time reference* (FTR), affects people's attitude to future reward timing. FTR refers to when and how languages require speakers to mark the timing of events. Different languages have different ways of grammatically referencing the future or marking FTR (e.g. Dahl, 2000). A strong-FTR language speaker is required to grammatically mark future time, while a weak-FTR language speaker does not need to grammatically distinguish between the present and future. For example, in the sentence *It will/is going to be cloudy tomorrow*, English marks the future using "will/is going to". In English, it is grammatically wrong to use the present tense of the copula, "is", to talk about the weather tomorrow. However, in Chinese there is no tenses. Chinese speakers can simply replace *jintian* (today) with *mingtian* (tomorrow) without changing any other parts of the sentence.

English and Chinese speakers talk about the weather *today*:

English speaker:	*It*	*is*	*cloudy*	*today.*
Chinese speaker (pinyin):	*Jintian*	*shi*	*duoyun.*	
Chinese (translation):	*Today*	*is*	*cloudy.*	

English and Chinese speakers talk about the weather *tomorrow*:

English speaker:	*It*	*will/is going to be*	*cloudy*	*tomorrow.*
Chinese speaker (pinyin):	*Mingtian*	*shi*	*duoyun.*	
Chinese (translation):	*Tomorrow*	*is*	*cloudy.*	

The difference in language FTR induces speakers' different perception on future timing. According to Chen (2013), strong FTR makes speakers hold more precise beliefs on the timing of future rewards, because speakers who grammatically mark future time pay more attention to time and/or encode the markers in memory. Similarly, weak-FTR speakers hold less precise beliefs about the timing of future rewards. Among the main languages in the world, German, Chinese and Japanese have weak FTR, while English, French and Spanish have strong FTR. Chen (2013) empirically test the linguistic-precision effect for time perception by examining how FTR influences individual saving and other economic decisions. He finds strong evidence that weak-FTR language speakers save more.

Although language FTR affects people's beliefs on the timing of a future reward, it does not directly affect managers' beliefs on how much the reward will be. Therefore, language FTR separates the two dimensions of R&D reward uncertainty, and is an appropriate measure of managers' perceived reward-timing uncertainty. A weak-FTR language speaker has higher perceived reward-timing uncertainty.

2.3 Empirical Design and Main Variables

To test our hypothesis, we run both country-level and firm-level regressions, and further conduct DiD tests based on Hong Kong and within country tests based on Belgium. At the country level, we propose the following model,

$$R\&D_{kt} = \alpha + \beta \cdot \textit{Weak-FTR}_k + \Omega \mathbb{X}_{kt} + \epsilon_{kt} \tag{6}$$

$R\&D_{kt}$ is R&D expenditures of country k in year t. We in particular use three alternative dependent variables: R&D per capita, aggregate R&D as a percentage of GDP and R&D of the business sector as a percentage of GDP. $\textit{Weak-FTR}_k$ is a binary variable that equals 1 if the official language of a country is classified as weak-FTR, and 0 otherwise. Alternatively, we also replace this dummy variable by the two continuous measures of FTR strength, *Verb Ratio* and *Sentence Ratio*, also developed by (Chen, 2013). They are respectively the frequency of verbs and sentences that are grammatically future-marked in weather forecasts of various languages. By construction, they are both continuous and inverse indicators of *Weak-FTR* and ranges from zero to one.

$\mathbb{X}_{kt}$ includes country-specific control variables, such as economic, cultural, legal and religion variables. First, the economic variables are *GDP per capita*, defined as the logarithm of GDP per capita in U.S. dollars, stock market capitalization as a percentage of GDP (*Stock Market*) or domestic credit to private sectors as a percentage of GDP (*Credit Market*). Low GDP or developing countries may be financially constrained, even if they are willing to invest more in R&D. Including GDP per capita in the regression controls for such an effect. Stock and credit markets are important for a country's financial development that affects R&D (e.g., Maskus, Neumann, and Seidel, 2012). Second, the legal variables consists of legal origins (La Porta, Lopez-de Silanes, and Shleifer, 2008), as well as proxies for protection of shareholder rights (*Shareholder Rights*), creditor rights (*Creditor Rights*) and patent (*Patent Rights*), defined by Djankov, McLiesh, and Shleifer (2007) and Park (2008). Countries in our sample belong to four legal origins, namely, UK, French, German and Scandinavian legal origins. Third, the cultural variables are *Individualism*, *Uncertainty Avoidance*, *Masculinity*, *Power Distance* and *Long-term Orientation* (Hofstede, 1984, 2001). They are indexes measuring different dimensions of nation culture. Culture has impact on the economy and hence may affect firms' investment policy (e.g., Ahern, Daminelli, and Fracassi, 2015). Fourth, the religious variable (*Catholic*) is a dummy indicating whether the majority of a country's inhabitants are catholic. All the country-level control variables are defined in Panel D of Appendix I. We also control for continent fixed effects, as different languages within the same continents may share similar components.[3] For example, Chinese has influenced Japanese and Korean due to the past region wars (Chen, Cronqvist, Ni, and Zhang, 2015).

At the firm level, we run an OLS regression specified as

$$R\&D_{ikt} = \alpha + \beta \cdot \textit{Weak-FTR}_k + \Omega \mathbb{X}_{it} + \Gamma \mathbb{Z}_{ikt} + \epsilon_{ikt} \tag{7}$$

where $R\&D_{ikt}$ is R&D investment of firm i of country k in year t. Specifically, we construct two measures of firm R&D investment, *R&D/Assets* and *R&D/Sales*, defined as R&D expenditures divided by total assets and sales respectively, taking missing R&D as zero. Koh and Reeb (2015) document that over 10% of the U.S. firms with missing R&D in their financial statements receive patents, so it is inappropriate to recode all missing R&D as zero. Following Koh and Reeb (2015), we include a dummy variable for missing R&D (*R&D-missing*) in the regression. $\mathbb{X}_{it}$ are country-specific control variables, as described above. $\mathbb{Z}_{ikt}$ includes firm-specific control variables, such as firm size (*Firm Size*), asset tangibility (*Tangibility*), cash flow (*Cash Flow*), leverage (*Leverage*), the market-to-book ratio (*Market-to-Book*), capital intensity (*Capital Intensity*), as well as liquidity or cash holdings (*Cash Ratio*). These variables represent the general characteristics of the firm and have impact on corporate R&D (e.g., Brown, Fazzari, and Petersen, 2009; Maskus, Neumann, and Seidel, 2012). All the firm control variables are defined in Panel C of Appendix I. We also control for industry, year, and continent fixed effects, and cluster standard errors at the firm level.

[3] There are six continents: Africa, Asia, Europe, North America, Oceania, and South America.

As we do not have country fixed effects in the regressions, some (time-invariant) omitted country characteristics may be closely related to languages and, at the same time, drive R&D investment. To alleviate this concern, we control for a large set of country characteristics described above, and further purse two tests. First, after the Hong Kong handover in 1997, Chinese (a weak-FTR language) relative to English (a strong-FTR language) became increasingly important in the business domain of the country. This change offers a unique setting to identify the casual effect of languages on R&D. We thus employ a difference-in-differences approach to capture this effect. Second, Belgium is a country with both weak-FTR (Dutch) and strong-FTR (French) languages. We thus conduct within-country tests for Belgium to exclude the effect of time-invariant country-specific factors.

3 Country-level R&D Investment

We test our hypothesis using both country-level and firm-level R&D investment data. In this section, we present evidence on national R&D expenditures. Section 4 and 5 discuss cross-country and within-country evidence respectively based on firm R&D expenditures.

3.1 Data, Sample and Statistics

The country-level R&D analysis is based on three alternative measures of national R&D expenditures, namely *R&D per capita*, Total R&D expenditures as a percentage of GDP (*Total R&D/GDP*) and Business R&D expenditures, performed by business enterprises, as a percentage of GDP (*Business R&D/GDP*) respectively. We obtain data on country-level R&D expenditures from the UNESCO Institute for Statistics (UIS) website, which is based on the UIS R&D statistics survey on human and financial resources devoted to R&D conducted on a biennial basis.[4] We examine a sample of up to 56 countries in six continents, including almost all large economies of the world, such as U.S., Japan, Germany, U.K., France, China, India, and Brazil. Sixteen countries are classified as countries with mainly weak-FTR languages according to Chen (2013). In our full regression models, with non-missing country-level economic, legal, cultural, and religious variables, our sample is

[4]The data is downloadable from `http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx`

dropped to 43 countries. Appendix I provides variable definitions and data sources.

Table 1 presents country-level summary statistics. Panel A shows that, of all 56 countries during the period of 1996-2013, *R&D per capita* is on average over 424 U.S. dollars, and total R&D and business R&D are on average 1.4% and 0.9% of GDP. Panel B reports Spearman's rank correlations between the key variables of interest. The three alternative national R&D expenditures measures are highly correlated, with correlation coefficients above 0.9. The three language-based alternative measures of reward-timing uncertainty are also highly correlated. In particular, *Weak-FTR* is highly negatively correlated with two inverse indicators of weak-FTR, namely *Verb Ratio* and *Sentence Ratio*, with correlation coefficients around -0.8. Furthermore, as expected, *Weak-FTR*, is positively correlated with *R&D per capita* (0.432), *Total R&D/GDP* (0.444) and *Business R&D/GDP* (0.466), while *Verb Ratio* and *Sentence Ratio* have strong negative correlations with *Weak-FTR*, and the three national R&D measures.

To easily have an overview of R&D across countries, we also graphically show the time means of *R&D per capita*, *Total R&D/GDP* and *Business R&D/GDP* of all countries in three figures. Figure 1 shows, perhaps strikingly, that all top six countries regarding *R&D per capita* are weak-FTR countries, and within the top 10 countries, eight are weak-FTR countries. As a percentage of GDP, the R&D expenditures of weak-FTR countries are also much higher relative to that of strong-FTR countries. From Figure 2, among the top 10 countries in terms of the average *Total R&D/GDP*, seven are weak-FTR countries. Similarly, Figure 3 also shows that the average *Business R&D/GDP* of weak-FTR countries are much higher than that of strong-FTR countries. Specifically, seven of the top 10 countries are weak-FTR countries. Overall, consistent with our hypothesis, the summary statistics suggest that weak-FTR languages are positively associated with country-level R&D investment.

3.2 Weak FTR and National R&D Investment

Table 2 examines the impact of perceived reward-timing uncertainty, measured by the strength of speakers' language FTR, on *R&D per capita*, *Total R&D/GDP* and *Business R&D/GDP* respectively. The tests are based on the empirical model specified in Equation (6).

In the first six columns, we regress *R&D per capita* on *Weak-FTR*, controlling for country-level economic, legal, cultural and religious variables. Columns (1)-(5) report results of pooled OLS regressions. Column (1) only controls for the country economic variables, including *GDP per capita*, and financial development measures, namely *Stock Market* and *Credit Market*. From Column (2) to Column (4), we subsequently add the legal, cultural, and religious variables in the regression. Column (5) further includes continent and year fixed effects. In all these columns, *Weak-FTR* enters with a positive coefficient that is significant at 1% level, indicating that the reward-timing uncertainty do significantly increase national R&D expenditures at an aggregate level. The effect is economically large. For example, according to Column (5) with a full set of controls and fixed effects included, the R&D per capita of weak-FTR countries is approximately 57.3 U.S. dollars higher than that of strong-FTR countries. This difference is 13.5% of the sample average of GDP per capita (424.88). To mitigate the effect of serially correlated R&D expenditures over time, Column (6) reports results from a Fama-MacBeth regression. The positive coefficient of *Weak-FTR* is also statistically and economically significant, suggesting that the positive relation between *Weak-FTR* and national R&D expenditures is not driven by autocorrelation of R&D.

In Columns (7)-(8), we replace the dependent variable by *Total R&D/GDP* and include all control variables and fixed effects. Consistent with findings from the previous columns, *Weak-FTR* has a positive and statistically significant effect (at 1% level) on *Total R&D/GDP*. The effect is also substantial. According to Column (7), *Total R&D/GDP* of weak-FTR countries is on average over 0.2 percentage points higher than that of strong-FTR countries. This is about 14% of the sample average of *Total R&D/GDP* (1.4%). In Columns (9)-(10), we use *Business R&D/GDP* as the dependent variable. We further find supporting evidence that R&D performed by business enterprises in weak-FTR countries are significantly higher. For example, Column (9) shows that on average business R&D as a percentage of GDP is over 0.18 percentage points higher in weak-FTR countries. Consistent with our hypothesis, the above results suggest that speaking weak-FTR languages, associated with higher reward-timing uncertainty, has a significant and positive effect on national R&D expenditures.

The effects of some control variables are interesting and consistent across specifications. National R&D expenditures are positively associated with national wealth, as in all columns

GDP per capita has a significantly positive sign. Possibly, poor countries are financially constrained and hence have less capacity to conduct R&D. Stock market development, *Stock Market*, has a significantly negative effect on national R&D expenditures in the regressions with all country-specific controls. This result is consistent with the previous literature that documents a negative relation between stock market capitalization and firm R&D investment and suggests that better access to equity financing does not necessarily leads to more R&D activities (e.g., Shao, Kwok, and Zhang, 2013). Among the legal origin variables, only the U.K. legal origin has a positive and significant effect on national R&D expenditures in most of the columns. Furthermore, *Creditor Rights* has a significantly negative effect on national R&D expenditures in almost all specifications. This finding is in line with existing evidence that R&D raises corporate risk while strong creditor rights reduce corporate risk-taking (e.g., Acharya, Amihud, and Litov, 2011). In contrast, consistent with previous country-level study, *Patent Rights* seems have a significantly positive effect on national R&D expenditures, largely because stronger patent protection allows the innovators to exploit the monopolistic power generated from their R&D activities (Varsakelis, 2001). Among the culture variables, *Power Distance* has a negative and significant effect on R&D investment. This finding can be attributed to the fact that in low power distance societies the social mobility is relatively stronger. To improve social status, people in low power distance countries need to invest more in technology and knowledge (Varsakelis, 2001). *Masculinity* also has a negative and significant effect on R&D investment, consistent with the argument of Shao, Kwok, and Zhang (2013) that people in masculine societies may not pursue achievement through R&D activities. *Long-term Orientation* has a positive effect probably because countries with higher long-term orientation scores encourage perseverance and long-term commitment which in turn may drive R&D investment. Finally, Catholic-dominated countries on average have lower level of R&D expenditures. This finding may be explained by the fact that innovators in Catholic countries have relatively limited access to external finance as documented by Stulz and Williamson (2003) that Catholic countries have significantly fewer equity issues, lower stock market capitalization, and less bank credit.

3.3 Alternative Measures of FTR

Table 3 further uses two alternative measures of language FTR, *Verb Ratio* and *Sentence Ratio*, to examine the effect of perceived reward-timing uncertainty on R&D investment at the country level. Recall that these two ratios are defined as the frequency of verbs and sentences that are grammatically future-marked in languages used for weather forecasts. By construction, a larger ratio indicates strong-FTR of a particular language. Thus, in the empirical model specified in Equation (6), we expect both *Verb Ratio* and *Sentence Ratio* to have negative coefficients.

Consistent with this expectation, both ratios have negative and significant (at 1% or 5% level) coefficients in all columns, except Column (7), of Table 3, no matter whether we use *R&D/GDP* or *R&D per capita* as the dependent variable, and whether OLS or Fama-MacBeth as the estimation method. The results further confirm our earlier findings that higher perceived reward-timing uncertainty, as indicated by weak-FTR languages, raise national R&D investment both on a per capita basis and as a percentage of GDP.

3.4 Further Robustness Tests

In Table 4, we perform several robustness tests. First, in our sample, thirteen out of the 56 countries have less than 10 years' R&D data. In Columns (1)-(3), we exclude these 13 countries and run the same regressions as Columns (5), (7) and (9) of Table 2. The effects of *Weak-FTR* on *R&D per capita*, *Total R&D/GDP* and *Business R&D/GDP* are still positive and significant at 1% level.

Second, there is a R&D boom in the past 20 years, partially due to the rising high-tech industries. Also, our sample period includes the Global Financial Crisis of 2007-08. We explore whether the effect of language-FTR has a time trend or a special pre- and post- crisis pattern. In Columns (4)-(12), we compare the effects of *Weak-FTR* across three subsample periods. Columns (4)-(6), Columns (7)-(9) and Columns (10)-(12) are based on the following three periods respectively: 1996-2001, 2002-2007 and 2008-2013. The subperiod results are largely consistent with the full sample analysis. In particular, the effects of *Weak-FTR* on both *Total R&D/GDP* and *Business R&D/GDP* are positive and significant in both 2002-2007 and 2008-2013 periods, although the positive relation between *Weak-FTR* and *R&D*

per capita becomes marginally insignificant after the financial crisis. Overall, our key finding of a positive relation between *Weak-FTR* and national R&D investment is reasonably robust across various subsamples.

4 Firm-level R&D: International Evidence

In this section, we conduct cross-country analysis to examine how perceived reward-timing uncertainty affects R&D investment at the firm level.

4.1 Data, Sample and Statistics

We obtain firm accounting and financial data from the Thomson Reuters Worldscope database. The Worldscope database offers fundamental data on the world's leading public and private companies, including detailed historical financial statement content, per share data, calculated ratios, and pricing information. Its coverage represents more than 95% of global market capitalization. We restrict our sample to the primary quotes (i.e., non-cross-listings), and exclude financial firms (ICB code 8000) and utility firms (ICB code 7000). We further delete firm-years with missing data for any of the firm-specific and country-specific control variables used in Equation (7). This results in a final sample consisting of 40 countries, 32,470 firms and 222,820 observations for the 1985-2013 period. We start our sample from 1985 because the Worldscope coverage is relatively limited prior to 1985. As did earlier, we obtain measures of language FTR from Chen (2013) and the country-level data from various sources as outlined in Appendix I. Appendix I provides variable definitions and data sources. We winsorize all firm-level variables at the 1st and 99th percentile to reduce the impact of outliers.

Table 5 presents summary statistics for firm-level R&D investments. Panel A shows statistics for the main variables. The average *R&D/Assets* and *R&D/Sales* of all firms in our sample are 2.3% and 6% respectively.[5] Fifteen out of the 40 countries are classified as Weak-FTR language speaking countries. The average *Verb Ratio* and *Sentence Ratio* are ap-

[5]The two averages are obtained by assuming that all missing R&D items are zero. In our sample, 49.5% of observations have missing R&D values. If we exclude these observations, the average *R&D/Assets* and *R&D/Sales* are 4.8% and 12.7% respectively.

proximately the same as those at the country level, indicating that our observations are not concentrated on one type (weak-FTR or strong-FTR) of countries. Panel B reports Spearman's rank correlations between the main variables. The two measures of firm R&D intensity, *R&D/Assets* and *R&D/Sales*, are highly positively correlated (correlation=0.996). They are both positively correlated with *Weak-FTR* but negatively correlated with *Verb Ratio* and *Sentence Ratio.* The signs of the correlations between the two R&D intensity measures and the three language-FTR measures are consistent with our hypothesis that managers' perceived reward-timing uncertainty, as reflected by the managers' weak-FTR languages, is positively associated with firm R&D investment.

4.2 Language FTR and Firm R&D Investment

Table 6 and Table 7 present the baseline results employing the empirical model specified in Equation (7). The dependent variables are the two firm R&D intensity measures, *R&D/Assets* and *R&D/Sales.* As the language FTR measures have no time variation for any given country, we cannot control for country fixed effects. To reduce omitted variable biases, we control for country-level economic, cultural, legal and religious variables in all the regressions.

In Table 6, *Weak-FTR* is the proxy for speakers' perceived timing uncertainty. We in Column (1) regress *R&D/Assets* on *Weak-FTR* and the country-specific variables, as well as continent fixed effects. As suggested by Koh and Reeb (2015), we include a dummy indicator for missing R&D in the regression. Column (2) further controls for firm-specific variables and industry fixed effects. Column (3) adds year fixed effects. All the three columns report results based on OLS regressions. *Weak-FTR* always has a positive and statistically significant effect on *R&D/Assets* at 1% level. This effect is economically sizable. According to Column (3), *R&D/Assets* of firms in weak-FTR countries is on average 0.6 percentage points higher than those in strong-FTR countries. The difference is over one fourth of the sample average (2.3%) of *R&D/Assets*. These results support our hypothesis that managers' perceived reward-timing uncertainty significantly raises firm R&D investment. This positive and significant effect is further confirmed by the Fama-MacBeth regression in Column (4), suggesting that our results are not subject to potential biases due to autocorrelation of firm

R&D over time.

In Columns (5)-(6) of Table 6, we use *R&D/Sales* as an alternative measure of firm R&D. *Weak-FTR* still has a positive and statistically significant effect on R&D at 1% level. According to Column (5), *R&D/Sales* of firms in weak-FTR countries is on average 1.8 percentage points, which is almost one-third of the sample average (6%), higher than those in strong-FTR countries. To conclude, our main findings that *Weak-FTR*, as a proxy for the perceived reward-timing uncertainty of firm managers, increases firm R&D investment is robust to alternative firm R&D measures and alternative estimation methods.

It is worth mentioning the effects of some firm-specific control variables. First, *Firm Size* and *Cash Flow* both have a negative and significant effect on R&D, consistent with previous studies (e.g., Barker and Mueller, 2002; Hitt, Hoskisson, Ireland, and Harrison, 1991). This supports the view that the market power associated with large firm size may reduce managers' incentive to innovate and that firms with poor past financial performance may have more incentive to improve future performance by engaging in R&D. Second, high leverage discourages R&D investment because firms are often reluctant to invest in long-term and risky R&D projects facing high financial distress costs associated with high debt levels. Third, the positive sign of *Market-to-Book*, as a proxy for firms' future growth opportunities, indicates that R&D investment raises future growth opportunities (e.g., Ryan Jr and Wiggins III, 2002), while the positive sign of *Capital Intensity* may be explained by the fact that highly capital-intensive firms are often in industrial or manufacturing sectors rather than service sectors and therefore tend to be more R&D intensive (Hirshleifer, Low, and Teoh, 2012). Fourth, the positive relation between *Cash Ratio* and R&D investment is consistent with the well-established result that firms finance R&D largely with internal funds. Finally, as expected, *R&D-missing*, that takes the value of one if a firm's R&D is not reported and zero otherwise, has a significantly negative coefficient in all the columns.[6]

Compared with Table 2, in Table 6, the coefficients of *GDP per capita*, *Patent Rights* and *Long-term Orientation* switch signs and/or change significance between the country-level and firm-level analysis, while *Power Distance*, *Masculinity*, and *Creditor Rights* still

[6]In untabulated tests, the significant positive relation between *Weak-FTR* and firm R&D investment still holds even if the R&D missing dummy is not controlled.

have relatively consistent impacts. All in all, the positive relation between *Weak-FTR* and R&D investment is highly significant, even after controlling for not only firm and country heterogeneities but also continent, year and industry fixed effects.

Furthermore, Table 7 examines the effects of *Verb Ratio* and *Sentence Ratio* on firm R&D investment. As expected, these two inverse measures of *Weak-FTR* have negative and statistically significant effects (at 1% level) on R&D. In brief, evidence based on the two alternative measures of language FTR is consistent with our country-level evidence (in Section 3.3) and confirms the main findings using *Weak-FTR*.

4.3 Robustness of Firm-level Evidence

We further conduct a set of robustness checks on the effect of perceived reward-timing uncertainty on firm R&D. Table 8 presents the results.

Non-US Firms. Over 25% (56,006/222,820) of observations in our sample are U.S. firms. Since language FTR is invariant within a country, a sample largely concentrated on a single country cannot be very representative. We thus rerun the regression by excluding U.S. firms in Columns (1)-(2). The effects of *Weak-FTR* on R&D remains positive and statistically significant at 1% level.

Sub-Periods. In Columns (3)-(8), we compare the effects of *Weak-FTR* across three subsamples. Columns (3)-(4), Columns (5)-(6) and Columns (7)-(8) are based on the following three periods respectively: 1985-1999, 2000-2007 and 2008-2013. The results based on these subperiods are consistent with the full sample analysis. All the coefficients on the *Weak-FTR* are positive and statistically significant in Columns (3)-(8). The statistical and economic significance of the effects of the *Weak-FTR* on both $R\&D/Assets$ and $R\&D/Sales$ are relatively weaker during the post-crisis period (2008-2013). To sum up, our key finding of a positive relation between *Weak-FTR* and firm R&D investment is robust across various subsamples.

Excluding observations with missing R&D. We conduct further robustness tests excluding observations with missing R&D. In our main analysis, we replace missing R&D values with zero and control for the dummy for missing R&D. Koh and Reeb (2015) document that over 10% of the US firms with missing R&D file and receive patents. In this case, it is inappropriate to recode missing R&D as zero. To address this particular concern, in untabulated tests we examine the effect of *Weak-FTR* on firm R&D based on a subsample excluding the observations with missing R&D. We still find a positive and significant relation between *Weak-FTR* and both *R&D/Assets* and *R&D/Sales* for the subsample with non-missing R&D. In addition, the effects of two alternative language measures, *Verb Ratio* and *Sentence Ratio*, on firm R&D investment are also significant and consistent with our previous results based on the full sample. Thus, our main findings that weak FTR increases firm R&D investment are not sensitive to whether missing R&D values are recoded as zero or discarded.

4.4 R&D v.s. Capital Expenditure

In addition to R&D investment, firms have another major long-term investment, capital expenditure (Capex). We present a model about R&D investment in Section 2.1. R&D investment of the model can actually be replaced by any kinds of investment. That is, reward-timing uncertainty should have a positive effect on all kinds of firm long-term investment. To check whether this is the case, in Table 9 we first examine the effect of weak-FTR on firms' long-term investment including both R&D and Capex. *(R&D+Capex)/Assets* is the ratio of long-term investment to total assets. According to Column (1), this ratio is approximately 0.6 percentage points higher for firms located in weak-FTR countries. Columns (2) and (3) further confirm that perceived reward-timing uncertainty, as proxied by two alternative inverse measures of weak FTR (*Verb Ratio* and *Sentence Ratio*), significantly increases firms' total long-term investment.

Although reward-timing uncertainty affects all investments, unlike the reward of R&D investment, the reward of capital investment is typically much less uncertain in terms of when the reward will be materialized. Arguably, the lower timing uncertainty makes capital expenditure less sensitive to language FTR. We thus conduct further analysis to examine whether managers who speak weak-FTR languages invest more in R&D relative to capital expenditure in Columns (4) to (6). The dependent variable, *R&D share*, is defined as firm R&D expenditures divided by the sum of R&D and Capex. As expected, the coefficients on *Weak-FTR* are positive and statistically significant at 1% level. Regarding the economic significance, R&D investment as a proportion of total long-term investment of firms in weak-

FTR countries is on average 4 percentage points higher than that in strong-FTR countries, according to the OLS regression in Column (1). This finding is robust to alternative weak FTR measures, namely *Verb Ratio* and *Sentence Ratio* in Columns (5) and (6), respectively. The significant positive relation between weak FTR and *R&D share* implies that the perceived reward-timing uncertainty, as a key element of our model, increases firm R&D investment relative to capital expenditure.

5 Firm-level R&D: Within-country Analysis

We have documented so far that weak-FTR of languages, reflecting a higher perceived reward-timing uncertainty of language speakers, is significantly positively associated with firm R&D. As language FTR is very persistent over time - it takes centuries for a country or nation to form its language, our empirical strategy does not face the reverse causality problem. However, all measures of language FTR are time-invariant at the country level, so our tests cannot control for country fixed effects. This raises the concern of omitted variable biases. It could be some omitted country-level variables that are closely related to languages and at the same time drive firm R&D investment, causing the positive association between them. To alleviate this endogeneity concern, we have already controlled for a large set of country characteristics (such as economic, legal, cultural and religious variables) as well as continent fixed effects. Moving further, in this section, we first conduct difference-in-differences (DiD) tests to examine the casual effect of an increased importance of a weak-FTR language (Chinese) on R&D investment, based on the 1997 handover of Hong Kong. We then examine the effect of language FTR within one country where both weak-FTR and strong-FTR languages are spoken in different regions of the country (e.g., Belgium).

5.1 Difference-in-Differences Tests: Hong Kong

Before 1997, although Chinese was also an official language of Hong Kong, English and Cantonese were mostly spoken. After 1997, the official language status of Chinese is emphasized by Chapter 1, Article 9 of the Hong Kong Basic Law: "In addition to the Chinese language, English may also be used as an official language by the executive authorities, legislature, and judiciary of the Hong Kong Special Administrative Region." Also due to the growing economic impact of China mainland, the Chinese language relative to English became increasingly important in the business domain of Hong Kong. This natural experiment offers a nice setting to examine whether an increasing use of a weak-FTR language affects firm R&D in Hong Kong, as implied in our theoretical model.

We conduct DiD tests to identify the casual effect of language FTR changes on firm R&D investment. We use all Hong Kong firms as the treatment group. The DiD tests are based on two samples of control groups. In Columns (1)-(2) we use firms in the other two Asian Tigers, namely Singapore and South Korea, as the control group, while in Columns (3)-(4) we use firms in countries affected by the 1997 Asian Financial Crisis as the control group including Indonesia, South Korea, Thailand, Malaysia and Philippines.[7] We add an interaction term, *Hong Kong ∗Post-1997*, in our empirical model specified in Equation (7). *Hong Kong* is the treatment assignment variable that equals 1 if a firm is located in Hong Kong and 0 otherwise. *Post-1997* is the post-treatment indicator that equals 1 in the post-treatment period, 1998-2001 and 0 in the pre-treatment period, 1994-1997. We also include the two individual terms, *Hong Kong* and *Post-1997*, to respectively control for fixed differences in R&D investment between the treatment group and the control group and common trends influencing firms in both groups.

The coefficient of the interaction term captures the effect of an increased importance of Chinese (a weak-FTR language) on R&D investment of Hong Kong firms. Table 10 presents results of the DiD tests. We find that the coefficients on the interaction term are significantly positive in all columns. Specifically, Columns (1) and (2) shows that Hong Kong firms increase $R\&D/Assets$ and $R\&D/Sales$ by around 0.4 and 0.5 percentage points respectively after the 1997 handover. This increased R&D investment of Hong Kong firms can be attributed to the fact that Chinese, as a weak-FTR language, is more widely used in Hong Kong after 1997 handover. In Columns (3) and (4), using countries affected by the 1997 Asian Financial Crisis, the coefficients on *Hong Kong∗Post-1997* are still statistically significant at 5% level, although their economic significance slightly decreases. To conclude, the DiD estimation provides important casual evidence that the increased importance of a weak-FTR language can lead to more intensive firm R&D investment.

[7]Taiwan is one of the four Asian Tigers. However, Taiwan firms are not used as part of the control group due to data unavailability.

5.2 Within-country Effects: Belgium

Evidence on the positive relation between weak-FTR and firm R&D investment presented in Section 3 and 4 are based on cross-country comparisons. We now provide within country evidence. In particular, we focus on Belgium where both weak (Dutch) and strong-FTR (French) official languages are spoken. We compare R&D intensity of firms in different regions of the same country that have different dominant languages. The benefit of conducting within-country analysis, compared with cross-country analysis, is that we do not need to consider country heterogeneity. In within-country analysis, it is unlikely that the effect of *Weak-FTR* on firm R&D investment can be driven by some omitted country-level factors, mitigating potential endogeneity concerns.

Table 11 presents the effects of weak-FTR languages on firm R&D investment in Belgium. Two main official languages in Belgium are Dutch and French which are weak-FTR and strong-FTR languages respectively. There are 11 provinces in Belgium which belong to three regions, namely Brussels region, Walloon region and Flemish region. *Weak-FTR Region* is a dummy variable that equals 1 if a firm is located in a province with weak-FTR languages (Dutch or German) and 0 if a firm is located in a French-speaking province. In Column (1), we find that *Weak-FTR Region* has a positive and significant effect on *R&D/Assets* at 5% level. In Column (2), *Weak-FTR Region* also has a positive and significant effect on *R&D/Sales* at 10% level. The *Weak-FTR Region* increases *R&D/Assets* and *R&D/Sales* by 1.7 and 7 percentage points respectively. In brief, the Belgium evidence confirms the cross-country evidence and suggests that managers who speak weak-FTR languages and thus have higher perceived reward-timing uncertainty tend to invest more in R&D.

6 Conclusion

This paper proposes and tests a simple model that articulates the role of reward-timing uncertainty in explaining the R&D investment decision. Due to the time convexity of the discount function, uncertainty about the timing of future payoffs raises the present value of these payoffs, suggesting that a decision maker with higher perceived reward-timing uncertainty tends to invest more in R&D. Empirically, inspired by Chen (2013), we employ a special language structure, namely weak future-time reference (FTR), to measure managers' perceived reward-timing uncertainty. We find that weak-FTR countries have significantly higher national R&D expenditures both as a percentage of GDP and on a per capita basis after controlling for economic, cultural, legal and religious variables. We also find that firms in weak-FTR countries make significantly more R&D investment. Our results are maintained even if we employ different estimation methods, alternative measures of R&D and language FTR, and within-country tests. Our evidence illustrates the important economic effect of managerial traits and beliefs, for example, the perceived reward-timing uncertainty as captured by a special language structure, on corporate policies. Future studies may develop a firm-specific, not necessarily language-based, measure of perceived reward-timing uncertainty and examine its effect on corporate investment decisions.

References

Acharya, V., Y. Amihud, L. Litov, 2011. Creditor Rights and Corporate Risk-Taking. Journal of Financial Economics 102, 150–166.

Ahern, K. R., D. Daminelli, C. Fracassi, 2015. Lost in translation? The Effect of Cultural Values on Mergers around the World. Journal of Financial Economics 117, 165–189.

Barker, V., G. Mueller, 2002. CEO Characteristics and Firm R&D Spending. Management Science 48, 782–801.

Bertrand, M., A. Schoar, 2003. Managing With Style: The Effect Of Managers On Firm Policies. Quarterly Journal of Economics 118, 1169–1208.

Bhagat, S., I. Welch, 1995. Corporate R&D Investments International Comparisons. Journal of Accounting and Economics 19, 443–470.

Block, J., 2012. R&D Investments in Family and Founder Firms: An Agency Perspective. Journal of Business Venturing 27, 248–265.

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

Brown, J., B. Petersen, 2011. Cash Holdings and R&D Smoothing. Journal of Corporate Finance 17, 694–709.

Caggese, A., 2012. Entrepreneurial Risk, Investment, and Innovation. Journal of Financial Economics 106, 287–307.

Chen, M., 2013. The Effect of Language on Economic Behavior: Evidence from Savings Rates, Health Behaviors, and Retirement Assets. American Economic Review 103, 690–731.

Chen, S., H. Cronqvist, S. Ni, F. Zhang, 2015. Languages and Corporate Savings Behavior. SSRN: `http://ssrn.com/abstract=2556061` pp. 1–44.

Cronqvist, H., A. K. Makhija, S. E. Yonker, 2012. Behavioral Consistency in Corporate Finance: CEO Personal and Corporate Leverage. Journal of Financial Economics 103, 20–40.

Dahl, O., 2000. The Grammar of Future Time Reference in European Languages. Empirical Approaches to Language Typology pp. 309–328.

Dixit, A. K., R. S. Pindyck, 1994. Investment Under Uncertainty. Princeton university press, NJ, USA.

Djankov, S., C. McLiesh, A. Shleifer, 2007. Private Credit in 129 Countries. Journal of Financial Economics 84, 299–329.

Fernández-Villaverde, J., P. Guerrón-Quintana, J. F. Rubio-Ramírez, M. Uribe, 2011. Risk Matters: The Real Effects of Volatility Shocks. American Economic Review 101(6), 2530–61.

Galasso, A., T. Simcoe, 2011. CEO Overconfidence and Innovation. Management Science 57, 1469–1484.

Goldberg, L. S., 1993. Exchange Rates and Investment in United States Industry. The Review of Economics and Statistics pp. 575–588.

Griffith, R., R. Harrison, H. Simpson, 2010. Product Market Reform and Innovation in the EU*. The Scandinavian Journal of Economics 112, 389–415.

Hirshleifer, D., A. Low, S. H. Teoh, 2012. Are Overconfident CEOs Better Innovators?. Journal of Finance 67, 1457–1498.

Hitt, M., R. Hoskisson, D. Ireland, J. Harrison, 1991. Effects of Acquisitions on R&D Inputs and Outputs. Academy of Management Journal 34, 693–706.

Hofstede, G., 1984. Culture's Consequences: International Differences in Work-Related Values vol. 5. Sage, CA.

——— , 2001. Culture's Consequences: Comparing Values, Behaviors, Institutions and Organizations across Nations. Sage, CA.

Huizinga, J., 1993. Inflation Uncertainty, Relative Price Uncertainty, and Investment in US Manufacturing. Journal of Money, Credit and Banking pp. 521–549.

Kacelnik, A., M. Bateson, 1996. Risky Theories - the Effects of Variance on Foraging Decisions. American Zoologist 36, 402–434.

Koh, P.-S., D. Reeb, 2015. Missing R&D. Journal of Accounting and Economics 60, 73–94.

La Porta, R., F. Lopez-de Silanes, A. Shleifer, 2008. The Economic Consequences of Legal Origins. Journal of Economic Literature 46, 285–332.

Li, K., D. Griffin, H. Yue, L. Zhao, 2013. How does Culture Influence Corporate Risk-Taking?. Journal of Corporate Finance 23, 1–22.

Liang, H., C. Marquis, L. Renneboog, S. Sun, 2014. Speaking of Corporate Social Responsibility. Harvard Business School Organizational Behavior Unit Working Paper (14-082).

Maskus, K., R. Neumann, T. Seidel, 2012. How National and International Financial Development Affect Industrial R&D. European Economic Review 56, 72–83.

Oriani, R., M. Sobrero, 2008. Uncertainty and the Market Valuation of R&D Within a Real Options Logic. Strategic Management Journal 29, 343–361.

Park, W. G., 2008. International Patent Protection: 1960–2005. Research policy 37, 761–766.

Qiu, J., C. Wan, 2015. Technology Spillovers and Corporate Cash Holdings. Journal of Financial Economics 115, 558–573.

Redelmeier, D., D. Heller, 1993. Time Preference in Medical Decision Making and Cost-Effectiveness Analysis. Medical Decision Making 13, 212–217.

Rothschild, M., J. Stiglitz, 1970. Increasing Risk: I. A Definition. Journal of Economic Theory 2, 225–243.

Ryan Jr, H., R. Wiggins III, 2002. The Interactions between R&D Investment Decisions and Compensation Policy. Financial Management pp. 5–29.

Shao, L., C. C. Kwok, R. Zhang, 2013. National Culture and Corporate Investment. Journal of International Business Studies 44, 745–763.

Stein, L., E. Stone, 2014. The Effect of Uncertainty on Investment, Hiring, and R&D: Causal Evidence from Equity Options. Available at SSRN: http://ssrn.com/abstract=1649108.

Stulz, R. M., R. Williamson, 2003. Culture, openness, and finance. Journal of financial Economics 70, 313–349.

Sutter, M., S. Angerer, D. Rützler, P. Lergetporer, 2015. The Effect of Language on Economic Behavior: Experimental Evidence from Children's Intertemporal Choices. CESifo Working Paper Series.

Varsakelis, N., 2001. The Impact of Patent Protection, Economy Openness and National Culture on R&D Investment: a Cross-Country empirical investigation. Research Policy 30, 1059–1068.

Whorf, B., 1956. Language, Thought, and Reality: Selected Writings of Benjamin Lee Whorf. Edited by John B. Carroll. Cambridge, MA: MIT Press, .

Winawer, J., N. Witthoft, M. Frank, L. Wu, A. Wade, L. Boroditsky, 2007. Russian Blues Reveal Effects of Language on Color Discrimination. Proceedings of the National Academy of Sciences 104, 7780–7785.

Appendix I: Variable Definitions

Data source: 1 - UNESCO Statistics; 2 - World Bank; 3 - Worldscope database; 4 - Chen (2013); 5 - La Porta et .al. (2008); 6 - Djankov et. al. (2007, 2008); 7 - Park (2008); 8 - Hofstede Website.

Variable	Definition	Data Source
Panel A: Dependent variables		
R&D per capita	Country-level: total domestic expenditures on R&D (in constant 2005 U.S. dollars), divided by the total population	1
Total R&D/GDP	Country-level: total domestic expenditures on R&D, as a percentage of GDP	1
Business R&D/GDP	Country-level: domestic expenditures on R&D performed by business enterprises, as a percentage of GDP	1
R&D/Assets	Firm-level: R&D expenditures, divided by total assets	3
R&D/Sales	Firm-level: R&D expenditures, divided by sales	3
Capex/Assets	Firm-level: Capital expenditures, divided by total assets	3
R&D Share	Firm-level: R&D expenditures, divided by the sum of R&D and capital expenditures	3
Panel B: Language-based measures of perceived reward-timing uncertainty		
Weak-FTR	Dummy=1 if the official language of a nation is classified as a weak future-time reference (FTR) language	4
Verb Ratio	In the country's weather forecast: the number of verbs that are grammatically future-marked, divided by the total number of future-referring verbs	4
Sentence Ratio	In the country's weather forecast: the proportion of sentences regarding the future which contain a grammatical future marker	4
Panel C: Firm-level control variables		
Firm Size	The logarithm of total assets in U.S. dollars	3
Leverage	Total debt divided by total assets	3
Tangibility	PP&E divided by total assets	3
Cash Flow	EBITDA divided by total assets	3
Market-to-Book	Firm market value (i.e., total assets - common equity + market capitalization), divided by total assets	3
Cash Ratio	Cash divided by total assets	3
Capital Intensity	The logarithm of (1 + the ratio of total assets in U.S. dollars to the number of employees)	3
R&D-missing	Dummy=1 if R&D observation is missing	3

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Panel D: Country-level control variables		
GDP per capita	The logarithm of GDP in constant 2005 U.S. dollars, divided by midyear population	2
Stock Market	Market capitalization of listed domestic companies, as a percentage of GDP (scaled by 100)	2
Credit Market	Domestic credit to private sectors, as a percentage of GDP (scaled by 100)	2
UK Legal Origin	Dummy=1 for UK legal origin	5
French L. O.	Dummy=1 for French legal origin	5
German L. O.	Dummy=1 for German legal origin	5
Scandinavian L. O.	Dummy=1 for Scandinavian legal origin	5
Shareholder Rights	The anti-self-dealing index, a measure of shareholder protection against expropriation by firm directors	6
Creditor Rights	Creditor rights aggregate score between 0 and 4, measuring the legal rights of creditors against defaulting debtors	6
Patent Rights	An index of patent protection, considering five aspects of patents: coverage; membership in international treaties; duration of protection; enforcement mechanisms; and restrictions	7
Catholic	Dummy=1 if the largest proportion of a country's population practices catholic religion	5
Individualism	National culture index related to the level of individualism in a society (scaled by 100)	8
Uncertainty Avo.	National culture index related to the level of uncertainty avoidance in a society (scaled by 100)	8
Power Distance	National culture index related to power distance between different members of a society (scaled by 100)	8
Masculinity	National culture index related to the level of masculinity in a society (scaled by 100)	8
Long-term Ort.	National culture index related to the long-term orientation of a society (the score is constructed based on the World Value Survey) (scaled by 100)	8

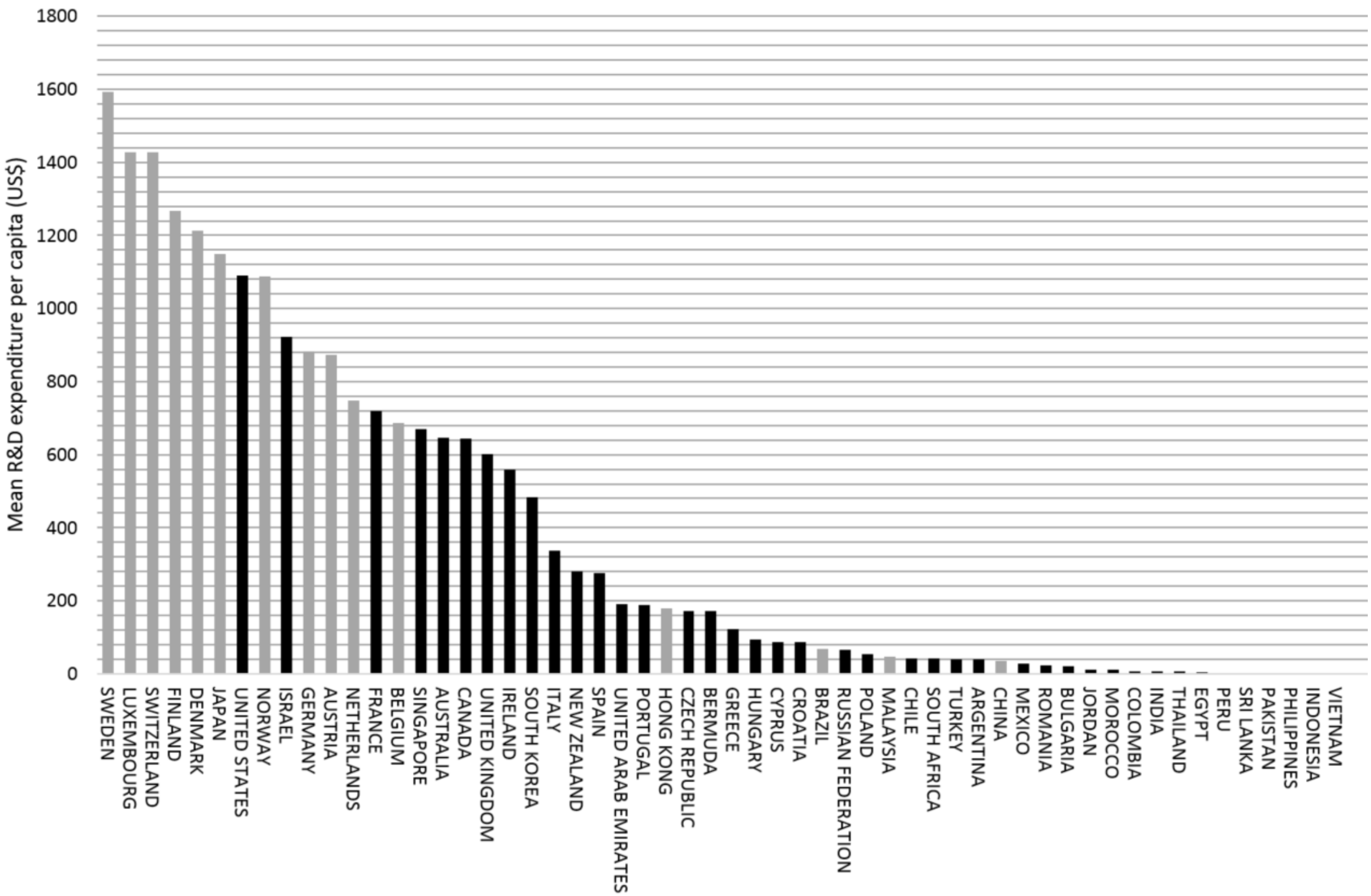

Figure 1: Mean R&D expenditures per capita in US dollars (56 countries, 1996-2013)

The figure shows the mean R&D expenditures per capita in US dollars for different countries. Light-color bars represent weak-FTR countries, while dark-color bars represent strong-FTR countries. The classification of weak-FTR and strong-FTR languages is based on Chen (2013). All variables are defined in Appendix I.

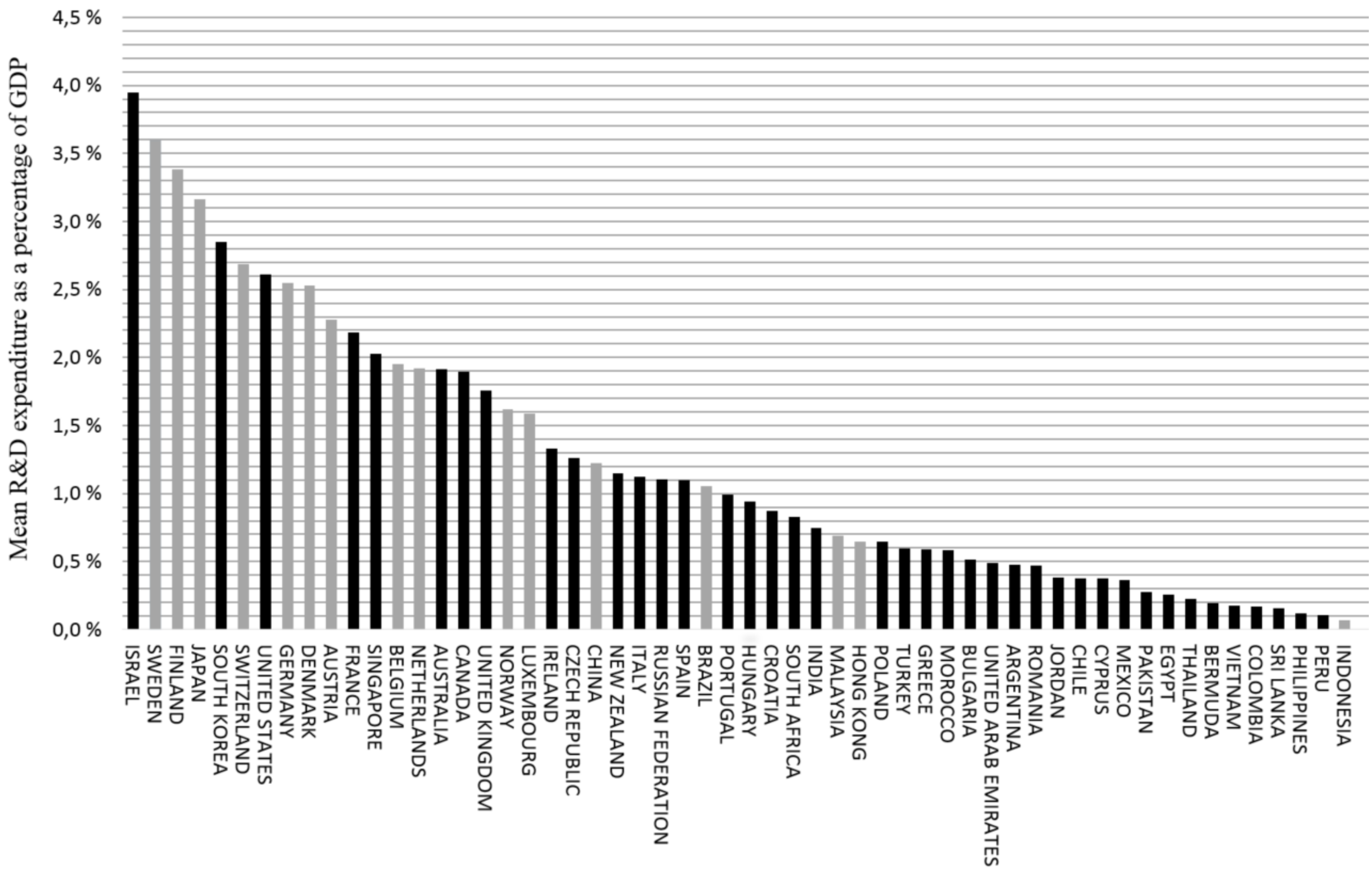

Figure 2: Mean R&D expenditures as a percentage of GDP (56 countries, 1996-2013)

The figure shows the mean R&D expenditures as a percentage of GDP in different countries. Light-color bars represent weak-FTR countries, while dark-color bars represent strong-FTR countries. The classification of weak-FTR and strong-FTR languages is based on Chen (2013). All variables are defined in Appendix I.

Figure 3: Mean Business R&D expenditures as a percentage of GDP (56 countries, 1996-2013)

Table 1: Country-level Summary Statistics

This table presents summary statistics for the main variables used in our country-level analysis. Our sample comprises over 600 country-year observations from 56 countries in the 1996-2013 period. Panel A reports statistics for all country-years. Panel B reports Spearman correlation coefficients between the main variables. All variables are defined in Appendix I.

Panel A: Summary Statistics of Country-level Variables

	N	Mean	Median	SD	Min	Max
R&D per capita	598	424.88	305.45	381.73	2.50	1536.70
Total R&D/GDP	615	1.40	1.15	0.98	0.05	4.48
Business R&D/GDP	573	0.91	0.71	0.80	0.01	3.76
Weak-FTR	615	0.31	0.00	0.46	0.00	1.00
Verb Ratio	498	0.52	0.72	0.38	0.00	1.00
Sentence Ratio	498	0.55	0.74	0.39	0.00	1.00
GDP per capita	615	9.56	10.00	1.14	6.40	11.18
Stock Market	615	0.77	0.53	0.80	0.00	5.09
Credit Market	615	0.96	0.95	0.54	0.09	1.91
Individualism	574	0.50	0.51	0.23	0.13	0.91
Uncertainty Avo.	574	0.68	0.75	0.24	0.08	1.12
Power Distance	574	0.54	0.60	0.20	0.11	1.04
Masculinity	574	0.52	0.52	0.18	0.05	0.95
Long-term Ort.	595	0.50	0.48	0.22	0.07	1.00
UK Legal Origin	615	0.32	0.00	0.47	0.00	1.00
French L. O.	615	0.37	0.00	0.48	0.00	1.00
German L. O.	615	0.26	0.00	0.44	0.00	1.00
Shareholder Rights	599	0.51	0.46	0.24	0.16	1.00
Creditor Rights	589	1.94	2.00	1.10	0.00	4.00
Patent Rights	599	3.95	4.13	0.68	1.38	4.88
Catholic	589	0.45	0.00	0.50	0.00	1.00

Panel B: Spearman Correlation between Main Variables

	(1)	(2)	(3)	(4)	(5)	(6)
(1) R&D per capita	1.000					
(2) Total R&D/GDP	0.938	1.000				
(3) Business R&D/GDP	0.922	0.985	1.000			
(4) Weak-FTR	0.432	0.444	0.466	1.000		
(5) Verb Ratio	-0.181	-0.197	-0.213	-0.812	1.000	
(6) Sentence Ratio	-0.136	-0.144	-0.151	-0.813	0.984	1.000

Table 2: Weak Future Time Reference (FTR), and National R&D investment

This table presents estimation results examining how language structure affects national R&D investment. Our sample comprises country-year observations from 56 countries in the 1996-2013 period. We use three alternative measures of national R&D investment: R&D per capita in Columns (1)-(6), Total R&D/GDP in Columns (7)-(8) and Business R&D/GDP in Columns (9)-(10). R&D per capita is defined as total domestic expenditures on R&D during a given year divided by the total population (in constant 2005 U.S. dollars). Total R&D/GDP is defined as total domestic expenditures on R&D during a given year, as a percentage of GDP. Business R&D/GDP is defined as domestic expenditures on R&D performed by business enterprise, as a percentage of GDP. The measure of language future time reference (FTR) is the dummy variable, *Weak-FTR*, which is equal to one if a country's dominant language is identified as a weak-FTR language based on Chen (2013). Columns (1)-(5), Column (7) and (9) present OLS regressions. Columns (6), (8) and (10) present Fama-MacBeth regressions. Year and continent fixed effects are denoted as Year FE and Continent FE, respectively. Standard errors are clustered at the country level and corrected for heteroscedasticity. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. An intercept is included but not reported. All variables are defined in Appendix I.

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	Dependent Variable = R&D per capita						Total R&D/GDP		Business R&D/GDP	
	OLS					Fama-Mac.	OLS	Fama-Mac.	OLS	Fama-Mac.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Weak-FTR	118.33***	115.54***	73.68***	101.90***	57.30***	89.20***	0.211***	0.213***	0.181***	0.228***
	(5.21)	(4.71)	(3.52)	(4.81)	(2.75)	(6.15)	(3.98)	(4.27)	(3.37)	(3.72)
GDP per capita	221.57***	178.51***	175.36***	199.98***	254.84***	264.65***	0.370***	0.400***	0.251***	0.393***
	(22.28)	(13.29)	(9.48)	(10.93)	(13.55)	(6.34)	(8.48)	(3.65)	(6.11)	(3.13)
Stock Market	6.33	-31.97	-37.57**	-30.15*	-39.15*	-65.15**	-0.130***	-0.166*	-0.112***	-0.177***
	(0.29)	(-1.64)	(-2.06)	(-1.70)	(-2.29)	(-2.61)	(-3.23)	(-1.86)	(-3.19)	(-3.01)
Credit Market	31.86	32.62	-0.24	-16.37	-53.04**	-141.77***	-0.02	-0.21**	-0.02	-0.09
	(1.22)	(1.15)	(-0.01)	(-0.65)	(-2.01)	(-8.40)	(-0.31)	(-2.68)	(-0.36)	(-1.35)
UK Legal Origin		100.55*	268.31***	423.36***	233.29***	208.68***	0.278	0.555***	0.268	0.528***
		(1.90)	(4.25)	(6.63)	(3.55)	(4.77)	(1.38)	(4.01)	(1.49)	(3.23)
French L. O.		-214.45***	-207.10***	68.19	31.09	86.11	-0.526***	-0.352*	-0.502***	-0.523**
		(-5.27)	(-4.17)	(1.15)	(0.46)	(0.83)	(-2.61)	(-1.85)	(-2.87)	(-2.78)
German L. O.		-46.189	-155.10**	102.74	135.09*	103.55	-0.036	-0.110	-0.193	-0.206
		(-1.08)	(-2.58)	(1.61)	(1.95)	(1.38)	(-0.17)	(-0.55)	(-1.05)	(-0.69)
Shareholder Rights		-133.69**	-231.75***	-241.90***	-88.70	12.44	-0.119	-0.296*	-0.121	-0.153
		(-2.23)	(-3.74)	(-3.61)	(-1.53)	(0.28)	(-0.91)	(-2.01)	(-0.85)	(-0.74)
Creditor Rights		-16.128	-91.38***	-126.45***	-116.15***	-108.18***	-0.270***	-0.281***	-0.251***	-0.242***
		(-1.49)	(-7.22)	(-10.03)	(-8.89)	(-5.50)	(-8.44)	(-5.67)	(-8.74)	(-6.17)
Patent Rights		95.05***	133.19***	116.75***	30.52	52.70	0.390***	0.359***	0.297***	0.274***
		(5.25)	(6.16)	(5.48)	(1.39)	(1.47)	(5.87)	(3.24)	(5.15)	(3)
Individualism			-366.86***	-314.45***	120.77	7.07	0.947***	0.490	0.445**	0.114
			(-5.14)	(-4.33)	(1.48)	(0.05)	(5.14)	(1.36)	(2.54)	(0.38)
Uncertainty Avo.			-73.26	-171.02**	-162.52**	-200.43***	0.743***	0.804***	0.729***	1.054***
			(-0.97)	(-2.38)	(-2.40)	(-3.87)	(4.87)	(5.09)	(5.21)	(4.92)
Power Distance			-451.31***	-513.02***	-510.61***	-496.22***	-1.551***	-1.632***	-1.573***	-1.155***
			(-6.48)	(-7.65)	(-8.83)	(-6.65)	(-8.58)	(-5.67)	(-8.11)	(-3.40)
Masculinity			-120.37**	-193.76***	-343.97***	-266.08***	-1.090***	-0.875***	-0.593***	-0.876**
			(-2.28)	(-3.80)	(-6.14)	(-4.12)	(-6.26)	(-3.23)	(-3.65)	(-2.38)
Long-term Ort.			718.58***	588.63***	534.67***	558.87***	1.679***	2.134***	1.550***	1.593***
			(14.62)	(10.79)	(7.33)	(7.07)	(8.64)	(9.08)	(7.81)	(4.48)
Catholic				-169.13***	-109.22***	-100.50*	-0.197***	-0.181	-0.214***	-0.215*
				(-5.03)	(-3.64)	(-1.91)	(-2.89)	(-1.28)	(-3.14)	(-1.81)
Continent FE	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	Yes	No	Yes	No	Yes	No
N	598	555	529	529	529	529	546	546	513	513
adj. R^2	0.564	0.645	0.743	0.759	0.807	0.918	0.809	0.909	0.779	0.908

Table 3: Alternative Measures of FTR, and National R&D Investment

This table presents estimation results examining how language structure affects national R&D investment. Our sample comprises country-year observations from 56 countries in the 1996-2013 period. We use three alternative measures of national R&D investment: R&D per capita in Columns (1)-(4), Total R&D/GDP in Columns (5)-(6) and Business R&D/GDP in Columns (7)-(8). R&D per capita is defined as total domestic expenditures on R&D during a given year divided by the total population (in constant 2005 U.S. dollars). Total R&D/GDP is defined as total domestic expenditures on R&D during a given year, as a percentage of GDP. Business R&D/GDP is defined as domestic expenditures on R&D performed by business enterprise, as a percentage of GDP. The measures of language future time reference (FTR) are *Verb Ratio* and *Sentence Ratio*, proposed by Chen (2013). Verb Ratio is the number of verbs in a country's weather forecast that are grammatically future-marked divided by the total number of future-referring verbs. Sentence Ratio is the proportion of sentences in a country's weather forecast regarding the future which contains a grammatical future marker. Country controls are the full set of country-level control variables used in Table 2. Columns (1), (3) and (5)-(8) present OLS regressions. Columns (2) and (4) present Fama-MacBeth regressions. Year and continent fixed effects are denoted as Year FE and Continent FE, respectively. Standard errors are clustered at the country level and corrected for heteroscedasticity. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. An intercept is included but not reported. All variables are defined in Appendix I.

	Dependent Variable = R&D per capita				Total R&D/GDP		Business R&D/GDP	
	OLS	Fama-Mac.	OLS	Fama-Mac.	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Verb_ratio	-76.83***	-72.01***			-0.16**		-0.10	
	(-3.28)	(-4.55)			(-2.26)		(-1.56)	
Sentence_ratio			-86.75***	-89.03***		-0.22***		-0.15**
			(-3.79)	(-5.23)		(-3.21)		(-2.39)
Country Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	No	Yes	Yes	Yes	Yes
N	456	456	456	456	473	473	450	450
adj. R^2	0.876	0.972	0.877	0.973	0.830	0.832	0.808	0.809

Table 4: Robustness of Country-level Evidence

This table presents OLS estimation results examining the robustness of the effect of language structure on national R&D investment. The robustness tests are based on various subsamples. In Columns (1)-(3), we exclude countries with less than 10 years' data. In Columns (4)-(6), Columns (7)-(9) and Columns (10)-(12), we respectively focus on three subsample periods: 1996-2001, 2002-2007 and 2008-2013. We use three alternative measures of national R&D investment: R&D per capita in Columns (1), (4), (7) and (10), Total R&D/GDP in Columns (2), (5), (8) and (11), and Business R&D/GDP in Columns (3), (6), (9) and (12). R&D per capita is defined as total domestic expenditures on R&D during a given year divided by the total population (in constant 2005 U.S. dollars). Total R&D/GDP is defined as total domestic expenditures on R&D during a given year, as a percentage of GDP. Business R&D/GDP is defined as domestic expenditures on R&D performed by business enterprise, as a percentage of GDP. The measure of language future time reference (FTR) is the dummy variable, *Weak-FTR*, which is equal to one if a country's dominant language is identified as a weak-FTR language based on Chen (2013). Country controls are the full set of country-level control variables in Table 2. Year and continent fixed effects are denoted as Year FE and Continent FE, respectively. Standard errors are clustered at the country level and corrected for heteroscedasticity. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. An intercept is included but not reported. All variables are defined in Appendix I.

Sample	Countries with no less than 10-year data			1996-2001			2002-2007			2008-2013		
Y-variable	per capita (1)	Total (2)	Business (3)	per capita (4)	Total (5)	Business (6)	per capita (7)	Total (8)	Business (9)	per capita (10)	Total (11)	Business (12)
Weak-FTR	60.25***	0.19***	0.19***	57.75*	0.13	-0.06	66.44**	0.23***	0.20**	45.16	0.27***	0.29***
	(2.96)	(3.70)	(3.83)	(1.89)	(1.22)	(-0.60)	(2.01)	(2.70)	(2.50)	(1.40)	(3.11)	(3.50)
Country Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	485	502	469	159	165	152	202	208	199	168	173	162
adj. R^2	0.816	0.812	0.788	0.870	0.879	0.861	0.814	0.799	0.760	0.869	0.829	0.831

Table 5: Firm-level Summary Statistics

This table presents firm-level summary statistics for the main variables used in our study. We include observations with missing R&D while takes them as zero R&D. Panel A reports statistics of the main variables (including both country-level and firm-level) for all firm-years. Panel B reports the Spearman correlation coefficients between firm R&D intensity measures and language structure measures. All variables are defined in Appendix I.

Panel A: Statistics for All Variables

	N	Mean	Median	SD	Min	Max
R&D/Assets	413,397	0.023	0.000	0.066	0.000	0.433
R&D/Sales	413,397	0.060	0.000	0.293	0.000	2.442
Weak-FTR	413,397	0.344	0.000	0.475	0.000	1.000
Verb Ratio	355,683	0.533	0.769	0.386	0.000	1.000
Sentence Ratio	355,683	0.591	0.875	0.425	0.000	1.000
GDP per capita	413,397	9.912	10.434	1.118	6.427	10.880
Stock Market	413,397	1.103	0.902	1.302	0.137	10.769
Credit Market	413,397	1.322	1.300	0.482	0.194	2.193
Individualism	413,397	0.615	0.680	0.283	0.140	0.910
Uncertainty Avo.	413,397	0.558	0.460	0.230	0.080	1.120
Power Distance	413,397	0.524	0.400	0.186	0.110	1.040
Masculinity	413,397	0.610	0.620	0.175	0.050	0.950
Long-term Ort.	413,397	0.528	0.509	0.262	0.212	1.000
UK Legal Origin	413,397	0.583	1.000	0.493	0.000	1.000
French L. O.	413,397	0.103	0.000	0.303	0.000	1.000
German L. O.	413,397	0.294	0.000	0.456	0.000	1.000
Shareholder Rights	413,397	0.628	0.651	0.199	0.178	1.000
Creditor Rights	413,397	1.973	2.000	1.066	0.000	4.000
Patent Rights	413,397	4.311	4.540	0.619	1.020	4.880
Catholic	413,397	0.137	0.000	0.343	0.000	1.000
Firm Size	413,397	11.78	11.76	2.107	6.258	16.961
Tangibility	413,397	0.307	0.266	0.229	0.003	0.913
Cash Flow	413,397	0.022	0.095	0.367	-2.358	0.462
Leverage	413,397	0.252	0.202	0.261	0.000	1.565
Market-to-Book	382,136	1.913	1.251	2.216	0.456	16.120
Cash Ratio	339,888	5.355	5.303	1.150	2.641	8.756
Capital Intensity	286,875	0.105	0.055	0.135	0.000	0.703

Panel B: Spearman Correlation between Main Variables

	(1)	(2)	(3)	(4)	(5)
(1) R&D/Sales	1.000				
(2) R&D/Assets	0.996	1.000			
(3) Weak-FTR	-0.022	-0.020	1.000		
(4) Verb Ratio	-0.022	-0.023	-0.856	1.000	
(5) Sentence Ratio	0.005	0.004	-0.856	0.979	1.000

Table 6: Weak Future Time Reference (FTR) and Firm-level R&D

This table presents estimation results examining how managers' perceived reward timing uncertainty, proxied by a special language structure, affects firm R&D investment. The dependent variable is R&D/Assets in Columns (1)-(4) and R&D/Sales in Columns (5)-(6). R&D/Assets is defined as R&D expenditures divided by book assets (missing R&D values are recoded as zero). R&D/Sales is defined as R&D expenditures divided by annual sales (missing R&D values are recoded as zero). The language future time reference (FTR) measure is the dummy, *Weak-FTR*, which is equal to one if a country's dominant language is identified as a weak-FTR language, based on Chen (2013). Columns (1)-(3) and Column (5) present OLS regressions. Columns (4) and (6) present Fama-MacBeth regressions. We control for a large set of country and firm characteristics that are used in the literature. Year, industry and continent fixed effects are denoted as Year FE, Industry FE and Continent FE, respectively. Standard errors are clustered at the firm level and corrected for heteroscedasticity. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. An intercept is included but not reported. All variables are defined in Appendix I.

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Dependent Variable	R&D/Assets				R&D/Sales	
	OLS			Fama-Mac.	OLS	Fama-Mac.
	(1)	(2)	(3)	(4)	(5)	(6)
Weak-FTR	0.004***	0.007***	0.006***	0.007***	0.018***	0.015***
	(5.28)	(9.74)	(8.24)	(6.33)	(5.42)	(4.84)
Firm Size		-0.001***	-0.000***	-0.000***	-0.003***	-0.003***
		(-3.81)	(-3.33)	(-3.69)	(-5.87)	(-6.63)
Tangibility		-0.001	-0.001	-0.000	-0.003	0.006
		(-1.22)	(-1.32)	(-0.36)	(-0.54)	(1.42)
Cash Flow		-0.046***	-0.046***	-0.053***	-0.251***	-0.273***
		(-30.09)	(-29.84)	(-16.05)	(-32.98)	(-14.46)
Leverage		-0.016***	-0.016***	-0.019***	-0.081***	-0.076***
		(-10.47)	(-10.41)	(-11.36)	(-12.37)	(-12.91)
Market-to-Book		0.002***	0.002***	0.003***	0.006***	0.010***
		(11.79)	(11.63)	(9.25)	(6.45)	(6.55)
Capital Intensity		0.003***	0.003***	0.002***	0.038***	0.030***
		(11.03)	(10.77)	(7.58)	(26.55)	(9.87)
Cash Ratio		0.046***	0.046***	0.036***	0.262***	0.204***
		(17.86)	(17.97)	(8.90)	(18.61)	(9.94)
R&D-missing	-0.044***	-0.034***	-0.034***	-0.034***	-0.082***	-0.073***
	(-86.74)	(-66.28)	(-66.55)	(-23.30)	(-38.18)	(-11.35)
GDP per capita	0.000	0.002***	0.003***	0.005***	-0.003*	-0.003
	(1.12)	(4.45)	(5.83)	(4.20)	(-1.79)	(-1.42)
Stock Market	-0.000	-0.001***	-0.001***	0.006	-0.005***	-0.003
	(-0.79)	(-10.04)	(-8.50)	(0.98)	(-7.40)	(-0.43)
Credit Market	0.012***	0.000	-0.001	-0.011*	-0.013***	-0.014*
	(14.99)	(0.47)	(-1.00)	(-1.76)	(-3.59)	(-1.83)
UK Legal Origin	0.020***	0.015***	0.014***	0.014***	0.048***	0.028***
	(8.18)	(6.07)	(5.42)	(2.84)	(3.82)	(2.77)
French L. O.	0.024***	0.014***	0.014***	0.020***	0.033***	0.028***
	(8.93)	(5.15)	(5.40)	(3.07)	(2.61)	(3.04)
German L. O.	0.022***	0.008***	0.010***	0.019**	0.008	0.011
	(7.29)	(2.68)	(3.14)	(2.40)	(0.55)	(1.02)
Shareholder Rights	0.005**	0.000	0.001	0.005	0.015	0.036***
	(2.45)	(0.17)	(0.57)	(0.93)	(1.60)	(3.19)
Creditor Rights	-0.004***	-0.002***	-0.002***	-0.002*	-0.002	-0.002
	(-9.67)	(-4.25)	(-4.25)	(-1.74)	(-0.93)	(-0.87)
Patent Rights	0.000	-0.006***	-0.009***	-0.005***	-0.030***	-0.015***
	(1.14)	(-12.92)	(-13.15)	(-3.47)	(-10.48)	(-4.82)
Individualism	0.001	0.004	0.010***	-0.002	0.040***	-0.005
	(0.59)	(1.46)	(3.47)	(-0.21)	(3.24)	(-0.44)
Uncertainty Avo.	-0.016***	0.000	-0.002	-0.005*	0.002	-0.013**
	(-10.33)	(0.19)	(-0.82)	(-1.94)	(0.20)	(-2.08)
Power Distance	-0.022***	-0.011***	-0.010***	-0.005	-0.022*	-0.009
	(-9.29)	(-4.38)	(-3.68)	(-0.85)	(-1.77)	(-0.72)
Masculinity	-0.022***	-0.007***	-0.006***	-0.004**	-0.026**	-0.021***
	(-9.72)	(-3.03)	(-2.62)	(-2.17)	(-2.33)	(-3.03)
Long-term Orientation	-0.022***	-0.014***	-0.012***	-0.021**	-0.016	-0.016
	(-9.17)	(-5.37)	(-4.68)	(-2.39)	(-1.31)	(-1.45)
Catholic	-0.005***	-0.002**	-0.003**	-0.005	0.009	0.008
	(-4.57)	(-1.98)	(-2.41)	(-1.68)	(1.43)	(1.65)
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	No	Yes	No
N	413,397	222,820	222,820	222,820	222,820	222,820
adj. R^2	0.182	0.386	0.387	0.406	0.288	0.299

Table 7: Alternative Measures of FTR and Firm-level R&D

This table presents estimation results examining how managers' perceived reward timing uncertainty, proxied by a special language structure, affects firm R&D investment. The dependent variable is R&D/Assets in Columns (1)-(4) and R&D/Sales in Columns (5)-(8). R&D/Assets is defined as R&D expenditures divided by book assets (missing R&D values are recoded as zero). R&D/Sales is defined as R&D expenditures divided by annual sales (missing R&D values are recoded as zero). The language future time reference (FTR) measures are Verb Ratio and Sentence Ratio, proposed by Chen (2013). Verb Ratio is the number of verbs in a country's weather forecast that are grammatically future-marked divided by the total number of future-referring verbs. Sentence Ratio is the proportion of sentences in a country's weather forecast regarding the future which contains a grammatical future marker. Columns (1), (3), (5) and (7) present OLS regressions. Columns (2), (4), (6) and (8) present Fama-MacBeth regressions. Country controls are the full set of country-level control variables in Table 6. Firm controls are the full set of firm-level control variables in Table 6. Year, industry and continent fixed effects are denoted as Year FE, Industry FE and Continent FE, respectively. Standard errors are clustered at the firm level and corrected for heteroscedasticity. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. All variables are defined in Appendix I.

	Dependent Variable=R&D/Assets				R&D/Sales			
	OLS	Fama-Mac.	OLS	Fama-Mac.	OLS	Fama-Mac.	OLS	Fama-Mac.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Verb Ratio	-0.008***	-0.008**			-0.025***	-0.025*		
	(-6.47)	(-2.61)			(-4.52)	(-1.80)		
Sentence Ratio			-0.007***	-0.009**			-0.024***	-0.033
			(-6.92)	(-2.57)			(-4.97)	(-1.61)
Country Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	No	Yes	No	Yes	No
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	198,229	198,229	198,229	198,229	198,229	198,229	198,229	198,229
R^2	0.390	0.409	0.390	0.409	0.294	0.304	0.294	0.304

Table 8: Robustness of Firm-level Evidence

This table presents OLS estimation results examining the robustness of the effect of managers' perceived reward timing uncertainty, proxied by a special language structure, on firm R&D investment. The robustness tests are based on various subsamples. In Columns (1)-(2), we focus on non-US firms. In Columns (3)-(4), Columns (5)-(6) and Columns (7)-(8), we focus on three subsample periods: 1985-1999, 2000-2007 and 2008-2013, respectively. The dependent variable is R&D/Assets in Columns (1), (3), (5) and (7) and R&D/Sales in Columns (2), (4), (6) and (8). R&D/Assets is defined as R&D expenditures divided by book assets (missing R&D values are recoded as zero). R&D/Sales is defined as R&D expenditures divided by annual sales (missing R&D values are recoded as zero). The language future time reference (FTR) measure is the dummy, *Weak-FTR*, which is equal to one if a country's dominant language is identified as a weak-FTR language, based on Chen (2013). Country controls are the full set of country-level control variables in Table6. Firm controls are the full set of firm-level control variables in Table 6. Year, industry and continent fixed effects are denoted as Year FE, Industry FE and Continent FE, respectively. Standard errors are clustered at the firm level and corrected for heteroscedasticity. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. All variables are defined in Appendix I.

	Non-US Firms		1985-1999		2000-2007		2008-2013	
	R&D/Assets	R&D/Sales	R&D/Assets	R&D/Sales	R&D/Assets	R&D/Sales	R&D/Assets	R&D/Sales
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Weak-FTR	0.006***	0.012***	0.007***	0.014***	0.008***	0.025***	0.004***	0.013**
	(7.26)	(3.52)	(6.01)	(3.32)	(8.14)	(5.04)	(2.96)	(2.04)
Country Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	166,814	166,814	63,783	63,783	90,302	90,302	68,735	68,735
adj. R^2	0.324	0.220	0.421	0.278	0.388	0.289	0.381	0.309

Table 9: Firm Total Long-term Investment (R&D and Capex)

This table presents OLS estimation results examining how managers' perceived reward timing uncertainty, proxied by a special language structure, affects firms' total long-term investment including both R&D and capital expenditures (Capex). The dependent variable is (R&D + Capex)/Assets in Columns (1)-(3) and R&D Share in Columns (4)-(6). R&D plus Capex is considered as the total long-term investment of the firm. R&D Share is defined as firm-level R&D expenditures, divided by total long-term investment. The language future time reference (FTR) measures are Weak-FTR, Verb Ratio and Sentence Ratio, proposed by Chen (2013). Weak-FTR is a dummy variable which is equal to one if a country's dominant language is identified as a weak-FTR language. Verb Ratio is the number of verbs in a country's weather forecast that are grammatically future-marked divided by the total number of future-referring verbs. Sentence Ratio is the proportion of sentences in a country's weather forecast regarding the future which contain a grammatical future marker. Country controls are the full set of country-level control variables in Table 6. Firm controls are the full set of firm-level control variables in Table 6. Year, industry and continent fixed effects are denoted as Year FE, Industry FE and Continent FE, respectively. Standard errors are clustered at the firm level and corrected for heteroscedasticity. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. All variables are defined in Appendix I.

Dependent Variable	(R&D+Capex)/Assets			R&D/(R&D+Capex)		
	(1)	(2)	(3)	(4)	(5)	(6)
Weak-FTR	0.006***			0.041***		
	(4.50)			(11.02)		
Verb Ratio		-0.009***			-0.051***	
		(-4.39)			(-8.87)	
Sentence Ratio			-0.008***			-0.049***
			(-4.42)			(-9.57)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Country Controls	Yes	Yes	Yes	Yes	Yes	Yes
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
N	222,820	198,229	198,229	220,745	196,317	196,317
adj. R^2	0.287	0.298	0.298	0.551	0.554	0.554

Table 10: Difference-in-Differences Test: Hong Kong

This table presents results from Difference-in-Differences (DiD) tests based on Hong Kong. We examine how managers' perceived reward timing uncertainty, proxied by a special language structure, affects firm R&D investment. All Hong Kong firms are used as the treatment group. The DiD tests are based on two samples with different control groups. In Columns (1)-(3), we use firms located in the other two Asian Tigers, namely Singapore and South Korea, as the control group and the sample comprises 4,083 firm-year observations from 1994 to 2001. In Columns (4)-(6), we use firms located in countries affected by the 1997 Asian Financial Crisis as the control group and the sample comprises 6,868 firm-year observations from 1994-2001. The dependent variable is R&D/Assets in Columns (1) and (3) and R&D/Sales in Columns (2) and (4). R&D/Assets is R&D expenditures divided by book assets (missing R&D values are recoded as zero). R&D/Sales is R&D expenditures divided by annual sales (missing R&D values are recoded as zero). Hong Kong is a dummy variable that is equal to one for firms based in Hong Kong, and zero otherwise. Post-1997 is a dummy variable that is set to one after the 1997 Hong Kong transfer of sovereignty, and zero otherwise. Country controls are the full set of country-level control variables in Table 6. Firm controls are the full set of firm-level control variables in Table 6. Year and industry fixed effects are denoted as Year FE and Industry FE, respectively. Standard errors are clustered at the firm level and corrected for heteroscedasticity. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. All variables are defined in Appendix I.

Sample	Asian Tigers		Countries Affected by the 1997 Asian Financial Crisis	
Dependent Variable	R&D/Assets (1)	R&D/Sales (2)	R&D/Assets (3)	R&D/Sales (4)
Post-1997	-0.004***	-0.004***	-0.001**	-0.002**
	(-3.41)	(-2.88)	(-2.54)	(-2.35)
Hong Kong * Post-1997	**0.004*** **	**0.005** **	**0.002** **	**0.004** **
	(2.99)	**(2.35)**	**(2.55)**	**(2.42)**
Country Controls	Yes	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
N	4,083	4,083	6,868	6,868
adj. R^2	0.171	0.123	0.149	0.108

Table 11: Within-country Evidence: Belgium

This table presents within-country estimation results examining how managers' perceived reward timing uncertainty, proxied by a special language structure, affects firm R&D investment. We focus on Belgium, which include regions speaking both Weak-FTR and Strong-FTR languages. The dependent variable is R&D/Assets in Columns (1) and R&D/Sales in Columns (2). R&D/Assets is defined as R&D expenditures divided by book assets (missing R&D values are recoded as zero). R&D/Sales is defined as R&D expenditures divided by annual sales (missing R&D values are recoded as zero). Weak-FTR is an indicator variable that is equal to one if a firm is headquartered in a region where the main language is weak-FTR, and zero otherwise. Country controls are the full set of country-level control variables in Table 6. Firm controls are the full set of firm-level control variables in Table 6. Year, industry and continent fixed effects are denoted as Year FE, Industry FE and Continent FE, respectively. Standard errors are clustered at the firm level and corrected for heteroscedasticity. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. All variables are defined in Appendix I.

Dependent Variable	R&D/Assets (1)	R&D/Sales (2)
Weak-FTR	**0.017**** **(2.228)**	**0.070*** **(1.923)**
Firm Controls	Yes	Yes
Year FE	Yes	Yes
Industry FE	Yes	Yes
N	1,551	1,551
adj. R^2	0.503	0.396