JOURNAL OF FINANCIAL AND QUANTITATIVE ANALYSIS Vol. 57, No. 4, June 2022, pp. 1377–1408

doi:10.1017/S002210902100020X

Corporate R&D and Stock Returns: International Evidence

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Abstract

Firms with higher R&D intensity subsequently experience higher stock returns in international stock markets, highlighting the role of intangible investments in international asset pricing. The R&D effect is stronger in countries where growth option risk is more likely

We thank Rui Albuquerque, Hiroyuki Aman, Geert Bekaert, Jan Bena, Yuk Ying Chang, Lauren Cohen, Bernard Dumas, Ron Giammarino, Jarrad Harford (the editor), Robert Hodrick, Dana Kiku, Howard Kung, Cheng-Few Lee, Xiaoji Lin, Alexander Ljungqvist, Christian Lundblad, David Ng, Dimitris Papanikolaou, Gordon Phillips, David Reeb, Jay Ritter, Mark Schankerman, Clemens Sialm, Akhtar Siddique (the referee), Stephan Siegel, René M. Stulz, Hanwen Sun, Kevin Tseng, Mika Vaihekoski, Rossen Valkanov, Siri Valseth, Wei Xiong, Holly Yang, Tong Yao, Motohiro Yogo, and Shih-Ti Yu, and the conference and seminar participants at Development Bank of Japan, Hitotsubashi University, 2016 Nippon (Japan) Finance Association Meeting, National Chiao-Tung University, National Tsing Hua University, Fudan University, and Shanghai University of Finance and Economics for their comments and suggestions. We are grateful to Kai Yan for his research assistance and especially thank Masahiro Watanabe for his great help. Hsu and Xu acknowledge the support from the General Research Fund sponsored by the Research Grants Council in Hong Kong (Refs. 17502514 and 17511716). Hsu acknowledges financial support from Ministry of Science and Technology and Ministry of Education in Taiwan (MOST108-2410-H-007-099-MY2, MOST109-2628-H-007-001-MY4, MOST109-2634-F-002-045, MOE109J0321Q2, and MOE109L900202). Watanabe acknowledges financial support from Social Sciences and Humanities Research Council of Canada (SSHRC).

priced, but is unrelated to country characteristics representing market sentiments and limits-of-arbitrage. Moreover, we find that R&D intensity is associated with higher future operating performance, return volatility, and default likelihood. Our evidence suggests that the cross sectional relation between R&D intensity and stock returns is more likely attributable to risk premium than to mispricing.

I. Introduction

Research and development is the major driver of technological change – hence the central role of R&D in economic growth and welfare improvement. The impact of R&D and technological change on economic growth has long been recognized by proponents of free market economies such as Adam Smith, Marshall, Keynes, and Solow. Even two of the most ardent critics of capitalist societies, Marx and Engels, argued in the Communist Manifesto that capitalism depends for its very existence on the constant introduction of new products and processes.

– Lev (1999)

Research and development (R&D) is one of the firm's key business activities in today's knowledge economy and, to a great extent, determines the growth and uncertainty of a firm's long-term value. Since the 1970s, U.S. public firms have significantly raised their R&D investments; in fact, their R&D investments increased faster than capital expenditures (Jensen (1993), Skinner (2008)). These heavy investments in R&D are perceived as value-relevant for stock investors as prior studies based on U.S. data have shown that R&D-intensive firms are associated with higher market value (Hall (1993), Jensen (1993), and Sougiannis (1994)) and higher subsequent stock returns (Lev and Sougiannis (1996), Lev (1999), and Chan, Lakonishok, and Sougiannis (2001)). Although such a positive R&D-return relation has been confirmed by subsequent studies, whether such a relation is driven by risk premium or behavioral biases remains an important issue under debate and calls for further analyses.

R&D spending has also risen globally. Non-U.S. firms have become more aggressive with respect to R&D activities. In fact, 9 of the top 20 global R&D spenders in 2014 are not based in the U.S.[1] In the Worldscope database, total R&D expenditures reported by non-U.S. public firms have increased 10.45% annually from 1980 to 2008, in comparison with an annual increase rate of 7.89% from U.S. firms. All these observations suggest a global phenomenon of intensive R&D activities, and motivate us to analyze the asset pricing implications of R&D from an international perspective.

In this article, we examine the cross sectional return predictability associated with R&D in international equity markets.[2] Our investigation extends our

[1]According to PwC's Strategy& (http://www.strategyand.pwc.com/global/home/what-we-think/innovation1000/top-innovators-spenders), these 9 non-U.S. companies include (ranks in parentheses): Volkswagen (1), Samsung (2), Roche (5), Novartis (6), Toyota (7), Daimler (12), Sanofi-Aventis (16), Honda (17), and GlaxoSmithKline (19).

[2]By using international data to reexamine specific patterns found in U.S. markets, we guard against data mining concerns and provide new insights on the causes and consequences of these patterns. For example, Hou, Karolyi, and Kho (2011) document that momentum and cash flow-to-price factors can account for the time-series variation of global stock returns. Fama and French (1998) present

understanding of the role of intangible assets and technological innovation in asset pricing from 3 angles. First, the heterogeneity in institutional environments across countries enables us to analyze whether the R&D effect can be explained by particular country characteristics. Second, the cross section of stock returns spanned by countries around the world not only allows us to conduct an out-of-sample test for the R&D-return relation reported in U.S. stock markets, but also enables us to better understand the causes of the R&D effect. Third, there is a lack of asset pricing tests in a cross-country setting.[3] Our investigation thus fills this gap in the finance literature.

Lev and Sougiannis (1996) are among the first to report that U.S. public firms' R&D intensity predicts subsequent stock returns and subsequent operating performance after controlling for size, book-to-market ratio (BM), and survivorship bias. They conclude that R&D investments are value-relevant and suggest future studies to examine whether such an R&D effect results from investors' under-reaction to R&D information or from extra systematic risk related to R&D investments. Subsequent studies on the R&D effect, mostly based on U.S. data, collectively suggest 2 possible explanations: risk premium and mispricing.[4] First, R&D investments create growth options and may increase firms' exposure to unspecified systematic risk factors. Second, investors may be pessimistic in assessing the value of R&D activities and thus may tend to over-discount future cash flows associated with innovations. In addition, market frictions such as information lags, short-sale constraints, and financial constraints may delay stock markets' reactions to R&D-related information and thus enhance return predictability due to mispricing.

We begin our empirical analysis by testing whether R&D-intensive firms provide higher subsequent stock returns using both portfolio sorts and Fama–MacBeth regressions. Next, we study if the variation in the R&D effect across countries can be explained by country-specific institutional factors related to risk

international evidence for the value premium based on 13 countries. Rouwenhorst (1998) shows that the momentum effect exists in 12 European markets. McLean, Pontiff, and Watanabe (2009) report negative subsequent stock returns associated with share-issuance in 41 non-U.S. markets. Watanabe, Xu, Yao, and Yu (2013) show that firms with higher asset growth subsequently experience lower stock returns in 51 stock markets. In addition, Eisdorfer, Goyal, and Zhdanov (2018) explore the distress anomaly using 34 countries.

[3]There are few studies that explore the R&D effect in specific countries. For example, the relation between R&D intensity and subsequent stock returns has been studied using Canadian data by Callimaci and Landry (2004), using French data by Cazavan-Jeny and Jeanjean (2006), and using U.K. data by Oswald and Zarowin (2007).

[4]Chan et al. (2001) confirm the finding of Lev and Sougiannis (1996) after taking more systematic risk factors and prior stock return performance into account, and advocate the behavioral explanation that investors tend to be over-pessimistic about R&D activities. This viewpoint is further supported by Eberhart, Maxwell, and Siddique (2004) and (2008), which report higher abnormal stock returns and higher abnormal operating performance after substantial R&D increases. Market frictions enhance behavioral biases because information lags or limited risk-bearing due to financial constraints create and prolong investors' under-reactions to R&D news (see Penman and Zhang (2002); Lev, Sarath, and Sougiannis (2005); Ciftci, Lev, and Radhakrishnan (2011)). Lastly, several studies advocate the risk premium explanation as R&D activities may create growth options or may increase systematic risk exposure (e.g., Chambers, Jennings, and Thompson (2002), Kothari, Laguerre, and Leone (2002), Berk, Green, and Naik (2004), Hsu (2009), Li (2011), Lin (2012), and Hsu, Lee, and Zhou (2022) (2020)).

https://doi.org/10.1017/S002210902100020X Published online by Cambridge University Press

premium or mispricing. Finally, we examine the relationship between firms' R&D intensity and operating performance, return volatility, and probability of default.

Using a panel of public firms listed in 21 countries with stock returns from 1981 July to 2018 June,[5] we find that R&D-intensive firms are associated with higher subsequent stock returns. Our primary proxy for R&D intensity, R&D_ME, is defined as a firm's annual R&D expenditure divided by its market capitalization.[6] We use U.S. dollar returns in all our analyses, so our empirical results may naturally have practical investment implications for a U.S. individual who invests globally.

In 1-way portfolio sorts, we group all stocks reporting R&D expenditure from fiscal year $t-1$ into quintile portfolios at the end of June of year t by their R&D intensity, and then track the equal- and value-weighted portfolio returns for the 12 months starting from July of year t to June of year $t+1$. We consider both global sorts and country-neutral sorts. In the global sorts, the top quintile portfolio outperforms the bottom one by 1.024% (0.537%) per month in equal-weighted (value-weighted) returns. When we conduct country-neutral sorts by sorting all stocks reporting R&D expenditure within each country into quintile portfolios and then combining them,[7] we find that the top quintile portfolio outperforms the bottom one by 0.636% (0.531%) per month in equal-weighted (value-weighted) returns. Similar results are found when we exclude U.S. firms from our sample. Furthermore, we find that these top-minus-bottom return spreads generally cannot be explained by the international return factors of Hou et al. (2011).

To accommodate the different propensity to invest in R&D between large and small firms (e.g., Acs and Audretsch (1987); Cohen, Levin, and Mowery (1987); Li (2011)), we sort all stocks first by USD market capitalization then by R&D intensity into 5×5 quintiles. We find that the R&D effect is not concentrated in smaller or larger firms. Controlling for size does not erode the R&D effect: the equal- and value-weighted average returns of the 5 portfolios in the high R&D intensity quintile still significantly outperform the average returns of the 5 portfolios in the low R&D intensity quintile by 0.665% and 0.670% per month, respectively.

We consider multiple robustness checks. First, capitalization of R&D expenditure may create a potential lead–lag relationship with future stock returns. Therefore, we augment R&D expenditure with its capitalization in the numerator of R&D intensity measures and repeat all analyses. We find that the results are very similar. Second, we also use different denominators such as total assets, book equity (BE), or sales to measure R&D intensity. We find that return predictability remains strong when we use total assets and BE. Scaling R&D expenditure with sales is the only exception, which is consistent with the evidence in the existing literature. Third,

[5]Many countries are excluded because they do not have a sufficient number of firms with nonmissing and nonzero R&D records in the cross-section.

[6]We conduct various robustness checks (e.g., accounting for the capitalization of R&D, using total assets as the denominator). Generally, we find consistent results. More discussions are provided in Section III.

[7]The country-neutral sorts mitigate the influence of large numbers of firms with extreme values from developed countries and also appropriately control for different accounting standards and tax treatments for R&D across countries.

to also mitigate any industry effect in our portfolio sorts analysis, we construct a matched sample, in which we pair every firm with positive R&D expenditure with a control firm with either zero or a missing value of R&D expenditure; further, this control firm, which is in the same industry in the same country, is also of similar size and shares a similar BM. We then calculate the positive-R&D firm's industry-adjusted monthly return as its monthly return minus the monthly return of its control firm, and then perform the same portfolio analysis based on the industry-adjusted return. When we do so, we still find significantly positive return spreads.

Fama–MacBeth regressions including country and industry fixed effects suggest that the return-predictive power of R&D intensity remains significant after controlling for size, book-to-market, momentum (MOM), profitability, and asset growth (AG). When U.S. firms are included (excluded), the slopes on R&D intensity range from 0.038 to 0.065 (0.029 to 0.048) per month using ordinary least squares (OLS) regressions. We obtain similar results when we use market equity to weigh the Fama–MacBeth regressions, and the slopes on R&D intensity range from 0.040 to 0.085 (0.028 to 0.048) per month. Our analyses suggest that the R&D effect exists in international equity markets and cannot be attributed to exposure to existing risk factors and firm characteristics. We also note that the influence of country-specific factors (e.g., currency risk and political and economic uncertainty) on the R&D effect has been mitigated in our results based on country-neutral sorts and Fama–MacBeth regressions including country fixed effects.

We then study the role of country-specific variables in driving the cross-country variation in return predictability. The idea is to quantify the magnitude of the R&D effect in each country in a month, and then examine if the effect can be explained by country-level proxies that reflect risk premium or mispricing following Watanabe et al. (2013) and Eisdorfer et al. (2018). We use 4 measures to quantify the R&D effect for each country in every month: R&D return spreads (both equal- and value-weighted) and R&D slopes (both OLS and weighted least squares (WLS)). For each country in every month, we group all stocks reporting R&D expenditure into quintile portfolios based on R&D intensity and then track the equal- and value-weighted returns of the top-minus-bottom portfolio to form country-specific R&D return spreads. To form country-specific R&D slopes, we conduct cross sectional regressions to calculate the slope of stock returns on R&D intensity across all firms in one country in each month using OLS and WLS regressions. These 4 measures exhibit substantial variation of the R&D effect across countries.

The country-level proxies for the risk premium explanation consist of dispersions in 2 common measures of growth option values: price-dividend ratios (PE) and the present value of growth options (PVGO) (Cao, Simin, and Zhao (2008)). Theoretically, technological innovation generates growth options and thus commands risk premium in the cross section (Carlson, Fisher, and Giammarino (2004), Garleanu, Panageas, and Yu (2012), Kumar and Li (2016), and Hsu, Lee, and Zhou (2022)). Therefore, we expect that a large dispersion in the market value of growth options suggests that the risk premium of growth options is more likely to be priced. Then, if the R&D effect is indeed driven by risk generated from growth options, we expect it to be more pronounced in countries with larger dispersions in growth option values.

The country-level proxies for the mispricing explanation consists of market frictions and behavioral biases. To proxy for country-level market frictions, we consider 3 limits-to-arbitrage proxies: short-sale permission (SHORT; Bris, Goetzmann, and Zhu (2007), McLean et al. (2009)), idiosyncratic volatility (Li and Zhang (2010)), and dollar trading turnover (DVOL, Watanabe et al. (2013)). If the R&D effect is driven by mispricing and cannot be corrected by arbitrageurs due to higher costs and risks, then it should be more pronounced in those countries with stronger limits-to-arbitrage. On the other hand, to proxy for country-level behavioral biases, we consider 2 sentiment measures: the number of newly listed firms and volatility premium (PVOL), both proposed by Baker, Wurgler, and Yuan (2012). If the R&D effect is driven by investors' behavioral biases (mainly "high-tech fad"), then it is expected to be correlated with these sentiment proxies.

When we regress measures of country-level R&D effects on country proxies for dispersions in growth option values, limits-to-arbitrage, or sentiments, we find that both R&D spreads and slopes are significantly related to dispersions in growth option proxies but not to limits-to-arbitrage or sentiment proxies. These results indicate that, in countries with larger dispersions in growth option values, stock returns are more sensitive to R&D activities as these markets more likely recognize the value of growth options driven by R&D investments. Thus, our country-level analyses support that the R&D effect is attributable to risk premium rather than mispricing.

Lastly, we examine the relation between R&D investments and future operating performance, future return volatility, and future probability of default, since growth options are valuable yet entail higher systematic risk, and also since the exercise of growth options leads to changes in operations (Bloom and van Reenen (2002), Chambers et al. (2002)). Fama–MacBeth regression results indicate that R&D-intensive firms are associated with higher future operating performance, return volatility, and default likelihood; all these results collectively support that the R&D effect is closely related to risk premium.

This article contributes to the empirical asset pricing literature in two ways. First, we find that globally R&D-intensive firms are associated with higher subsequent stock returns, which serves as out-of-sample evidence for prior findings in the U.S. Thus, our study further extends the studies of asset pricing anomalies to an international setting, following Griffin (2002), McLean et al. (2009), Hou et al. (2011), and Watanabe et al. (2013).

Second, we present both country- and firm-level evidence supporting a risk-based explanation for our findings: R&D investments increase firms' growth options and thus lead to higher expected stock returns as growth options are risky. Our results thus support the implications of previous theoretical models of Berk, Green, and Naik (1999), Carlson et al. (2004), Zhang (2005), Garleanu et al. (2012), Ai and Kiku (2013), and Kogan and Papanikolaou (2014).

The rest of the article is organized as follows: Section II describes the data sources and variable construction. Section III presents our portfolio and regression analyses for the R&D-return relation. Section IV examines if country factors can explain the variation in the R&D effect. Section V relates R&D intensity to future operating performance, return volatility, and default likelihood. Section VI concludes.

II. Data

We obtain the data on stock market variables and company accounting items for international public firms from Thomson-Reuters Datastream and Worldscope databases. Our sample covers 21 countries/markets for which stock returns and nonmissing R&D data are available. They are Australia, Canada, China, Finland, France, Germany, Greece, Hong Kong, India, Israel, Italy, Japan, Malaysia, Singapore, South Korea, Sweden, Switzerland, Taiwan, Turkey, the U.K., and the U.S. We consider only firms listed in the largest stock exchange in most countries except China (Shanghai and Shenzhen), Japan (Tokyo and Osaka), and the U.S. (NYSE, Amex, and Nasdaq). Since data errors are common in international return data, we impose the standard return filters suggested by Ince and Porter (2006) to ensure the quality of the data from the Datastream database.[8] We also follow McLean et al. (2009) to winsorize all variables from the Worldscope database at the top and bottom 1 percentiles of their distributions within each country. We take a U.S. investor's perspective and report all results on returns denominated in U.S. dollars. Firms in financial industries with Datastream industry codes (INDM) corresponding to the 4-digit SIC (Standard Industrial Classification) codes between 6,000 and 6,999 are removed from our sample.

Our primary measure for R&D intensity for firm i in year t is R&D_ME, which is defined as firm i's annual R&D expenditure (Worldscope data item WC01201) divided by the firm's market capitalization (WC08001) in fiscal year t.[9] It is worth noting that about 70% of firm-year observations in our sample report either missing or zero R&D expenditure. Following the literature (Chan et al. (2001), Eberhart et al. (2004)), we only include firm-year observations with positive R&D expenditure in our analysis.

Our sample consists of 418,067 firm-year observations when the U.S. is included and 319,261 observations when the U.S. is excluded. The country-level summary statistics for the sample that includes the U.S. is reported in Table 1. We note that the data for most developed countries are available from the early 1980s, whereas the data coverage for emerging countries is more limited. Most developed

[8]If r_t and r_{t-1} are the gross returns in month t and $t-1$, we set r_t and r_{t-1} to missing if r_t or r_{t-1} is greater than 300% and $(1+r_t)(1+r_{t-1})-1<50\%$. We also eliminate all monthly observations for delisted stocks from the end of the sample period to the first nonzero return date since Datastream keeps padding the last available return after the delisting date.

[9]We acknowledge that R&D investments can be capitalized in some countries or after the adoption of the International Financial Reporting Standards (IFRS); thus, we consider alternative definitions of R&D intensity by including capitalized R&D following Kress, Eierle, and Tsalavoutas (2019) and Mazzi, Slack, Tsalavoutas, and Tsoligkas (2019). Our results based on these alternative measures are discussed in Section III. It is worth noting that we scale R&D expenditure using firm's market capitalization following Chan et al. (2001) and Mazzi et al. (2019). Chan et al. (2001) argue that "Our second measure of intensity, the ratio of R&D expenditure to the market value of equity, is more in keeping with many indicators that are widely used in financial economics… such as earnings- or book-to-price ratios" (pp. 2437–2438). Moreover, they argue that return predictability reflects how market investors perceive firms' R&D expenditures and, in turn, impound such information in stock prices. Also, Mazzi et al. (2019) study the R&D capitalization under IFRS and also scale R&D investment with market equity. Nevertheless, for the sake of completeness, we scale R&D expenditure by total assets and discuss our results in Section III.

TABLE 1

Sample Descriptive Statistics

Table 1 provides the summary statistics for the 21 markets from the Datastream-Worldscope sample. Columns 2 and 3 report the beginning and ending dates during which each country is included in our sample. Each country's total number of firm-year observations, the average number of firms per year, and the average annual total market capitalization in millions of U.S. dollars are provided in columns 4, 6, and 8, respectively. The values of these statistics represented as percentages of the corresponding total value across all countries are given in columns 5, 7, and 9, respectively. The last 2 columns report the medians and standard deviations of the R&D intensity (R&D_ME), which is defined as annual R&D expenses scaled by market value, for each market.

Country	Start Date	End Date	Firm-Year Obs.	% of Total Obs.	No. of Firms per Year	% of Total Firm	Total Mkt Value (USD$M)	% of Total Mkt Value	R&D_ME Median (%)	R&D_ME Std. Dev. (%)
Australia	198107	201806	22,669	5.42	613	5.17	324,303	1.85	6.15	11.06
Canada	198107	201806	27,496	6.58	743	6.27	572,460	3.27	9.62	17.54
China	199107	201806	26,586	6.36	1,023	8.63	1,331,089	7.60	1.01	1.25
Finland	198707	201806	3,158	0.76	105	0.89	168,686	0.96	5.04	6.51
France	198107	201806	10,818	2.59	292	2.47	869,133	4.97	8.86	13.14
Germany	198107	201806	11,587	2.77	313	2.64	696,056	3.98	9.04	11.77
Greece	198807	201806	4,021	0.96	139	1.17	27,725	0.16	4.26	11.00
Hong Kong	198107	201806	9,799	2.34	265	2.24	334,016	1.91	2.99	4.90
India	198107	201806	22,265	5.33	618	5.22	293,097	1.67	1.17	2.44
Israel	198607	201806	3,886	0.93	125	1.06	49,794	0.28	13.48	23.51
Italy	198107	201806	4,753	1.14	128	1.08	270,394	1.54	7.83	10.22
Japan	198107	201806	62,306	14.90	1,684	14.21	2,223,320	12.70	4.26	5.26
Malaysia	198107	201806	12,587	3.01	350	2.95	112,598	0.64	0.85	1.61
Singapore	198107	201806	4,492	1.07	121	1.02	103,703	0.59	4.09	8.08
South Korea	198107	201806	26,964	6.45	749	6.32	336,394	1.92	2.97	4.22
Sweden	198207	201806	5,893	1.41	168	1.42	207,903	1.19	6.22	9.00
Switzerland	198107	201806	6,328	1.51	171	1.44	523,049	2.99	7.38	10.03
Taiwan	198710	201806	12,790	3.06	426	3.60	299,835	1.71	3.63	4.49
Turkey	198807	201806	4,973	1.19	171	1.45	60,188	0.34	1.19	1.85
U.K.	198107	201806	35,890	8.58	970	8.19	1,457,143	8.32	5.44	9.18
U.S.	198107	201806	98,806	23.63	2,670	22.54	7,242,410	41.38	8.01	12.29
All			418,067	100.00	11,847	100.00	17,503,295	100.00	5.52	10.03
All excluding the U.S.			319,261	76.37	9,176	77.46	10,260,886	58.62	4.54	8.36

countries enter our sample in July 1981, whereas Greece, Turkey, and China are the latest entrants (1988, 1988, and 1991, respectively). U.S. firms account for 23.63% of our total firm-year observations and 41.38% of the total market capitalization. In Table 1, we report the median and standard deviation of R&D intensity. We find that firms in Israel lead the world in terms of R&D intensity with a median of 13.48%. We also observe considerable cross-country variation in the statistics of R&D intensity, with the median ranging from 0.85% (Malaysia) to 13.48% (Israel) and the standard deviation ranging from 1.25% (China) to 23.51% (Israel).

Our sample coverage of 21 countries may look narrower compared to the literature. For example, both McLean et al. (2009) and Watanabe et al. (2013) include 41 countries in their studies on international capital markets. Karolyi, Lee, and van Dijk (2012) study a sample of 40 countries. The sample used in Hou et al. (2011) broadly includes 49 countries. We have to exclude many countries from emerging markets, as our cross-country analysis requires a reliable estimate of the country-level R&D effect, which in turn requires a sizeable cross section of stocks with positive R&D expenditure within each market in a given year, to mitigate the concern that our estimate may be driven by only a few firms. Nevertheless, our sample consists of both developed countries and emerging markets, rather than solely a specific region. We explain our data requirements in further detail in the next section.

https://doi.org/10.1017/S002210902100020X Published online by Cambridge University Press

III. Empirical Analysis

A. Portfolios Analysis

We use 3 different 1-way portfolio sorts to examine the R&D effect. To ensure that our portfolios do not include micro-caps that are hard to trade, we exclude the bottom 10% of firms based on the market value for each country. In addition, we require each country-month cross section to have at least 50 firms to be included in our analysis. Our first approach is global sorts, in which we rank all sample firms by their R&D intensity measures in year $t-1$ and then group them into 5 equal-sized portfolios at the end of June in year t. The low quintile contains the 20% of firms with the lowest R&D intensity, while the high quintile consists of the 20% with the highest R&D intensity. Then, for each month from July in year t to June in year $t+1$, we calculate the equal- and value-weighted returns of each portfolio. Table 2 reports that the 5 quintile portfolios (from low to high) produce equal-weighted returns of 0.950%, 1.041%, 1.238%, 1.488%, and 1.974% per month. The return spread between the high and low quintiles is 1.024% per month with a t-statistic of 5.23. The value-weighted returns of the 5 quintile portfolios (from low to high) are 0.687%, 0.864%, 0.953%, 1.132%, and 1.224% per month. The return spread between the high and low quintiles is 0.537% per month with a t-statistic of 3.34. Our finding that the equal-weighted spread is more significant than the value-weighted one is consistent with Chan et al. (2001) and Eberhart et al. (2004), (2008), and suggests that substantially higher subsequent returns for more intensive R&D investments are more pronounced among smaller firms.

Our second approach uses country-neutral sorts, in which we rank all firms in a country by their R&D intensity measures in year $t-1$ and then group them into

TABLE 2

One-Way Sorted Portfolio Returns

Table 2 reports the monthly returns (in percentage) on R&D intensity (R&D_ME) sorted portfolios. At the end of June of each year, we sort stocks into 5 R&D intensity quintiles by their R&D intensity in year $t-1$ using 3 approaches: global sorting, country-neutral, and country-neutral excluding the U.S. For country-neutral sorting, we rank all sample firms in 1 country by their R&D intensity measures in year $t-1$. We first compute the quintile equal- or value-weighted returns within each country and then calculate the average to obtain the country-neutral portfolio returns. We then compute the equal-weighted and value-weighted returns on the resulting 5 portfolios and the return spreads between the top and bottom R&D_ME quintiles (High–Low). Equal- and value-weighted returns are computed from July of year t to June of year $t+1$. The sample period is from July of 1981 to June of 2018. The rows labeled "t-stat" show t-statistics for the High–Low return spreads. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

	Global		Country-Neutral		Country-Neutral (Non-U.S.)	
Weighting	Equal	Value	Equal	Value	Equal	Value
Low R&D_ME	0.950	0.687	1.005	0.844	1.148	0.938
	(3.61)	(3.00)	(4.20)	(3.48)	(4.23)	(3.37)
	1.041	0.864	1.107	1.096	1.292	1.267
	(4.13)	(4.04)	(4.56)	(4.70)	(4.76)	(4.74)
	1.238	0.953	1.171	1.015	1.305	1.073
	(5.03)	(4.36)	(4.77)	(4.22)	(4.82)	(3.98)
	1.488	1.132	1.365	1.120	1.441	1.213
	(5.98)	(4.95)	(5.38)	(4.33)	(5.24)	(4.22)
High R&D_ME	1.974	1.224	1.641	1.375	1.725	1.493
	(6.80)	(4.83)	(6.19)	(4.95)	(6.06)	(4.85)
High–Low	1.024***	0.537***	0.636***	0.531***	0.577***	0.555***
t-stat	(5.23)	(3.34)	(6.02)	(3.59)	(4.71)	(3.37)

5 quintile portfolios at the end of June in year t. We first compute the quintile equal- or value-weighted returns within each country and then average across countries to arrive at the country-neutral portfolio returns. In comparison with global sorts, country-neutral sorts not only avoid that some quintiles are dominated by firms from specific countries, but also appropriately control for different accounting standards and tax treatments for R&D across countries. The averages of the equal-weighted returns of the high and low portfolios are 1.641% and 1.005%, respectively; the averages of the value-weighted returns of the high and low portfolios are 1.375% and 0.844%, respectively. The return spread between the high and low quintiles based on equal-weighted returns is 0.636% (t = 6.02), whereas the return spread based on value-weighted returns is 0.531% (t = 3.59).

To better examine if the R&D effect still holds in international capital markets other than the U.S., our third approach then is country-neutral sorts without U.S. firms. Using this approach, we examine if the R&D effect still holds outside the U.S. The spread based on equal-weighted returns is a statistically significant 0.577% (t = 4.71), whereas the spread based on value-weighted returns is again a statistically significant 0.555% (t = 3.37). The consistent results from the 3 sorting procedures suggest that the R&D-return relation is a global phenomenon and serve as out-of-sample evidence for the R&D effect reported in U.S.-based studies.

To further separate the R&D effect from the size effect, we conduct 2-way portfolio sorting based on market capitalization and R&D intensity. We rely on global sorts to ensure a proper number of firms in each group. Specifically, all sample firms are ranked by U.S. dollar-denominated market value at the end of year $t-1$ and then sorted into 5 size quintile portfolios at the end of June in year t. Subsequently, all firms within each size quintile are ranked by their R&D intensity in year $t-1$ and then sorted into 5 R&D quintile portfolios in the beginning of July in year t. This 2-way sorting results in 25 portfolios, and the equal- and value-weighted returns of these portfolios are calculated from July in year t to June in year $t+1$.

Table 3 shows that the R&D effect exists within all size groups for both equal- and value-weighted portfolios (Panels A and B, respectively). We calculate the high-minus-low spread for the high and low R&D intensity portfolios within each size quintile. The return spreads and associated t-statistics are presented in the rightmost columns of 2 panels. In Panel A, the high-minus-low spreads of the 5 size quintile portfolios (from small to big) are 0.649%, 0.769%, 0.667%, 0.829%, and 0.413% per month with t-statistics of 2.43, 3.01, 2.47, 3.85, and 2.42, respectively. In addition, a size-neutral high-minus-low spread is calculated by averaging the high-minus-low spreads across size quintiles following Fama and French (1993), and appears to be substantial (the average is 0.665% with a t-statistic of 6.24), which is close to the 1-way equal-weighted spread from global sorting in Table 2 (0.76%). This number is reported at the bottom of the high-minus-low R&D-return spread in the rightmost column of Panel A.

We report similar results in Panel B, based on value-weighted portfolios. The high-minus-low spreads of the 5 size quintile portfolios (from small to big) are 0.657%, 0.758%, 0.696%, 0.832%, and 0.407% per month with t-statistics of 2.51, 2.94, 2.58, 3.97, and 2.18, respectively. In addition, the size-neutral high-minus-

TABLE 3

Two-Way Sorted Portfolio Returns: Controlling for Size

Table 3 reports the monthly returns (in percentage) on 2-way sorted portfolios, which measure the R&D effect after controlling for firm size. At the end of June of each year, we conduct sequential sorts by grouping all stocks by firm size quintiles first and then grouping all stocks into R&D_ME quintiles within each size quintile. We then compute the equal-weighted (Panel A) and value-weighted (Panel B) returns on the resulting 25 portfolios and the return spreads between the top and bottom R&D_ME quintiles (High–Low) within each size group. Finally, we average these return spreads and report this average and associated *t*-statistics in the last column. Returns are computed from July of year *t* to June of year *t*+1. The sample period is from July of 1981 to June of 2018. *t*-statistics are reported in parentheses. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

	Low R&D_ME	2	3	4	High R&D_ME	High–Low
Panel A. Equal-Weighted Portfolios						
Small	1.926	1.790	1.842	2.213	2.575	0.649
	(6.02)	(6.38)	(6.86)	(7.92)	(7.72)	(2.43)
	1.073	1.142	1.189	1.332	1.842	0.769
	(3.68)	(4.20)	(4.46)	(4.93)	(5.52)	(3.01)
	0.790	1.044	1.145	1.337	1.457	0.667
	(2.63)	(3.56)	(3.94)	(4.72)	(4.51)	(2.47)
	0.660	0.774	1.086	1.248	1.489	0.829
	(2.27)	(2.72)	(4.00)	(4.65)	(4.96)	(3.85)
Large	0.853	0.814	1.029	1.200	1.266	0.413
	(3.49)	(3.40)	(4.33)	(4.88)	(4.86)	(2.42)
						0.665***
						(6.24)
Panel B. Value-Weighted Portfolios						
Small	1.682	1.582	1.597	2.009	2.339	0.657
	(5.23)	(5.65)	(5.86)	(7.03)	(7.06)	(2.51)
	1.053	1.157	1.198	1.334	1.811	0.758
	(3.58)	(4.24)	(4.48)	(4.92)	(5.45)	(2.94)
	0.755	1.036	1.129	1.321	1.452	0.696
	(2.49)	(3.53)	(3.86)	(4.65)	(4.51)	(2.58)
	0.682	0.763	1.081	1.240	1.514	0.832
	(2.34)	(2.70)	(4.00)	(4.60)	(5.14)	(3.97)
Large	0.719	0.876	0.949	1.090	1.126	0.407
	(3.11)	(4.14)	(4.34)	(4.76)	(4.22)	(2.18)
						0.670***
						(6.26)

low spread, reported at the bottom of the high-minus-low R&D-return spread in the rightmost column, is similar to that of Panel A, at 0.670% with a *t*-statistic of 6.26.

These results confirm the global existence of the R&D effect. Compared to our findings in Table 2, we find a sharper contrast in the returns between high and low R&D intensity portfolios along the size groups. Overall, we conclude that the R&D-return relation is statistically significant in small, medium-sized, and large firms.

The R&D effect in Table 2 may be attributed to higher risk exposures to international risk factors. Thus, we regress the high-minus-low spreads from Table 2 on the 3 factors proposed by Hou et al. (2011), which include a global market factor (Rm_rf), a global cash flow-to-price factor ($F_{C/P}$), and a global MOM factor (F_{MOM}).[10] In Table 4, we find that the alphas from the 3-factor model are smaller but still close to the raw return spreads in magnitude. For example, the alpha from the equal-weighted global sorts is 0.809% ($t = 3.341$), which is close to

[10]The original factors from Hou et al. (2011) are up to 2010 only. We closely follow their procedures and use their sample of countries (not the smaller R&D sample of countries) to extend the factors up to June 2018.

TABLE 4

Time-Series Regression with the Factors of Hou et al.

Table 4 examines the risk-based models' explanatory ability of R&D intensity for portfolio returns. We conduct factor regressions of equal- and value-weighted return spreads separately, using the Hou et al. (2011) factor pricing model. These return spreads are High–Low from Table 2 and are constructed by using global sorts, country-neutral sorts, and country-neutral sorts that exclude U.S. firms. Returns are computed from July of year t to June of year $t+1$. The model of Hou et al. (2011) includes a global market factor (Rm_rf), a global cash flow-to-price factor ($F_{C/P}$), and a global momentum factor (F_{MOM}). The sample period is from July of 1981 to June of 2018. The t-statistics based on Newey–West adjusted for time-series autocorrelation are reported in parentheses. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

	Global		Country-Neutral		Country-Neutral (Non-U.S.)	
Weighting	Equal	Value	Equal	Value	Equal	Value
Alpha	0.809***	0.363**	0.598***	0.422***	0.541***	0.523***
	(3.341)	(2.310)	(4.442)	(2.801)	(3.884)	(3.293)
Rm_rf	−0.01	0.074	0.049*	0.118***	0.052	0.085*
	(−0.209)	(1.471)	(1.803)	(2.798)	(1.569)	(1.734)
F_{MOM}	0.137	0.017	0.013	0.009	−0.006	−0.026
	(1.341)	(0.253)	(0.303)	(0.144)	(−0.154)	(−0.422)
$F_{C/P}$	0.280***	0.238***	0.009	0.135**	0.015	0.160**
	(2.596)	(3.342)	(0.202)	(2.115)	(0.310)	(2.474)
R^2	8.182	5.876	0.844	3.709	0.769	3.099

the equal-weighted high-minus-low spread of 1.024%. More importantly, we find that the alpha from the value-weighted global sorts is a positive 0.363% with a t-statistic of 2.310. We obtain similar evidence on country-neutral sorts either with or without the U.S. Overall, these results suggest that the R&D effect cannot be explained by common risk factors in global stock returns. In addition, we also find that the R&D spreads load positively on the global cash flow-to-price factor and sometimes on the global market factor, but are not significantly related to the global MOM factor at all.

Overall, all results in Tables 2–4 based on portfolio sorts and factor regressions provide strong support for an R&D effect in international stock returns.

B. Fama–MacBeth Regressions

Lev et al. (2005) and subsequent studies employ Fama–MacBeth regressions to examine whether the U.S. R&D effect is robust when we control for the return predictability of firm characteristics, such as size and BM. In this section, we employ the same approach to examine the international R&D effect and include additional controls such as MOM, return on equity (ROE), AG, industry fixed effects, and country fixed effects.

In each month from July of year t to June of year $t+1$, we regress the returns of all stocks from all sample countries on corresponding R&D intensity (R&D_ME), size (ME), BM, MOM, ROE, AG, industry fixed effects, and country fixed effects. ME is the natural logarithm of market capitalization of the prior month. BM is defined as the natural logarithm of the book value in fiscal year $t-1$ scaled by market capitalization of the prior month. MOM is defined as the cumulative return from Jan. to May in year t. ROE is defined as net income minus preferred dividends over common equity in fiscal year $t-1$, and AG is defined as the change of total assets over lagged total assets in fiscal year $t-1$. It is necessary for us to control for industry fixed effects because there is substantial cross-industry variation in R&D expenditure and intensity due to the different natures of industries (e.g., Chan et al. (2001)); also, the cost of capital varies across industries (Fama and French (1997)). More importantly, we also include country fixed effects because country-level attributes such as accounting rules and political instability may affect the level of stock returns in a particular country.

Table 5 reports the time-series averages and associated *t*-statistics of the estimated coefficients from cross sectional regressions. We proceed first with the simple regression such that the R&D intensity is the only return predictor. We then add more controls, starting with country fixed effects, then both country and industry fixed effects, then ME, BM, MOM, and finally also ROE and AG, one group at a time. For brevity's sake, we do not report the average coefficients on industry and country fixed effects.

Based on OLS Fama–MacBeth regressions, Panel A presents our results when we use all 21 countries and Panel B presents our results when we exclude U.S. firms. In Panel A, we find that the average coefficients of R&D intensity range from 0.038 to 0.065 per month with the smallest *t*-statistic of 4.001 and the largest *t*-statistic of 5.329. When we only control for industry and country fixed effects, the average coefficient of R&D intensity is 0.057 per month. This estimate changes to 0.042 per month when 3 commonly used firm characteristics (ME, BM, and MOM) are added to the regression. When we further control for ROE and AG, the average coefficient of R&D intensity becomes 0.038, which is still highly significant. We find similar yet slightly weaker results in Panel B, in which the average coefficient of R&D intensity is 0.029 ($t = 3.737$) per month after we control for all fixed effects and firm characteristics.

We report in Panel C the results of WLS Fama–MacBeth regressions, in which the weight is each firm's market value denominated in U.S. dollars at the June of year *t*. We find that the average coefficients on R&D intensity range from 0.040 to 0.085 per month with *t*-statistics ranging from 2.222 to 3.649. When we only control for industry and country fixed effects, the average coefficient of R&D intensity is 0.080 per month. This value changes to 0.047 per month when we control for ME, BM, and MOM. When we further include ROE and AG, the average coefficient of R&D intensity becomes 0.040. Again, we find similar yet weaker results in Panel D, in which we exclude U.S. stocks; the average coefficient on R&D intensity is 0.028 ($t = 2.264$) per month after we control for all fixed effects and firm characteristics.

Overall, our predictive regression results strongly support the existence of an R&D effect in international equity markets, and further suggest that this R&D effect is not driven by common firm characteristics.

C. Robustness Checks

1. Alternative Definitions of R&D Intensity

One concern about our results is that countries may adopt different accounting standards regarding R&D expenditure. For example, there are important differences in the treatment of R&D expenditure between the IFRS and the GAAP

TABLE 5

Fama–MacBeth Regressions

Table 5 reports the time-series averages and *t*-statistics of the coefficients from cross sectional regressions of individual stock returns on R&D intensity, control variables, and country and industry fixed effects. Panel A reports the OLS regression results for all countries, Panel B reports the OLS regression results for all countries excluding the U.S., Panel C reports the WLS regression results for all countries, and Panel D reports the WLS regression results for all countries excluding the U.S. The dependent variable, monthly stock return, is measured during the first year holding horizon after June of year *t*. The control variables include ME (the natural logarithm of June-end market value of year *t*), BM (the natural logarithm of the year *t* − 1 fiscal year-end book-to-market ratio), MOM (the year *t* Jan.-to-May returns), ROE (return on equity of fiscal year *t* − 1), and AG (asset growth of fiscal year *t* − 1). The coefficients on country/industry fixed effects are suppressed to save space. The Newey–West *t*-statistics are adjusted for time-series autocorrelation and reported in parentheses. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

Panel A. OLS Fama–MacBeth Regressions – All Countries

R&D_ME	0.065***	0.062***	0.057***	0.042***	0.038***
	(4.963)	(5.109)	(5.329)	(4.307)	(4.001)
ME				−0.001***	−0.001**
				(−2.641)	(−2.583)
BM				0.007***	0.007***
				(7.092)	(7.140)
MOM				0.003	0.002
				(1.337)	(1.193)
ROE					0.000
					(0.248)
AG					−0.003***
					(−4.798)
Cty		Yes	Yes	Yes	Yes
Ind			Yes	Yes	Yes
R^2	0.007	0.095	0.114	0.123	0.126

Panel B. OLS Fama–MacBeth Regressions – Non-U.S.

R&D_ME	0.044***	0.048***	0.042***	0.033***	0.029***
	(3.855)	(4.904)	(5.650)	(4.261)	(3.737)
ME				−0.001**	−0.001**
				(−2.228)	(−2.378)
BM				0.008***	0.008***
				(7.912)	(8.147)
MOM				0.007***	0.006***
				(3.206)	(3.199)
ROE					0.002
					(0.895)
AG					−0.007***
					(−3.914)
Cty		Yes	Yes	Yes	Yes
Ind			Yes	Yes	Yes
R^2	0.008	0.143	0.173	0.181	0.186

Panel C. WLS Fama–MacBeth Regressions – All Countries

R&D_ME	0.085***	0.078***	0.080***	0.047**	0.040**
	(3.649)	(3.350)	(3.189)	(2.586)	(2.222)
ME				−0.006***	−0.006***
				(−6.945)	(−6.335)
BM				0.004	0.005
				(0.898)	(1.082)
MOM				−0.009	−0.010
				(−1.015)	(−1.090)
ROE					0.001
					(0.164)
AG					−0.009*
					(−1.913)
Cty		Yes	Yes	Yes	Yes
Ind			Yes	Yes	Yes
R^2	0.009	0.069	0.140	0.152	0.165

(continued on next page)

TABLE 5 (continued)

Fama–MacBeth Regressions

Panel D. WLS Fama–MacBeth Regressions – Non-U.S.

R&D_ME	0.048***	0.038**	0.036***	0.030**	0.028**
	(2.904)	(2.391)	(2.862)	(2.306)	(2.264)
ME				−0.005***	−0.004***
				(−5.815)	(−4.993)
BM				0.009***	0.009***
				(5.512)	(4.666)
MOM				0.003	0.002
				(0.769)	(0.386)
ROE					0.001
					(0.174)
AG					−0.007**
					(−2.509)
Cty		Yes	Yes	Yes	Yes
Ind			Yes	Yes	Yes
R^2	0.018	0.148	0.276	0.284	0.301

regimes. Under IFRS, R&D expenditure can be capitalized and amortized in subsequent periods. To examine the role that the capitalization and amortization play with respect to R&D intensity, we adopt 2 revised definitions of R&D intensity: R&D_ME* and R&D_ME**. The numerator of R&D_ME* is the sum of R&D expenditure (WC01201) and capitalized R&D (which is the sum of the amortization of R&D assets (WC01153) and the change in net development costs (WC02504)).[11] The numerator of R&D_ME** is the sum of R&D expenditures (WC01201) and the change in the gross value of capitalized expenditures relating to development (WC02505).[12] We implement our main tests (i.e., 1-way sorts, 2-way sorts, factor regressions, and Fama–MacBeth regressions) using these 2 alternative measures, and present the results in Table 6 and Supplementary Tables S1–S6. Overall, these test results are fairly consistent with our previous findings. For example, in the sample without U.S. firms, the low and high country-neutral value-weighted R&D_ME* average monthly returns are respectively 0.946% (t = 3.39) and 1.486% (t = 4.81), yielding a high-minus-low return spread of 0.540% (t = 3.15). These estimates and t-values are all very similar to their counterparts in Table 2.

We also consider total assets (TA), BE, and sales (S) as 3 alternative denominators in calculating R&D intensity (Hall (1993), Lev and Sougiannis (1996)). Results using R&D intensity based on total assets (R&D_TA) are reported in Panel A of Table 7. We first find that the R&D_TA has predictive power for global-sorted stock portfolios and equal-weighted country-neutral portfolios. Although the return spreads for value-weighted country-neutral portfolios are not strong, however, this

[11]We are very grateful to the reviewer for this suggestion. The definition follows Kress et al. (2019) and Mazzi et al. (2019); the latter adopts a setting around IFRS. As noted in the Worldscope data definitions guide, these items are generally not available prior to 2006. Their coverage is also limited in comparison to R&D expenditure. Therefore, when the value of capitalized R&D is missing, we simply use the nonmissing value of R&D expenditure alone.

[12]As this item begins no earlier than 2006, and again when it is missing, we rely on R&D expenditure to represent R&D intensity.

TABLE 6

One-Way Sorted Portfolio Returns Based on R&D_ME* and R&D_ME**

Table 6 reports the monthly returns (in percentage) on 2 alternative measures sorted portfolios. In Panel A, the first alternative R&D intensity is R&D_ME*, defined as the sum of R&D expenditure (item01201) and capitalized R&D (which is sum of change in development cost – net (item02504) and amortization of R&D asset (item01153)). In Panel B, the second alternative R&D intensity is R&D_ME**, denotes the sum of R&D expenditure (item01201) and change in development cost – gross (item02505). At the end of June of each year, we sort stocks into 5 R&D intensity quintiles by their R&D intensity in year $t-1$ using 3 approaches: global sorting, country-neutral, and country-neutral excluding the U.S. For country-neutral sorting, we rank all sample firms in 1 country by their R&D intensity measures in year $t-1$. We first compute the quintile equal- or value-weighted returns within each country and then calculate the average to obtain the country-neutral portfolio returns. We then compute the equal-weighted and value-weighted returns on the resulting 5 portfolios and the return spreads between the top and bottom R&D intensity (R&D_ME* or R&D_ME**) quintiles (High – Low). Equal- and value-weighted returns are computed from July of year t to June of year $t+1$. The sample period is from July of 1981 to June of 2018. The rows labeled "t-stat" show t-statistics for the High – Low return spreads. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

	Global		Country-Neutral		Country-Neutral (Non-U.S.)	
Weighting	Equal	Value	Equal	Value	Equal	Value
Panel A. R&D/ME*						
Low R&D_ME*	0.959	0.699	1.012	0.888	1.148	0.946
	(3.64)	(2.99)	(4.22)	(3.72)	(4.21)	(3.39)
	1.056	0.849	1.127	1.121	1.301	1.289
	(4.17)	(3.85)	(4.62)	(4.77)	(4.75)	(4.80)
	1.246	0.969	1.175	0.972	1.291	1.008
	(5.04)	(4.43)	(4.79)	(4.01)	(4.77)	(3.7)
	1.484	1.119	1.412	1.172	1.488	1.277
	(5.96)	(4.88)	(5.58)	(4.53)	(5.42)	(4.45)
High R&D_ME*	1.986	1.246	1.672	1.378	1.737	1.486
	(6.83)	(4.83)	(6.27)	(4.95)	(6.07)	(4.81)
High–Low	1.027***	0.547***	0.660***	0.489***	0.590***	0.540***
t-stat	(5.26)	(3.51)	(6.32)	(3.4)	(4.77)	(3.15)
*Panel B. R&D**/ME*						
Low R&D_ME**	0.954	0.689	1.006	0.850	1.150	0.945
	(3.63)	(3.01)	(4.21)	(3.53)	(4.24)	(3.40)
	1.044	0.864	1.114	1.093	1.299	1.263
	(4.14)	(4.03)	(4.59)	(4.69)	(4.79)	(4.72)
	1.238	0.955	1.158	0.988	1.290	1.044
	(5.04)	(4.39)	(4.72)	(4.10)	(4.77)	(3.87)
	1.489	1.125	1.379	1.118	1.457	1.211
	(5.99)	(4.93)	(5.44)	(4.30)	(5.30)	(4.19)
High R&D_ME**	1.962	1.222	1.631	1.373	1.714	1.493
	(6.76)	(4.74)	(6.14)	(4.92)	(6.02)	(4.83)
High–Low	1.008***	0.533***	0.625***	0.522***	0.565***	0.548***
t-stat	(5.14)	(3.30)	(5.91)	(3.50)	(4.61)	(3.30)

concern can be addressed after we conduct 2-way sorted portfolio analysis in Supplementary Table S7, where the R&D_TA-sorted return spread is statistically significant averaging across all size groups. We also find very similar results based on book equity (R&D_BE), as shown in Panel B of Table 7 and Supplementary Table S8. On the other hand, the R&D intensity measure based on sales (R&D_S) does not predict stock returns at all (see Supplementary Tables S9 and S10), which is consistent with Chan et al. (2001) and Hou, Xue, and Zhang (2015) that use U.S. data.

2. Industry-Adjusted Returns Based on a Matched Sample

To examine if our results are sensitive to any industry effect, we follow Barber and Lyon (1996), (1997) to implement the following procedure and construct a

TABLE 7

One-Way and Two-Way Sorted Portfolio Returns Based on R&D_TA and R&D_BE

Table 7 reports the monthly returns (in percentage) on R&D/TA and R&D_BE sorted portfolios in Panel A and B. R&D_TA denotes an alternative R&D intensity in which the denominator is total assets, and R&D_BE denotes an alternative R&D intensity in which the denominator is BE (stockholders' equity minus value of preferred stock plus deferred taxes and investment tax credit). At the end of June of each year, we sort stocks into 5 R&D intensity quintiles by their R&D intensity in year $t-1$ by using 3 approaches: global sorting, country-neutral, and country-neutral excluding the U.S. For country-neutral sorting, we rank all sample firms in one country by their R&D intensity measures in year $t-1$. We first compute the quintile equal- or value-weighted returns within each country and then calculate the average to obtain the country-neutral portfolio returns. We then compute the equal-weighted and value-weighted returns on the resulting 5 portfolios and the return spreads between the top and bottom R&D_TA or R&D_BE quintiles (High–Low). Equal- and value-weighted returns are computed from July of year t to June of year $t+1$. The sample period is from July of 1981 to June of 2018. The rows labeled "t-stat" show t-statistics for the High–Low return spreads. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

	Global		Country-Neutral		Country-Neutral (Non-U.S.)	
Weighting	Equal	Value	Equal	Value	Equal	Value
Panel A. One-Way Sorted Portfolios on R&D_TA						
Low R&D_TA	1.179	0.824	1.184	1.136	1.243	1.230
	(4.63)	(3.75)	(4.97)	(4.64)	(5.05)	(4.86)
	1.180	0.837	1.242	1.046	1.319	1.135
	(5.01)	(4.01)	(5.38)	(4.42)	(5.59)	(4.7)
	1.221	0.868	1.245	0.963	1.318	1.037
	(5.09)	(3.67)	(5.18)	(3.94)	(5.34)	(4.1)
	1.377	0.985	1.441	1.189	1.506	1.255
	(5.32)	(4.24)	(5.73)	(4.81)	(5.85)	(4.92)
High R&D_TA	1.771	1.242	1.541	1.285	1.608	1.342
	(5.07)	(4.78)	(5.83)	(4.93)	(6.03)	(5.03)
High–Low	0.592**	0.418 **	0.361***	0.152	0.370***	0.116
t-stat	(2.16)	(2.22)	(3.09)	(1.13)	(3.20)	(0.90)
Panel B. One-Way Sorted Portfolios on R&D_BE						
Low R&D_BE	1.156	0.827	1.188	1.108	1.249	1.207
	(4.69)	(3.75)	(5.05)	(4.61)	(5.13)	(4.88)
	1.160	0.795	1.246	1.133	1.331	1.230
	(4.91)	(3.78)	(5.45)	(4.77)	(5.67)	(5.05)
	1.235	0.838	1.224	0.979	1.289	1.066
	(5.03)	(3.51)	(5.07)	(3.97)	(5.22)	(4.23)
	1.376	1.022	1.417	1.179	1.494	1.246
	(5.3)	(4.5)	(5.68)	(4.77)	(5.84)	(4.85)
High R&D_BE	1.729	1.142	1.560	1.251	1.626	1.311
	(5.49)	(4.83)	(5.86)	(4.75)	(6.02)	(4.81)
High–Low	0.573***	0.315**	0.370***	0.141	0.375***	0.103
t-stat	(2.63)	(2.17)	(3.18)	(1.04)	(3.20)	(0.77)

matched sample[13]: For each firm with positive R&D expenditure, we first find a control group of firms either with zero R&D expenditure or that do not report R&D expenditure in the same industry and the same country for every period. We again exclude financial firms for this exercise. After identifying the control group, we focus on firms whose market values of equity fall between 70% and 130% of the market value of equity of the sample firm. From this smaller set of firms, we finally choose a control firm with the BM closest to that of the sample firm.

We then calculate a positive-R&D firm's industry-adjusted monthly return as its monthly return minus the monthly return of its control firm, and then perform portfolio analyses based on industry-adjusted returns. When we do so, we still find a

[13]We thank our reviewer for suggesting us to consider this matching method.

TABLE 8

One-Way and Two-Way Sorted Portfolio Returns: R&D_ME and Industry-Adjusted Return

Table 8 reports the monthly industry-adjusted returns (in percentage) on R&D intensity (R&D_ME) sorted portfolios. At the end of June of each year, we sort stocks into 5 R&D intensity quintiles by their R&D intensity in year $t-1$ using 3 approaches: global sorting, country-neutral, and country-neutral excluding the U.S. For country-neutral sorting, we rank all sample firms in one country by their R&D intensity measures in year $t-1$. We first compute the quintile equal- or value-weighted industry-adjusted returns within each country and then calculate the average to obtain the country-neutral portfolio returns. A portfolio stock's industry-adjusted returns is its stock return minus the stock return on its control firm (i.e., a firm that has the closest book-to-market ratio, is in the same industry based on Industry Classification Benchmark (ICB), does not positive R&D expenses, and has market values of equity between 70% and 130% of the market value of equity of the portfolio stock). We then compute the equal-weighted and value-weighted returns on the resulting 5 portfolios and the return spreads between the top and bottom RD_ME quintiles (High–Low). Equal- and value-weighted returns are computed from July of year t to June of year $t+1$. The sample period is from July of 1981 to June of 2018. The rows labeled "t-stat" show t-statistics for the High–Low return spreads. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

	Global		Country-Neutral		Country-Neutral (Non-U.S.)	
Weighting	Equal	Value	Equal	Value	Equal	Value
Low R&D_ME	−0.015	−0.028	0.119	0.119	0.111	0.115
	(−0.28)	(−0.29)	(1.66)	(1.09)	(1.17)	(0.77)
	0.125	0.084	0.246	0.292	0.285	0.310
	(2.16)	(1.02)	(3.28)	(2.91)	(2.96)	(2.49)
	0.218	0.240	0.260	0.250	0.285	0.256
	(3.43)	(2.55)	(3.31)	(2.47)	(2.98)	(2.12)
	0.460	0.529	0.410	0.399	0.374	0.369
	(6.74)	(5.18)	(5.15)	(3.60)	(3.91)	(2.83)
High R&D_ME	0.705	0.464	0.694	0.561	0.720	0.632
	(7.59)	(3.44)	(7.15)	(4.10)	(6.64)	(4.24)
High_Low	0.720***	0.491***	0.575***	0.442***	0.609***	0.517***
t-stat	(7.71)	(3.61)	(6.01)	(3.06)	(5.04)	(2.94)

significant R&D effect using industry-adjusted returns for 1-way sorts, 2-way sorts, and factor regressions, respectively. For example, in the global 1-way sort portfolio analysis, the low and high R&D_ME value-weighted average monthly industry-adjusted returns are respectively −0.028% ($t=-0.29$) and 0.464% ($t=3.44$), yielding a high-minus-low return spread of 0.491% ($t=3.61$). The estimated values and t-values are all very similar to their counterparts in Table 2. All these test results are reported in Table 8 and Supplementary Tables S11–S15 and suggest that the R&D effect is robust to industry effects.

IV. Cross-Country Analysis

To better understand the source of the R&D effect, we turn to a country-level analysis in this section. Specifically, we aim to distinguish the risk-based explanation (i.e., there is risk premium associated with R&D investment due to its generation of risky growth options), from mispricing explanations. In the spirit of Li and Zhang (2010), Lam and Wei (2011), and Watanabe et al. (2013), we examine whether the R&D effect is more pronounced in countries where growth options more likely command risk premium, or rather in countries where behavioral bias and limits-to-arbitrage are more severe.

By treating each country as an individual unit of analysis, we examine which country characteristics explain the variation of the R&D effect across different countries, following Watanabe et al. (2013) and Eisdorfer et al. (2018). Our strategy is to quantify the magnitude of the R&D effect (i.e., the sensitivity of stock returns to R&D intensity) in each country in a month, and then examine if this effect can be explained by country-specific variables that reflect various possible reasons for the return predictability. We quantify the magnitude of the R&D effect for each country in a month using 4 measures: high-minus-low R&D return spreads (i.e., the difference in returns of the high and low portfolios, both equal- and value-weighted) and R&D slopes from cross sectional regressions (both OLS and WLS). We again require all the investment strategies to have at least 50 firms within each cross section to sort within each country for every year, and we then calculate the equal- and value-weighted returns of the high-minus-low portfolio as the monthly R&D return spreads from July of year t to June of year $t+1$. We use the same sample to calculate R&D slopes as follows. For each month from July of year t to June of year $t+1$, we conduct cross sectional regressions by regressing firms' monthly stock returns on R&D intensity in year $t-1$ to calculate the monthly R&D slope using OLS and WLS regressions.

To help explain the R&D effect, we construct 3 sets of country-specific variables as proxies for dispersions in growth option values, limits-to-arbitrage, and sentiments. The risk premium explanation can be tested based on growth option values, and the mispricing explanation can be tested based on limits-to-arbitrage and sentiments.

We first construct variables that are related to growth option-induced risks. Under the risk-based explanation that growth options command risk premium, when firms in a country exhibit significant heterogeneity in growth option values, growth options are more likely to be priced differently in the cross section. Also, if the R&D effect is related to growth options, then we expect it to be more pronounced in stock markets with higher levels of dispersions in growth option values. On the other hand, in countries in which firms have homogeneous growth option values, we would expect the R&D effect to be weaker.

To measure country-level dispersions in growth option values, we construct 2 variables. Our dispersion measure is the difference between the 75th percentile and 25th percentile of each variable.[14] We first consider the dispersion in PE, the value of which is shown to predict future economic growth (Bekaert, Harvey, Lundblad, and Siegel (2007)). We then consider the dispersion in the PVGO (Cao et al. (2008)).[15] A larger dispersion in these market values of growth options suggests that the risk of growth options is more likely to be priced in the cross section.

To proxy for limits-to-arbitrage, we consider SHORT, idiosyncratic risk (IRISK), and DVOL (Watanabe et al. (2013)). SHORT is an indicator variable that equals 1 if short-selling is allowed and 0 otherwise. We obtain this information from Bris et al. (2007).[16] IRISK is the annual value-weighted average of idiosyncratic volatility of all stocks in a country. For each stock, its IRISK is the standard deviation of the residuals from regressing daily stock returns on the value-weighted

[14]The cutoff points are not critical to our empirical results. We obtain similar results when we use 80th vs. 20th percentiles, or 90th vs. 10th percentiles.

[15]The details of constructing all the country-level variables are provided in the Appendix.

[16]In addition, if short-selling was legal prior to 1990, we assume that short-selling was allowed in each of the years before 1990, following McLean et al. (2009).

market returns from July 1st of year $t-1$ to June 30th of year t, following Li and Zhang (2010). DVOL is the logarithm of annual dollar trading volume for all stocks in a country scaled by total market capitalization in the country. Each stock's dollar trading volume is the product of share volume and the daily closing price, summed from July of year $t-1$ to June of year t (Watanabe et al. (2013)). Since limits-to-arbitrage impose higher costs and risks on arbitragers who may correct mispricing, we expect them to influence the R&D effect driven by mispricing.

To proxy for sentiments, we consider the number of newly listed firms (NIPO) and PVOL (Baker et al. (2012)). The number of NIPO is the number of firms that first appear in Datastream and approximates the number of IPOs within each country's capital market. We then scale it with the total number of firms in that country for that year. The PVOL is the log of the ratio of the value-weighted average market-to-book ratio of high volatility stocks to that of low volatility stocks at year end. High (low) volatility stocks are those in the top (bottom) 3 deciles of the variance of the previous year's monthly returns, for which decile break points are determined in each country for every year. Because IPOs are more likely high-tech firms and R&D activities are associated with uncertainty, investors' over-reaction to the "high-tech" fad may result in the R&D effect.

After constructing country-month panels of R&D spreads and slopes as well as country-specific variables, we present the time-series averages of all these variables for 21 countries in Table 9. While all the R&D spreads and slopes are measured monthly, the remaining variables are measured annually.

TABLE 9

Country Characteristics

Table 9 reports the 4 measures of the R&D effect and country-specific variables used in the cross-country analysis. The 4 measures of the R&D effect include equal-weighted spreads (EWSPRD), value-weighted spreads (VWSPRD), OLS-based slopes (OLSSLOPE), and WLS-based slopes (WLSSLOPE). The country-specific variables include proxies for dispersion in growth options, limits-to-arbitrage, and investor sentiment. The proxies for the dispersion in growth option value include dispersion in PE (price-dividend) and PVGO (present value of growth options). The limits-to-arbitrage proxies include the average idiosyncratic stock return volatility IRISK(in percentage points), the logarithm of dollar trading volume over market capitalization (DVOL), and the indicator for equity short-sale permission (SHORT). The proxies for investor sentiment include the number of newly listed equities (NIPO) and volatility premium (PVOL). We report the averages of these variables for each country. The sample period is from July of 1981 to June of 2018.

COUNTRY	EWSPRD (%)	VWSPRD (%)	OLSSLOPE (%)	WLSSLOPE (%)	PE	PVGO	SHORT	IRISK	DVOL	NIPO	PVOL
Australia	0.900	0.549	3.324	13.696	25.29	0.64	1.00	2.30	−1.49	0.87	−0.21
Canada	1.280	0.782	3.737	5.658	26.98	0.77	1.00	2.32	−1.62	0.70	−0.07
China	0.399	0.600	15.621	24.295	40.95	0.35	0.32	2.04	−0.11	2.44	0.29
Finland	0.259	0.278	4.093	8.978	25.37	0.55	0.66	2.80	−0.94	1.81	−0.25
France	0.214	0.242	−0.119	−0.330	22.44	0.62	1.00	2.90	−0.53	0.70	−0.09
Germany	0.930	0.954	2.139	2.180	20.30	0.70	1.00	3.38	−1.85	0.69	0.14
Greece	−0.273	−0.374	−10.584	−17.051	21.02	0.49	0.00	0.56	−1.91	1.19	−0.42
Hong Kong	1.158	0.624	11.266	6.252	11.98	0.72	0.61	3.47	−1.06	1.06	−0.02
India	0.915	1.085	4.097	22.021	23.13	0.63	0.00	2.18	−2.08	1.14	−0.71
Israel	−1.029	−0.977	−2.407	−8.396	21.35	0.47	0.00	1.58	−1.53	1.20	0.55
Italy	0.230	−1.029	0.987	−2.292	19.06	0.79	1.00	4.04	−0.45	0.79	−0.40
Japan	0.419	0.466	4.010	4.888	24.70	0.68	1.00	4.45	−0.55	0.52	0.12
South Korea	1.283	1.283	11.376	12.862	19.82	0.83	0.00	2.51	−0.59	1.22	0.25
Sweden	0.236	0.682	0.522	−2.059	21.58	0.54	0.76	2.95	−1.14	1.14	0.00
Switzerland	0.382	0.420	2.896	−1.651	18.03	0.91	1.00	2.65	−1.31	0.52	−0.12
Taiwan	0.667	0.087	7.400	0.503	12.68	0.37	1.00	1.66	−0.08	1.21	−0.13
Turkey	0.913	1.822	11.576	27.544	27.16	0.44	1.00	2.39	−0.64	1.11	0.15
U.K.	0.921	0.292	6.808	3.516	15.32	0.85	1.00	2.95	0.97	0.56	0.10
U.S.	1.261	1.115	4.555	7.795	20.48	0.67	1.00	1.67	0.32	0.67	0.23

The first 4 variables reported following the country names are measures of the R&D effect, all of which are reported in percentage points. Of these countries, South Korea, the U.S., and Canada have the largest equal-weighted monthly average return spreads (EWSPRD): 1.283%, 1.280%, and 1.261%, respectively. Although most of the countries exhibit a positive R&D-return relation, there are also countries like Israel that present a monthly spread of −1.029%. The next column reports the value-weighted monthly average return spread (VWSPRD), and generally its magnitude is smaller than its counterpart under EWSPRD, which is consistent with our previous results. The next 2 columns report the OLS regression slope (OLSSLOPE) and WLS regression slope (WLSSLOPE). A large dispersion in the magnitude of the slopes across countries also exists, which motivates us to conduct a cross-country analysis in the next stage. For example, the EWSLOPE ranges from −10.584% (Greece) to 15.621% (China), and the VWSLOPE ranges from −17.051% (Greece) to 27.544% (Turkey).

In Table 10 we report the pooling correlations among all these variables. We first find that the correlation between the equal- and value-weighted R&D spreads (EWSPRD and VWSPRD) is 0.587, and the correlation between the OLS- and WLS-based R&D slopes (OLSSLOPE and WLSSLOPE) is 0.552 with statistical significance. We also note that R&D spreads and slopes generally have a correlation

TABLE 10

Correlations of Country-Specific Variables

Table 10 reports the correlations among the measures of the R&D effect and country-specific variables used in the cross-country analysis. *p* values are reported in parentheses. The 4 measures of the R&D effect include equal-weighted spreads (EWSPRD), value-weighted spreads (VWSPRD), OLS slopes (OLSSLOPE), and WLS slopes (WLSSLOPE). The country-specific variables include proxies for dispersion in growth options, limits-to-arbitrage, and investor sentiment. The proxies for the dispersion in growth option value include dispersion in PE (price-dividend) and PVGO (present value of growth options). The limits-to-arbitrage proxies include the average idiosyncratic stock return volatility IRISK (in percentage points), the average logarithm of dollar trading volume over market capitalization (DVOL), and the indicator for equity short-sale permission (SHORT). The proxies for investor sentiment include the number of newly listed equities (NIPO) and volatility premium (PVOL). We report the averages of these variables for each country. The sample period is from July of 1981 to June of 2018.

	EWSPRD	VWSPRD	OLSSLOPE	WLSSLOPE	PE	PVGO	SHORT	IRISK	DVOL	NIPO	PVOL
EWSPRD	1.000										
VWSPRD	0.587 (0.00)	1.000									
OLSSLOPE	0.513 (0.00)	0.279 (0.00)	1.000								
WLSSLOPE	0.390 (0.00)	0.559 (0.00)	0.552 (0.00)	1.000							
PE	0.009 (0.53)	−0.012 (0.42)	0.007 (0.62)	−0.005 (0.73)	1.000						
PVGO	0.049 (0.00)	0.033 (0.02)	0.015 (0.29)	0.028 (0.06)	−0.066 (0.00)	1.000					
SHORT	0.011 (0.45)	−0.003 (0.85)	0.004 (0.77)	−0.011 (0.45)	0.059 (0.00)	−0.038 (0.01)	1.000				
IRISK	−0.005 (0.72)	0.008 (0.59)	−0.007 (0.63)	0.011 (0.43)	0.132 (0.00)	−0.059 (0.00)	0.001 (0.95)	1.000			
DVOL	0.022 (0.14)	0.004 (0.80)	0.048 (0.00)	0.023 (0.12)	0.097 (0.00)	0.008 (0.58)	0.236 (0.00)	−0.041 (0.01)	1.000		
NIPO	−0.025 (0.09)	−0.017 (0.26)	−0.013 (0.37)	−0.003 (0.86)	0.086 (0.00)	−0.074 (0.00)	−0.002 (0.88)	0.180 (0.00)	0.037 (0.01)	1.000	
PVOL	−0.051 (0.00)	−0.032 (0.03)	−0.008 (0.57)	−0.017 (0.26)	0.103 (0.00)	−0.095 (0.00)	0.119 (0.00)	0.075 (0.00)	0.135 (0.00)	0.167 (0.00)	1.000

coefficient of about 0.5, suggesting that although each represents an investment strategy outcome, they are not particularly highly correlated. Within the dispersions in growth options proxies, PE and PVGO are correlated at −0.066. Within the limits-to-arbitrage proxies, SHORT is positively correlated with IRISK and DVOL (0.001 and 0.236), and IRISK and DVOL are negatively correlated (−0.041). Within the sentiment proxies, the correlation coefficient between NIPO and PVOL is 0.167.

We next present cross-country regression results in Tables 11–13, in which the dependent variables are either averaged spreads or slopes generated using returns from July of year t to June of year $t+1$, whereas the independent variables are country-specific variables at the end of June of year t (or in the year end of year $t-1$). We report the pooling regression results with yearly fixed effects, and cluster the standard errors in 2 ways, along both countries and time. Our regression analysis thus also delivers asset allocation implications for investment strategies, such that investors may tilt toward countries that may have stronger R&D effects, as predicted by country characteristics. For convenience, we express the spreads and slopes in percentage points.

Table 11 reports the estimation results when we regress the 4 measures for the R&D effect on country-specific proxies for dispersions in growth options. We find that R&D return spreads and slopes can be significantly explained by growth option dispersions. For example, in the left part of Panel A for equally weighted spreads, the coefficients of dispersions in PVGO and PE are 0.277 and 0.007 with t-statistics of

TABLE 11

R&D Effect and Dispersions in Growth Option Values

Table 11 reports the results of panel regressions that examine the relation between the dispersion in growth option value and the R&D effect on stock returns. The dependent variables are the monthly equal- and value-weighted R&D return spread and slope. SPREAD is the equal-weighted or value-weighted average of the monthly return difference between the top and bottom RD_ME (High–Low), and their returns are cumulated from July of year t to June of year $t+1$. The value-weighting of SPREAD is based on firms' market capitalizations in June of year t. SLOPE is given by regressing buy-and-hold stock returns from July of year t to June of year $t+1$ on the RD_ME measured over year $t-1$. The regressions are either OLS or WLS. The WLS version of SLOPE is based on WLS regressions, in which the weights are proportional to market capitalizations in June of year t. Panel A reports the regression results in which the equal- or value-weighted SPREAD is used as the dependent variable. Panel B presents the regression results in which the OLS or WLS SLOPE is used as the dependent variable. The explanatory variables are the proxies of the dispersion in growth option value, including PE (price-dividend ratio) and PVGO (present value of growth options). The t-statistics reported in parentheses are computed using 2-way clustered standard errors by country and year. Year fixed effects are included. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

Panel A. SPREAD as Dependent Variable

	Equal-Weighted SPREAD			Value-Weighted SPREAD		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
PVGO	0.277***		0.293***	0.357***		0.374***
	(4.118)		(4.147)	(2.811)		(2.935)
PE		0.007*	0.009***		0.007**	0.009***
		(1.709)	(2.351)		(1.960)	(2.501)
R^2	0.059	0.056	0.059	0.063	0.060	0.063

Panel B. SLOPE as Dependent Variable

	OLS SLOPE			WLS SLOPE		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
PVGO	0.729		0.818	3.886***		3.935**
	(0.889)		(1.014)	(2.354)		(2.325)
PE		0.096*	0.099**		0.030	0.047
		(1.947)	(1.983)		(0.257)	(0.374)
R^2	0.055	0.056	0.056	0.066	0.064	0.066

TABLE 12

R&D Effect and Limits-to-Arbitrage

Table 12 reports the results of panel regressions that examine the relation between limits-to-arbitrage and the R&D effect on stock returns. The dependent variables are the monthly equal- and value-weighted spread (SPREAD) and slope (SLOPE). SPREAD is the equal-weighted or value-weighted average of the monthly return difference between the top and bottom RD_ME quintile, and their returns are cumulated from July of year t to June of year $t+1$. The value-weighting of SPREAD is based on firms' market capitalizations in June of year t. SLOPE is given by regressing buy-and-hold stock returns from July of year t to June of year $t+1$ on RD_ME measured over year $t-1$. The regressions are either OLS or WLS. The WLS version of SLOPE is based on WLS regressions, in which the weights are proportional to market capitalizations in June of year t. Panel A reports the regression results for which the equal- or value-weighted SPREAD is used as the dependent variable. Panel B presents the regression results in which the OLS or WLS SLOPE is used as the dependent variable. The explanatory variables are the limits-to-arbitrage proxies, including idiosyncratic stock return volatility (IRISK), dollar trading volume scaled by total market capitalization (DVOL), and permission for equity short-sale (SHORT). The t-statistics reported in parentheses are computed using 2-way clustered standard errors by country and year. Year fixed effects are included. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

Panel A. SPREAD as Dependent Variable

	Equal-Weighted SPREAD				Value-Weighted SPREAD			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
SHORT	0.113			0.134	0.040			0.063
	(0.315)			(0.417)	(0.118)			(0.211)
IRISK		0.092		0.116		0.136*		0.152*
		(1.353)		(1.292)		(1.911)		(1.731)
DVOL			0.061	0.047			0.028	0.018
			(0.778)	(0.650)			(0.386)	(0.264)
R^2	0.023	0.024	0.023	0.025	0.029	0.029	0.029	0.029

Panel B. SLOPE as Dependent Variable

	OLS SLOPE				WLS SLOPE			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
SHORT	−1.753*			−2.011**	−0.038			1.486
	(−1.753)			(−2.011)	(−0.021)			(0.241)
IRISK		1.181		1.260		3.328*		3.758
		(1.545)		(1.366)		(1.754)		(1.533)
DVOL			0.310	0.345			0.625	0.244
			(0.444)	(0.762)			(0.488)	(0.252)
R^2	0.022	0.023	0.021	0.024	0.020	0.024	0.020	0.04

4.118 and 1.709, respectively, when each is the only explanatory variable in the regression (Models 1 and 2). In terms of economic significance, when dispersions in PVGO and PE increase by 1 standard deviation, the return spread increases by 0.14% and 0.06% per month, respectively. When we include both variables in the same regression (Model 3), the coefficients of dispersions in PVGO and PE retain economic and statistical significance. In the right half of Panel A for value-weighted spreads, the coefficients of dispersions in PVGO and PE are 0.357 and 0.007 with t-statistics of 2.811 and 1.960, respectively, in Models 1 and 2. When dispersions in PVGO and PE increase by 1 standard deviation, the return spreads increase by 0.18% and 0.06% per month, respectively. For the OLS- and WLS-based slopes, our results are slightly weaker but still largely consistent. These results thus support a risk-based explanation for the R&D effect: if the effect is associated with growth option risk, it is expected to be more pronounced in countries with larger dispersions in growth option values because R&D-induced growth options are more likely priced in these countries.

Table 12 presents estimation results from regressing the R&D effect measures on limits-to-arbitrage proxies. These results suggest that R&D return spreads and slopes cannot be explained by mispricing. For example, in Panel A for equal-weighted spreads, the coefficients of SHORT, IRISK, and DVOL are 0.113, 0.092,

TABLE 13

R&D Effect and Sentiments

Table 13 reports the results of panel regressions that examine the relation between investor sentiment and the R&D effect on stock returns. The dependent variables are the monthly equal- and value-weighted spread (SPREAD) and slope (SLOPE). SPREAD is the equal-weighted or value-weighted average of the monthly return difference between the top and bottom RD_ME quintile, and their returns are cumulated from July of year t to June of year $t+1$. The value-weighting of SPREAD is based on firms' market capitalizations in June of year t. SLOPE is given by regressing buy-and-hold stock returns from July of year t to June of year $t+1$ on the RD_ME measured over year $t-1$. The regressions are either OLS or WLS. The WLS version of SLOPE is based on WLS regressions, in which the weights are proportional to market capitalizations in June of year t. Panel A reports the regression results for which the equal- or value-weighted SPREAD is used as the dependent variable. Panel B presents the regression results for which the OLS or WLS SLOPE is used as the dependent variable. The explanatory variables include the number of newly listed equities (NIPO), and volatility premium (PVOL). The t-statistics reported in parentheses are computed using 2-way clustered standard errors by country and year. Year fixed effects are included. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

Panel A. SPREAD as Dependent Variable

	Equal-Weighted SPREAD			Value-Weighted SPREAD		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
NIPO	−0.306		−0.221	−0.330		−0.293
	(−1.198)		(−0.784)	(−1.192)		(−0.908)
PVOL		−0.166	−0.132		0.055	0.099
		(−1.315)	(−0.945)		(0.234)	(0.384)
R^2	0.024	0.024	0.024	0.029	0.029	0.029

Panel B. SLOPE as Dependent Variable

	OLS SLOPE			WLS SLOPE		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
NIPO	0.547		2.253	0.923		0.952
	(0.145)		(0.620)	(0.184)		(0.168)
PVOL		−2.110	−2.438		1.771	1.632
		(−1.017)	(−1.296)		(0.461)	(0.407)
R^2	0.021	0.022	0.022	0.020	0.020	0.020

and 0.061 with t-statistics of 0.315, 1.353, and 0.778, respectively, in Models 1–3. For value-weighted spreads, the coefficients of SHORT, IRISK, and DVOL are 0.040, 0.136, and 0.028 with t-statistics of 0.118, 1.911, and 0.386, respectively, in Models 1–3.[17] When we include all 3 variables in a regression (Model 4), we obtain similar results. This general pattern also appears for other R&D effect measures, suggesting that these country-specific variables for market frictions generally cannot explain the country-level R&D effect.

Next in Table 13, we regress the R&D effect measures on 2 sentiment proxies and find that R&D spreads and slopes cannot be explained by these variables. For example, in Panel A for equal-weighted spreads, the coefficients of NIPO and PVOL are −0.306 and −0.166 with t-statistics of −1.198 and −1.315, respectively, when each is the only explanatory variable in the regression. Similarly, we find insignificant coefficients in Model 3, which includes both variables for market sentiments. Moreover, we do not detect any significant coefficient on market sentiment measures when we vary the dependent variables, indicating the lack of explanatory power of these measures for the international R&D effect.

The sharp contrast between the explanatory power of growth option dispersions and that of the limits-to-arbitrage and sentiments allows us to validate these

[17]We note that the WLS-based slope is strongly positively related to IRISK, consistent with the findings in Watanabe et al. (2013).

different hypotheses in an international setting. Still, examining the joint effects of these country characteristics should allow us to further differentiate these hypotheses. Therefore, we continue to rely on the above empirical framework and run multiple regression analyses. Specifically, we follow Watanabe et al. (2013) and conduct a joint estimation by examining the role of either proxy of dispersions in growth option values, after controlling all proxies of limits-to-arbitrage and sentiments. In Supplementary Tables S16 and S17, we re-examine the explanatory power of dispersions in PVGO and PE controlling for the other variables. We find that the explanatory power of dispersions in PVGO and PE is fairly robust, and does not weaken in most of our models. Overall, our cross-country analysis indicates that the international R&D-return relation is more likely driven by risk premium associated with growth options that increase with R&D investments.

V. Operating Performance, Return Volatility, and Probability of Default

The risk-based explanation of the R&D-return relationship suggests that R&D investment generates options that are riskier than the underlying asset, because of the implicit leverage of the options. Indeed, R&D investment is generally riskier and less flexible, and generates more uncertain business prospects than does regular capital investment.[18] Therefore, we further examine whether the option-based rational explanation might be compatible with empirical patterns when we also conduct Fama–MacBeth regressions on operating performance, return volatility, and probability of default. Specifically, we examine if R&D-intensive firms are associated with better operating performance, if their stock returns are more volatile, and if they are associated with a higher probability of default. These tests are motivated by the above argument from the literature, along with our observations that more growth options lead to higher and more volatile payoffs.

We first use the Fama–MacBeth regression to analyze the effect of R&D intensity on future operating performance. We conduct a cross sectional regression, in which the dependent variable is total sales scaled by total assets in year $t+1$ (OP_{t+1}) and the independent variables include R&D intensity, lagged operating performance (OP_t), ME, BM, MOM, ROE, and AG in year t. Industry and country fixed effects are also included. We then report the time-series averages and t-statistics in Table 14. We find that R&D intensity is associated with significantly higher operating performance in the future. For example, in Panel A for all

[18] In the model of Garleanu et al. (2012), growth options are priced in all securities and tend to increase the volatility of equity prices and the risk premia in the economy in the early stage of the technological cycle. The risk premia decrease as the growth options are converted into assets in place. Berk et al. (2004) argue that although idiosyncratic uncertainty on R&D investment does not command risk premium, the resolution of idiosyncratic uncertainty can dramatically alter the risk premium earned on R&D. Their model shows that indeed the required risk premium for R&D is higher. Kumar and Li (2016) further argue that even capital investment can generate growth options that potentially put firms at risk, which leads to higher expected stock returns, instead of lower expected stock returns as documented in the literature. Although not directly related to an option explanation of the R&D effect, Chambers et al. (2002) and Kothari et al. (2002) find that the standard deviation of excess returns for high-R&D firms is much larger than that for either non-R&D firms or for low-R&D firms.

TABLE 14

R&D Intensity and Future Operating Performance

Table 14 reports the time-series averages and t-statistics of coefficients from cross sectional regressions of individual firms' operating performance, defined as total sales scaled by total assets, in year $t+1$ on R&D intensity in year t. Panel A reports the regression results for the entire sample, and Panel B reports the regression results for all countries excluding the U.S. The control variables include operating performance in year t, ME (the natural logarithm of June-end market value of year t), BM (the natural logarithm of the year $t-1$ fiscal year-end book-to-market ratio), MOM (the year t Jan.-to-May), ROE (return on equity of fiscal year $t-1$), and AG (asset growth of fiscal year $t-1$). The coefficients on country/industry fixed effects are suppressed to save space. The t-statistics are adjusted for time-series autocorrelation and reported in parentheses. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

Panel A. All Countries

R&D_ME	0.096***	0.098***	0.096***	0.063**	0.059**
	(3.906)	(3.946)	(3.978)	(2.572)	(2.405)
OP_t	0.902***	0.898***	0.886***	0.885***	0.898***
	(175.890)	(195.245)	(198.754)	(172.748)	(190.809)
ME				−0.007***	−0.005***
				(−6.803)	(−4.269)
BM				−0.019***	−0.016***
				(−6.748)	(−7.809)
MOM				0.001	0.003
				(0.134)	(0.450)
ROE					−0.040***
					(−3.183)
AG					0.041***
					(9.344)
Cty		Yes	Yes	Yes	Yes
Ind			Yes	Yes	Yes
R^2	0.821	0.824	0.829	0.843	0.849

Panel B. Non-U.S.

R&D_ME	0.069**	0.073***	0.066**	0.065**	0.078**
	(2.607)	(2.993)	(2.540)	(2.372)	(2.511)
OP_t	0.916***	0.911***	0.900***	0.897***	0.907***
	(117.450)	(122.951)	(114.469)	(106.813)	(121.084)
ME				−0.007***	−0.005***
				(−10.239)	(−5.445)
BM				−0.017***	−0.017***
				(−7.547)	(−7.202)
MOM				−0.001	0.002
				(−0.120)	(0.311)
ROE					−0.035***
					(−3.564)
AG					0.049***
					(4.996)
Cty		Yes	Yes	Yes	Yes
Ind			Yes	Yes	Yes
R^2	0.843	0.847	0.852	0.863	0.868

countries, the coefficient of R&D intensity is 0.096 with a t-statistic of 3.906 in the first column. In terms of economic magnitude, a 1-standard deviation increase in R&D intensity (10%) increases future operating performance by 1%. When we only control for lagged operating performance, industry fixed effects, and country fixed effects, the coefficient of R&D intensity is 0.096 with a t-statistic of 3.978. When we include ME, BM, and MOM in the regression, the coefficient of R&D intensity is 0.063 with a t-statistic of 2.572. When we control further for ROE and AG, we obtain an estimate of 0.059 ($t = 2.405$). We present consistent – albeit slightly weaker – results in Panel B in which we exclude U.S. firms from our sample. Overall, Table 14 supports that higher R&D intensity leads to stronger future operating performance as growth options increase.

We then analyze the effect of R&D intensity on future return volatility. We conduct a cross sectional regression, in which the dependent variable is monthly return volatility between July of year t and June of year $t+1$ (σ_{t+1}) and the independent variables include R&D intensity, lagged return volatility (σ_t), ME, BM, MOM, ROE, and AG observed in June of year t. Industry fixed effects and country fixed effects are also included. The time-series averages and t-statistics of coefficients reported in Table 15 suggest that R&D intensity is associated with significantly higher return volatility in the future. For example, in the first model in Panel A for all countries, the coefficient of R&D intensity is 0.104 with a t-statistic of 7.612. A 1-standard deviation increase in R&D intensity increases future return volatility by 1.06% per month. In addition, adding conventional controls does not seem to weaken the effect of R&D intensity. These results are also consistent with

TABLE 15

R&D Intensity and Future Return Volatility

Table 15 reports the time-series averages and t-statistics of coefficients from cross sectional regressions of individual firms' stock return volatility (σ) in year $t+1$ on R&D intensity in year t, return volatility (σ) in year t, control variables in year t, and country and industry fixed effects. Panel A reports the results for all countries, and Panel B reports the results for all countries excluding the U.S. The dependent variable, monthly stock return volatility, is measured at the first year holding horizon after June of year t. The control variables include lagged return volatility, ME (the natural logarithm of June-end market value of year t), BM (the natural logarithm of the year $t-1$ fiscal year-end book-to-market ratio), MOM (the year t Jan.-to-May), ROE (return on equity of fiscal year $t-1$), and AG (asset growth of fiscal year $t-1$). The coefficients on country/industry fixed effects are suppressed to save space. The Newey–West t-statistics are adjusted for time-series autocorrelation and reported in parentheses. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

Panel A. All Countries

R&D_ME	0.104***	0.127***	0.116***	0.083***	0.075***
	(7.612)	(9.532)	(8.885)	(9.094)	(9.228)
σ_t	0.475***	0.433***	0.421***	0.333***	0.316***
	(27.894)	(35.170)	(33.901)	(28.604)	(28.175)
ME				−0.007***	−0.007***
				(−18.743)	(−17.262)
BM				−0.002***	−0.001
				(−2.732)	(−1.389)
MOM				−0.026***	−0.024***
				(−9.235)	(−8.453)
ROE					−0.016***
					(−11.779)
AG					0.007***
					(7.675)
Cty		Yes	Yes	Yes	Yes
Ind			Yes	Yes	Yes
R^2	0.253	0.315	0.342	0.351	0.360

Panel B. Non-U.S.

R&D_ME	0.035***	0.079***	0.069***	0.047***	0.039***
	(2.733)	(7.237)	(6.479)	(5.222)	(5.120)
σ_t	0.463***	0.395***	0.381***	0.293***	0.283***
	(14.673)	(16.723)	(13.981)	(14.241)	(16.207)
ME				−0.006***	−0.006***
				(−18.041)	(−18.046)
BM				0.001	0.001
				(0.662)	(0.797)
MOM				−0.021***	−0.020***
				(−4.719)	(−4.712)
ROE					−0.015***
					(−8.201)
AG					0.006***
					(3.172)
Cty		Yes	Yes	Yes	Yes
Ind			Yes	Yes	Yes
R^2	0.220	0.307	0.331	0.328	0.335

the findings of Chambers et al. (2002) and Kothari et al. (2002) in that R&D investments lead to more volatile returns in the future.

Lastly, we examine the effect of R&D intensity on the future probability of default. We follow Eisdorfer et al. (2018) and estimate default probability based on the Merton (1974) model. We conduct a cross sectional regression, in which the dependent variable is firm-level probability of default estimated for year $t+1$, and the independent variables include R&D intensity, lagged probability of default, ME, BM, MOM, ROE, and AG observed in year t. Industry fixed effects and country fixed effects are also included. The time-series averages and t-statistics of coefficients reported in Table 16 suggest that R&D intensity is associated with a

TABLE 16

R&D Intensity and Probability of Default

Table 16 reports the time-series averages and t-statistics of coefficients from cross sectional regressions of individual firms' probability of default (PD) estimated from Merton distance to default (DD) model in year $t+1$ on R&D intensity in year t, probability of default (PD) in year t, control variables in year t, and country and industry fixed effects. Panel A reports the results for all countries, and Panel B reports the results for all countries excluding the U.S. The dependent variable, probability of default, is measured for the July year t to June year $t+1$. The control variables include the lagged PD, ME (the natural logarithm of June-end market value of year t), BM (the natural logarithm of the year $t-1$ fiscal year-end book-to-market ratio), MOM (the year t Jan.-to-May), ROE (return on equity of fiscal year $t-1$), and AG (asset growth of fiscal year $t-1$). The coefficients on country/industry fixed effects are suppressed to save space. The Newey–West t-statistics are adjusted for time-series autocorrelation and reported in parentheses. ***, **, and * indicate statistical significance at the1%, 5%, and 10% levels, respectively.

Panel A. All Countries

R&D_ME	0.074***	0.077***	0.079***	0.059***	0.052***
	(4.954)	(5.012)	(4.978)	(4.706)	(4.443)
PD_t	0.328***	0.302***	0.317***	0.174***	0.168***
	(14.008)	(12.802)	(11.013)	(6.344)	(6.450)
ME				−0.003***	−0.002***
				(−6.121)	(−5.894)
BM				0.005***	0.005***
				(4.160)	(4.206)
MOM				0.032***	0.033***
				(5.552)	(5.536)
ROE					−0.012***
					(−5.406)
AG					−0.001
					(−0.611)
Cty		Yes	Yes	Yes	Yes
Ind			Yes	Yes	Yes
R^2	0.135	0.171	0.188	0.160	0.171

Panel B. Non-U.S.

R&D_ME	0.058***	0.062***	0.067***	0.046***	0.039***
	(5.370)	(4.967)	(4.065)	(5.203)	(4.751)
PD_t	0.378***	0.336***	0.356***	0.229***	0.223***
	(13.002)	(12.630)	(8.557)	(4.300)	(4.476)
ME				−0.003***	−0.002***
				(−5.214)	(−5.381)
BM				0.002**	0.003**
				(2.267)	(2.515)
MOM				0.034***	0.034***
				(5.133)	(5.225)
ROE					−0.012***
					(−4.308)
AG					−0.001
					(−0.521)
Cty		Yes	Yes	Yes	Yes
Ind			Yes	Yes	Yes
R^2	0.154	0.207	0.194	0.179	0.205

significantly higher probability of default in the future. For example, in the first model in Panel A for all countries, the coefficient of R&D intensity is 0.074 with a *t*-statistic of 4.954. A 1-standard deviation increase in R&D intensity increases the future probability of default by 7.5% annually. Moreover, accounting for conventional controls does not weaken the effect of R&D intensity.

Overall, Tables 14, 15, and 16 provides evidence that R&D-intensive firms are associated with higher future operating performance, higher return volatility, and a higher probability of default. These results are consistent with the notion that R&D investment creates growth options for a firm.

VI. Conclusion

In this article, we document that in international equity markets, firms with higher R&D intensity subsequently experience higher stock returns. This finding, combined with the U.S. evidence in the literature (Lev and Sougiannis (1996), Lev (1999), and Chan et al. (2001)), suggests a fundamentally important role of intellectual capital in asset pricing. Although the existing literature provides several explanations for the positive relation between R&D intensity and subsequent stock returns, the extent to which these explanations hold internationally has remained unexplored.

We conduct a cross-country analysis to provide further insights into the debate regarding the sources of the R&D effect. We find that the R&D effect is stronger in countries for which growth options are more likely to be priced, but is unrelated to country characteristics related to mispricing. Combined with the finding that R&D-intensive firms are also associated with higher future operating performance, return volatility, and default likelihood, our empirical evidence suggests that the predictive ability of R&D intensity for stock returns is more likely attributable to risk associated with innovation than to mispricing.

Supplementary Material

To view supplementary material for this article, please visit http://doi.org/10.1017/S002210902100020X.

Appendix. Country Characteristic Variables

Dispersions in PE: The difference between the 75th percentile and 25th percentile of the price-dividend ratio distributions of each country for every year. Source: Datastream.

Dispersions in the PVGO: The present value of growth options is calculated following Cao et al. (2008). First, for each firm, we use the previous 4 years' ROE to compute a weighted average ROE for year *t* with declining weights of 0.4, 0.3, 0.2, and 0.1 for years t, $t-1$, $t-2$, and $t-3$, respectively. We then obtain the projected earnings by multiplying this average ROE by the end-of-period book value of long-term liability, not including debt. Second, we estimate the value of asset-in-place, defined as the discounted projected cash-flows. We follow Cao et al. (2008) to assume a market beta of one for all, then aggregate all firm-level returns to calculate a country-year's average market returns. Finally, we obtain the PVGO, the total market value of equity minus the value of asset-in-place divided by the total market value of equity. Next, the dispersion is computed as the difference between the 75th percentile and 25th percentile of the PVGO distributions of each country for every year. Source: Datastream.

IRISK: The annual value-weighted average of idiosyncratic volatility of all stocks in a country. We follow Li and Zhang (2010) and estimate idiosyncratic volatility for an individual stock for every year by regressing daily stock returns on the value-weighted market return from July 1st of year $t-1$ to June 30th of year t. A stock's idiosyncratic risk is the standard deviation of the regression residuals. Source: Datastream.

DVOL: The logarithm of annual dollar trading volume over market capitalization for all stocks in a country. Dollar trading volume for each stock is the product of share volume and the daily closing price, summed from July of year $t-1$ to June of year t. Source: Datastream.

SHORT: An indicator variable that equals 1 if short-selling is allowed and 0 otherwise. We obtain this information from Bris et al. (2007). Following McLean et al. (2009), if short-selling was legal prior to 1990, we assume that short-selling was allowed in each of the years prior to 1990.

NIPO: The number of firms that first appear in Datastream in a year, approximating the number of IPOs within each country's capital market. We then scale it with the total number of firms in that country for that year. Source: Datastream.

PVOL: The log of the ratio of the value-weighted average market-to-book ratio of high volatility stocks to that of low volatility stocks at year end. High (low) volatility stocks are those in the top (bottom) 3 deciles of the variance of the previous year's monthly returns, where decile break points are determined in each country for every year. Source: Datastream.

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