Why do innovative firms hold more cash? The international evidence

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Abstract

Using 8,379 innovative firms from 23 non-U.S. countries over 1990-2012, we find that firms with higher innovation efficiency hoard more cash. To establish causality, we use a differences-in-differences approach based on country patent reforms and legalization of same-sex marriage. We also find that innovatively efficient firms use cash to alleviate financial constraints, invest in future R&D, and exploit innovation opportunities. They increase cash holdings by saving from cash flows and paying out less. The result is stronger for firms with better governance, in industries with higher innovation competition, and in countries that encourage competitiveness more and provide higher human capital.

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1. Introduction

The massive cash holdings of U.S. firms since the 1980s not only have important implications for governments and economists but also attract the attention of academic researchers.[1] Meanwhile, Pinkowitz, Stulz, and Williamson (2016) find that foreign firms hold as much or more cash as well-matched U.S. firms do. Our findings indicate that by the end of 2012, the aggregate cash and equivalents of innovative firms from 23 non-U.S. countries were about 2 trillion U.S. dollars and twice as large as that of U.S. innovative firms (see Figure 1 Panel A).[2] But why do innovative firms across the world hold so much cash? In this paper, we provide international evidence for the determinants of corporate cash holdings with respect to technological innovation.

The motivation of this study is the sheer size and importance of research and development (R&D) activities around the world. As a key input of innovation, R&D investment has risen rapidly in recent decades. For example, the total R&D spending of non-U.S. firms in 2012 was 401 billion U.S. dollars, which was much larger than 249 billion of U.S. firms (see Figure 1 Panel B). In fact, nine of the top 20 global R&D spenders in 2014 were not based in the U.S.[3] Given the heightened global competition in technology, intensive R&D activities outside the U.S., and heterogeneous institutional environments, exploring how innovation influences firms' cash holdings across countries is essential to understand (1) the cash holdings of innovative firms,

[1] There has been a surge of studies on cash holdings of U.S. firms (e.g., Kim, Mauer, and Sherman, 1998; Harford, 1999; Opler, Pinkowitz, Stulz, and Williamson, 1999; Almeida, Campello, and Weisbach, 2004; Faulkender and Wang, 2006; Acharya, Almeida, and Campello, 2007; Foley, Hartzell, Titman, and Twite, 2007; Han and Qiu, 2007; Harford, Mansi, and Maxwell, 2008; Bates, Kahle, and Stulz, 2009; Denis and Sibilkov, 2010; Brown and Petersen, 2011; Gao, Harford, and Li, 2013; Falato and Sim, 2014; Wang, Wei, and Zhang, 2014; Ma, Mello, and Wu, 2014; Qiu and Wan, 2015; Lyandres and Palazzo, 2015).

[2] The non-U.S. sample consists of 60,004 firm-year observations for 8,379 unique firms from 23 countries over 1990-2012, and the U.S. sample consists of 59,397 firm-year observations for 7,947 unique firms over 1990-2012. The U.S. sample uses the same filters as for non-U.S. sample firms (i.e., excluding financial firms and utilities, and requiring non-zero 5-year cumulative R&D expenses and non-missing data for all the variables in equation (3)).

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

(2) corporate cash policy in general, and (3) the role of country-specific institutional environments in firms' financial policies.

Initiating and maintaining innovation is challenging for most firms. It is difficult to finance innovation with external capital not only because of the inherent information asymmetry between innovative firms and outsiders, but also because of the lack of liquidity of unfinished R&D projects. Moreover, firms that raise external funds may need to disclose proprietary information about innovation prospects to the public including existing and potential competitors (e.g., Bhattacharya and Ritter, 1983; Yosha, 1995). Besides, external financing takes time, which might delay the optimal timing of innovation that is critical for firms to succeed (e.g, Barzel, 1968; Reinganum, 1989). Hence, firms often have to rely on internal resources—cash holdings, in particular—to invest in innovation, as cash holdings offer the most convenient resource to fund innovations efficiently (e.g., Himmelberg and Petersen, 1994; Brown, Fazzari, and Petersen, 2009; Hall and Lerner, 2010). Consistently, recent studies provide evidence that firms' cash holdings increase with innovation competition (Lyandres and Palazzo, 2015; Ma, Mello, and Wu, 2014; Qiu and Wan, 2015).

As funding resources for innovation are often limited, the ability to generate more innovation outputs from given R&D inputs (i.e., high innovation efficiency) is thus an important competitive advantage in the technology race (Ahuja, Lampert, and Tandon, 2008). Intuitively, innovation efficiency can be considered as the return on R&D investment, which is the ratio of the marginal product of R&D capital to the marginal cost of R&D investment.[4]

Innovatively efficient firms are expected to have higher incentives to hold larger cash balances, as we discuss in further detail in the hypothesis development section (Section 2). Since

[4] As implied by the model of Lin (2012), firms with higher innovation efficiency tend to be more productive. Consistently, Hirshleifer, Hsu, and Li (2013) find that firms that are more efficient in innovation have higher future operating performance and market valuation.

innovatively efficient firms have lower costs to innovate, they can invest in more R&D projects with positive net present values that will require additional cash holdings to support (e.g., Qiu and Wan, 2015). Besides, innovatively efficient firms are better positioned to exploit technology opportunities than average firms and thus reserve more cash to fund future projects. Moreover, these firms have higher implicit leverage, as they have more growth options from their innovations (Berk, Green, and Naik, 2004; Lin, 2012), which leads to higher costs of capital as the impact of adverse shocks and financial distress increases with growth options (e.g., Opler, Pinkowitz, Stulz, and Williamson, 1999). Accordingly, we hypothesize that *firms with higher innovation efficiency (i.e., more innovation output per R&D input) reserve more cash for future R&D investments*.

To test our hypothesis, we use a sample of 8,379 innovative firms from 23 non-U.S. countries over the period 1990 to 2012.[5] Innovation efficiency (IE hereafter) is measured as a firm's ability to generate patents or citations per million dollars of R&D investment (Cohen, Diether, and Malloy, 2013; Hirshleifer, Hsu, and Li, 2013). We first retrieve all patent data from the REGPAT database maintained by the Organization for Economic Co-operation and Development (OECD). This database offers ample coverage of patenting activities across a large number of countries other than the U.S.[6] We then combine international patent and financial data that includes R&D expenditures by manually matching patent assignees to corresponding public firms listed in the Compustat Global database.

We find a positive association between firms' innovation efficiency and cash holdings, after controlling for other known determinants, industry-year joint fixed effects, and country-year

[5] We exclude U.S. firms; otherwise, our sample will be dominated by U.S. firms. Nevertheless, our results remain consistent after including U.S. firms, as shown in Table 11. To be included in the sample, each country must have at least 100 patents owned by all public firms that report R&D expenditures.
[6] See, for example, Maraut et al. (2008) and D'Agostino, Laursen, and Santangelo (2013).

joint fixed effects. Our estimates indicate that, given one million U.S. dollars of R&D investment, a firm that increases its patent count from one to two raises cash holdings by 1.9%, which is about 11.2% of the average of cash holdings. Our results show that innovatively efficient firms hold more cash around the world.

While the baseline results are consistent with our main hypothesis, a typical concern raised is that innovation efficiency and cash holdings might be endogenously determined. For example, our result that cash holdings and innovation efficiency are positively related could be driven by a firm's corporate governance and information asymmetry. Specifically, both good governance and information transparency lead to lower agency issues, which may facilitate firms' operational efficiency and encourage shareholders to delegate more cash to managers. To address these concerns and establish the causality, we use two identification strategies.

The first identification strategy is to rely on patent reforms undertaken by Australia in 1995, Finland in 1995, and India in 2005 (Arora, Branstetter, and Chatterjee, 2008; Qiu and Yu, 2010). These patent reforms substantially strengthen patent protection that, in turn, reduces the imitation risk that innovative firms face, as well as lowers legal costs and raises the market value of every patent for these firms (Yang and Maskus, 2001). Therefore, firms with certain R&D expenses have a higher incentive to produce more and better-quality patents by improving their innovation efficiency. Using the differences-in-differences (DID) approach (Angrist and Krueger, 1999), we find that the impact of innovation efficiency on cash holdings is more pronounced after patent reforms. This result alleviates the reverse causality concern, as patent reforms are unlikely to affect firms' cash holdings except through innovation.

The second identification strategy is to use exogenous shocks from cultural diversification. Specifically, following Gao and Zhang (2016), we use the passage of same-sex marriage

legislation in eight countries to capture improvements in cultural diversification. The legalization of same-sex marriage points to the open-mindedness of a country's citizens, which is related to creativity and innovation. As a result, given the same R&D investment, firms may generate more and better-quality patents, leading to higher innovation efficiency. Based on the DID method, our findings show that the IE effect on cash holdings becomes stronger after the legalization of same-sex marriage. This identification strategy also supports our causal interpretation as the legalization of same-sex marriage is unlikely to be associated with other determinants of corporate cash policy.

In addition to cross-country analyses, we also conduct the same analysis country by country. We find that the positive relation between innovation efficiency and cash holdings exists in 18 out of 23 countries, 10 of which are statistically significant (71% of our sample). This finding corroborates our baseline result that innovation efficiency positively affects firms' cash holdings in most countries, and helps to alleviate the concern that our result is driven by single or certain countries.

We next examine the economic mechanisms to understand why innovatively efficient firms hold more cash. We find that the IE-cash effect is more pronounced for financially constrained firms, suggesting that the demand for cash holdings is larger when innovatively efficient firms have difficulties in obtaining credit. We also find an increase in future R&D investment by innovatively efficient firms with large cash holdings, especially in industries with higher R&D intensity (i.e., reflecting more technology opportunities). This finding shows that innovatively efficient firms hold more cash so that they are better able to aggressively invest in technology opportunities. Collectively, these results support the precautionary motive of cash holdings and also point to a causal interpretation of our baseline findings.

We also verify how innovatively efficient firms increase their cash holdings. Since it is difficult for them to raise external funds, internally generated cash flows should be an important potential source of cash. We examine the cash flow sensitivity of cash using the approach of Almeida, Campello, and Weisbach (2004) and find that innovatively efficient firms have a higher propensity to save cash out of cash flows. Meanwhile, we find supportive evidence from firms' payout policies that firms with high innovation efficiency pay out less cash through dividends and repurchases than other firms do. This finding is consistent with Hoberg, Phillips, and Prabhala (2014) in that firms hold higher cash balances and have a lower propensity to pay dividends or repurchase shares when they face changes in their product markets, particularly competitive threats from rival firms.

We conduct several additional tests to investigate how our baseline result varies across different country and firm characteristics, which deepens our understandings of the IE-cash association. First, Harford, Mansi, and Maxwell (2008) find that poorly governed U.S. firms tend to hold lower cash reserves as they spend excess cash quickly on acquisitions and capital expenditures and invest less in R&D. We thus conjecture that innovatively efficient firms hold more cash when they are under better governance, as shareholders of these firms have more confidence that managers will seize technology opportunities. Our findings show that the IE-cash effect is more pronounced in better-governed firms based on both the revised anti-director and anti-self-dealing indexes from Djankov, La Porta, López-de-Silanes, and Shleifer (2008), as well as a firm-level governance index from Aggarwal, Erel, Ferreira, and Matos (2011). These results suggest that investors allow managers of these firms to hold more cash for future investments when shareholders' rights are well protected.

Second, existing studies examine the critical role of legal institutions in fostering innovation (e.g., Acharya and Subramanian, 2009; Acharya, Baghai, and Subramanian, 2013). The increased global competition forces firms to innovate more quickly and efficiently to build lasting competitive advantage. Thus, to enhance competitiveness, firms are more likely to hold large amounts of cash in order to be able to react faster to technological changes. Innovative firms with large cash reserves can invest heavily in radical R&D investments that enable them to be the leaders in disruptive technology (Lev, Radhakrishnan, and Tong, 2016). Consistently, we find that the IE-cash effect is stronger among firms in countries where the legal institutions encourage the competitiveness of enterprises.[7]

Third, as innovation process is labor-intensive and requires substantial human effort in each stage (Holmstrom, 1989), human capital can enhance firms' ability to innovate efficiently. Thus, firms in countries with more human capital in R&D are more likely to have higher innovation efficiency, which needs more cash holdings. We use the sum of researchers and technicians in R&D (per million people) each year in the country as a proxy for human capital in R&D. Our results show that IE-cash association is larger for firms in countries with higher level of human capital.

Fourth, a large amount of cash is crucial for the survival of firms in industries with high globally innovation competition (Hitt, Hoskisson, Johnson, and Moesel, 1996). Using the Herfindahl-Hirschman index (HHI) based on R&D expenditures, as a proxy for innovation competition, we find that innovatively efficient firms in industries with lower HHIs (i.e., higher competition) tend to hold more cash. This result is consistent with the previous studies that

[7] We use the index from World Competitiveness Yearbook executive survey question that "The legal and regulatory framework encourages the competitiveness of enterprises".

product market competition affects innovative firms' cash holdings (e.g. Lyandres and Palazzo, 2015; Ma, Mello, and Wu, 2014).

Finally, we perform a variety of robustness tests for our main findings. Specifically, we (1) include U.S. innovative firms and also run separate regressions for U.S. innovative firms only; (2) use a shorter sample period of 1990-2008 to mitigate the truncation issues of patent applications and citations; (3) control for lagged cash holdings to further confirm that our findings are less likely driven by reverse causality; (4) adopt an alternative measure for cash holdings: the natural logarithm of cash-to-net-assets ratio, and cash-to-sales ratio; (5) use changes in all the variables, rather than levels, to eliminate the impact of time-invariant firm characteristics on cash holdings; and (6) construct a sample by using firms with at least one patent. In addition, we also find that innovation efficiency predicts future cash holdings. All these tests yield consistent results to support that innovation efficiency positively affects corporate cash holdings.

Our paper contributes to the literature in several ways. First, most international studies of cash holdings focus on agency costs (e.g., Dittmar, Mahrt-Smith, and Servaes, 2003; Pinkowitz, Stulz, and Williamson, 2006; Kalcheva and Lins, 2007). We add to this literature by showing that innovation efficiency is a critical determinant of firms' cash and payout policies. Second, recent studies highlight the role of R&D-intensive firms for explaining the cash holdings of U.S. firms (e.g., Begenau and Palazzo, 2016; Pinkowitz, Stulz, and Williamson, 2016). In addition, several papers examine the relation between innovation competition and cash holdings of U.S. innovative firms (e.g., Lyandres and Palazzo, 2015; Ma, Mello, and Wu, 2014; Qiu and Wan, 2015).[8] Our paper provides novel evidence to the cash holdings literature by showing the

[8] In an earlier version of their paper, Lyandres and Palazzo argue that innovative firms' cash holdings are associated with expected competition intensity and innovation efficiency, and find that cash holdings increase with innovation efficiency for more financially unconstrained firms, while this relation is reversed for less financially constrained firms.

importance of innovation efficiency in understanding the large amount of cash reserves around the world. Moreover, our cross-country analysis allows us to better understand how institutional environments affect firms' cash policies. Finally, our paper is also related to the literature on innovation itself, especially from an international perspective. There has been a large literature on the financing of R&D, and a burgeoning literature uses cross-country specifications to examine the mechanisms firms use to promote innovation.[9] Our paper contributes to these two streams of literature by providing international evidence on the precautionary motive of cash holdings for innovation opportunities.

The remainder of the paper is organized as follows. Section 2 reviews relevant prior studies and develops hypotheses. Section 3 describes the data and provides summary statistics. Section 4 discusses empirical results for our hypotheses. Section 5 investigates cash flow sensitivity of cash and payout policy. Section 6 presents additional tests and various robustness checks. Section 7 concludes this paper.

2. Hypothesis development

As Keynes (1936) points out, one of the motives for firms holding cash is precautionary motive, which suggests that firms hold cash as a buffer against adverse conditions or to meet future investment needs. This motive is particularly relevant for innovatively efficient firms for the following reasons.

First, previous studies show that large cash holdings allow firms to undertake valuable projects that might otherwise be bypassed (e.g., Myers and Majluf, 1984; Han and Qiu, 2007;

[9] The literature on the financing of R&D includes Kamien and Schwartz (1978), Himmelberg and Petersen (1994), Hall (2002), Hall and Lerner (2010), Ferreira, Manso, and Silva (2014), and others. The literature on the determinants of innovation based on cross-country specifications includes Acharya and Subramanian (2009), Brown, Martinsson, and Petersen (2013), Acharya, Baghai, and Subramanian (2013), and Hsu, Tian, and Xu (2014).

Denis and Sibilkov, 2010). In particular, innovatively efficient firms can undertake more R&D projects than average firms because efficient firms' costs to innovate are lower. Hence, innovatively efficient firms hoard more cash for future R&D investments. As pointed out by Lev, Radhakrishnan, and Tong (2016), R&D activities are associated with high uncertainty that is mainly from technological disruptions, thus large cash holdings enable firms to invest heavily in radical R&D and be the leaders in developing and/or adapting to disruptive technologies. In addition, Qiu and Wan (2015) argue that an innovative firm reserves more cash when the expected marginal profit of future R&D investments increases, which depends on both the marginal productivity of R&D input and the marginal profit of innovation output. More innovatively efficient firms should produce greater output given the same input and are more likely to generate successful and commercially implementable patents that will likely yield higher profits. Therefore, if a firm anticipates that the increased innovation output can be translated into high profits, then the firm has a higher incentive to save cash for future R&D investments.

Second, innovatively efficient firms also need to hold more cash to exploit technology opportunities. When a particular opportunity arises, innovatively efficient firms can exploit this opportunity to a greater extent to develop more inventions. More importantly, an opportunity that appears marginal (i.e., zero net present value) to average firms can be profitable to an efficient firm. Hence, to maximize firm value, it will be optimal for an efficient firm to have more cash reserves to capture good timing and invest more in R&D and production, which can then be converted into future profits.

Third, firms with greater investment opportunities tend to hold more cash as the costs of adverse shocks and financial distress are higher for them (e.g., Opler, Pinkowitz, Stulz, and

Williamson, 1999).[10] Innovatively efficient firms can generate more growth options for given R&D input, which in turn increase implicit leverage (Berk, Green, and Naik, 2004; Lin, 2012). Thus, these firms are subject to higher exposure to economic uncertainty, and also have higher costs of capital due to cash flow volatility.

Based on all these arguments, we propose the following hypotheses:

H1: Firms with higher innovation efficiency (i.e., more innovation output per R&D input) reserve more cash for future R&D investments.

H2: When financially constrained, firms with higher innovation efficiency reserve more cash.

H3: When they have higher cash holdings, firms with higher innovation efficiency invest more in future R&D.

H4: When they observe better technology opportunities, firms with higher innovation efficiency and higher cash holdings invest more in future R&D.

3. Data and summary statistics

We begin our sample construction by retrieving all patent data from the REGPAT database (2013 January edition) maintained by the Organization for Economic Co-operation and Development (OECD). The REGPAT database includes patents filed to and granted by the European Patent Office (EPO) and patents filed to the Patent Co-operation Treaty (PCT) from 1977-2012. When compared with the NBER patent database that is based on patents filed to and granted by the U.S. Patent and Trademark Office (USPTO), the OECD patent database covers patenting activities in non-U.S. countries more fully; specifically, the OECD database contains

[10] Prior studies show that firms with high R&D expenses have more cash holdings than other firms (e.g., Dittmar, Mahrt-Smith, and Servaes, 2003; Bates, Kahle, and Stulz, 2009; Brown and Petersen, 2011). In addition, the high adjustment costs of R&D investments require firms to hoard cash in response to transitory shocks (e.g., Himmelberg and Petersen, 1994; Hall, 2002).

patents filed from 43 countries. We also use the harmonized applicant names (HAN) database, again from the OECD, to group all patents by assignee names and then manually link all assignee names to public firms in the Compustat Global database by using company names, locations, and industry categories. As a result, we obtain patent records of international public firms since 1986.

We also collect firm-level accounting data from the Compustat Global database.[11] We exclude financial firms (SIC codes 6000-6999) and utilities (SIC codes 4900-4999), as well as require firms to have non-missing information for all the variables in our baseline regression equation (3) and require each country to have at least one hundred patent counts. We drop the U.S. in our sample; otherwise, our sample would be dominated by U.S. firms. Nevertheless, our results remain consistent after we include U.S. firms. After this filtering process, our main sample consists of 60,004 firm-year observations for 8,379 unique firms from 23 non-U.S. countries during the period 1990-2012.[12]

Following Hirshleifer, Hsu, and Li (2013), we use four proxies for innovation efficiency (IE): patents scaled by five-year R&D capital (*IE_pat*) and adjusted patent citations scaled by five-year R&D expenses (*IE_cit1*, *IE_cit3*, and *IE_cit4*). The IE proxies measure a firm's ability to generate patents or citations per million U.S. dollars of R&D investment, which reflects the efficiency of R&D activities and is relevant for valuation (Cohen, Diether, and Malloy, 2013; Hirshleifer, Hsu, and Li, 2013). Specifically, *IE_pat* is defined as the number of successful patent applications filed in year t (and granted by the end of 2012) divided by the 5-year cumulative R&D expenses from year $t-4$ to t, assuming an annual depreciation rate of 20% as in Chan, Lakonishok, and Sougiannis (2001) and Lev, Sarath, and Sougiannis (2005):

[11] For Canadian firms, we use the Compustat North America database.
[12] After we include non-missing data for all the variables, our patent sample merged with Compustat Global begins in 1990.

$$Patents_{i,j,t} / (R\&D_{i,j,t} + 0.8\times R\&D_{i,j,t-1} + 0.6\times R\&D_{i,j,t-2} + 0.4\times R\&D_{i,j,t-3} + 0.2\times R\&D_{i,j,t-4}), \quad (1)$$

in which subscript *i* indexes the individual firm and subscript *j* indexes the country. $R\&D_{i,j,t}$ denotes the R&D expense of firm *i* in country *j* in year *t*, and so forth. We set missing R&D to zero. Meanwhile, the premise of *IE_pat* is that R&D expenses over the five years all contribute to successful patent applications in year *t*. The three remaining IE proxies are based on adjusted patent citations. Specifically, *IE_cit1*, *IE_cit3*, and *IE_cit4* are the total number of adjusted citations scaled by the five-year cumulative R&D expenses:

$$Adjusted\ Citations_{i,j,t} /(R\&D_{i,j,t} + R\&D_{i,j,t-1} + R\&D_{i,j,t-2} + R\&D_{i,j,t-3} + R\&D_{i,j,t-4}), \quad (2)$$

in which *Adjusted Citations* is calculated as the total number of adjusted subsequent citations received by all patents filed by firm *i* in country *j* in year *t*. For each patent, we calculate its adjusted citations based on three different technology classes (IPC1, IPC3, and IPC4) issued by the EPO as the number of subsequent citations received by this patent by the end of 2012, divided by the average number of subsequent citations received by all patents categorized in the same technology class and filed in the same year as the focal patent.[13]

As IEs are highly skewed, we use the natural logarithm of one plus IE in regressions. To mitigate the influence of outliers, we winsorize all the continuous variables at the 1st and 99th percentiles by country.

[TABLE 1 ABOUT HERE]

Panel A of Table 1 reports the pooled mean of patents, citations, the natural logarithm of one plus IE, R&D to sales, R&D expenses, market capitalization, total assets, and cash holdings

[13] OECD patents are classified by International Patent Classification (IPC), which is a hierarchical classification system that separates the whole body of technical knowledge using the hierarchical levels, i.e., section, class, subclass, group and subgroup, in descending order of hierarchy. In 2016, the IPC consists of eight sections, 130 classes, and 639 subclasses. Each classification term consists of a symbol. The first digit is a letter for section symbol. This is followed by a two-digit number to give a class symbol. The fourth digit is a capital letter to make up the subclass. If we consider only the first digit of IPC, patents are classified according to the 8 sections (the highest level of hierarchy of the classification), referring to IPC1. The 3-digit IPC (IPC3) and 4-digit IPC (IPC4) are narrower levels of classification.

across all firm-year observations for each of the 23 countries. The patents and citations vary widely across countries. For example, a firm produces an average of 9.858 patents per year in Germany, and an average of 0.242 patents per year in Australia. However, the average Ln(1+*IE_pat*) is 0.035 in Australia, which is higher than 0.030 in Germany, which suggests that IE measures capture the R&D investment efficiency, which can be quite different from innovation output. The average corporate cash holdings range from 0.050 (Iceland) to 0.319 (Israel). Also, the average firm market capitalization ranges from 0.395 (Iceland) to 6.562 (Switzerland) billion U.S. dollars. Finally, the average number of firms per year ranges from 2 (Iceland) to 1,202 (Japan). Panel B of Table 1 presents Pearson correlation between main variables. The cash ratio is positively associated with the four innovation efficiency measures.

[FIGURE 1 ABOUT HERE]

In Figure 1, we plot the annual aggregate cash and equivalents (Panel A), R&D expenditures (Panel B), and patent counts (Panel C) for our sample firms from 23 non-U.S. countries and U.S. innovative firms, separately. The U.S. sample consists of 59,397 firm-year observations for 7,947 unique firms, after using the same filters for selecting non-U.S. firms. Panel A shows that non-U.S. innovative firms have more cash and equivalents (short-term investments) than U.S. innovative firms over the period 1991 to 2012. Panel B shows that the total R&D expenditures of non-U.S. firms has been increasing and surpassed U.S. firms since 1999. Panel C indicates that the differences in patent counts between non-U.S. and U.S. firms are becoming smaller (the sharp drop in the last column is due to truncation issue of patents; more details are provided in robustness tests).

4. Innovation efficiency and cash holdings

In this section, we first examine the effect of innovation efficiency on corporate cash holdings. We then address the endogeneity concerns employing differences-in-differences analyses based on country patent reforms and the legalization of same-sex marriage. Finally, we provide evidence to support the precautionary saving motive that explains why innovatively efficient firms hold more cash.

4.1 Estimation model and variables

Our regression analysis is generally based on Opler, Pinkowitz, Stulz, and Williamson (1999) and Bates, Kahle, and Stulz (2009). We first introduce our main variable of interest, IE, into the determinants of corporate cash holdings. Specifically, for firm *i* in country *j* in year *t*, we construct the following ordinary least squares (OLS) regression:

$$Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}, \quad (3)$$

in which the dependent variable *Cash* is cash holdings defined as cash and short-term investments scaled by total assets in year *t*.[14] *IE* represents the four innovation efficiency measures defined in the previous section: *IE_pat*, *IE_cit1*, *IE_cit3*, and *IE_cit4*. Because IE measures are often equal to zero and the distributions are highly skewed, we use Ln(1+ *IE*) in our regressions.

Following the cash holdings literature (e.g., Opler, Pinkowitz, Stulz, and Williamson, 1999; Bates, Kahle, and Stulz, 2009), the vector *X* includes these firm-specific control variables measured in year *t*: *Market to book*, as a proxy for investment opportunities (e.g., Smith and Watts, 1992), as firms with higher market-to-book ratio hold more cash since the costs are higher for these firms if they become financially constrained; *Size*, as there are economies of scale in

[14] In robustness checks, we find consistent results when we use cash-to-net-assets ratio, change in cash holdings, and future cash holdings as the dependent variables.

cash holdings (Miller and Orr, 1966), and larger firms with easier access to external financing may hold less cash; *Cash flow*, since cash flow provides a ready source of liquidity (e.g., Kim, Mauer, and Sherman, 1998) and can be considered a substitute for cash; *Net working capital*, as this capital can be converted to cash easily, and firms with more net working capital hold less cash; *Capital expenditure*, for if assets created by capital expenditures can be used as collateral, then these assets can reduce a firm's need to hold cash; *Leverage*, for if firms use cash to reduce leverage, then leverage can be expected to be negatively related with cash; *R&D/sales*, which serves as a proxy for growth opportunities, as firms with lower tangibility accumulate more cash; *Dividend dummy*, for firms paying dividends are less risky and have better access to capital markets, and consequently hold less cash; *Acquisition*, which reflects the cash outflows associated with acquisitions and is expected to be negatively associated with cash; and *Cash flow risk*, which is the industry-average cash flow volatility, for firms with greater cash flow uncertainty hold more cash, reflecting precautionary savings. We provide detailed definitions of these variables in the Appendix.

In addition, we include industry-year joint fixed effects to control for time-varying industry effects on cash policy. We also include country-year joint fixed effects to absorb the time-varying country characteristics, such as government policies and economic development. Finally, we use two-way clustered standard errors by industry and year to adjust for cross-sectional and time-series correlations in cash holdings (Petersen, 2009).[15]

4.2 Baseline regression results

Table 2 shows the regression results from our estimation of equation (3). *IE* represents *IE_pat*, *IE_cit1*, *IE_cit3*, and *IE_cit4* in columns 1 to 4, respectively. The coefficients of Ln(1+

[15] Our results remain consistent if we use two-way clustered standard errors by country and year.

IE) are positive and statistically significant at the 1% level, which means that firms with higher innovation efficiency tend to hold more cash. Specifically, the coefficient of Ln(1+ *IE*) ranges from 0.047 in column 1 to 0.056 in column 2. Given one million U.S. dollars of R&D investment, if a firm's patent count increases from 0 to 1 (*IE_pat* also increases from 0 to 1) and all other factors are held constant, then that firm's cash holdings increase by 3.3% (0.047×Ln(1+1/1))=0.033).[16] The magnitude is about 19.2% of the mean of cash holdings. If a firm's patent count increases from 1 to 2 (*IE_pat* also increases from 1 to 2), then cash holdings increase by 1.9% (0.047×Ln(1+1/2)=0.019), or roughly 11.2% of the mean value of cash holdings. The economic magnitudes of citation-based IE measures are very similar. The results in Table 2 provide supportive evidence for our main hypothesis (*H1*) that innovatively efficient firms tend to hold more cash.

[TABLE 2 ABOUT HERE]

The coefficients of control variables are consistent with prior results in the literature (e.g., Opler, Pinkowitz, Stulz, and Williamson, 1999; Bates, Kahle, and Stulz, 2009). For example, the coefficients of *Market to book* and *R&D/sales* are significantly positive, which suggest that firms with more growth opportunities hold more cash for future investments. Also, the positive coefficient of *Cash flow risk* indicates that firms with greater cash flow risk have more precautionary savings in cash.

4.3 DID tests based on patent reforms

[16] In Table 2, across all the observations from 23 countries, *Cash* has a pooled mean of 0.170 and a standard deviation of 0.166. *IE_pat* has a pooled mean of 0.046 and a standard deviation of 0.501. *IE_cit1* has a pooled mean of 0.033 and a standard deviation of 0.365. *IE_cit3* has a pooled mean of 0.033 and a standard deviation of 0.304. *IE_cit4* has a pooled mean of 0.034 and a standard deviation of 0.374. Assuming that all other factors are equal, if IE increases by ΔIE from IE to IE′, then $\Delta Cash = \beta_1 Ln(1+IE') - \beta_1 Ln(1+IE) = \beta_1 Ln((1+IE')/(1+IE)) = \beta_1 Ln(1 + \Delta IE/(1+IE))$.

To establish that the effect of innovation efficiency on cash holdings is causal, we use patent reforms as an identification strategy. Patent protection that can provide safeguards against misappropriation of proprietary technology is significantly strengthened by patent reforms. Stronger patent protection reduces the imitation risk faced by the licensor, reduces licensing cost, enhances innovative firms' ability to appropriate the returns to their R&D investments and raises the market value of every patent (Yang and Maskus, 2001). As a result, firms with certain R&D expenses would be motivated to produce more and better-quality patents by improving efficiency in their R&D activities. Patent reforms are arguably unrelated with other factors that may affect corporate cash policy, except through innovation. Due to data limitations, we focus on patent reforms undertaken by Australia in 1995, Finland in 1995, and India in 2005 (Arora, Branstetter, and Chatterjee, 2008; Qiu and Yu, 2010).[17]

We use the following regression-adjusted DID model (Angrist and Krueger, 1999) to identify the effect of patent reforms on the relation between innovation efficiency and cash holdings:

$$Cash_{i,j,t} = \beta_0 + \beta_1 Post\ treatment_{j,t} \times \text{Ln}(1+ IE_{i,j,t}) + \beta_2 \text{Ln}(1+ IE_{i,j,t}) + \beta_3 Post\ treatment_{j,t} + \delta' X + Country\ FE + Industry\ FE + Year\ FE + \varepsilon_{i,j,t}, \quad (4)$$

in which *Post treatment* is a dummy variable that equals one if country *j* has implemented patent reforms by year *t*, and zero otherwise. We control for country, industry, and year fixed effects in the regressions.[18] The coefficient of the interaction term, or β_1, measures the difference in the effect of innovation efficiency on cash holdings between firms in countries that have experienced patent reforms and other firms. A positive coefficient of the interaction term would suggest a

[17] Most countries' patent reforms occurred in the 1980s.

[18] Because *Post treatment* is equal to an interaction term of a dummy indicating the post-reform time period and a dummy indicating treatment countries. To avoid the multicollinearity problem, we do not include country-year fixed effects.

more pronounced effect of innovation efficiency on cash holdings after patent reforms.

[TABLE 3 ABOUT HERE]

In Panel A of Table 3, we show that innovation efficiency raises cash holdings to a greater extent after patent reforms. The coefficients of the interaction term are significantly positive for all the IE measures, ranging from 0.072 to 0.172. These results support our causal interpretation of innovation efficiency's positive impact on cash holdings, as patent reforms affect cash holdings most likely only through corporate innovation activities.

4.4 Exogenous shocks to innovation from cultural diversification

In this subsection, we employ the legalization of same-sex marriage as an exogenous positive shock to the innovation efficiency. The intuition is that the legalization of same-sex marriage creates a more diversified cultural environment, which inspires creativity and innovation (Gao and Zhang, 2016). Given the same R&D investment, firms' innovation efficiency improves, as firms experience a significant increase in innovation output due to cultural diversity. By the end of 2012, eight countries in our sample had legalized same-sex marriage (approved year in parentheses), including the Netherlands (2000), Belgium (2003), Canada (2005), Spain (2005), Norway (2009), Sweden (2009), Iceland (2010), and Denmark (2012). To identify the effect of legalization of same-sex marriage on the association between IE and cash holdings, we use the setup of equation (4) and note that *Post treatment* dummy equals 1 if country *j* has passed a same-sex marriage law by year *t*, and zero otherwise.[19]

In Panel B of Table 3, the coefficients of the interaction term are significantly positive for all IE measures. Specifically, the results show that the impact of innovation efficiency on cash

[19] Setting the *Post treatment* dummy to be 0 for the approved year does not change our results. We also get similar results if we define the *Post treatment* dummy based on the effective year.

holdings becomes stronger after positive exogenous shocks to innovation, thereby mitigating reverse causality concerns as the passage of same-sex marriage legislation is unlikely to affect firms' cash policies.

4.5 Country-by-country analysis of IE-cash effect

So far, we have presented cross-country evidence suggesting that firms with higher innovation efficiency hold more cash. To better understand the IE-cash effect, we now consider country-by-country analysis. Specifically, for each country, we estimate equation (3) using patent-based IE measure. As one of the control variables is industry-year average cash flow risk within the country, here we use industry fixed effect and year fixed effect instead of industry-year joint fixed effects.[20] Figure 2 presents the coefficients of Ln(1+IE_pat) with 90% confidence intervals for each of the 23 non-U.S. countries. We find positive coefficients for 18 countries, 10 of which are statistically significant at least at the 10% level. These ten countries include Australia, Austria, Canada, Denmark, Iceland, Israel, Japan, Spain, Sweden, and United Kingdom, which comprise a total of 42,821 observations or 71% of our main sample. In untabulated results, we find similar evidence using citation-based IE measures. Overall, our results suggest that the positive effect of innovation efficiency on corporate cash holdings exists in most countries. These findings also help to alleviate the concern that our result only exists in very few big countries.

[FIGURE 2 ABOUT HERE]

4.6 Precautionary motive for holding cash

As discussed in Section 2, the precautionary motive is the reason why innovatively efficient

[20] Alternatively, we drop control variable *Cash flow risk* and use industry-year fixed effects, and find similar results.

firms hold more cash. In this section, we provide supporting evidence for this motive and examine Hypotheses 2 to 4.

Opler, Pinkowitz, Stulz, and Williamson (1999) argue that firms with greater investment opportunities find it profitable to hold more cash, so they may mitigate the costs of adverse shocks and financial distress. Likewise, Faulkender and Wang (2006) find that an extra dollar of cash holdings is more valuable for shareholders in financially constrained firms, and Denis and Sibilkov (2010) show that higher cash holdings allow constrained firms to undertake valuable projects that they might otherwise bypass. Thus, we expect that the IE-cash effect will be larger for financially constrained firms. We use the size-age index (SA-index) developed by Hadlock and Pierce (2010) to measure financial constraints of international firms (see, e.g., Bessler, Drobetz, Haller, and Meier, 2013). A higher SA-index value indicates greater financial constraints. The SA-index is calculated as follows:

$$SA\text{-}index_{i,j,t} = -0.737 \times Size_{i,j,t} + 0.043 \times Size^2_{i,j,t} - 0.040 \times Age_{i,j,t}, \quad (5)$$

in which *Size* is the natural logarithm of total assets, and *Age* denotes the number of years that the firm is listed with a non-missing stock price in Compustat Global (or North America).[21] We then calculate the 30th and 70th percentiles of the cross-sectional distribution of the SA-index in year *t*, and consider a firm as either financially constrained if its SA-index is above the 70th percentile or unconstrained if its SA-index is below the 30th percentile. We exclude other firms from this analysis.

[TABLE 4 ABOUT HERE]

As Panel A of Table 4 shows, the effect of innovation efficiency on cash holdings is more substantial for constrained firms. In particular, the magnitude of coefficients on IE proxies for

[21] Following Hadlock and Pierce (2010), we winsorize (i.e., cap) *Size* at the natural logarithm of $4.5 billion and winsorize *Age* at thirty-seven years.

constrained firms is greater than that of unconstrained firms. For unconstrained firms, the positive effect of innovation efficiency on cash holdings also exists, but is much weaker. As reported in the bottom two rows of Table 4, the differences of the IE coefficients between the constrained and the unconstrained firms are statistically significant based on *z*-statistics. Consistent with our hypothesis (*H2*), these results suggest that managers of innovative firms tend to save more cash when they have more financial constraints.

Since innovatively efficient firms tend to have more future investment opportunities, such as implementing innovations and marketing their products, managers have more incentives to reserve cash for firms' future operations. To explore this implication, we examine whether larger cash holdings are associated with greater future R&D investments for innovatively efficient firms. Specifically:

$$R\&D/Sales_{i,j,t+1} = \beta_0 + \beta_1 \, High\ IE\ dummy_{i,j,t} \times Cash_{i,j,t} + \beta_2 \, Cash_{i,j,t} + \beta_3 \, High\ IE\ dummy_{i,j,t} + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t+1}, \quad (6)$$

in which vector *X* represents a set of firm-specific control variables measured in year *t* that are related to firms' investment policies, including market to book, cash flow, sales growth, leverage, size, and lagged R&D investment. *High IE dummy* equals one if the value of the firm's IE measure is above the 90th percentile in a particular country. We also control for industry-year and country-year fixed effects.

Panel B of Table 4 reports the results of future R&D investments. The *IE* measure denotes *IE_pat*, *IE_cit1*, *IE_cit3*, and *IE_cit4* in columns 1-4, respectively. The coefficients of the interaction term *High IE dummy* × *Cash* are positive and statistically significant at the 1% level across all regressions. For example, in column 1, the coefficient of the interaction term is 0.168 and the coefficient of *Cash* is 0.149, which indicates that the effect of cash holdings on future

R&D investments is more than doubled for firms with high innovation efficiency. These results support our hypothesis (*H3*) that cash-rich firms invest more in future R&D activities when they are more efficient in innovation.

We now focus on the role of innovation opportunities. With larger cash holdings, firms with higher innovation efficiency can more optimally time their investments in R&D and production when a profitable opportunity arises. Thus, the effect of IE-cash holdings on future R&D investments should be more pronounced for firms with higher levels of investment opportunities. We test this assumption by dividing our sample into two groups based on industry-level R&D intensity, which is the ratio of total R&D expenses to the total sales in an industry (2-digit SIC code) in year *t*. A higher ratio reflects greater technology opportunities. Firms with industry-level R&D intensity above (below) the median in year *t* are categorized into the high (low) investment opportunity group. We re-estimate equation (6) based on these two subsamples, and we present our results in Panel C of Table 4.

As expected, we find that the joint effect of cash holdings and innovation efficiency on future R&D investments is larger in firms with relatively more investment opportunities than in firms with relatively less investment opportunities. The coefficients of the interaction term *High IE dummy* × *Cash* are significantly positive in the high group, but insignificant in the low group. Also, the differences between the two estimates of high and low groups are statistically significant based on *z*-statistics. This finding is consistent with our hypothesis (*H4*) that firms with better technology opportunities hold more cash to invest in future R&D.

5. How do innovative firms increase cash holdings?

In this section, we examine how innovative firms increase their cash holdings. Since

innovative firms often rely on internal funds for financing R&D investments (e.g., Himmelberg and Petersen, 1994; Hall and Lerner, 2010), cash flows should be important potential source of cash. We first analyze the sensitivity of cash holdings to cash flow and the extent to which it is affected by innovation efficiency. We then examine firms' payout policies to see whether innovatively efficient firms pay out less in order to retain more cash.

5.1 Cash flow sensitivity of cash

Similar to Almeida, Campello, and Weisbach (2004), we estimate the cash flow sensitivity of cash as follows:

$$\Delta Cash_{i,j,t} = \beta_0 + \beta_1 Ln(1+IE_{i,j,t}) \times Cash\ flow_{i,j,t} + \beta_2 Cash\ flow_{i,j,t} + \beta_3 Ln(1+IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}, \quad (7)$$

in which the dependent variable is the change in cash ratio. The vector X includes the control variables: market to book, size, capital expenditure, acquisition, change in net working capital, and change in short debt. The coefficient β_2 captures a firm's propensity to save cash out of cash inflows, which refers to the cash flow sensitivity of cash. We introduce an interaction term between IE and cash flow into their model. A positive β_1 would suggest that the cash flow sensitivity of cash increases with innovation efficiency. We expect that firms with higher innovation efficiency have a higher propensity to save cash out of cash flows.

[TABLE 5 ABOUT HERE]

Table 5 reports the results we obtain by fitting equation (7). The coefficients of interaction terms are positive and significant in all the regressions. This increase in estimated cash flow sensitivity of cash is consistent with our expectation that firms with higher innovation efficiency tend to save a greater proportion of their cash flows.

5.2 Payout policy

In order to save more cash, innovatively efficient firms might pay out less cash through dividends or repurchases. Previous studies find that dividends remain the principal payout method for firms in many countries outside the U.S. (e.g., Von Eije and Megginson, 2008; Chay and Suh, 2009). We focus on cash dividends scaled by sales because sales are less dependent on accounting conventions and also less subject to manipulation through accounting practices and can be more comparable across countries (La Porta et al., 2000).[22] We also use total payout (i.e., distribution to shareholders through dividends and repurchases, scaled by sales) as an alternative measure. Following the literature, we construct the following Tobit regressions:

$$Payout_{i,j,t+1} = \beta_0 + \beta_1 \, High\ IE\ dummy_{i,j,t} \times Cash_{i,j,t} + \beta_2 \, Cash_{i,j,t} + \beta_3 \, High\ IE\ dummy_{i,j,t} + \delta' X$$
$$+ Industry\ FE + Year\ FE + Country\ FE + \varepsilon_{i,j,t+1}, \quad (8)$$

in which the dependent variable is cash dividend scaled by sales (*DIV/Sales*) or the total amount of cash paid through dividends and repurchases scaled by sales (*TotalPayout/Sales*). The vector *X* includes a set of firm-specific control variables measured in year *t* that are related to firms' payout policies, including market to book, size, leverage, ROA, retained earnings, non-operating income, capital expenditure, sales growth, and age. Since firms' payout policies are usually quite persistent, we also control for the lagged payout ratio. *High IE dummy* equals one if the value of a firm's IE measure is above the 90th percentile in a particular country. A negative β_1 would suggest that higher innovation efficiency leads to less payout of cash.

[TABLE 6 ABOUT HERE]

Table 6 presents the results of *DIV/Sales* in columns 1 to 4 and *TotalPayout/Sales* in columns 5 to 8. The *IE* measure denotes *IE_pat* in columns 1 and 5, *IE_cit1* in columns 2 and 6,

[22] We obtain similar results (untabulated) when we scale cash dividends by the total assets.

IE_cit3 in columns 3 and 7, and *IE_cit4* in columns 4 and 8. The interaction terms of *High IE dummy* × *Cash* are significantly negative, ranging from −0.015 to −0.008. The results suggest that when a firm is more innovatively efficient, it pays out less cash, which is in line with our hypothesis that innovatively efficient firms reserve cash for precautionary motive.

6. Additional tests and robustness checks

In this section, we examine how the IE-cash relation varies under different situations including corporate governance (both country-level and firm-level), legal environment, and human capital for R&D. Because Japan has the largest sample size (accounts for 44% of our sample) and is at the median of the distribution of each country-level index, we exclude Japan from subsample analyses when using country-level indexes (except for firm-level governance index). Further, we conduct various robustness checks for our main findings.

6.1 The effect of corporate governance

Previous studies show that corporate governance is related to firms' cash holdings. For example, Harford, Mansi, and Maxwell (2008) find that firms with weaker shareholder rights have smaller cash reserves; such firms invest less in R&D when compared with their industry peers, and they also spend cash quickly on acquisitions and capital expenditures. Meanwhile, Pinkowitz, Stulz, and Williamson (2006) show that a dollar of cash is worth less in countries with poor investor protection, as the appropriation of private benefits by controlling shareholders is easier. Thus, we expect that the effect of innovation efficiency on cash holdings becomes stronger for firms with better governance because shareholders expect that better-governed managers will use cash more efficiently. We use both country-level and firm-level governance indexes to test this argument.

First, we follow Djankov, La Porta, López-de-Silanes, and Shleifer (2008) and use the revised anti-director and anti-self-dealing index as proxies for the level of shareholder rights protection in each country. We then divide firms from 22 countries into high (i.e., an index value above the median) and low investor protection subsamples, and re-estimate equation (3).

[TABLE 7 ABOUT HERE]

In Table 7, Panel A and Panel B report the results based on the anti-director index and anti-self-dealing index, respectively. As expected, the coefficients on IE proxies are only significantly positive for firms with higher investor protection. The differences of the coefficients of IEs between firms with high and low investor protection are statistically significant, as reported in the bottom of each panel.

Second, we follow Aggarwal, Erel, Ferreira, and Matos (2011) and use the firm-level governance index, which is based on 41 individual attributes; higher values in this index indicate higher levels of firm governance. After matching with our sample firms, the final sample consists of 757 firms from 17 countries over the period 2004-2008. Again, we re-estimate equation (3) based on high (index above the yearly cross-sectional median) and low governance subsamples. In Panel C, the results show that the IE-cash effect only exists in well-governed firms. The coefficients on IE proxies are not significantly different from zero for poor-governed firms.

This set of results suggests that firms with better corporate governance (at both country and firm levels) give investors the confidence that their money will be well spent so that investors will let managers of innovatively efficient firms hold more cash for future R&D investments.

6.2 Legal environment on competitiveness of enterprises

With the pressure from increasing global competition in technology, firms are incentivized to innovate more rapidly and efficiently to enhance their competitiveness. For firms in a country encouraging competitiveness of enterprises, we expect that innovation efficiency will have a stronger effect on cash holdings. We use a country-level index from World Competitiveness Yearbook (WCY) executive survey question that "The legal and regulatory framework encourages the competitiveness of enterprises" as a proxy for the legal environment in each country.[23] This index is available from 1997 to 2011 and takes value from 0 to 10 with higher value indicates more encouragement in competitiveness. We place firms from 22 countries into high (low) competitiveness group if their index values are above (below) the yearly cross-sectional median, and re-estimate equation (3).

[TABLE 8 ABOUT HERE]

As shown in Table 8, the IE-cash effect is much larger for firms in the high competitiveness group. The *z*-statistics suggest that the differences of coefficients on IEs between the two subgroups are significantly positive. The results imply that innovation efficiency has a larger impact on cash holdings for firms in countries with legal environments that encourage competitiveness.

6.3 Human capital for innovation

Human capital is embodied skills, abilities and knowledge of individuals. Holmstrom (1989) argues that innovation is labor intensive, which requires substantial human effort in all stages. Since human capital is an essential part of innovation and a key source of competitive advantages for firms and countries, firms with higher level of human capital in R&D will be better able to produce more innovative output from given R&D input. Thus, the efficiency of

[23] Source: IMD World Competitiveness online, 1995-2011 (updated May 2011).

firms' innovation activities will be enhanced, which might affect firms' cash holdings.

We measure human capital for innovation at the country level as the sum of researchers and technicians in R&D (per million people) each year in the country. According to World Bank definition, researchers in R&D are professionals (including PhD students engaged in R&D) who create new knowledge, products, processes, methods, or systems and manage the projects, and technicians in R&D perform scientific and technical tasks, normally under the supervision of researchers. We assign firms from 22 countries into high (low) group if the level of human capital in R&D is above (below) the yearly cross-sectional median, and re-estimate equation (3).

[TABLE 9 ABOUT HERE]

Table 9 shows that the IE-cash relation is stronger among firms in countries with higher level of human capital in R&D. The positive differences of coefficients on IEs between high and low groups are significant at 10% level. Our findings indicate that with more available human capital in R&D, firms' innovation efficiency improves and demands a higher level of cash holdings.

6.4 Innovation competition

The increasing global innovation competition puts pressure on firms to improve the quality and productivity of their R&D efforts. Cash plays a fundamental role in this competition as it enables firms to react faster to technological changes. We expect that managers of innovatively efficient firms in a more competitive industry have a stronger precautionary demand for cash. Our measure of innovation competition is the Herfindahl-Hirschman index (HHI) of R&D expenditures. The HHI is calculated as the sum of squared market share of each firm within an industry (2-digit SIC code) across 23 countries in year *t*. When computing the HHI, we use all

available firms from 23 countries in Compustat and calculate market shares of firms' R&D expenditures (million U.S dollars).[24] The HHI is equal to zero for a perfectly competitive industry and equal to one for a monopolistic industry. We assign firms into high (above median) and low HHI groups by the yearly cross-sectional median.

[TABLE 10 ABOUT HERE]

In Table 10, the coefficients of IE measures are significantly positive in the low HHI groups but insignificant in the high HHI groups. The result shows that innovatively efficient firms hoard more cash when they are in industries with more competitive pressure (lower Herfindahl index). This evidence is consistent with the findings of Lyandres and Palazzo (2015) that innovative firms' cash holdings are related to the intensity of expected future product market competition.

To sum up, these results suggest that innovatively efficient firms tend to hold more cash when they have better governance and when they are in environments encouraging competitiveness more and providing more R&D human capital and in industries with intense competition.

6.5 Robustness tests

We perform a variety of robustness tests for our main findings. First, we combine U.S. innovative firms with our sample of non-U.S. innovative firms. Due to the different technology classes issued by EPO and USPTO, here we use the total number of non-adjusted citations instead of adjusted citations to calculate the citation-based IE. In columns 1 and 2 of Table 11, the coefficients of IEs remain positive and significant after including U.S. firms. In columns 3 and 4, we run separate regressions for U.S. firms only and find similar results, suggesting that our results remain robust with or without U.S. firms.

[24] In unreported robustness checks, we also use HHI based on patent counts and find very similar results.

[TABLE 11 ABOUT HERE]

Second, to mitigate the truncation problems, we use a shorter period of 1990 to 2008. The truncation problem regarding patent counts stems from the fact that there is a significant application-grant lag (2 years on average). As our sample includes patent applications that are granted by the end of 2012, we do not observe patent applications that may eventually be granted (but are not granted yet). Citation counts are inherently truncated because patents receive citations over long periods of time and we can only observe citations until the last day of the available data. Appendix Table 1 shows that our results are not biased by the truncation issues when we end the sample in 2008.

Third, we control for lagged cash holdings in equation (3), as firms' cash holdings can be persistent (e.g. Opler, Pinkowitz, Stulz, and Williamson, 1999). The positive effect of innovation efficiency on cash holdings remains statistically significant (Appendix Table 2), which confirms that our finding is less likely driven by reverse causality. We also use the natural logarithm of cash-to-net-assets ratio and cash-to-sales ratio as two alternative measures for cash holdings, and find qualitatively similar results (Appendix Table 3). Furthermore, we follow Bates, Kahle, and Stulz (2009) and re-estimate equation (3) by using changes in all the variables, rather than levels, to eliminate the impact of time-invariant firm characteristics on cash holdings. Our conclusion remains the same for citation-based measures, as we report in Appendix Table 4.

Fourth, we verify our main results by using a filter is stricter than the original one, which requires firms with at least one patent to show that the results are not heavily influenced by including firms with zero patents into our sample. We report consistent results in Appendix Table 5, and confirm that adopting a stricter filter does not change our conclusion.

Finally, we also find that innovation efficiency strongly predicts future cash holdings

(Appendix Table 6), even after we control for contemporaneous cash holdings (Appendix Table 7). Collectively, these tests suggest that innovation efficiency positively affects future corporate cash holdings, and point to necessary long-term investments in R&D activities.

7. Conclusion

Given the large cash holdings of innovative firms and the increasing R&D expenditures out of the U.S., our study explores why innovative firms hold so much cash around the world. Specifically, we examine the impact of innovation efficiency on firms' cash holdings across 23 non-U.S. countries over the period 1990-2012. We find strong evidence that firms with higher innovation efficiency reserve more cash for precautionary motive. To address potential endogeneity concerns, we use a DID approach based on patent reforms and exogenous shocks with respect to cultural diversification. The results based on these two identification strategies support our causal interpretation. The country-by-country analysis shows that the positive effect of innovation efficiency on cash holdings exists in 18 out of 23 non-U.S. countries, 10 of which are statistically significant. We also provide supportive evidence for the precautionary motive that innovatively efficient firms hold more cash to alleviate financial constraints, invest in future innovation, or exploit innovation opportunities.

Moreover, we find that the cash flow sensitivity of cash increases with innovation efficiency, indicating that innovatively efficient firms are more likely to save cash out of cash flows. Supporting evidence from payout policy shows that these firms pay out less cash and conduct fewer share repurchases. In addition, we show that the IE-cash effect is stronger for firms with better governance and firms in environments that encourage competitiveness more and provide more R&D human capital and in industries with high competition.

In sum, our paper provides novel and comprehensive evidence that innovation efficiency plays an important role in determining corporate cash holdings. Our findings have implications for future research on corporate innovation and financial policies not only in the U.S. but also around the world.

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Table 1
Summary Statistics

The sample consists of 60,004 firm-year observations for 8,379 unique firms from 23 countries during the period 1990-2012. The reported statistic is the pooled mean value of each variable by country. *Firm No.* is the average number of firms per year. *Patent* is the number of successful patent applications filed by firm *i* in country *j* in year *t* (and granted by the end of 2012). *Cit1*, *Cit3*, and *Cit4* are the total adjusted number of subsequent citations received by patents filed by firm *i* in country *j* in year *t* based on three different technology classes (IPC1, IPC3, and IPC4) issued by the European Patent Office (EPO) in year *t*. *Ln(1+IE_pat)* is innovation efficiency (IE) measure as the natural logarithm of one plus patents in year *t* scaled by R&D capital. R&D capital is the 5-year cumulative R&D expenses from year *t*−4 to *t*, assuming an annual depreciation rate of 20%. *Ln(1+IE_cit1)*, *Ln(1+IE_cit3)*, and *Ln(1+IE_cit4)* are IE measures defined as the natural logarithm of one plus adjusted patent citations in year *t* scaled by the sum of 5-year R&D expenses from year *t*−4 to *t*. *R&D/Sales* is R&D expense in year *t* divided by sales in year *t*. *R&D* is the research and development expense in year *t* in billion U.S. dollars. *MV* and *Assets* are market capitalization of the firm and book value of total assets in billion U.S. dollars, respectively. *Cash* is cash and short-term investments divided by total assets in year *t*. The detailed definitions of these variables are given in the Appendix. All continuous variables are winsorized at the 1st and 99th percentiles by country. Panel A reports the descriptive statistics. Panel B presents the Pearson correlation matrix. Correlations statistically significant at the 5% level ($p < 0.05$) level are in bold.

Panel A: Descriptive statistics

Country	*Patent*	*Cit1*	*Cit3*	*Cit4*	*Ln(1+IE_pat)*	*Ln(1+IE_cit1)*	*Ln(1+IE_cit3)*	*Ln(1+IE_cit4)*	*R&D/Sales*	*R&D*	*MV*	*Assets*	*Cash*	*Firm No.*
Australia	0.242	0.278	0.287	0.273	0.035	0.018	0.017	0.017	1.211	0.005	0.779	0.899	0.250	178
Austria	0.854	0.623	0.731	0.701	0.018	0.015	0.013	0.012	0.063	0.022	1.244	2.461	0.124	25
Belgium	4.605	7.910	7.589	7.703	0.021	0.026	0.026	0.025	0.305	0.063	1.862	3.507	0.154	30
Canada	0.366	0.468	0.466	0.425	0.014	0.010	0.010	0.010	1.366	0.013	0.809	0.885	0.228	160
China	1.110	0.732	0.717	0.678	0.007	0.001	0.001	0.002	0.023	0.063	1.777	7.691	0.198	57
Denmark	3.015	8.551	6.599	5.992	0.032	0.031	0.026	0.023	0.955	0.071	2.029	2.274	0.186	36
Finland	0.636	0.682	0.702	0.628	0.028	0.013	0.015	0.015	0.087	0.080	1.631	1.964	0.140	65
France	3.390	3.532	3.389	3.285	0.039	0.022	0.022	0.022	0.161	0.140	4.019	6.954	0.166	148
Germany	9.858	12.585	12.958	12.322	0.030	0.020	0.021	0.021	0.114	0.179	3.094	6.533	0.168	174
Iceland	4.870	3.231	4.630	5.300	0.260	0.034	0.043	0.051	0.055	0.020	0.395	0.622	0.050	2
India	0.293	0.283	0.232	0.215	0.027	0.011	0.010	0.010	0.019	0.003	0.599	0.583	0.091	304
Israel	0.488	0.557	0.523	0.552	0.017	0.012	0.011	0.011	0.463	0.016	0.624	0.731	0.319	68
Italy	1.970	2.628	2.827	2.763	0.075	0.046	0.049	0.048	0.064	0.076	2.287	7.213	0.110	47
Japan	3.807	6.787	6.745	6.774	0.036	0.030	0.030	0.031	0.024	0.057	1.260	2.307	0.163	1202
Korea	0.790	0.105	0.082	0.056	0.031	0.007	0.006	0.005	0.016	0.035	0.949	2.417	0.136	97
Netherlands	9.503	15.011	14.912	14.654	0.026	0.019	0.021	0.021	0.351	0.292	5.038	9.554	0.146	39
New Zealand	0.337	0.355	0.410	0.432	0.046	0.030	0.030	0.029	0.492	0.003	0.612	0.609	0.155	17
Norway	1.102	2.095	2.042	1.955	0.040	0.033	0.033	0.031	2.513	0.018	2.657	3.585	0.200	38
Spain	1.016	1.151	1.150	1.211	0.035	0.028	0.025	0.026	0.026	0.052	5.370	9.530	0.102	19
Sweden	1.957	2.514	2.686	2.557	0.025	0.018	0.018	0.018	0.422	0.068	1.428	2.102	0.181	98
Switzerland	0.959	1.724	1.449	1.586	0.019	0.017	0.017	0.018	0.318	0.193	6.562	4.515	0.189	74
Turkey	1.646	1.929	2.074	1.989	0.028	0.024	0.025	0.023	0.008	0.006	0.738	1.540	0.105	42
UK	0.466	0.711	0.796	0.809	0.016	0.009	0.010	0.010	0.597	0.039	2.656	2.514	0.189	273

Table 1 *(continued)*

Panel B: Pearson correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) Cash														
(2) Ln(1+IE_pat)	**0.011**													
(3) Ln(1+IE_cit1)	**0.018**	**0.626**												
(4) Ln(1+IE_cit3)	**0.017**	**0.630**	**0.985**											
(5) Ln(1+IE_cit4)	**0.016**	**0.632**	**0.972**	**0.987**										
(6) Market to book	**0.291**	**0.021**	**0.021**	**0.021**	**0.019**									
(7) Size	**-0.277**	**0.008**	**0.035**	**0.035**	**0.035**	**-0.282**								
(8) Cash flow	**-0.264**	0.003	**0.008**	**0.010**	**0.011**	**-0.534**	**0.389**							
(9) Net working capital	**-0.091**	**0.022**	**0.019**	**0.019**	**0.020**	**-0.349**	**0.098**	**0.455**						
(10) Capital expenditure	**-0.178**	**0.020**	**0.021**	**0.020**	**0.019**	**0.046**	**0.059**	**0.056**	**-0.007**					
(11) Leverage	**-0.336**	-0.004	**-0.011**	**-0.011**	**-0.011**	**0.091**	**0.077**	**-0.200**	**-0.489**	**0.078**				
(12) R&D/sales	**0.224**	-0.001	-0.001	-0.002	-0.003	**0.206**	**-0.136**	**-0.302**	**-0.085**	**-0.024**	**-0.012**			
(13) Dividend dummy	**-0.155**	**0.022**	**0.035**	**0.036**	**0.038**	**-0.189**	**0.412**	**0.268**	**0.196**	**0.069**	**-0.102**	**-0.119**		
(14) Acquisition	**-0.011**	**-0.012**	**-0.011**	**-0.011**	**-0.011**	**0.018**	**-0.013**	0.007	0.005	**0.010**	-0.007	-0.004	**-0.061**	
(15) Cash flow risk	**0.213**	-0.007	**-0.018**	**-0.017**	**-0.018**	**0.250**	**-0.281**	**-0.251**	**-0.106**	**0.013**	**-0.079**	**0.117**	**-0.264**	**0.056**

Table 2
Innovation efficiency and cash holdings: OLS regression analysis

This table shows the effect of innovation efficiency on cash holdings when we estimate the following OLS regression:

$$Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t},$$

in which $Cash_{i,j,t}$ is the cash holdings for firm *i* in country *j* in year *t*, and vector *X* includes a set of firm-specific control variables measured in year *t*. The dependent variable *Cash* is calculated as cash and short-term investments divided by total assets in year *t*. *IE_pat* is innovation efficiency measured as the number of successful patent applications filed by firm *i* in country *j* in year *t* scaled by R&D capital. R&D capital is the 5-year cumulative R&D expenses from year *t*−4 to year *t*, assuming an annual depreciation rate of 20%. *IE_cit1*, *IE_cit3*, and *IE_cit4* are the total number of adjusted citations received by patents filed by firm *i* in country *j* in year *t* scaled by the 5-year cumulative R&D expenses. For each patent, we calculate its adjusted citations based on three different technology classes (IPC1, IPC3, and IPC4) issued by the EPO as the number of subsequent citations received by this patent divided by the average number of subsequent citations received by all patents categorized in the same technology class and filed in the same year as the focal patent. Ln(1+ *IE*) is calculated as the natural logarithm of one plus IE. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
Ln(1+ IE_pat)	0.047***			
	(0.013)			
Ln(1+ IE_cit1)		0.056***		
		(0.020)		
Ln(1+ IE_cit3)			0.054***	
			(0.019)	
Ln(1+ IE_cit4)				0.050***
				(0.017)
Market to book	0.016***	0.016***	0.016***	0.016***
	(0.002)	(0.002)	(0.002)	(0.002)
Size	-0.009***	-0.009***	-0.009***	-0.009***
	(0.002)	(0.002)	(0.002)	(0.002)
Cash flow	-0.025**	-0.024**	-0.024**	-0.024**
	(0.012)	(0.012)	(0.012)	(0.012)
Net working capital	-0.132***	-0.131***	-0.131***	-0.131***
	(0.014)	(0.014)	(0.014)	(0.014)
Capital expenditure	-0.379***	-0.379***	-0.379***	-0.379***
	(0.061)	(0.060)	(0.060)	(0.060)
Leverage	-0.308***	-0.308***	-0.308***	-0.308***
	(0.014)	(0.014)	(0.014)	(0.014)
R&D/sales	0.024***	0.024***	0.024***	0.024***
	(0.001)	(0.001)	(0.001)	(0.001)
Dividend dummy	-0.012	-0.012	-0.012	-0.012
	(0.009)	(0.009)	(0.009)	(0.009)
Acquisition	-0.280***	-0.280***	-0.280***	-0.280***
	(0.043)	(0.043)	(0.043)	(0.043)
Cash flow risk	0.082***	0.082***	0.082***	0.082***
	(0.023)	(0.023)	(0.023)	(0.023)
Constant	0.209***	0.214***	0.213***	0.214***
	(0.021)	(0.021)	(0.021)	(0.021)
Industry-year FE	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	60,004	60,004	60,004	60,004
Adjusted R^2	0.384	0.384	0.384	0.384

Table 3
Differences-in-differences (DID) tests based on patent reforms and the legalization of same-sex marriage

This table shows the effect of innovation efficiency on cash holdings using a DID method based on country patent reforms (Panel A) and the legalization of same-sex marriage (Panel B). The regression-adjusted DID model (Angrist and Krueger, 1999) is: $Cash_{i,j,t} = \beta_0 + \beta_1 Post\ treatment_{j,t} \times \text{Ln}(1+ IE_{i,j,t}) + \beta_2 \text{Ln}(1+ IE_{i,j,t}) + \beta_3 Post\ treatment_{j,t} + \delta' X + Country\ FE + Industry\ FE + Year\ FE + \varepsilon_{i,j,t}$, where *Post treatment* is a dummy that equals 1 for firms in countries that have experienced patent reforms or have legalized same-sex marriage by year *t* (including the reform year or approved year) and 0 otherwise. In Panel A, the three countries that have undertaken patent reforms include: Australia (1995), Finland (1995), and India (2005). In Panel B, the eight countries that have legalized same-sex marriage (approved year in parentheses) include: Netherlands (2000), Belgium (2003), Canada (2005), Spain (2005), Norway (2009), Sweden (2009), Iceland (2010), and Denmark (2012). The dependent variable *Cash* is calculated as cash and short-term investments divided by total assets in year *t*. *Post treatment* × Ln(1+ *IE*) is the interaction term of *Post treatment* and Ln(1+ *IE*), using *IE_pat*, *IE_cit1*, *IE_cit3*, and *IE_cit4* in columns 1-4, respectively. The definitions of other variables are given in the Appendix. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

Panel A: *Post treatment*=1 if country *j* has undertaken patent reform by year *t*

	(1)	(2)	(3)	(4)
Post treatment × Ln(1+ IE)	0.072**	0.155***	0.172***	0.156***
	(0.032)	(0.037)	(0.043)	(0.035)
Ln(1+ IE_pat)	0.029**			
	(0.012)			
Ln(1+ IE_cit1)		0.040**		
		(0.018)		
Ln(1+ IE_cit3)			0.038**	
			(0.017)	
Ln(1+ IE_cit4)				0.035**
				(0.016)
Post treatment	0.014**	0.015**	0.015**	0.015**
	(0.006)	(0.006)	(0.006)	(0.006)
Market to book	0.015***	0.015***	0.015***	0.015***
	(0.002)	(0.002)	(0.002)	(0.002)
Size	-0.008***	-0.008***	-0.008***	-0.008***
	(0.002)	(0.002)	(0.002)	(0.002)
Cash flow	-0.025**	-0.025**	-0.025**	-0.025**
	(0.010)	(0.010)	(0.010)	(0.010)
Net working capital	-0.128***	-0.128***	-0.128***	-0.128***
	(0.014)	(0.014)	(0.014)	(0.014)
Capital expenditure	-0.384***	-0.383***	-0.383***	-0.383***
	(0.057)	(0.057)	(0.057)	(0.057)
Leverage	-0.302***	-0.302***	-0.302***	-0.302***
	(0.013)	(0.013)	(0.013)	(0.013)
R&D/sales	0.025***	0.025***	0.025***	0.025***
	(0.001)	(0.001)	(0.001)	(0.001)
Dividend dummy	-0.011	-0.010	-0.010	-0.010
	(0.008)	(0.008)	(0.008)	(0.008)
Acquisition	-0.301***	-0.300***	-0.300***	-0.300***
	(0.048)	(0.047)	(0.047)	(0.047)
Cash flow risk	0.093***	0.093***	0.093***	0.093***
	(0.020)	(0.020)	(0.020)	(0.020)
Constant	0.243***	0.244***	0.244***	0.243***
	(0.013)	(0.013)	(0.013)	(0.013)
Country FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	60,004	60,004	60,004	60,004
Adjusted R^2	0.383	0.383	0.383	0.383

Table 3 *(continued)*

Panel B: *Post treatment*=1 if country *j* has legalized same-sex marriage by year *t*

	(1)	(2)	(3)	(4)
Post treatment × Ln(1+ IE)	0.117*	0.264***	0.251***	0.223***
	(0.062)	(0.073)	(0.085)	(0.070)
Ln(1+ IE_pat)	0.039***			
	(0.011)			
Ln(1+ IE_cit1)		0.040**		
		(0.016)		
Ln(1+ IE_cit3)			0.038**	
			(0.016)	
Ln(1+ IE_cit4)				0.034**
				(0.015)
Post treatment	-0.005	-0.005	-0.005	-0.005
	(0.007)	(0.007)	(0.007)	(0.007)
Market to book	0.015***	0.015***	0.015***	0.016***
	(0.002)	(0.002)	(0.002)	(0.002)
Size	-0.008***	-0.008***	-0.008***	-0.008***
	(0.002)	(0.002)	(0.002)	(0.002)
Cash flow	-0.025**	-0.025**	-0.025**	-0.025**
	(0.010)	(0.010)	(0.010)	(0.010)
Net working capital	-0.128***	-0.128***	-0.128***	-0.128***
	(0.014)	(0.014)	(0.014)	(0.014)
Capital expenditure	-0.383***	-0.383***	-0.383***	-0.382***
	(0.056)	(0.056)	(0.056)	(0.056)
Leverage	-0.302***	-0.302***	-0.302***	-0.302***
	(0.013)	(0.013)	(0.013)	(0.013)
R&D/sales	0.025***	0.025***	0.025***	0.025***
	(0.001)	(0.001)	(0.001)	(0.001)
Dividend dummy	-0.010	-0.010	-0.010	-0.010
	(0.008)	(0.008)	(0.008)	(0.008)
Acquisition	-0.300***	-0.300***	-0.300***	-0.300***
	(0.047)	(0.047)	(0.047)	(0.047)
Cash flow risk	0.093***	0.094***	0.094***	0.093***
	(0.020)	(0.020)	(0.020)	(0.020)
Constant	0.244***	0.244***	0.244***	0.244***
	(0.013)	(0.013)	(0.013)	(0.013)
Country FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	60,004	60,004	60,004	60,004
Adjusted R^2	0.383	0.383	0.383	0.383

Table 4
The precautionary motive for innovative firms to hold cash

This table presents the supporting evidence for precautionary motive of cash holdings in innovatively efficient firms. In Panel A, we divide firms into financially constrained and unconstrained groups by using the size-age index (SA-index) developed by Hadlock and Pierce (2010). A higher (lower) SA-index value indicates greater (smaller) financial constraints. Firms with an SA-index above the 70th percentile (below the 30th percentile) of the cross-sectional distribution in year *t* are considered as financially constrained (unconstrained). The estimated regression is: $Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}$. Panel B shows the effect of IE and cash holdings on future R&D investments by using the following regression: $R\&D/Sales_{t+1} = \beta_0 + \beta_1 High\ IE\ dummy_{i,j,t} \times Cash_{i,j,t} + \beta_2 Cash_{i,j,t} + \beta_3 High\ IE\ dummy_{i,j,t} + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t+1}$. The dependent variable is $R\&D/Sales_{t+1}$, calculated as R&D expenses scaled by sales in year *t*+1. *High IE dummy* equals 1 if the value of the firm's IE measure (*IE_pat*, *IE_cit1*, *IE_cit3*, and *IE_cit4* in columns 1-4, respectively) is above the 90th percentile in the country, and 0 otherwise. In Panel C, our sample is divided into two groups based on industry-level R&D intensity, which is the ratio of total R&D expenses to the total sales in each industry (2-digit SIC code) in year *t*. Firms with industry-level R&D intensity above (below) the median in year *t* are assigned to the high (low) group. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in brackets are *z*-statistics for the difference tests of the coefficients of Ln(1+ *IE*) between the two groups. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

Panel A: Financially constrained vs. unconstrained

	Dependent variable: *Cash*							
	Const.	Unconst.	Const.	Unconst.	Const.	Unconst.	Const.	Unconst.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(1+ IE_pat)	0.102***	0.032**						
	(0.028)	(0.014)						
Ln(1+ IE_cit1)			0.115***	0.025**				
			(0.041)	(0.010)				
Ln(1+ IE_cit3)					0.106***	0.025**		
					(0.041)	(0.011)		
Ln(1+ IE_cit4)							0.099**	0.025**
							(0.040)	(0.012)
Market to book	0.014***	0.029***	0.014***	0.029***	0.014***	0.029***	0.014***	0.029***
	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)	(0.004)
Size	-0.003	-0.004**	-0.003	-0.004**	-0.003	-0.004**	-0.003	-0.004**
	(0.006)	(0.002)	(0.006)	(0.002)	(0.006)	(0.002)	(0.006)	(0.002)
Cash flow	-0.036***	-0.115***	-0.036***	-0.113***	-0.036***	-0.113***	-0.036***	-0.113***
	(0.010)	(0.034)	(0.010)	(0.033)	(0.010)	(0.033)	(0.010)	(0.033)
Net working capital	-0.123***	-0.121***	-0.123***	-0.121***	-0.123***	-0.121***	-0.123***	-0.121***
	(0.015)	(0.018)	(0.015)	(0.018)	(0.015)	(0.018)	(0.015)	(0.018)
Capital expenditure	-0.472***	-0.367***	-0.471***	-0.367***	-0.471***	-0.367***	-0.471***	-0.367***
	(0.074)	(0.054)	(0.074)	(0.054)	(0.074)	(0.054)	(0.074)	(0.054)
Leverage	-0.325***	-0.261***	-0.324***	-0.261***	-0.324***	-0.261***	-0.325***	-0.261***
	(0.018)	(0.019)	(0.018)	(0.019)	(0.018)	(0.019)	(0.018)	(0.019)
R&D/sales	0.009***	0.449***	0.009***	0.448***	0.009***	0.448***	0.009***	0.447***
	(0.000)	(0.055)	(0.000)	(0.055)	(0.000)	(0.055)	(0.000)	(0.055)
Dividend dummy	-0.003	-0.004*	-0.003	-0.004*	-0.003	-0.004*	-0.003	-0.004*
	(0.016)	(0.002)	(0.016)	(0.002)	(0.016)	(0.002)	(0.016)	(0.002)
Acquisition	-0.398***	-0.187***	-0.399***	-0.188***	-0.399***	-0.188***	-0.399***	-0.188***
	(0.082)	(0.049)	(0.082)	(0.049)	(0.082)	(0.049)	(0.081)	(0.049)
Cash flow risk	0.130***	0.025	0.130***	0.025	0.130***	0.025	0.131***	0.025
	(0.046)	(0.023)	(0.045)	(0.023)	(0.045)	(0.023)	(0.045)	(0.023)
Constant	0.195***	0.225***	0.203***	0.226***	0.197***	0.226***	0.200***	0.226***
	(0.025)	(0.017)	(0.026)	(0.017)	(0.025)	(0.017)	(0.025)	(0.017)
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17,999	17,997	17,999	17,997	17,999	17,997	17,999	17,997
Adjusted R^2	0.402	0.374	0.402	0.373	0.402	0.374	0.402	0.374
Difference test	0.070**		0.090**		0.081*		0.074*	
z-statistic	[2.236]		[2.133]		[1.908]		[1.772]	

Table 4 *(continued)*

Panel B: The effect of IE and cash holdings on future R&D investments

	Dependent variable: $R\&D/Sales_{t+1}$			
	(1)	(2)	(3)	(4)
High IE dummy × Cash	0.168***	0.157***	0.156***	0.159***
	(0.033)	(0.054)	(0.054)	(0.055)
Cash	0.149***	0.154***	0.154***	0.154***
	(0.048)	(0.047)	(0.047)	(0.047)
High IE_pat dummy	-0.021***			
	(0.005)			
High IE_cit1 dummy		-0.016**		
		(0.007)		
High IE_cit3 dummy			-0.016**	
			(0.007)	
High IE_cit4 dummy				-0.017**
				(0.007)
Market to book	0.002	0.002	0.002	0.002
	(0.001)	(0.001)	(0.001)	(0.001)
Cash flow	-0.015	-0.015	-0.015	-0.015
	(0.017)	(0.017)	(0.017)	(0.017)
Sales growth	0.016**	0.016**	0.016**	0.016**
	(0.007)	(0.006)	(0.006)	(0.006)
Leverage	-0.009	-0.009	-0.009	-0.009
	(0.008)	(0.008)	(0.008)	(0.008)
Size	-0.001**	-0.001**	-0.001**	-0.001**
	(0.001)	(0.001)	(0.001)	(0.001)
$R\&D/Sales_t$	0.627***	0.628***	0.628***	0.628***
	(0.019)	(0.019)	(0.019)	(0.019)
Constant	0.004	0.003	0.003	0.003
	(0.006)	(0.005)	(0.005)	(0.005)
Industry-year FE	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	57,098	57,098	57,098	57,098
Adjusted R^2	0.754	0.754	0.753	0.754

Table 4 *(continued)*

Panel C: High vs. Low industry-level R&D intensity (Total $R\&D_t$ /Total $Sales_t$)

	Dependent variable: $R\&D/Sales_{t+1}$							
	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High IE dummy × Cash	0.165***	0.044	0.164***	-0.002	0.164***	-0.003	0.167***	-0.003
	(0.027)	(0.043)	(0.043)	(0.063)	(0.043)	(0.063)	(0.045)	(0.063)
Cash	0.149***	0.095***	0.154***	0.097***	0.154***	0.098***	0.154***	0.098***
	(0.057)	(0.028)	(0.055)	(0.028)	(0.055)	(0.028)	(0.054)	(0.028)
High IE_pat dummy	-0.021***	-0.004						
	(0.006)	(0.005)						
High IE_cit1 dummy			-0.018***	0.004				
			(0.005)	(0.006)				
High IE_cit3 dummy					-0.018***	0.004		
					(0.005)	(0.006)		
High IE_cit4 dummy							-0.019***	0.004
							(0.005)	(0.006)
Market to book	0.001	0.005*	0.001	0.005*	0.001	0.005*	0.001	0.005*
	(0.001)	(0.003)	(0.001)	(0.003)	(0.001)	(0.003)	(0.001)	(0.003)
Cash flow	-0.014	-0.012	-0.014	-0.012	-0.014	-0.012	-0.014	-0.012
	(0.014)	(0.026)	(0.014)	(0.027)	(0.014)	(0.027)	(0.014)	(0.027)
Sales growth	0.019**	0.009**	0.019**	0.009**	0.019**	0.009**	0.019**	0.009**
	(0.008)	(0.004)	(0.008)	(0.004)	(0.008)	(0.004)	(0.008)	(0.004)
Leverage	-0.012	-0.009	-0.011	-0.009	-0.011	-0.009	-0.011	-0.009
	(0.011)	(0.008)	(0.011)	(0.008)	(0.011)	(0.008)	(0.011)	(0.008)
Size	-0.002*	-0.001***	-0.002*	-0.001***	-0.002*	-0.001***	-0.002*	-0.001***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
$R\&D/Sales_t$	0.643***	0.527***	0.644***	0.528***	0.644***	0.528***	0.644***	0.528***
	(0.009)	(0.031)	(0.009)	(0.031)	(0.009)	(0.031)	(0.009)	(0.031)
Constant	0.015	0.001	0.015*	0.001	0.011	-0.001	0.009	-0.001
	(0.009)	(0.005)	(0.008)	(0.006)	(0.008)	(0.005)	(0.009)	(0.005)
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	28,712	28,386	28,712	28,386	28,712	28,386	28,712	28,386
Adjusted R^2	0.785	0.617	0.785	0.617	0.785	0.617	0.785	0.617
Difference test	0.121**		0.166**		0.167**		0.170**	
z-statistic	[2.383]		[2.176]		[2.189]		[2.196]	

Table 5
Innovation efficiency and cash flow sensitivity of cash

This table shows the effect of innovation efficiency on the cash flow sensitivity of cash. The estimated regression is:

$$\Delta Cash_{i,j,t} = \beta_0 + \beta_1 Ln(1+ IE_{i,j,t}) \times Cash\ flow_{i,j,t} + \beta_2 Cash\ flow_{i,j,t} + \beta_3 Ln(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}.$$

The dependent variable $\Delta Cash_{i,j,t}$ is the change in the cash ratio, which is calculated as cash and short-term investments divided by total assets in year *t*. *Cash flow* is the ratio of earnings before extraordinary items and depreciation (minus interest, taxes, and dividends) to total assets. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
Ln(1+ IE) × Cash flow	0.033**	0.072***	0.070***	0.079***
	(0.016)	(0.014)	(0.016)	(0.021)
Cash flow	0.042***	0.042***	0.042***	0.042***
	(0.006)	(0.006)	(0.006)	(0.006)
Ln(1+ IE_pat)	0.002			
	(0.003)			
Ln(1+ IE_cit1)		0.004**		
		(0.002)		
Ln(1+ IE_cit3)			0.004**	
			(0.002)	
Ln(1+ IE_cit4)				0.003
				(0.002)
Market to book	0.002**	0.002**	0.002**	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)
Size	-0.023	-0.026	-0.026	-0.025
	(0.028)	(0.028)	(0.028)	(0.028)
Capital expenditure	-0.249***	-0.249***	-0.249***	-0.249***
	(0.023)	(0.022)	(0.022)	(0.022)
Acquisition	-0.564***	-0.564***	-0.564***	-0.564***
	(0.068)	(0.068)	(0.068)	(0.068)
ΔNet working capital	-0.212***	-0.212***	-0.212***	-0.212***
	(0.027)	(0.027)	(0.027)	(0.027)
ΔShort debt	-0.285***	-0.285***	-0.285***	-0.285***
	(0.018)	(0.018)	(0.018)	(0.018)
Constant	0.005	0.003	0.004	0.003
	(0.006)	(0.006)	(0.006)	(0.006)
Industry-year FE	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	59,756	59,756	59,756	59,756
Adjusted R^2	0.093	0.093	0.093	0.093

Table 6
Innovation efficiency, cash holdings, and payout policy

This table presents regression results of the effect of innovation efficiency on firms' payout policies when we use Tobit regressions. The estimated regression is: $Payout_{i,j,t+1} = \beta_0 + \beta_1 High\ IE\ dummy_{i,j,t} \times Cash_{i,j,t} + \beta_2 Cash_{i,j,t} + \beta_3 High\ IE\ dummy_{i,j,t} + \delta' X + Industry\ FE + Year\ FE + Country\ FE + \varepsilon_{i,j,t+1}$, in which vector *X* includes a set of firm-specific control variables measured in year *t*. The dependent variable is $DIV/Sales_{t+1}$ or $TotalPayout/Sales_{t+1}$. $DIV/Sales_{t+1}$ is the number of dividends paid scaled by sales in year *t*+1. $TotalPayout/Sales_{t+1}$ is the total amount of cash paid through dividends and repurchases scaled by sales in year *t*+1. *High IE dummy* equals 1 if the value of the firm's IE measure (*IE_pat* in columns 1 and 5, *IE_cit1* in columns 2 and 6, *IE_cit3* in columns 3 and 7, and *IE_cit4* in columns 4 and 8) is above the 90th percentile in the country, and 0 otherwise. *Cash* is the cash holdings in year *t*. The definitions of other variables are given in the Appendix. All regressions control for country, industry and year fixed effects. *Market to book* and *Age* are divided by 100 in regressions. Numbers in parentheses are standard errors clustered at the industry-year level. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

Dependent variable	$DIV/Sales_{t+1}$				$TotalPayout/Sales_{t+1}$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High IE dummy × Cash	-0.009***	-0.008**	-0.009***	-0.008**	-0.012***	-0.014***	-0.015***	-0.014***
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
Cash	0.002*	0.002*	0.002*	0.002*	0.004*	0.003*	0.004*	0.003*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
High IE_pat dummy	0.002***				0.002***			
	(0.000)				(0.001)			
High IE_cit1 dummy		0.001***				0.002***		
		(0.000)				(0.001)		
High IE_cit3 dummy			0.001***				0.002***	
			(0.001)				(0.001)	
High IE_cit4 dummy				0.001***				0.002***
				(0.001)				(0.001)
Market to book	0.010	0.010	0.011	0.010	0.160***	0.161***	0.161***	0.161***
	(0.037)	(0.037)	(0.037)	(0.037)	(0.030)	(0.030)	(0.030)	(0.030)
Size	0.001***	0.001***	0.001***	0.001***	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Leverage	-0.010***	-0.010***	-0.010***	-0.010***	-0.013***	-0.013***	-0.013***	-0.013***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
ROA	0.057***	0.057***	0.057***	0.057***	0.047***	0.047***	0.047***	0.047***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
Retained earnings	0.005**	0.005**	0.005**	0.005**	0.001*	0.001*	0.001*	0.001*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Non-operating income	0.023***	0.023***	0.023***	0.023***	0.031***	0.031***	0.031***	0.031***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Capital expenditure	-0.014***	-0.014***	-0.014***	-0.014***	-0.007*	-0.007	-0.007*	-0.007*
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Sales growth	-0.002***	-0.002***	-0.002***	-0.002***	-0.003***	-0.003***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age	0.051**	0.051**	0.051**	0.051**	0.058*	0.058*	0.059*	0.059*
	(0.025)	(0.025)	(0.025)	(0.025)	(0.032)	(0.032)	(0.032)	(0.032)
$DIV/Sales_t$	0.809***	0.810***	0.810***	0.810***				
	(0.015)	(0.015)	(0.015)	(0.015)				
$TotalPayout/Sales_t$					0.754***	0.754***	0.754***	0.754***
					(0.017)	(0.017)	(0.017)	(0.017)
Constant	-0.024***	-0.024***	-0.024***	-0.024***	-0.032***	-0.032***	-0.032***	-0.032***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	57,173	57,173	57,173	57,173	57,173	57,173	57,173	57,173

Table 7
Corporate governance and the effect of innovation efficiency on cash holdings

This table presents the effects of country-level and firm-level corporate governance on the relation between innovation efficiency and cash holdings. The estimated regression is: $Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}$. The dependent variable is cash ratio. Panel A and B use country-level index of shareholder rights protection from Djankov, La Porta, López-de-Silanes, and Shleifer (2008). Panel A uses the revised anti-director index and Panel B uses the anti-self-dealing index. Higher index values indicate higher levels of investor protection in the country. Japan is excluded from this analysis to eliminate subsample bias. Firms from 22 countries are divided into high (above median) and low investor protection groups by the median of each index. Panel C presents subsample tests using the firm-level governance index from Aggarwal, Erel, Ferreira, and Matos (2011). Higher index values indicate higher levels of firm governance. The sample consists of 757 firms from 17 countries during the period 2004-2008 and is divided into high (above median) and low governance groups by the yearly cross-sectional median. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in brackets are *z*-statistics for the difference tests of the coefficients of Ln(1+ *IE*) between the high and low index groups. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

Panel A: High vs. Low anti-director index

	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(1+ IE_pat)	0.065***	0.005						
	(0.017)	(0.015)						
Ln(1+ IE_cit1)			0.122***	0.020				
			(0.024)	(0.025)				
Ln(1+ IE_cit3)					0.118***	0.017		
					(0.026)	(0.023)		
Ln(1+ IE_cit4)							0.125***	0.015
							(0.027)	(0.022)
Market to book	0.014***	0.028***	0.014***	0.028***	0.014***	0.028***	0.014***	0.028***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Size	-0.010***	-0.008***	-0.010***	-0.008***	-0.010***	-0.008***	-0.010***	-0.008***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Cash flow	-0.042***	-0.109*	-0.042***	-0.108*	-0.042***	-0.109*	-0.042***	-0.108*
	(0.010)	(0.058)	(0.010)	(0.058)	(0.010)	(0.058)	(0.010)	(0.058)
Net working capital	-0.098***	-0.187***	-0.097***	-0.187***	-0.097***	-0.187***	-0.097***	-0.187***
	(0.020)	(0.018)	(0.020)	(0.018)	(0.020)	(0.018)	(0.020)	(0.018)
Capital expenditure	-0.329***	-0.419***	-0.329***	-0.421***	-0.329***	-0.420***	-0.329***	-0.420***
	(0.064)	(0.111)	(0.064)	(0.112)	(0.064)	(0.112)	(0.064)	(0.112)
Leverage	-0.293***	-0.392***	-0.293***	-0.392***	-0.293***	-0.392***	-0.293***	-0.392***
	(0.013)	(0.041)	(0.013)	(0.041)	(0.013)	(0.041)	(0.013)	(0.041)
R&D/sales	0.008***	0.002**	0.008***	0.002**	0.008***	0.002**	0.008***	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Dividend dummy	-0.021	-0.014*	-0.020	-0.014*	-0.021	-0.014*	-0.021	-0.014*
	(0.017)	(0.008)	(0.017)	(0.008)	(0.017)	(0.008)	(0.017)	(0.008)
Acquisition	-0.298***	-0.171***	-0.296***	-0.170***	-0.296***	-0.170***	-0.296***	-0.170***
	(0.049)	(0.036)	(0.049)	(0.036)	(0.049)	(0.036)	(0.049)	(0.036)
Cash flow risk	0.102***	0.046***	0.103***	0.046***	0.103***	0.046***	0.103***	0.046***
	(0.037)	(0.008)	(0.036)	(0.008)	(0.037)	(0.008)	(0.037)	(0.008)
Constant	0.214***	0.285***	0.235***	0.284***	0.218***	0.286***	0.230***	0.284***
	(0.020)	(0.032)	(0.019)	(0.032)	(0.019)	(0.030)	(0.019)	(0.032)
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,858	12,653	20,858	12,653	20,858	12,653	20,858	12,653
Adjusted R^2	0.380	0.385	0.380	0.385	0.380	0.385	0.380	0.385
Difference test	0.060***		0.102***		0.101***		0.110***	
z-statistic	[2.646]		[2.943]		[2.910]		[3.158]	

Table 7 *(continued)*

Panel B: High vs. Low anti-self-dealing index

	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(1+ IE_pat)	0.103***	0.014						
	(0.025)	(0.017)						
Ln(1+ IE_cit1)			0.139***	0.011				
			(0.039)	(0.013)				
Ln(1+ IE_cit3)					0.138***	0.011		
					(0.039)	(0.012)		
Ln(1+ IE_cit4)							0.142***	0.010
							(0.040)	(0.012)
Market to book	0.011***	0.028***	0.012***	0.029***	0.012***	0.029***	0.012***	0.029***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Size	-0.013***	-0.004***	-0.013***	-0.004***	-0.013***	-0.004***	-0.013***	-0.004***
	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
Cash flow	-0.038***	-0.140**	-0.037***	-0.144**	-0.037***	-0.144**	-0.037***	-0.144**
	(0.009)	(0.063)	(0.009)	(0.064)	(0.009)	(0.064)	(0.009)	(0.064)
Net working capital	-0.095***	-0.158***	-0.094***	-0.161***	-0.094***	-0.161***	-0.094***	-0.161***
	(0.021)	(0.012)	(0.021)	(0.013)	(0.021)	(0.013)	(0.021)	(0.013)
Capital expenditure	-0.495***	-0.212***	-0.496***	-0.218***	-0.496***	-0.218***	-0.497***	-0.218***
	(0.104)	(0.043)	(0.103)	(0.043)	(0.104)	(0.043)	(0.104)	(0.043)
Leverage	-0.290***	-0.329***	-0.289***	-0.334***	-0.289***	-0.334***	-0.289***	-0.334***
	(0.016)	(0.027)	(0.016)	(0.028)	(0.016)	(0.028)	(0.016)	(0.028)
R&D/sales	0.007***	0.003**	0.007***	0.003**	0.007***	0.003**	0.007***	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Dividend dummy	-0.036*	-0.002	-0.037*	-0.002	-0.037*	-0.002	-0.037*	-0.002
	(0.020)	(0.007)	(0.020)	(0.007)	(0.020)	(0.007)	(0.020)	(0.007)
Acquisition	-0.293***	-0.160***	-0.292***	-0.161***	-0.292***	-0.161***	-0.292***	-0.161***
	(0.046)	(0.026)	(0.045)	(0.027)	(0.045)	(0.027)	(0.045)	(0.027)
Cash flow risk	0.089***	0.039***	0.090***	0.042***	0.090***	0.041***	0.090***	0.041***
	(0.021)	(0.011)	(0.021)	(0.010)	(0.021)	(0.010)	(0.021)	(0.010)
Constant	0.316***	0.167***	0.325***	0.172***	0.317***	0.179***	0.319***	0.171***
	(0.014)	(0.016)	(0.013)	(0.018)	(0.013)	(0.018)	(0.014)	(0.017)
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,771	18,740	14,771	18,740	14,771	18,740	14,771	18,740
Adjusted R^2	0.346	0.393	0.346	0.391	0.346	0.391	0.346	0.391
Difference test	0.089***		0.128***		0.127***		0.132***	
z-statistic	[2.944]		[3.114]		[3.112]		[3.161]	

Table 7 *(continued)*

Panel C: High vs. Low firm-level governance index

	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(1+ IE_pat)	0.121***	0.014						
	(0.046)	(0.027)						
Ln(1+ IE_cit1)			0.066**	0.022				
			(0.028)	(0.021)				
Ln(1+ IE_cit3)					0.067***	0.031		
					(0.025)	(0.022)		
Ln(1+ IE_cit4)							0.070***	0.036
							(0.024)	(0.023)
Market to book	0.027***	0.058***	0.026***	0.058***	0.026***	0.057***	0.026***	0.057***
	(0.008)	(0.009)	(0.008)	(0.009)	(0.008)	(0.009)	(0.008)	(0.010)
Size	-0.005	-0.011*	-0.006	-0.011*	-0.006	-0.011*	-0.006	-0.011*
	(0.004)	(0.007)	(0.004)	(0.007)	(0.004)	(0.007)	(0.004)	(0.007)
Cash flow	-0.156**	-0.039	-0.147*	-0.040	-0.148*	-0.039	-0.147*	-0.038
	(0.074)	(0.116)	(0.079)	(0.116)	(0.079)	(0.117)	(0.079)	(0.117)
Net working capital	-0.141***	-0.182***	-0.142***	-0.183***	-0.142***	-0.184***	-0.142***	-0.185***
	(0.050)	(0.043)	(0.050)	(0.043)	(0.050)	(0.043)	(0.050)	(0.043)
Capital expenditure	-0.622***	-0.462***	-0.626***	-0.464***	-0.623***	-0.465***	-0.623***	-0.467***
	(0.182)	(0.155)	(0.182)	(0.156)	(0.182)	(0.157)	(0.182)	(0.157)
Leverage	-0.196***	-0.317***	-0.194***	-0.317***	-0.195***	-0.317***	-0.195***	-0.317***
	(0.053)	(0.047)	(0.053)	(0.047)	(0.053)	(0.047)	(0.053)	(0.047)
R&D/sales	0.502***	0.585***	0.505***	0.588***	0.504***	0.591***	0.504***	0.592***
	(0.035)	(0.108)	(0.028)	(0.108)	(0.028)	(0.108)	(0.027)	(0.108)
Dividend dummy	-0.020	-0.013	-0.020	-0.013	-0.020	-0.014	-0.020	-0.014
	(0.013)	(0.016)	(0.013)	(0.015)	(0.013)	(0.015)	(0.013)	(0.015)
Acquisition	-0.647**	-1.315	-0.646**	-1.317	-0.643**	-1.329	-0.645**	-1.336
	(0.321)	(0.917)	(0.321)	(0.930)	(0.321)	(0.935)	(0.320)	(0.944)
Cash flow risk	-0.019	-0.184	-0.018	-0.184	-0.018	-0.187	-0.018	-0.187
	(0.043)	(0.468)	(0.043)	(0.465)	(0.042)	(0.465)	(0.043)	(0.467)
Constant	0.147***	0.266***	0.146***	0.267***	0.146***	0.268***	0.146***	0.268***
	(0.016)	(0.050)	(0.028)	(0.050)	(0.027)	(0.050)	(0.029)	(0.050)
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,552	1,560	1,552	1,560	1,552	1,560	1,552	1,560
Adjusted R^2	0.435	0.538	0.432	0.538	0.432	0.539	0.432	0.539
Difference test	0.107**		0.044		0.036		0.034	
z-statistic	[2.006]		[1.257]		[1.081]		[1.023]	

Table 8
Legal environment on competitiveness of enterprises and the effect of innovation efficiency on cash holdings

This table presents results for the impact of legal environment on competitiveness of enterprises on the IE-cash relation. The estimated regression is: $Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}$. The dependent variable is cash ratio in year *t*. The index is from WCY executive survey question that "The legal and regulatory framework encourages the competitiveness of enterprises". This index takes value from 0 to 10 with higher value indicates more encouragement in competitiveness. Japan is excluded from this analysis to eliminate subsample bias. Firms from other 22 countries are divided into high and low index groups by the yearly cross-sectional median. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in brackets are *z*-statistics for the difference tests of the coefficients of Ln(1+ *IE*) between the high and low index groups. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	High vs. Low competitiveness							
	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(1+ IE_pat)	0.087***	0.020						
	(0.020)	(0.015)						
Ln(1+ IE_cit1)			0.106***	0.028**				
			(0.027)	(0.012)				
Ln(1+ IE_cit3)					0.114***	0.029**		
					(0.030)	(0.012)		
Ln(1+ IE_cit4)							0.114***	0.030**
							(0.030)	(0.013)
Market to book	0.015***	0.022***	0.015***	0.022***	0.015***	0.022***	0.015***	0.022***
	(0.004)	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)
Size	-0.010***	-0.007***	-0.010***	-0.007***	-0.010***	-0.007***	-0.010***	-0.007***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Cash flow	-0.041***	-0.041**	-0.041***	-0.041**	-0.041***	-0.041**	-0.041***	-0.041**
	(0.009)	(0.020)	(0.009)	(0.020)	(0.009)	(0.020)	(0.009)	(0.020)
Net working capital	-0.142***	-0.152***	-0.142***	-0.152***	-0.141***	-0.152***	-0.142***	-0.152***
	(0.018)	(0.015)	(0.018)	(0.015)	(0.018)	(0.015)	(0.018)	(0.015)
Capital expenditure	-0.438***	-0.263***	-0.437***	-0.263***	-0.437***	-0.263***	-0.437***	-0.263***
	(0.085)	(0.050)	(0.085)	(0.050)	(0.085)	(0.050)	(0.085)	(0.050)
Leverage	-0.343***	-0.350***	-0.343***	-0.350***	-0.343***	-0.349***	-0.343***	-0.350***
	(0.018)	(0.027)	(0.018)	(0.026)	(0.018)	(0.026)	(0.018)	(0.026)
R&D/sales	0.011***	0.041***	0.011***	0.041***	0.011***	0.041***	0.011***	0.041***
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Dividend dummy	-0.021	-0.006	-0.021	-0.006	-0.021	-0.007	-0.021	-0.007
	(0.015)	(0.008)	(0.014)	(0.008)	(0.014)	(0.008)	(0.014)	(0.008)
Acquisition	-0.405***	-0.074	-0.405***	-0.074	-0.404***	-0.074	-0.404***	-0.074
	(0.096)	(0.060)	(0.094)	(0.060)	(0.094)	(0.060)	(0.094)	(0.060)
Cash flow risk	0.072**	0.067	0.073**	0.066	0.073**	0.066	0.073**	0.066
	(0.031)	(0.051)	(0.031)	(0.051)	(0.031)	(0.051)	(0.031)	(0.051)
Constant	0.281***	0.219***	0.280***	0.221***	0.282***	0.218***	0.283***	0.220***
	(0.033)	(0.017)	(0.032)	(0.017)	(0.029)	(0.016)	(0.029)	(0.017)
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,467	16,590	15,467	16,590	15,467	16,590	15,467	16,590
Adjusted R^2	0.409	0.403	0.409	0.404	0.409	0.404	0.409	0.404
Difference test	0.067***		0.078***		0.085***		0.084**	
z-statistic	[2.680]		[2.640]		[2.631]		[2.569]	

Table 9
Human capital for innovation and the effect of innovation efficiency on cash holdings

This table presents regression results on the impact of human capital in R&D on the relation between innovation efficiency and cash holdings. The estimated regression is: $Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}$. The dependent variable is cash ratio. Human capital for innovation is measured as the sum of technicians in R&D (per million people) and researchers in R&D (per million people) each year in the country from World Bank database. Japan is excluded from this analysis to eliminate subsample bias. Firms from other 22 countries are divided into high (above median) and low groups by the yearly cross-sectional median. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in brackets are *z*-statistics for the difference tests of the coefficients of Ln(1+ *IE*) between the high and low index groups. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	High vs. Low level of human capital for innovation							
	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(1+ IE_pat)	0.076***	0.022*						
	(0.028)	(0.011)						
Ln(1+ IE_cit1)			0.141***	0.054**				
			(0.036)	(0.026)				
Ln(1+ IE_cit3)					0.143***	0.056**		
					(0.035)	(0.028)		
Ln(1+ IE_cit4)							0.146***	0.056*
							(0.036)	(0.031)
Market to book	0.015***	0.023***	0.015***	0.023***	0.015***	0.023***	0.015***	0.023***
	(0.005)	(0.002)	(0.005)	(0.002)	(0.005)	(0.002)	(0.005)	(0.002)
Size	-0.012***	-0.003**	-0.012***	-0.003**	-0.012***	-0.003**	-0.012***	-0.003**
	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
Cash flow	-0.027***	-0.051*	-0.027***	-0.052*	-0.027***	-0.052*	-0.027***	-0.052*
	(0.010)	(0.030)	(0.010)	(0.030)	(0.010)	(0.030)	(0.010)	(0.030)
Net working capital	-0.147***	-0.119***	-0.146***	-0.119***	-0.146***	-0.119***	-0.146***	-0.119***
	(0.019)	(0.014)	(0.019)	(0.014)	(0.019)	(0.014)	(0.019)	(0.014)
Capital expenditure	-0.574***	-0.162***	-0.572***	-0.163***	-0.572***	-0.162***	-0.572***	-0.162***
	(0.110)	(0.046)	(0.110)	(0.046)	(0.110)	(0.046)	(0.110)	(0.046)
Leverage	-0.341***	-0.304***	-0.340***	-0.304***	-0.340***	-0.304***	-0.340***	-0.304***
	(0.018)	(0.021)	(0.019)	(0.021)	(0.018)	(0.021)	(0.018)	(0.021)
R&D/sales	0.010***	0.040***	0.010***	0.040***	0.010***	0.040***	0.010***	0.040***
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Dividend dummy	-0.027*	-0.002	-0.027*	-0.002	-0.027*	-0.002	-0.027*	-0.002
	(0.014)	(0.007)	(0.014)	(0.007)	(0.014)	(0.007)	(0.014)	(0.007)
Acquisition	-0.382***	-0.236***	-0.378***	-0.236***	-0.378***	-0.236***	-0.378***	-0.236***
	(0.083)	(0.048)	(0.081)	(0.048)	(0.082)	(0.048)	(0.082)	(0.048)
Cash flow risk	0.077***	0.132***	0.079***	0.133***	0.079***	0.132***	0.079***	0.132***
	(0.030)	(0.038)	(0.030)	(0.038)	(0.030)	(0.038)	(0.030)	(0.038)
Constant	0.263***	0.175***	0.268***	0.174***	0.276***	0.176***	0.265***	0.173***
	(0.026)	(0.013)	(0.025)	(0.013)	(0.025)	(0.013)	(0.025)	(0.011)
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,210	13,391	13,210	13,391	13,210	13,391	13,210	13,391
Adjusted R^2	0.380	0.399	0.380	0.399	0.380	0.399	0.380	0.399
Difference test	0.054*		0.087*		0.087*		0.090*	
z-statistic	[1.795]		[1.959]		[1.941]		[1.894]	

Table 10
Innovation competition and the effect of innovation efficiency on cash holdings

This table presents regression results on the impact of innovation competition on the relation between innovation efficiency and cash holdings. The estimated regression is: $Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}$. The dependent variable is cash ratio. Innovation competition is measured by Herfindahl-Hirschman index based on R&D expenditures (million U.S. dollars), defined as the sum of the squares of the market shares of the firms within the industry (2-digit SIC code) across 23 countries in year *t*. Our sample firms are divided into high (above median) and low groups by the yearly cross-sectional median of Herfindahl index. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in brackets are *z*-statistics for the difference tests of the coefficients of Ln(1+ *IE*) between the high and low index groups. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	High vs. Low Herfindahl index based on R&D expenditures							
	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(1+ IE_pat)	0.016	0.060***						
	(0.017)	(0.012)						
Ln(1+ IE_cit1)			0.033	0.063***				
			(0.024)	(0.021)				
Ln(1+ IE_cit3)					0.033	0.062***		
					(0.023)	(0.019)		
Ln(1+ IE_cit4)							0.031	0.058***
							(0.022)	(0.017)
Market to book	0.016***	0.014***	0.016***	0.014***	0.016***	0.014***	0.016***	0.014***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Size	-0.010***	-0.007***	-0.010***	-0.007***	-0.010***	-0.007***	-0.010***	-0.007***
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)
Cash flow	0.009	-0.042***	0.009	-0.042***	0.009	-0.042***	0.009	-0.042***
	(0.015)	(0.009)	(0.015)	(0.009)	(0.015)	(0.009)	(0.015)	(0.009)
Net working capital	-0.118***	-0.146***	-0.118***	-0.145***	-0.118***	-0.145***	-0.118***	-0.145***
	(0.015)	(0.017)	(0.015)	(0.017)	(0.015)	(0.017)	(0.015)	(0.017)
Capital expenditure	-0.248***	-0.475***	-0.248***	-0.473***	-0.248***	-0.473***	-0.248***	-0.473***
	(0.054)	(0.078)	(0.053)	(0.079)	(0.053)	(0.078)	(0.053)	(0.078)
Leverage	-0.278***	-0.326***	-0.278***	-0.326***	-0.278***	-0.326***	-0.278***	-0.326***
	(0.026)	(0.019)	(0.026)	(0.019)	(0.026)	(0.019)	(0.026)	(0.019)
R&D/sales	0.110***	0.013***	0.110***	0.013***	0.110***	0.013***	0.110***	0.013***
	(0.015)	(0.001)	(0.015)	(0.001)	(0.015)	(0.001)	(0.015)	(0.001)
Dividend dummy	0.006	-0.023*	0.006	-0.023*	0.006	-0.023*	0.006	-0.023*
	(0.005)	(0.013)	(0.005)	(0.013)	(0.005)	(0.013)	(0.005)	(0.013)
Acquisition	-0.239***	-0.319***	-0.239***	-0.318***	-0.239***	-0.319***	-0.239***	-0.319***
	(0.063)	(0.076)	(0.063)	(0.076)	(0.064)	(0.076)	(0.064)	(0.076)
Cash flow risk	0.039**	0.083***	0.039**	0.084***	0.039**	0.084***	0.039**	0.084***
	(0.018)	(0.017)	(0.018)	(0.016)	(0.018)	(0.016)	(0.018)	(0.016)
Constant	0.237***	0.246***	0.239***	0.250***	0.235***	0.246***	0.240***	0.245***
	(0.014)	(0.035)	(0.015)	(0.033)	(0.015)	(0.035)	(0.015)	(0.033)
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	29,596	30,385	29,596	30,385	29,596	30,385	29,596	30,385
Adjusted R^2	0.388	0.396	0.388	0.395	0.388	0.395	0.388	0.395
Difference test	-0.044**		-0.030		-0.029		-0.027	
z-statistic	[-2.115]		[-0.941]		[-0.972]		[-0.971]	

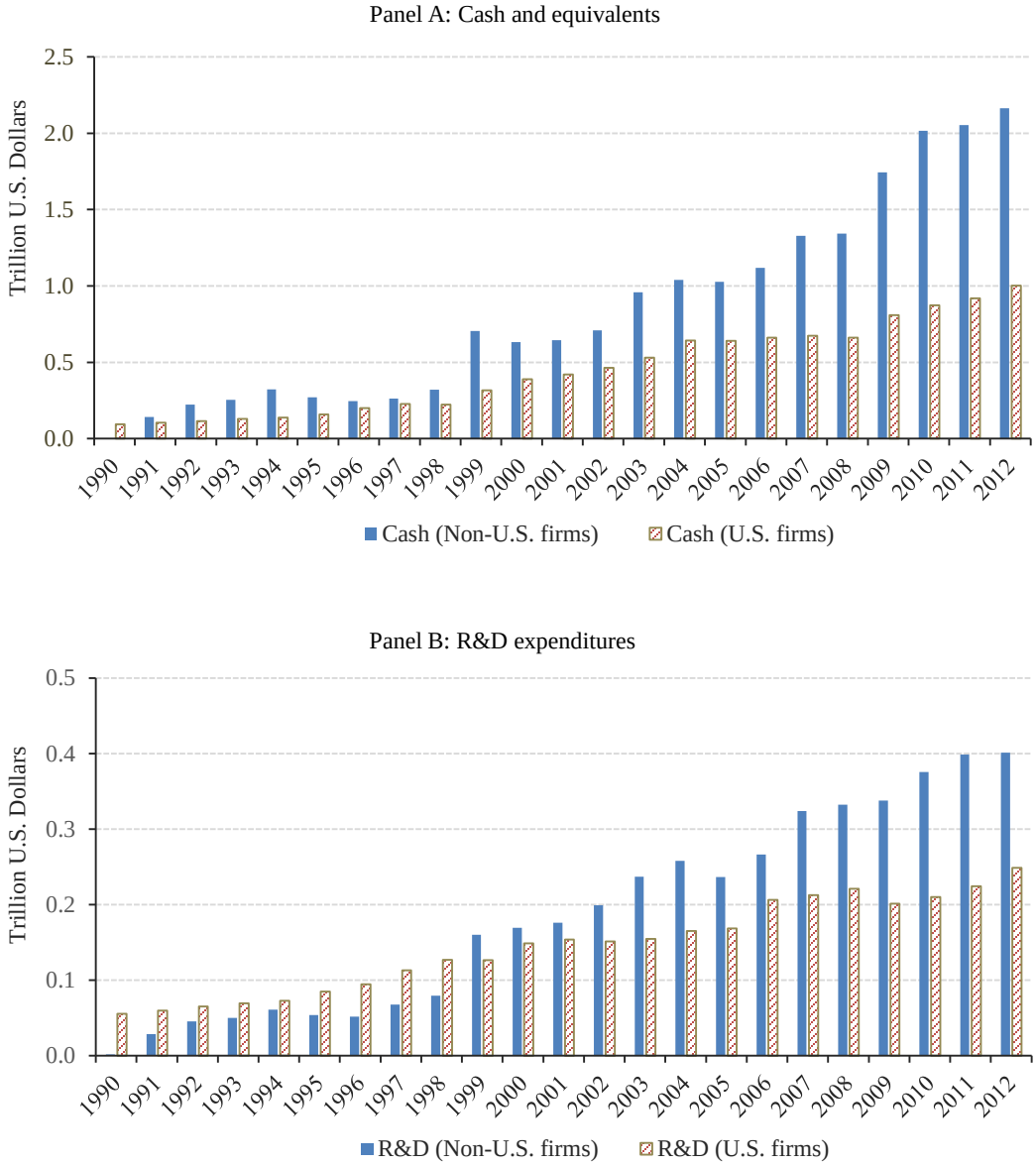
Table 11
Robustness tests: Innovation efficiency and cash holdings by including U.S. firms

This table shows the effect of innovation efficiency on cash holdings based on a sample of non-U.S. firms combined with U.S. firms in columns 1-2 and U.S. firms only in columns 3-4. The estimated OLS regression is: $Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}$. The dependent variable is cash ratio. The U.S. sample uses the same filters as for non-U.S. sample firms (i.e. excluding financial firms and utilities, and requiring non-missing data for all the variables in equation (3)). Due to the different technology classes issued by EPO and USPTO, *Ln(1+ IE_cit)* is calculated using the total number of non-adjusted citations (instead of adjusted citations). The definitions of other variables are given in the Appendix. Columns 1-2 control for industry-year and country-year fixed effects. Columns 3-4 control for industry fixed effect and year fixed effect. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	Non-U.S. and U.S. firms		U.S. firms only	
	(1)	(2)	(3)	(4)
Ln(1+ IE_pat)	0.039***		0.038**	
	(0.015)		(0.015)	
Ln(1+ IE_cit)		0.030***		0.029***
		(0.004)		(0.004)
Market to book	0.004***	0.004***	0.003***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Size	-0.008***	-0.009***	-0.002	-0.003
	(0.002)	(0.002)	(0.003)	(0.002)
Cash flow	-0.001	-0.001	0.001	0.001
	(0.006)	(0.006)	(0.005)	(0.005)
Net working capital	-0.042***	-0.042***	-0.034***	-0.033***
	(0.009)	(0.008)	(0.009)	(0.009)
Capital expenditure	-0.487***	-0.495***	-0.507***	-0.520***
	(0.106)	(0.106)	(0.119)	(0.120)
Leverage	-0.161***	-0.160***	-0.133***	-0.131***
	(0.017)	(0.016)	(0.018)	(0.018)
R&D/sales	0.005***	0.005***	0.004***	0.004***
	(0.000)	(0.000)	(0.000)	(0.000)
Dividend dummy	-0.056***	-0.055***	-0.113***	-0.111***
	(0.020)	(0.020)	(0.033)	(0.033)
Acquisition	-0.467***	-0.459***	-0.476***	-0.467***
	(0.057)	(0.057)	(0.057)	(0.057)
Cash flow risk	0.164***	0.164***	0.027	0.015
	(0.061)	(0.061)	(0.034)	(0.035)
Constant	0.224***	0.234***	0.315***	0.323***
	(0.017)	(0.017)	(0.025)	(0.025)
Industry-year FE	Yes	Yes	No	No
Country-year FE	Yes	Yes	No	No
Industry FE	No	No	Yes	Yes
Year FE	No	No	Yes	Yes
Observations	119,401	119,401	59,397	59,397
Adjusted R^2	0.305	0.309	0.282	0.288

Figure 1. Cash and equivalents, R&D expenditures, and patents of non-U.S. and U.S. innovative firms over 1990-2012

This figure shows aggregate cash and equivalents, R&D expenditures, and patents of non-U.S. and U.S. innovative firms over 1990-2012. Non-U.S. firms are our sample firms from 23 countries. The U.S. sample consists of 59,397 firm-year observations for 7,947 unique firms. The U.S. sample uses the same filters as for non-U.S. sample firms (i.e. excluding financial firms and utilities, and requiring non-missing data for all the variables in equation (3)). Panel A presents the annual aggregate cash and equivalents (short-term investments) in trillion U.S. dollars. Panel B presents the annual aggregate R&D expenditures in trillion U.S. dollars. Panel C shows the aggregate patent counts by application year.



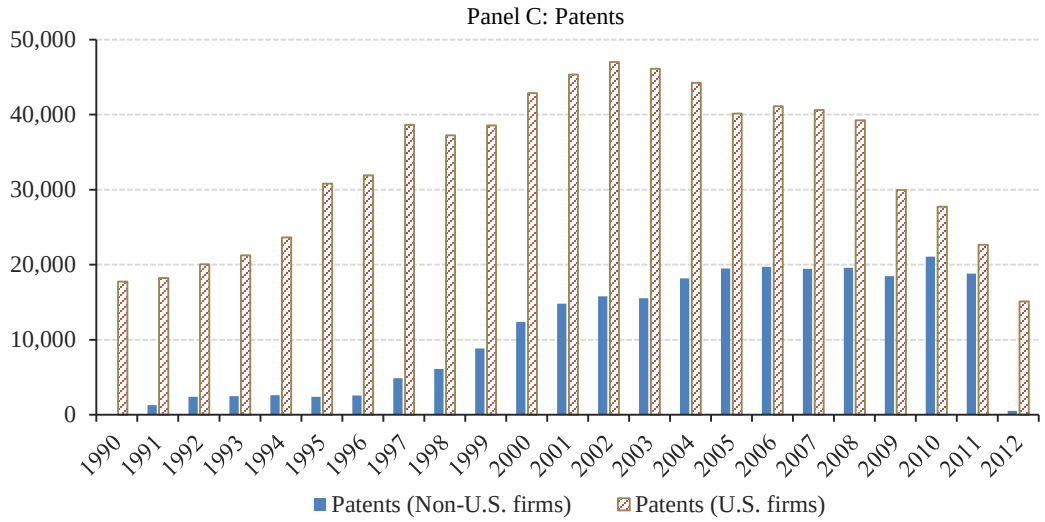
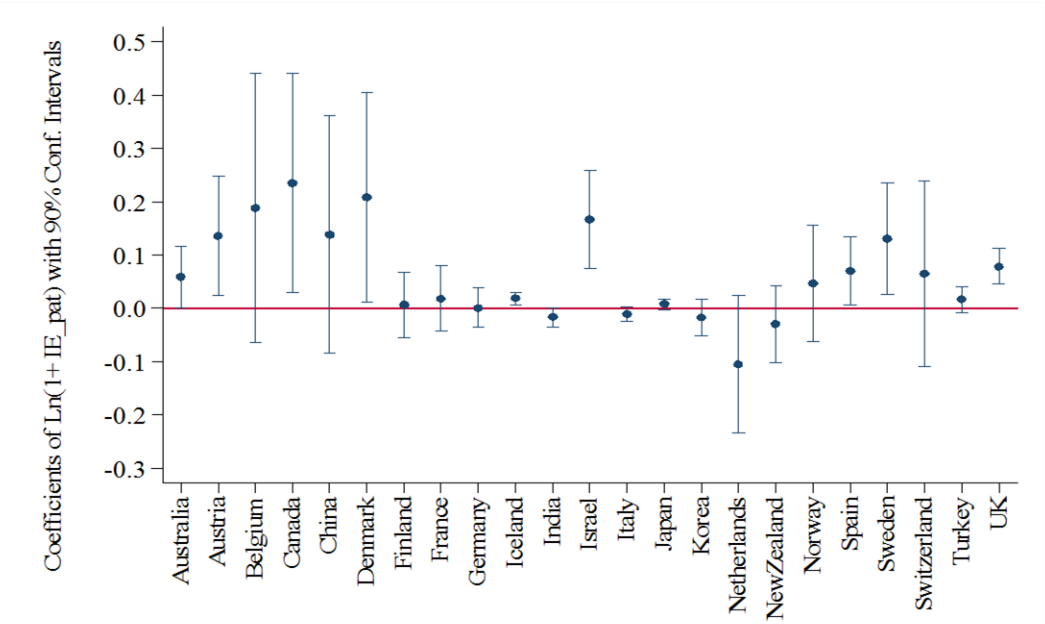

Panel C: Patents
50,000
40,000
30,000
20,000
10,000
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Patents (Non-U.S. firms)
Patents (U.S. firms)

Figure 2. The coefficients of patent-based innovation efficiency by country

This figure shows the coefficients of patent-based innovation efficiency, Ln(1+IE_pat), with 90% confidence intervals for each country by estimating the following regression: $Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE\_pat_{i,j,t}) + \delta' X + Industry\ FE + Year\ FE + \varepsilon_{i,j,t}$. The vector X include all the control variables as in baseline equation (3). The coefficients of Ln(1+IE_pat) are statistically significant in ten countries, including Australia, Austria, Canada, Denmark, Iceland, Israel, Japan, Spain, Sweden, and United Kingdom, which comprise a total of 42,821 observations or 71% of our sample.



Appendix
Variable Definitions

Variable	Definition
Patent	The number of successful patent applications filed by firm *i* in country *j* in year *t* (and granted by the end of 2012).
Cit1, Cit3, or Cit4	The total number of adjusted subsequent citations received by patents filed by firm *i* in country *j* in year *t*. For each patent, we calculate its adjusted citation based on technology class IPC1, IPC3, or IPC4 issued by the EPO as the number of subsequent citations received by this patent divided by the average number of subsequent citations received by all patents categorized in the same technology class and filed in the same year as the focal patent.
IE_pat	Patent-based innovation efficiency measure, defined as *Patent* in year *t* scaled by R&D capital. R&D capital is the 5-year cumulative R&D expenses from year *t*−4 to year *t*, assuming an annual depreciation rate of 20% ($R\&D_{i,j,t} + 0.8\times R\&D_{i,j,t-1} + 0.6\times R\&D_{i,j,t-2} + 0.4\times R\&D_{i,j,t-3} + 0.2\times R\&D_{i,j,t-4}$).
IE_cit1, IE_cit3, or IE_cit4	Citation-based innovation efficiency measure, defined as *Cit1*, *Cit3*, or *Cit4* in year *t* scaled by the sum of 5-year R&D expenses from year *t*−4 to year *t* ($R\&D_{i,j,t} + R\&D_{i,j,t-1} + R\&D_{i,j,t-2} + R\&D_{i,j,t-3} + R\&D_{i,j,t-4}$).
R&D/Sales	R&D expense in year *t* divided by sales in year *t*, *xrd/sale*, *xrd* is set to 0 if missing. Source: Compustat global and North America
R&D	R&D expense in billion U.S. dollars in year *t*, *xrd* (set to 0 if missing).
Cash	Cash holdings, calculated as cash and short-term investments divided by total assets, *che/at*.
MV	Stock price times share outstanding at the end of fiscal year *t*, *mv* is in billion U.S dollars (*cshoc*×*prccd* from Compustat global, or *csho*×*prcc_f* from Compustat North America).
Assets	The book value of total assets in billion U.S. dollars, *at*.
Market to book	Market value of assets over book value of assets: *(at−ceq+mv)/at*.
Size	Log of the book value of total assets (in million U.S dollars), *at*.
Cash flow	Cash flow to total assets, *(oibdp−xint−txt−dvc)/at*.
Net working capital	Net working capital to total assets, *(wcap−che)/at*.
Capital expenditure	Capital expenditures to total assets, *capx/at*.
Leverage	Total debt divided by total assets, *(dltt+dlc)/at*.
Dividend dummy	Dummy equals 1 if the firm pays dividends, dummy=1 if *dvc*>0.
Acquisition	Acquisitions to total assets, *aqc/at*, *aqc* is set to 0 if missing.
Cash flow risk	Industry average cash flow volatility (within the country). For each firm-year observation, the standard deviation of cash flow is calculated for the previous 16 quarters. A quarterly cash flow is the sum of income before extraordinary items (*ibq*) and depreciation and amortization (*dpq*) scaled by total assets (*atq*), *(ibq+dpq)/atq*. The standard deviation of cash flow is averaged each year across two-digit SIC codes.
Sales growth	The change in sales (*sale*) from year *t*−1 to year *t* divided by sales in year *t*−1.
ROA	Return on assets, *oibdp/at*.
Retained earnings	Retained earnings to total assets, *re/at*.
Non-operating income	Non-operating income divided by total assets, *nopi/at*.
DIV/Sales	Dividend paid scaled by sales, *dvc/sale*.
TotalPayout/Sales	The total amount of cash paid through dividends and repurchases scaled by sales. The total payout is the sum of common dividends (dvc), preferred dividends (dvp) and purchase of common and preferred stock (prstkc). Following Grullon and Michaely (2002), we use Compustat item *prstkc* as a proxy for share repurchase (they also subtract item *pstkrv* from *prstkc*, but Compustat global does not have this item), *(dvc+dvp+prstkc)/sale.*
Age	The natural log of firm age, which is calculated as the number of years that the firm has existed in Compustat.
Anti-self-dealing index	This index measures the legal protection of minority shareholders against self-dealing by the controlling shareholder, with higher values indicating stronger protection. Constructed

	by Djankov, La Porta, López-de-Silanes, and Shleifer (2008).
Anti-director index	The revised anti-director index summarizes the protection of minority shareholders in the corporate decision-making process including the right to vote, with higher values indicating stronger protection of minority shareholders against insider expropriation, from Djankov, La Porta, López-de-Silanes, and Shleifer (2008).
SA-index	Following Hadlock and Pierce (2010), $SA\text{-}index = -0.737 \times Size + 0.043 \times Size^2 - 0.040 \times Age$, in which *Size* is the natural logarithm of total assets and *Age* denotes the number of years that the firm is listed with a non-missing stock price on Compustat. *Size* is winsorized at the natural logarithm of $4.5 billion, and *Age* is winsorized at thirty-seven years.
ΔNet working capital	Changes in noncash net working capital
ΔShort debt	Changes in short-term debt
Technicians in R&D (per million people)	Technicians participate in R&D by performing scientific and technical tasks involving the application of concepts and operational methods, normally under the supervision of researchers. Source: World Bank database
Researchers in R&D (per million people)	Researchers in R&D are professionals (including PhD students engaged in R&D) who create new knowledge, products, processes, methods, or systems and manage the projects. Source: World Bank database

Appendix Table 1
Innovation efficiency and cash holdings over period 1990-2008

This table shows the effect of innovation efficiency on cash holdings over period 1990-2008, to mitigate the truncation issues. The estimated OLS regression is: $Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}$. The dependent variable is cash ratio. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
Ln(1+ IE_pat)	0.038***			
	(0.009)			
Ln(1+ IE_cit1)		0.040***		
		(0.011)		
Ln(1+ IE_cit3)			0.039***	
			(0.011)	
Ln(1+ IE_cit4)				0.037***
				(0.010)
Market to book	0.013***	0.013***	0.013***	0.013***
	(0.002)	(0.002)	(0.002)	(0.002)
Size	-0.008***	-0.008***	-0.008***	-0.008***
	(0.002)	(0.002)	(0.002)	(0.002)
Cash flow	-0.031***	-0.031***	-0.031***	-0.031***
	(0.011)	(0.011)	(0.011)	(0.011)
Net working capital	-0.142***	-0.142***	-0.142***	-0.142***
	(0.017)	(0.017)	(0.017)	(0.017)
Capital expenditure	-0.403***	-0.403***	-0.403***	-0.403***
	(0.059)	(0.059)	(0.059)	(0.059)
Leverage	-0.318***	-0.318***	-0.318***	-0.318***
	(0.017)	(0.017)	(0.017)	(0.017)
R&D/sales	0.024***	0.024***	0.024***	0.024***
	(0.001)	(0.001)	(0.001)	(0.001)
Dividend dummy	-0.019**	-0.019**	-0.019**	-0.019**
	(0.009)	(0.009)	(0.009)	(0.009)
Acquisition	-0.269***	-0.269***	-0.269***	-0.269***
	(0.041)	(0.041)	(0.041)	(0.041)
Cash flow risk	0.063***	0.064***	0.064***	0.064***
	(0.009)	(0.009)	(0.009)	(0.009)
Constant	0.175***	0.170***	0.180***	0.179***
	(0.028)	(0.026)	(0.027)	(0.027)
Industry-year FE	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	38,506	38,506	38,506	38,506
Adjusted R^2	0.396	0.396	0.396	0.396

Appendix Table 2
The effect of innovation efficiency on cash holdings controlling for lagged cash holdings

This table shows the robustness tests of the effect of innovation efficiency on cash holdings after controlling for lagged cash holdings. The regression is:

$$Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \beta_2 Cash_{i,j,t-1} + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}.$$

The dependent variable is cash ratio. $Cash_{i,j,t-1}$ is the cash holdings in year $t-1$. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
Ln(1+ IE_pat)	0.011***			
	(0.004)			
Ln(1+ IE_cit1)		0.018***		
		(0.005)		
Ln(1+ IE_cit3)			0.018***	
			(0.005)	
Ln(1+ IE_cit4)				0.018***
				(0.005)
$Cash_{t-1}$	0.742***	0.742***	0.742***	0.742***
	(0.013)	(0.013)	(0.013)	(0.013)
Market to book	0.005***	0.005***	0.005***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)
Size	-0.002***	-0.002***	-0.002***	-0.002***
	(0.001)	(0.001)	(0.001)	(0.001)
Cash flow	0.021***	0.021***	0.021***	0.021***
	(0.004)	(0.004)	(0.004)	(0.004)
Net working capital	-0.068***	-0.068***	-0.068***	-0.068***
	(0.006)	(0.006)	(0.006)	(0.006)
Capital expenditure	-0.289***	-0.289***	-0.289***	-0.289***
	(0.030)	(0.030)	(0.030)	(0.030)
Leverage	-0.092***	-0.092***	-0.092***	-0.092***
	(0.005)	(0.005)	(0.005)	(0.005)
R&D/sales	0.006***	0.006***	0.006***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)
Dividend dummy	0.001	0.001	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Acquisition	-0.512***	-0.512***	-0.512***	-0.512***
	(0.053)	(0.053)	(0.053)	(0.053)
Cash flow risk	0.025***	0.025***	0.025***	0.025***
	(0.004)	(0.004)	(0.004)	(0.004)
Constant	0.065***	0.061***	0.059***	0.060***
	(0.007)	(0.007)	(0.007)	(0.007)
Industry-year FE	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	59,839	59,839	59,839	59,839
Adjusted R^2	0.745	0.745	0.745	0.745

Appendix Table 3
Alternative measure of cash holdings

This table shows the effect of innovation efficiency on cash holdings by using an alternative measure of cash holdings based on OLS regression:

$$Ln(Cash/Net\ Assets)_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t},$$

$$Cash/Sales_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}.$$

For columns 1-4, the dependent variable is the natural logarithm of the ratio of cash and short-term investments to net assets in year *t*. For columns 5-8, the dependent variable is the ratio of cash and short-term investments to sales in year *t*. Net assets is total assets minus cash and short-term investments. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	Dependent variable							
	Ln(Cash/Net Assets)				Cash/Sales			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(1+ IE_pat)	0.314***				0.190***			
	(0.104)				(0.063)			
Ln(1+ IE_cit1)		0.355**				0.196**		
		(0.139)				(0.088)		
Ln(1+ IE_cit3)			0.349**				0.189**	
			(0.138)				(0.081)	
Ln(1+ IE_cit4)				0.338**				0.174**
				(0.134)				(0.076)
Market to book	0.123***	0.123***	0.123***	0.123***	0.020***	0.020***	0.020***	0.020***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.005)	(0.005)	(0.005)	(0.005)
Size	-0.044***	-0.045***	-0.045***	-0.044***	-0.015**	-0.015**	-0.015**	-0.015**
	(0.014)	(0.015)	(0.015)	(0.015)	(0.006)	(0.006)	(0.006)	(0.006)
Cash flow	-0.130	-0.129	-0.130	-0.129	-0.253***	-0.253***	-0.253***	-0.253***
	(0.080)	(0.080)	(0.080)	(0.080)	(0.034)	(0.034)	(0.034)	(0.034)
Net working capital	-0.970***	-0.968***	-0.968***	-0.968***	-0.184***	-0.183***	-0.183***	-0.183***
	(0.095)	(0.096)	(0.096)	(0.096)	(0.058)	(0.058)	(0.058)	(0.058)
Capital expenditure	-2.485***	-2.484***	-2.483***	-2.483***	-0.790***	-0.789***	-0.788***	-0.787***
	(0.459)	(0.459)	(0.458)	(0.458)	(0.256)	(0.255)	(0.255)	(0.255)
Leverage	-2.473***	-2.471***	-2.472***	-2.472***	-0.682***	-0.681***	-0.682***	-0.682***
	(0.065)	(0.065)	(0.065)	(0.065)	(0.073)	(0.073)	(0.073)	(0.073)
R&D/sales	0.144***	0.144***	0.144***	0.144***	0.190***	0.190***	0.190***	0.190***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)
Dividend dummy	-0.016	-0.016	-0.016	-0.016	-0.145***	-0.145***	-0.145***	-0.145***
	(0.057)	(0.057)	(0.057)	(0.057)	(0.043)	(0.043)	(0.043)	(0.043)
Acquisition	-2.050***	-2.049***	-2.048***	-2.049***	-0.630***	-0.629***	-0.629***	-0.629***
	(0.376)	(0.377)	(0.377)	(0.376)	(0.164)	(0.163)	(0.163)	(0.163)
Cash flow risk	0.593***	0.595***	0.594***	0.594***	0.292***	0.294***	0.294***	0.294***
	(0.183)	(0.183)	(0.183)	(0.183)	(0.092)	(0.092)	(0.092)	(0.092)
Constant	-2.031***	-2.027***	-2.037***	-2.028***	0.426***	0.450***	0.453***	0.449***
	(0.125)	(0.128)	(0.125)	(0.125)	(0.077)	(0.080)	(0.080)	(0.080)
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	59,545	59,545	59,545	59,545	60,004	60,004	60,004	60,004
Adjusted R^2	0.367	0.367	0.367	0.367	0.500	0.500	0.499	0.499

Appendix Table 4
The effect of changes in innovation efficiency on changes in cash holdings

This table shows the effect of the changes in innovation efficiency on the changes in cash holdings. Following Bates, Kahle, and Stulz (2009), we construct the following regression:

$$Change\ in\ cash_{i,j,t} = \beta_0 + \beta_1\, Change\ in\ IE_{i,j,t} + \delta' X + \varepsilon_{i,j,t},$$

in which vector X includes a set of changes in the variables. The dependent variable is the changes in cash holdings from year $t-1$ to year t. *Change in IE* is calculated as the changes in IE measures (not taken log) from year $t-1$ to year t. Similarly, for other variables, the change in the variable represents the change in the level of the variable from year $t-1$ to year t. The definitions of the level of variables are given in the Appendix. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
Change in IE_pat	0.001			
	(0.002)			
Change in IE_cit1		0.002***		
		(0.001)		
Change in IE_cit3			0.002***	
			(0.001)	
Change in IE_cit4				0.002***
				(0.001)
Lag change in cash	-0.129***	-0.129***	-0.129***	-0.129***
	(0.008)	(0.008)	(0.008)	(0.008)
Lag cash	-0.115***	-0.115***	-0.115***	-0.115***
	(0.009)	(0.009)	(0.009)	(0.009)
Change in market to book	0.003**	0.003**	0.003**	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
Change in size	0.019**	0.019**	0.019**	0.019**
	(0.009)	(0.009)	(0.009)	(0.009)
Change in cash flow	0.033***	0.033***	0.033***	0.033***
	(0.008)	(0.008)	(0.008)	(0.008)
Change in net working capital	-0.099***	-0.099***	-0.099***	-0.099***
	(0.013)	(0.013)	(0.013)	(0.013)
Change in capital expenditure	-0.199***	-0.199***	-0.199***	-0.199***
	(0.028)	(0.028)	(0.028)	(0.028)
Change in leverage	-0.102***	-0.102***	-0.102***	-0.102***
	(0.010)	(0.010)	(0.010)	(0.010)
Change in R&D/sales	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Change in dividend dummy	0.007**	0.007**	0.007**	0.007**
	(0.003)	(0.003)	(0.003)	(0.003)
Change in acquisition	-0.225***	-0.225***	-0.225***	-0.225***
	(0.024)	(0.024)	(0.024)	(0.024)
Change in cash flow risk	0.027***	0.026***	0.026***	0.026***
	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.017***	0.017***	0.017***	0.017***
	(0.003)	(0.003)	(0.003)	(0.003)
Observations	50,862	50,862	50,862	50,862
Adjusted R^2	0.145	0.145	0.145	0.145

Appendix Table 5
The effect of IE on cash holdings based on subsample of firms with at least one patent

This table reports robustness tests of the effect of innovation efficiency on cash holdings based on a subsample of 1,968 firms with at least one patent from the period 1990-2012 in 23 countries. The regression is:

$$Cash_{i,j,t} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t}.$$

The dependent variable is cash ratio. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
Ln(1+ IE_pat)	0.017*			
	(0.010)			
Ln(1+ IE_cit1)		0.027***		
		(0.008)		
Ln(1+ IE_cit3)			0.027***	
			(0.008)	
Ln(1+ IE_cit4)				0.026***
				(0.008)
Market to book	0.015***	0.015***	0.015***	0.015***
	(0.002)	(0.002)	(0.002)	(0.002)
Size	-0.007***	-0.007***	-0.007***	-0.007***
	(0.002)	(0.002)	(0.002)	(0.002)
Cash flow	-0.044***	-0.039***	-0.039***	-0.039***
	(0.015)	(0.015)	(0.015)	(0.015)
Net working capital	-0.198***	-0.204***	-0.204***	-0.204***
	(0.019)	(0.020)	(0.020)	(0.020)
Capital expenditure	-0.581***	-0.588***	-0.587***	-0.587***
	(0.077)	(0.087)	(0.087)	(0.087)
Leverage	-0.364***	-0.367***	-0.367***	-0.367***
	(0.030)	(0.030)	(0.030)	(0.030)
R&D/sales	0.024***	0.024***	0.024***	0.024***
	(0.002)	(0.002)	(0.002)	(0.002)
Dividend dummy	-0.027**	-0.028***	-0.028***	-0.028***
	(0.011)	(0.011)	(0.011)	(0.011)
Acquisition	-0.484***	-0.506***	-0.505***	-0.506***
	(0.098)	(0.123)	(0.123)	(0.123)
Cash flow risk	0.021	0.023	0.023	0.023
	(0.015)	(0.019)	(0.019)	(0.019)
Constant	0.226***	0.231***	0.231***	0.231***
	(0.026)	(0.024)	(0.024)	(0.026)
Industry-year FE	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	20,556	20,556	20,556	20,556
Adjusted R^2	0.457	0.464	0.464	0.464

Appendix Table 6
The predictability of innovation efficiency on cash holdings

This table shows the predictability of innovation efficiency on cash holdings based on the following OLS regressions:

$$Cash_{i,j,t+1} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t+1}.$$

The dependent variable is cash ratio in year t+1. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
Ln(1+ IE_pat)	0.037***			
	(0.010)			
Ln(1+ IE_cit1)		0.047***		
		(0.016)		
Ln(1+ IE_cit3)			0.046***	
			(0.015)	
Ln(1+ IE_cit4)				0.043***
				(0.014)
Market to book	0.016***	0.016***	0.016***	0.016***
	(0.001)	(0.001)	(0.001)	(0.001)
Size	-0.009***	-0.009***	-0.009***	-0.009***
	(0.002)	(0.002)	(0.002)	(0.002)
Cash flow	-0.040***	-0.039***	-0.039***	-0.039***
	(0.010)	(0.010)	(0.010)	(0.010)
Net working capital	-0.106***	-0.105***	-0.105***	-0.105***
	(0.011)	(0.011)	(0.011)	(0.011)
Capital expenditure	-0.362***	-0.363***	-0.362***	-0.362***
	(0.058)	(0.059)	(0.058)	(0.058)
Leverage	-0.287***	-0.287***	-0.287***	-0.287***
	(0.012)	(0.012)	(0.012)	(0.012)
R&D/sales	0.023***	0.023***	0.023***	0.023***
	(0.001)	(0.001)	(0.001)	(0.001)
Dividend dummy	-0.014*	-0.014*	-0.014*	-0.014*
	(0.008)	(0.008)	(0.008)	(0.008)
Acquisition	-0.228***	-0.228***	-0.228***	-0.228***
	(0.045)	(0.045)	(0.045)	(0.045)
Cash flow risk	0.072***	0.072***	0.072***	0.072***
	(0.014)	(0.014)	(0.014)	(0.014)
Constant	0.204***	0.206***	0.205***	0.206***
	(0.017)	(0.017)	(0.017)	(0.017)
Industry-Year FE	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	57,631	57,631	57,631	57,631
Adjusted R^2	0.377	0.377	0.377	0.377

Appendix Table 7
The predictability of innovation efficiency on cash holdings after controlling for lagged cash holdings

This table shows the predictability of innovation efficiency on cash holdings after controlling for lagged cash holdings. The regression is:

$$Cash_{i,j,t+1} = \beta_0 + \beta_1 \text{Ln}(1+ IE_{i,j,t}) + \beta_2 Cash_{i,j,t} + \delta' X + Industry \times Year\ FE + Country \times Year\ FE + \varepsilon_{i,j,t+1}.$$

The dependent variable is cash ratio in year t+1. $Cash_{i,j,t}$ is the cash holdings in year t. The definitions of other variables are given in the Appendix. All regressions control for industry-year and country-year fixed effects. Numbers in parentheses are two-way clustered standard errors by industry and year. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
Ln(1+ IE_pat)	0.008***			
	(0.002)			
Ln(1+ IE_cit1)		0.009**		
		(0.004)		
Ln(1+ IE_cit3)			0.008**	
			(0.004)	
Ln(1+ IE_cit4)				0.008**
				(0.003)
$Cash_t$	0.778***	0.778***	0.778***	0.778***
	(0.010)	(0.010)	(0.010)	(0.010)
Market to book	0.004***	0.004***	0.004***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
Size	-0.002***	-0.002***	-0.002***	-0.002***
	(0.001)	(0.001)	(0.001)	(0.001)
Cash flow	-0.024***	-0.024***	-0.024***	-0.024***
	(0.003)	(0.003)	(0.003)	(0.003)
Net working capital	-0.000	-0.000	-0.000	-0.000
	(0.004)	(0.004)	(0.004)	(0.004)
Capital expenditure	-0.068***	-0.068***	-0.068***	-0.068***
	(0.020)	(0.020)	(0.020)	(0.020)
Leverage	-0.046***	-0.046***	-0.046***	-0.046***
	(0.002)	(0.002)	(0.002)	(0.002)
R&D/sales	0.003***	0.003***	0.003***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Dividend dummy	-0.004***	-0.004***	-0.004***	-0.004***
	(0.002)	(0.002)	(0.002)	(0.002)
Acquisition	-0.010	-0.010	-0.010	-0.010
	(0.022)	(0.022)	(0.022)	(0.022)
Cash flow risk	0.009*	0.009*	0.009*	0.009*
	(0.005)	(0.005)	(0.005)	(0.005)
Constant	0.036***	0.037***	0.037***	0.036***
	(0.007)	(0.007)	(0.007)	(0.007)
Industry-year FE	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	57,631	57,631	57,631	57,631
Adjusted R^2	0.745	0.745	0.745	0.745