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# The impact of country-level corporate governance on research and development

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**Abstract**
We investigate the process through which country-level corporate governance facilitates firm-level investment in research and development (R&D). Taking cash flow as one of the main determinants of R&D, we derive an econometric model that introduces a number of corporate governance factors (legal protection, financial system, and control mechanisms) to analyze their impact on R&D-cash flow sensitivity. Using data from nine European Union countries, Japan, and the United States, we show that R&D at the firm level is less sensitive to internal cash flow in countries with effective investor protection, developed financial systems, and strong corporate control mechanisms. Specifically, our analysis suggests that the characteristics of the corporate governance system that facilitate R&D are a common law legal environment, minority shareholder protection, strong law enforcement, a bank-based financial system, effective board control, and a strong market for corporate control. This evidence points to corporate governance as a key element in R&D investment, and contributes to the debate on whether country-level corporate governance systems can facilitate R&D projects and, indirectly, promote economic growth.
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## INTRODUCTION

Over 50 years ago, Solow (1956) argued that technological change has a positive impact on economic growth. Since then, policy-makers have focused efforts on creating an economic environment that encourages research and development (R&D), an important driver of economic growth in contemporaneous economies (Brown, Fazzari, & Petersen, 2009).

Prior research (Beck & Levine, 2002; Beck, Levine, & Loayza, 2000b; Demirgüç-Kunt & Maksimovic, 2002; King & Levine, 1993; La Porta, Lopez-de-Silanes, Shleifer, & Vishny, 1997, 1998; Rajan & Zingales, 1998) has shown that macro governance factors – including economic, legal, and financial development – may positively affect economic growth. Given that these characteristics are essentially exogenous inputs to firm-level corporate decision-making, knowledge of the extent to which they facilitate R&D is of value to policymakers and regulators, who attempt to stimulate economic growth through their macro-level decisions.

We investigate the impact of country-level corporate governance on R&D investment. Although we focus on country-level corporate

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governance, our objective is to better understand investment decisions at the firm level. Therefore we examine the sensitivity of R&D investment to firm-level internal cash flow, and the extent to which exogenous and macro-level corporate governance factors moderate this relation. That is, we do not consider the direct effect of country-level corporate governance on R&D, which bypasses the necessary firm-level decisions driving this type of investment. Instead, our approach fully embeds the exogenous macro-level governance factors into the decision-making process, and, as a result, we fully capture their indirect effect at the firm level.

Previous literature has paid very little attention to the role of country-level corporate governance on firm-level decision-making. With the exception of Demirgüç-Kunt and Maksimovic (2002), who examine financing decisions, no other research of which we are aware considers the interaction between macro-level governance factors and firm-level decision-making. Although a large body of research has shown that firm-level governance characteristics (e.g., board and ownership structure) affect corporate decisions and strategy, we focus on the indirect effect of exogenous macro-level governance factors rather than possibly endogenous firm-level governance characteristics. Furthermore, a recent study by Doidge, Karolyi, and Stulz (2007), which shows that country-level variation in governance contributes more toward standard corporate governance indices than differences in corporate governance at the firm-level, supports our decision to concentrate on country-level governance.[1]

R&D is very different from other corporate investments. More than 50% of spending on R&D is directed to the salaries of innovators, who contribute to their firms' future expected earnings in the form of new products and services (Hall & Lerner, 2010). Because a significant proportion of R&D's inherent value comes from the innovators' human capital, this intangible asset may be lost to the company's shareholders if the innovator leaves the firm. Moreover, the current and future outputs associated with R&D are highly uncertain, and there is an asymmetry between information held by insiders and that held by outside shareholders. Given these issues, the cost of external capital for R&D funding is significantly greater than for other corporate investments, and more sensitive to fluctuations in internal cash flow.

The R&D literature has, to date, focused on two main areas: R&D's effect on the market value of firms (Bae & Kim, 2003; Chan, Lakonishok, & Sougiannis, 2001; Chauvin & Hirschey, 1993; Chen & Ho, 1997; Doukas & Switzer, 1992; Eberhart, Maxwell, & Siddique, 2004; Filatotchev & Piesse, 2009; Szewczyk, Tsetsekos, & Zantout, 1996) and the main determinants of R&D spending (e.g., cash flow, debt, size, industry classification; Cumming & Macintosh, 2000; Galende & Suárez, 1999; Lee & Sung, 2005). Surprisingly – especially given that good governance is found to reduce both moral hazard in firms and information asymmetry between managers and shareholders – few studies have examined the broad relation between R&D and corporate governance. Beck and Levine (2002) find that firms with a strong dependence on external financing grow faster in countries with higher levels of financial development and more efficient legal systems. Booth, Junttila, Kallunki, Rahiala, and Sahlström (2006) analyze how the financial environment influences the stock market valuation of R&D spending. Their results support the notion that R&D expenditures are more valued by the stock market in a market-based financial system. However, they also find that the degree of financial development does not affect the market valuation of R&D. Their results conflict with Islam and Mozumdar (2007), who find that tangible investment is positively influenced by financial development. Finally, Lee and O'Neill (2003) analyze the relation between ownership structure and R&D in US and Japanese firms. They find a positive relation between stock concentration and the level of R&D investment in US firms, but no such relation in Japanese firms.

Cash flow sensitivity is an influential determinant of R&D (Bloch, 2005; Hall, 1992; Himmelberg & Petersen, 1994).[2] We hypothesize that, in the presence of market imperfections, external funds may not provide a perfect substitute for internal funds, given that the premium for external financing will be higher (Hall & Lerner, 2010; Islam & Mozumdar, 2007). As a result, R&D is likely to incur an even higher premium, because it is characterized by opaque information flows and private managerial knowledge. If good governance is synonymous with greater disclosure and accountability, we expect that countries with strong governance structures will facilitate the availability of external financing for R&D investment.

Taking cash flow as one of the main determinants of R&D investment, we derive an econometric model to investigate how corporate governance affects R&D projects. Specifically, we interact cash flow with a selection of corporate governance factors to determine their effect on the sensitivity of R&D investment to fluctuations in cash flow. Using data from nine European Union countries, the United States, and Japan, we show that the sensitivity of R&D to internal cash flow is moderated by country-level corporate governance. Specifically, R&D is less sensitive to cash flow in countries with strong investor protection, developed financial systems, and effective corporate control mechanisms. These findings suggest a very important role for country-level corporate governance in facilitating R&D investment.

Further tests reveal a lower R&D-cash flow sensitivity for firms operating in common law countries with a high level of minority shareholder protection and better law enforcement. We also find that bank-based financial systems, compared with market-based systems, reduce the sensitivity of R&D investment to cash flow. In addition, cash flow has less importance for R&D in firms with an effective board, and in countries with a stronger market for corporate control.

We also employ a factor elasticity analysis to determine the comparative effect of country-level corporate governance characteristics on total R&D spending. By far the most important factor in reducing the sensitivity of R&D to internal cash flow is investor protection. This finding is understandable, given that shareholders in countries with strong investor protection are more willing to invest in activities where the potential private benefits of control are greater. Financial system development and corporate control mechanisms also reduce R&D-cash flow sensitivity, although to a much lesser extent.

Our paper makes a significant contribution to the literature in at least three ways. First, by conducting a cross-country analysis, we offer additional evidence on the determinants of R&D investment. Considerable work has examined the determinants of R&D using data from a single country. By jointly considering 11 countries, we are able to differentiate among institutional, regulatory, and legal systems, which is impossible when examining one country alone.

Second, our analysis pays particular attention to the specificity of R&D investment, in that the level of R&D is strongly linked to the strategy of the firm (i.e., how the firm competes in the market, the propensity to innovate, and other unobservable characteristics). Our econometric method incorporates this unobservable heterogeneity through the integration of individual firm characteristics in the cross-country sample.

Third, we present new evidence on how country-level corporate governance factors affect firm-level R&D investment and its sensitivity to cash flow. The objective of corporate governance is to introduce efficiency in resource allocation. Efficient resource allocation positively affects the quality of information flowing from a firm, which in turn reduces information asymmetries and agency costs. Consequently, our research is useful for characterizing the appropriate country-level corporate governance structures that promote and facilitate R&D and, consequently, encourage faster economic growth. As a result, the identification of these country-level corporate governance mechanisms could inform the decisions made by policymakers toward improving social welfare.

Clearly, any analysis of country-level corporate governance characteristics is affected by confounding factors. For example, common law countries have historically been associated with strong capital markets, and civil law environments tend to be dominated by banks and concentrated shareholdings. Disentangling these relationships completely is exceptionally difficult, if not impossible. However, the heterogeneity of countries in our sample provides considerable variation in corporate governance environments, and although this variation does not eliminate the issue of confounding factors altogether, it does significantly mitigate their impact on the analysis.

The remainder of the paper is structured as follows. In the next section, we develop our model and explain the theoretical arguments to support the selection of the explanatory variables. We then describe the corporate governance features considered in the analysis, and review the theoretical arguments behind our central hypotheses. Next, we describe the data and estimation method, and report the empirical results. Finally, the paper concludes with a discussion and summary of the main findings.

## EMPIRICAL MODEL

In this section we introduce the explanatory variables for our base empirical model before discussing the country-level governance variables in detail.[3] Fazzari, Hubbard, and Petersen (1988) find that cash flow is an important determinant of R&D investment, and that asymmetric information is considerably greater for R&D than for tangible fixed investments. Consequently, the cost of external funds will necessarily be higher for R&D than for tangible investments (Cleary, Povel, & Raith, 2007; Domadenik, Prasnikar, & Svejnar, 2008). Firms with high cash flow levels are also less averse to R&D activity (Ascioglu, Hegde, & McDermott, 2008). Thus we expect cash flow to be positively related to R&D investment.

Market imperfections are also likely to make external financing (i.e., long-term debt[4]) more expensive than internal financing. Because external capital does not provide a perfect substitute for internal funds, these market imperfections encourage R&D projects to be financed through internal resources (Islam & Mozumdar, 2007). Moreover, the probability of bankruptcy forces firms to rely on retained earnings to finance innovations (see Blundell, Griffith, & Reenen, 1999). Accordingly, we expect a negative relation between debt and R&D investment.

Following Lev and Sougiannis (1996), who find that strong returns on R&D encourage and incentivize future R&D investment, we use lagged values of R&D to explain current R&D expenditure. Dunlap-Hinkler, Kotabe, Mishra, and Parente (2007) also measure R&D resources by using the lag of R&D spending. Other control variables we consider are firm size, market share, tangible assets, and dividends.

The evidence concerning the relation between R&D and firm size is mixed. Some studies suggest that the relation is linear and positive, whereas others show that R&D and firm size are independent (see, e.g., Lee & Sung, 2005). Blundell et al. (1999) investigate the relation between innovation and market share, and find that firms with high market share innovate more. Given that the R&D process is basically a source of innovation (Booth et al., 2006), we use market share as a control variable in our analysis.

Previous research shows that firms with a high level of investment in physical capital face more financial constraints (Aghion, Bond, Klemm, & Marinescu, 2004; Fazzari, Hubbard, & Petersen, 1988; Hsiao & Tahmiscioglu, 1997), and that these constraints affect their ability to invest in R&D. As a result, we expect a negative relation between tangible assets and R&D. We also expect an inverse relation between dividends and R&D, because firms that pay more dividends tend to invest less in R&D (Fama & French, 2001).

Firm characteristics explain much of the variation in R&D investment. However, R&D activity is also strongly characterized by unquantifiable factors, such as corporate strategy, firm culture, and the propensity to innovate. Because these factors are impossible to measure, we incorporate them into our empirical model through an individual effect ($\eta_i$), which controls for the unobservable heterogeneity across firms in our analysis.

Consequently, the core explanatory model is

$$\begin{aligned}\left(\frac{RD}{K}\right)_{it} = {} & \beta_0 + \beta_1\left(\frac{RD}{K}\right)_{i,t-1} + \beta_2\left(\frac{CF}{K}\right)_{i,t-1} \\ & + \beta_3\left(\frac{LDT}{K}\right)_{i,t-1} + \beta_4\left(\frac{TANG}{K}\right)_{i,t-1} \\ & + \beta_5\left(\frac{DIV}{K}\right)_{i,t-1} + \beta_6 S_{i,t-1} \\ & + \beta_7 MS_{i,t-1} + \eta_i + \varepsilon_{it}\end{aligned} \tag{1}$$

where *RD*, *CF*, *LDT*, *TANG*, *DIV*, *S*, and *MS* denote R&D, cash flow, long-term debt, tangible fixed assets, dividends, size, and market share, respectively. The subscripts $i$ and $t$ refer to the company and time period, respectively; $\varepsilon_{it}$ is the random disturbance. We also scale the variables by the replacement value of total assets to avoid heteroskedasticity problems.

## HYPOTHESES

In the development of our hypotheses, we consider a broad definition of corporate governance. Specifically, following Mallin, Pindado, and de la Torre (2006), our definition incorporates the characteristics of legal and financial systems, ownership structure, boards of directors, and the market for corporate control. This definition is consistent with the Organization for Economic Co-operation and Development's (2004) *Principles on Corporate Governance*.

### Investor Protection

Since the seminal work of La Porta et al. (1997, 1998), scholars have investigated the efficiency of legal systems for corporate finance (Bianco, Jappelli, & Pagano, 2005; La Porta, Lopez-de-Silanes, & Shleifer, 2006; La Porta, Lopez-de-Silanes, Shleifer, & Vishny, 2002). La Porta et al. (1997, 1998) compare common and civil law systems, and report significant variation in the level of investor protection and regulatory enforcement across countries. Demirgüç-Kunt and Maksimovic (1998) find that the legal environment directly affects the level of information asymmetry between corporate insiders and investors. Specifically, these prior studies show that common law systems reduce information asymmetry and offer increased investor protection. Therefore we anticipate that R&D in common law countries will depend less on internal cash flow, and therefore will facilitate investment in R&D.

Minority shareholder protection can also affect R&D investment. Weak minority shareholder protection can increase the probability that firms will make non-value-maximizing investments, given that minority shareholder rights are positively related to better capital allocation (La Porta et al., 1998; Wurgler, 2000). In addition, in an environment with poor minority shareholder protection, markets may respond negatively to R&D (Hall & Oriani, 2006).

For minority shareholder protection to be effective, it must be enforced. Thus sufficient law enforcement is needed to mitigate the informational advantage of corporate insiders and, consequently, reduce the cost of external finance. Defond and Hung (2004) suggest that strong law enforcement is more efficient than extensive investor protection laws in improving corporate governance. They show that chief executive officer turnover is more likely to be associated with inefficient performance and poor stock returns, because, under strong law enforcement, stock prices are inherently more informative. This finding also implies that capital will be more efficiently allocated in a strong enforcement environment (Durnev, Morck, & Yeung, 2004). As a result, better law enforcement should lessen the sensitivity of R&D to fluctuations in cash flow, and thus encourage investment in R&D.

Taking these results together, we hypothesize that strong investor protection reduces the sensitivity of R&D to cash flow. Consequently, our first hypothesis is formally stated as follows:

> **Hypothesis 1**: Firms operating in countries with higher effective investor protection exhibit a lower sensitivity of R&D to cash flow.

To operationalize this hypothesis, we measure effective investor protection as the sum of three subindices that stem from the country-level governance indices of La Porta et al. (1997, 1998). We define a dummy variable, $DCL_{it}$, which equals 1 if the firm is located in a common law country and zero if the firm is located in a civil law country. La Porta et al. (1997, 1998) also compute an index, anti-director rights, to proxy for the level of minority shareholder rights. We use their combined index to build a dummy variable, $DAR_{it}$, which equals 1 if the firm is located in a country with anti-director rights higher than the sample median, and zero otherwise. Finally, La Porta et al. (1998) measure law enforcement using two indices: efficiency of the judicial system, and law and order. We sum these two indices to build a combined law enforcement index, and create another dummy variable, $DEF_{it}$, which equals 1 if the firm is located in a country with a higher than median law enforcement index, and zero otherwise. Finally, we proxy effective investor protection by summing the three dummy variables, *DCL*, *DAR*, and *DEF*, and constructing a new dummy variable, $DEP_{it}$, which equals 1 if the firm is located in a country with a higher than median investor protection, and zero otherwise.

## The Financial System

Despite a large body of research (e.g., Beck & Levine, 2002; Beck et al., 2000b; Demirgüç-Kunt & Maksimovic, 2002; King & Levine, 1993; Levine, 2002; Rajan & Zingales, 1998), there is no consensus on the correlation between the financial system and economic growth. In fact, whether the structure of the financial system (i.e., bank-based or market-based) matters remains an open question. Given that technological innovation is a channel through which the financial system affects economic growth (Aghion & Howitt, 1992; Grossman & Helpman, 1991; Romer, 1990), we investigate its role in moderating the relation between R&D and cash flow.

Two contrasting arguments prevail. Bank-based systems mitigate R&D agency costs and informational asymmetry, because banks hold both equity and debt in firms, and the informal bank-firm information channel reduces this asymmetry. Moreover, bank-oriented systems have advantages over their market-oriented counterparts in financing firm expansion, because they promote the establishment of new firms and are efficient in allocating capital (see Beck & Levine, 2002). Some firms are therefore willing to pay the premium required by banks to obtain continued support for their long-term growth (see, e.g., Hoskisson, Kim, Wan, & Yiu, 2008). However, although informed banks make flexible financing decisions and increase capital allocation efficiency, they also have the potential to take projects hostage once an investment has started (Rajan, 1992), thereby offsetting some of the benefits of bank-based financial systems.

Beck and Levine (2002) find that external financing is more common in countries with a high degree of financial system development, and Islam and Mozumdar (2007) show that the sensitivity of corporate investments to internal cash flow is higher for firms that operate in countries with less-developed financial markets. Also, Brown and Petersen (2009) suggest that an improvement in the availability of public equity reduces investment-cash flow sensitivity. Accordingly, we predict that financial system development will reduce the sensitivity of R&D to cash flow.

**Hypothesis 2**: Financial system development reduces the sensitivity of R&D to cash flow.

We test this hypothesis by creating a dummy variable, $DFSD_{it}$, which equals 1 if the firm is located in a country with a high index of financial system development, and zero otherwise. Financial system development is measured as the sum of two subindices: market development and banking development. The market development index is defined as the average of two measures: market capitalization to gross domestic product (GDP), and total equity value traded to GDP. The banking development index is the average of three variables: liquid bank liabilities, bank assets, and domestic bank deposits (Demirgüç-Kunt & Levine, 2001); all are standardized by GDP.

### Control Mechanisms

Ownership structure is perhaps the most widely studied control mechanism in corporate governance. Research provides strong evidence on the importance of ownership structure in resolving conflicts of interests between shareholders and managers (Jensen & Meckling, 1976; Shleifer & Vishny, 1986), as well as its importance in reducing informational asymmetries, which are particularly severe for R&D investments (Lee & O'Neill, 2003; Leland & Pyle, 1977). Also, Francis and Smith (1995) suggest that ownership concentration alleviates the agency cost associated with innovation. Consequently, ownership concentration may play an important role in lessening the sensitivity of R&D investment to fluctuations in cash flow.

In recent years, corporate boards have drawn considerable attention from regulators and industry practitioners without any real consensus on their optimal structure. Given that board independence is a determinant of board effectiveness (John & Senbet, 1998), Anglo-Saxon boards may appear more efficient, with their higher proportion of nonexecutive (or independent) directors. Furthermore, from an agency perspective, independent boards are mechanisms that reduce informational opacity, which will likely lead to lower R&D investment-cash flow sensitivity (Ascioglu et al., 2008), and are better at interfacing with the external environment (Pfeffer & Salancik, 1978). Offsetting these findings, when a firm requires specific knowledge about operations, such as R&D, a higher fraction of insiders on the board leads to better performance (Coles, Daniel, & Naveen, 2008).

The effectiveness of the board as a corporate governance tool is also determined by its organizational structure. Unitary board structures are prevalent in Anglo-Saxon countries (Dargenidou, McLeay, & Raonic, 2007; Hopt & Leyens, 2004), Japan (Jackson & Moerke, 2005), and Europe – with the exception of Germany, the Netherlands, and Austria, which have adopted a two-tiered board structure (De Jong, Gispert, Kabir, & Renneboog, 2002; Maassen & van den Bosch, 1999).

In a single-tier board, managers and directors have the same seniority because they jointly manage and supervise the firm's activities. In contrast, two-tier boards have an executive and supervisory board, which reduces the power and control of the executive board. Thus a two-tier board may find it easier to replace a director with poor performance or opportunistic behavior than in firms with a single-tier board. Board structure may also have a positive impact on R&D spending, given that effective boards allocate resources more efficiently. Consequently, an effective board will encourage managers to undertake value-increasing R&D investment instead of other short-term alternatives, regardless of cash flow levels.

Finally, the market for corporate control is an external mechanism that may affect firm-level investment, given that the takeover market plays an important role in disciplining management. One of the features of a market-based financial system is the existence of active markets for corporate control (Franks & Mayer, 1996; Jensen & Ruback, 1983). In contrast, this type of activity in bank-based financial systems is limited (Berglöf & Perotti, 1994; Franks & Mayer, 1998; Höpner & Jackson, 2001).

Jensen and Ruback (1983) argue that a strong market for corporate control checks managerial opportunism when asymmetries are severe. With respect to R&D investment, Meulbroek, Mitchell, Mulherin, Netter, and Poulsen (1990) show that anti-takeover provisions reduce the level of R&D intensity in a firm. Thus an active market for corporate control may facilitate R&D investment by reducing the sensitivity of R&D to cash flow.

Taken together, ownership concentration, board effectiveness, and the market for corporate control represent the external and internal control mechanisms that firms face when making decisions. Strong control mechanisms should improve the efficiency of capital allocation and, consequently, reduce the sensitivity of investment to cash flow. In fact, given the opaque nature of R&D investment, they should have even greater importance.

**Hypothesis 3**: Strong corporate control mechanisms reduce the sensitivity of R&D to cash flow.

We proxy for control mechanisms by combining the effect of ownership structure, board structure, and the market for corporate control into one index. Following La Porta et al. (1998; see also Carlin & Mayer, 2003; Leuz, Nanda, & Wysocki, 2003), we construct an index measuring ownership concentration and create a dummy variable, $DOC_{it}$, which equals 1 if a firm is located in a country with a high level of ownership concentration,[5] and zero otherwise. Similarly, we define a dummy variable, $DEB_{it}$, to proxy for board structure, which equals 1 if the country has a two-tier board structure or when nonexecutive directors represent a significant proportion (50% or more) on boards, and zero otherwise. Finally, $DMCC_{it}$ equals 1 if the firm is located in a country with an active market for corporate control,[6] and zero otherwise. The control mechanisms index is then computed as the sum of the ownership concentration, board effectiveness, and market for corporate control dummy variables. $DCM_{it}$ equals 1 if the firm has a control mechanisms index above the sample median, and zero otherwise.

## Aggregate Corporate Governance

Valuable insights can be gained by analyzing the aggregate effects of corporate governance on the sensitivity of R&D to cash flow. Some precedents for this type of analysis exist. La Porta et al. (1997), La Porta, Lopez-de-Silanes, Shleifer, and Vishny (2000) show that investor protection facilitates the development of financial systems. Kwok and Tadesse (2006) point out the substantial role played by legal systems in differentiating between financial systems across countries. In addition, Demirgüç-Kunt and Maksimovic (1998) suggest that both legal and financial systems reduce the magnitude of market imperfections caused by agency problems. Consequently, the evidence is sufficient to argue that the influence of corporate governance on the sensitivity of R&D to cash flow could arise from either (a) the legal or financial system (because both systems interact to further affect the sensitivity of R&D to cash flow) or (b) internal or external control mechanisms (e.g., ownership concentration, board structure, and the market for corporate control). Consequently, we posit that a strong corporate governance system has a mitigating impact on the sensitivity of R&D to cash flow.

**Hypothesis 4**: Strong corporate governance reduces the sensitivity of R&D to cash flow.

We test this hypothesis by creating a dummy variable, $DCG_{it}$, which equals 1 when the country's corporate governance index is higher than the median, and zero otherwise. Our corporate governance index is defined as the average of the effective investor protection (*DEP*), financial system development (*DFSD*), and control mechanisms (*DCM*) dummy variables.

# DATA AND METHOD

## Data

Our initial sample comprises all listed companies in the European Union, the United States, and Japan that are included on the Worldscope database for the years 1990 2003. Data on the growth of capital goods prices and the rate of interest on short-term and long-term debt come from the Main Economic Indicators service of the OECD.

Similar to La Porta et al. (2000), we remove companies from Luxembourg because of the very low number of listed firms. We also drop Finnish and Portuguese companies because of the lack of R&D data for these countries. As a result, the sample comprises companies from 11 countries, namely Austria, Belgium, France, Germany, Greece, Ireland, Italy, the Netherlands, the United States, the United Kingdom, and Japan. In addition, we omit financial firms, because their corporate structure is fundamentally different from the rest of the sample. Table 1 provides the distribution of the sample by number of companies and number of observations per country. The distribution of firms we use mirrors that of the whole sample of firms listed in each country; the United States, Japan, and the United Kingdom make up the majority of the sample.

The data are presented as an unbalanced panel (Table 1), consisting of 1287 companies and 6466

**Table 1** Breakdown of samples by country

| *Country* | *Number of companies* | *Percentage of companies* | *Number of observations* | *Percentage of observations* |
|---|---|---|---|---|
| Austria | 14 | 1.09 | 101 | 1.56 |
| Belgium | 12 | 0.93 | 87 | 1.35 |
| France | 105 | 8.16 | 798 | 12.34 |
| Germany | 105 | 8.16 | 808 | 12.50 |
| Greece | 20 | 1.55 | 132 | 2.04 |
| Ireland | 32 | 2.49 | 257 | 3.98 |
| Italy | 43 | 3.34 | 339 | 5.24 |
| Japan | 350 | 27.19 | 1,400 | 21.65 |
| Netherlands | 26 | 2.02 | 224 | 3.46 |
| United Kingdom | 209 | 16.24 | 836 | 12.93 |
| United States | 371 | 28.83 | 1,484 | 22.95 |
| Total | 1,287 | 100.00 | 6,466 | 100.00 |

*Notes:* This table presents a breakdown of sample companies into country of incorporation. To be included in the sample, the firm must have 6 consecutive years of financial information, including R&D, between 1990 and 2003. Financial firms are excluded in the financial system because of the nature of their data. Financial information comes from Worldscope, and economic data are taken from the Organization for Economic Co-operation and Development.

firm-year observations. We select an unbalanced panel in preference to a balanced approach to mitigate survivorship bias problems. The sample period (1990–2003) is fairly long, and many companies delisted, merged, or were acquired during the 14-year period. Imposing a requirement that all firms must have the same number of observations would reduce the sample to an unacceptable size: hence we include in the final sample firms that ceased to exist.

Table 2 presents a breakdown of the sample by economic sector. We categorized companies according to their Compustat Economic Sector Code, a classification system pertaining to nine different industry groupings (including financial firms).[7] The spread of firms across industries is balanced with most companies listed within the 6000 Industrials grouping. As expected, the total number of firms in the 4000 Energy and 9000 Utilities industry groups is quite low, with 73 companies – less than 6% of the total sample.

Table 3, Panel A, provides the summary statistics (mean, standard deviation, maximum, and minimum). Panel B of Table 3 displays some additional information on our dependent variable, *RD*/*K*. More than 90% of the sample report some form of R&D investment between 1990 and 2003. During the sample period the median of R&D was 1.78% of the replacement value of total assets, although one-fourth of the sample had R&D greater than 4.34% of the firm's replacement value of total assets.

Table 4 presents the distribution of country-level corporate governance variables. Given their dichotomous nature, the corporate governance variables essentially partition the sample into relevant groups according to the specific hypotheses. As the results in Table 4 show, the numbers of zeros and 1s are substantially different from one subsample to another, resulting in an appreciable level of variation across countries.

**Table 2** Sample distribution by economic sector classification

| *Economic sector code* | *Companies* | | *Observations* | |
|---|---|---|---|---|
| | *n* | % | *n* | % |
| 1000 materials | 216 | 16.78 | 1068 | 16.52 |
| 2000 consumer-discretionary | 139 | 10.80 | 752 | 11.63 |
| 3000 consumer-staples | 223 | 17.33 | 1120 | 17.32 |
| 3500 health care | 227 | 17.64 | 1070 | 16.55 |
| 4000 energy | 28 | 2.17 | 179 | 2.77 |
| 6000 industrials | 270 | 20.98 | 1339 | 20.71 |
| 8000 information technology | 139 | 10.80 | 723 | 11.18 |
| 9000 utilities | 45 | 3.50 | 215 | 3.32 |
| Total | 1287 | 100.00 | 6466 | 100.00 |

*Notes*: The table presents a breakdown of the sample into industrial groups, classified using Compustat Economic Sector Codes. 1000 materials include all construction materials, chemicals, gases, and commodity firms. 2000 consumer-discretionary include automobile manufacturers, homebuilders, hotels, casinos, retail, and electrical appliance firms. 3000 consumer-staples include food and drug retail and brewers. 3500 health care include health care and pharmaceuticals. 4000 energy include all types of oil and gas firms. 6000 industrials include conglomerates, construction, aerospace and defense, heavy machinery, airlines, marine, trucking, railroads, and office services and supplies. 8000 information technology include telecommunications, information technology, software, electronics, and semiconductor firms. 9000 utilities include electric, gas, water, and shipping firms. 5000 financial was not included in the sample research design.

**Table 3** Summary statistics for key variables

| *Variable* | *Mean* | *s.d.* | *Minimum* | *Maximum* |
|---|---|---|---|---|
| *Panel A Summary statistics* | | | | |
| *RD/K* | 0.0331 | 0.0466 | 0.0000 | 0.4634 |
| *CF/K* | 0.0495 | 0.1032 | −0.8719 | 0.5985 |
| *LTD/K* | 0.0656 | 0.0661 | 0.0000 | 0.6064 |
| *TANG/K* | 0.2522 | 0.1477 | 0.0022 | 0.9684 |
| *DIV/K* | 0.0110 | 0.0204 | 0.0000 | 0.6934 |
| *S* | 13.5688 | 2.1446 | 6.2095 | 19.8770 |
| *MS* | 0.0005 | 0.0015 | $<0.0001$ | 0.02756 |

*Panel B Additional information on the dependent variable*

| *Variable* | *1st quartile* | *2nd quartile* | *3rd quartile* | *% of zeros* |
|---|---|---|---|---|
| (*RD/K*) | 0.0047 | 0.0178 | 0.04339 | 9.4804 |

*Notes*: The table presents summary statistics for key variables in our analysis. *RD/K* is measured by research and development scaled by the replacement value of total assets; *CF/K* is cash flow scaled by the replacement value of total assets; *LTD/K* is long-term debt scaled by the replacement value of total assets; *TANG/K* is tangible fixed assets scaled by the replacement value of total assets; *DIV/K* is total dividends scaled by the replacement value of total assets; *S* is size, measured as the logarithm of the replacement value of the firm's assets (€000s); and *MS* is market share, measured as the firm's total sales as a proportion of sales by all other firms in its economic sector code. See the Appendix for more detail on the definitions of these variables.

## Method

Our main econometric method draws on panel data techniques, and thus we estimate all the models specified using panel data methodology. R&D is strongly linked to the unquantifiable characteristics of firms, such as strategy, firm culture, and the propensity to innovate. Any methodology must address this specificity, and consequently, unlike cross-sectional analysis, panel data methods allow us to control for individual heterogeneity. Therefore, to eliminate the risk of obtaining biased results, we control for firm-level heterogeneity by modeling it as an individual effect, $\eta_i$, which is then eliminated by taking the first differences of the variables. Consequently, the basic specification of our model is

$$\left(\frac{RD}{K}\right)_{it} = \beta_0 + \beta_1\left(\frac{RD}{K}\right)_{i,t-1} + \beta_2\left(\frac{CF}{K}\right)_{i,t-1} + \beta_3\left(\frac{LDT}{K}\right)_{i,t-1} + \beta_4\left(\frac{TANG}{K}\right)_{i,t-1} + \beta_5\left(\frac{DIV}{K}\right)_{i,t-1} + \beta_6 S_{i,t-1} + \beta_7 MS_{i,t-1} + \eta_i + d_t + c_i + i_i + v_{it} \quad (2)$$

**Table 4** Summary statistics for corporate governance factors across countries

| Country | $DCL_{it}$ | $DAR_{it}$ | $DEF_{it}$ | $DEP_{it}$ | $DMB_{it}$ | $DFSD_{it}$ | $DOC_{it}$ | $DMCC_{it}$ | $DEB_{it}$ | $DCM_{it}$ | $DCG_{it}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| Belgium | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| France | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Germany | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| Greece | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Ireland | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| Italy | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Japan | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Netherlands | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| UK | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| USA | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| Zeros (*n*) | 3889 | 1356 | 3171 | 2489 | 3923 | 1613 | 4999 | 3665 | 2756 | 3565 | 2164 |
| Zeros (%) | 60.15 | 20.97 | 49.03 | 38.49 | 60.66 | 24.95 | 77.31 | 56.68 | 42.62 | 55.12 | 33.47 |
| 1s (*n*) | 2577 | 5110 | 3295 | 3987 | 2543 | 4853 | 1467 | 2801 | 3710 | 2901 | 4302 |
| 1s (%) | 39.85 | 79.03 | 50.97 | 61.51 | 39.34 | 75.05 | 22.69 | 43.32 | 57.38 | 44.88 | 66.53 |

*Notes*: The table presents summary statistics for key corporate governance variables in our analysis. *DCL* equals 1 if a firm is located in a common law country, and zero otherwise. *DAR* equals 1 if the firm is located in a country with antidirector rights above the median for the sample, and zero otherwise. *DEF* equals 1 if the firm is located in a country with legal enforcement stronger than the median country in the sample, and zero otherwise. *DEP* equals 1 if the firm is located in a country with investor protection stronger than the median, and zero otherwise. *DMB* equals 1 if a firm is located in a market-based country, and zero otherwise. *DFSD* equals 1 if the firm is located in a country with financial system development above the median for the sample, and zero otherwise. *DOC* equals 1 if the firm belong to a country with ownership concentration (measured by the three largest shareholders in the 10 largest nonfinancial, privately owned domestic firms) higher than the median, and zero otherwise. *DEB* equals 1 if the firm is located in a country with a two-tier board structure system, or when nonexecutive directors represent a significant proportion (50% or more) on boards financial, and zero otherwise. *DMCC* equals 1 if the firm is located in a country with an active market for corporate control, and zero otherwise. *DCM* equals 1 if the firm has a combined corporate control index (computed as the sum of ownership concentration, board effectiveness, and market for corporate control) above the sample median, and zero otherwise *DCG* equals 1 if the firm has a corporate governance index value higher than the sample median, and zero otherwise. The corporate governance index is defined as the average of the shareholder rights index (*DEP*), the financial system development index (*DFSD*), and ownership concentration (*DOC*), effective board of directors (*DEB*), and market for corporate control (*DMCC*).

The error term has several components besides the individual or firm-specific effect ($\eta_i$). The time dummy variable, $d_t$, measures time-specific effects so that we can control for the impact of macroeconomic variables on R&D; $c_i$ is a country dummy variable representing country-specific effects; $i_i$ is an industry dummy variable representing industry-specific effects because R&D is strongly related to a company's specific business area; and $v_{it}$ is the random disturbance term.

In our analysis we also face the challenge of addressing factor endogeneity, which is likely to arise because the explanatory variables are simultaneously determined with R&D. Therefore we treat the explanatory variables as predetermined variables: that is, $E[x_{it} v_{is}]=0$ for all $s \geqslant t$, where $x_{it}$ stands for the explanatory variables in Eq. (2).

From an economic perspective, the explanatory variables can be affected by current and past realizations of R&D but must be uncorrelated with any future realization of the error term. As a consequence, we estimate all models using an instrumental variable method to control for the endogeneity problem. The best option is generalized method of moments (GMM), because it embeds all other instrumental variables methods as special cases (Ogaki, 1993). In addition, all the models control for dynamic effects by including a lag of the dependent variable, $(RD/K)_{i,t-1}$. In this context, prior research has shown that ordinary least squares (OLS) gives an estimation of the coefficient that is biased upward in the presence of individual heterogeneity (see Hsiao, 1986). Moreover, Nickell (1981) shows that the within-groups estimator is seriously biased downward, and Alonso-Borrego and Arellano (1999) report that the first-differenced GMM estimator is subject to a weak instruments problem. Correspondingly, Blundell and Bond (1998) propose the system GMM estimator, which is the method we use for estimating all our models.

To ensure that the econometric theory holds in our basic model, Table 5 presents the estimation results obtained from the different estimators previously discussed. The coefficient of the benchmark model estimation (system GMM) for the lag of R&D is 0.77764 (column 4). Consistent with Hsiao (1986), the coefficient (0.84781) from the OLS regression (column 1) is biased upward. Similarly, the coefficient (0.01964) from the within-groups regression (column 2) is biased downward.

In contrast to the OLS and within-groups estimators, no clear rule dictates the comparison between the first differenced GMM and the system GMM. According to Bond, Hoeffler, and Temple (2001), the first differenced GMM estimator is biased downward due to weak instruments, and the coefficient takes a value close to or below the within-groups estimator. As column 3 of Table 5 shows, the coefficient value is 0.55867, which is greater than the within-groups estimator (0.01964) but lower than the system GMM estimator (0.77764). Additionally, the $t$ value (98.76) is less than the $t$ value (756.31) of the same coefficient for the system GMM, which shows that the instruments from the first differenced GMM estimator are weaker than those from the system GMM estimator.

Furthermore, the stationarity assumption holds in our model, because the changes in variables that are instrumented are uncorrelated with the unobserved heterogeneity: that is, $E[\Delta x_{i,t-1}\eta_i]=0\ \forall\ i$ and $t$, where $x_{it}$ refers to the explanatory variables from Eq. (2). As a result, Arellano and Bover (1995) show that the following linear moment conditions could be exploited: $E[u_{it}\Delta x_{i,t-1}]=0\ \forall\ t \geqslant 2$. Blundell and Bond (1998) later generalized this result by letting $u_{it}=\eta_i+v_{it}$, (i.e., the error in levels), and taking into account that the explanatory variables are uncorrelated with the first differenced error. They show that the increment of the lag of the right-hand-side variables is uncorrelated with the error in levels; that is,

$$E[\Delta x_{i,t-1}u_{it}] = E[\Delta x_{i,t-1}\eta_i] + E[x_{i,t-1}v_{it}] - E[x_{i,t-2}v_{it}] = 0 + 0 - 0 = 0 \quad (3)$$

Consequently, we estimate all the models in our study by using the system GMM estimator, derived by Blundell and Bond (1998). From Eq. (3) we know that previous realizations of the explanatory variables can be used as instruments. Specifically, we use as instruments each right-hand-side variable in the models, lagged one to three times in the difference equations and just once in the level equations.

In sum, by using the panel data methodology (specifically, the system GMM estimator), we solve two important and well-known problems in the literature: individual factor heterogeneity and endogeneity. In addition to these two advantages, panel data methodology also has an advantage over a pure cross-sectional regression when estimating models with data spanning several countries. In a cross-sectional regression the country-specific effects are entered as part of the error term, which can lead to biased coefficients whenever the country-specific effects are correlated with explanatory

**Table 5** The basic model and the choice of estimator

| Variables | Ordinary least squares estimator | Within-groups estimator | First-differenced generalized method of moments estimator | System generalized method of moments estimator |
|---|---|---|---|---|
| $(CF/K)_{i,t-1}$ | 0.01179* | −0.00013 | 0.00885* | 0.00849* |
| | (0.02280) | (0.00314) | (0.00186) | (0.00051) |
| $(RD/K)_{i,t-1}$ | 0.84781* | 0.01964 | 0.55867* | 0.77764* |
| | (0.00699) | (0.01447) | (0.00786) | (0.00131) |
| $(LTD/K)_{i,t-1}$ | −0.00245 | −0.01137 | 0.00450* | −0.01066* |
| | (0.00464) | (0.00784) | (0.00380) | (0.0087) |
| $(DIV/K)_{i,t-1}$ | −0.03922* | −0.00290 | −0.05396* | −0.028091* |
| | (0.01489) | (0.01846) | (0.00157) | (0.00053) |
| $(TAN/K)_{i,t-1}$ | −0.01108* | −0.01258* | −0.00013 | −0.00928* |
| | (0.00224) | (0.00561) | (0.00187) | (0.00063) |
| $(SIZE)_{i,t-1}$ | 0.00010 | 0.00101 | 0.00482* | 0.00011* |
| | (0.00017) | (0.00090) | (0.00066) | (0.00003) |
| $(MS)_{i,t-1}$ | −0.32919 | −0.059161 | 0.02216 | −0.55583* |
| | (0.23786) | (0.54835) | (0.16093) | (0.04076) |
| $z_1$ | 2,311.41 | 8.63 | 1,103.41 | 57,703.66 |
| | (7) | (7) | (7) | (7) |
| $z_2$ | 1.74 | 3.09 | 37.80 | 216.42 |
| | (12) | (12) | (12) | (12) |
| $z_3$ | 2.33 | 2.48 | 135.32 | 149.77 |
| | (9) | (10) | (9) | (9) |
| $z_4$ | 10.38 | 1.22 | 280.95 | 334.81 |
| | (7) | (8) | (7) | (7) |
| $m_1$ | | | −3.42 | −3.49 |
| $m_2$ | | | 0.42 | 0.45 |
| Hansen | | | 236.97 | 361.35 |
| | | | (224) | (313) |

*Notes*: The table presents parameter estimates for the basic model of research and development using the most common estimators to choose the estimation method. The interpretation for each coefficient is the change in *RD* associated with a one unit change in the determinant. Variable definitions are presented in the Appendix. Heteroskedasticity consistent asymptotic standard errors are in parentheses. $z_1$ is a Wald test of the joint significance of the reported coefficients, asymptotically distributed as $\chi^2$ under the null of no relationship. $z_2$ is a Wald test of the joint significance of the time dummy variables, asymptotically distributed as $\chi^2$ under the null of no relationship. $z_3$ is a Wald test of the joint significance of the country dummy variables, asymptotically distributed as $\chi^2$ under the null of no relationship. $z_4$ is a Wald test of the joint significance of the sector dummy variables, asymptotically distributed as $\chi^2$ under the null of no relationship. $m_i$ is a serial correlation test of order $i$ using residuals in first differences, asymptotically distributed as $N(0, 1)$ under the null of no serial correlation. Hansen is a test of the overidentifying restrictions, asymptotically distributed as $\chi^2$ under the null. Degrees of freedom are in parentheses. * indicates significance at the 0.10% level.

variables (Beck, Levine, & Loayza, 2000a). However, our model decomposes the error term, and we control for the country-specific effects by using the dummy variable $c_i$ in Eq. (2).

Finally, we check for potential misspecification of the models. First, we use the Hansen *J*-statistic of overidentifying restrictions to test for the absence of correlation between the instruments and the error term. This test is distributed as a $\chi^2$ with $r-k$ degrees of freedom under the null hypothesis of the validity of the $r$ instruments, where $k$ is the number of parameters. The results in Tables 5, 6 and 7 support the validity of the instruments. Second, we use the $m_2$ statistic, developed by Arellano and Bond (1991), to test for a lack of second-order serial correlation in the first-difference residuals. As a result of the first-differenced transformation, the error term suffers from first-order serial correlation, which is confirmed in Tables 5 and 6. However, no second-order serial correlation exists. Third, we conduct four Wald tests: $z_1$ is a test of the joint significance of the reported coefficients, $z_2$ is a test of the joint significance of the time dummies, $z_3$ is a test of the joint significance of the country dummies, and $z_4$ is a test of the joint significance of industry dummies. All the Wald tests support the joint significance of the coefficients, as shown in Tables 5 and 6.

## RESULTS

Table 5 (column 4) presents the parameter estimates of the GMM panel data regression of R&D

**Table 6** The effect of corporate governance on research and development

| *Variables* | *(1)* | *(2)* | *(3)* | *(4)* |
|---|---|---|---|---|
| $(CF/K)_{i,t-1}$ | 0.01475* | 0.01209* | 0.01202* | 0.01223* |
| | (0.00044) | (0.00047) | (0.00039) | (0.00035) |
| $(RD/K)_{i,t-1}$ | 0.77388* | 0.78240* | 0.78173* | 0.78011* |
| | (0.00116) | (0.00108) | (0.00101) | (0.00096) |
| $(LTD/K)_{i,t-1}$ | −0.00762* | −0.01056* | −0.01025* | −0.00911* |
| | (0.00049) | (0.00080) | (0.00070) | (0.00069) |
| $(DIV/K)_{i,t-1}$ | −0.02816* | −0.02579* | −0.02694* | −0.02799* |
| | (0.00041) | (0.00037) | (0.00039) | (0.00037) |
| $(TAN/K)_{i,t-1}$ | −0.01073* | −0.00975* | −0.01156* | −0.01090* |
| | (0.00039) | (0.00043) | (0.00053) | (0.00050) |
| $(SIZE)_{i,t-1}$ | 0.00012* | 0.00006 | 0.00004 | 0.00009* |
| | (0.00003) | (0.00003) | (0.00003) | (0.00003) |
| $(MS)_{i,t-1}$ | −0.54928* | −0.61692* | −0.59031* | −0.66821* |
| | (0.03485) | (0.03557) | (0.03563) | (0.03990) |
| $DEP_{it}\ (CF/K)_{i,t-1}$ | −0.00743* | | | |
| | (0.00045) | | | |
| $DFSD_{it}\ (CF/K)_{i,t-1}$ | | −0.00357* | | |
| | | (0.00067) | | |
| $DCM_{it}\ (CF/K)_{i,t-1}$ | | | −0.00256* | |
| $DCG_{it}\ (CF/K)_{i,t-1}$ | | | (0.00050) | −0.00314* |
| | | | | (0.00055) |
| $t$ | 26.63 | 15.63 | 23.01 | 20.09 |
| $z_1$ | 93,728.78 | 67,031.56 | 94,651.85 | 100,000.00 |
| | (8) | (8) | (8) | (8) |
| $z_2$ | 665.48 | 573.94 | 636.09 | 579.96 |
| | (12) | (12) | (12) | (12) |
| $z_3$ | 180.68 | 598.22 | 253.90 | 262.08 |
| | (9) | (9) | (9) | (9) |
| $z_4$ | 536.04 | 775.11 | 634.05 | 622.41 |
| | (7) | (7) | (7) | (7) |
| $m_1$ | −3.50 | −3.50 | −3.50 | −3.50 |
| $m_2$ | 0.45 | 0.44 | 0.45 | 0.44 |
| Hansen | 378.20 | 371.20 | 381.73 | 373.65 |
| | (356) | (356) | (356) | (356) |

*Notes*: The table presents parameter estimates from panel generalized method of moments regressions for research and development (*RD*) on several different specifications. The interpretation for each coefficient is the change in *RD* associated with a one-unit change in the determinant. Variable definitions are presented in the Appendix. *DEP* equals 1 if the firm is located in a country with investor protection stronger than the median, and zero otherwise. *DFSD* equals 1 if the firm is located in a country with financial system development above the median for the sample, and zero otherwise. *DCM* equals 1 for firms with a combined corporate control index above the sample median, and zero otherwise. *DCG* equals 1 if the firm has a corporate governance index value higher than the sample median, and zero otherwise. The corporate governance index is defined as the average of the shareholder rights index (*DEP*), the financial system development index (*DFSD*), and control mechanisms index (*DCM*). Heteroskedasticity consistent asymptotic standard errors are in parentheses. * indicates significance at the 1% level. The *t*-statistic for the linear restriction test under the null hypothesis $H_0$ is $\beta_3+\alpha=0$. $z_1$ is a Wald test of the joint significance of the reported coefficients, asymptotically distributed as $\chi^2$ under the null of no relationship; degrees of freedom in parentheses. $z_2$ is a Wald test of the joint significance of the time dummy variables, asymptotically distributed as $\chi^2$ under the null of no relationship; degrees of freedom in parentheses. $z_3$ is a Wald test of the joint significance of the country dummy variables, asymptotically distributed as $\chi^2$ under the null of no relationship; degrees of freedom in parentheses. $z_4$ is a Wald test of the joint significance of the sector dummy variables, asymptotically distributed as $\chi^2$ under the null of no relationship. $m_i$ is a serial correlation test of order $i$ using residuals in first differences, asymptotically distributed as $N(0, 1)$ under the null of no serial correlation. Hansen is a test of the over-identifying restrictions, asymptotically distributed as $\chi^2$ under the null, degrees of freedom in parentheses.

expenditure on the explanatory variables. With the exception of market share, all variable coefficients are statistically significant and have the expected sign. Taking each in turn, the coefficient for the lagged R&D variable is positive, indicating the time persistence of R&D expenditure. That is, firms with high R&D in 1 year are likely to continue to invest heavily in R&D in the future. As we anticipated, the cash flow coefficient is positively related to R&D investment. Long-term debt negatively affects R&D, which is consistent with our expectations and Hall (1992). Size, dividends, and tangible assets

**Table 7** Summary statistics of predicted research and development values assuming a censored model

| *Variable* | *Mean* | *s.d.* | *Minimum* | *Maximum* | *Correct classification* |
|---|---|---|---|---|---|
| *CRD*91 | 0.02852 | 0.01883 | −0.02297 | 0.06282 | 83.33 |
| *CRD*92 | 0.02762 | 0.02018 | −0.04108 | 0.06312 | 84.28 |
| *CRD*93 | 0.02498 | 0.01860 | −0.04345 | 0.05931 | 84.44 |
| *CRD*94 | 0.02485 | 0.01417 | −0.02820 | 0.05342 | 88.89 |
| *CRD*95 | 0.02680 | 0.01514 | −0.04001 | 0.05428 | 91.20 |
| *CRD*96 | 0.02705 | 0.01399 | −0.03517 | 0.06019 | 93.27 |
| *CRD*97 | 0.02899 | 0.01014 | 0.00114 | 0.05723 | 95.22 |
| *CRD*98 | 0.02771 | 0.01161 | −0.01565 | 0.06566 | 92.20 |
| *CRD*99 | 0.02939 | 0.01050 | −0.01627 | 0.05124 | 96.14 |
| *CRD*00 | 0.02634 | 0.01151 | −0.02351 | 0.04834 | 91.01 |
| *CRD*01 | 0.03176 | 0.02327 | −0.04981 | 0.11312 | 91.25 |
| *CRD*02 | 0.03219 | 0.02539 | −0.04790 | 0.14163 | 90.96 |
| *CRD*03 | 0.03050 | 0.02223 | −0.04552 | 0.11552 | 90.20 |
| *CRD* | 0.02405 | 0.02228 | −0.04981 | 0.14162 | |

*Notes*: This table present summary statistics of fitted research and development (R&D) values from a censored model. *CRD*91, for instance, is the predicted R&D estimated by using a Tobit model for 1991 to solve the censoring problem. Correct classification stands for the percentage of correct classification arising from a Probit model including the same set of explanatory variables.

coefficients are all as expected. Surprisingly, the market share coefficient is unexpectedly significant and negative. Although inconsistent with our core model, a negative influence for market share has been previously suggested. Vossen (1999) shows that – especially for firms with high market share – the return from new products cannibalizes sales of existing products, which may lead to less innovative corporate behavior.

To test our main hypotheses, we interact the R&D variable with the four dummy governance variables: *DEP*, *DFSD*, *DCM*, and *DCG*. Taking investor protection as an example, the basic model in Eq. (2) is written as

$$\begin{aligned}\left(\frac{RD}{K}\right)_{it} =& \beta_0 + \beta_1\left(\frac{RD}{K}\right)_{i,t-1} \\ &+ (\beta_2 + \alpha_1 DEP)\left(\frac{CF}{K}\right)_{i,t-1} \\ &+ \beta_3\left(\frac{LDT}{K}\right)_{i,t-1} + \beta_4\left(\frac{TANG}{K}\right)_{i,t-1} \\ &+ \beta_5\left(\frac{DIV}{K}\right)_{i,t-1} + \beta_6 S_{i,t-1} + \beta_7 MS_{i,t-1} \\ &+ \eta_i + d_t + c_i + i_i + v_{it} \qquad (4)\end{aligned}$$

Recall that $DEP_{it}$ is a dummy variable equal to 1 if the firm is domiciled in a country with investor protection stronger than the median and zero otherwise. With this model, $\beta_2$ is the coefficient of cash flow in countries with poor (i.e., below median) investor protection (because $DEP_{it}=0$), and $\beta_2+\alpha_1$ is the coefficient for countries with strong (above median) investor protection (because $DEP_{it}=1$). In the latter case, if both parameters are significant, a linear restriction test is needed to determine whether their sum $(\beta_2+\alpha_1)$ is significantly different from zero.

Considering investor protection first, column 1 of Table 6 shows R&D investment is less sensitive to cash flow among firms that operate in countries with more effective investor protection ($\beta_2+\alpha_1=0.0147-0.0074=0.0073$, significantly different from zero, $t=26.63$) than in other countries ($\beta_2=0.0147$). This result not only supports Hypothesis 1 but is convincing evidence of the importance of legal protection in reducing the sensitivity of R&D to cash flow.

To test Hypothesis 2, which concerns financial system development, we change the dummy variable in Eq. (4) to the dummy variable $DFSD_{it}$, which equals 1 if a firm is located in a country with a high index of financial system development, and zero otherwise. Column 2 of Table 6 shows that a higher level of financial system development reduces the sensitivity of R&D to cash flow. The coefficient for firms operating in countries with a high level of financial system development is lower ($\beta_2+\alpha_1=0.0121-0.0036=0.0085$, $t=15.63$) than for those firms belonging to countries with a lower level of financial system development ($\beta_2=0.0121$). These results suggest that a more developed financial system improves the efficiency of capital allocation, which results in firm R&D that is less sensitive to cash flow. Hypothesis 2 is therefore supported, and is consistent with the rationale that the R&D expenditures of firms in countries with more developed financial systems are less sensitive to cash flow.

Table 6 (column 3) also shows the coefficient for the impact of corporate control mechanisms on the sensitivity of R&D to cash flow. $DCM_{it}$ equals 1 if a firm has a control mechanisms index above the sample median, and zero otherwise. The coefficient for firms located in countries with strong corporate control mechanisms is lower ($\beta_2+\alpha_1=$ 0.0120−0.0026=0.0094, $t$=23.01) than for those firms located in other countries ($\beta_2$=0.0120). These results support Hypothesis 3 and confirm our proposition that effective control mechanisms, such as board structures, the market for corporate control, and ownership concentration, lead managers to take a longer view in their investment decisions.

Finally, we test for the effect of corporate governance on the sensitivity of R&D to cash flow by using an aggregate index of corporate governance. We test-substitute the dummy variable in Eq. (4) with the dummy variable $DCG_{it}$, which equals 1 if the index of corporate governance is higher than the median, and zero otherwise. The corporate governance index is defined as the average of the effective investor protection index (*DEP*), the financial system development index (*DFSD*), and the control mechanisms index (*DCM*). As the results in Table 6 (column 4) show, the coefficient of the cash flow variable is significantly smaller for firms operating in countries with strong corporate governance ($\beta_2+\alpha_1$=0.0122−0.0031 =0.0091, $t$=20.09) than for those firms located in countries with weak corporate governance ($\beta_2$=0.0122). Consequently, this result not only specifically supports Hypothesis 4 but also, in general, confirms the impact of country-level corporate governance on R&D.

Overall, our results indicate strongly that corporate governance is a key factor in R&D investment.

## Robustness Tests: Is Censoring a Problem?

The dependent variable in our model is a censored variable in that some firms invest in R&D and others do not. For the whole sample, 9.48% of firm observations report zero R&D investment, and thus the analysis may suffer from a censoring problem. To ensure that such a problem does not bias our results, we conduct a two-phase test, following prior econometric literature.

First, we predict a new R&D variable for each year of our sample between 1991 to 2003 by using the following Tobit model:

$$\left(\frac{CRD}{K}\right)_{it}=\beta_0+\beta_1\left(\frac{RD}{K}\right)_{i,t-1}+\beta_2\left(\frac{CF}{K}\right)_{i,t-1}+\beta_3\left(\frac{LDT}{K}\right)_{i,t-1}+\beta_4\left(\frac{TANG}{K}\right)_{i,t-1}+\beta_5\left(\frac{DIV}{K}\right)_{i,t-1}+\beta_6 S_{i,t-1}+\beta_7 MS_{i,t-1}+u_{it} \quad (5)$$

where $RD_{it}=CRD_{it}$ if $CRD_{it}>0$, and $RD_{it}=0$ if $CRD_{it}\leqslant 0$. $CRD_{it}$ is a latent variable that is observable only when it is positive; when $CRD_{it}$ is negative it is unobservable, and our censored proxy, $RD_{it}$, equals zero.

Assuming that $CRD_{it}$ follows a normal distribution with mean $\mu$ and variance $\sigma^2$ and letting

$$\beta_0+\beta_1\left(\frac{RD}{K}\right)_{i,t-1}+\beta_2\left(\frac{CF}{K}\right)_{i,t-1}+\beta_3\left(\frac{LDT}{K}\right)_{i,t-1}+\beta_4\left(\frac{TANG}{K}\right)_{i,t-1}+\beta_5\left(\frac{DIV}{K}\right)_{i,t-1}+\beta_6 S_{i,t-1}+\beta_7 MS_{i,t-1}+u_{it}=X'_{it}\beta$$

then the logarithmic likelihood function of our model is

$$\ln L=\sum_{RD_{it}>0}-\frac{1}{2}\left[\ln(2\pi)+\ln\sigma^2+\frac{(RD_{it}-X'_{it}\beta)^2}{\sigma^2}\right]+\sum_{RD_{it}=0}\ln\left[1-\Phi\left(\frac{X'_{it}\beta}{\sigma}\right)\right]$$

where the first term picks up the observations for which $RD_{it}>0$ (i.e., observations for which the R&D variable is observable and, consequently, the density function is known), and the second term refers to the remainder of the observations for which the R&D variable is unobservable, assuming that the function $\Phi(\cdot)$ is distributed as $N(0,1)$.

Table 7 provides the summary statistics (i.e., mean, standard deviation, minimum, and maximum) of the R&D variable obtained by maximum likelihood estimation of the Tobit model in Eq. (5). In addition, the estimation of a Probit model including the same set of explanatory variables allows us to check the predictive ability of the model in Eq. (5). The last column of Table 7 provides the

**Table 8** The effect of corporate governance on research and development assuming censoring

| *Variables* | *(1)* | *(2)* | *(3)* | *(4)* |
|---|---|---|---|---|
| $(CF/K)_{i,t-1}$ | 0.00366* | 0.02232* | 0.00186 | 0.00516* |
| | (0.00079) | (0.00075) | (0.00090) | (0.00093) |
| $(RD/K)_{i,,t-1}$ | 0.03400* | 0.02523* | 0.03090* | 0.03694* |
| | (0.00128) | (0.00144) | (0.00135) | (0.00147) |
| $(LTD/K)_{i,t-1}$ | −0.13983* | −0.13871* | −0.14244* | −0.13012* |
| | (0.00087) | (0.00126) | (0.00139) | (0.00156) |
| $(DIV/K)_{i,t-1}$ | −0.05097* | −0.04496* | −0.04319* | −0.05981* |
| | (0.00097) | (0.00079) | (0.00077) | (0.00064) |
| $(TAN/K)_{i,t-1}$ | −0.10796* | −0.11135* | −0.10866* | −0.11048* |
| | (0.00041) | (0.00047) | (0.00056) | (0.00050) |
| $(SIZE)_{i,t-1}$ | 0.00084* | 0.00100* | 0.00061* | 0.00089* |
| | (0.00004) | (0.00006) | (0.00005) | (0.00005) |
| $(MS)_{i,t-1}$ | −0.31651* | −0.37121* | −0.13920* | −0.28481* |
| | (0.03963) | (0.05364) | (0.05292) | (0.05375) |
| $DEP_{it}\ (CF/K)_{i,t-1}$ | −0.09050* | | | |
| | (0.00078) | | | |
| $DFSD_{it}\ (CF/K)_{i,t-1}$ | | −0.10835* | | |
| | | (0.00187) | | |
| $DCM_{it}\ (CF/K)_{i,t-1}$ | | | −0.08341* | |
| | | | (0.00139) | |
| $DCG_{it}\ (CF/K)_{i,t-1}$ | | | | −0.09303* |
| | | | | (0.00115) |
| $t$ | −152.78 | −51.45 | −81.06 | −141.13 |
| $z_1$ | 21,527.64 | 11,271.73 | 10,444.24 | 14,993.13 |
| | (8) | (8) | (8) | (8) |
| $z_2$ | 4,662.95 | 1,107.41 | 1,121.08 | 1,321.32 |
| | (12) | (12) | (12) | (12) |
| $z_3$ | 673.54 | 316.49 | 373.47 | 754.83 |
| | (9) | (8) | (9) | (9) |
| $z_4$ | 37.89 | 17.11 | 16.94 | 37.26 |
| | (7) | (7) | (7) | (7) |
| $m_1$ | −5.66 | −4.38 | −5.16 | −5.55 |
| $m_2$ | −0.52 | −0.30 | 0.16 | −0.58 |
| Hansen | 646.45 | 658.08 | 675.33 | 581.05 |
| | (352) | (352) | (352) | (352) |

*Notes*: The table presents parameter estimates from panel generalized method of moments regressions for research and development (*RD*) on several different specifications. The interpretation for each coefficient is the change in *RD* associated with a one-unit change in the determinant. Variable definitions are presented in the Appendix. *DEP* equals 1 if the firm is located in a country with investor protection stronger than the median, and zero otherwise. *DFSD* equals 1 if the firm is located in a country with financial system development above the median for the sample, and zero otherwise. *DCM* equals 1 for firms with a combined corporate control index above the sample median, and zero otherwise. *DCG* equals 1 if the firm has a corporate governance index value higher than the sample median, and zero otherwise. The corporate governance index is defined as the average of the shareholder rights index (*DEP*), the financial system development index (*DFSD*), and control mechanisms index (*DCM*). Heteroskedasticity consistent asymptotic standard errors are in parentheses. * indicates significance at the 1% level. The *t*-statistic for the linear restriction test under the null hypothesis $H_0$ is $\beta_3+\alpha=0$. $z_1$ is a Wald test of the joint significance of the reported coefficients, asymptotically distributed as $\chi^2$ under the null of no relationship; degrees of freedom in parentheses. $z_2$ is a Wald test of the joint significance of the time dummy variables, asymptotically distributed as $\chi^2$ under the null of no relationship; degrees of freedom in parentheses. $z_3$ is a Wald test of the joint significance of the country dummy variables, asymptotically distributed as $\chi^2$ under the null of no relationship; degrees of freedom in parentheses. $z_4$ is a Wald test of the joint significance of the sector dummy variables, asymptotically distributed as $\chi^2$ under the null of no relationship. $m_i$ is a serial correlation test of order *i* using residuals in first differences, asymptotically distributed as $N(0, 1)$ under the null of no serial correlation. Hansen is a test of the over-identifying restrictions, asymptotically distributed as $\chi^2$ under the null, degrees of freedom in parentheses.

correct classification index for the R&D censored variable. The last row of the table shows the summary statistics of the new variable, $CRD_{it}$, for which the censoring problem is already solved.

Second, we estimate Eq. (4) by using the fitted R&D variable, $CRD_{it}$. Table 8 provides the results of the estimation. These results confirm the results in Table 6, with no differences in the signs or the significance of the coefficients obtained. Therefore the results in Table 8 provide a good robustness check for our model, and show that the censoring problem does not exist or, at least, does not lead to biased results.

## Comparative Analysis of Corporate Governance Factors

We show that different corporate governance factors play an important role in explaining R&D investment. However, we have yet to examine which country-level corporate governance factors are the most efficient drivers of R&D when, for example, a country wishes to boost its firms' R&D investment and improve its economic growth. To examine this question we use an elasticity index (*EI*), which, even though the effect of each factor on R&D is computed in different regressions, allows us to compare all the factors from a homogeneous base.

To construct this index, we calculate the elasticities of the estimated corporate governance coefficients. Table 9 presents the elasticities for the coefficients of each variable in the four models of Table 6. Elasticities are computed as

$$h_k = b_k \frac{\bar{x}_k}{b'\bar{x}} \quad (6)$$

where $k$ represents each corporate governance variable, $b_k$ denotes its coefficient, $\bar{x}_k$ is its mean, and $b'\bar{x}$ is the estimate of the expected value for the dependent variable using the mean value of each regressor. Because the elasticities from the different models cannot be compared directly, we compute an *EI*, which measures the proportional power of each corporate governance factor as

$$EI_f = \frac{h_{CF} + h_f}{\sum h} \quad (7)$$

where $h_{CF}$ is the elasticity of cash flow; $h_f$ is the elasticity of the corporate governance factor, $f$; and $\sum h$ is the sum of the elasticity for the coefficients on all the explanatory variables. In this way, we capture the explanatory power of each corporate governance factor with respect to R&D investment. Furthermore, the larger the explanatory power of a factor, the more this factor facilitates R&D investment.

As column 3 of Table 9 shows, the highest explanatory power is for the control mechanisms index ($EI_{CM}$=0.02489), which includes ownership concentration, board effectiveness, and the market for corporate control. Investor protection ($EI_{EP}$=0.02187) and financial system development ($EI_{FSD}$=0.01923) follow. Finally, the aggregate index of corporate governance captures the combined impact of all factors, and the *EI* score is 0.02359, which is reflective of the weight of the different corporate governance factors.

According to these results, the main drivers of R&D investment at a country level are internal and external control mechanisms, followed by effective investor protection, and the orientation and development of the financial system.

**Table 9** Factor elasticities

| *Variables* | *(1)* | *(2)* | *(3)* | *(4)* |
|---|---|---|---|---|
| $(CF/K)_{i,t-1}$ | 0.02309 | 0.01891 | 0.01881 | 0.01881 |
| $(RD/K)_{i,t-1}$ | 0.79242 | 0.80076 | 0.80008 | 0.80008 |
| $(LTD/K)_{i,t-1}$ | −0.01518 | −0.02101 | −0.02040 | −0.02040 |
| $(DIV/K)_{i,t-1}$ | −0.00960 | −0.00879 | −0.00918 | −0.00918 |
| $(TAN/K)_{i,t-1}$ | −0.08388 | −0.07618 | −0.09031 | −0.09031 |
| $(SIZE)_{i,t-1}$ | 0.05182 | 0.02678 | 0.01755 | 0.01754 |
| $(MS)_{i,t-1}$ | −0.00933 | −0.01047 | −0.01002 | −0.01002 |
| $DEP_{it}\ (CF/K)_{i,t-1}$ | −0.00519 | | | |
| $DFSD_{it}\ (CF/K)_{i,t-1}$ | | −0.00366 | | |
| $DCM_{it}\ (CF/K)_{i,t-1}$ | | | −0.0016 | |
| $DCG_{it}\ (CF/K)_{i,t-1}$ | | | | −0.00157 |
| *EI* | 0.02187 | 0.01923 | 0.02489 | 0.02359 |

*Notes*: The table presents parameter estimates from panel generalized method of moments regressions of research and development (*RD*) on several different specifications. The interpretation for each coefficient is the change in *RD* associated with a one-unit change in the determinant. Variable definitions are presented in the Appendix. *DEP* equals 1 if the firm is located in a country with investor protection stronger than the median, and zero otherwise. *DFSD* equals 1 if the firm is located in a country with financial system development above the median for the sample, and zero otherwise. *DCM* equals 1 for firms with a corporate control mechanisms index above the sample median, and zero otherwise. *DCG* equals 1 if a firm has a corporate governance index value higher than the sample median, and zero otherwise. The corporate governance index is defined as the average of the shareholder rights index (*DEP*), the financial system development index (*DFSD*), and corporate control mechanisms index (*DCM*). *EI* is the elasticity index.

## Further Tests

We now examine the impact of corporate governance on R&D-cash flow sensitivity in more detail, and decompose the three country-level governance variables of the main analysis into their respective subcomponents.

***Investor protection.*** We consider the three subcomponents of investor protection: legal tradition, minority shareholder protection, and law enforcement. The model specification is essentially the same as the main analysis, except that the interactive dummy variables now relate to the subcomponents. Taking legal tradition, the basic model in Eq. (2) is written as

$$\left(\frac{RD}{K}\right)_{it} = \beta_0 + \beta_1\left(\frac{RD}{K}\right)_{i,t-1} + (\beta_2 + \alpha_1 DCL)\left(\frac{CF}{K}\right)_{i,t-1} + \beta_3\left(\frac{LDT}{K}\right)_{i,t-1} + \beta_4\left(\frac{TANG}{K}\right)_{i,t-1} + \beta_5\left(\frac{DIV}{K}\right)_{i,t-1} + \beta_6 S_{i,t-1} + \beta_7 MS_{i,t-1} + \eta_i + d_t + c_i + i_i + v_{it} \quad (8)$$

where $DCL_{it}$ is a dummy variable equal to 1 if the firm belongs to a common law country, and zero if the firm belongs to a civil law country.

Table 10 provides the results of the analysis of the three subcomponents of investor protection. In column 1 we find that the cash flow coefficient for firms belonging to common law countries ($\beta_2+\alpha_1$=0.0143−0.0070=0.0073, significantly different from zero, $t$=26.23) is significantly smaller than the coefficient for firms belonging to civil law countries ($\beta_2$=0.0143). This result is consistent with Demirgüç-Kunt and Maksimovic (1998), and suggests that countries with a common law tradition facilitate R&D investment. Common law environments are more conducive to R&D investment because they are more effective at reducing information asymmetry than civil law countries, which consequently reduces the cost of external funds.

With minority shareholder rights protection, we substitute the dummy variable in Eq. (8) with the dummy variable $DAR_{it}$, which equals 1 if a firm is located in a country with anti-director rights higher than the sample median, and zero otherwise. Column 2 of Table 10 shows that firms located in countries with higher minority shareholder protection have a smaller cash flow coefficient ($\beta_2+\alpha_1$= 0.0267−0.0199=0.0068, $t$=5.26) than firms located in countries with a lower minority shareholder protection ($\beta_2$=0.0267). This finding suggests that a high level of antidirector rights reduces the sensitivity of R&D to cash flow and, in agreement with La Porta et al. (1998) and Wurgler (2000), that strong legal protection of minority shareholders is related to more efficient capital allocation.

Finally, we change the dummy variable in Eq. (8) to the dummy variable $DEF_{it}$, which equals 1 if the firm is located in a country with high levels of law enforcement, and zero otherwise. The results, provided in column 3 of Table 10, show that R&D in firms located in countries with stronger law enforcement ($\beta_2+\alpha_1$=0.0149−0.0103=0.0046, $t$=16.45) is less sensitive to cash flow than in firms located in countries with weaker enforcement of laws ($\beta_2$=0.0149). This result suggests that law enforcement is another way to mitigate the asymmetric information problem between insiders and outsiders, which leads to a reduction in the cost of external funds and thereby lessens the sensitivity of R&D to cash flow. This finding is also consistent with Durnev et al. (2004), who point to the benefits of law enforcement in improving the efficiency of capital allocation.

***The financial system.*** Column 4 of Table 10 presents the estimation of Eq. (8), which we now use to consider the effect of the financial system on the sensitivity of R&D investment to cash flow. We replace the legal dummy variable with the financial system dummy variable $DMB_{it}$, which equals 1 if a firm is located in a market-based economy, and zero otherwise. The results show that the R&D expenditures of firms located in a market-based financial system ($\beta_2+\alpha_1$=0.0073+0.0056=0.0129, $t$=12.59) have a higher sensitivity to cash flow than the R&D expenditures of companies located in bank-based environments ($\beta_2$=0.0073). This finding suggests that bank-based financial systems mitigate asymmetric information problems associated with R&D.

Several explanations are possible. First, the informal information channel between firms and banks in bank-based environments may reduce the asymmetric information problems that are more prevalent in market-based systems. Second, in market-based economies, such as the United States and the United Kingdom, market pressure leads managers to undertake short-term investment to maintain short-term earnings growth. One of the consequences of this behavior is that R&D spending is more likely to fall in periods of constrained cash flow. This result is consistent with the rationale that firms in countries with more developed financial systems have R&D expenditure that is less sensitive to cash flow.

***Corporate control mechanisms.*** Finally, we examine the impact of corporate control mechanisms on the sensitivity of R&D to cash flow. First, we substitute the dummy variable in Eq. (8) with the dummy variable $DOC_{it}$, which equals 1 for environments

**Table 10** Detailed analysis of corporate governance variables

| *Variables* | *(1)* | *(2)* | *(3)* | *(4)* | *(5)* | *(6)* | *(7)* |
|---|---|---|---|---|---|---|---|
| $(CF/K)_{i,t-1}$ | 0.014286* | 0.02674* | 0.01488* | 0.00731* | 0.01126* | 0.02078* | 0.01099* |
| | (0.00042) | (0.00068) | (0.00050) | (0.00032) | (0.00051) | (0.00062) | (0.00039) |
| $(RD/K)_{i,t-1}$ | 0.77451* | 0.78476* | 0.78220* | 0.78737* | 0.79120* | 0.78521* | 0.78236* |
| | (0.00116) | (0.00103) | (0.00099) | (0.00102) | (0.00102) | (0.00096) | (0.00092) |
| $(LTD/K)_{i,t-1}$ | −0.00855* | −0.00955* | −0.00631* | −0.01142* | −0.01249* | −0.00882* | −0.01147* |
| | (0.00050) | (0.00088) | (0.00087) | (0.00066) | (0.00067) | (0.00085) | (0.00077) |
| $(DIV/K)_{i,t-1}$ | −0.02760* | −0.02742* | −0.03385* | −0.02855* | −0.02533* | −0.02654* | −0.02784* |
| | (0.00039) | (0.00039) | (0.00031) | (0.00026) | (0.00045) | (0.00039) | (0.00037) |
| $(TAN/K)_{i,t-1}$ | −0.011452* | −0.01294* | −0.01233* | −0.01251* | −0.01032* | −0.01160* | −0.01213* |
| | (0.00038) | (0.00050) | (0.00055) | (0.00044) | (0.00043) | (0.00048) | (0.00041) |
| $(SIZE)_{i,t-1}$ | 0.00009* | 0.00017* | 0.00018* | 0.00020* | 0.00011* | 0.00018* | 0.00009 |
| | (0.00003) | (0.00004) | (0.00003) | (0.00002) | (0.00003) | (0.00004) | (0.00003) |
| $(MS)_{i,t-1}$ | −0.53445* | −0.65999* | −0.63182* | −0.64742* | −0.64676* | −0.67684* | −0.60361* |
| | (0.03723) | (0.04118) | (0.03498) | (0.02989) | (0.05011) | (0.04441) | (0.04140) |
| $DCL_{it}\ (CF/K)_{i,t-1}$ | −0.00700* | | | | | | |
| | (0.00043) | | | | | | |
| $DAR_{it}\ (CF/K)_{i,t-1}$ | | −0.01988* | | | | | |
| | | (0.00070) | | | | | |
| $DEF_{it}\ (CF/K)_{i,t-1}$ | | | −0.01027* | | | | |
| | | | (0.00102) | | | | |
| $DMB_{it}\ (CF/K)_{i,t-1}$ | | | | 0.00556* | | | |
| | | | | (0.00122) | | | |
| $DOC_{it}\ (CF/K)_{i,t-1}$ | | | | | −0.00474* | | |
| | | | | | (0.00069) | | |
| $DEB_{it}\ (CF/K)_{i,t-1}$ | | | | | | −0.01387* | |
| | | | | | | (0.00066) | |
| $DMCC_{it}\ (CF/K)_{i,t-1}$ | | | | | | | −0.00157* |
| | | | | | | | (0.00058) |
| $t$ | 26.23 | 5.26 | 16.45 | 12.59 | 20.86 | 16.69 | 20.37 |
| $z_1$ | 92,371.40 | 96,675.92 | 83,707.42 | 95,839.25 | 1.0e+05 | 91,686.11 | 1.4e+05 |
| | (8) | (8) | (8) | (8) | (8) | (8) | (8) |
| $z_2$ | 935.97 | 1,092.59 | 509.08 | 1,073.23 | 758.56 | 463.47 | 547.32 |
| | (12) | (12) | (12) | (12) | (12) | (12) | (12) |
| $z_3$ | 183.18 | 365.96 | 425.62 | 441.08 | 300.54 | 370.50 | 192.82 |
| | (9) | (9) | (9) | (9) | (9) | (9) | (9) |
| $z_4$ | 530.49 | 531.56 | 938.70 | 679.42 | 647.08 | 926.83 | 459.29 |
| | (7) | (7) | (6) | (7) | (7) | (7) | (7) |
| $m_1$ | −3.50 | −3.51 | −3.52 | −3.48 | −3.50 | −3.51 | −3.50 |
| $m_2$ | 0.45 | 0.44 | 0.44 | 0.45 | 0.45 | 0.44 | 0.45 |
| Hansen | 382.91 | 378.08 | 374.24 | 371.80 | 370.30 | 376.58 | 372.92 |
| | (356) | (356) | (356) | (356) | (356) | (350) | (356) |

*Notes*: The table presents parameter estimates from panel generalized method of moments regressions of research and development (*RD*) on several different specifications. The interpretation for each coefficient is the change in *RD* associated with a one-unit change in the determinant. Variable definitions are presented in the Appendix. *DCL* equals 1 if a firm is located in a common law country, and zero otherwise. *DAR* equals 1 if the firm is located in a country with antidirector rights above the median for the sample, and zero otherwise. *DEF* equals 1 if the firm is located in a country with legal enforcement stronger than the median country in the sample, and zero otherwise. *DMB* equals 1 if a firm is located in a market-based country, and zero otherwise. *DOC* equals 1 if the firm belongs to a country with ownership concentration (measured by three largest shareholders in the 10 largest nonfinancial, privately owned domestic firms) higher than the median, and zero otherwise. *DEB* equals 1 if the firm is located in a country with a two-tier board structure system, or when nonexecutive directors represent a significant proportion (50% or more) on boards, and zero otherwise. *DMCC* equals 1 if the firm is located in a country with an active market for corporate control, and zero otherwise. Heteroskedasticity consistent asymptotic standard errors are in parentheses. * indicates significance at the 1% level.

with high levels of ownership concentration, and zero otherwise. As a result, column 5 of Table 10 shows that firms in countries with higher ownership concentration are less sensitive to cash flow constraints when undertaking R&D. Specifically, the coefficient is smaller for firms in countries with concentrated ownership ($\beta_2+\alpha_1$=0.0113−0.0047= 0.0066, $t$=20.86) than for widely held domiciles

($\beta_2$=0.0113). This result is consistent with the agency theory perspective proposed by Lee and O'Neill (2003).

Second, to investigate the effect of board effectiveness on the relation between R&D and cash flow, we change the dummy variable in Eq. (8) to the dummy variable $DEB_{it}$, which equals 1 when a country has a two-tier board structure or when nonexecutive directors represent a significant proportion (50% or more) on boards, and zero otherwise. The board dummy variable coefficient in column 6 of Table 10 suggests that an effective board facilitates R&D investment and reduces the sensitivity of R&D to cash flow. The coefficient of the cash flow for firms with effective boards is lower ($\beta_2+\alpha_1$=0.0208−0.0139=0.0069, $t$=16.69) than for other firms ($\beta_2$=0.0208), highlighting the role of effective boards in corporate strategy.

Finally, we test for the role of the market for corporate control by substituting the dummy variable in Eq. (7) with the dummy variable $DMCC_{it}$, which equals 1 for firms operating in countries with an active market for corporate control, and zero otherwise. Column 7 of Table 10 shows that countries with an active market for corporate control have a smaller coefficient ($\beta_2+\alpha_1$=0.0109−0.0016= 0.0093, $t$=20.37) than those firms operating in other countries ($\beta_2$=0.0109). Building on Jensen (1991), who shows a positive relation between R&D spending and merger and acquisition activity, our results imply that the fear of a takeover may restrain opportunistic and myopic managerial behavior.

***Summary.*** In sum, all governance variable coefficients are consistent with expectations. With respect to investor protection, firms that are located in countries with common law traditions, strong minority shareholder rights, and effective law enforcement have significantly lower R&D-cash flow sensitivities. Similarly, bank-based financial systems, high ownership concentration, effective boards, and a market for corporate control all lower the sensitivity of R&D expenditures to cash flow. Hence the robustness tests strongly corroborate the key role played by country-level corporate governance in R&D investment.

## CONCLUSIONS

This paper focuses on how corporate governance influences the efficiency of R&D investment. Using cash flow as the main determinant of R&D expenditure, we derive an empirical model to explain the role of corporate governance in moderating the sensitivity of R&D investment to cash flow.

Our results, which support our three hypotheses, show that, in general, strong corporate governance lessens the sensitivity of R&D to cash flow. First, we find that effective investor protection facilitates R&D investment. Our analysis of the three subcomponents of investor protection (legal tradition, minority shareholder protection, and law enforcement) also supports this evidence. R&D projects undertaken by firms operating in common law countries are less sensitive to cash flow fluctuations, because common law systems more effectively mitigate asymmetric information. Also, strong minority shareholder protection lessens the sensitivity of R&D to cash flow, because minority shareholder rights are crucial for efficient capital allocation, and strong law enforcement reduces the gap in information quality between insiders and outsiders, which consequently reduces the cost of external financing.

Second, financial system development plays a key role in reducing the sensitivity of R&D to cash flow. Specifically, bank-based financial systems facilitate R&D investment. The internal information channels between companies and banks help to lessen the asymmetric information problems between outside investors and the firm. Moreover, in market-based systems, market pressure may lead managers to undertake myopic investment strategies to maintain short-term earnings growth.

Third, firms operating under strong corporate control mechanisms are less constrained by cash flow when undertaking R&D. Evidence on the three individual control mechanisms (ownership concentration, board effectiveness, and the market for corporate control) also supports this result. Higher levels of ownership concentration lessen R&D dependence on cash flow, suggesting that ownership plays an important role in resolving conflicts of interests between managers and shareholders. In addition, an effective board and an active market for corporate control also facilitate R&D, confirming the role of boards in corporate strategy and suggesting that the fear of takeover may alleviate the opportunistic behavior of directors and better align manager and shareholder objectives.

Overall, corporate governance, understood as the combination of legal and financial systems and corporate control mechanisms, affects the development of R&D projects. That is, we find that effective investor protection, a bank-based financial system, and strong corporate control mechanisms lead to greater disclosure and accountability, which, in turn, facilitates the availability of external financing for R&D. This topic is an important issue for those agents who play a crucial role in defining a corporate governance system (i.e., governments), because, through corporate governance, they can promote R&D investment and, as a result, economic growth and improved social welfare.

Finally, we acknowledge that country-level governance factors may interact with firm-level governance mechanisms in ways that have not yet been determined. How does the interaction between firm-level and country-level corporate governance affect corporate decisions such as investment, capital structure, or short-term capital management? These questions remain for future study, which will further improve our understanding of this new area of research.

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## NOTES

[1]The extent to which country-level corporate governance and firm-level governance interact is still uncertain. Collecting firm-level corporate governance information for many of the companies in our sample is difficult, because of differences in the quality of disclosure across countries. However, a relation between country-level and firm-level corporate governance is likely, although whether they act in a complementary fashion or as substitutes is still to be ascertained. Pay-performance sensitivity is an example (for an overview of executive compensation and corporate practices, see Faulkender, Kadyrzhanova, Prabhala, & Senbet, 2010). Given that R&D investment can dampen profitability in the short run, poorly governed firms with short-term sales targets may delay R&D (especially when cash flow is low) to ensure that performance measures are not affected. In such a situation, both the level of R&D and its sensitivity of cash flow will be affected (see Du & Choi, 2010, for the impact of Western pay-performance practices in China, a country with lower levels of development).

[2]We focus on cash flow because of the wealth of research that finds it to be of importance in R&D investment. However, other variables have also been shown to be influential. For example, Brown et al. (2009) and Brown and Petersen (2009) identify external equity as an important driver.

[3]The empirical framework is general enough to allow any number of moderating factors. Although the focus of our study is on country-level corporate governance, other variables, such as accounting standards (e.g., IASB, GAAP, local), political links, and private vs publicly traded status could be considered.

[4]We use long-term debt because most of the arguments in agency theory are related to this type of debt (see, e.g., Miguel & Pindado, 2001).

[5]High ownership concentration is defined as higher than the median percentage of ownership by the three largest shareholders in the 10 largest nonfinancial, privately owned domestic firms.

[6]These countries are Ireland, the Netherlands, the United Kingdom, and the United States. The classification coincides with that of market-based countries, with the exception of Ireland.

[7]To avoid a huge number of dummy variables in the model, we use the most general industrial classification system.

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## APPENDIX

The variables used in our analysis are defined. With the exception of the items that come from the Main Economic Indicators, published by the Organization for Economic Cooperation and Development, we obtain the items used in the construction of our from Worldscope.

### Research and Development (R&D)

The R&D variable, $RD_{it}$, represents all direct and indirect costs related to the creation and development of new processes, techniques, applications, and products with commercial possibilities.

### Cash Flow

We compute a firm's cash flow as $CF_{it}=NIAPD_{it}+DEP_{it}$, where $NIAPD_{it}$ denotes net income after preferred dividends, and $DEP_{it}$ denotes the book depreciation expense.

### *Long-term Debt*

The market value of long-term debt, $MVLTD_{it}$, is obtained as

$$MVLTD_{it} = \left(\frac{1 + l_{it}}{1 + i_l}\right) BVLTD_{it}$$

where $BVLTD_{it}$ is the book value of the long-term debt, $i_l$ is the rate of interest of the long-term debt reported in the Main Economic Indicators, and $l_{it}$ is the average cost of long-term debt, defined as $l_{it}=(IPLTD_{it}/BVLTD_{it})$, where $IPLTD_{it}$ is the interest payable on the long-term debt, which has been obtained by distributing the interest payable between the short- and long-term debt depending on the interest rates. That is,

$$IPLTD_{it} = \frac{i_l BVLTD_{it}}{i_s BVSTD_{it} + i_l BVLTD_{it}} IP_{it}$$

where $IP_{it}$ is the interest payable; $i_s$ is the rate of interest of the short-term debt, also reported in the Main Economic Indicators; and $BVSTD_{it}$ is the book value of the short-term debt.

### Market Share

This variable is computed as

$$MS_{it} = \frac{NS_{it}}{\sum_{i=1}^{n} NS_{it}}$$

where $NS_{it}$ denotes the net sales of firm $i$, and $\sum_{i=1}^{n} NS_{it}$ is the total net sales of its industry.

### Size

Firm size is calculated as the natural logarithm of the replacement value of total assets.

Replacement value of total assets is calculated as

$$K_{it} = RF_{it} + RI_{it} + (TA_{it} - BF_{it} - BI_{it})$$

where $RF_{it}$ is the replacement value of tangible fixed assets, $RI_{it}$ is the replacement value of inventories, $TA_{it}$ is the book value of total assets, $BF_{it}$ is the book value of tangible fixed assets, and $BI_{it}$ is the book value of inventories. We obtain the last three terms from the firm's balance sheet, and we calculate the first two following the formulas described in Miguel and Pindado (2001).

### Dividends

We compute the dividends as the dividends paid based on the current year's net income, scaled by the replacement value of total assets.

### Tangible Fixed Assets

We compute the tangible fixed assets as the net book value of property plant and equipment, scaled by the replacement value of total assets.

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